FIRE, HERBICIDES, AND GRAZING

IN THE CROSS TIMBERS

By

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Fire, Herbicides, and Grazing Effects on Cattle Gain and Vegetation Within Cross Timbers Experimental Range 1985 Through 1994

Introduction

Grassland ecosystems of the North American Great Plains evolved with varying frequency and intensity of fire, and large herbivore grazing disturbances which are considered critical to ecological processes, biological diversity, and habitat heterogeneity (Fuhlendorf & Engle 2004; Fuhlendorf & Smeins 1999; Collins 1992). Pre-settlement tallgrass prairie is thought to have developed and flourished in an environment that included recurring fire at one to ten year intervals (Axelrod 1985), with many early travelers having recorded observations of fire during their journeys. For instance, one such traveler stated, "The indians burn portions of the prairie every fall, setting the fires so as to burn as vast an extent of country as possible, and yet preserve unburned a good section in the vicinity where they purpose to make their fall hunt" (Dodge 1877). Before Europeans settled the Great Plains and removed most native, large ungulates (Hartnett et al. 1996), additional disturbances were provided by bison (*Bison bison*), one of the primary grazing animals in these grasslands.

As early travelers moved from the eastern U.S., they passed through a component of the eastern deciduous forest called the Ozark Plateaus, which comprised nearly 20 million ha of the 125 million ha of eastern forest in the United States (Garrison et al. 1977, Office of Technology Assessment 1982). In certain eastern regions, oak species

(*Quercus* spp.) were a dominant component of pre-settlement forests (Abrams and Downs 1990, Spurr 1951, Whitney and Davis 1986). The current distribution of oak greatly exceeds that of the original vegetation, suggesting that changes in disturbance regimes allowed for higher levels of oak dominance (Abrams 1986, Kucera 1956).

Within the Ozark Plateau, a unique habitat called Cross Timbers developed in a transition zone between the tallgrass prairie and the oak-hickory forest (Oosting 1956). The Cross Timbers is a major vegetation type consisting of 3.2 to 4.1 million ha (Powell 1982) located in central and eastern Oklahoma, north Texas, southeastern Kansas, southern Missouri, and northern Arkansas. The Cross Timbers and other hardwood vegetation types in the Ozark Plateaus form a substantial forage base for wildlife and livestock (Byrd et al. 1984, Garrison et al.1977, Soil Conservation Service 1981). In Oklahoma, the Cross Timbers region is a heterogeneous system comprised of forested regions dominated by post oak (*Quercus stellata* Wangenh), blackjack oak (*Quercus marilandica* Muenchh), and occasional black hickory (*Carya texana*), scattered tree and grassland areas (i.e. savannah) and areas of tallgrass prairie. The mosaic of vegetation types within the Cross Timbers has occurred through a variety of ecological pathways and disturbance conditions (Abrams 1992).

Because precipitation in the tallgrass prairie region was adequate to sustain forest vegetation on all but the most xeric sites, it was generally assumed that frequent fires limited forest development (Abrams 1986, Howell and Kucera 1956, Gleason 1913). Frequent fire in the Central Plains region was historically a result of lightning strikes as well as Native American activity (i.e. cooking, communication, field preparation for cultivation, combating insects, and hunting) (Day 1953). Guyette and McGinnes (1982) used dendrochronology of eastern redcedar (*Juniperus virginiana* L.) as a means of reconstructing fire history of an Ozark glade in southwest Missouri. Their results indicated that from 1630 to 1870 fire occurred at an average interval of 3.2 years, whereas fire return interval decreased to once every 22 years after European settlement and displacement of the Osage Indians in the early 1800's (Wilson 1985). The observed increase in the density of timber since European settlement is primarily attributed to the cessation of Native American activities (i.e. use of large broadcast fires). This resulted from altered activities of the new settlers, who restricted all fires, thus reducing fire frequency (Blinn 1958).

Research studies of fire on rangelands and woodlands number in the hundreds, (e.g. Knighton 1977, Sharrow and Wright 1977, Nimir and Payne 1978, DeBano et al. 1979, Dunn et al. 1979, Griffin and Friedel 1984, Marion et al. 1991, Cook et al. 1994 Emmerich 1999) however, very few of these studies have been conducted in a vegetation type similar to that of the Cross Timbers (Wright and Bailey 1980; Powell 1982). Burning, an old, widely used practice, has long been an important ecological factor and management tool in the bluestem range area. Most research conducted regarding effects of burning on soils has been done in forests and woodland areas (Owensby and Wyrill 1973). Tallgrass prairie was investigated for vegetation response to wild fires of differing intensity. Fire intensity at the soil surface on the high fuel-load plot was four times that on the low fuel burn plot. The data suggest that fire intensity is an important factor to consider when developing fire disturbance theory for tallgrass prairie (Ewing and Engle 1988). Although the production of forage following brush control with herbicides has been documented, this CTER study documents understory vegetation responses on savannah range sites in the Cross Timbers following herbicide and fire treatments to management-size units grazed by cattle (Engle et al. 1991). One of the few Cross Timbers studies conducted suggested that burning within several years after herbicide treatment was a more effective way to control brush on sites in the Cross Timbers where warm-season grasses occur in greater abundance either because of a more open overstory before treatment or because of the previous herbicide treatment (Stritzke et al. 1975). The fires conducted in this study were of low intensity within the upland hardwood forest type and did not greatly affect the woody plant overstory following herbicide treatment (Stritzke et al. 1991).

The removal of overstory tree cover has been shown to increase production of herbaceous vegetation and utilization of available forage and browse (George and Powell 1979). However, livestock grazing behavior and performance in response to brush management practices within the Cross Timbers are not known. A four year grazing study within the Cross Timbers in north central Oklahoma on the Pawhuska Research Station compared intensive early grazing (IES) and season-long grazing systems (SLS) without prescribed burns. Results of the study indicated that distribution of utilization was not improved by IES with cattle gains (kg/head) during the early-season similar for both grazing systems. However, total beef production increased 19% with IES as a result of increased stocking density (McCollum et al.1990).

Within the southern Great Plains, the Cross Timbers Experimental Range (described in Ewing et al. 1984) was used to assess the long-term effects of fire and herbicide use to control woody species in a study initiated in 1983 (Stritzke et al. 1991, Engle et al. 2006). An additional component of the study was to apply a grazing treatment to the experimental design two years after initiation of the study. The objective of this portion of the study was to evaluate long-term individual and combined effects of fire, herbicide, and season-long cattle grazing on vegetation response and cattle weight gain. I hypothesized that the presence of a single disturbance (i.e. herbicide) with or without prescribed fire would increase herbaceous plant community components, subsequently increasing stocker cattle gains. In contrast, the absence of these management practices would limit production of herbaceous species and result in a reduced livestock weight gain.

Materials and Methods

Study Area

The Cross Timbers Experimental Range (CTER) (Figure 1) is a 648 ha series of cross-fenced pastures located 11 km southwest of Stillwater, Oklahoma (36˚04.340'N; 97˚11.635'W, elev. 280m). Long-term (1971-2000), mean annual precipitation for the area is 934 mm (Figures 2 and 3). Mean monthly temperature is highest for July at 27.7 ˚C and lowest for January at 2.2 ˚C (Weather Summary, Oklahoma Climatalogical Survey, 1971 through 2005). Precipitation received during the study period (1985 to 1994) ranged from a high of 1160 mm to a low of 770 mm (Figure 2).

The most common ecological sites throughout CTER are shallow savannah (Stephenville-Darnell soil complex, 1 to 8% slopes) and sandy savannah (Harrah-Pulaski soil complex, 0 to 8% slopes) (Dwyer and Santelmann 1964, Ewing et al. 1984). The woody species on sandy savannah sites have greater overstory canopy cover of chinquapin oak (*Quercus muehlenbergii* Engelm.) and roughleaf dogwood (*Cornus drummondii* C.A.Mey). These two ecological sites normally occur in a mosaic, with the sandy savannah site located on lower slopes and ridge shoulders with deeper soils along stream channels. Shallow savannah sites are located on ridges and upper slopes with shallow soils overlaying sandstone (Stritzke et al.1991). Both of these ecological sites have varying occurrence of eastern redcedar in both the understory (< 1 m height) and the overstory (> 1 m in height).

Previous herbicide studies within Cross Timbers sites found that little bluestem (*Schizachyrium scoparium* (Michx. Nash) was the most abundant, desirable warm-season grass within the mature hardwood stands, occupying both sandy savannah and shallow savannah range sites prior to treatment with herbicides (Ewing et al. 1984). At the beginning of this study herbaceous species dominant in the plant community included little bluestem, big bluestem (*Andropogon gerardii*), indiangrass (*Sorghastrum nutans*), Scribner's panicum (*Dicanthelium oligosanthes*), purpletop (*Tridens flavus*), western ragweed (*Ambrosia psilostachya*), and various lespedeza species (*Lespedeza* spp.) (Ewing et al. 1984).

Experimental Design

This research was conducted as a randomized complete block design with 20, 32.4ha pastures, blocked into four replications based on soils and pre-treatment canopy cover of woody species (Figure 1). A 3 X 2 factorial arrangement of treatments (Table 1) was used with herbicide treatment and prescribed fire as the main effects. The three herbicide levels were tebuthiuron applied aerially at 2.2 kg ai/ha (pellets) in March 1983, a low volatile ester liquid formulation of triclopyr aerially applied at 2.2 kg ai/ha in June of 1983, and a no herbicide control. Rainfall, after application of tebuthiuron, was sufficient to aid in the movement of tebuthiuron into the soil. Environmental conditions and tree growth in June were satisfactory for adequate foliar uptake and herbicide activity for triclopyr. The second factor included presence or absence of prescribed fire and an unburned (no prescribed fire) control.

Burning

Prescribed burn pastures were strip head fired in 1985, 1986, and 1987 when air temperature was approximately 18º C, wind speed >10 km/hr, and relative humidity between 30 to 50%. Following 1987, prescribed burns were applied every three years (i.e. 1990 and 1993). To allow fine fuel accumulation for the 1993 prescribed fire burn treatment application, neither triclopyr treatments were grazed during 1992. Burning was conducted in late March or early April to coincide with the appearance of approximately 5 cm of new growth of warm season grasses and leaf expansion of oaks and buckbrush (*Symphorcarpos orbiculatus* Moench).

From 1985 to 1987, prescribed fires were mosaic (or incomplete due to patchy fine fuel loads. For instance, in 1985, areas that actually burned within the pastures were limited to the non-brush areas. In 1986, the brush area that burned was primarily limited to the shallow savannah sites. During the 1987 burn, an increase in surface areas with adequate fine fuels to carry a fire within triclopyr treated pastures allowed for about 25% of the brush areas to be burned and tebuthiuron treated pastures burned over 50% of the area (Stritzke et al. 1991). In 1992, this burn patchiness was addressed by altering the management practice (see details below in grazing management)

Grazing Management

From 1985 through 1994, a season long stocking (SLS) grazing system was used to manage yearling cattle on pastures from approximately early April through late

September. During the study period, the SLS grazing period averaged 146 days (range: 105 to 166 days). The SLS grazing period was reduced in 1987 and 1989 due to dry conditions. Based on availability, either single-sex herds of steers or heifers were used each year. The average weight of cattle used to start the grazing season each year was 216-kg (range of 186 kg to 248 kg). Individual cattle on weights and off weights were collected each year.

Stocking rate by pasture was annually set according to expected change in forage production in response to brush treatment and by adjusting to the previous year's end-of-season residue of herbaceous standing crop. We used a pasture mean of 1,500 kg/ha of residual herbaceous standing crop as a desired target value in all pastures except, for the control pastures. Given that the plant community within the control pastures was dominated by an oak overstory and encroaching eastern red cedar, to estimate end-of-season residue, we used residue quadrat sampling from areas away from the closed canopy. Grazing intensity was adjusted (i.e. reduced grazing intensity or deferred grazing) in 1992 to allow for accumulation of fine fuels required for more complete burns.

Vegetation Sampling

End-of-season biomass sampling was initiated in 1989. Vegetation residue was sampled at the end of the growing season after cattle removal and killing frost. Forty ($0.25m^2$) quadrats were sampled at 20 systematically designated points within each pasture. Visual dry weight estimates were recorded for each quadrat before clipping as follows: 1 = highest (70%) biomass estimate grouping, 2 = second highest biomass weight estimate (21%); 3 = lowest percent biomass weight estimate (9%) (Gillen and Smith 1986). The following functional forms or species were estimated within each quadrat: little bluestem, tallgrasses, other grasses, annual grasses, and forbs. The quadrats were placed 3m apart in a general east and west line from each pasture map designated point. Vegetation within each quadrat were clipped to ground-level, placed in bags, and dried at 70˚C. When the samples reached a constant dry weight they were weighed and used to quantify end-of-season residue (Gillen and Smith 1986).

Statistical Analysis

Data were analyzed using analysis of variance (PROC MIXED, SAS Inst. 2003) to assess treatment and yearly differences in cattle performance (i.e. weight gain) and residue of herbaceous plant components (see Engle et al. 2006). Treatments that were applied over the life of the study are listed in Table 1. All tests were conducted at the minimum significance level of $P < 0.05$. Differences in cattle performance and vegetation response were tested for levels of significance by treatment, year, and treatment by year interaction.

Results and Discussion

Vegetation Response

Responses of all vegetation components to the various herbicide and fire combinations varied among years and treatments (Table 2). Residue of tallgrasses, one of the dominant herbaceous components in the tallgrass prairie component of the Cross Timbers, exhibited lowest productivity in the no herbicide no fire treatment (Table 3). The herbicide no fire treatments had lower amounts of tallgrass residue than treatments with fire suggesting that the reduction of woody brush species in the fire treatments enhanced tallgrass production. These results suggest the absence of fire and the subsequent increase in Eastern redcedar had a limiting effect on the production of tallgrasses, as did an increase in litter which might have limited regrowth of perennial C4 grasses which evolved with fire (Engle et al. 2006).

Little bluestem (*Schizachyrium scoparium* (Michx. Nash) residue showed no treatment by year interaction (Table 4). In the treatments that included a combination of fire and herbicide, a greater amount of little bluestem residue was recorded and might be explained by a reduction in oak overstory (Engle et al. 2006). The lowest little bluestem production was found in the no herbicide no fire treatment, suggesting little bluestem would be reduced to the point of becoming a subdominant component in a Cross Timbers habitat that received no management (i.e. fire, herbicide). Previous herbicide studies within Cross Timbers sites found that little bluestem was the most abundant, warm-season grass occupying both sandy savannah and shallow savannah range sites prior to treatment with herbicides (Ewing et al. 1984) and continues to be abundant in the presence of appropriate management practices (i.e. fire, herbicide).

The forb component sampled in this Cross Timbers plant community showed significant treatment by year interaction. However, a mixed response of forbs was exhibited throughout all years of the study and among all herbicide and fire treatments (Table 5). The increased abundance of forbs in 1992 might be explained by the deferred grazing that occurred in 1992. However, the decreased forb residue in the triclopyr plus fire and tebuthiuron plus fire treatment in 1993 relative to the same treatment in 1992 was most likely an effect of increased grazing pressure during regrowth following the prescribed fire application in 1993. Reduced precipitation levels in 1994 (Figure 3) most likely limited forb production in all treatments that year. The large reduction of forbs in the triclopyr no fire treatment in 1994 most likely was associated with the follow-up treatment of picloram plus 2,4-D to reduce sumac cover.

The absence of management in the no herbicide no fire treatment resulted in reduced production of the other grasses component of the sampled vegetation (Table 6). The use of any herbicide with or without fire increased the other grass biomass approximately three to five times over the control treatment. No statistical differences in biomass of other grasses were seen in any other treatment and no general trend could be determined. This vegetation component within the Cross Timbers plant community includes broomsedge bluestem (*Andropogon virginicus*), split-beard bluestem (*Andropogon ternarius*), purple top (*Tridens flavus*), and scribner's panicum (*Panicum oligosanthes*) which include foliage and seeds produced for livestock and wildlife use.

Annual grasses had greater productivity in all treatments in 1989 relative to the

1990-1994 sampling years (Table 7). The triclopyr plus fire treatment had approximately twice the annual grass production in 1989 as all other treatments. This treatment received an annual applied prescribed fire during 1985, 1986, and 1987, as well as a 2,4-D application in 1988 for follow-up, woody brush control. Most likely the 2,4-D (i.e. a broad-leaf herbicide) application resulted in the greater production of annual grasses since there was a reduction in forb production during this 1989 sampling year.

Livestock Performance

Average daily gain (ADG; kg hd^{-1} day^{-1}) and individual cattle gain (kg hd^{-1}) had significant treatment by year interactions, whereas, cattle performance on a gain per unit area (kg ha^{-1}) showed significant treatment effects and year effects (Table 2) with no treatment by year interaction.

Treatments containing a prescribed fire component typically exhibited the highest ADG (Table 8) in this study; however, significant differences were only observed in 1985 and 1986 compared to other treatments. The no herbicide no fire treatment consistently had the lowest ADG, suggesting that the lack of management in Cross Timbers limits livestock productivity. Overstory woody plant cover was highest in the no herbicide no fire treatment (Engle et al. 2006) and most likely was associated with a decreased production of available forage, a limiting factor in livestock production (George & Powell 1979).

Individual cattle performance (kg hd^{-1}) showed variable results throughout all years and treatments. Even with the significant treatment by year interaction, there were no consistent fire or herbicide effects on livestock production which ranged from a low of 73 kg hd^{-1} to a high of 143 kg hd^{-1} throughout the study. Quantity and quality of forage production, although not measured in this study, most likely contributed to the variation in animal weight gain over the course of the study.

Livestock production (Table 10) at the pasture level showed higher kg ha^{-1} gains in the tebuthiuron plus fire and the triclopyr plus fire treatments, suggesting that the presence of fire could result in an increase in cattle gains, most likely associated with a reduction in woody plant species and an increase in herbaceous forage production. The higher livestock production in the fire treatments could be explained by the higher little bluestem, tallgrass, and periodically higher forb production that were also observed in the herbicide plus fire treatments. In contrast, the absence of fire and herbicide application in the no herbicide no fire treatment resulted in reduced livestock production as well as reduced tallgrass and little bluestem production. Overall, brush management with herbicides and fire resulted in increased livestock production.

Conclusion

The absence of applied management practices (i.e. fire and grazing) in a livestock production system within the Cross Timbers will result in a reduction in forage production (i.e. tallgrasses, little bluestem, other grasses) limiting cattle gain.

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Table 1. Treatment applications from 1983-1994. Prescribed burns were conducted in the spring of burn years (March-April). Consecutive burns were conducted in 1985, 1986, and 1987, then once every three years (1990 and 1993). Herbicide applications were made as per label instructions. Grazing treatments were held constant across treatments, but varied in years (i.e. 1992, due to need for increased fine fuel loading preceding prescribed burn in 1993). SLS = season-long stocking.

TREATMENT			
Herbicide	**Burn**	**Individual Tree Burn**	**Grazing**
Tebuthiuron-1983	None		SLS 1985-1994; Light Grazed in 1992
Tebuthiuron-1983	1985, 1986, 1987, 1990, 1993	1990, 1993	SLS 1985-1994; Light Grazed in 1992
Triclopyr-1983 2, 4-D-1988 Grazon P+D-1994	1993		SLS 1985-1991; Deferred Grazing 1992 for fine fuels accumulation. SLS 1993-1994
Triclopyr-1983 2, 4-D-1988	1985, 1986, 1987, 1990, 1993	1990, 1993	SLS 1985-1991; Deferred Grazing 1992 for fine fuels accumulation. SLS 1993-1994
None	None		SLS 1985-1994; Grazed in 1992

Table 2. Vegetation response and cattle performance. Expressed as effect by levels of significance of treatment, year, and treatment by year.

	EFFECT		
Vegetation Response	**Treatment**	**Year**	**Treatment by Year**
Tallgrass (kg/ha)	<0.0001	0.61	0.97
Little Bluestem (kg/ha)	<0.0001	0.01	0.63
Forbs (kg/ha)	<0.0001	<0.0001	0.0008
Other Grasses (kg/ha)	<0.0001	<0.0001	0.362
Annual Grasses (kg/ha)	0.094	<0.0001	0.0021
Cattle Performance	**Treatment**	**Year**	**Treatment by Year**
Avg Daily Gain (kg/day)	<0.0001	<0.0001	<0.0036
Gain/Hd (kg/hd)	<0.0001	<0.0001	<0.0077
Gain/Ha(kg/ha)	<0.0001	<0.0001	<0.86

‡SAS Mixed Procedure P<0.05

Table 3. Treatment effects on tallgrasses. Means are from yearly treatment means averaging together years 1989-1994. Means are from herbaceous components rated and clipped each fall of the stated years. Units are Kg Ha^{-1}‡. Treatment means followed by the same letter are not significantly different.

	YEAR
TREATMENT	**1989 – 1994**
Tebuthiuron No Fire	129.7
Tebuthiuron Plus Fire	342.1
Triclopyr No Fire	210.6
Triclopyr Plus Fire	367.9
No Herbicide, No Fire	29.4

‡SAS Mixed Procedure P<0.05

Table 4. Treatment effects on little bluestem. Table means are from yearly treatment means averaging together years 1989-1994. Means are from herbaceous components rated and clipped each fall of the stated years. Units are Kg Ha^{-1}‡. Treatment means followed by the same letter are not significantly different.

	YEAR
TREATMENT	**1989 – 1994**
Tebuthiuron No Fire	436.2b
Tebuthiuron Plus Fire	486.7b
Triclopyr No Fire	438.8b
Triclopyr Plus Fire	632.4a
No Herbicide, No Fire	165.6c

‡SAS Mixed Procedure P<0.05

Table 5. Effect of herbicide and burn treatments on forb production in the Cross Timbers. Significant treatment ($p<0.05$) by year interaction occurred in 1989, 1990, 1991, and 1992.

	YEAR					
TREATMENT	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**
Tebuthiuron No Fire	262.8a	40.5bc	78.3b	120.0bc	102.9ab	64.2a
Tebuthiuron Plus Fire	152.3b	354.4a	223.1a	330.8a	188.9a	70.8a
Triclopyr No Fire	303.1ab	124.6bc	42.0b	219.0ab	210.0a	23.0a
Triclopyr Plus Fire	190.2b	391.0a	337.0a	356.2a	189.8a	84.6a
No Herbicide, No Fire	73.2b	92.6bc	23.1b	63.7c	39.8b	6.7a

†Means followed by the same letter are not significantly different within same year
† SAS Mixed Procedure $P<0.05$

Table 6. Treatment effects on other grasses. Table means are from yearly treatment means averaging together years 1989-1994. Means are from herbaceous components rated and clipped each fall of the stated years. Units are Kg Ha^{-1}‡. Treatment means followed by the same letter are not significantly different.

	YEAR
TREATMENT	**1989 - 1994**
Tebuthiuron No Fire	800.3b
Tebuthiuron Plus Fire	982.3a
Triclopyr No Fire	570.8cd
Triclopyr Plus Fire	678.8bc
No Herbicide, No Fire	185.0e

‡SAS Mixed Procedure P<0.05

Table 7. Effect of herbicide and burn treatments on annual grass production in Cross Timbers. Significant differences due to treatment ($p<0.05$) were noted for 1989. This increased annual grass production from the Triclopyr+2, 4-D application the preceding year. No significant differences due to treatment were noted in annual grass production from 1990-1994.

	YEAR					
TREATMENT	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**
Tebuthiuron No Fire	86.0b	67.4a	5.0a	14.1a	19.9a	5.6a
Tebuthiuron Plus Fire	109.2b	58.9a	12.1a	14.6a	15.4a	38.1a
Triclopyr No Fire	137.1b	80.7a	9.5a	26.8a	3.8a	9.9a
Triclopyr Plus Fire	262.3a	52.5a	23.2a	10.3a	1.4a	4.0a
No Herbicide, No Fire	92.1b	32.0a	1.4a	3.6a	26.9a	9.8a

†Means followed by the same letter are not significantly different within same year
† SAS Mixed Procedure P<0.05

Table 8. Treatment effects on cattle average daily gain (kg $hd^{-1} day^{-1}$) over years 1985-1994. Weights were not sampled year 1992, as triclopyr treatments 3 and 4 were not grazed to allow fine fuel accumulation for 1993 prescribed fire application.

	YEAR								
TREATMENT	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1993**	**1994**
Tebuthiuron No Fire	0.81b	0.82b	0.72ab	0.55a	0.77b	0.75b	0.70ab	0.62bc	0.65ab
Tebuthiuron + Fire	0.93a	0.91a	0.81a	0.59a	0.81ab	0.88a	0.72a	0.69ab	0.71a
Triclopyr No Fire	0.81b	0.83b	0.71ab	0.54a	0.78ab	0.81ab	0.72a	0.77a	0.72a
Triclopyr + Fire	1.0a	0.88b	0.75a	0.57a	0.85a	0.88a	0.69ab	0.72a	0.66ab
No Herbicide, No Fire	0.76b	0.74b	0.64b	0.56a	0.77b	0.78b	0.62b	0.56c	0.62b

†Means followed by the same letter are not significantly different within same year
† SAS Mixed Procedure $P<0.05$

Table 9. Treatment effects on cattle gains per head (kg hd^{-1}) over years 1985-1994. Weights were not sampled year 1992, as treatments 3 and 4 were not grazed to allow fine fuel accumulation for 1993 prescribed fire application.

	YEAR								
TREATMENT	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1993**	**1994**
Tebuthiuron No Fire	125.1ab	128.1a	81.0ab	88.5a	76.8b	121.6c	115.4ab	98.5bc	89.8ab
Tebuthiuron + Fire	131.5a	140.3a	91.6a	95.7a	85.9ab	142.8a	118.2a	111.6ab	97.4ab
Triclopyr No Fire	127.2ab	129.1a	80.0ab	88.0a	79.3ab	131.8ab	118.8a	123.8a	100.0a
Triclopyr + Fire	137.4a	136.1a	84.8ab	91.1a	91.1a	143.1a	115.1ab	115.4a	91.8ab
No Herbicide, No Fire	116.4b	101.7b	72.7b	90.7a	85.7ab	126.5bc	103.4b	89.5c	85.6b

†Means followed by the same letter are not significantly different within same year
† SAS Mixed Procedure $P<0.05$

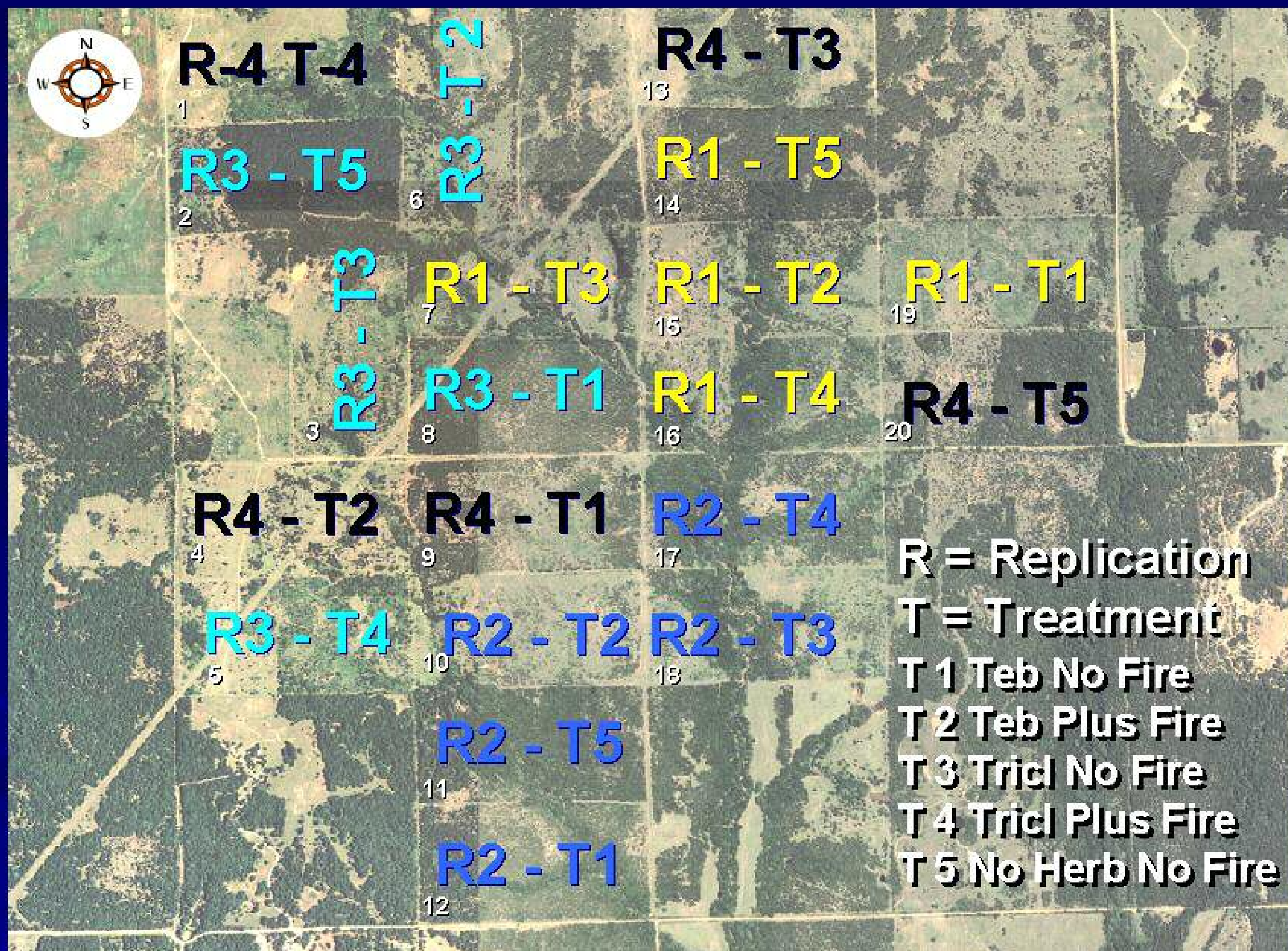
Table 10. Treatment effects on cattle gain, over years 1985-1994. Weights were not sampled year 1992, as triclopyr treatments 3 and 4 were not grazed to allow fine fuel accumulation for 1993 prescribed fire application. Treatment means followed by the same letter are not significantly different.

TREATMENT	ANNUAL GAINS kg/ha
Tebuthiuron No Fire	43.8bc
Tebuthiuron Plus Fire	51.7
Triclopyr No Fire	39.5
Triclopyr Plus Fire	47.6ab
No Herbicide, No Fire	21.1d

†Means followed by the same letter are not significantly different within same year
† SAS Mixed Procedure $P<0.05$

Figure 1. Aerial photo image of study area in northcentral Oklahoma (36º 03´ N; 97º 12´ W; elevation 331 m). Replication and treatment designations are included for reference. This image was taken after the study period (1994). Eastern redcedar and other woody plant cover differences can be noted in treatment units. Teb = Tebuthiuron, N-[5-(1,1-dimethylethyl)-1,3,4-thiadiazol-2-yl]-N,N-dimethylurea; Tricl = triclopyr, [(3,5,6-trichloro-2-pyridinyl)oxy] acetic acid.

CROSS TIMBERS EXPERIMENTAL RESEARCH RANGE (CTER)



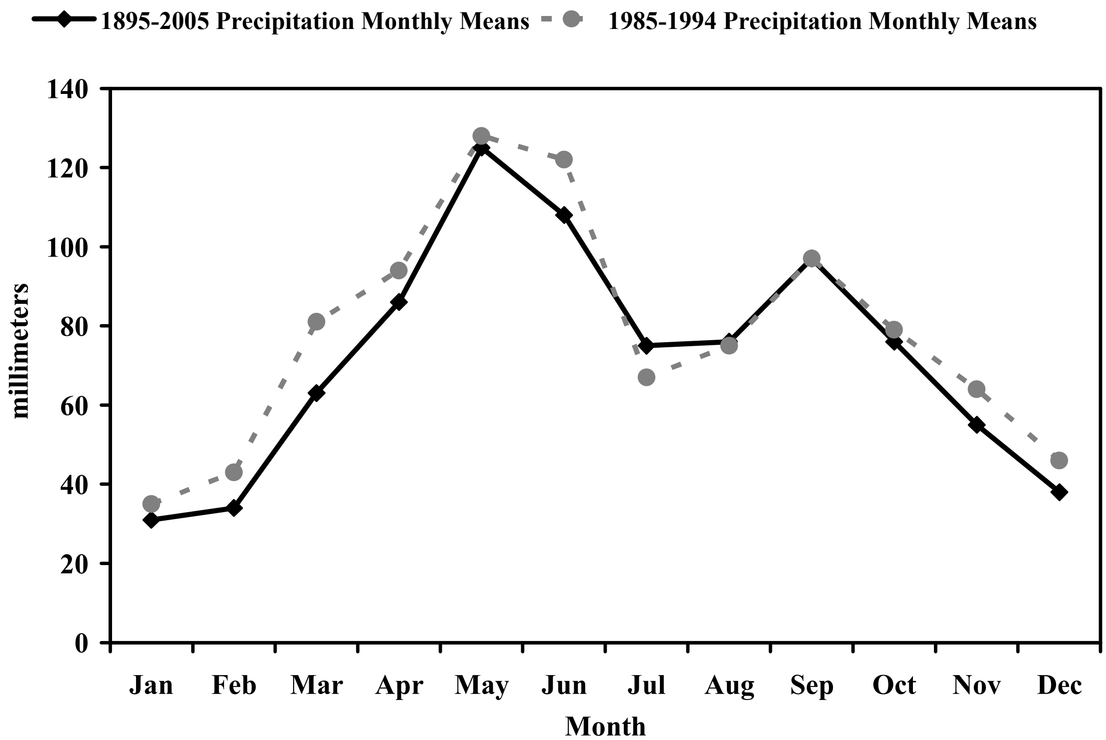


Figure 2. Comparison of monthly precipitation data from the actual study period (1985-1994) and a 110 year (1895-2005) monthly precipitation average. Precipitation during the study corresponded well with the long-term average.

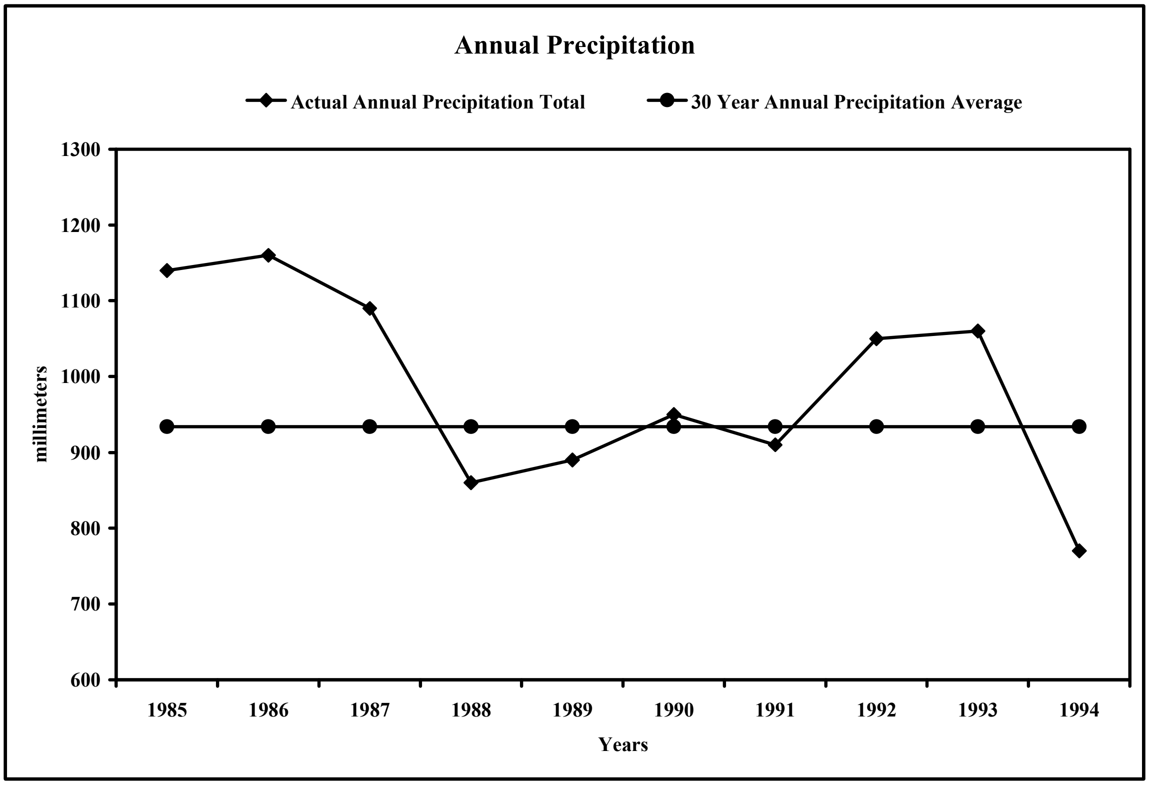


Figure 3. Actual annual precipitation data for the study period (1985-1994). The 30-year average is indicated on the figure (934 mm). Only four years (1988, 1989, 1991, 1994) were below the average precipitation for the area.

VITA

Kenneth Arnold Nelson

Candidate for the Degree of

Master of Science

Thesis: FIRE, HERBICIDES, AND GRAZING IN THE CROSS TIMBERS

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Title of Study: FIRE, HERBICIDES, AND GRAZING IN THE CROSS TIMBERS

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Scope and Method of Study: Effects of fire, herbicide, and grazing on cattle weight gain and plant community production in the Cross Timbers of Oklahoma. were studied. Tebuthiuron and triclopyr were applied alone and in combination with fire in 1983. Cattle began grazing in 1984. The burned pastures were strip head fired in late spring of 1985 to 1987, thereafter, prescribed fire treatments were applied every three years. Cattle weight gains and residue of various plant community components were quantified yearly.

Findings and Conclusions**:** Responses of all vegetation components to various herbicide and fire combinations varied among years and treatments. The absence of management in the no herbicide no fire treatment resulted in reduced production. Results suggest absence of fire had a limiting effect on animal and forage production. The absence of applied management practices in a livestock production system within Cross Timbers will result in a reduction in forage production limiting cattle gain.

Nomenclature: Tebuthiuron, N-[5-(1,1-dimethylethyl)-1,3,4-thiadiazol-2-yl]-N,N-dimethylurea; triclopyr, [(3,5,6-trichloro-2-pyridinyl)oxy]acetic acid.

Keywords: Tebuthiuron., triclopyr, understory, overstory, prescribed burning, hardwood forest.

Advisor's Approval: Dr. Karen R. Hickman