

# Mesquite Cover Responses in Rotational Grazing/ Prescribed Fire Management Systems: Landscape Assessment Using Aerial Images

R. J. Ansley<sup>1</sup>  
W. E. Pinchak<sup>2</sup>  
W. R. Teague<sup>3</sup>

**Abstract:** Prescribed fire is used to reduce rate of mesquite (*Prosopis glandulosa*) encroachment and dominance on grassland ecosystems, but is difficult to apply in continuous-grazed systems because of the difficulty in accumulating sufficient herbaceous biomass (that is, 'fine fuel') that is needed to fuel fire. We evaluated the potential of rotationally grazing cattle as a means to defer grazing to provide fine fuel burning. Mesquite cover changes from 1995 to 2000 were compared in four systems: continuous grazing, mesquite untreated (Cont.), 4 pasture/1 herd with fire (4:1F), 8 pasture/1 herd with fire (8:1F), and 4:1 with fire + herbicide (4:1F+H). There were two replicate systems per treatment, each 1,400-2,100 ha. The initial goal in the 4:1F and 8:1F systems was to burn 25 percent of the total area each year (1 pasture in 4:1F; 2 pastures in 8:1F). Fires were conducted in late winter. Mesquite cover was measured using digitized aerial images in 1995 (pre-treatment) and 2000. Droughts limited burning over this 5-year period to half the intended area of each system. Stocking rates, while adjusted in response to droughts, were maintained at similar levels in all systems. Net change in mesquite cover, scaled to account for soil types and pasture sizes in each system, was +34 percent, +15 percent, +5 percent, and -41 percent in the Cont., 4:1F, 8:1F, and 4:1F+H systems, respectively. Cattle performance was similar for all systems during the study period. Rotational grazing and fire systems slowed the rate of mesquite cover increase but did not reduce it. Fire was easier to apply in the 8:1F than the 4:1F system during drought because total area burned could be reduced to 1/8 instead of 1/4 of the system.

## Introduction

Prescribed fire is an attractive option for reducing mesquite dominance on grasslands because it is less costly than other options and reduces the need for chemical and/or mechanical applications (Wright and Bailey 1982; Teague and others 1997; Ansley and Jacoby 1998). However, for fire to be an effective method for mesquite control, a grazing management strategy must be devised to accumulate the herbaceous biomass (otherwise called 'fine fuel') that fuels a fire. Moreover, because fire kills very few mesquite and only provides a 'top-killing' suppression effect at best (Ansley and others 1998; Ansley and Jacoby 1998), a management system must allow for frequent planned burning (at least every 8 to 10 years) to maintain sufficient suppression of mesquite regrowth.

It is difficult in continuous-grazed systems to accumulate sufficient herbaceous fine fuel to carry a fire of sufficient intensity to suppress woody vegetation. Prescribed burning may be more easily incorporated into systems using one-herd and multiple-paddocks (Scifres and Hamilton 1993). Using such management systems, we hypothesized that fire could be applied every 4 to 6 years and that the deferral period required to accumulate fuel could be 'internalized' within a management system by burning a small percentage of the system each year and rotating burning each year to different paddocks. Not

burning riparian vegetation and burning to create a savanna effect in selected areas on a site specific basis allowed for maintenance of wildlife habitat and biodiversity that did not impact livestock operations (Teague and others 1997).

Our objectives were to (1) evaluate the utility of rotational grazing and deferment as a means of facilitating use of prescribed fire for mesquite suppression through the accumulation of herbaceous fine fuel, and (2) determine system-level changes in mesquite cover in different rotational grazing and fire/herbicide management scenarios. Mesquite aerial cover was used as an indicator of level of mesquite dominance in the each system.

## Methods

### *Site Description*

The investigation was conducted in the Rolling Plains in north central Texas on a 14,400 ha portion of the W.T. Waggoner Estate termed the "Kite Camp." The climate is continental with an average 220 frost-free growing days. Mean annual precipitation is 648 mm, bimodally distributed with peaks in May and September. The mean annual temperature is 17°C and elevation ranges from 335 m to 396 m.

In: Sosebee, R.E.; Wester, D.B.; Britton, C.M.; McArthur, E.D.; Kitchen, S.G., comp. 2007. Proceedings: Shrubland dynamics—fire and water; 2004 August 10-12; Lubbock, TX. Proceedings RMRS-P-47. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 173 p.

Mesquite trees with aerial cover of 15 to 20 percent dominated the vegetation matrix. The herbaceous understory consisted of roughly an equal mixture of C<sub>4</sub> and C<sub>3</sub> perennial grasses. The major C<sub>4</sub> grasses are shortgrass buffalograss (*Buchloe dactyloides*), and mid-grasses sideoats grama (*Bouteloua curtipendula*), silver bluestem (*Bothriochloa saccharoides*), and meadow dropseed (*Sporobolus asper*). Mid-grass Texas wintergrass (*Nassella leucotricha*) and the annual grass, Japanese brome (*Bromus japonicus*), are the major C<sub>3</sub> grasses. Soils are variable on the Kite Camp with approximately 50 percent shallow clays (3 to 8 percent slopes), 40 percent moderately deep clay-loams (1 to 3 percent slopes), and 10 percent deep loamy bottomlands in riparian zones (0 to 1 percent slopes). The clay-loam areas are where mesquite size, density, and cover are greatest and pose the greatest problems for livestock management.

### Mesquite Treatments

The experiment consisted of four treatments with two replicate pastures of 1,400 to 2,100 ha each per treatment. Initial treatments were (1) continuous grazing with no mesquite treatment, (2) a 4-pasture, 3-herd rotation where one pasture was burned each year (4:3F), (3) a 4-pasture, 1-herd rotation where one pasture was burned each year (4:1F), and (4) an 8-pasture, 1-herd rotation where two pastures were burned each year (8:1F). A total of 34 paddocks were involved in the study (2 in continuous, 8 in 4:3s, 8 in 4:1s, 16 in 8:1s). Area of paddocks within each system were not exactly the same but were roughly 25 percent of the total area in four pasture systems and 12.5 percent of the total area in eight pasture systems. Paddocks were fenced in 1995 and first burns were conducted in January-March 1996. Fires were applied as headfires that were burned into pre-burned blacklines (50 m wide) according to procedures outlined by Wright and Bailey (1982).

In the fire-based systems, the goal was to burn a different 25 percent of the area of each system each year. Burns were conducted in winter months (January to March) and were planned as high-intensity mesquite top-killing fires to maximize mesquite suppression. To accumulate herbaceous fuel on the 25 percent to be burned, cattle were rotationally grazed on the remaining 75 percent of each system for 4 to 6 months *without* a reduction in stocking rate determined for the entire system. Thus, costs of deferral were internalized. Fire was to be used when average or above-average precipitation resulted in sufficient fine fuel (> 1,500 kg ha<sup>-1</sup>) to suppress mesquite. During drought years deferred pastures were not burned but grazed as needed.

A severe spring drought following 1996 fires forced us to discontinue the 4:3 system and in 1998 these pastures were converted to 4:1 systems with herbicide as the method of mesquite control. These paddocks had an initial fire in one paddock in 1996 and herbicide aerial spray in the other paddocks in 1999 (0.28 kg/ha clopyralid+0.28 kg/ha triclopyr; see Ansley and others 2003). This treatment was designated as 4:1 fire+herbicide (4:1F+H). Herbicide spray was

concentrated on the clay loam soils where mesquite cover was greatest. Most of the mesquite on shallow soils was not sprayed because of light cover and density.

Livestock were managed in each pasture as a cow-calf operation (Hereford breed). Cattle stocking rates were maintained at similar levels in all systems throughout the study and were initially set at 7 ha per cow in 1995. Rates were reduced to 11 ha per cow in 1996 and 14 ha per cow by 2001 following several droughts.

### Mesquite Cover Quantification

Color infrared (CIR) aerial images of Kite Camp (1:7,000) were taken in October 1995 and September 2000. Images were scanned and geo-referenced in Arcview GIS using ortho-quads available from the USGS (Ansley and others 2001). Green vegetation appears as varying shades of pink or red on CIR images. Normally, on late summer/early fall images, mesquite canopies appear as a bright pink color and the herbaceous understory is light gray. However, because of well-above average precipitation, herbaceous vegetation remained green throughout 1995 and it was not possible to use the automated color classification system within ArcView to digitally separate mesquite cover from understory vegetation because both vegetation types had similar shades of pink. We could visually discern individual mesquite canopies from the understory, however, because canopy margins cast a small shadow. Therefore, mesquite cover was quantified on the images using a variation of the line intercept technique (Canfield 1941). Two 1 ha (100 x 100 m) plots each were randomly located on clay loam and shallow soil types on images of each paddock of each system. Ten parallel computer generated lines, each scaled at 100 m length, were placed in each 1 ha plot and mesquite canopy intercept was measured manually along each line using the distance measure feature in Arcview (after Ansley and others 2003). Cover values from images were verified with field transects ( $r^2 = 0.94$ ;  $\hat{y} = 0.97x - 0.98$ ;  $n = 12$ ). The same process was used for images taken in 2000, although color separation between mesquite canopies and understory was very good. Cover was determined on 1,360 separate 100 m transect lines (34 paddocks x two soil types/paddock x two 1-ha plots/soil type x 10 lines/plot); far more than would be possible using field measurements.

Plot-level changes in mesquite cover were scaled to the system (pasture) level for each system (4:1, 8:1, etc). Scale factors were percent area of each soil type (shallow or clay loam) in each paddock and percent area of each paddock relative to the total area of each system. Riparian areas were excluded from the analysis.

### Statistical Analysis

Mesquite percent change values relative to pre-treatment levels were analyzed using a completely randomized design with treatment (Continuous, 4:1F, 8:1F and 4:1F+H) or paddock (1-4 or 1-8) as the main effect (two replicates per treatment or paddock) (SAS 1988). Percentage data were

arc-sine transformed prior to analysis. Means were separated using LSD ( $P < 0.05$ ).

## Results and Discussion

### Precipitation and Fire History

The 1995 growing season (March-October) was much wetter than average, followed by an extremely dry period from November 1995 through June 1996 (fig. 1). Severe growing season droughts were experienced in 1996, 1998, and 2000. The years 1997 and 1999 had key periods during each growing season when precipitation was less than average and, with the exception of the July-August period in 1997, there was no 2-month period from 1996 through 2000 when precipitation during the growing season was much above average.

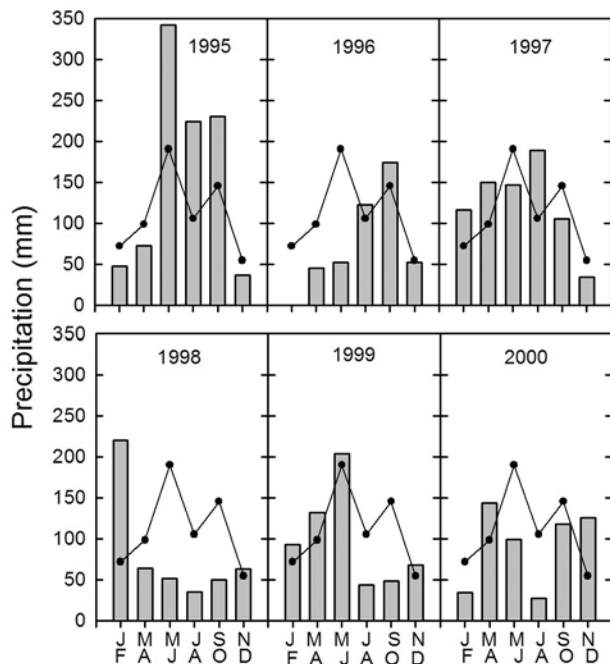
A burn ban due to drought during most of February-March 1996 limited burning to five of the eight paddocks that were scheduled to burn. One paddock in the remaining unburned pasture was burned in 1997 to equalize replicates so that one paddock had been burned in every system. Droughts in 1996 and 1998 reduced grass production, which limited the number of paddocks that were burned to 14 of the original 36 that were planned (table 1).

With the exception of the 1996 fires, droughts also limited the intensity of fires because of low herbaceous fine fuel amounts. In addition, intensity of the 1998 fires was limited because a wet and warm January-February 1998 increased  $C_3$

grass growth and green tissue content in the fine fuel retarded combustion. Of the 14 fires conducted, 6 had high (60 to 90 percent), 4 had moderate (40 to 60 percent), and 4 had poor (10 to 40 percent) levels of mesquite top-kill (table 2). As expected, none of the fire treatments killed more than 2 percent of the mesquite and most plants re-sprouted from stem bases following top-killing fires. The herbicide treatments root-killed over 60 percent and top-killed nearly 100 percent of the mesquite plants. Herbicide results were viewed as typical for this mixture (Ansley and others 2003; Mitchell and others 2004). Detailed summaries of herbaceous vegetation responses and cattle performance are available elsewhere (Teague and others 2001a).

### Mesquite Cover Changes Within Each Soil Type

In continuous-grazed, untreated systems, mesquite cover increased on clay loam soils from 22.3 to 35.6 percent from 1995 to 2000, an increase of 13.3 percentage units, or 2.7 percentage units per year. This is a slightly faster rate of cover increase than the 2.2 percentage unit per year rate that Ansley and others (2001) found over a 20-year period on a clay loam site near the current study area. On shallow soils in the continuous-grazed, untreated systems, mesquite cover increased from 5.8 to 6.9 percent from 1995 to 2000, or 0.2 percentage units per year. Mesquite cover was not high on shallow soils at study initiation and did not increase at a rate that was considered a management problem. However,



**Figure 1.** Bi-monthly precipitation at the research site from 1995-2000. Line indicates 30-yr average precipitation for each 2-month period.

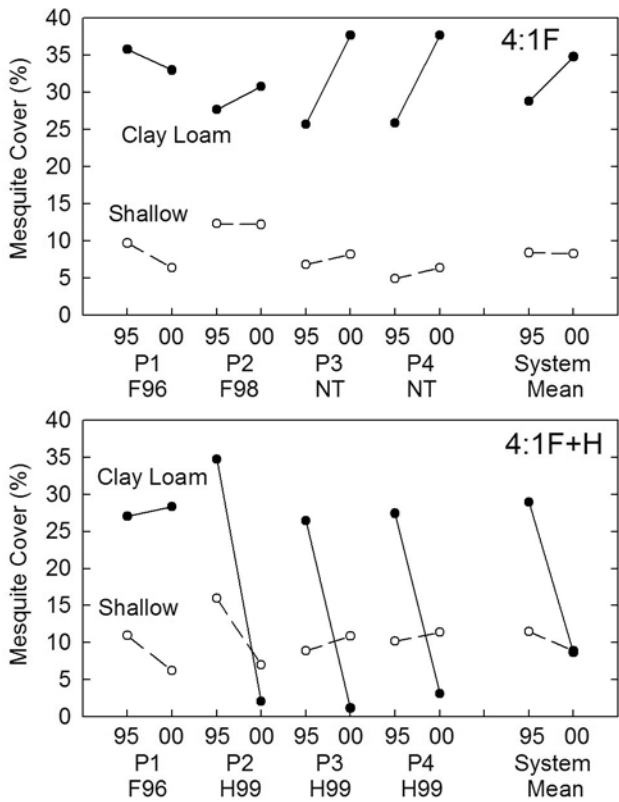
**Table 1.** Planned burns vs. completed burns on the Kite Camp study, 1996-2000.

Burn dates	Paddocks planned to burn	Paddocks burned	Comments
Jan-March 1996	8	5	Burn ban Feb-March
Jan-March 1997	8	1	1996 drought - low fine fuel
Jan-March 1998	8	6	Feb - March very wet, green
Jan-March 1999	6	0	1998 drought - low fine fuel
Jan-March 2000	6	2	High <i>Opuntia</i> ; low fuel in one
1996 - 2000	36	14	

<sup>1</sup> Planned burns were reduced from eight to six in 1999 because two systems were changed from fire to herbicides as the means for mesquite control.

**Table 2.** Effectiveness of prescribed fires on mesquite topkill, Kite Camp.

Burn year	Good topkill 60 - 90 %	Moderate topkill 40 - 60 %	Poor topkill 20 - 40 %
1996	4	1	0
1997	0	1	0
1998	1	2	3
2000	1	0	1
<b>1996-2000</b>	<b>6</b>	<b>4</b>	<b>4</b>



**Figure 2.** Mesquite cover from 1995 to 2000 within each paddock (P) and soil type (clay loam = solid; shallow = open) and the mean of all four paddocks in 4:1F (top) and 4:1F+H (bottom) systems (n = 2). F = fire, H = herbicide, NT = no treatment.

mesquite did attain a level of dominance on clay loam soils over the 5-year period of the study that was of considerable management concern. Ansley and others (2004) found on a clay loam site near the current study site that mesquite cover did not reduce  $C_4$  midgrass production until it was greater than 25 percent. However, at that point  $C_4$  midgrass production declined sharply to levels that were 25 percent of the maximum recorded values ( $50 \text{ g m}^{-2}$  vs  $200 \text{ g m}^{-2}$ ). Thus, an increase in mesquite cover on clay loam soils in the present study from 22 to 36 percent would be expected to reduce  $C_4$  midgrass production to a much greater degree in 2000 than in 1995, assuming similar climatic conditions.

Increases in mesquite cover in untreated paddocks of the 4:1F systems followed a similar pattern as that of the continuous-grazed, untreated systems (fig. 2). In untreated paddocks 3 and 4, cover increased slightly on shallow soils and from about 26 percent to 38 percent on clay loam soils. Responses were similar on each soil type in untreated paddocks of the 8:1F systems (data not shown). Thus, the type of grazing pattern (continuous, 4:1 or 8:1) did not appear to affect the rate of mesquite cover increase on either soil type if mesquite was left untreated. Thus, rotational grazing alone (that is, without fire or some other mesquite treatment) did not increase the competitive ability of the herbaceous community to slow the rate of mesquite canopy growth, as measured by aerial cover.

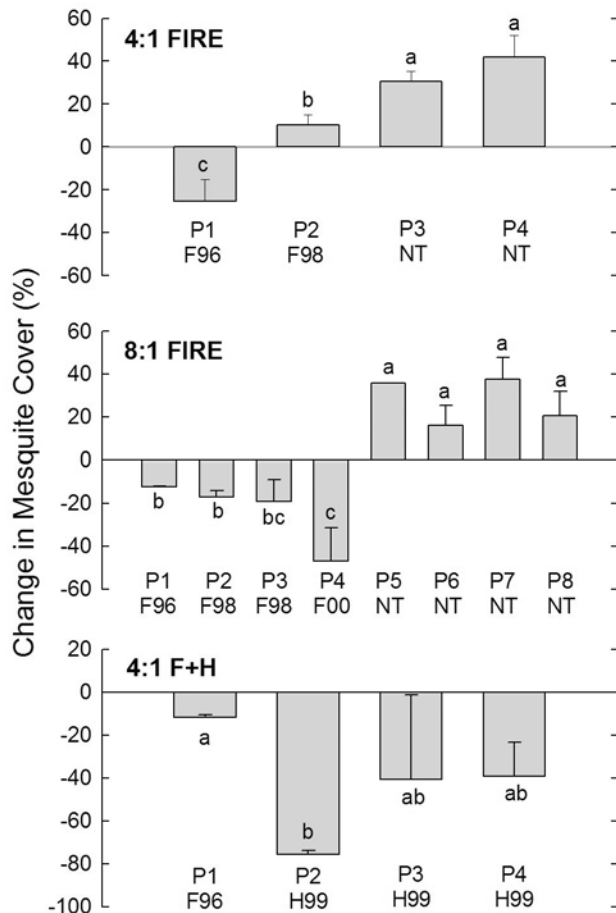
In treated paddocks in each system, mesquite cover changes on each soil type varied considerably with treatment type

and/or intensity. In the 4:1F systems, paddocks 1 and 2 were burned in 1996 and 1998, respectively. The 1996 fire, which was very intense, initially reduced mesquite cover on clay loam soils from 36 percent to less than 10 percent (data not shown). However, by 2000, mesquite cover had increased due to mesquite regrowth to levels that were only slightly lower than in 1995 on both soil types (fig. 2). The 1998 fires were much less effective in top-killing mesquite than the 1996 fires. As a result, by 2000, mesquite cover had increased on clay loam soils to levels that were greater than the initial level of 27 percent. This was a slower rate of increase than what was found in the untreated paddocks 3 and 4, however. Clearly, the fires reduced the rate at which mesquite cover increased. Averaged over the four paddocks in the 4:1F systems, cover increased on clay loam soils from 29 to 35 percent and did not change on shallow soils (fig 2). Averaged over the eight paddocks in the 8:1F systems, cover increased on clay loam soils from 32 to 35 percent and did not change on shallow soils (data not shown in a figure).

In the 4:1F+H systems, the 1996 fire in paddock 1 of each replicate yielded a similar result as found for paddock 1 in the 4:1F systems (fig. 2). The other three paddocks were treated with herbicides in 1999 that reduced mesquite cover on clay loam soils to < 5 percent. Much of the mesquite that occurred on shallow soils was not sprayed because of light cover and density. When averaged over the four paddocks, mesquite cover in the 4:1F+H systems was reduced from 30 percent to 9 percent on clay loam soils and from 12 to 8 percent on shallow soils. These results agree with what other studies have found for this clopyralid+triclopyr treatment (Ansley and others 2003; Mitchell and others 2004). This treatment is not only effective at reducing mesquite cover but also reduces mesquite density (root-kill is usually 60 to 70 percent) and has a treatment life of > 20 years (Ansley and others 2004). However, typical cost for this treatment is \$25 per acre compared to \$2 to 3 for fire (Teague and others 2001b).

### Scaling Mesquite Cover Responses Over Soil Types

Following scaling mesquite cover changes over both soil types in each paddock, the 1996 fires (paddock 1) were the only treatment in the 4:1F systems that reduced mesquite cover from 1995 to 2000 (fig. 3). Cover increased in the other three paddocks but at a slower rate in paddock 2 due to the 1998 fires. In contrast, the four paddocks that received prescribed fire in the 8:1F systems all yielded lower mesquite cover in 2000 than 1995. In this treatment, the most recent fires were in the year 2000 (paddock 4) just 8 months prior to the date of the 2000 CIR images. We were unable to burn in the 4:1F systems after 1998 because droughts prevented grazing deferral on 25 percent of the system. The remaining 75 percent of the system simply could not sustain the herd for any length of time even though stocking rates had been reduced for each system. We were able to burn one paddock in each of the 8:1 systems in 2000 because we could defer grazing in 1/8 of the area of each system and rotate the herd on the remaining 7/8 of the area.

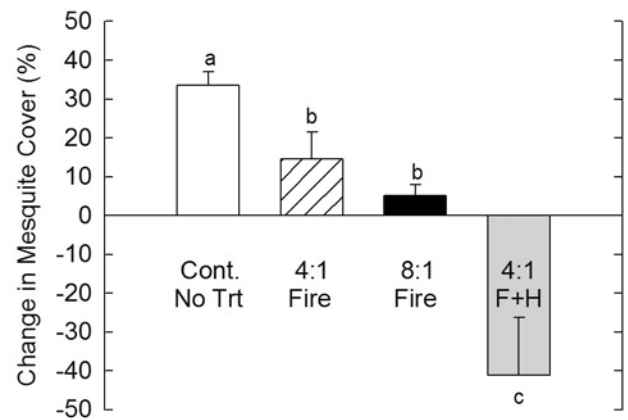


**Figure 3.** Percent change in mesquite cover from 1995 to 2000 within each paddock (P) in 4:1F, 8:1F, and 4:1F+H systems when scaled over both soil types. Error bars indicate  $\pm 1$  S. E. (n = 2). Means with similar letters are not significant at  $P < 0.05$ .

In the 4:1F+H systems, mesquite cover decreased from 1995 to 2000 in all four paddocks (fig. 3) due to the intense fire in 1996 (paddock 1) and the herbicide treatments in the other three paddocks. The reason mesquite cover reduction was greater in paddock 2 than paddocks 3 and 4 was because there was more clay loam soil in paddock 2 and therefore more area was sprayed. Paddocks 3 and 4 had a high percentage of shallow soils.

### Scaling Mesquite Cover Changes Over Soils and Paddocks

Net change in mesquite cover, when scaled over soil type and area of each paddock within each system, was +34 percent, +15 percent, +5 percent, and -41 percent in the Continuous, 4:1F, 8:1F, and 4:1F+H systems, respectively (fig. 4). Mesquite cover was reduced only in the fire+herbicide system during the period of the study. However, the rate of system-level increases in mesquite cover were much lower in the 4:1F and 8:1F systems compared to the continuous grazed, untreated systems. In addition system-level increases in mesquite cover were slower in the 8:1F than the 4:1F systems.



**Figure 4.** Percent change in mesquite cover from 1995 to 2000 within each management system when scaled over area per paddock in each system and area per soil type within each paddock. Error bars indicate  $\pm 1$  S. E. (n = 2). Means with similar letters are not significant at  $P < 0.05$ .

## Conclusions

Rotational grazing and fire systems (4:1F and 8:1F) slowed the rate of increases in mesquite cover but did not reduce it within the time-frame of this study. Severe droughts in 1996, 1998, and 2000 limited burning to only 14 paddocks in 5 years compared to the original goal of 36. It should be noted, however, that, while we did not conduct the number of fires intended over the scheduled time frame, we were able to conduct more fires during these periods of severe drought than any ranch in the region. This was attributed to the utilization of rotational grazing systems. As a result, increases in system-level mesquite cover were lower in both fire-only systems compared to the untreated system.

System-level rate of mesquite cover increase was slower in the 8:1F than the 4:1F systems. We believe that one of the most significant discoveries in this study was that fire was easier to apply in the 8:1F than the 4:1F systems during droughts because the area deferred and burned could be reduced to 1/8 (that is, one paddock) instead of 1/4 of the total area of the system. Eight paddocks provided more flexibility for burning in drought years than did four paddock systems.

Mesquite cover was reduced to a much greater degree in the fire+herbicide systems than the two fire-only systems. We believe the fire-only systems would have been more effective at suppressing mesquite had precipitation been near average. One of the advantages of the herbicide option is that, unlike prescribed fire, it requires virtually no pre-planning and is not as dependent as is a fire plan on long-term weather patterns. However, typical cost for this treatment is \$25 per acre compared to \$2-3 for fire (Teague and others 2001b).

## Acknowledgments

The authors wish to acknowledge Kelli Barnett and Betty Kramp who quantified mesquite cover on the aerial images.

David Jones, Betty Kramp, Gerral Schulz, Steve Dowhower, Tim Tunnell, Matt Angerer, Doug Tolleson, Bob Cross, and many others assisted with the prescribed fires. This research was funded by grants from USDA-NRI Managed Ecosystems, Dow AgroSciences, Indianapolis, IN, and the North Texas Brush Control Association, Albany, TX. The E. Paul and Helen Buck Waggoner Foundation, Vernon, TX, provided significant funding, land area, and cattle for the project and Waggoner Ranch personnel assisted with all phases of live-stock handling.

## References

- Ansley, R. J.; Jones, D. L.; Tunnell, T. R.; Kramp, B. A.; Jacoby, P. W. 1998. Honey mesquite canopy responses to single winter fires: relation to fine fuel, weather and fire temperature. *International J. Wildland Fire*. 8: 241-252.
- Ansley, R. J.; Jacoby, P. W. 1998. Manipulation of fire intensity to achieve mesquite management goals in north Texas. Pages 195-204. In: Pruden, T. L.; Brennan, L. A. (eds). *Fire in Ecosystem Management: Shifting the Paradigm from Suppression to Prescription*. Tall Timbers Fire Ecology Conf. No. 20. Tall Timbers Research Station, Tallahassee, FL.
- Ansley, R. J.; Wu, X. B.; Kramp, B. A. 2001. Observation: Long-term increases in mesquite canopy cover in a north Texas savanna. *Journal of Range Management*. 54: 171-176.
- Ansley, R. J.; Kramp, B. A.; Jones, D. L. 2003. Converting mesquite thickets to savanna through foliage modification with clopyralid. *Journal of Range Management*. 56: 72-80.
- Ansley, R. J.; Teague, W. R.; Pinchak, W. E.; Kramp, B. A.; Jones, D. L. 2004. Long-term grass yields following chemical control of honey mesquite. *Journal of Range Management*. 57: 49-57.
- Archer, S.; Schimel, D. S.; Holland, E. A. 1995. Mechanisms of shrubland expansion: land use, climate or CO<sub>2</sub>? *Climatic Change*. 29: 91-99.
- Bedunah, D. J.; Sosebee, R. E. 1984. Forage response of a mesquite-buffalograss community following range rehabilitation. *Journal of Range Management*. 37: 483-487.
- Blackburn, W. H.; Tueller, P. T. 1970. Pinyon and juniper invasion in black sagebrush communities in east-central Nevada. *Ecology*. 51: 841-848.
- Canfield, R. H. 1941. Application of line interception in sampling range vegetation. *Journal of Forest*. 39: 388-394.
- Carlson, D. H.; Thurow, T. L.; Knight, R. W.; Heitschmidt, R. K. 1991. Effect of honey mesquite on water balance of Texas Rolling Plains rangeland. *Journal of Range Management*. 43: 491-496.
- Dahl, B. E.; Sosebee, R. E.; Goen, J. P.; Brumley, C. S. 1978. Will mesquite control with 2,4,5-T enhance grass production. *Journal of Range Management*. 31:129-131.
- Koos, W. M.; Williams, J. C.; Dixon, M. L. 1962. Soil survey of Wilbarger County, Texas. USDA Soil Conservation Service, Soil Survey Series 1959 No. 18, Fort Worth, TX.
- Kramp, B. A.; Ansley, R. J.; Tunnell, T. R. 1998. Survival of mesquite seedlings emerging from cattle and wildlife feces in a semi-arid grassland. *The Southwestern Naturalist*. 43: 300-312.
- Mitchell, R.; Whisenant, S.; Sosebee, R. 2004. A paradigm shift. Chap. 6, pages 67-75. In: W. T. Hamilton and others (Editors), *Brush Management—Past, Present and Future*. Texas A&M University Press, College Station, TX.
- SAS. 1988. SAS/STAT User's Guide Version 6.03, SAS Inst., Inc., Cary, N.C.
- Scifres, C. J.; Hamilton, W. T. 1993. Prescribed burning for brushland management: The south Texas example. Texas A&M Press, College Station, Texas.
- Teague, R.; Borchart, R.; Ansley, J.; Pinchak, B.; Cox, J.; Foy, J.; McGrann, J. 1997. Sustainable management strategies for mesquite rangeland: the Waggoner Kite project. *Rangelands* 19: 4-8.
- Teague, W. R.; Ansley, R. J.; McGrann, J. M.; Pinchak, W. E. 2001a. Developing sustainable grazing management strategies for mesquite rangeland. Pages 493-502. In: *Proceedings: First National Conference on Grazing Lands—Heightening the Awareness of the Economic and Environmental benefits of Grazing Lands*, Las Vegas, Nevada, 5-8 Dec. 2000.
- Teague, W. R.; Ansley, R. J.; Kreuter, U. P.; Pinchak, W. E.; McGrann, J. M. 2001b. Economics of managing mesquite in north Texas: a sensitivity analysis. *J. Range Management* 54: 553-560.
- Wright, H. A.; Bailey, A. W. 1982. *Fire ecology—United States and southern Canada*. Wiley-Interscience, John Wiley & Sons, New York.

## The Authors

<sup>1</sup> Professor of Rangeland Shrub and Fire Ecology, Texas Agricultural Experiment Station, Vernon, TX. r-ansley@tamu.edu

<sup>2</sup> Professor of Range Animal Nutrition, Texas Agricultural Experiment Station, Vernon, TX.

<sup>3</sup> Professor of Rangeland Ecology, Texas Agricultural Experiment Station, Vernon, TX.