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Vegetation response to stocking rate in southern mixed-grass prairie

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Abstract

Stocking rate directly influences the frequency and intensity of defoliation of individual plants which, in turn, impacts energy flow and plant succession in grazed ecosystems. The objective of this study was to determine the effect of stocking rate on standing crop dynamics and plant species composition of a southern mixed-grass prairie over a 7-year period (1990 through 1996). Long-term (30-year) mean precipitation has been 766 mm per year. Growing conditions were generally favorable for the study period. Yearling cattle (initial weight 216 kg, SD = 12 kg) grazed at 6 stocking rates, ranging from 23 to 51 AUD ha^{-1}, from 14 April to 24 September (162 days). The currently suggested year-long stocking rate is 25 AUD ha^{-1}. Herbage standing crop was measured in July and September every year while species composition was determined in July in even years. Total and dead standing crop declined as stocking rate increased but live standing crop was not related to stocking rate. Slopes of regression lines relating standing crop and stocking rate were constant over years, indicating no response for plant productivity. The major vegetation components, sideoats grama [*Bouteloua curtipendula* (Mich.) Torr.], shortgrasses, and forbs were not affected by stocking rate over years. Tallgrasses responded by increasing at the lower stocking rates over the study period. However, these grasses contributed less than 5% of the total standing crop. Red and purple threeawn (*Aristida longiseta* Steud. and *A. purpurea* Nutt.) increased at all stocking rates from 1990 to 1996 but the increase was greater at the lower stocking rates. This mixed-grass vegetation showed little response to stocking rate over the 7-year study period. The vegetation may have been in equilibrium with previous heavy stocking rates so that little change would be expected at those rates. Increases in grazing sensitive species at lighter stocking rates may occur over longer time intervals.

Resumen

La carga animal influye directamente en la frecuencia e intensidad de defoliación de las plantas individuales, lo cual a su vez, impacta en el flujo de energía y la sucesión vegetal de los ecosistemas bajo apacentamiento. El objetivo de este estudio fue determinar, durante un período de 7 años (1990 a 1996), el efecto de la carga animal en la dinámica de la producción de forraje en pie y la composición botánica de un pradera de zacates mixtos del sudeste. La media de precipitación a largo plazo (30 años) ha sido de 766 mm por año. Durante el período de estudio, las condiciones de crecimiento para las plantas generalmente fueron favorables. Ganado de año (peso inicial 216 kg, SD = 12 kg) apacentó bajo seis cargas animal que variaron de 23 a 51 UAD ha^{-1}, el período se apacentamiento fue del 14 de Abril al 24 de Septiembre (162 días). La carga animal que actualmente se recomienda es de 25 UAD ha^{-1}. La producción de forraje en pie se midió en Julio y Septiembre de cada año, mientras que la composición botánica se determinó cada dos años en Julio. La cosecha total de forraje en pie y la cantidad de forraje muerto disminuyó conforme la carga animal aumento, pero el forraje vivo en pie no se relaciono con la carga animal. Las pendientes de las líneas de regresión que relacionan la cosecha en pie y la carga animal fueron constantes a través de los años, indicando una falta de respuesta en la productividad de las plantas. Los componentes principales de la vegetación, "Sideoat grama" [Bouteloua curtipendula (Mich.) Torr.], zacates cortos y hierbas no fueron afectados por la carga animal a través de los años. Durante el período de estudio, los zacates altos respondieron incrementandose en las cargas animal bajas. Sin embargo, estos zacates contribuyeron con menos del 5% del total de forraje en pie. Los zacates "Red threeawn"y "Purple threeawn" (*Aristida longiseta* Steud. y *A. Purpurea* Nutt.) se incrementaron en todas las cargas animal evaluadas, pero el aumento fue mayor en las cargas animal bajas. La vegetación de zacates- mixtos mostró poca respuesta a la carga animal durante el período de estudio de 7 años. La vegetación pudo haber estado en equilibrio con cargas animal altas previas al periodo de estudio de tal manera que se esperarían solo cambios menores con las cargas animal altas. El aumento de especies sensitivas a la carga animal que se registró con cargas animal bajas puede ocurrir en períodos de tiempo mas largos.

Key Words: standing crop, plant succession, grazing impacts, *Bouteloua, Aristida*

Vegetation dynamics on Great Plains grasslands are a function of grazing, fire, climate, and soils. Of these factors, managers can exert a major influence on grazing and fire. Over the great majority of these grasslands, grazing is currently the primary management factor. The fundamental principle of grazing management is to control the frequency and intensity of defoliation of individual

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plants (Heitschmidt and Walker 1996). The primary method for controlling the frequency and intensity of defoliation has been to control the stocking rate or the number of animals present per unit land area for a specified time.

Mixed-grass vegetation in west central Kansas changed considerably as stocking rate increased (Launchbaugh 1967) but little change was observed in western Nebraska (Burzlaff and Harris 1969). Differences between studies can be attributed to weather, the levels of stocking rate included, the length of the study, and the particular mix of plant species at a location (Hart and Norton 1988). If the range of stocking rates is wide enough in mixed prairie, midgrasses are generally more abundant at lower stocking rates while shortgrasses are more abundant at higher stocking rates (Launchbaugh 1967, Sims et al. 1976, Thurow et al. 1988, Fuhlendorf and Smeins 1997). The specific objective of this study was to measure the effect of cattle stocking rate on standing crop dynamics and species composition of a southern mixed-grass prairie.

Materials and Methods

Study Area

The study area is located 15 km southwest of Clinton, Okla. on the Marvin Klemme Range Research Station (35° 50' N, 99° 8' W), a unit of the Oklahoma Agricultural Experiment Station. The study area is characterized by rolling uplands (2–15% slopes) dissected by moderately deep, steep-walled drainages. The mean elevation is 490 m. The predominant soil of the experimental pastures is the Cordell silty clay loam (Loamy, mixed, thermic Lithic Ustochrepts). Cordell soils are shallow with a depth of 25 to 36 cm (Moffatt and Conradi 1979). Rocky outcrops of hard red siltstone make up 0–25% of Cordell mapping units.

The nearest reporting station for long-term climatological data (1961–1990) is located at Clinton, Okla. (35° 22' N, 99° 04' W), 14 km northeast of the research station. The climate is continental with cool winters and hot summers. The mean annual precipitation is 766 mm, ranging from 510 to 817 mm. The mean precipitation from April through September is 518 mm or 68% of the annual precipitation. The mean frost-free growing period is 206 days from April to October. The mean temperature is 16.1°C with January as the coldest month (mean 8.9°C) and July as the hottest month (mean 28.4°C).

Red Shale ecological sites dominate the study pastures. This site supports mixed-grass prairie as the potential natural vegetation with mean forage production of 1,050 kg ha^{-1}. Major grass species include sideoats grama [*Bouteloua curtipendula* (Michx.)Torr.], blue grama [*B. gracilis* (Willd. *ex* Kunth) Lag. *ex* Griffiths], hairy grama [*B. hirsuta* Lag.], buffalograss [*Buchlöe dactyloides* (Nutt.) Englem.], silver bluestem [*Bothriochloa saccharoides* (Sw.) Rydb.], red threeawn [*Aristida longiseta* Steud.], purple threeawn [*A. purpurea* Nutt.], and little bluestem [*Schizachyrium scoparium* (Michx.) Nash]. Major forbs include western ragweed [*Ambrosia psilostachya* DC.] and curlycup gumweed [*Grindelia squarrosa* (Pursh) Dun.]. Scattered populations of the half-shrub broom snakeweed [*Gutierrezia sarothrae* (Pursh) Britt. & Rusby] are found on shallow sites.

Approximately 30% of the Klemme Station was previously cultivated. Old fields (3 to 27 ha) are scattered across all study pastures. About two-thirds of these old fields were reseeded to mixtures of native grasses 25 to 35 years ago. The exact seed mixtures used are not known but likely included sand bluestem [*Andropogon hallii* Hack.], little bluestem, indiangrass [*Sorghastrum nutans* (L.) Nash], sideoats grama, and blue grama. The reseeded fields are now dominated by sideoats grama. The remaining fields revegetated naturally and supported mixed-grass vegetation.

Grazing management on the study pastures is not documented prior to 1988. Livestock have grazed the pastures since at least 1900. Stocking rates since 1965 are estimated to have been moderately heavy to heavy.

Methods

Stocking rates of 23, 26, 34, 41, 48, or 51 AUD ha^{-1} were randomly allocated to 6 pastures. The currently recommended sustainable stocking rate is 25 AUD ha^{-1} (SCS 1960). Average pasture area was 65 ha. The pastures were continuously stocked with mixed breed yearling beef steers (*Bos taurus x Bos indicus*; maximum 1/8 *B. indicus*) typical of commercial stocker cattle originating in the southeastern U.S. Herd size varied from 10 to 25 steers depending on stocking rate. During the 7-year study period (1990 through 1996), the mean start and end of the grazing season was 15 April and 24 September.

Initial body weight of the steers averaged 216 kg (SD = 12 kg). We attempted to equalize average body weight of steers among treatments. To do this, steers were first classified into weight groups based on 23 kg increments. We then calculated the number of steers required from each weight group for each treatment based on proportional representation of all weight groups within each treatment. Finally, specific steers from each weight group were randomly allocated to treatments. The steers had access to a free-choice mineral supplement during the grazing season. All procedures for animal care and management were in accordance with accepted guidelines (Consortium 1988).

Herbage standing crop was measured each year around 20 July and 24 September. For each sample date, 50 quadrats were clipped to ground level to determine total standing crop in each pasture. Quadrat area was 0.1 m^2. Quadrats were systematically spread across each pasture along pace transects. The same approximate transects were sampled on each date. In each pasture, 2 to 3 samples of pure live and dead herbage were collected to determine ratios of live and dead tissue in the total herbage (Gillen and Tate 1993).

Species composition was determined around mid-July every other year from 1990 to 1996. Species composition was measured using the dry-weight rank method (Gillen and Smith 1985) with 100 quadrats per pasture (50 of which were also used for standing crop sampling). The 0.1 m^2 quadrats were systematically distributed across the pastures along pace transects. Species groups were: sideoats grama, shortgrasses (buffalograss, blue grama, and hairy grama), silver bluestem, threeawns (red and purple threeawn), tallgrasses (little bluestem and sand bluestem), other perennial grasses, annual grasses, forbs, and broom snakeweed.

For the statistical analysis, we used an analysis-of-covariance model (Littell et al. 1991). The model contained terms for stocking rate, year, and the stocking rate x year interaction. Year was a classification variable while stocking rate was a quantitative covariate. Since stocking rate varied slightly in a given pasture over years because of differences in the length of the grazing season or initial steer weight, we used the mean stocking rate over the 7-year study period. Dependent variables were standing crop or relative species composition.

The analysis-of-covariance model fit a linear regression between the dependent variable and stocking rate for each year. For instance, if the stocking rate effect was significant for July standing crop, there was a linear relationship between July standing crop and stocking rate. If the year effect was significant, the intercept for the regression lines was different between some years. If the stocking rate x year interaction was significant, the slope of the line relating the July standing crop and stocking rate was different for some of the years in the analysis. If the stocking rate x year interaction was not significant, the slope of the regression relating July standing crop and stocking rate was constant over years.

We initially fit a full covariance model to our data for standing crop and relative species composition. If the stocking rate x year interaction was significant in the initial model, we examined all regression coefficients for the full model. We then dropped all coefficients that were not significant ($P > 0.10$) and fit a reduced regression model. If the stocking rate x year interaction was not significant ($P > 0.10$), we fit a reduced model containing only stocking rate and year. If year was significant in the reduced model, we made pair-wise comparisons of least squares means between years ($P = 0.05$).

With this procedure, we essentially fit a linear regression between a dependent variable and stocking rate for different years, for instance 1990 and 1996 as a simplified example. We then compared the lines for the 2 years. If the slopes of the lines for 1990 and 1996 were different, stocking rate had a significant effect over years. If the slopes of the lines for 1990 and 1996 were not different, stocking rate had no effect over years, regardless of the relationship in 1990. We assumed any significant relationship present between species composition and stocking rate in July 1990 to be a chance relationship. This was the first year of the study and we would not expect stocking rate to have an effect on plant populations within 3 months. To address our research objective, we emphasized interactions of stocking rate with year. Significant effects of stocking rate were not considered important unless they changed over years.

Results and Discussion

Precipitation

Means of annual and growing season precipitation during the study were 6% and 14% above the long-term means, respectively (Table 1). The most stressful conditions occurred in 1994 when growing season precipitation was 69% of the mean. This was offset by high precipitation in 1995 and 1996 although much of the growing season precipitation in 1995 fell in large intense storms with considerable runoff. Overall growing conditions were average to favorable during the study period.

Table 1. Precipitation during the study period and 30-year average precipitation (1961–1990) at Clinton, Okla.

Year	Precipitation Annual	Precipitation Apr. through Sep.
	(mm)	(mm)
1990	670	514
1991	733	535
1992	774	484
1993	709	496
1994	575	361
1995	1195	935
1996	817	781
Study average	813	591
30-year average	766	518

Standing Crop

Total Standing Crop. Total standing crop, averaged over stocking rates and years, was similar in July (1,920 kg ha^{-1}) and September (1,870 kg ha^{-1}, $P = 0.96$). Total standing crop was only different among months ($P < 0.05$) in 1991, with 2,460 and 1,880 kg ha^{-1} present in July and September, respectively. Herbage growth and consumption were in rough balance in the later portion of the growing season.

Total standing crop and stocking rate had an inverse relationship because of greater total forage demand at higher stocking rates (Table 2, Fig. 1). Averaged over months, standing crop decreased approximately 17.5 kg ha^{-1} for every AUD ha^{-1} increase in stocking rate. We found no interaction between stocking rate and year (Table 2). This suggests stocking rate did not affect the herbage production potential of the pastures over the term of the study.

Live Standing Crop. Averaged over stocking rates and years, live standing herbage averaged 930 kg ha^{-1} in July and 720 kg ha^{-1} in September. Live standing crop in July was not related to stocking rate and there was no stocking rate by year interaction (Table 2). Live standing crop varied among years, ranging from 630 kg ha^{-1} in 1995 to 1,410 kg ha^{-1} in 1992.

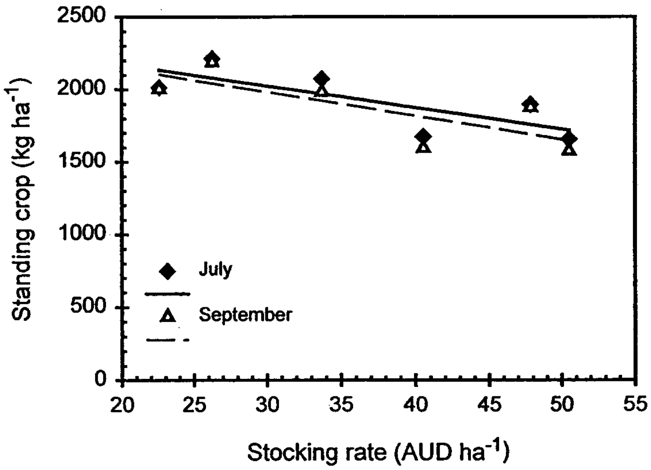
There was a stocking rate by year interaction for live standing crop in September. From 1990 to 1995, live standing crop in September was not affected by stocking rate (Fig. 2). In 1996, live standing crop was negatively related to stocking rate. Precipitation for the July to September period in 1996 totaled 294 mm, 40% above the long-term mean, and was well distributed. The favorable precipitation regime may have delayed transfer of herbage from the live to the dead component and allowed an accumulation of live herbage as stocking rates decreased.

Percentage live standing crop was significantly related to stocking rate in both July and September (Table 2). Averaged over sample dates and years, percentage live standing crop ranged from 42% at 23 AUD ha^{-1} to 52% at 51 AUD ha^{-1}. Percentage live standing crop increased by 0.4% for each increase of 1 AUD ha^{-1} ($P = 0.05$), a relationship that was constant over sample dates and years. Percentage live standing crop was similar ($P = 0.96$) for July and September at 48% and 46% of total standing crop, respectively, when averaged over stocking rates and years. Live standing crop ranged from a low of 28% in September 1990 to a high of 67% in July 1992.

Dead Standing Crop. Dead standing crop was related to stocking rate ($P < 0.01$) in both July and September (Table 2, Fig. 3). As stocking rate increased, the standing crop of dead herbage decreased.

Table 2. P-values from analyses of variance for standing crop components in July and September from a 7-year stocking rate study on mixed-grass prairie in western Oklahoma.

Item	Stocking rate	Year	Stocking rate x year
Total Standing Crop			
July	<0.01	<0.01	0.31
September	<0.01	<0.01	0.55
Live Standing Crop			
July	0.96	<0.01	0.92
September	0.43	<0.01	0.08
% Live Standing Crop			
July	<0.01	<0.01	0.20
September	<0.01	<0.01	0.24
Dead Standing Crop			
July	<0.01	<0.01	0.08
September	<0.01	<0.01	0.48



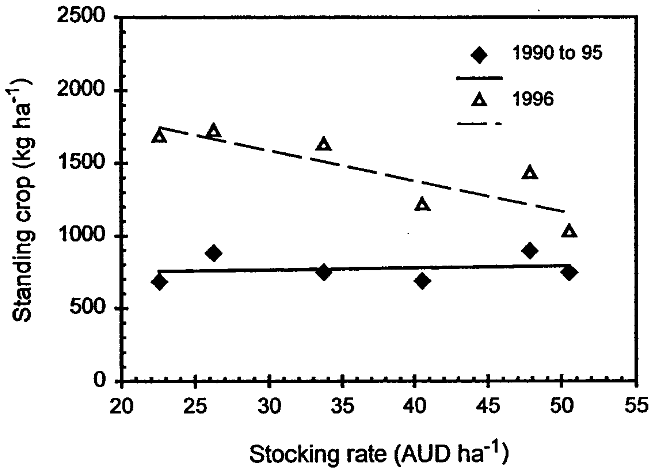


Fig. 1. Total standing crop of herbage in July and September as affected by stocking rate. Points are averages of 7 years. For July, standing crop = 2483 – 15.2 (stocking rate). For September, standing crop = 2458 – 14.4 (stocking rate). For the combined regression model, R^2 = 0.59, P = 0.06. Slope and intercept terms for July and September are not different (P > 0.90).

Fig. 2. Standing crop of live herbage in September as affected by stocking rate. For 1990-95, standing crop = 721 + 1.4 (stocking rate). For 1996, standing crop = 2222 – 21.0 (stocking rate). For the combined model, R^2 = 0.92, P < 0.01. Intercepts and slopes are different between sets of years (intercepts P < 0.01, slopes P = 0.02).

The only exception to this relationship occurred in July 1990, the first year of the study. On that date, there was no relationship between dead standing crop and stocking rate. Grazing treatments had been imposed for about 3 months at that time and had not exerted a measurable impact on dead standing crop. By the end of the first year in September of 1990, a relationship had been established between dead standing crop and stocking rate and this relationship remained constant over the following years and sample dates. Dead standing crop declined 17.4 kg ha^{-1} for each increase of 1 AUD ha^{-1} (P < 0.01). Standing crop of dead herbage averaged 1,660 kg ha^{-1} in July and 1560 kg ha^{-1} in September (P = 0.85).

Effects of stocking rate on standing crop components were manifest in the dead herbage component. This suggests the amount of herbage transferred from the live to the dead component was greater at lower stocking rates because more herbage would reach physiological maturity and move into the dead component. Conversely, at higher stocking rates a portion of this herbage would be consumed before it could transfer to the dead compartment. In north central Texas, a high stocking rate reduced both live and dead standing crop of the grass component (Heitschmidt et al. 1989).

With 2 minor exceptions, the relationship between standing crop and stocking rate did not change over the 7-year study period. This suggests the impact of stocking rate was simply increased herbage consumption due to greater numbers of livestock as stocking rate increased. There is no evidence of an effect on plant productivity at the community level. If plant productivity had declined over years at the higher stocking rates, the slope of standing crop versus stocking rate would have become more negative.

Table 3. Coefficients and statistics of regression models describing response of species composition (%) to stocking rate between 1990 and 1996. Year is coded 0 for 1990 and 1 for 1996. Stocking rate is AUD ha^{-1}.

Period	N	Intercept	Year	Stocking rate	Year x Stocking rate	R^2	C.V.	MSE
Sideoats grama	12	14.8** (2.8)[1]		0.1^+ (0.8)		0.27	13.0	6.7
Shortgrasses	12	37.4** (4.9)		–0.3* (0.1)		0.39	18.0	21.1
Silver bluestem	12	1.0 (2.0)		0.1* (0.05)		0.41	31.0	3.8
Threeawns	12	5.8** (0.7)	11.7** (2.7)		–0.14+ (0.07)	0.84	20.5	3.0
Other grasses	12	9.8** (1.1)				0.00	39.4	14.8
Annual grasses	12	2.7** (0.3)	–2.7** (0.4)			0.81	51.8	0.5
Forbs	12	22.1** (1.5)				0.00	23.7	27.5
Broom snakeweed	12	4.4** (0.7)				0.00	58.0	6.7

**, *, + significant at the 0.01, 0.05, and 0.10 levels respectively.
[1]Standard error of estimate.

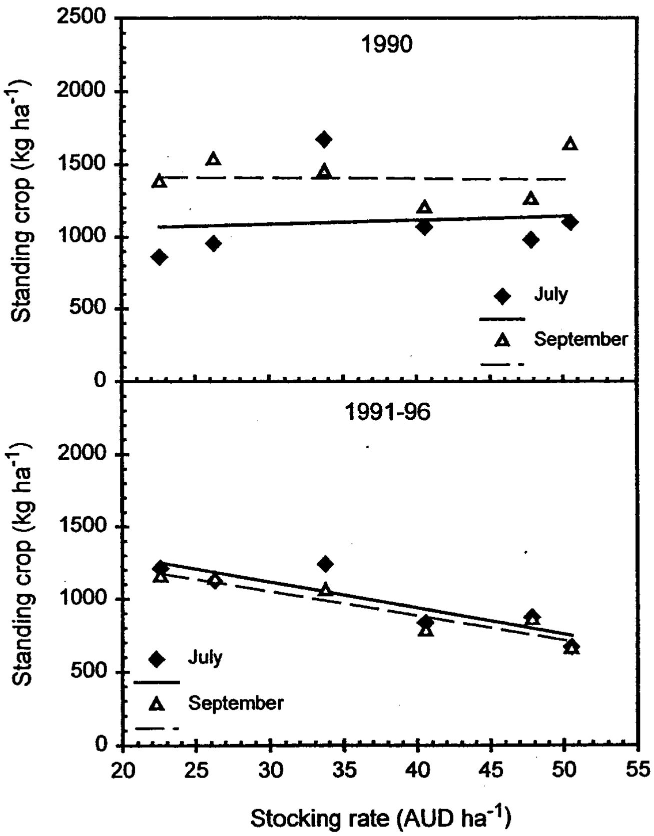


Fig. 3. Standing crop of dead herbage as affected by stocking rate. For 1990, slopes are not different from 0 (P > 0.96) and are not different between July and September (P = 0.83). For 1991 to 1996, July standing crop = 1655 – 18.0 (stocking rate); September standing crop = 1640 – 16.8 (stocking rate). For the combined model, 1991 to 1996, R^2 = 0.82, P < 0.01. Intercept and slope terms for July and September are not different (P > .67).

of the vegetation. Buffalograss was the major species in this category. As with sideoats grama, shortgrasses did not respond to either stocking rate or year (Tables 3 and 4, Fig. 4). Other studies have reported increases in the relative composition of shortgrasses as stocking rate increased (Klipple and Costello 1960, Launchbaugh 1967, Thurow et al. 1988, Heitschmidt et al. 1989).

Silver bluestem was most abundant at the higher stocking rates (Table 3, Fig. 4). This relationship was present at the beginning of the study and remained constant over years indicating no effect of stocking rate on silver bluestem. There was also no relationship with year (Fig. 4). Silver bluestem percentage composition averaged 6% and remained unchanged over the 7 years of the study. Silver bluestem is also a secondary species in Texas mixed-grass prairies and increased slightly as stocking rate was decreased (Fuhlendorf and Smeins 1997) or else was not affected by stocking rate (Heitschmidt et al. 1989).

There was no relationship between threeawns and stocking rate in 1990. By 1996, threeawns were more abundant at the lower stocking rates (Table 3, Fig. 4). The response of threeawns to stocking rate has been variable in other studies. Studies in Texas found either little response of perennial threeawns to stocking rate (Heitschmidt et al. 1989, Taylor et al. 1997) or higher abundance of threeawns at intermediate stocking rates (Fuhlendorf

Species Composition

Sideoats grama was the most abundant single species, comprising approximately 20% of the vegetation, and was not affected by stocking rate. While the relative composition of sideoats grama was greater at the higher stocking rates, this positive relationship was already present in 1990 at the initiation of the study and did not change over 7 years (Table 3, Fig. 4). This was unexpected because sideoats grama is often considered a decreaser in mixed-grass prairie (SCS 1960, Taylor et al. 1997). Heitschmidt et al. (1985, 1989) also reported the composition of sideoats grama was not influenced by stocking rate in mixed-grass prairie. In central Texas, sideoats grama increased as stocking rate was decreased but changes were not immediate and were mediated by soil depth (Fuhlendorf and Smeins 1997, 1998). Sideoats grama declined slightly on all pastures in 1994 but returned to initial levels in 1996 (Table 4).

The shortgrasses were prominent in all pastures, contributing approximately 25%

Table 4. Relative composition (%) for species or species groups over years, averaged over stocking rate from a 7-year stocking rate study on mixed-grass prairie in western Oklahoma.

	Year			
Species	1990	1992	1994	1996
	(%)			
Sideoats grama	20.8[ab1]	22.5[a]	17.6[c]	19.1[bc]
	(2.9)[2]	(3.0)	(3.6)	(2.8)
Shortgrasses	27.1	22.4	26.7	23.9
	(6.5)	(2.9)	(5.3)	(4.6)
Silver bluestem	6.8	5.2	5.6	5.6
	(2.7)	(1.5)	(1.5)	(2.0)
Threeawns	5.2[c]	6.0[c]	9.0[b]	11.7[a]
	(2.1)	(3.0)	(2.7)	(1.9)
Tallgrasses	2.0	3.1	3.2	2.5
	(0.8)	(1.6)	(2.4)	(1.9)
Other perennial grasses	11.2	10.7	7.8	8.3
	(3.4)	(4.4)	(3.6)	(4.0)
Annual grasses	2.7[a]	2.4[a]	0.8[b]	0.0[c]
	(1.0)	(0.7)	(0.2)	(0.0)
Forbs	20.2	19.0	21.8	24.0
	(6.3)	(2.4)	(3.8)	(3.5)
Broom snakeweed	3.9[c]	8.6[a]	7.5[ab]	5.0[bc]
	(1.7)	(2.9)	(3.3)	(3.3)

[1]Means within a row followed by different letters are different using protected pair-wise t-tests, P < 0.05.
[2]Standard deviation.

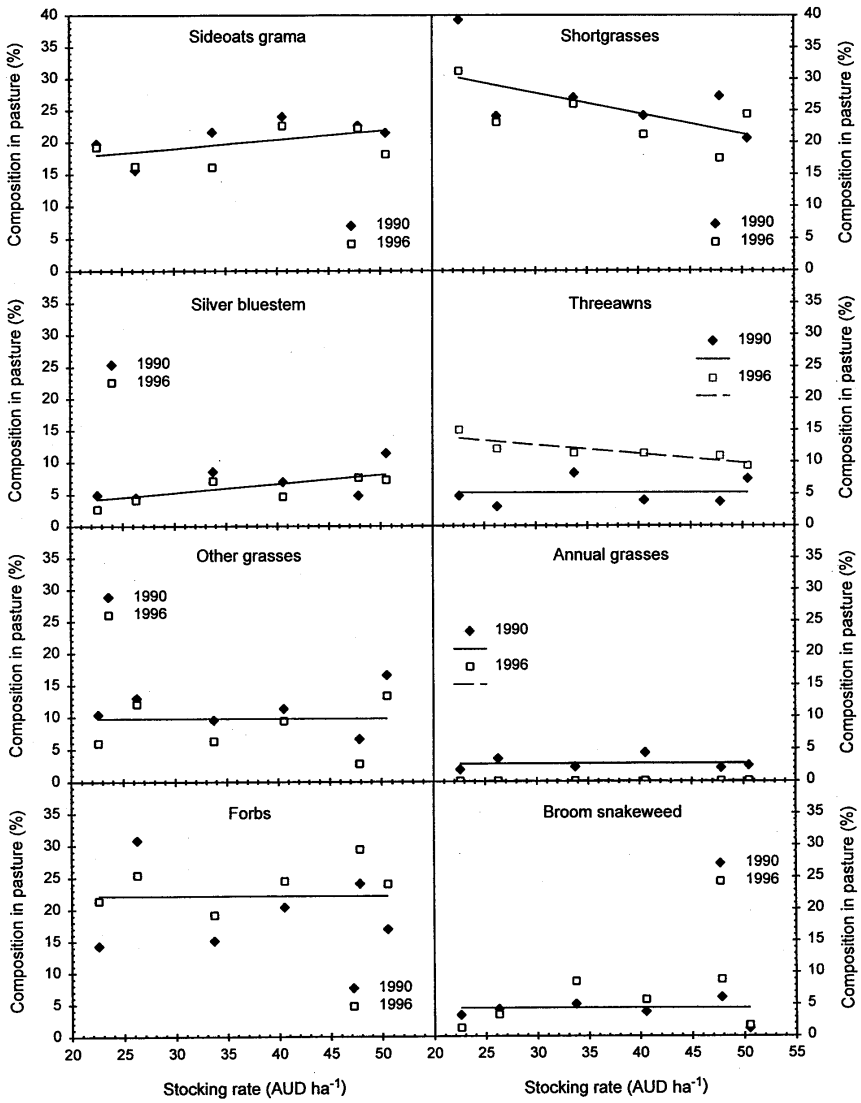


Fig. 4. Relative composition of vegetation components as affected by stocking rate in 1990 and 1996. Regression models for each component are found in Table 4. A single line indicates no difference between years.

and Smeins 1997). In contrast, threeawns decreased at higher stocking rates in shortgrass prairie in northeastern Colorado (Klipple and Costello 1960). Later work at the same site found heavy grazing after June was generally detrimental to red threeawn (Hyder et al. 1975).

Threeawns are classified as increasers or invaders on virtually all ecological site descriptions used by the Natural Resources Conservation Service in western Oklahoma. This means threeawns should increase in abundance as stocking rates increase. Results from the current and previous studies suggest this classification should be reconsidered. These grasses appear to remain unchanged or decrease as stocking rate increases. Threeawns are unpalatable and are often the last plants to be grazed as stocking rates increase (Klipple and Costello 1960). As the more palatable plants are grazed, threeawns become more visually prominent. This may explain why they have been considered increasers.

Threeawns increased at all stocking rates from 1990 to 1996 (Table 4) but the increase was greater at the lower stocking rates (Fig. 4). The reason for this general increase is not known. Red threeawn appeared to be favored in wet years but reduced in dry years in shortgrass prairie (Hyder et al. 1975). The increase in threeawns in this study cannot be easily attributed to weather since precipitation was well above average only in years 6 and 7 of the study while threeawns increased between years 3 and 5 (Table 4).

Tallgrasses were negatively related to stocking rate but there was an interaction of stocking rate and year. In the first year of the study (1990), tallgrasses were not related to stocking rate (Fig. 5). By 1992, there was a negative relationship between the tallgrass component and stocking rate. This relationship remained constant through 1996. Although tallgrasses increased at the lower stocking rates, they still contributed no more than 5 to 6% of the total herbage. Descriptions of the potential natural community for the Red Shale ecological site suggest that little bluestem could be co-dominant on this site with sideoats grama (SCS 1960). More than 7 years of moderate stocking rates would be required for little bluestem to increase to such levels. It may be that the initial response of tallgrasses was due to the short-term process of increasing the size of existing plants while further increases in relative composition must wait for the long-term process of establishing new plants.

Other perennial grasses were about 10% of the vegetation. Hairy tridens [*Erioneuron pilosum* (Buckl.) Nash], tall dropseed [*Sporobolus asper* (Michx.) Kunth], and windmillgrass [*Chloris verticillata* Nutt.] were the major grasses in this category. This component was not affected by stocking rate or year and there was no interaction between stocking rate and year (Table 3, Fig. 4). Different responses among species could have prevented any discernible group response.

The annual grass category was primarily Japanese brome [*Bromus japonicus* Thunb.]. This component was not prominent in the study pastures. The annual grasses were not affected by stocking rate (Table 3, Fig. 4) but declined significantly from 2.8% to less than 0.1% over the study period (Table 4). Japanese brome fluctuates greatly over years in response to favorable winter and spring precipitation (Launchbaugh 1967).

Forbs were one of the larger vegetation categories, contributing 20 to 24% of the herbage. Forbs were not affected by stocking rate or year (Table 3, Fig. 4). This supports the results of previous studies, which reported no difference in forb abundance due to stocking rates (Sims et al. 1976, Hart et al. 1988, Heitschmidt et al. 1989). Launchbaugh (1967), in contrast, found that forbs decreased as stocking rate increased. This is contrary to much popular opinion that holds that forbs increase as stocking rates increase. Differences in the effect of stocking rate on forb composition among studies may be attributable to indi-

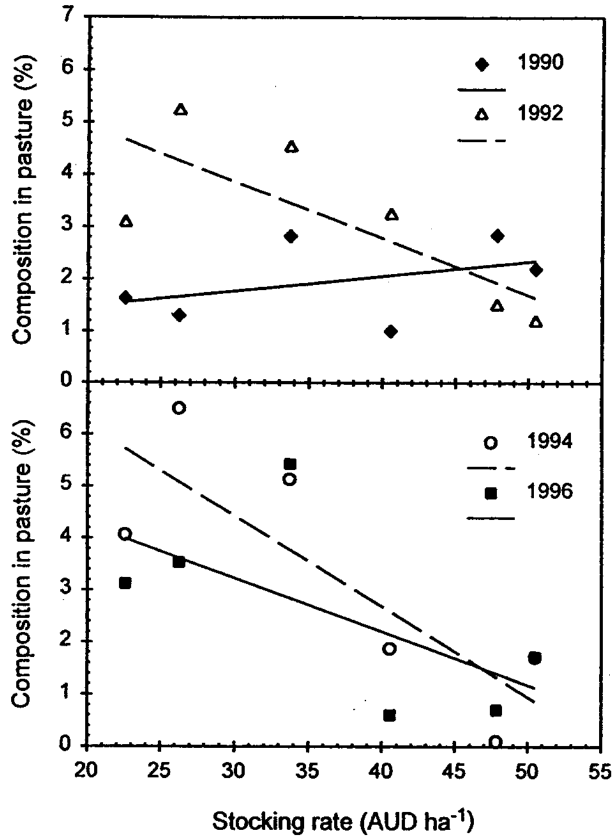


Fig. 5. Relative composition of tallgrasses as affected by stocking rate. Intercept coefficients are 0.9, 7.1, 9.7, and 6.3 for 1990, 1992, 1994, and 1996, respectively. Slope coefficients are 0.03, –.11, –.17, and –.10 for 1990, 1992, 1994, and 1996, respectively. For the combined model, R^2 = 0.60, P = 0.02. Coefficients for 1990 are different from 1992–1996 (P < 0.05), which are not different from each other (P > 0.24).

vidual species responses. Species within this group should probably be studied individually for a better understanding of the influence of stocking rate on their relative composition (Heitschmidt et al. 1985).

The half-shrub broom snakeweed was not affected by stocking rate (Table 3, Fig. 4). Broom snakeweed composition more than doubled from 1990 to 1992 before declining back to near initial levels in 1996 (Table 4). These changes over years were independent of stocking rate. Klipple and Costello (1960) reported that broom snakeweed was not affected by stocking rate and was cyclic in nature. In addition, broom snakeweed populations fluctuated dramatically in response to weather in New Mexico (McDaniel et al. 1993).

Conclusions

Stocking rate had few impacts on our experimental pastures over the course of this study. Effects on herbage standing crop can be attributed to the simple fact that livestock demand for forage increased as stocking rate increased rather than to long-term impacts on plant vigor. Stocking rate affected the relative species contribution of only 2 vegetation components, threeawns and tallgrasses. There may be potential for further changes in tallgrasses over longer time periods. Broom snakeweed fluctuated over time, but this effect was independent of stocking rate. The vegetation was, for all practical purposes, unchanged at the end of this study.

Several hypotheses could be advanced to explain the moderate vegetation response. First, the stocking rates studied may have been too light to cause significant effects. We place lesser weight on this hypothesis because the stocking rates used were substantially higher than the recommended rates. The impact of these stocking rates was further compounded because all of the grazing occurred during the growing season.

Second, weather conditions during the study period may have ameliorated the impact of stocking rate. Both annual and growing season precipitation were above average for the study period. However, precipitation during the last 2 years of the study was much greater than in the earlier years. During the first 5 years, annual precipitation was 85% of average and growing season precipitation was 81% of average. These precipitation levels would not constitute a severe drought but were below average. We expected these precipitation levels in combination with high stocking rates to trigger vegetation changes but the mixed-grass vegetation was resistant under the observed stocking rates and weather conditions.

A third hypothesis considers the influence of initial conditions. Significant changes may have already occurred in the 80 years the pastures were grazed at high stocking rates before the study began and the vegetation may have already been in equilibrium with the higher stocking rates used in our study. In that case, little change would be observed at high stocking rates but change could potentially occur at lower stocking rates. This is suggested by the slight increase in tallgrasses at the lower stocking rates. Since this component was at low levels initially, increases might take many more years to be practically significant. A similar situation has been reported from central Texas (Fuhlendorf and Smeins 1997). Additionally, grazing sensitive species may not increase immediately because lower stocking rates alone are not enough of a disturbance to cause grazing resistant species to relinquish resources (Fuhlendorf and Smeins 1998). Increases in grazing sensitive species may be delayed until a climatic stress reduces the grazing resistant species and opens space for colonization. We believe this third hypothesis best fits the observed vegetation responses from this study.

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