VEGETATIONAL DYNAMICS OF A CENTRAL OKLAHOMA TALLGRASS PRAIRIE UNDER FOUR DIFFERENT MANAGEMENT STRATEGIES

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PREFACE

Roughly half of the total land area in Oklahoma can be classified as rangeland. The productivity of rangeland can be sustained if these lands are managed by the ecological principles outlined in the vast body of knowledge that contributes to the distinct discipline known as range science. Several factors, however, have stifled the proper management of Oklahoma rangelands. These include an incorrect rangeland philosophy, apathy, a lack of scientific knowledge, inadequate management ability, and financial, legal and social constraints.

It behooves all Oklahomans, especially those responsible for making decisions on policy, to ensure that the productivity of our land is maintained indefinitely. It is distressing to think that rangeland has not received the emphasis it deserves in Oklahoma. However, comparing the number of professional rangeland scientists and rangeland educational facilities in Oklahoma with those of neighboring states, this appears to be the case. The urgency of proper natural resource management must be realized before it is too late.

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This thesis was written in a format to facilitate immediate submission for a technical article in the Journal of Range Management. Approval for presenting the thesis in this manner is based on the Graduate College's policy of accepting theses written in manuscript form. This approval is subject to the Graduate College's acceptance of the major professor's request for a waiver of the standard format.

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CHAPTER I

INTRODUCTION

The optimum ecological and economical use of land is attained only under a sound management strategy. In use, the range manager's tools, e.g. stocking rate, fire, fertilization, etc., can damage, maintain or improve the productivity and condition of the land. A thorough knowledge of the responses of the vegetation to various practices is obligatory before effective recommendations can be made. Since many aspects of the vegetation are dynamic, one-time measurements are of limited utility in assessing these effects.

The primary objective of this study was to describe and compare the dynamics of the vegetation of a central Oklahoma tallgrass prairie subjected to four different management strategies. A secondary objective was to manipulate conditions to obtain a range in grazing pressure and determine effects of grazing pressure on the vegetation.

There is no doubt that grazing animals influence the vegetation on which they feed. The results of numerous experiments dealing with stocking rates showed that moderate and conservative stocking rates consistently give greater returns than heavy stocking rates (Heady 1975). Generally all plants preferred by animals increase when grazing pressures are reduced (Ellison 1960). Although a number of generalizations can be made concerning the effects of grazing on the vegetation, Heady (1975) points out that the influence of day-to-day changes in grazing pressure on range condition and production needs further clarification. A number of studies have been concerned with the grazing of central Oklahoma grasslands (Kelting 1954, Powell et al. 1978, Sims et al. 1978, Sims and Singh 1978a, Sims and Singh 1978b, Sims and Singh 1978c). Although all of these studies at least partially describe the seasonal dynamics of the vegetation, not one has examined the seasonal changes in grassland under a range of different grazing pressures.

Fertilization of central Oklahoma grasslands generally results in only moderate increases in production (Powell et al. 1979). Although desirable species may increase under fertilization when annual grasses are suppressed by herbicides (Baker and Powell 1978) or by grazing management (Powell et al. 1973), increases in production are often caused by a disproportionate increase in undesireable opportunistic plants that utilize nitrates more efficiently than the desireable species (Owensby 1980). Nitrification appears to be inhibited by the production of allelopathic substances in climax ecosystems (Rice and Pancholy 1972, Rice and Pancholy 1973, Rice and Pancholy 1974). The conclusion of these studies is that ammonia rather than nitrate is the predominant form of nitrogen absorbed by the desirable plant species that dominate a climax grassland. Therefore the production of the desirable climax plants may show only a moderate response to nitrate fertilizers.

Fire is a natural phenomenon and perhaps necessary for maintaining the productivity of many ecosystems. Numerous beneficial effects on grassland communities are associated with burning (Anderson et al. 1970, Smith and Owensby 1972, Vogl 1974, Anderson 1976, Mueggler 1976). Despite this knowledge the use of fire in Oklahoma is not as common as in adjacent areas such as the bluestem ranges of the Kansas Flint

Hills.

Gay and Dwyer (1965), Powell et al. (1979), Owensby and Smith (1979), and Owensby and Smith (1980) reported on the combined effects of fire and nitrogen fertilization on Oklahoma and Kansas grasslands. Burning and fertilization in combination increase forage production significantly over either fire or fertilization alone (Gay and Dwyer 1965). Burning to correct undesireable changes in species composition often associated with the application of fertilizer is an additional justification for using the two treatments simultaneously (Owensby 1980).

Although a basic understanding of the effects of grazing, burning and fertilizing bluestem grasslands in Oklahoma exists, relatively few studies have been concerned with a detailed examination of the seasonal dynamics of plant species subjected to these treatments. Studies detailing plant dynamics under four different combinations of fire, fertilization, and grazing pressure which might represent different strategies of management in central Oklahoma are non-existent.

CHAPTER II

STUDY AREA

The study area is located in Canadian County, Oklahoma on land managed by the Southwestern Livestock and Forage Research Station (lat. 35° 30'N, long. 98° 00'W, elevation 600 m). The dry, subhumid climate of the study area is characterized by the following arithmetic means of weather data recorded at El Reno, Oklahoma. Annual precipitation averages 749 mm with nearly 80% occurring during the 208 day, frost-free growing season from early April to early November. Monthly precipitation ranges from 23 mm in January to 130 mm in May.

Slopes of 1 to 4% were measured within the study area and generally faced west. Argiustolls and Paleustolls represented by the Bethany, the Kirkland and the Renfrow series are the predominant soils based on several core samples described at the beginning of the study. All are deep, well-drained silt loam to loam soils which developed from either shale or clayey and loamy sedimentary parent materials. The vegetation on these soils is dominated by *Schizachyrium scoparium*, *Andropogon gerardi*, *Panicum virgatum*, and *Sorghastrum nutans* when the range is in "excellent" condition (U.S.D.A. 1976). Common increaser and invader species include *Bouteloua curtipendula*, *B. gracilis*, *Buchloe dactyloides*, annual *Bromus* spp., *Ambrosia psilostachya*, and *Achillea lanulosa*. A detailed description of the site is given by Dunn and Powell (1979).

The study area has a rather long and varied history of grazing, but it was never plowed. After the extripation of the bison the area was part of the Cherokee Outlet which was leased to Texas cattlemen (Gibson 1965). During World War II the U.S. Army controlled the land and a large number of horses and mules grazed near and on the present location (Armold, no date). For about 30 years prior to the study the area was part of a pasture grazed moderately (0.25 a.u./ha) by a cow-calf beef herd in a rotational grazing system. In the fall of 1977 the area was mowed but the hay was not removed. The area was deferred from grazing during 1978, the year before the study.

CHAPTER III

METHODS AND MATERIALS

Four, 1.6 ha paddocks were fenced on the study area and numbered 1 through 4. Each paddock was fenced separately so livestock grazing could be controlled. Grazing with mixed-breed steer and heifer beef calves with an average initial weight of 250 kg was on a put-and-take basis from 15 June to 10 October 1979. The mean yearlong stocking rates were 0.57 (very heavy grazing), 0.14 (light grazing), 0.23 (moderate grazing) and 0.43 (heavy grazing) animal units per hectare for paddocks 1 through 4 respectively. The animals were weighed immediately before and after being put into the paddocks. These weights were multiplied by an average "shrink factor" of 0.947 calculated from full and empty weights for each animal at the beginning and end of the grazing season. The difference in animal weight gain among the different paddocks were tested with an analysis of covariance. The mean gains were adjusted to the concomitant variable, initial animal weight, by the least squares method (Ostle 1963).

Paddock 4 was burned on 1 April 1979 and paddocks 4 and 2 were fertilized on 5 April 1979 with 56 kg of nitrogen (33-0-0) per hectare and 22 kg of phosphorous (0-20-0) per hectare. The combination of vegetation manipulation and different stocking rates resulted in each paddock being subjected to different grazing pressures. Thus each paddock represented a different management strategy; very heavy grazing (paddock 1), fertilization and light grazing (paddock 2), moderate grazing (paddock 3) and fire, fertilization and heavy grazing (paddock 4).

The vegetation was sampled approximately monthly (more frequently during grazing) throughout the entire year. Three permanent sampling locations, distinguished from each other by the relative slope positions of upper, middle and lower, were established in each of the four paddocks. Production and composition of the vegetation were determined by the short-term harvest technique using a combination of the double-sampling (Wilm et al. 1944) and weight-estimate (Pechanec and Pickford 1937) methods. Live weights of each plant species or species class, Total Live vegetation, Standing Dead vegetation, Total Above-Ground Standing vegetation (Live + Dead) and Ground Litter were estimated within four 0.5 m^2 rectangular quadrats at each sampling location on each sampling date. Each kind of material was collected, bagged and weighed from one of the four estimated quadrats. Total standing vegetation was clipped at ground level, weighed, separated into Live or Dead components, oven-dried at 60 C and reweighed. Percent dry weight and the estimation correction factor for the standing vegetation were determined from the clipped sample and used to adjust the estimated weights for all 4 samples at each location.

These data were analyzed as a split-plot experiment with main units in a completely randomized design. The 12 "treatments" (4 paddocks X 3 locations within each paddock) were in a 3 X 4 factorial arrangement with sampling dates (days) as the subunits. Analysis of variance tests were performed for the oven-dry weights of Total Above-Ground Standing vegetation, Live vegetation, Standing Dead vegetation, Litter and individual species. All analysis of variance tables are shown in the appendix. Unless otherwise stated, all differences discussed were significant at the 5% level.

The weights for both animals and vegetation were used to determine grazing pressure. Individual animal weights were converted to animal units (weight in kilograms raised to the 0.75 power, multiplied by .01), then the total animal units on a paddock were divided by the estimated weight of Total Above-Ground Standing vegetation on that same paddock. Grazing pressure was expressed as total animal units per megagram of oven-dry available forage and was calculated for each paddock during each grazing period.

Polynomial equations were fitted to the data to aid in describing the seasonal trends of the various components of the vegetation. The highest degree of the equation fitted was determined by the highest degree linear coefficient that tested significantly different from zero by the least square method (Draper and Smith 1966). Regression analyses were performed on the dry weight data for Litter, Standing Total, Standing Dead, Live, Andropogon gerardi and Schizachyrium scoparium and curves representing seasonal trends for these components of the vegetation were obtained for each sampling location.

Rates of increase of plant biomass were calculated for the separate grazing periods to compare the effects of the different management strategies on primary productivity. Dry weights of total standing vegetation on each paddock were predicted by fitting a polynomial equation to the actual values of total standing vegetation measured on 14 sampling dates through the grazing season. Consumption of forage by livestock, assumed to average 10 kg per animal unit per day (Cordova et al. 1978, Powell 1972), was added to the predicted weights. No other losses, such as trampling of the vegetation by livestock or consumption by invertebrates, were considered.

CHAPTER IV

RESULTS AND DISCUSSION

Annual precipitation in 1979 was 818 mm, or slightly above the long-term average. More importantly however, the distribution of rainfall events was rather uniform throughout most of the growing season. Monthly precipitation was greater than average every month from March through August, with rainfall for these months totaling 140% of the long-term mean. The high water input resulted in high levels of soil water storage, high plant water potentials and increased plant growth in relation to drier years (unpublished data).

The vegetation of the study area was dominated by *Andropogon gerardi* (Table 1) and the area was in excellent range condition. The relatively low abundance of *Andropogon gerardi* and high abundance of *Schizachyrium scoparium* at the upper and middle positions of the moderately grazed paddock were not caused by grazing during this study but existed before treatments were applied (unpublished data). Compared to other sampling locations, more shallow (15 cm or less) A1 soil horizons and finer textured (clay loam) B1t horizons existed at these locations. These soil differences partially explain the observed difference in species composition because *Schizachyrium scoparium* is more common on shallow upland soils than is *Andropogon gerardi* (Weaver and Albertson 1956).

Table 1. Mean species composition (% of oven-dry weight) at the upper (U), middle (M) and lower (L) locations of the 4 tallgrass prairie paddocks in central Oklahoma, 1979.

	Paddock 2 Light grazing, fertilized			Paddock 3 Moderate grazing			Paddock 4 Heavy grazing, burned, fertilized			Paddock 1 Very heavy grazing		
	U	M	L	U	M	L	U	M	L	U	M	L
GRASSES	79	72	81	73	67	69	66	60	68	73	78	73
Andropogon gerardi	38	30	37	8	14	24	21	32	34	34	35	40
Aristida oligantha	0	0	0	1	1	T[1]	2	0	T	1	3	1
Bouteloua curtipendula	1	T	T	5	4	T	3	T	1	2	1	T
B. gracilis	1	0	T	1	1	1	3	0	T	1	1	T
Bothriochloa saccharoides	0	0	T	T	1	2	T	T	T	2	1	T
Bromus spp.	21	21	22	18	18	20	14	4	10	20	20	19
Buchloe dactyloides	1	T	T	1	T	2	T	T	1	1	1	1
Chloris verticillata	1	T	T	2	4	3	5	T	1	1	5	1
Leptoloma cognatum	T	T	T	T	1	1	1	1	T	T	T	T
Panicum oligosanthes	6	4	4	6	7	6	7	6	7	4	4	3
Schizachyrium scoparium	4	8	6	20	14	4	9	8	4	2	1	1
Sporobolus asper	6	9	11	10	2	5	T	4	7	4	5	6
Other grasses	T	T	T	1	T	1	0	2	2	T	1	T
Grass-like	4	4	3	3	4	6	6	7	8	4	5	8
FORBS	17	24	16	25	29	26	28	33	24	23	17	17
Achillea lanulosa	1	1	1	2	2	1	1	1	3	1	1	1
Ambrosia psilostachya	11	13	9	11	20	19	16	16	9	15	9	11
Artemisia ludoviciana	T	1	T	2	T	0	3	2	1	T	T	0
Cirsium spp.	2	T	0	3	2	T	1	1	T	2	3	1
Gutierrezia dracunculoides	0	2	T	T	1	T	0	T	T	T	T	0
Lactuca spp.	1	T	0	1	1	T	1	T	T	T	T	T
Nothoscordum bivalve	1	T	T	T	T	T	T	2	0	T	0	0
Oxalis corniculata	T	1	T	1	T	T	1	1	2	T	T	T
Psoralea tenuiflora	T	T	0	2	0	2	T	T	T	0	1	T
Schrankia uncinata	0	0	0	1	T	0	1	T	0	0	0	0
Tradescantia occidentalis	1	2	2	T	1	2	T	4	4	T	1	2
Tragopogon major	T	1	T	1	T	T	1	T	0	4	0	T
Other forbs	1	2	3	2	1	2	3	5	5	1	1	1

[1] Less than 1%

A difference in species composition due to treatments was obvious on the burned paddock. Sampling after the fire revealed that the burn was somewhat patchy. Estimates of the percent of each sampling location burned were 100% (middle), 80% (lower) and 50% (upper). The percent composition of cool season Bromus spp., primarily B. japonicus, decreased as the percent of each sampling location burned increased (Table 1).

The elimination of much of the Bromus spp. at the middle and lower positions of the burned paddock created an "open habitat" which apparently was occupied by the cool season forb Tradescantia occidentalis and other forbs (Table 1). Also Salvia azurea was observed only on the burned paddock. Both of these forbs were highly preferred by cattle (unpublished data).

The analyses of variance for the sample weights of the various components of the vegetation are given in the appendix. Significant differences ($P < .05$) among sampling locations in the seasonal trends of biomass (day X paddock X location interaction) were detected for Litter, Total Above-Ground Standing vegetation, Standing Dead vegetation and Live vegetation. The day by paddock by location interaction was not significant for the individual species, Andropogon gerardi and Schizachyrium scoparium. However both the day by paddock and day by location interaction were significant which suggests that the different management strategies affected the seasonal trends in species weights differently.

These results were expected since different combinations of management practices of fire, fertilization and grazing, represented by the paddock main effect, affect the productivity and seasonal dynamics

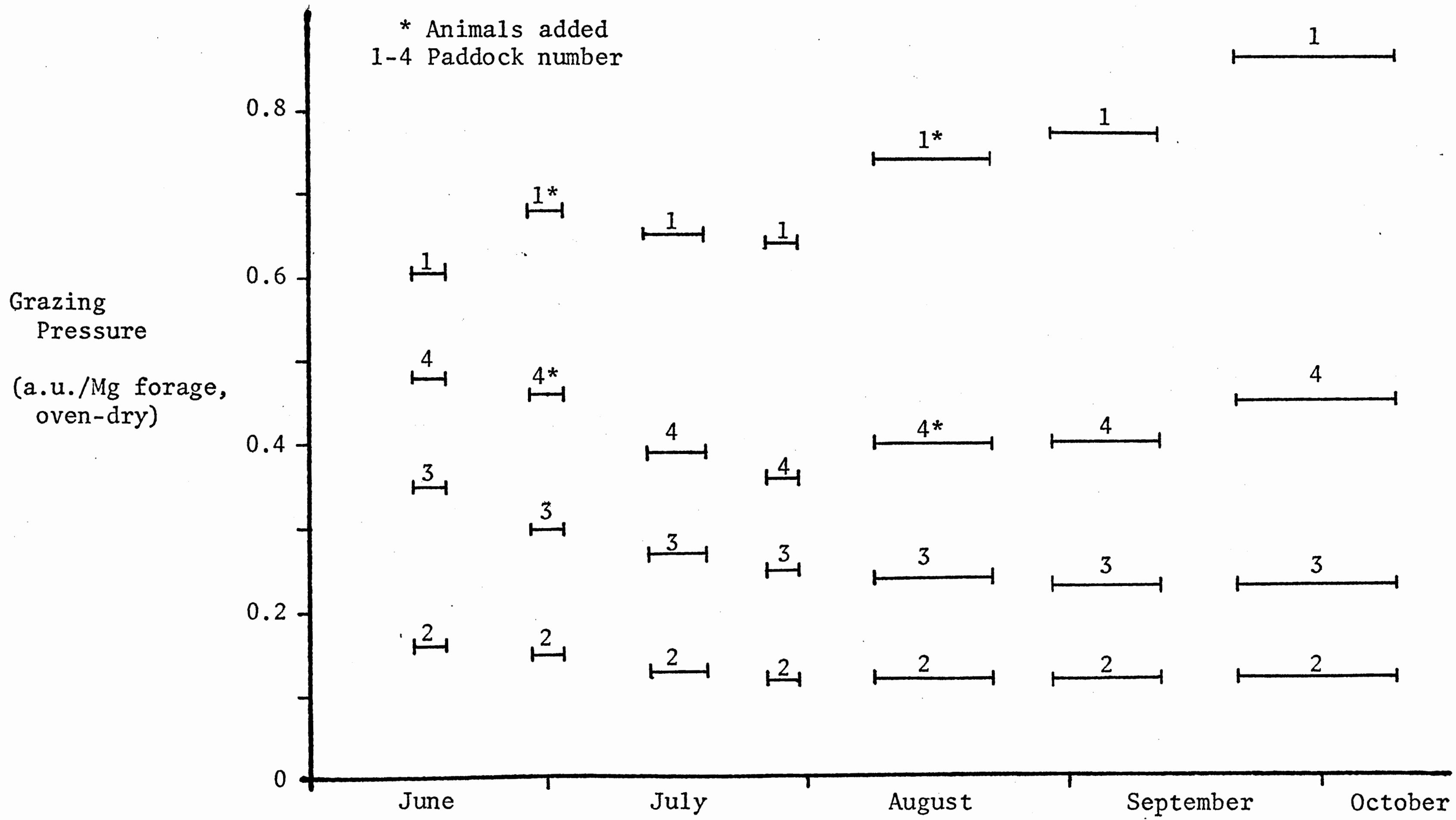

Fig. 1. Grazing pressure during each grazing period on the four tallgrass prairie paddocks in central Oklahoma, 1979.

of the vegetation. Differences in site conditions, such as shallow soils and the high abundance of Schizachyrium scoparium at the upper and middle locations of the moderately grazed paddock, contributed to the inconsistency of the effects among locations within a paddock.

Animals grazed the paddocks during seven different periods from 15 June through 10 October. The average grazing pressure on each paddock for each period is shown in Figure 1. A gradual increase in stocking rates on each paddock occurred in this study as is common when grazing young, growing animals (Heady 1975). However, the above average precipitation during the 1979 growing season resulted in increased plant growth and grazing pressures declined through most of the grazing season. The increases in grazing pressure on paddock 1 during the second and fifth grazing periods were caused by the addition of an animal at each of these times. An animal was also added to paddock 4 during the same periods, but grazing pressure actually decreased early in the season because of the high rates of plant growth caused by burning, adequate precipitation and fertilization.

Grazing pressures on the lightly grazed (2) and moderately grazed (3) paddocks followed the same trend, a gradual decline and leveling off toward the end of the season. In contrast, grazing pressures on the heavily grazed paddocks (1 and 4) decreased during the first of the season then increased toward season's end. This increase was most pronounced on the very heavily grazed paddock (1).

Analysis of covariance indicated no significant differences in weight gain among the animals grazing different paddocks. As expected lighter animals gained significantly more than heavier animals. Therefore mean gains were adjusted to initial animal weights (Table 2).

Table 2. Least squares adjusted means for total gain (kg/head) and daily gain (kg/head/day) of beef calves on the four tallgrass prairie paddocks in central Oklahoma, 1979.

Paddock	Management Strategy	Total Gain	Daily Gain
1	Very heavy grazing	58.2	0.50
2	Fertilization, light grazing	59.2	0.51
3	Moderate grazing	54.2	0.46
4	Fire, fertilization, heavy grazing	62.7	0.54
	observed significance level	0.55	0.55

The average daily gain for all animals during the grazing season was about 0.5 kg per day per head.

Season-long mean weights of the various components of the vegetation are summarized by sampling location in Table 3. Burning reduced Litter substantially more than did any other management practice. This was expected and is sometimes desireable since heavy accumulations of litter can decrease primary production in grasslands (Penfound 1964, Vogl 1974). Heavier grazing pressures also reduced Litter since the ultimate source of Litter was Live vegetation which was reduced by grazing.

Season-long mean weights of Standing Dead vegetation were very responsive to changes in grazing pressure. Dead vegetation was derived directly from Live vegetation. At heavier grazing pressures the amount of Live vegetation was reduced and there was less material available to be transferred to Standing Dead. The amount of Dead vegetation was directly related to grazing pressure.

With respect to livestock production Live vegetation is the most important component of the vegetation since animals consume primarily living vegetation during the growing season. Assuming an average forage consumption of 10 kg of dry matter per animal unit per day (Powell 1972, Cordova et al. 1978), the total amount of Live vegetation consumed by livestock in this study was approximately 2,000, 550, 800, and 1,500 kg/ha from paddocks 1 through 4 respectively. An increase of the mean season-long weights of Live vegetation (Table 3) plus calculated consumption indicates interdependent influences of grazing pressure, fertilization, and fire on primary production. In general these results substantiate the conclusion of Gay and Dwyer (1965) that burning

Table 3. Season-long mean weights (kg/ha x 100, oven-dry) of various components of the vegetation at the upper (U), middle (M), lower (L) locations of the 4 tallgrass prairie paddocks in central Oklahoma, 1979.

	Light Grazing, Fertilized				Moderate Grazing				Heavy Grazing, Burned, Fertilized				Very Heavy Grazing			
	U	M	L	$\bar{X}$	U	M	L	$\bar{X}$	U	M	L	$\bar{X}$	U	M	L	$\bar{X}$
Litter	38	40	40	39	38	35	35	36	14	14	14	14	33	31	34	33
Total Standing	54	54	57	55	46	42	41	43	41	49	42	44	34	37	39	37
Dead	34	34	36	35	30	27	26	28	22	27	25	25	21	22	23	22
Live	20	20	21	20	16	15	15	15	19	22	18	20	13	14	15	14
Andropogon gerardi	12	9	12	11	2	3	6	4	7	12	10	10	6	8	9	8
Schizachyrium scoparium	1	2	2	2	5	3	1	3	3	3	1	2	1	1	1	1

and fertilization together increase production of bluestem grassland much more than fertilization alone. The use of fire and fertilization alone and in combination under different grazing pressures in Oklahoma deserves further study.

The curves representing the general seasonal dynamics of the various components of the vegetation are shown in Figure 2. Litter dynamics tend to be erratic because litter has varied sources, e.g., standing dead vegetation and live vegetation, and variable rates of disappearance (Sims and Singh 1978a). Although seasonal trends in litter are difficult to determine, results of this study are in agreement with those of Powell et al. 1978. They reported that litter shows a gradual increase from spring, to a high in late summer, and a decrease through the winter (Figure 2). The different management strategies affected the magnitude of the peak in Litter. The burned paddock had less than one-third the amount of Litter of any other paddock throughout the growing season. All sampling locations in the fertilized and lightly grazed paddock had the highest peak weights of Litter, i.e. 4,500 to 5,000 kg/ha. Sampling locations on the moderately grazed paddock were the most variable with respect to peak litter weights and ranged from 3,500 kg/ha to about 4,500 kg/ha. Peak litter weights on the very heavily grazed paddock were about 4,000 kg/ha at all sampling locations. In general these results confirm Sims and Singh's (1978a) observation that the magnitude of litter followed the pattern exhibited by total standing vegetation.

Trends and peak values of Total Standing vegetation were different among the paddocks due to the different management practices. The lowest peaks for Total Standing vegetation were on all sampling locations in the very heavily grazed paddocks. The high grazing pressure on this

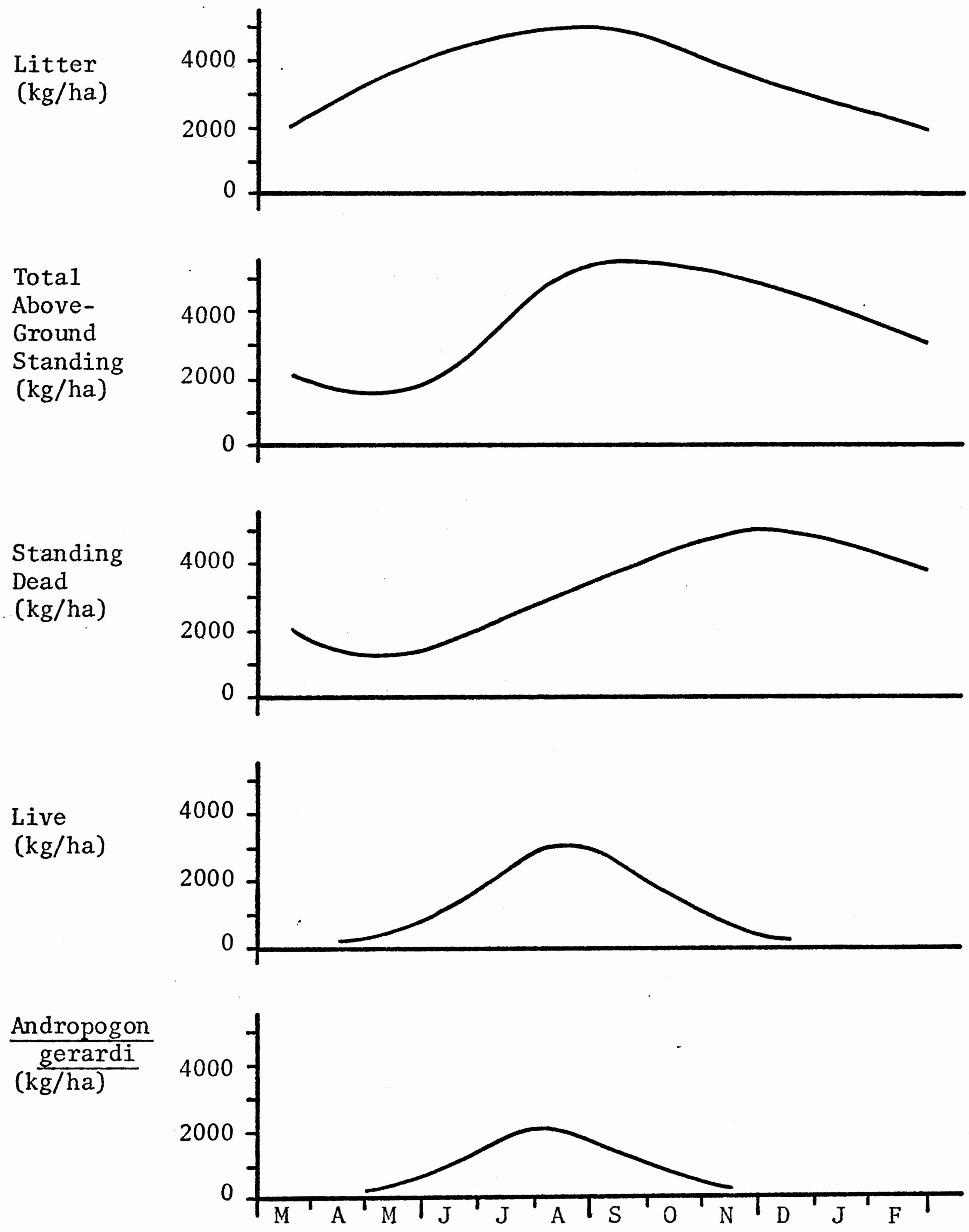

Fig. 2. General seasonal dynamics of the various components of the vegetation on the four tallgrass prairie paddocks in central Oklahoma, 1979. Biomass weights are expressed as kg/ha, oven-dry material.

paddock noticeably flattened the curves for Total vegetation compared to those for the other paddocks. In contrast Total Standing vegetation on the middle location of the burned, fertilized, and heavily grazed paddock had the highest peak, over 7,000 kg/ha. Also the trend was almost bell-shaped, increasing rapidly, peaking, then decreasing rapidly due to heavy grazing pressure later in the season. This was the location where Litter and Standing Dead were completely burned in the sampling area.

The trends in Total Standing vegetation for all 3 sampling locations in the fertilized and lightly grazed paddock were similar and peaked near 7,000 kg/ha. Differences among sampling locations in peak Total Standing vegetation were noted on the moderately grazed paddock and ranged from over 6,000 kg/ha at the upper location to under 5,000 kg/ha at the lower location.

Growth of Live vegetation began in April and peaked between late July and early August on all sampling locations. The time of peak production of live vegetation in the tallgrass prairie can vary from June through August and depends on the species composition, soil water, grazing intensity and other factors (Broyles 1978, Conant and Risser 1974, Smeins and Olsen 1970, Tomanek and Albertson 1957). Although later production peaks usually occur under light grazing (Powell et al. 1978) the completely burned middle location of paddock 4, which was heavily grazed, maintained peak Live biomass well into August. Also, the magnitude of the peak at this location, 3,800 kg/ha, was greater than the peak live biomass at any other sampling.

The fertilized and lightly grazed paddock also had very high values for peak Live biomass. These were about 3,500 kg/ha for each sampling location. The peak values reported in this study are greater than the largest peak in live biomass, 336 g/m^2 (3,360 kg/ha), reported by Sims and Singh (1978a) in a three year study of ten North American grasslands. Their value was for an ungrazed tallgrass prairie in Oklahoma, however fire and fertilization were not involved.

As was true of Total Standing vegetation, increased grazing pressure on paddock 1 flattened the Live vegetation curve and caused a lower peak value of about 2,500 kg/ha. Moderate grazing resulted in intermediate peak values which averaged 2,800 kg/ha.

The general trends in Standing Dead vegetation were similar at all locations in all paddocks. These included a gradual increase through the growing season, a peak in early winter, and a gradual decline until the beginning of the next growing season. This pattern was similar to that of other reports of the dynamics of standing dead vegetation in Oklahoma tallgrass prairie (Powell et al. 1978, Sims and Singh 1978a).

The main differences in Standing Dead dynamics among the paddocks were in magnitude. As was true of Total Standing vegetation and Live vegetation, very heavy grazing tended to flatten the curves for Standing Dead and reduce peak values. Standing Dead biomass peaked at about 3,200 kg/ha at all sampling locations in the very heavily grazed paddock. The highest peak values were about 6,000 kg/ha on the fertilized, lightly grazed paddock and at the upper location of the moderately grazed paddock.

Peak values of Standing Dead biomass, Total Standing vegetation and Live vegetation were related to fire on paddock 4. The middle location, which burned completely, had the greatest peak production of live biomass. This resulted in an increased peak Standing Dead weight at the end of the growing season (4,500 kg/ha). Unburned areas at the upper elevations had less plant growth and a lower peak for Standing Dead vegetation (3,500 kg/ha). The lower sampling location which was intermediate between the other locations in the percent of the area burned was also intermediate in the peak production of Live biomass and in the peak for Standing Dead vegetation (4,000 kg/ha).

The peak Standing Dead biomass at the upper location of the moderately grazed paddock was much greater than the peaks at the middle and lower locations in this paddock (6,000 kg/ha vs. 4,000 kg/ha). This difference was apparently caused by differences in species composition (Table 1) among the locations and differences in animal preference for the dominant plants (unpublished data). The upper location in paddock 3 was dominated by *Schizachyrium scoparium* while the lower location was dominated by *Andropogon gerardi*. Because of these differences in plant species composition the cattle grazed the lower positions of this paddock more intensely than the upper locations. Moderate grazing pressures allowed the animals to select the more highly preferred *Andropogon gerardi*. Grazing removed more material at the lower locations and reduced peak Standing Dead. Numerous ungrazed culms of *Schizachyrium scoparium* observed at the upper location of paddock 3 at the end of the grazing season indicated less grazing and caused the greater peak Standing Dead biomass.

It may seem contradictory that the lower location of paddock 3 had a higher peak production of Live biomass than the other paddock locations if it received heavier grazing. However stands within the study area dominated by *Andropogon gerardi* tend to be more productive than those dominated by *Schizachyrium scoparium*. Unpublished data indicated that the mean Total Standing vegetation of ungrazed sites increased as the percent composition of Andropogon gerardi increased (r = + 0.60) whereas the amount of Schizachyrium scoparium and Total Standing vegetation were negatively, but not highly correlated (r = - 0.28) on those same sites. Also, compared to the other locations, peak Live biomass was not maintained as long at the lower location of the moderately grazed paddock, which suggests removal of the vegetation by grazing.

Peak standing crops of Andropogon gerardi on all sampling locations ranged from 400 to 2,400 kg/ha and depended on the initial abundance of that species as well as the effects of grazing, fire and fertilization. The lowest value of 400 kg/ha was for the upper location of the moderately grazed paddock and was due to the relatively low initial abundance of Andropogon gerardi at that location. The highest value of 2,400 kg/ha occurred at both the lower location of the fertilized, lightly grazed paddock and despite heavy grazing, at the completely burned, middle location in paddock 4. This seems to support the findings of Peet et al. (1975) that the production of Andropogon gerardi is increased by fire.

Because it was a highly preferred forage and readily consumed by the animals, Andropogon gerardi reached peak production earlier in the growing season on locations receiving heavier grazing pressures. Peak standing crops of Andropogon gerardi were attained by late June on the very heavily grazed paddock, by early June on the burned, fertilized, heavily grazed paddock and the preferred lower location of the moderately grazed paddock, but not until late July on the other locations of the moderately grazed paddock and all locations in the fertilized, lightly grazed paddock due to light grazing. The favorable growing conditions during this study allowed Andropogon gerardi to maintain relatively high plant water potentials (unpublished data) and associated high rates of production throughout most of the growing season resulting in peak biomass persisting through early August at all of the sampling locations.

Figure 3 summarizes the calculated rates of plant biomass increase during the seven different grazing periods. Rates of biomass increase for the burned, fertilized, heavily grazed paddock were higher than for any other paddock throughout the first half of the grazing season then rapidly decreased at the end of the grazing season. The calculated rates were nearly identical for both the moderately grazed paddock and the fertilized, lightly grazed paddock, being relatively high through the first of August then declining during the remainder of the grazing season. Rates of biomass increase on the very heavily grazed paddock were initially high, but decreased steadily with each successive grazing period. The high value calculated during the last grazing period may have been caused by over-estimating consumption.

The maximum rates of increase calculated for this study and their approximate times of occurrence were 67 kg/ha/day during mid-June for the burned, fertilized, heavily grazed paddock, 54 kg/ha/day during the same time period for the heavily grazed, 46 kg/ha/day during mid-July for the moderately grazed paddock, and 45 kg/ha/day for the fertilized, lightly grazed paddock. These values were generally in agreement with maximum rates of increase in live biomass reported by Sims and Singh (1978a). They reported average maximum rates from 4.75 to 6.21 g/m^2/day (48-62 kg/ha/day) for a tallgrass prairie site in Osage County, Oklahoma.

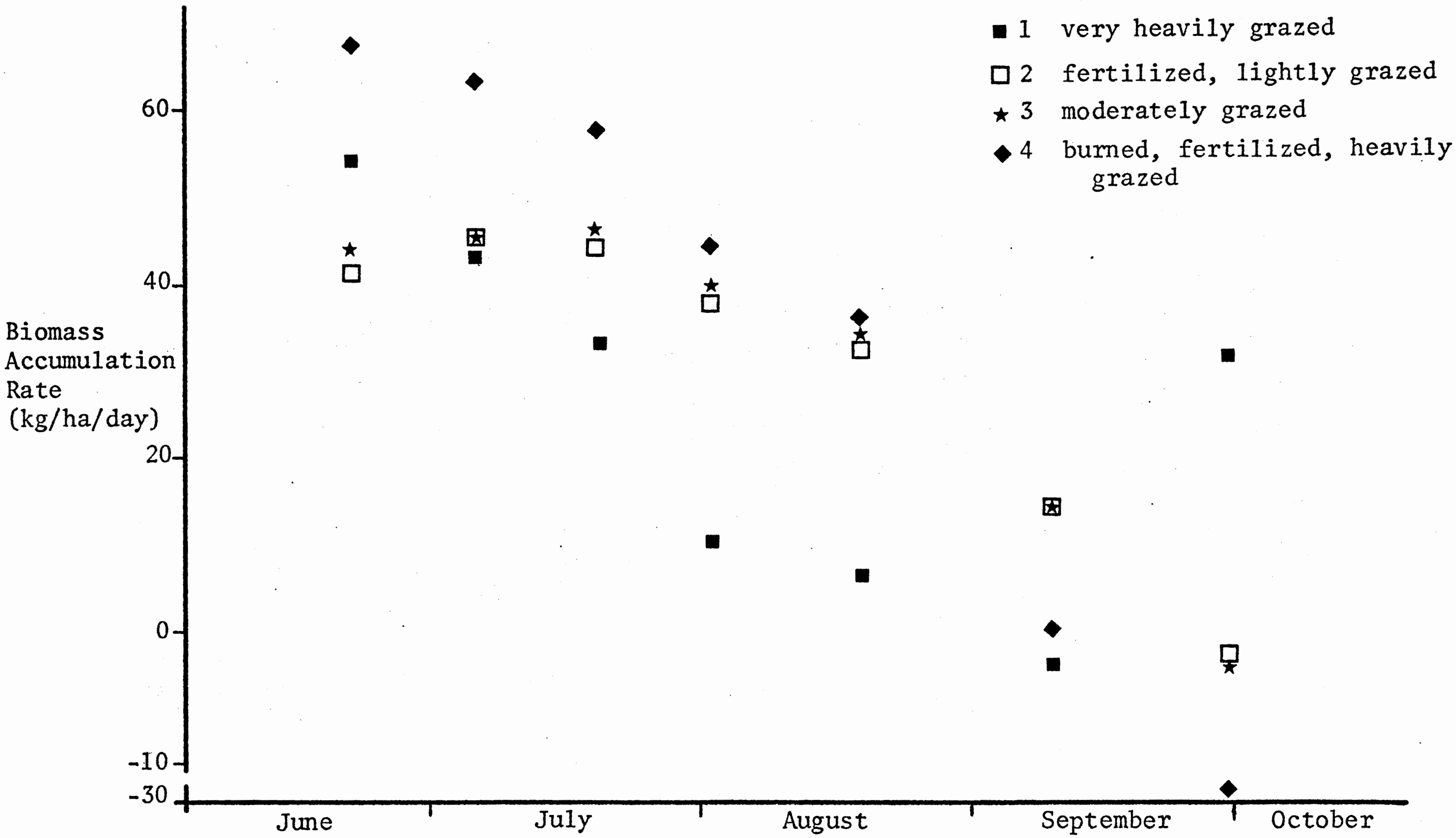

Fig. 3. Rates of biomass accumulation during each grazing period on the four tallgrass prairie paddocks in central Oklahoma, 1979.

Assuming rates calculated for this study are an adequate indication of at least relative differences in productivity, differences in the effects of management practices on primary productivity can be compared. Productivity should naturally decline with advanced plant maturity as the growing season progresses. This trend in productivity is evident on both the moderately grazed and the fertilized, lightly grazed paddocks. The trends in productivity on these two paddocks were very similar and should serve as a standard to compare the effects of the other management practices. Fire in combination with fertilization increased productivity. However with heavy grazing pressures productivity eventually declined below the productivity of areas subjected to moderate and light grazing pressures. Very heavy grazing pressures resulted in rather immediate decreases in productivity.

CHAPTER V

CONCLUSIONS

The response of tallgrass prairie vegetation in central Oklahoma to different strategies of management depends on many factors, foremost of which include the ability of the manager, the condition (species composition and vigor of the plants) of the land and the weather. In this study the expertise of one of the two or three rangeland scientists in Oklahoma was utilized, the land was in excellent condition and precipitation was above average. These conditions are not meant to discount the results of the study, but rather are mentioned to define its limitations.

The management strategy of very heavy grazing (0.57 a.u./ha) is the most harmful to the vegetation in the long run. Some of the short-term effects of very heavy grazing noted during this study were: an increase in grazing pressure during the latter part of the grazing season, a decrease in season-long mean weights of Litter, Total Standing vegetation, Standing Dead vegetation, Live vegetation and individual species, a dampening of the seasonal dynamics curves for these components of the vegetation along with reduced and earlier-occurring peak values, and an immediate decrease in primary productivity. Grazing central Oklahoma tallgrass prairies heavily, i.e. at the grazing pressures used in this study, is strongly discouraged.

Fertilization and light grazing (0.14 a.u./ha) resulted in a steady decrease in grazing pressure through most of the grazing season. Because of light grazing, adequate precipitation, and perhaps a moderate response to fertilizer, season-long mean values as well as seasonal peaks of the various components of the vegetation were generally higher under this management strategy than any of the other strategies. Primary productivity was assumed to follow a natural decreasing trend through the grazing season caused by advanced phenological stages of plant growth. Therefore the short-term effects of light grazing and fertilization are not harmful, but the abundant plant material remaining may eventually accumulate to a point that limits productivity.

The management strategy producing the most uniform biomass accumulation rate was the traditional and conservative practice of moderate grazing (0.23 a.u./ha). Despite some sampling locations being heavily dominated by Schizachyrium scoparium (which is less productive than Andropogon gerardi), primary productivity of the moderately grazed paddock was nearly identical to that of the fertilized lightly grazed paddock through the entire grazing season. Compared to some of the other treatments, mean season-long and peak values for the various components of the vegetation were not as great under moderate grazing pressures. However the central objective of any land management strategy should be to maintain quality and productivity rather than to maximize means and peaks.

Fire and fertilization combined with heavy grazing (0.43 a.u./ha) had diametrically opposing effects as exhibited by the bell-shaped curves detailing the dynamics of Total Standing vegetation and Live vegetation on the burned, fertilized, heavily grazed paddock. Primary productivity was very high early in the season resulting in abundant plant growth. However heavy grazing pressures caused productivity to decline later in the season. Although not statistically significant, the higher livestock weight gains on the burned paddock may be of practical significance since many studies proved higher livestock weight gains result when bluestem rangelands are burned. Although heavy grazing cannot be recommended, the management strategy for central Oklahoma tallgrass prairie used for beef production should consider the use of fire, controlled grazing pressure, and possibly fertilizer.

The "optimum grazing pressure" should be the maximum grazing pressure which maintains primary productivity for the longest period through the growing season and every year thereafter. In this study the optimum grazing pressure was between 0.2 and 0.4 animal units per Mg of available forage. Additional research is needed that pinpoints optimum grazing pressures under a wide variety of conditions. Being able to quantify grazing pressures would undoubtedly be more broadly applicable than recommendations based on stocking rates. These optimum values should also aid in planning grazing systems, reduce the uncertainty of many management decisions involving rangeland livestock, and hopefully alleviate some of our current problems.

LITERATURE CITED

Anderson, K.L., E.F. Smith, and C.E. Owensby. 1970. Burning bluestem range. J. Range Manage. 23:81-92.

Anderson, R.C. 1976. Role of fire in grassland management. Pp. 27-43 in The Grasses and Grasslands of Oklahoma, Symposium Proceedings. Oklahoma Academy of Science and The Nobel Foundation. J.R. Estes and R.J. Tyrl (eds.). The Nobel Foundation, Ardmore. 182p.

Armold, E.M. No date. The history of Fort Reno. Mimeograph material.

Baker, R.L. and J. Powell. 1978. Oklahoma tallgrass prairie response to atrazine with 2,4-D and fertilizer. Pp. 681-683 in Proc. First International Rangeland Congress. 742p.

Broyles, P.J. 1978. Oklahoma tallgrass prairie species composition and production responses to rotation fertilization on different range sites. Thesis. Oklahoma State University, Stillwater, 70p.

Conant, S., and P.G. Risser. 1974. Canopy structure of a tallgrass prairie. 27:313-318.

Cordova, F.J., J.D. Wallace and R.D. Pieper. 1978. Forage intake by grazing livestock: A review. J. Range Manage. 31:430-438.

Draper, N.R. and H. Smith. 1966. Applied regression analysis. John Wiley and Sons, Inc., New York. 407p.

Dunn, G.L. and J. Powell. 1979. Effect of grassland management on range condition, run-off, and water quality: Annual Progress Report. Oklahoma Agricultural Experiment Station and U.S.D.A., (SEA). 30p.

Ellison, L. 1960. Influence of grazing on plant succession of rangelands. Bot. Rev. 26:1-78.

Gay, C.W. and D.D. Dwyer. 1965. Effects of one year's nitrogen fertilization on native vegetation under clipping and burning. J. Range Manage. 18:273-277.

Gibson, A.M. 1965. Oklahoma; a history of five centuries. Harlow Publishing Co., Norman. 523p.

Heady, F. 1975. Rangeland management. McGraw-Hill, Inc., New York. 460p.

Kelting, R.W. 1954. Effects of moderate grazing on the composition and plant production of a native tallgrass prairie in central Oklahoma. Ecology 35:200-207.

Meuggler, W.F. 1976. Ecological role of fire in western woodlands and range ecosystems. Pp. 1-9 in Use of Prescribed Burning in Western Woodland and Range Ecosystems, a Symposium. Utah State Univ., Logan.

Ostle, B. 1963. Statistics in research. The Iowa State University Press, Ames, Iowa. 585p.

Owensby, C.E. 1980. Introductory range management. Kans. State Univ. Processed Teaching Manual. Agron. Dept.

Owensby, C.E. and E.F. Smith. 1979. Fertilizing and burning Flint Hills bluestem. J. Range Manage. 32:254-258.

Pechanec, J.F. and G.D. Pickford. 1937. A weight estimate method for the determination of range or pasture production. J. Amer. Soc. Agron. 29:894-904.

Peet, M., R. Anderson and M.S. Adams. 1975. Effect of fire on big bluestem production. Am. Midl. Nat. 94:15-26.

Penfound, W.T. 1964. The relation of grazing to plant succession in the tallgrass prairie. J. Range Manage. 17:256-260.

Powell, J. 1972. More efficient use of range herbage with short duration grazing. Okla. Agr. Exp. Sta. Res. Rept. P-672, pp.27-42.

Powell, J., R.W. Hammond and J.F. Stritzke. 1973. Managing rangeland forbs with fertilization, herbicide application and seasonal grazing. Okla. Agr. Exp. Sta. Res. Rept. P-686, pp.27-31.

Powell, J., F.R. Crow and D.H. Wagner. 1978. Plant biomass and nutrient cycling on a grazed, tallgrass prairie watershed. Pp. 216-220. In Proc. First International Rangeland Congress. 742p.

Powell, J., H.T. Zawi, J.J. Crockett, L.I. Croy and R.D. Morrison. 1979. Central Oklahoma rangeland response to fire, fertilization, and grazing by sheep. Okla. Agr. Exp. Sta. Bull. B-744. 25p.

Rice, E.L. and S.K. Pancholy. 1972. Inhibition of nitrification by climax ecosystems. Amer. J. Bot. 59:1033-1040.

Rice, E.L. and S.K. Pancholy. 1973. Inhibition of nitrification by climax ecosystems. II. Additional evidence and possible role of tannins. Amer. J. Bot. 60:691-702.

Rice, E.L. and S.K. Pancholy. 1974. Inhibition of nitrification by climax ecosystems. III. Inhibitors other than tannins. Amer. J. Bot. 61:1095-1103.

Sims, L., J.S. Singh, and W.K. Lauenroth. 1978. The structure and function of ten western North American grasslands. I. Abiotic and vegetational characteristics. J. Ecol. 66:251-285.

Sims, L. and J.S. Singh. 1978a. The structure and function of ten western North American grasslands. II. Intraseasonal dynamics in primary producer compartments. J. Ecol. 66:547-572.

Sims, L. and J.S. Singh. 1978b. The structure of ten western North American grasslands. III. Net primary production, turn-over, and efficiencies of energy capture and water use. J. Ecol. 66:573-597.

Sims, L. and J.S. Singh. 1978c. The structure and function of ten western North American grasslands. IV. Compartmental transfers and energy flow within the ecosystem. J. Ecol. 66:983-1009.

Smeins, F.E. and D.E. Olson. 1970. Species composition and production of a native northwestern Minnesota tallgrass prairie. 84:398-410.

Smith, E.F. and C.E. Owensby. 1972. Effects of fire on true prairie grasslands. Proc. Tall Timbers Fire Ecology Conf. 12:9-22.

Tomanek, G.W. and F.W. Albertson. 1957. Variations in cover, composition, production, and roots of vegetation on two prairies in western Kansas. Ecol. Mono. 27:267-281.

U.S.D.A. 1976. Soil survey of Canadian County, Oklahoma. Soil Conserv. Serv. in Coop. with Okla. Agr. Exp. Sta. 64p.

Vogl, R.J. 1974. Effects of fire on grasslands. Pp. 139-194. In Fire and Ecosystems. T.T. Kozlowski and C.E. Ahlgren (eds.). Academic Press, New York. 542p.

Weaver, J.E. and F.W. Albertson. 1956. Big bluestem community. Little bluestem community. Pp. 65-74. In Grasslands of the Great Plains: Their Nature and use. Johnsen Publ. Co., Lincoln, Neb. 395p.

Wilm, H.G., D.F. Costello, and G.E. Klipple. 1944. Estimating forage by the double-sampling method. J. Agron. 36:194-203.

APPENDIX

TABLE I

ANALYSIS OF VARIANCE FOR LITTER (KG/HA, OVEN-DRY) ON THE FOUR TALLGRASS PRAIRIE PADDOCKS IN CENTRAL OKLAHOMA, 1979

Source of Variation	df	Mean Square	OSL[1/]
Paddock	3	203,368,563	< .01
Location	2	216,113	.81
Paddock X Location	6	1,243,776	.32
Error a	36	1,029,402	
Day	12	32,222,982	< .01
Day X Paddock	36	7,474,322	< .01
Day X Location	24	1,603,249	< .01
Day X Paddock X Location	72	1,104,335	< .01
Error b	432	650,527	
Total	623		

[1/]Observed significance level (probability of a greater F value).

TABLE II

ANALYSIS OF VARIANCE FOR TOTAL ABOVE-GROUND STANDING VEGETATION (KG/HA, OVEN-DRY) ON THE FOUR TALLGRASS PRAIRIE PADDOCKS IN CENTRAL OKLAHOMA, 1979

Source of Variation	df	Mean Square	OSL[1/]
Paddock	3	94,293,107	< .01
Location	2	1,970,907	.39
Paddock X Location	6	5,306,135	.03
Error a	36	2,026,597	-
Day	12	102,856,298	< .01
Day X Paddock	36	6,900,936	< .01
Day X Location	24	1,267,606	.16
Day X Paddock X Location	72	1,790,781	< .01
Error b	432	978,946	-
Total	623		

[1/] Observed significance level (probability of a greater F value).

TABLE III

ANALYSIS OF VARIANCE FOR STANDING DEAD VEGETATION (KG/HA, OVEN-DRY) ON THE FOUR TALLGRASS PRAIRIE PADDOCKS IN CENTRAL OKLAHOMA, 1979

Source of Variation	df	Mean Square	OSL[1/]
Paddock	3	45,691,914	< .01
Location	2	347,343	.74
Paddock X Location	6	2,146,337	.12
Error a	36	1,179,916	-
Day	12	58,171,576	< .01
Day X Paddock	36	4,330,337	< .01
Day X Location	24	785,649	.19
Day X Paddock X Location	72	134,892	< .01
Error b	432	627,944	-
Total	623		

[1/] Observed significance level (probability of a greater F value).

TABLE IV

ANALYSIS OF VARIANCE FOR LIVE VEGETATION (KG/HA, OVEN-DRY) ON THE FOUR TALLGRASS PRAIRIE PADDOCKS IN CENTRAL OKLAHOMA, 1979

Source of Variation	df	Mean Square	OSL[1/]
Paddock	3	15,267,334	< .01
Location	2	701,033	.20
Paddock X Location	6	1,140,835	.03
Error a	36	411,423	-
Day	12	85,760,408	< .01
Day X Paddock	36	2,451,395	< .01
Day X Location	24	791,562	< .01
Day X Paddock X Location	72	637,926	< .01
Error b	432	367,055	-
Total	623		

[1/]Observed significance level (probability of a greater F value).

TABLE V

ANALYSIS OF VARIANCE FOR ANDROPOGON GERARDI (KG/HA, OVEN-DRY) ON THE FOUR TALLGRASS PRAIRIE PADDOCKS IN CENTRAL OKLAHOMA, 1979

Source of Variation	df	Mean Square	OSL[1/]
Paddock	3	14,857,059	< .01
Location	2	3,277,636	.01
Paddock X Location	6	1,474,775	.07
Error a	36	679,997	-
Day	12	30,271,687	< .01
Day X Paddock	36	1,786,984	< .01
Day X Location	24	1,152,489	< .01
Day X Paddock X Location	72	562,904	.56
Error b	432	582,093	-
Total	623		

[1/]Observed significance level (probability of a greater F value).

TABLE VI

ANALYSIS OF VARIANCE FOR SCHIZACHYRIUM SCOPARIUM (KG/HA, OVEN-DRY) ON THE FOUR TALLGRASS PRAIRIE PADDOCKS IN CENTRAL OKLAHOMA, 1979

Source of Variation	df	Mean Square	OSL[1/]
Paddock	3	2,237,610	< .01
Location	2	1,135,572	.06
Paddock X Location	6	558,998	.22
Error a	36	379,562	-
Day	12	1,340,055	< .01
Day X Paddock	36	267,803	< .01
Day X Location	24	303,198	< .01
Day X Paddock X Location	72	159,202	.28
Error 6	432	144,444	-
Total	623		

[1/]Observed significance level (probability of a greater F value).

TABLE VII

ANALYSIS OF COVARIANCE FOR TOTAL ANIMAL WEIGHT GAIN (KG)
ON THE FOUR TALLGRASS PRAIRIE PADDOCKS
IN CENTRAL OKLAHOMA, 1979

Source of Variation	df	Mean Square	OSL[1/]
Paddock	3	48	0.55
Initial Weight	1	1063	< 0.01
Error	13	64	
Total	17		

[1/]Observed significance level (probability of a greater F value).

2

VITA

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