Fig. 1. Fire in bluestem grassland. Experimental plots being burned on May 1.

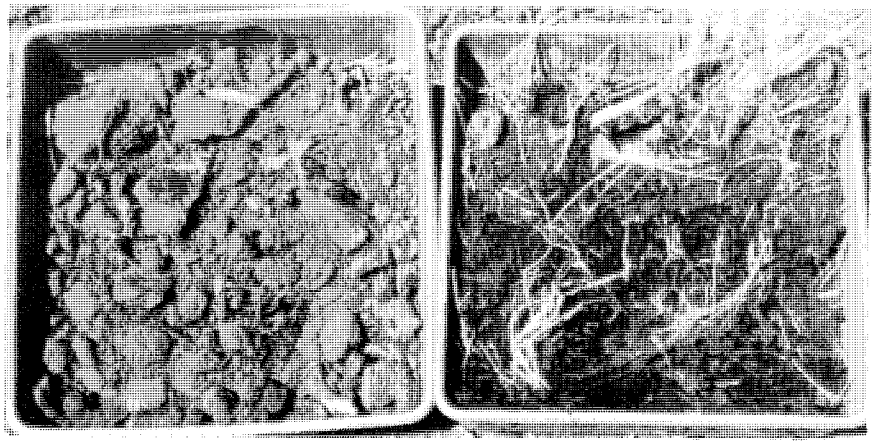

Fig. 2. Burning bluestem range affects the physical condition of the surface soil. The dry, cloddy soil was taken in early April from the surface of a plot burned in the winter. The other sample is from the surface of an adjacent unburned plot.

Burning Flint Hills Bluestem Ranges*

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GRASSLANDS have developed in an environment that included fire, and bluestem ranges are no exception. They have burned at varying intervals since they first emerged as grasslands. Lightning fires must have been common, and when man appeared he simply intensified burning and its effects on vegetation. There was, of course, no thought of the results in terms of plants or their welfare. Primitive man was likely to employ fire at any time whenever the need, real or fancied, arose; hunting, signaling, and for his incessant warfare, to name a few uses, and probably also just for sport. A leaping grass fire running before a brisk wind can be a spectacular and thrilling sight.

The Indian found that wild grazing animals would be attracted by the new, fresh grass that appeared after burning. Thus, it was not strange that the white settler soon learned from his Indian predecessors that grazing animals sought the new, fresh grass in burned-over areas in preference to that on unburned ones. Annual fire soon became a "necessity" in his livestock programs on grassland ranges.

Heavy and widespread use of range in the Flint Hills for grazing began in the early 1880's when southwestern cattlemen discovered

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that they could ship thin steers to market in April, stop them enroute to fatten on the bluestem ranges, and then ship them on to slaughter in late summer or fall. Thus, a system of transient grazing came to dominate the Flint Hills, and that system is still in use. Each year, nearly a quarter million cattle are handled in that manner, but in the early days the number was far greater. Breeding herds now are gradually taking the place of these transient animals.

The cattle owners of the Southwest, who leased Flint Hills range, soon discovered that their steers gained a little more and did so a little faster if the range had been burned in the spring before grazing started. And so, grazing leases came to contain a clause demanding spring burning. As a result, the Flint Hills were blackened by fire each year. Relatively little range remained unburned, and the burning was usually done in February or March. We shall see later that such early burning was a great deal less desirable than burning later in the spring.

Many factors affect range productivity. Some, such as precipitation or other climatic factors, most soil characteristics, slope, terrain, and exposure are completely beyond the control of the range manager. Grazing management and related activities (including fire) are, on the other hand, fully within his control. Still other factors, such as soil moisture and plant populations, can at least be affected by use and management, and one of the important management activities affecting them is fire.

The old saying that a depleted range is a droughty one is doubly apt in dry periods when every bit of water lost needlessly by runoff or allowed to evaporate unnecessarily is reflected in reduced forage production. Not only does depleted range actually lose water by reduced infiltration, accelerated runoff, and increased evaporation, but its botanical composition also is changed, the surface mulch is reduced, the vigor of its forage plants declines, and their root systems become shallower, less extensive, and more poorly distributed in the soil mass. Therefore, water is extracted less effectively from the soil by the forage species, and the competing invaders use much soil moisture that otherwise would be available to the forage plants. Losses of that kind will reduce forage yields, especially in dry years. In wet ones moisture is more likely to be adequate; then the loss of small amounts

may not make much difference so long as it is not accompanied by erosion.

Upland ranges in the prairie climate have less soil moisture most of the time than their vegetation could use effectively. They occasionally have enough soil water, at least for brief periods, but they almost never have too much. In most seasons, then, the saving of even an inch or so of moisture from needless runoff or evaporation will result in some increase in production. Improper use of fire can lead to severe losses in yield and these losses are, to a large extent, traceable to reduced soil moisture.

That grassland developed in an environment which included fire is not to say that burning benefited the vegetation, but that the kinds of plants it harmed most were gradually reduced or driven out while the more fire-tolerant species survived. These fortunately have included our major forage grasses.

Nor is this to say that burning caused grasslands. If that were the case, there would be grasslands everywhere, because there is evidence that all (or nearly all) vegetation has been subject to fire. Burning may destroy a forest, but when redevelopment (succession) occurs, forest eventually reappears. It is response to the climate that determines what kind of vegetation will finally dominate. The Flint Hills climate says "grassland"; both the climate and its vegetation favor fire. Furthermore, grasslands exhibit great tolerance to fire.

Natural fires and those by primitive man were promiscuous. When the settlers came, they began to use fire for specific management purposes and limited its use to certain times of the year. Like the Indians before them, however, they gave no thought to the effect on the vegetation, either its botanical composition (range condition) or its yield. They did not realize, for example, that range burning was making it possible to graze a little harder and thus to make a little extra profit at the expense of future production. There is hardly a Flint Hills pasture that will now carry as many cattle as it could in the early days, and at least a part of that reduction in productivity is the result of frequent, early burning. Burning bluestem range has had some effect on plant population, but the greatest effect seems to be a reduction of soil moisture, and that is directly reflected in lower yields of vegetation.

In attempting to relate burning to the behavior of bluestem grasslands, many experiments have been conducted in the past quarter century or more at the Kansas Experiment Station. Hensel (1923) reported that yields of forage were reduced by burning and that soil temperatures were increased. Total numbers of plants were not changed significantly, but there were some changes in botanical composition; for example, big bluestem (*Andropogon gerardi*) decreased while little bluestem (*A. scoparius*) increased under burning.

Aldous (1934), who conducted a series of plot trials near Manhattan, also reported reductions in yield, particularly from early burning. He pointed out, however, that yields early in the season were not reduced and that burned bluestem grasses were actually more leafy than unburned ones for a time in the early part of their growing season. He could find no decrease in soil fertility in the 5-year period of the tests.

Hanks and Anderson (1957) reported that infiltration rates in bluestem range were reduced significantly by burning. Anderson (1961) pointed out that animal gains were somewhat greater following burning, particularly late spring burning. Forage yields are not necessarily correlated with animal gains, however, because McMurphy and Anderson (1963) showed significant reductions in forage yield.

One of the reasons for the relatively high animal gains following burning may have to do with the composition of the forage. Smith and Young (1959) reported that burned little bluestem had slightly higher protein and ash contents than unburned little bluestem. Smith *et al.* (1960) showed that digestibility of crude fiber in bluestem forage was increased by burning, but they could detect no effect on the amounts of forage consumed nor any change in the digestibility of the protein fraction.

Soil moisture in the upper 5 feet of burned, ordinary upland bluestem range in ungrazed plots near Manhattan has been measured at frequent intervals since April, 1959. Four dates of burning and an unburned check have been compared. The burning dates are early December, March 20, April 10, and May 1. Moisture conditions at Manhattan during that period were favorable until late October, 1962, but the period since then through 1963 and the first 3 months of 1964 was one of the driest in the more than 100 years of weather records.

Trends in soil moisture in the upper 5 feet of bluestem range soil have been charted since early 1959. Each year, a rapid decline in soil moisture takes place from late April to late August, the period of heaviest growth in bluestem grasses. This is, at the same time, the period of highest precipitation. Replenishment of soil moisture usually takes place in the fall and winter, a period of relatively low rainfall but also a period of little to no grass growth, hence little moisture use. Both the decline and the restoration are greater and more rapid in the upper soil layers than in deeper ones.

Close examination of the data reveals that soil moisture is less abundant in burned plots than in unburned ones, and yield reductions have occurred in direct proportion to the reductions in soil moisture. Among the burned plots, moisture is least abundant in those burned earliest, and yields of forage are closely correlated with moisture levels.

Comparison of 1963 soil moisture levels in these plots with those of the preceding four favorable seasons (Table 1) shows that they had more than average amounts of moisture throughout the upper 5 feet of soil at the beginning of the 1963 growing season. The same rapid spring draw-down occurred in 1963 as in previous years, but it occurred at a somewhat accelerated rate because of the low precipitation. It is also evident that low precipitation in 1963 allowed the summer levels of soil moisture to fall even lower than in previous years. Light fall rains replaced a little of the moisture but only in the surface foot of soil.

The bluestem range has gone through the winter with its soil moisture at a dangerously low level, and the need for significant amounts of precipitation is indicated if the range is not to be reduced greatly in productivity in 1964. Unless frequent, substantial rains come, the stocking rates will have to be reduced or the range will become seriously overgrazed. That will result in low productivity due to depletion, the effects of which may be felt many seasons.

Table 1 compares the moisture levels in the upper 5 feet of soil at various times in 1963 with those at comparable times in the previous 4 years. There was an average of about ½ inch more water present before the 1963 growing season began, but it fell to an average of approximately 3⅓ inches less at its lowest point. It failed to build

Table 1. Average amounts of water in upper 5 feet of soil in bluestem range burned at various times

	Time of Burning				
	December (inches)	March 20 (inches)	April 10 (inches)	May 1 (inches)	Unburned (inches)
Maximum amount before spring growth begins: 1963	21.11	21.36	21.50	22.17	22.57
Av. of 1959–62	19.65	21.19	21.42	21.91	21.94
Minimum amount in late summer: 1963	11.91	12.08	12.01	12.51	13.01
Av. of 1959–62	14.80	15.34	15.72	16.07	16.34
Amount at end of year: 1963	13.58	13.81	13.81	19.59	14.57
Av. of 1959–62	18.01	18.73	19.61	19.84	20.06

back in late 1963, so at the close of the year it averaged more than 5 inches below the 1959-62 levels. Also, regardless of the type of season, burned range has less moisture than unburned, and ranges burned early have had less than those burned late.

Table 2 shows the forage yields from these plots taken over an extended period of years. Burning reduces yields, and early burning reduces them more than late burning.

Table 2. Ordinary upland bluestem range: effect of 30 years of burning on yields

Time of Burning	Av. Yield lbs/acre
December	1957
March 20	2016
April 10	2147
May 1	2345
Unburned	2604

The preceding results have been obtained from ungrazed plots. To check them further under grazing, gains of yearling steers on bluestem range pastures burned approximately March 20, April 10, and May 1 each year (1950-63) have been compared with those on unburned range. The period of 1952 to 1956 was a dry one, rainfall was about average during the 1957-62 period, but it was far below normal in 1963. Gains per head as reported by Smith *et al.* (1963) have averaged high for the entire 14-year period under late spring burning. They started high but dropped somewhat under mid spring burning, and have been approximately equal to the check under early spring burning except during the last 3 years of the trials. The results agree closely with those obtained from forage yield trials on the ungrazed burned plots. Table 3 shows the gains by steers as affected by burning date.

Further comparison may be made by ranking the yields (steer gains) by years among the burned bluestem pastures and the non-

Fig. 3. Bluestem range burned annually on March 20 and stocked for the growing season at the rate of 5 acres per animal unit. Photo in late August.

Fig. 4. Bluestem range burned annually on May 1 and stocked for the growing season at the rate of 5 acres per animal unit. Photographed on same day as Figure 3. The range burned in late spring has far more forage than the one burned 6 weeks earlier.

Table 3. Gain of yearling steers on bluestem range burned annually at various spring dates—gains expressed as pounds per head for the growing season, May 1 to mid-October

	Time of Burning			
	Early Spring Mar. 20 (lbs)	Mid Spring Apr. 10 (lbs)	Late Spring May 1 (lbs)	Check (unburned) (lbs)
Av. gain per steer, 1950-56	239	260	262	235
Av. gain per steer, 1957-63	238	249	260	237

burned one. Table 4 shows those ranks year by year, beginning in 1950. The pasture burned May 1 (late spring) ranked first in animal gain in nine of the 14 years and second in four other years. Ranks for gains under April 10 burning were next highest.

Table 5 shows the number of years in which the various ranks occurred and breaks the 14-year period into segments. The pasture burned in early spring has never ranked high, but has ranked especially low near the end of the 14-year period. Those burned in mid and late spring have declined somewhat in rank, while rank of the unburned pasture has increased, being first in two of the last three years.

In a further attempt to relate yields and physical conditions, some attributes of the soils under the different burning treatments have been studied. Soil organic matter has been investigated in the ordinary upland and claypan range sites. Both range sites showed considerably more organic matter in their upper layers of soil than in deeper ones, and ordinary uplands more than claypans (Table 6).

Among the various grazing and burning treatments compared, no significant differences could be detected in organic matter contents in the claypan range site, but such differences were observed in ordinary uplands. Early spring (March 20) burning gave significantly lower percentages than the check (unburned) comparable, in fact, to those of overgrazed range. Neither mid (April 10) nor late (May 1)

Table 4. Gains of steers on burned bluestem range ranked year-by-year according to time of burning

Year	Time of Burning			Check Unburned (Rank)
	March 20 (Rank)	April 10 (Rank)	May 1 (Rank)	
1950	4	1	2	3
51	3	1	2	4
52	3	2	1	4
53	4	3	1	2
54	3	2	1	4
1955	3	2	1	4
56	4	2	1	3
57	2	3	1	4
58	3	1	2	4
59	3	2	1	4
1960	2	3	1	4
61	3	2	4	1
62	4	3	2	1
1963	4	3	1	2

spring burned pastures were significantly different from the check (Table 7).

During the investigations, approximate field capacities and wilting coefficients were determined at ⅓ and 15 atmospheres pressure, respectively. The values are somewhat higher for the claypan than for the ordinary upland range site (Table 8); early spring burning tends to decrease the field capacity in both range sites (Table 9). There is also a slight reduction in the wilting coefficient in ordinary upland burned in the early spring. These small soil differences are related directly to forage and animal gains.

Not all grassland species react alike to burning. Fortunately, the grasses which dominate bluestem ranges, which produce most of their forage, and which are relished most by cattle are, at the same time, highly tolerant to burning. They are the ones which decrease under heavy use while certain lesser ones increase.

Burning has brought about some change in the botanical com-

Table 5. Season-long gains of steers on bluestem range burned annually ranked year-by-year during various parts of the 14-year period beginning 1950

Years	Rank	Number of Times Rank Occurred			
		Time of Burning			Unburned Check (No.)
		March 20 (No.)	April 10 (No.)	May 1 (No.)	
1950-63	1st	0	3	9	2
	2nd	2	6	4	2
	3rd	7	5	0	2
	4th	5	0	1	8
1950-56	1st	0	2	5	0
	2nd	0	4	2	1
	3rd	4	1	0	2
	4th	3	0	0	4
1957-63	1st	0	1	4	2
	2nd	2	2	2	1
	3rd	3	4	0	0
	4th	2	0	1	4
1961-63	1st	0	0	1	2
	2nd	0	1	1	1
	3rd	1	2	0	0
	4th	2	0	1	0

position of the experimental pastures. Table 10, which summarizes the plant make-up, shows that after 14 years of annual burning the ones burned late in the spring have the highest percentage of decreaser grasses and the lowest percentage of the increasers. There was some decline in the percentage of decreaser grasses in all treatments during the drought of the mid 1950's, but the pastures burned in the mid and late spring have shown restoration of these in the 1960's. The fact that they are now high in decreasers may be taken as evidence that burning when properly controlled need not result in undesirable shifts in botanical composition in bluestem range, even though yields of forage may be reduced.

Table 6. Average organic matter content (percentage) in different soil layers in ordinary upland and claypan range sites in the Donaldson experimental bluestem range pastures (average of all grazing and burning treatments

Depth (inches)	Ordinary upland (%)	Claypan (%)
0-4	3.01	2.88
4-8	2.60	2.35
8-12	1.89	1.69
12-18	1.35	1.11
18-24	1.14	0.90
24-30	0.77	0.60
Average	1.79	1.59

Table 7. Organic matter percentage in the upper 30 inches of ordinary upland bluestem range soil as affected by grazing and burning treatments

Treatment	Organic Matter (%)
Moderate stocking, not burned	1.77[a]
Heavy " , " "	1.24[b]
Moderate " , burned March 20	1.47[b]
" " , " April 10	2.00[a]
" " , " May 1	1.86[a]

Percentages are not significantly different at the 0.05 level of probability when followed by the same letter, as shown by Duncan's new multiple range test.

Table 8. Approximate field capacities and wilting coefficients by depth and range site expressed as percentages—average of all grazing and burning treatments

	Average Approximate Field Capacity		Average Approximate Wilting Coefficient	
	Range Site		Range Site	
(inches)	OU[a] (%)	Cp[b] (%)	OU[a] (%)	Cp[b] (%)
0-4	36.5	40.1	12.2	14.3
4-8	35.9	39.0	11.9	13.2
8-12	35.1	38.4	11.5	12.7
12-18	34.9	38.0	10.8	12.3
18-24	33.8	37.0	10.5	11.7
24-30	33.2	36.1	10.2	11.2
Average	34.8	38.1	11.1	12.6

[a] OU = Ordinary upland
[b] Cp = Claypan

Table 9. Average approximate field capacities and wilting coefficients in upper 30 inches of soil as affected by burning. All pastures stocked moderately (5 acres per animal unit)

	OU range site		CP range site	
Treatment	Field Capacity (%)	Wilting Coef. (%)	Field Capacity (%)	Wilting Coef. (%)
Not burned	35.3	11.6	38.1	12.5
Early spring burning	34.0	10.8	37.3	12.6
Mid " "	35.1	11.4	38.2	12.6
Late " "	34.7	11.2	38.1	12.4

Table 10. Effect of annual burning on plant population, Donaldson pastures, 1950-1963, decreasing and increasing grasses shown as percent of total population

Year	Ordinary Upland Range Site				Limestone Breaks Range Site			
		Time of Spring Burning				Time of Spring Burning		
	Check (%)	Early (%)	Mid (%)	Late (%)	Check (%)	Early (%)	Mid (%)	Late (%)
				Grass Decreasers				
1950	69	60	57	62	67	75	62	72
1954	58	54	48	61	52	51	69	69
1958	47	34	50	62	66	48	49	66
1962	46	39	63	65	58	49	68	75
1963	47	42	71	72	62	47	68	82
				Grass Increasers				
1950	17	29	28	26	21	13	26	20
1954	24	37	33	29	32	31	18	25
1958	23	34	30	24	19	26	32	25
1962	35	31	18	19	24	24	21	18
1963	33	30	15	14	26	27	18	15

Burning is an established range management practice in the Flint Hills, and is likely to be continued regardless of possible consequences. A few general recommendations may be made to minimize the harmful effects and accentuate the desirable ones:

1. Burn only in late spring.
2. Burn only when the soil and plant crowns are damp after a rain.
3. Burn when there is a breeze to move the fire along briskly.
4. Avoid close and early grazing after burning.

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