

Effects of Range Burning on Kansas Flint Hills Soil



CLENTON E. OWENSBY AND JOHN BRUCE WYRILL, III

Highlight: Two tallgrass prairie areas burned annually for 20 (grazed) and 48 (ungrazed) years at different times showed differences in soil chemical and physical properties. Winter, early-spring, and mid-spring burned ungrazed plots were generally higher in soil pH, organic matter, and K than late-spring burned or unburned plots. Late-spring and winter burning lowered soil N on ungrazed and grazed plots. Differences in soil nutrient levels though statistically significant probably were not large enough to affect plant growth.

Burning, an old, widely used practice, has long been an important ecological factor and management tool in the bluestem range area. More than 3 million acres of Flint Hills bluestem pasture have burned periodically. Much of it is burned annually, with late spring burning most desirable. Burning is used to obtain greater animal gains, promote earlier grass growth in the spring, eliminate weeds and brush, and to promote uniform grazing distribution (Anderson et al. 1970).

There are also detrimental effects of burning bluestem range. Dry plant crowns of bunchgrasses may burn, destroying part or all of a plant. Removing (burning) protective top growth and mulch may cause erosion and reduce water infiltration into the soil. Removal of mulch also may reduce humus and nitrogen additions to the soil.

Most research conducted regarding

effects of burning on soils has been done in forests and woodland areas, where burning is relatively infrequent. Many have considered results from forests applicable to grassland areas, but differences in forest and grassland soils make such an extrapolation unreasonable.

The effects of fire on chemical and physical properties of a loamy upland, bluestem-range soil burned at different times were studied under grazed and nongrazed conditions.

Materials and Methods

Experimental Areas

True Prairie loamy upland range sites (Anderson and Fly, 1955) in two experimental units were studied near Manhattan, Kans., one grazed and one ungrazed. Soil was a pachic argiustoll; fine, montmorillonitic mesic.

The ungrazed unit was fenced and burning initiated in 1926. The original ten 2 x 4 rod plots in that area constituted five duplicated burning treatments, five burned annually and five biennially. The study was suspended in 1944, resumed in 1950, and continued to the present on the same plots burned annually. Treatments included *winter* (Decem-

ber 1), *early spring* (March 20), *mid-spring* (April 10), and *late spring* burning (May 1), and *unburned*.

There were two pastures in the grazed experimental unit. One (44 acres) was burned annually from 1950 to 1971 in late spring (May 1); the other (60 acres) was not burned between 1950 and 1971. Both were stocked at a moderate rate (5.0 acre/animal unit) from May 1 to October 1 with yearling steers (500-600 lb/hd). The pastures and plots were not always burned on exact dates indicated, because an effort was made to burn when the soil surface was wet to afford maximum protection to plant crowns.

Vegetation was primarily warm-season grasses, i.e. big bluestem (*Andropogon gerardi* Vitman), little bluestem (*A. scoparius* Michx.), and indiagrass (*Sorghastrum nutans* (L.) Nash). Numerous forbs and a few brush species constituted the remainder.

Procedure for Measuring Chemical Properties

Soil sampling procedure

Ten soil cores were taken in late November, 1970, from each of the nongrazed plots and five cores from each of three different areas in each of the two grazed pastures. The cores (1.5 inches in diameter) were taken with a hydraulic soil probe to 4 ft (1.22 m) and divided into seven depth increments: 0-3, 3-6, 6-9, 9-12, 12-18, 18-24, and 24-36 inches. The subsample soil cores from each plot were composited, air-dried six weeks, and ground in a mortar to a fine powder.

The authors are assistant agronomist and former graduate student, Department of Agronomy, Kansas State University, Manhattan.

The paper is contribution No. 1201, Department of Agronomy, KAES, Kansas State University.

Manuscript received May 30, 1972.

Each soil sample was analyzed for pH, organic matter, Ca, Mg, N, P, and K. Soil reaction was determined from a 1:1 soil (air-dry) -water paste by a pH meter.

Oxidizable organic matter was determined by adding 10 ml 1N potassium dichromate to 1 g air-dry soil, followed by adding 20 ml of concentrated H₂SO₄ (Graham, 1948). After 30 minutes, 100 ml of distilled water was added to the solution, which, on cooling, was filtered and read in a spectrophotometer at a wavelength of 620 m.

Exchangeable K, Ca, and Mg was determined by adding 25 ml of 1N ammonium acetate to 5 g of air-dry soil, shaking for 10 minutes on a wristaction shaker, and filtering immediately. K in the filtrate was then determined by flame photometry. One ml aliquots of the K extract were diluted to 100 ml with 0.1N HCl; then Ca and Mg were determined by atomic absorption spectrophotometry.

Available P was determined (4) by adding 20 ml of an acid-ammonium fluoride extracting solution (.025N HCl + .03N NH₄F) to 2 g of air-dry soil (Bray and Kurtz, 1945). The mixture was shaken 40 seconds and filtered immediately. To 6 ml of the filtrate, 2 ml of ammonium molybdate-hydrochloric acid reagent and 1 ml of stannous chloride were added. After 6 minutes the solutions were read at 660 m μ in a spectrophotometer standardized against similarly developed standard phosphate solutions.

Total soil nitrogen (%) was obtained by micro-kjeldahl (Cole and Parks, 1946).

Bulk Density

Bulk density was used to determine the effect of fire on physical properties of the soil. Samples were taken with a heavy steel probe that removed 347.3 cc of soil. Four samples, taken from the upper 3 inches (7.6 cm) of soil on all nongrazed, burned plots were oven dried and then weighed. Average weight of the four samples for each plot was divided by average volume to determine an average bulk density for each plot.

Statistical Analyses

A fixed-effect, three-way analysis of variance was used on the chemical analyses. Bulk density values were analyzed by

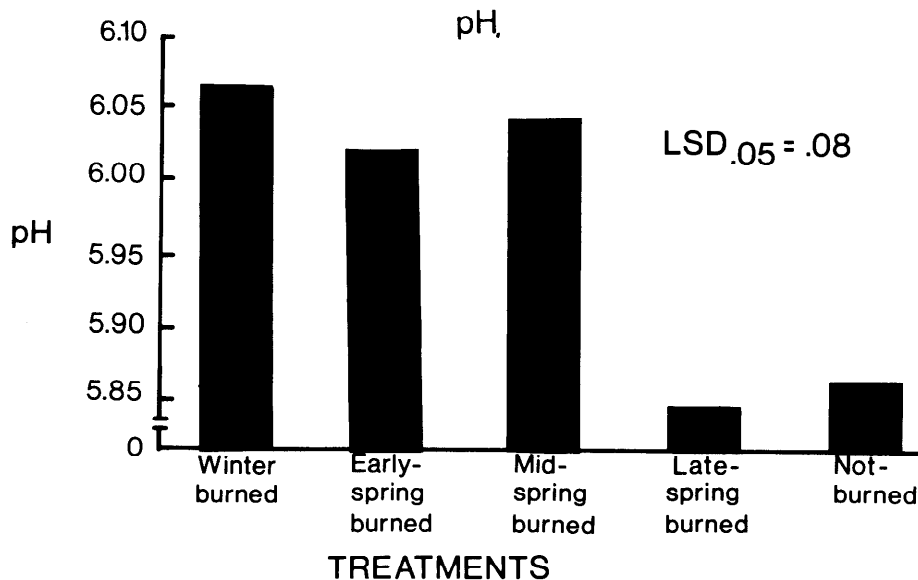


Fig. 1. pH of soil from nongrazed plots (averaged over all soil depths).

a fixed-effect, two-way analysis of variance.

Results and Discussion

Chemical Properties

pH

Soil pH for winter-burned, early-spring burned, and mid-spring burned, nongrazed plots was significantly higher than for plots burned in late spring and for nonburned plots (Fig. 1). Anderson (1965), studying moisture relations on the same plots, found moisture levels of burned treatments less than the level of the nonburned treatment. However, the difference between nonburned and burned was greater for the three earlier-burned treatments than for the late-spring burned treatment. Moisture differences may account for the lower pH on the late-spring burned and nonburned plots. With more water moving through the soil profile, more salts would leach from the soil and lower its pH. Likewise less water moving through the three earlier-burned plots would result in fewer salts moving from the profile and, consequently, a higher pH. Forage yields also have been lower on the earlier-burned plots than on

the late-spring burned and unburned plots (McMurphy and Anderson, 1965). Less plant growth would result in less nutrient use.

pH on the late-spring burned, grazed pastures was 0.25 higher than on nonburned, grazed pasture (Table 1). A similar higher pH was noted on the earlier-burned treatments than on the unburned in the nongrazed plots, but pH on late-spring burned plots and unburned did not differ.

The largest pH difference among treatments in this experiment (0.25 unit) contrasts with increases from 0.5 to 3.1 units in forested areas (Heyward and Barnette, 1964; Mayland, 1967). Greater increases on forest soil probably result from larger quantities of burned material. Researchers have noted decreases in pH with time after burning, which suggests that different data might have been obtained had soil samples in forest research been taken immediately after the fires instead of approximately 8 months later as in our study. The long history of burning in areas we studied probably makes the results representative for annual burning on pH of loamy upland soil.

Burning effects on soil pH were essentially the same at all depths. Fairly consistent amounts of vegetation were burned each year, so a consistent quantity of salts was deposited. Yearly, salts from surface deposition move farther into the soil profile and are replaced on the surface by salts from the burned vegetation, which probably explains the uniformity observed through all depths.

Table 1. Soil pH, organic matter, Ca, Mg, P, K, and total N under ungrazed pastures, averaged over all depths studied.

Treatment	pH	O.M. (%)	Ca (ppm)	Mg (ppm)	P (ppm)	K (lb/acre)	N (%)
Late-spring burned	6.66	3.00	4048.1	740.7	2.21	593	.146
Nonburned (check)	6.41	3.40	3773.9	547.8	3.31	638	.169
Difference	0.25* ^a	0.40*	274.2	192.9*	1.10*	45+	.023*

^aLSD .05 = * LSD .10 = +

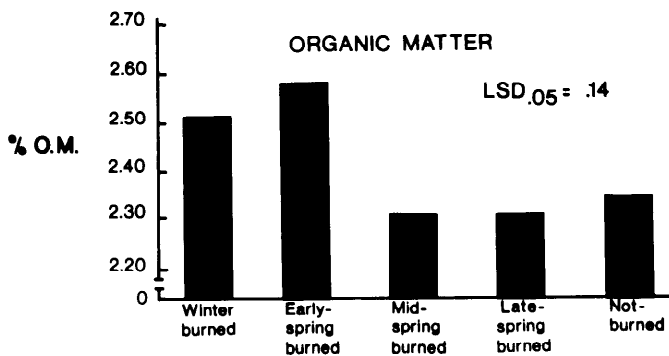


Fig. 2. O.M. of soil from nongrazed plots (averaged over all soil depths).

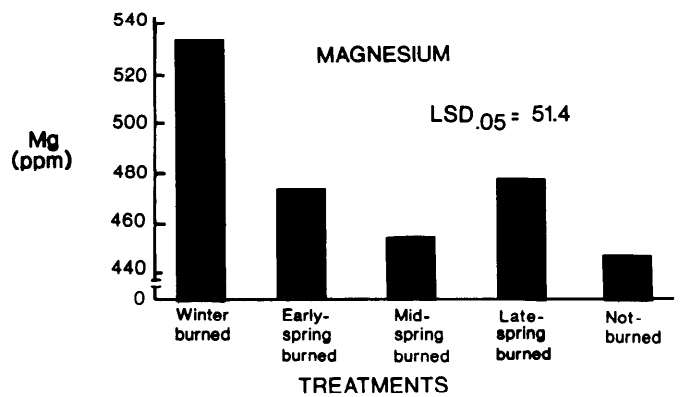


Fig. 4. Mg of soil from nongrazed plots (averaged over all soil depths).

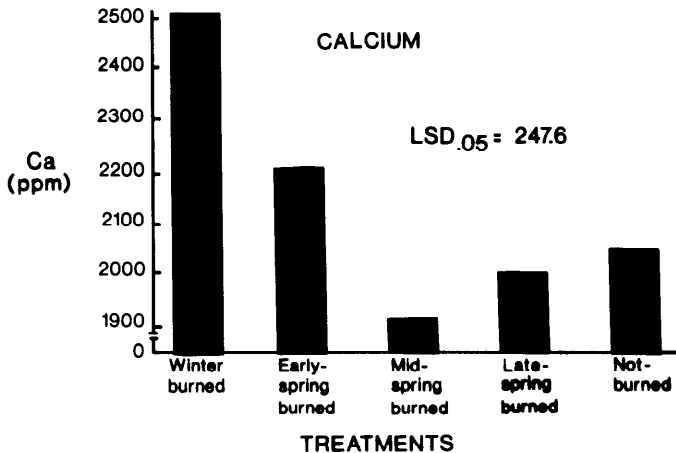


Fig. 3. Ca of soil from nongrazed plots (averaged over all soil depths).

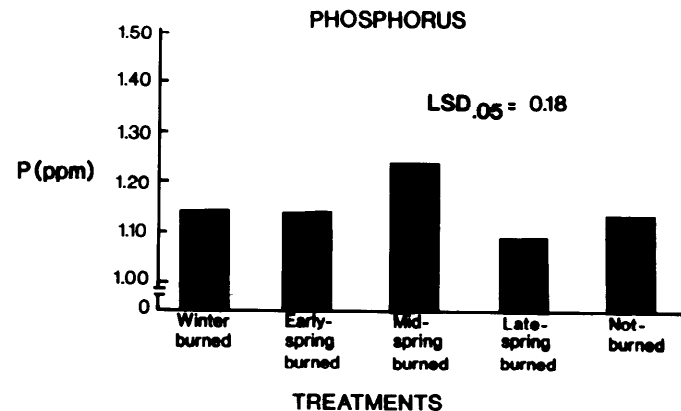


Fig. 5. P of soil from nongrazed plots (averaged over all soil depths).

Organic matter

Soil in the ungrazed area from winter burned and early-spring burned treatments had approximately 0.20% more organic matter than soil from mid-spring, late-spring, and nonburned plots (Fig. 2).

There was significantly lower organic matter in the grazed, late-spring burned pasture than the unburned one (Table 1). There was no obvious reason why fire reduced organic matter on the grazed pasture but not on the nongrazed plots with late-spring burning.

The relationship among burning treatments for soil organic matter was the same for all depths studied.

In a 5-year study using the same nongrazed experimental area we used, Aldous (1934) found that burning did not decrease the soil organic matter. Organic matter accumulation is regulated primarily by root development rather than surface accumulation of vegetative material, he explained.

Calcium

Soil from the winter burned, non-

grazed plots had significantly more Ca than soil from other burned plots (Fig. 3). The mid-spring, late-spring, and nonburned plots all had essentially the same soil calcium content. However, in winter, early-spring and mid-spring burned plots, Ca levels differed significantly from each other.

Soil Ca was similar on the grazed and nongrazed areas for the late-spring burned and nonburned plots (Table 1 and Fig. 3).

Like pH and organic matter, burning effects on calcium were the same over all depths studied among the burning treatments.

Kuccra and Ehrenreich (1962) found no significant differences between Ca contents of plants grown on burned and nonburned areas. But Elwell et al. (1941) considered burning to be responsible for reducing productivity of grassland soil by placing such minerals as Ca in a form readily removed by leaching and erosion.

Data from our study suggest a certain amount of leaching; Ca was observed to be higher in earlier burned plots than in late burned plots in upper as well as in

lower soil levels. Higher Ca content in winter burned plots likely resulted from less water moving through the plots.

Magnesium

Soil Mg content in the ungrazed plots was highest in the winter burned plot. Soil Mg levels in spring burned and nonburned plots did not differ significantly from each other (Fig. 4).

On grazed plots, late-spring burning significantly increased Mg content, compared with no burning (Table 1).

Phosphorus

On nongrazed plots burning did not affect soil P content (Fig. 5). However, on grazed plots late-spring burning significantly lowered soil P content below that of nonburned plots (Table 1).

Potassium

On nongrazed plots the three early burned plots had higher soil K than the unburned ones, but the late burned treatment did not differ from the unburned plots in soil K. On grazed pastures soil K in the late-spring burned plots was lower than in the nonburned plot (Table 1).

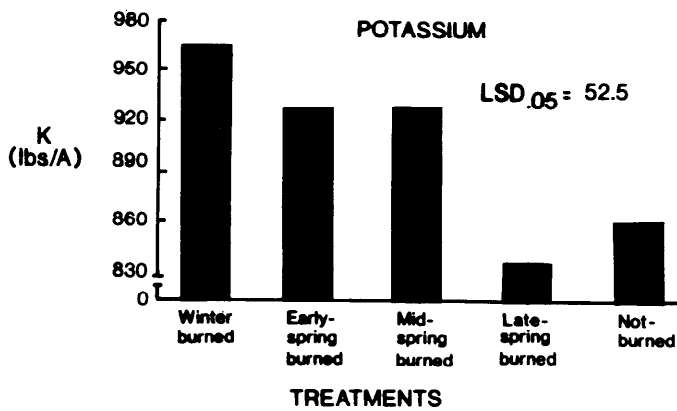


Fig. 6. K of soil from nongrazed plots (average of 0-3" depth).

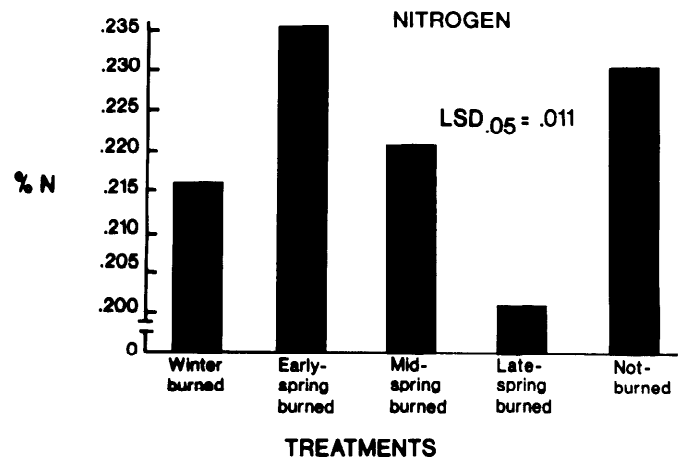


Fig. 7. N of soil from nongrazed plots (average of 0-3" depth).

Nitrogen

Differences in soil N existed only in the 0-3 inch soil layer on nongrazed plots. Not burned, early-spring burned and mid-spring burned treatments did not differ significantly in soil N, but late-spring and winter burning lowered soil N more than did not burning (Fig. 7). The results are inconsistent with the organic matter data.

In nongrazed plots, late-spring burning produced soil nitrogen content .030% lower than not burning (Fig. 7). In grazed plots, late-spring burning N was .023% lower than on nonburned plots (Table 1).

Aldous (1934), studying the effect of burning on bluestem range from the same nongrazed experimental area we used, found that burning 5 years caused no decrease in total nitrogen.

Physical Properties

Fire did not affect bulk density of the soil (Table 2). Others (Anderson, 1965; Hanks and Anderson, 1957; and McMurphy and Anderson, 1965), using the same experimental area that we used, found infiltration reduced in burned areas. Infiltration is aided by noncapillary porosity of the uppermost portion of the soil profile. Good crumb structure at the soil surface must be maintained for good infiltration. Therefore, some physical changes should occur on burning; however, they were so slight that they could

Table 2. Bulk density for indicated burning treatments on ungrazed plots (g/cc).

Burning date	Density (g/cc)
Winter	1.082
Early-spring	1.037
Mid-spring	1.051
Late-spring	1.093
Not burned	1.093

not be detected by bulk density measurements we used.

Conclusions

Time of burning ungrazed range affects fire's influence on soil chemical properties. Winter burning caused most changes, with higher soil pH, organic matter, Ca, Mg, K, and lower soil N than with other treatments. Late-spring burning had the least influence, resulting in only a decrease in soil nitrogen. The strong influence of earlier burning on pH and certain mineral salts was attributed to reduced infiltration by raindrop action on the bare soil. That would reduce salts leaching from the soil.

Bulk density of the 0-3 inch layer of soil was not affected by fire on nongrazed plots.

Late-spring burned, nongrazed plots had slightly lower soil N than plots not burned. Under grazing, soil organic matter, N, P, and K were lower and soil pH and Mg higher on late-spring burned pastures than on the nonburned pasture. The more pronounced influence of burning on grazed plots may be from unknown soil differences, or may be related to the difference in years the grazed (20) and ungrazed (48) areas have been burned. It also could be related to greater erosional losses of exposed soil and deposited salts on grazed areas. Grazing reduces mulch cover and increases runoff and erosion. Grazed area slopes were also steeper than those of the nongrazed area.

Except for K and N on nongrazed plots, effects of fire on soil chemical properties were uniform throughout the soil depths we studied. We attributed the uniformity to leaching over a long period of time.

Since late spring is recommended for burning pastures in Kansas Flint Hills, its effects on soil properties are especially

important. We concluded that late-spring burning will not appreciably affect physical or chemical properties studied of areas not grazed. However, late-spring burning of grazed areas over a long period may cause statistically significant changes in soil chemical properties. However, the statistically significant changes we observed were so small, it seems unlikely that they would cause adverse effects to native vegetation.

Literature Cited

Aldous, A. E. 1934. Effect of burning on Kansas bluestem pastures. Kansas Agr. Exp. Sta. Tech. Bull. 38.

Anderson, Kling L. 1965. Time of burning as it affects soil moisture in an ordinary upland bluestem prairie in the Flint Hills. J. Range Manage. 18:311-316.

Anderson, Kling L., and C. L. Fly. 1955. Vegetation-soil relationships in Flint Hills bluestem pastures. J. Range Manage. 8:163-169.

Bray, R. H., and L. T. Kurtz. 1945. Determination of total organic and available forms of phosphorus in soils. Soil Sci. 59:39-45.

Cole, J. O., and C. P. Parks. 1946. Semimicro Kjeldahl procedure for control laboratories. Analyt. Chem. 18:61.

Elwell, H. M., H. A. Daniel, and F. A. Fenton. 1941. The effect of burning pasture and woodland vegetation. Oklahoma Agr. Exp. Sta. Bull. B-247.

Graham, E. R. 1948. Determination of soil organic matter by means of a photoelectric colorimeter. Soil Sci. 65:181-183.

Hanks, R. J., and Kling L. Anderson. 1957. Pasture burning and moisture conservation. J. Soil and Water Conserv. 12:228-229.

Heyward, F., and R. M. Barnette. 1934. Effect of frequent fires on chemical composition of forest soil in the Longleaf Pine region. Florida Agr. Exp. Sta. Bull. 265.

Kucera, C. L., and J. H. Ehrenreich. 1962. Some effects of annual burning on central Missouri prairie. Ecology, 43:334-336.

Mayland, J. F. 1967. Nitrogen availability on fall-burned oak mountain mahogany chaparral. J. Range Manage. 20:33-35.

McMurphy, D. W., and K. L. Anderson. 1965. Burning Flint Hills range. J. Range Manage. 18:265-269.