EFFECT OF BURNING ON SOIL CHEMICAL AND PHYSICAL PROPERTIES OF LOAMY UPLAND BLUESTEM RANGE

by 6791

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INTRODUCTION

Burning is an old and widely used practice and has long been an important factor in the ecology of bluestem range. For years it has been a valuable tool in range management. There are more than three million acres of Flint Hills bluestem pasture that has periodically burned. A considerable amount is burned annually with late spring burning being most desirable. Burning is used for obtaining greater animal gains, promoting earlier growth in the spring, eliminating weeds and brush, and for promoting more uniform grazing distribution.

There are also detrimental effects of burning bluestem range. Dry plant crowns of bunchgrasses may burn, destroying part or all of a plant. Removal of 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 of the research conducted with respect to the effect of burning on soils, has been done in forests and woodland areas, where burning is relatively infrequent. Results generally showed severe losses of organic matter and nitrogen and increases in pH and various mineral salts. The bulk density on these soils usually increased under burning management. These detrimental effects associated with fire in forests have resulted in wide condemnation of fire. Many have considered results from forests to be applicable to grassland areas, but differences in forest and grassland soils make such an extrapolation unreasonable.

The purpose of this study was to determine the effect of fire on the chemical and physical properties of a loamy upland bluestem range soil burned at different times under grazed and ungrazed conditions.

REVIEW OF LITERATURE

Nitrogen: In forest soils total soil nitrogen is generally reduced in the surface organic layer as a result of burning. However, in the underlying mineral soils, gains in soil nitrogen were often recorded[8,12,22,23,25], although several investigators have noted decreases in nitrogen after burning, while others have observed no significant changes[2,9,17,36,37]. Nitrification usually increases after fire on forest soils[22,25,31,34]. In grassland soils, volatilization of nitrogen from the vegetative cover by burning does occur[13], but its effect on soil nitrogen has not been substantiated[1,10,15,28].

Organic Matter: Part of the surface organic matter on forested areas is destroyed by burning. If of a sufficiently high intensity, burning may reduce the organic matter content in the surface mineral soil, but in most cases that decrease is relatively small[8,16,30,32]. Several investigators have noted increases in organic matter after burning[12,18,21,37]. Research on grassland soils exhibited no consistent trend in organic matter. Both reductions and no losses were observed[1,5,10,14,15].

pH: The pH of forest soils usually increases immediately after a fire. That is usually attributed to deposition of mineral salts previously incorporated in plant material. Increases occur in both the organic surface layer and the upper mineral soil, but the increase is greater in the organic matter layer. With time after burning the pH in the surface organic layer decreases due to leaching of cations to mineral layers, and the pH of the mineral soil may actually increase [6,12,22,32,33]. Several investigators of forested areas have reported little or no differences between the pH of burned and unburned soils [2,31,32,34]. Research on grassland soils was insufficient to make any general conclusions.

Soil Nutrients: Immediately after burning forest soils the supply of K, Mg, and Ca regularly shows significant increases, with the increases in Ca usually being the largest. P content shows no consistent trend, exhibiting increases in some instances and decreases in others. Increases in these nutrients are generally limited to the upper layer of soil and with time, leaching consistently reduces their concentration[6,12,17,22,27,29,32,35]. These trends in concentration of exchangeable cations were not consistently observed in the limited amount of grassland research[15,24].

Physical Properties: On burned forested areas the soil is usually more dense. There is a reduction in total porosity and macropore space, and an increase in micropore space. That results in a higher bulk density and poorer infiltration characteristics[6,7,12,33,37]. No work was found that considered the effect of burning on physical properties of grassland soils.

MATERIALS AND METHODS

Experimental Areas: This study was conducted on loamy upland range sites[4] located in two experimental units located near Manhattan, Kansas, one grazed and the other ungrazed. The soil present in these units is described in detail in Table 1.

The ungrazed experimental unit is located in the college pasture on the northern part of the Kansas State University campus. The plots located here were established in 1926 by A. E. Aldous and since then have been ungrazed. The original ten plots in this area constituted five burning treatments, five burned annually and five burned biennially. This study was suspended in 1944 and resumed in 1950 and continued to the present on the same plots except that all were burned annually (Fig. 1).

The grazed experimental unit is referred to as Donaldson pastures. Two pastures in that area were sampled in this study. One (44 A or 17.8 ha) was burned annually from 1950 to present in the late spring (approx. May 1) and the other (60 A or 24.3 ha) was not burned during the same period. Both pastures were stocked at a moderate rate (5.0 A or 2.2 ha per animal unit) from May 1 to October 1 with yearling steers (500-600 lbs (227-273 kg) /hd). It is important to point out that the pastures and plots were not always burned on the exact dates indicated, because an effort was made to burn when the soil surface was wet, thus affording maximum protection to plant crowns.

Vegetation on loamy upland range is primarily warm season grasses, i.e. big bluestem (*Andropogon gerardi* Vitman), little bluestem (*A. scoparius* Michx.), and indiangrass (*Sorghastrum nutans*(L.) Nash). Numerous forbs and a few brush species constitute the remainder.

Table 1. Soil profile description of soil on the experimental areas[1/]

This soil is a pachic argiustoll; fine, montmorillonitic, mesic. It occurs on the uplands and on the oldest alluvial terraces in the vicinity of the Kansas river, its tributaries, the Republican river, and the Smoky Hill river.

Soil Profile:		Smolan Silt Loam. (SW¼, Sec. 6, T10S, R8E). This soil occurs on the ridge crest, and is on a convex slope of 1%.
	Inches	
A_1	0- 5	Dark Grayish brown (dry) to very dark gray (moist) silt loam; Slightly hard, friable; moderate medium and fine granular structure; abrupt lower boundary.
AB	5-12	Brown (dry) to dark brown (moist) silty clay loam; very hard, very firm; weak medium blocky breaking into moderate fine blocky structure; abrupt lower boundary.
B_{21}	12-18	Brown (dry) to dark reddish brown (moist) silty clay; very hard, very firm; weak medium blocky breaking into moderate fine blocky structure; abrupt lower boundary.
B_{22}	18-32	Brown (dry) to reddish brown (moist) silty clay; very hard, very firm; weak medium blocky breaking into moderate fine blocky structure; clear lower boundary.
B_3	32-48	A mixture of pink and light brown (dry) to brown (moist) silty clay; very hard, firm; massive structure; gradual lower boundary.
C	48-60	A mixture of brown and light brown (dry) to brown (moist) silty clay loam; very hard, firm; massive structure. The horizon contains abundant very fine sand grains.
Vegetation:		Natural vegetation consisted of bluestem prairie.
Root Distribution:		Abundant in the A horizon; plentiful to 18 inches, few below. (Water removal indicates that roots penetrate to 6 feet).
Note:		This soil, when described was completely dry to 3 feet, and very slightly moist below that depth.

Described 9-17-55, by Dr. O. W. Bidwell, Kansas State University, Manhattan, Kansas.

1/ Modified from O. W. Bidwell's description.

THIS BOOK CONTAINS NUMEROUS PAGES WITH DIAGRAMS THAT ARE CROOKED COMPARED TO THE REST OF THE INFORMATION ON THE PAGE.

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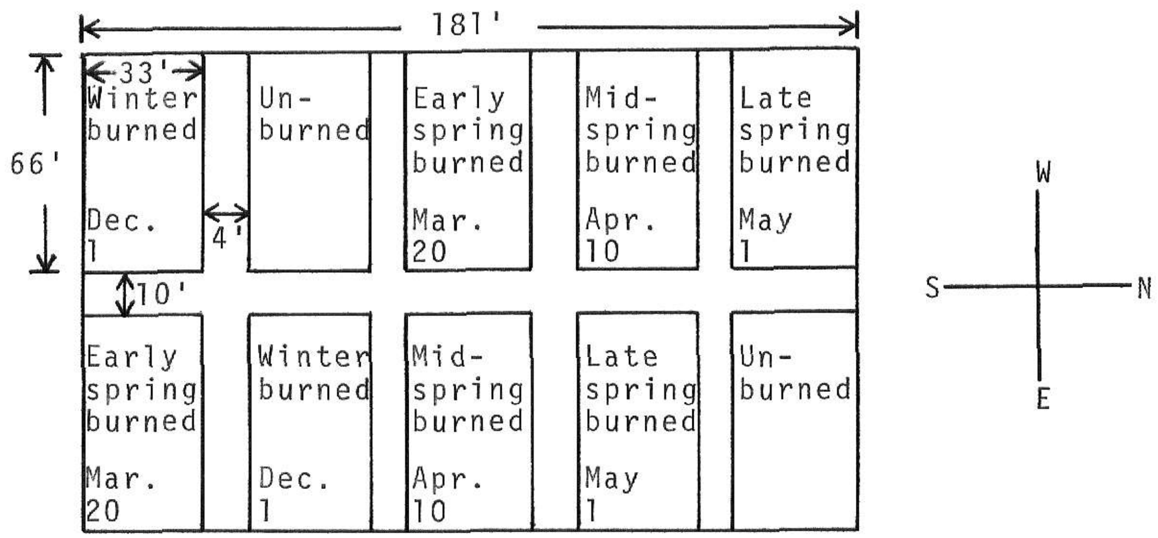


Figure 1. Diagram of college pasture burning plots, showing size and arrangement of plots, and approximate date of burning.

Procedure for Measuring the Chemical Properties:

Soil Sampling Procedure: Ten soil cores were taken in late November, 1970, from each of the ungrazed plots and five cores from each of three different areas in each of the two grazed pastures. The cores (1.5" (3.8 cm) in diameter) were taken with a hydraulic soil probe to a depth of 4 feet (1.22 m) and divided into seven depth increments: 0-3" (0-7.6 cm), 3-6" (7.6-15.2 cm), 6-9" (15.2-22.8 cm), 9-12" (22.8-30.2 cm), 12-18" (30.2-45.8 cm), 18-24" (45.8-60.1 cm), and 24-36" (60.1-91.5 cm). The subsample soil cores from each plot were composited, air-dried for six weeks, and ground in a mortar to a fine powder.

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

Oxidizable organic matter was determined (procedure by Graham[19]) by adding 10 ml 1N potassium dichromate to 1 gram air dry soil followed by the addition of 20 ml of concentrated H_2SO_4. After 30 minutes, 100 ml of distilled water were added to this solution which upon cooling was filtered and read in a spectrophotometer at a wavelength of 620 mu.

To determine exchangeable K, Ca and Mg, 25 ml of 1N ammonium acetate were added to 5 grams of air-dry soil, shaken for 10 minutes on a wrist-action shaker and immediately filtered. K in the filtrate was then determined by flame photometry. One ml aliquots of the K extract were diluted to 100 mls with 0.1N HCl, and from this Ca and Mg were determined by atomic absorption spectrophotometry.

Available P was determined (procedure by Bray[11]) by adding 20 ml of an acid-ammonium fluoride extracting solution (.025N HCl + .03N NH_4F) to 2 grams of air dry soil. The mixture was shaken for 40 seconds and then 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 mm in a spectrophotometer standardized against similarly developed standard phosphate solutions.

Total soil nitrogen (%) was obtained by a Micro-Kjeldahl method[13].

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

Statistical Analysis: A fixed-effect, three way analysis of variance was used to analyse the data obtained from the chemical analyses (Appendix, Tables 15 and 16). The bulk density values were analysed by a fixed-effect, two way analysis of variance (Appendix, Table 17).

RESULTS AND DISCUSSION

Chemical Properties: 1/

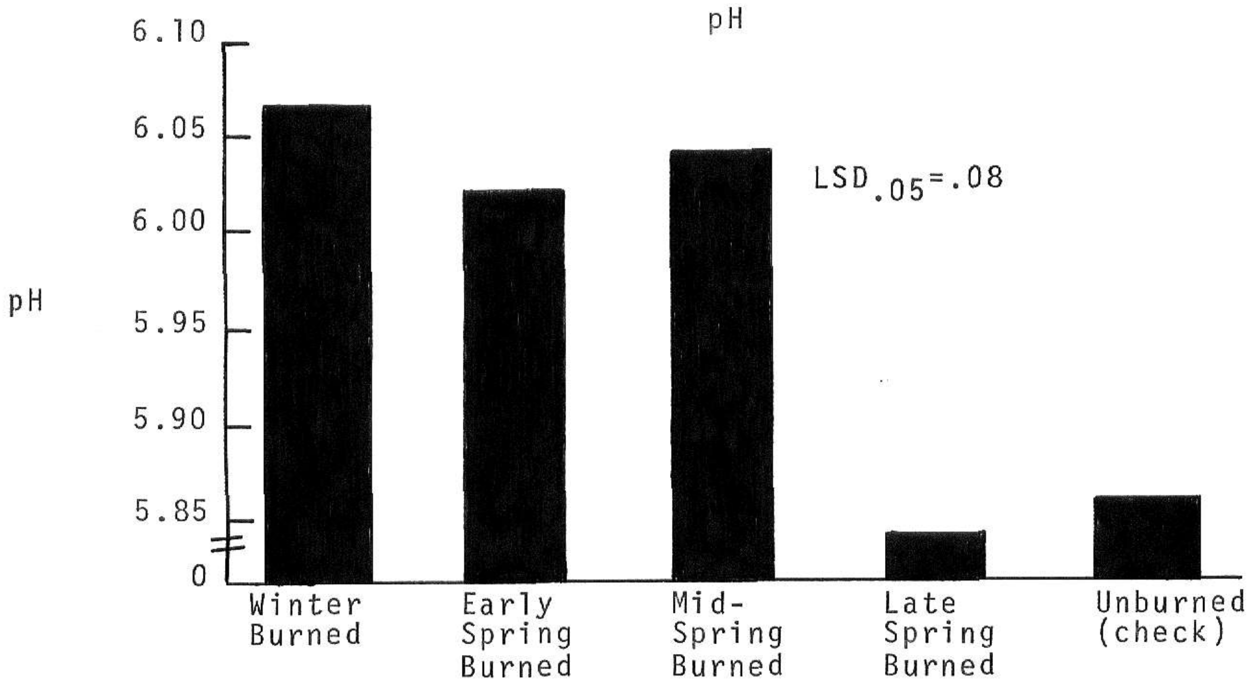
pH: Soil pH for winter burned, early spring burned, and mid-spring burned ungrazed plots did not differ significantly but was higher than that of plots burned in late spring and unburned plots which did not differ (Fig. 2). Anderson[3], studying moisture relations on these same plots, found moisture levels of burned treatments to be less than that of the unburned treatment. However, the difference was greater for the three earlier burned treatments than for the late spring burned treatment. This moisture difference may account for the lower pH on the late spring burned and unburned plots. With more water moving through the soil profile more salts would be leached out of the soil layer resulting in a lower pH. Likewise less water moving through the three earlier burned plots would result in movement of fewer salts out of the profile and consequently a higher pH.

No differences in soil pH were observed between the ungrazed late spring burned and unburned plots, but on the pastures late spring

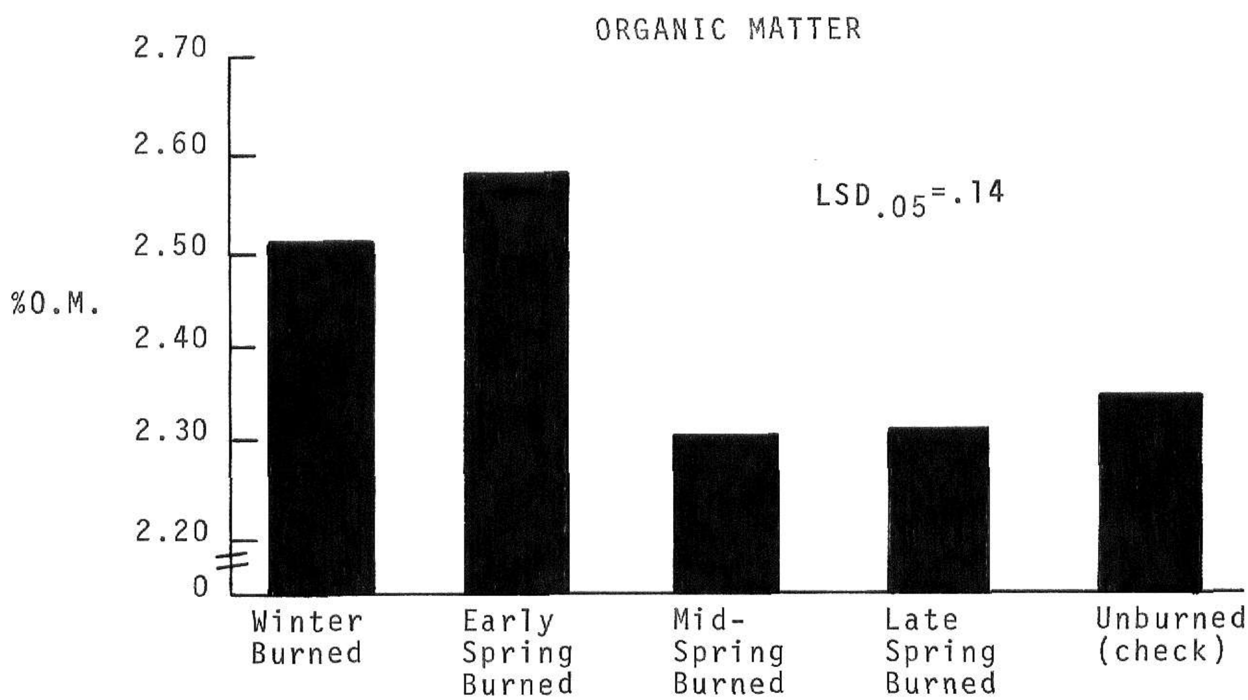
1/ Results summarized in appendix.

Figure 2. pH of soil from ungrazed plots burned at indicated times (avg. over all soil depths).

Figure 3. O.M. of soil from ungrazed plots burned at indicated times (avg. over all soil depths).



TREATMENTS
Figure 2



TREATMENTS
Figure 3

burning produced a pH value 0.25 units higher than that of the unburned pasture (Table 2). That increase was similar to the one noted on the earlier burned treatments in the ungrazed plots. While these increases are statistically significant they are very small.

Table 2. Soil pH, organic matter, Ca, Mg, P, K, and total N under the two grazed treatments as averaged over all depths studied.

Treatment	pH	%O.M.	Ca (ppm)	Mg (ppm)	P (ppm)	K (#/A)	%N
Late Spring Burned	6.66	3.00	4048.1	740.7	2.21	593	.146
Unburned (check)	6.41	3.40	3773.9	547.8	3.31	638	.169
Differences	0.25*[1/]	0.40*	274.2	192.9*	1.10*	45+	.023*

1/ $LSD_{.05}$ = * $LSD_{.10}$ = +

The largest pH increase noted in this experiment of 0.25 units is contrasted to increases ranging from 0.5 units to 3.1 units observed by investigators[21,22,25,27] working in various forested areas. The greater increases on forest soil is probably due to larger quantities of material being burned. Researchers have noted decreases in pH with time after burning, which suggests that different data might have been obtained had the soil samples in this experiment been taken immediately after the fire instead of approximately eight months later as in this study. However, because of the long history of burning in this study, the results are probably representative of the average effect of annual burning on pH of loamy upland soil.

Treatment effects on soil pH were essentially the same at all depths of the soil. In these plots there was fairly consistent amounts of vegetation burned each year and thus a consistent quantity of salts deposited on the surface each year. Yearly the deposited salts move farther down in the soil profile continually being replaced on the surface, which probably explains the observed uniformity through all depths.

Organic Matter: Soil from winter burned and early spring burned treatments have essentially the same organic matter content and soil from mid-spring, late spring and unburned treatments do not differ from each other. Differences occur, however between these two groups. The two earliest burned treatments have approximately 0.20% more organic matter than the other treatments (Fig. 3).

In the ungrazed plots there is no significant difference in soil organic matter between the late spring burned and unburned treatments. However, in the grazed pastures the late spring burned treatment produced a significantly lower amount of soil organic matter than did the unburned treatment (Table 2 and Fig. 2). There appears to be no obvious reason as to why fire causes a reduction on the grazed pasture and not on the ungrazed plots.

No interaction was shown between treatments and depths for soil organic matter, meaning that the relationship between treatments was the same for all depths studied.

In the same ungrazed experimental area used in this experiment, Aldous[1] found that burning did not decrease the organic matter content in a 5 year experiment. He attributed this to the concept that organic matter accumulation is regulated primarily by root development rather than surface accumulation of vegetative material.

Calcium: The only treatment differing significantly from the unburned treatment is the winter burned treatment, which has considerably more Ca than any of the other treatments (Fig. 4). The mid-spring, late spring, and unburned treatments, all have essentially the same soil calcium content. However, the winter, early spring and mid-spring burned treatments have soil Ca levels which are significantly different from each other.

Soil Ca was similar on the grazed and ungrazed areas for the late spring burned and unburned treatments (Table 2 and Fig. 4).

As was the case for pH and organic matter, calcium also shows no interaction between treatments and depths, thus indicating that treatment effects were the same for all depths studied.

Kucera and Ehrenneich[24], using nutrient composition of seasonal growth as an indicator for differences in burned and unburned plots, found no significant differences between the Ca content of plants grown on the burned and unburned areas. On the contrary Elwell et al.[15] considered burning to be responsible for reducing the productiveness of the grassland soil by placing the minerals contained in the vegetation, such as Ca, in a form which may be readily removed by leaching and erosion, but presented no evidence to support this idea.

Data from this present study suggests a certain amount of leaching, because a higher Ca content was observed in the earlier burned plots in the upper as well as in the lower soil levels, indicating some movement through the profile. The higher Ca content in the

Figure 4. Ca of soil from ungrazed plots burned at indicated times (avg. over all soil depths).

Figure 5. Mg of soil from ungrazed plots burned at indicated times (avg. over all soil depths).

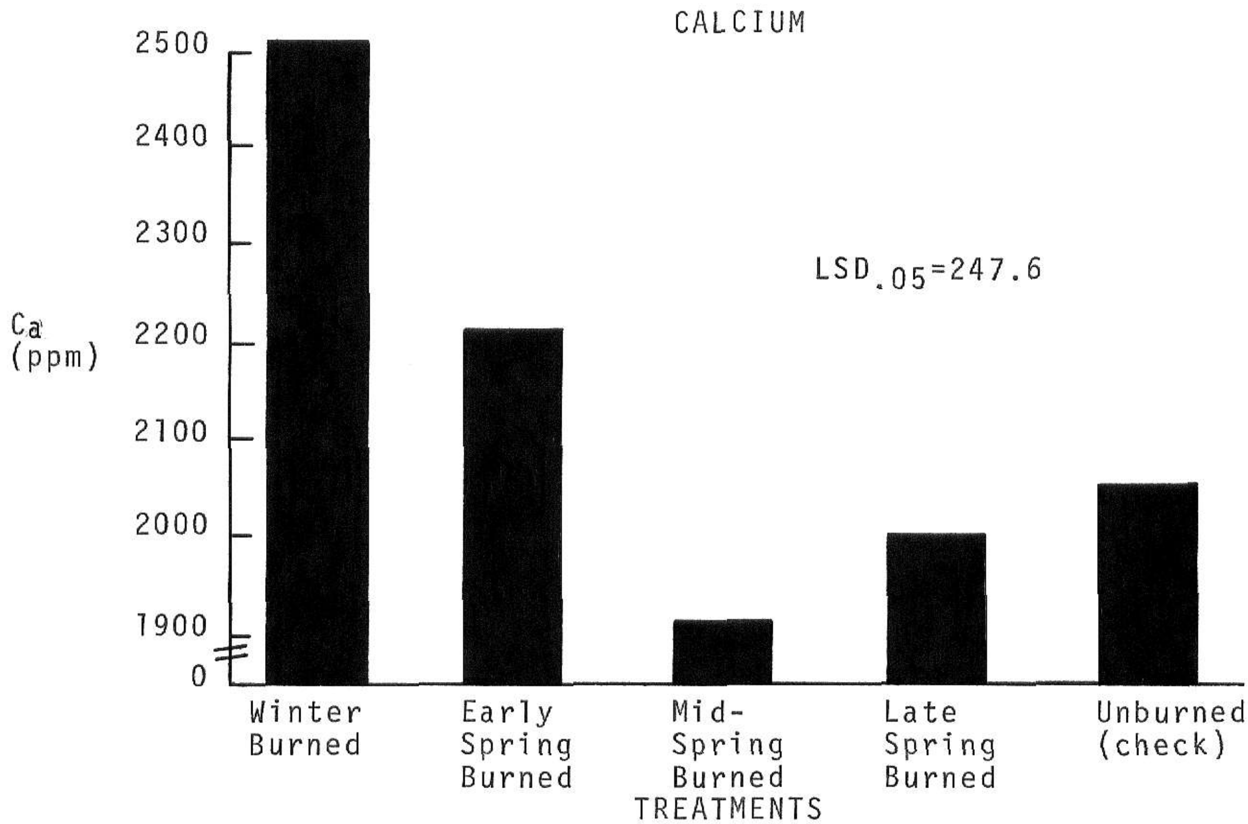


Figure 4

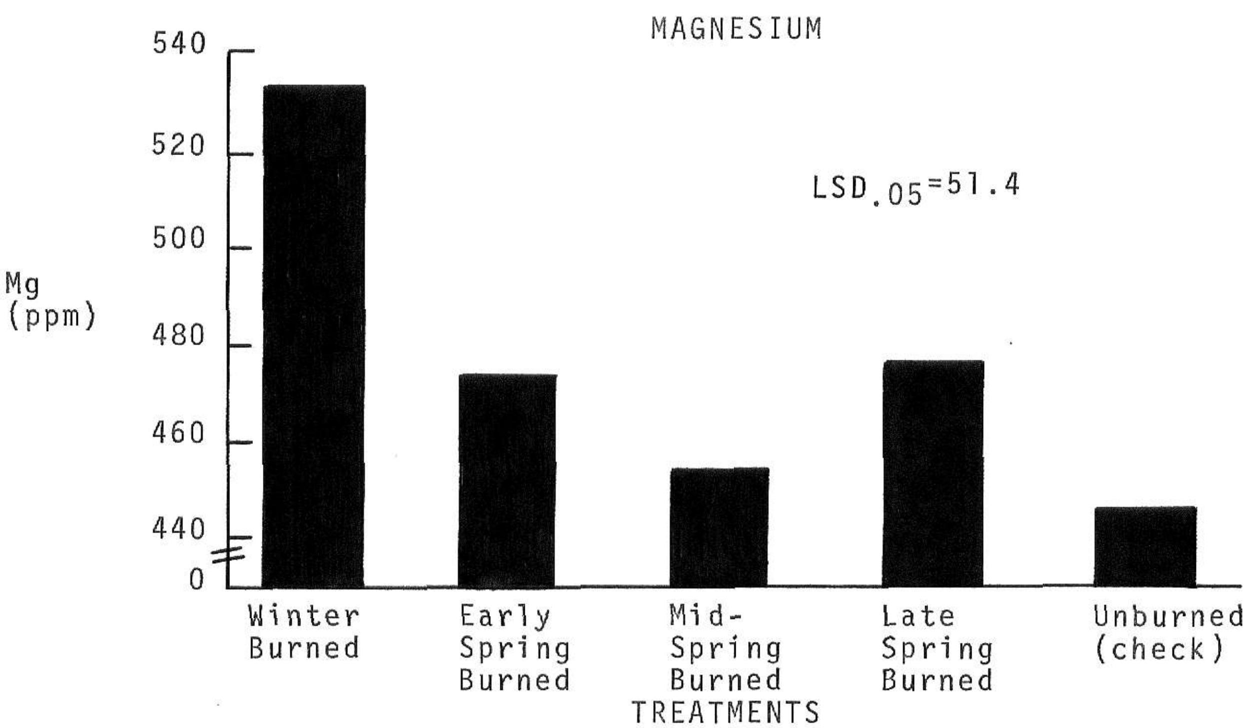


Figure 5

winter burned treatment is probably the result of less water moving through these treatment plots. Anderson[3] showed that among the burning treatments, late spring burning has the highest and winter burning the lowest moisture levels, suggesting less leaching of Ca on the winter burned plots.

Magnesium: Soil Mg content in the ungrazed plots was higher in the winter burned plots than in the three spring burned and unburned plots, which did not differ significantly from each other (Fig. 5). Soil Mg content, in relation to treatment, resembled that for Ca, pH and organic matter, in that winter burned plots were significantly higher in those constituents than the unburned plots. This again, may be related to lower moisture levels on the winter burned plots.

On grazed plots, late spring burning produced a significantly higher Mg content than no burning, while in the ungrazed plots no such difference existed (Fig. 5 and Table 2). That suggests that grazing or soil differences were responsible.

Phosphorus: Winter, early spring, mid-spring, or late spring burning on ungrazed plots did not affect soil P content (Fig. 6). However on grazed plots late spring burning significantly lowered soil P content below that of the unburned treatment (Table 2).

Potassium: No difference in exchangeable K existed on ungrazed plots between the late spring burned and the unburned treatments or between the winter, early spring, and mid-spring burned treatments (Fig. 7). The major difference occurs between these two groups in the 0-3" soil layer. The three early burned treatments caused increases in soil K while the late burned treatment did not. On the grazed

Figure 6. P of soil from ungrazed plots burned at indicated times (avg. over all soil depths).

Figure 7. K of soil from ungrazed plots burned at indicated times (avg. of 0-3" depth).

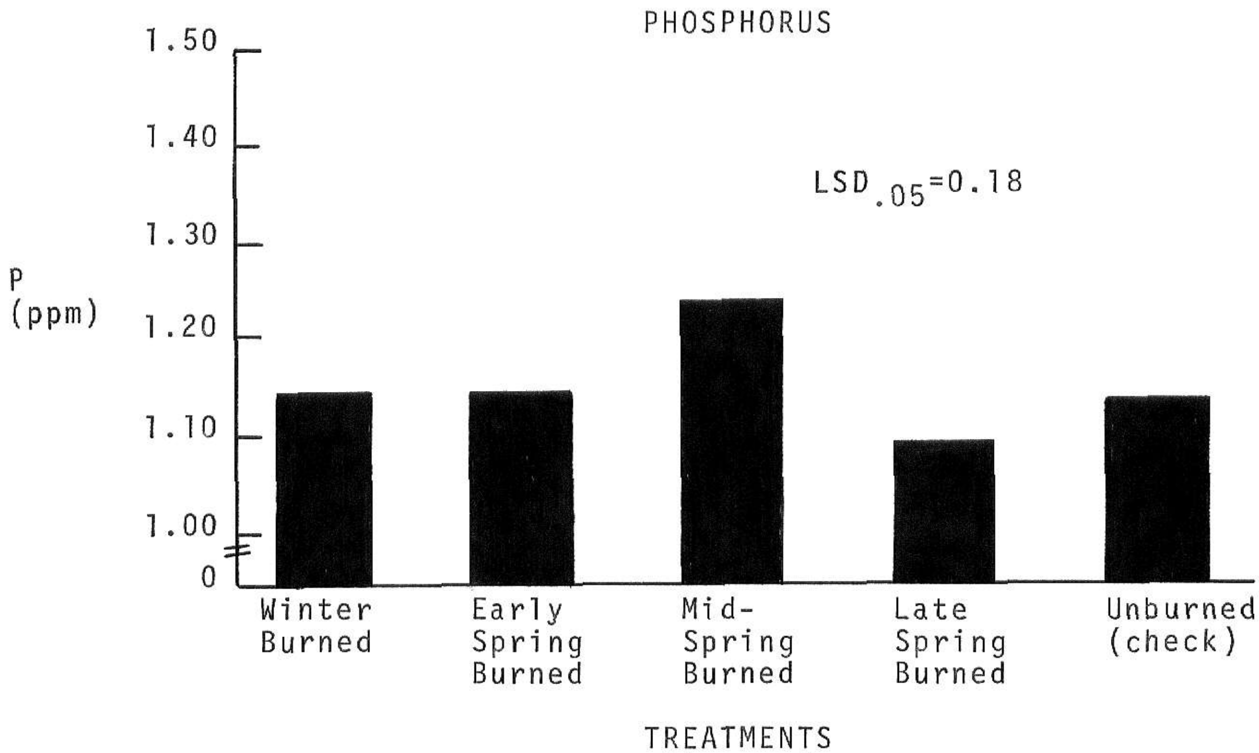


Figure 6

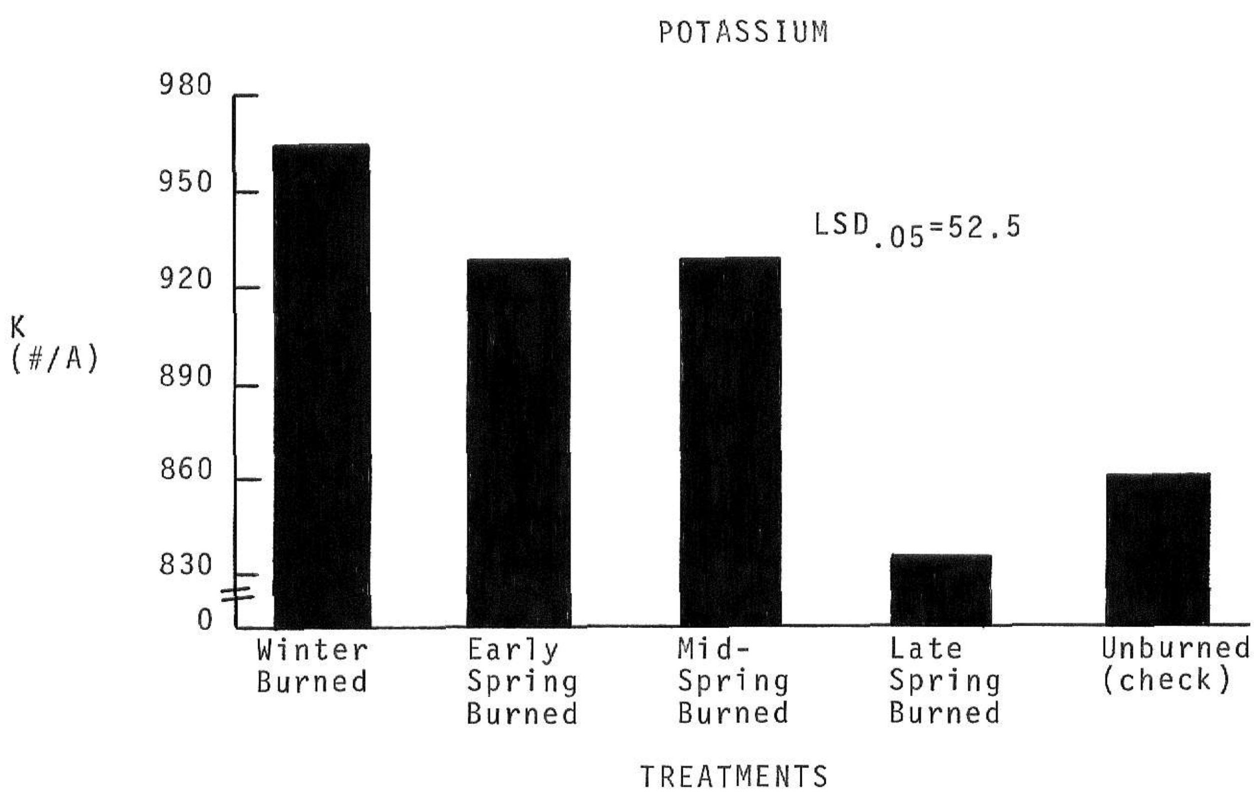


Figure 7

pastures a lower soil K content existed in the late spring burned than in the unburned treatment (Table 2). A similar situation existed with P.

Nitrogen: Soil N differences, in relation to treatments, are similar to those of K which showed up only in the 0-3" soil layer on ungrazed plots. Unburned, early spring burned and mid-spring burned treatments were not significantly different from each other, but late spring and winter burned treatments produced lower soil N than did the unburned treatment (Fig. 8). Contrary to what one might expect these results are totally inconsistent with the organic matter data. Burning caused decreases in nitrogen while it caused increases in organic matter.

In the ungrazed plots, the late spring burning produced a soil nitrogen content .030% lower than the unburned while in the grazed pasture the late spring burned had .023% lower soil N than the unburned (Fig. 8 and Table 2). While the ungrazed N data does not correspond to the organic matter data the grazed results do. The grazed pasture shows a .40% drop in organic matter along with the .023% drop in nitrogen.

Aldous[1] in studying the effect of burning on bluestem range from the same ungrazed experimental area as in this study found that burning did not cause any decrease in total nitrogen during a 5-year period. No decrease in N in his study may have been due to the relatively short period over which the experiment was run.

Figure 8. N of soil from ungrazed plots burned at indicated times (avg. of 0-3" depth).

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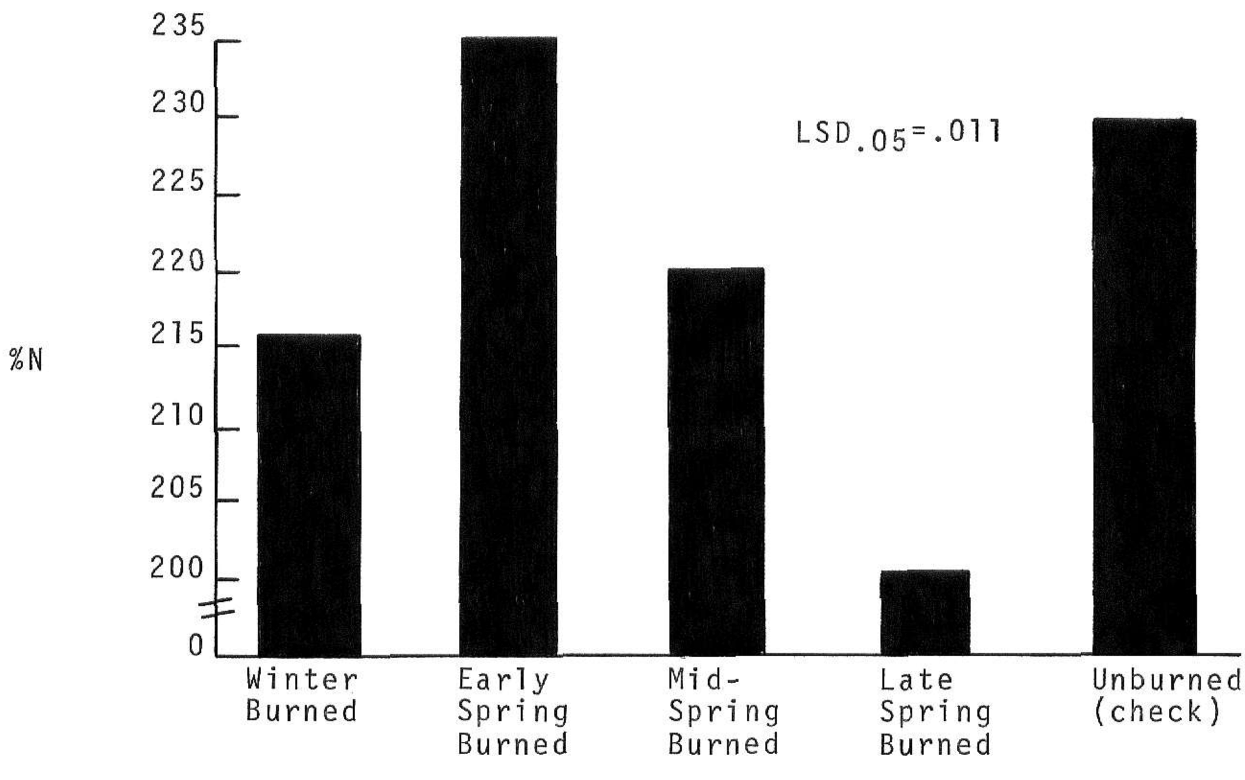

Figure 8

Physical Properties:

Table 3. A summary of the bulk density data for the ungrazed burned plots with means for the treatments and replications.

Replications	Winter Burned	Early Spring Burned	Mid-Spring Burned	Late Spring Burned	Unburned	Mean for Replications
1	1.105	1.027	1.038	1.066	1.114	1.070
2	1.059	1.047	1.065	1.121	1.072	1.073
Mean for Treatments	1.082	1.037	1.051	1.093	1.093	1.071 Grand Mean

Bulk Density: Fire had no effect on the physical properties of the soil that can be measured by bulk density (Table 3). Other studies conducted by Anderson[3], Hanks[18], and McMurphy[26] in the same experimental region as the one used in this experiment found that infiltration was reduced on burned areas. Infiltration is determined by non-capillary porosity of the uppermost portion of the soil profile and good crumb structure at the soil surface must be maintained for good infiltration. It therefore appears that some physical change does occur upon burning, but the changes are so slight that they can not be detected in bulk density measurements.

DISCUSSION AND CONCLUSIONS

Time of burning to some extent does vary the effects of fire on the soil chemical properties under ungrazed conditions. Winter burning has the strongest influence, causing increases in pH, organic matter, Ca, Mg, K, and decreases in N. Late spring burning is the least significant, causing only a small decrease in nitrogen. The strong influence of earlier burning on pH and certain mineral salts was attributed to reduced infiltration and thus reduced leaching of salts out of the soil profile on earlier burned plots.

Bulk density of the 0-3" layer of soil was not affected by fire under ungrazed conditions indicating that any change occurring in the physical properties of the soil must be very small.

Late spring burning under ungrazed conditions caused only a small decrease in N, while under grazed conditions, it caused reductions in organic matter, N, P, and K and increases in pH and Mg. The more pronounced influence of burning under grazed conditions may be attributed to soil differences, or related to the differences in the number of years the grazed and ungrazed areas have been burned (grazed 20, ungrazed 48). It also could be related to greater erosional losses of exposed soil and deposited salts on the denser grazed soils.

With the exceptions of K and N on the ungrazed plots the effect of fire on the soil chemical properties is the same for all soil depths studied. This uniformity through all depths is attributed to leaching over a long period of time.

Since late spring burning is the recommended time of burning in Kansas Flint Hills, its effect on the soil properties is especially important. It can be concluded that under ungrazed conditions, late spring burning will not significantly affect any of the physical or chemical properties studied, except N. However, under grazed conditions it may cause significant changes in soil chemical properties if practiced over a long period of time, but since the changes observed in this experiment were so small, it is doubtful if they are adverse to the native vegetation.

Although trends observed in this study upon a grassland soil by burning are generally similar to the trends noted in forested areas, the effects of fire are much more severe on forested areas. This difference is attributed mainly to characteristic differences that exist between forest and grassland soils and vegetation.

SUMMARY

This study was undertaken in Kansas Flint Hills range to determine the effects of fire on certain soil chemical and physical properties of loamy upland range, burned at different times under grazed and ungrazed conditions.

To varying degrees time of burning affected all the soil chemical properties studied except P. It did not however significantly affect any of the physical properties that could be measured by bulk density. Winter burning caused increases in pH, organic matter, Ca, Mg, and K and decreases in N, while late spring burning only caused a reduction in N. Early and mid-spring burning caused changes that generally ranged between these two extremes. Changes in pH and mineral nutrients observed with winter burning were attributed to less movement of water through the treatment soil profile.

Except in the case of N and K, leaching was considered responsible for the observed uniformity in treatment differences through all soil depths.

Late spring burning on the ungrazed area caused only a decrease in N, while on the grazed areas it caused reduction in N, P, K, and organic matter, increases in pH and Mg and had no effect on Ca. The difference between grazed and ungrazed late spring burning was attributed to either soil differences, differences in the number of years burned, or higher erosional losses of deposited salts and soil constituents of the denser grazed soil.

It was concluded that the practice of late spring burning on grazed bluestem range may cause significant changes in the soil chemical properties if practiced over a long period of time.

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APPENDIX

Table 1. pH values for treatments and depths on the ungrazed plots (avg. of two replications).

Depths	Winter Burned	Early Spring Burned	Mid-Spring Burned	Late Spring Burned	Unburned (check)	Mean Depth Value
0-3"	6.40	6.30	6.25	6.05	6.10	6.22
3-6"	6.00	6.00	6.10	5.75	5.75	5.92
6-9"	6.00	5.90	5.80	5.70	5.65	5.81
9-12"	5.90	5.90	5.95	5.65	5.80	5.84
12-18"	5.90	5.90	5.95	5.80	5.80	5.87
18-24"	6.05	6.00	6.05	5.90	5.90	5.97
24-36"	6.15	6.15	6.20	6.00	6.00	6.10
Mean treatment value	6.06	6.02	6.04	5.84	5.86	5.96 Grand Mean

$LSD_{.05}$ for treatment values=.08
$LSD_{.05}$ for depth values=.10

Table 2. Organic matter (%) for treatments and depths on the ungrazed burned plots (avg. of two replications).

Depths	Winter Burned	Early Spring Burned	Mid-Spring Burned	Late Spring Burned	Unburned (check)	Mean Depth Value
0-3"	4.55	4.90	4.35	4.20	4.50	4.50
3-6"	3.50	3.65	3.30	3.20	3.25	3.38
6-9"	3.05	3.10	2.75	2.85	2.90	2.93
9-12"	2.50	2.45	2.35	2.45	2.20	2.39
12-18"	1.95	1.75	1.65	1.65	1.70	1.74
18-24"	1.15	1.30	1.15	1.10	1.20	1.18
24-36"	0.90	0.95	0.70	0.80	0.75	0.82
Mean treatment value	2.51	2.59	2.32	2.32	2.36	2.42 Grand Mean

$LSD_{.05}$ for treatment values=.14
$LSD_{.05}$ for depth values=.17

Table 3. Calcium (ppm) for the treatments and depths on the ungrazed burned plots (avg. of two replications).

Depths	Winter Burned	Early Spring Burned	Mid-Spring Burned	Late Spring Burned	Unburned (check)	Mean Depth Value
0-3"	2467.3	2293.5	2054.5	1874.9	2059.2	2149.9
3-6"	2312.8	2060.4	1549.9	1562.4	1915.9	1880.3
6-9"	2438.0	2123.1	1805.5	1935.0	1846.5	2029.6
9-12"	2633.5	2204.9	2083.8	2150.6	2063.8	2227.3
12-18"	2783.2	2420.5	1739.5	2214.9	2254.2	2282.5
18-24"	2778.1	2113.0	2152.4	2390.4	2046.2	2296.0
24-36"	2117.2	2250.1	2062.1	1972.7	2229.2	2126.2
Mean treatment value	2504.3	2209.3	1921.1	2014.4	2059.3	2141.7 Grand Mean

$LSD_{.05}$ for treatment values=247.6
$LSD_{.05}$ for depth values=292.9

Table 4. Magnesium (ppm) for the treatments and depths on the ungrazed burned plots (avg. of two replications).

Depths	Winter Burned	Early Spring Burned	Mid-Spring Burned	Late Spring Burned	Unburned (check)	Mean Depth Value
0-3"	457.9	393.8	372.8	359.6	358.2	388.5
3-6"	479.2	405.2	385.2	373.3	391.8	406.9
6-9"	527.9	439.8	434.6	482.4	423.5	461.7
9-12"	588.1	479.2	450.6	359.3	445.6	484.1
12-18"	622.6	552.2	503.9	490.7	496.6	533.2
18-24"	550.7	537.5	521.9	663.6	488.4	552.4
24-36"	519.2	514.9	510.3	514.8	529.8	517.8
Mean treatment value	535.1	474.7	454.2	477.4	447.7	477.8 Grand Mean

$LSD_{.05}$ for treatment values=51.4
$LSD_{.05}$ for depth values=60.8

Table 5. Phosphorus (ppm) for the treatments and depths on the ungrazed burned plots (avg. of two replications).

Depths	Winter Burned	Early Spring Burned	Mid-Spring Burned	Late Spring Burned	Unburned (check)	Mean Depth Value
0-3"	2.38	2.64	2.64	2.71	1.93	2.44
3-6"	1.58	1.38	1.78	1.91	1.73	1.68
6-9"	1.19	1.28	1.39	1.46	1.31	1.33
9-12"	1.18	0.95	1.04	0.70	1.06	0.99
12-18"	0.67	0.75	0.77	0.72	0.53	0.69
18-24"	0.54	0.60	0.57	0.53	0.49	0.55
24-36"	0.42	0.34	0.41	0.35	0.30	0.36
Mean treatment value	1.14	1.13	1.24	1.08	1.14	1.15 Grand Mean

$LSD_{.05}$ for treatment values=.18
$LSD_{.05}$ for depth values=.22

Table 6. Potassium (#/A) for the treatments and depths on the ungrazed burned plots (avg. of two replications).

Depths	Winter Burned	Early Spring Burned	Mid-Spring Burned	Late Spring Burned	Unburned (check)	Mean Depth Value
0-3"	965	930	930	835	860	905
3-6"	735	740	730	740	705	730
6-9"	640	625	625	640	630	632
9-12"	515	535	540	580	545	543
12-18"	435	460	435	470	465	453
18-24"	355	370	375	390	385	375
24-36"	320	355	340	355	360	346
Mean treatment value	566	574	567	572	564	569 Grand Mean

$LSD_{.05}$ for treatment values=23
$LSD_{.05}$ for depth values=20

Table 7. Nitrogen (%) for the treatments and depths on the ungrazed burned plots (avg. of two replications).

Depths	Winter Burned	Early Spring Burned	Mid-Spring Burned	Late Spring Burned	Unburned (check)	Mean Depth Value
0-3"	.215	.235	.220	.200	.230	.220
3-6"	.170	.170	.170	.160	.165	.167
6-9"	.145	.150	.140	.140	.145	.144
9-12"	.125	.125	.115	.120	.115	.120
12-18"	.095	.090	.085	.090	.090	.090
18-24"	.060	.070	.060	.060	.060	.062
24-36"	.040	.045	.040	.040	.040	.041
Mean treatment value	.121	.126	.119	.116	.121	.121 Grand Mean

$LSD_{.05}$ for treatment values=.004

$LSD_{.05}$ for depths values=.005

Table 8. pH values for treatments and depths on the grazed pastures (avg. of three replications).

Depths	Late Spring Burned	Unburned (check)	Mean Depth Value
0-3"	6.50	6.43	6.47
3-6"	6.40	6.40	6.40
6-9"	6.47	6.33	6.40
9-12"	6.57	6.37	6.47
12-18"	6.70	6.37	6.53
18-24"	6.97	6.37	6.67
24-36"	7.03	6.57	6.80
Mean treatment Value	6.66	6.41	6.53 Grand Mean

$LSD_{.05}$ for mean depth values=.41

$LSD_{.05}$ for mean treatment values=.22

Table 9. Organic matter (%) for treatments and depths on the grazed pastures (avg. of three replications).

Depths	Late Spring Burned	Unburned (check)	Mean Depth Value
0-3"	4.80	5.50	5.15
3-6"	3.83	4.30	4.07
6-9"	3.57	3.38	3.70
9-12"	2.97	3.40	3.18
12-18"	2.53	2.93	2.73
18-24"	1.93	2.20	2.07
24-36"	1.37	1.67	1.52
Mean treatment value	3.00	3.40	3.20 Grand Mean

$LSD_{.05}$ for mean depth values=.26

$LSD_{.05}$ for mean treatment values=.33

Table 10. Calcium (ppm) for treatments and depths on the grazed pastures (avg. of three replications).

Depths	Late Spring Burned	Unburned (check)	Mean Depth Value
0-3"	3793.8	3816.7	3805.3
3-6"	3569.4	3805.5	3687.4
6-9"	3652.3	3603.9	3628.1
9-12"	4156.4	3558.2	3857.3
12-18"	4215.5	3564.9	3890.2
18-24"	4378.7	3682.4	4030.6
24-36"	4570.9	4385.9	4478.4
Mean treatment value	4048.1	3773.9	3911.0 Grand Mean

$LSD_{.05}$ for mean depth values=1124.7

$LSD_{.05}$ for mean treatment values=601.2

Table 11. Magnesium (ppm) for treatments and depths on the grazed pastures (avg. of three replications).

Depths	Late Spring Burned	Unburned (check)	Mean Depth Value
0-3"	569.3	484.6	527.0
3-6"	570.1	497.2	533.7
6-9"	582.6	514.4	548.5
9-12"	784.5	518.3	651.4
12-18"	840.4	533.0	686.7
18-24"	917.5	582.7	750.1
24-36"	920.3	704.2	812.3
Mean treatment value	740.7	547.8	644.2 Grand Mean

$LSD_{.05}$ for mean depth values=230.6

$LSD_{.05}$ for mean treatment values=123.3

Table 12. Phosphorus (ppm) for treatments and depths on the grazed pastures (avg. of three replications).

Depths	Late Spring Burned	Unburned (check)	Mean Depth Value
0-3"	7.04	8.83	7.94
3-6"	1.80	4.10	2.95
6-9"	1.79	2.76	2.28
9-12"	1.38	1.86	1.62
12-18"	1.18	1.12	1.20
18-24"	0.93	1.75	1.34
24-36"	1.32	2.63	1.98
Mean treatment value	2.21	3.31	2.76 Grand Mean

$LSD_{.05}$ for mean depth values=1.72

$LSD_{.05}$ for mean treatment values=.96

Table 13. Potassium (#/A) for treatments and depths on the grazed pastures (avg. of three replications).

Depths	Late Spring Burned	Unburned (check)	Mean Depth Value
0-3"	806	900	853
3-6"	590	730	660
6-9"	540	630	585
9-12"	576	600	588
12-18"	550	546	548
18-24"	560	546	553
24-36"	530	513	522
Mean treatment value	593	638	616 Grand Mean

$LSD_{.05}$ for mean depth values=100

$LSD_{.05}$ for mean treatment values=53

Table 14. Nitrogen (%) for treatments and depths on the grazed pastures (avg. of three replications).

Depths	Late Spring Burned	Unburned (check)	Mean Depth Value
0-3"	.250	.293	.272
3-6"	.190	.217	.203
6-9"	.170	.187	.178
9-12"	.130	.167	.148
12-18"	.123	.137	.130
18-24"	.093	.103	.098
24-36"	.060	.077	.071
Mean treatment value	.146	.169	.157 Grand Mean

$LSD_{.05}$ for mean depth values=.033

$LSD_{.05}$ for mean treatment values=.017

Table 15. Summary of the analysis of variance for all soil factors considered in the ungrazed plots.

Source of Variation	D.F.	pH M.S.	O.M. M.S.	Ca M.S.	Mg M.S.
Total	69				
Replicates	1	.014	.037	381.9	330.5
Treatments (Factor A)	4	.161*	.209*	726960.1*	16645.9*
Depths (Factor B)	6	.224*	16.782*	220303.8+	39236.7*
A X B	24	.007	.022	54975.4	2705.5
Error	34	.011	.033	104115.1	4483.2

Table 15. (cont.)

Source of Variation	D.F.	P M.S.	K M.S.	N M.S.
Total	69			
Replicates	1	0.220	59451.4	.00002
Treatments (Factor A)	4	0.045	225.0	.00022*
Depths (Factor B)	6	5.357*	407138.1*	.03881*
A X B	24	0.058	1483.3*	.00006*
Error	34	0.053	666.1	.00003

*=.05 +=.10

Table 16. Summary of the analysis of variance for all soil factors considered in the grazed pastures.

Source of Variation	D.F.	pH M.S.	O.M. M.S.	Ca M.S.	Mg M.S.
Total	41				
Replicates	2	.439	.447	785242.0	435797.1
Treatments (Factor A)	1	.694*	1.720*	789502.0	390747.9*
Depths (Factor B)	6	.133	9.140*	480751.3	76438.7+
A X B	6	.072	.035	208091.1	20210.5
Error	26	.117	.276	897646.7	37789.4

Table 16. (cont.)

Source of Variation	D.F.	P M.S.	K M.S.	N M.S.
Total	41			
Replicates	2	4.996	59621.42	.00197
Treatments (Factor A)	1	12.760*	21038.09+	.00526*
Depths (Factor B)	6	33.405*	77393.65*	.02728*
A X B	6	0.888	5849.20	.00027
Error	26	2.280	7041.94	.00075

*=.05 +=.10

Table 17. Summary of the analysis of variance for the bulk density measurements.

Source of Variation	D.F.	S.S.	M.S.
Total	9	.0090	
Replicates	1	.0000	.0000
Treatments	4	.0060	.0015
Error	4	.0030	.0006

*=.05 +=.10

EFFECT OF BURNING ON SOIL CHEMICAL AND PHYSICAL PROPERTIES OF LOAMY UPLAND BLUESTEM RANGE

by

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Effect of time of burning of grazed and ungrazed loamy upland range on certain soil chemical and physical properties was studied on two experimental units located near Manhattan, Kansas. Five burning treatments were studied: winter burning (Dec. 1), early spring burning (March 20), mid-spring burning (April 10), late spring burning (May 1), and no burning. Soil chemical factors considered were pH, organic matter, Ca, Mg, K, P, and total N. These factors were studied in the following soil layers: 0-3", 3-6", 6-9", 9-12", 12-18", 18-24", and 24-36". Bulk density, a measure of the physical properties, was studied on only the grazed unit in the 0-3" layer of soil.

Time of burning on the ungrazed areas did vary the effects of fire on the soil. Winter burning most affected soil factors, causing statistically significant increases in pH, organic matter, Ca, Mg, and K, and decreases in N. However, late spring burning caused only a small decrease in N. The early and mid-spring burning treatments were varied in their effect but changes were generally between these two extremes. None of the treatments had any significant effect on the P content or bulk density of the soil.

Treatment effects were similar at all soil depths, except in the case of K and N on the ungrazed plots, where differences were observed only in the 0-3" layer of soil.

While late spring burning affected only the N content under ungrazed conditions, it caused increases in the grazed areas in pH, Mg, decreases in P, K and total N, and had no effect on Ca. Therefore, late spring burning in the Kansas Flint Hills may change some soil chemical properties if practiced over long periods of time under grazed conditions. However, because the changes are so small they probably would not be harmful to the native vegetation.