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Soil water and temperature response to prescribed burning

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SOIL WATER AND TEMPERATURE RESPONSE TO PRESCRIBED BURNING[1]

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ABSTRACT.— Prescribed burning of Texas wintergrass (*Stipa leucotricha* Trin. & Rupr.) communities reduced soil water contents for two to six months, and additional reductions occurred when the subsequent crop of cool-season grasses and forbs began growth. These soil water reductions occurred despite reduced plant production following burning. Soil water reductions were greater at 15 to 45 cm depths than in the upper 15 cm and greater following spring burning. Soil temperatures were higher on burned plots for most of the first year following burning.

Fire can affect soil through: (1) direct action of heat, (2) removal of mulch and standing crop, and (3) the redistribution of certain nutrients. Grassland fires are flashy and seldom create prolonged high temperatures at the soil surface (Daubenmire 1968, Vogl 1974, Wright and Bailey 1982). Thus, it is unlikely that the direct action of heat has a significant effect on grassland soils. Although changes in soil temperatures during grassland fires are relatively small, soil temperatures may be increased following the fire due to increased solar insolation. Sharrow and Wright (1977) reported increased soil temperature at 8 cm depths for 15–45 days following burning of tobosagrass [*Hilaria mutica* (Buckl.) Benth.] on a Stamford clay site. Since the same change occurred on similar areas from which top growth and mulch were mechanically removed, soil insulation by mulch was apparently responsible for lower soil temperatures on unburned areas.

In most arid and semiarid grasslands, soil water content is the single most important factor influencing primary production (Webb et al. 1978). Fire is a natural phenomenon of most grassland ecosystems and can profoundly affect soil water levels (Daubenmire 1968). Following burning of grasslands, infiltration has been reported as both reduced (Hanks and Anderson 1957) and unaffected (Ueckert et al. 1979). Changes in infiltration rates of rangeland soils are usually attributed to litter removal rather than direct heat effects (Daubenmire 1968).

One innovative study (Sharrow and Wright 1977) found soil water levels were reduced in the 0–8 cm depths following litter removal on soil with active roots. However, when active roots were excluded litter removal did not reduce soil water levels. They concluded that "reduced soil moisture on burned areas is primarily due to increased transpirational water use by the rapidly growing plants rather than evaporation of water from bare soil." A long-term study of soil water trends following burning at Kansas Flint Hill bluestem ranges concluded that soil water reductions were greater following early burning and in the deeper soil levels (Anderson 1965).

The research data, to date, describes soil water and soil temperature changes occurring following burning of warm-season grasslands such as tobosagrass and big bluestem (*Andropogon gerardii* Vitman). Little information is available on changes in soil water and soil temperature following burning of a predominantly cool-season grassland. The objectives of this study were to evaluate the influence of fall, winter, and spring burning on soil water contents and soil temperatures in a Texas wintergrass (*Stipa leucotricha* Trin. & Rupr.) community.

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Study Areas and Methods

Research was conducted on a 6.5 ha study area in McCulloch County, Texas. This area typically has dry winters and hot summers, with precipitation peaks in April–May, and September–October. The mean annual precipitation is 59 cm (Bynum and Coker 1974).

Tobosa clay (fine, montmorillonitic, thermic, Typic Chromustert) soils occur on the lower areas of the study site, and Valera clay soils (fine, montmorillonitic, thermic, Petrocalcic Calcuistoll) occur on the uplands. The Tobosa clay is deep, moderately well drained, and cracks deeply when dry. Water enters the dry, cracked soil very rapidly, but water movement into wet soil is extremely slow. Runoff is medium and the available water storage capacity is high (Bynum and Coker 1974). The Valera clay is moderately deep and well drained, with moderately slow permeability. Surface runoff is slow to medium and available-water capacity is high (Bynum and Coker 1974).

Treatments were applied to 0.3 ha plots arranged as a randomized complete block experiment, with two replications. Treatments were: unburned, September 1979 burn, January 1980 burn, March 1980 burn, and November 1980 burn. Soil water contents were determined gravimetrically (Gardner 1965) on five soil samples each from 0 to 15, 15 to 30, and 30 to 45 cm depths from each replication. Soil water samples were collected monthly from November 1979 to April 1981 and oven dried at 100 C for 48 hr. Soil temperatures at 3, 15, and 30 cm below the surface were determined on burned and unburned plots using five placements of a probe-type dial thermometer. Temperature data were collected at midday at approximately 30-day intervals from September 1979 to March 1981.

Soil water data were subjected to analyses of variance using plot means. Treatment means were tested for significant differences with Duncan's multiple range test ($P \leq 0.05$) where appropriate.

Results and Discussion

Soil water content: Burning in September 1979 reduced soil water contents in the 0 to 15 cm depth zone for the first three months following burning (Table 1). Plots burned in March 1980 contained less soil water in the surface 15 cm zone in June 1980 than did unburned plots. Decreases in soil water contents of burned plots coincided with initiation of growth of Texas wintergrass and several cool-season, annual grasses and forbs (*Limnodea arkansana*, *Bromus japonicus*, and *Xanthocephalum dracunculoides*). A similar pattern was observed at another study area in Coleman County (Whisenant 1982).

Soil water contents at 15 to 30 and 30 to 45 cm depths followed similar trends to that of the surface 15 cm (Table 1). Soil water was reduced for two to six months following burning and again when the next season's cool-season grasses and forbs began growth. The greatest reductions in soil water contents occurred following March burns.

These data differ in some respects from studies of postburn soil water contents in rangelands dominated by warm-season grasses (Anderson 1975, Sharrow and Wright 1977). In this study, soil water reductions were greater following the later burns rather than the earlier burns as reported by Anderson (1965). Probably the most distinct difference was the reduction in soil water contents when the cool-season grasses initiated growth the following season. This trend was not apparent in studies of postburn soil water in rangelands dominated by warm-season grasses (Anderson 1965, Sharrow and Wright 1977). As in previous studies, soil water contents were depleted more at greater depths following burning.

Other researchers have reported that decreased soil water contents following burning were accounted for by increases in plant production and transpiration (Sharrow and Wright 1977). However, soil water on this study site was reduced despite greatly reduced primary production on the burned plots (Whisenant et al. 1984). This study area was on a concave site with a deep soil that cracked when dry, had little slope, and contained gilgai relief. Thus, it is unlikely that runoff was an important factor. Therefore, reduction in soil water content might be attributed to increases in transpiration from the remaining plants and greater evaporational

TABLE 1. Mean soil water contents (%) at 0 to 15, 15 to 30, and 30 to 45 cm depths at monthly intervals following burning on four dates in 1979–1980 in McCulloch County, Texas.[1]

		Date burned			
Date	Unburned	September 1979	January 1980	March 1980	November 1980
			0 to 15 cm		
Nov 1979	11a	8 b	—	—	—
Dec 1979	31a	29 b	—	—	—
Jan 1980	29a	29a	—	—	—
Feb 1980	32a	32a	29 b	—	—
Mar 1980	28a	28a	27a	—	—
Apr 1980	22ab	23a	19 b	21ab	—
May 1980	21a	23a	22a	20a	—
Jun 1980	16a	16a	15ab	14 b	—
Jul 1980	12a	11a	12a	11a	—
Aug 1980	11a	10a	11a	10a	—
Sep 1980	35a	36a	36a	33 b	—
Oct 1980	33a	32ab	31ab	31 b	—
Nov 1980	27a	24 b	24 b	23 b	—
Dec 1980	33a	33a	31a	30 b	30 b
Jan 1981	37a	32 b	35a	36 b	29 c
Feb 1981	31a	29ab	28ab	27 b	26 b
Mar 1981	33a	34a	31a	30a	30a
Apr 1981	30a	30a	29a	29a	27 b
			15 to 30 cm		
Nov 1979	11a	9 b	—	—	—
Dec 1979	30a	27 b	—	—	—
Jan 1980	29a	27 b	—	—	—
Feb 1980	31a	28 b	27 b	—	—
Mar 1980	25a	22 b	22 b	—	—
Apr 1980	24a	21 b	21 b	20 b	—
May 1980	18ab	18ab	20a	16 b	—
Jun 1980	17a	16ab	15 b	13 c	—
Jul 1980	15a	13 b	16a	13 b	—
Aug 1980	13a	12ab	12ab	11 b	—
Sep 1980	32a	32a	31a	26 b	—
Oct 1980	32a	31a	31a	30a	—
Nov 1980	29a	27a	27a	27a	—
Dec 1980	32a	32a	31a	29 b	29 b
Jan 1981	36a	31 b	32 b	30 bc	29 c
Feb 1981	30a	27 b	26 b	27 b	27 b
Mar 1981	32a	32a	32a	31a	29 b
Apr 1981	31a	31a	30a	30a	28 b
			30 to 45 cm		
Nov 1979	12a	8 b	—	—	—
Dec 1979	29a	27 b	—	—	—
Jan 1980	29a	26 b	—	—	—
Feb 1980	30a	27 b	25 b	—	—
Mar 1980	24a	24a	21 b	—	—
Apr 1980	20ab	23a	21ab	19 b	—
May 1980	18a	18a	18a	15 b	—
Jun 1980	17a	16a	15 b	14 c	—
Jul 1980	15ab	14 bc	16a	13 c	—
Aug 1980	14a	13ab	13a	12 b	—
Sep 1980	32a	31a	31a	30 b	—
Oct 1980	31a	31ab	31ab	28 b	—
Nov 1980	28a	28a	28a	27a	—
Dec 1980	31a	27 b	26 b	29a	28 b
Jan 1981	32a	29 b	28 b	29 c	28 c
Feb 1981	32a	29 b	29 b	25 c	26 bc
Mar 1981	35a	34a	31a	29 b	27 b
Apr 1981	31a	30a	29a	28a	27 b

[1]Means within a row followed by the same letter are not significantly different ($P \leq 0.05$) according to Duncan's multiple range test.

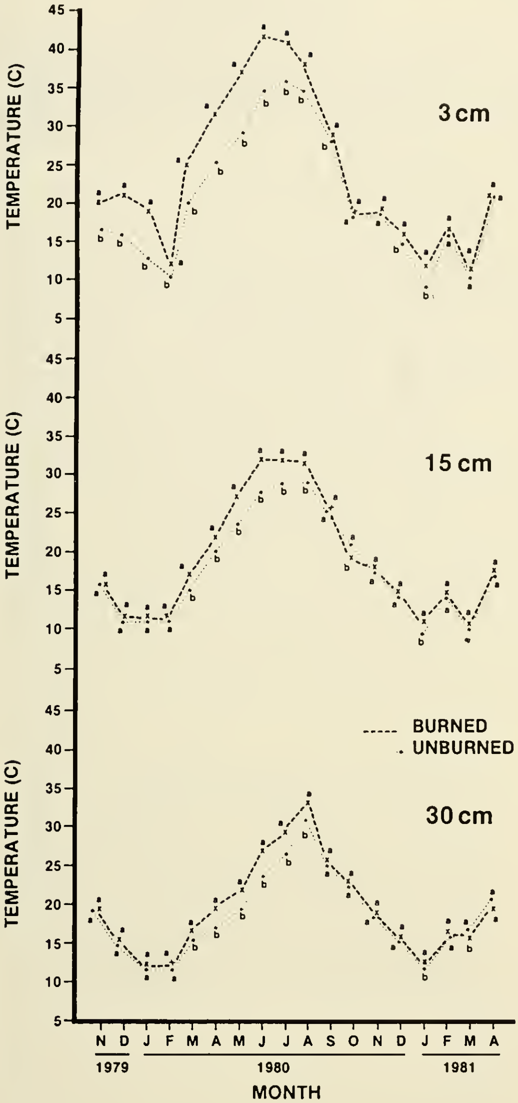

Fig. 1. Soil temperature (C) at 3 cm (top), 15 cm (middle), and 30 cm (bottom) at monthly intervals following burning in September 1979 in McCulloch County, Texas. Points within a depth and month followed by the same letter are not significantly different ($P \leq 0.05$) according to Duncan's multiple range test.

losses from the soil. Unburned plots contained 3 to 5 cm of ground mulch in addition to standing litter. Burning removed essentially all the ground mulch and standing litter, which should have increased the vapor pressure gradient between the soil surface and atmosphere. The high clay percentage (44%) of this soil would greatly facilitate capillary movement of soil water to the surface from lower soil layers. Reductions in soil water contents were greater at 15 to 30 and 30 to 45 cm depths than in the surface 15 cm, perhaps because the lower soil layers received little or no additions of water from the light rains of late spring and summer. Eliminating the standing litter created a more xeric micro-environment for the remaining plants, which could have increased transpiration rates of plants on burned relative to unburned areas.

Soil temperature: Burning affects postburn soil temperatures indirectly by removing living vegetation and mulch. A consequence of this reduction in ground cover is greatly increased solar insolation on the soil surface.

Soil temperatures at 3 cm depths were greater on the burned plots for the first 11 months after the September 1979 fires (Fig. 1). Soil temperatures at 3 cm on burned plots did not differ significantly from those of unburned plots in October and November 1980. Temperatures on burned plots in December 1980 and January 1981 were again greater than on the unburned plots. Surface temperatures equilibrated between the two treatments by February 1981 (16 months postburn).

Soil temperatures at 15 cm changed more slowly following burning than did temperatures at the surface (Fig. 1). The first significant soil temperature differences at 15 and 30 cm were not detected until 5 months postburn (March 1980). At that time, soil temperatures on burned plots were significantly higher than on unburned plots. Soil temperatures at 15 and 30 cm remained higher on burned than unburned plots until September 1980 (11 months postburn). Soil temperatures at 15 and 30 cm on burned plots appeared to equilibrate with unburned plots after 11 months. In general, soil temperatures were higher on burned plots for most of the first year following burning.

Conclusions

This research describes a somewhat different postburn soil water response in a cool-season grass-dominated rangeland than has been reported in warm-season grass-dominated rangelands. Several hypotheses are proposed that may explain the observed soil water change. Soil water contents were reduced for two to six months following burning and again when the next crop of cool-season grasses and forbs began growth. In contrast to other studies where reductions in soil water were accompanied by and attributed to increased plant production, soil water contents and net primary production were reduced by burning in this experiment. The reductions in soil water contents following burning were possibly a result of increased evaporation from the soil and greater transpiration from the remaining plants. Soil water reductions were greater at 15 to 45 cm than in the upper 15 cm, presumably because the deeper soil layers were in the zone of greatest root activity and received little or no water from the relatively light late spring and summer rains. In addition, capillary flow, caused by evaporation from the soil, may have depleted lower soil layers of water while increasing soil water in the upper layer.

Soil temperatures were increased on burned plots for most of the first year following burning compared to adjacent, unburned rangeland. Fire indirectly affected postburn soil temperature through removal of living vegetation and litter, which increased solar radiation on the soil surface, thus increasing soil temperatures.

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