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Vegetation response to late growing-season wildfire on Nebraska Sandhills rangeland

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Abstract

This study examined the effects of late growing-season (September) wildfire on the subsequent production and species composition of upland Nebraska Sandhills prairie vegetation. Three paired-plots (burn and control), 0.5 ha in size were established in 1995 on sands range sites on each of 3 replications in west-central Nebraska. Soil temperature data were collected the following growing season and herbage standing crop and species composition data were collected for 3 growing seasons following the burn. During March through May of the 1996 growing season, soil temperature in the burn treatment was an average of 1.6 ° C higher at both 15 and 30 cm depths compared to the control ($P < 0.05$). This small increase in spring soil temperature under the burn treatment did not appear to result in earlier growth or to increase herbage standing crop in May. Total herbage standing crop in August averaged 143, 142, and 185 g m^{-2} in 1996, 1997, and 1998, respectively, and did not differ between the burn treatment and control ($P > 0.05$). Little bluestem [*Schizchyrium scoparium* (Michx.) Nash] was the species most adversely affected by burning. Percentage composition by weight of little bluestem in August 1996 averaged 8% under the burn treatment compared to 47% in the control. Other species and species groups, however, were more abundant in burned plots, thus offsetting the lesser amounts of little bluestem. Little bluestem exhibited a marked recovery during the second and third growing seasons after the burn. During the third growing season, percent composition of little bluestem averaged 46% and was not different between treatments ($P > 0.05$). Forbs were more abundant under the burn treatment compared to the control only during the first growing season following the burn ($P < 0.05$).

Key Words: burning, species composition, herbage standing crop, soil temperature

Resumen

En este estudio se examinaron los efectos del fuego a fines de la estación de crecimiento (Septiembre) en la producción subsecuente y composición de especies de la vegetación de pradera de las mesetas de los pastizales "Sandhills"de Nebraska. En 1995, en sitios de pastizal "sand", se establecieron tres pares de parcelas (quema y control) de 0.5 ha en cada una de las 3 repeticiones localizadas en la región central-oeste de Nebraska. En la siguiente estación de crecimiento se colectaron datos de temperatura del suelo y durante las 3 estaciones de crecimiento posteriores a la quema se tomaron datos de producción forraje en pie y composición de especies. En el periodo de Marzo a Mayo de la estación de crecimiento de 1996, la temperatura del suelo a las profundidades de 15 y 30 cm fue en promedio 1.6°C mayor en el tratamiento con quema que en el control ($P < 0.05$). Este pequeño incremento de la temperatura del suelo durante la primavera no pareció resultar en un carecimiento mas temprano de la vegetación o en un incremento en la producción de forraje en pie de Mayo. La producción total de forraje en pie de Agosto promedio 143, 142 y 185 g m^{-2} en 1996, 1997 y 1998 respectivamente y no difirió entre los tratamientos con y sin quema ($P > 0.05$). La especie mas severamente afectada por el fuego fue "Little bluestem" [*Schizchyrium scoparium* (Michx.) Nash]. En Agosto de 1996 el porcentaje de composición por peso del "Little bluestem" promedio 8% en el tratamiento con quema y 47% en el control. Sin embargo, otras especies y grupos de especies fueron mas abundantes en las parcelas con quema, compensando así las menor producción de "Little bluestem". Durante la segunda y tercera estaciones de crecimiento después de la quema el "Little bluestem"mostro una marcada recuperación. Durante la tercer estación de crecimiento, el porcentaje de composición de "Little bluestem" promedio 46% y no hubo diferencia entre tratamientos ($P > 0.05$). Las hierbas fueron mas abundantes en las parcelas con quema que en las parcelas control, pero esta diferencia solo se dio en la primer estación de carecimiento después de la quema ($P < 0.05$).

Many early observers in the Nebraska Sandhills noted the frequent occurrence of prairie fires, from spring through fall (Wolfe 1973). There have, however, been few studies conducted to evaluate the effect of fire on the Nebraska Sandhills grasslands. Wildfires, as well as prescribed burning, have the potential to cause changes in plant cover or species composition on grasslands (Daubenmire 1968). While prescribed burning is not typically used to manage upland Sandhills range, wildfires caused by lightning or accidental means still occur. Immediate and obvious effects of late growing-season or dormant-season wildfires are loss of the forage resource as well as increased exposure of the soil surface to potential wind and water erosion for up to 8

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months until the next growing season. Pool (1914) observed that wildfires that removed protective plant cover for extended periods of time increased the frequency of blowout formation or at least some level of soil erosion, particularly on the choppy sands range sites. While this effect is only anecdotal, wind erosion is among concerns expressed with fire application in the Sandhills (Burzlaff 1962, Bragg and Steuter 1996).

Fires started by lightning in the Nebraska Sandhills may occur in the spring but the majority occur during late summer (Westover 1977). Fires started accidentally, however, can occur anytime when there is adequate dry fuel, primarily from fall through early spring. High winds often dramatically increase the extent of these fires. Variables such as season or date of the burn, fuel load, wind speed, humidity, soil moisture, range condition prior to the burn, and rainfall and management after the burn will influence the response of grasslands (Wright and Bailey 1982). Vegetation characteristics that are affected may include production, species composition, habitat structure, density, plant size, root development, nutrient content, and seed survival and germination. Soil characteristics that may also be affected include soil temperature, moisture, pH, nutrients, and erosion.

The reported effects of burning on individual plant species in the Sandhills has been variable. This is not unexpected given the spatial variability of fire conditions, fire behavior, and date of burning. Following spring burns, Wolfe (1973) for example, reported reductions in the amount of sand bluestem (*Andropogon hallii* Hack.) and sand dropseed [*Sporobolus cryptandrus* (Torr.) Gray] and an increase in prairie sandreed [*Calamovilfa longifolia* (Hook.) Scribn.] and needleandthread (*Stipa comata* Trin. & Rupr.). Bragg, (1978) however, reported that prairie sandreed and needleandthread declined with burning. Pfeiffer and Steuter (1994) reported that prescribed spring burning increased end-of-year standing crop of both rhizomatous grasses and bunchgrasses; however, summer burning (late July) reduced bunchgrass standing crop but did not affect rhizomatous grasses.

Late growing-season (August–September) wildfires occur at a time when warm-season species are near, or at full maturity. The impact of fire on Sandhills vegetation at this time of year has not been fully evaluated. Thus, the objective of this study was to compare soil temperatures, herbage production, and species composition of late-growing season burned and control plots on upland Sandhills range.

Materials and Methods

This study was conducted on Sandhills rangeland in west-central Nebraska. Three replicate study sites were selected in cooperation with landowners that had areas affected by individual wildfires that occurred within a 2-week period from late August to early September 1995. One of the study sites was located in Thomas County (41° 46' 30" N, 100° 45' 45" W) and the other 2 were in McPherson County (41° 28' 45" N, 101° 24' 00" W and 41° 25' 00" N, 100° 59' 30" W). The study sites ranged from 50 to 90 km from North Platte, Nebr. The long-term average annual precipitation for the general area is 484 mm (NOAA 1998). Precipitation was 106, 100, 86, and 117 % of the average during 1995, 1996, 1997, and 1998, respectively.

Study plots were established on sands range sites, the most abundant of upland Sandhills range sites. Soils were Valentine fine sand (mixed, mesic Typic Ustipsamments). Vegetation of sands range sites in west-central Nebraska is dominated by a mix of mid- and tall-grasses. Common warm-season grasses include prairie sandreed, little bluestem [*Schizchyrium scoparium* (Michx.) Nash], sand bluestem, switchgrass (*Panicum virgatum* L.), and sand dropseed. Hairy grama (*Bouteloua hirsuta* Lag.) and blue grama [*Bouteloua gracilis* (H.B.K.) lag. Ex Steud.] are also present. Common cool-season grasses include needleandthread, prairie junegrass [*Koeleria pyramidata* (Lam.) Beauv.], and Scribner panicum [*Dicanthelium oligosanthes* (Schult.) Gould var. *scribnerianum* (Nash) Gould]. Several species of sedges (*Carex* spp.) and forbs also occur on sands range sites.

During the 10 years before this study, grazing management of the pastures containing the study plots was similar for the 3 cooperating ranches. Pastures were generally grazed once per year with scheduled variation in the season or period of use each year. Stocking rates varied from 35 to 50 AUD ha^{-1} depending on annual growing conditions.

Three paired-plots (0.5 ha) were established at each study site. Paired-plots included adjacent 0.25 ha burned and 0.25 ha control (unburned) areas. To minimize confounding of pre-fire fuel-load and species composition with burn and control treatment response, plot locations were restricted to areas where fire-fighting efforts had suppressed the fire and created the burn line. These locations were burned by a flank fire. Additional selection criteria for paired-plot location included similarity of slope, aspect, and density of little bluestem plants. Fences were constructed to exclude cattle grazing during the subsequent 3 growing seasons.

Fuel load, estimated in September 1995 by clipping 10 quadrats (25 x 100 cm) per plot, was 212 g m^{-2}. Each of the wildfires at the 3 study locations began in the mid to late afternoon as a result of lightning associated with developing thunderstorms. Air temperatures ranged from 26 to 32° C with low relative humidity (22 to 40%). Wind speeds ranged from 20 to 35 km hr^{-1} with higher gusts closer to the thunderstorms. The fires consumed all fuel within the plot areas.

Soil temperatures (15 and 30 cm depth) were obtained at monthly intervals beginning in March 1996 and continued through July 1996. Soil temperature readings were taken at 5 random locations in each burn and control plot using a thermometer fitted with a thermocouple probe.

During 1996, the first post-burn growing season, vegetation sampling was conducted in May, June, July, and August. Additional sampling was conducted in June and August of 1997 and in August of 1998. Sampling occurred within the first or second weeks of these months. Peak standing crop of herbage typically occurs in August on this Sandhills vegetation type (Nosal 1983). Standing crop of herbage was determined at each sampling date by hand-clipping ten, 0.25 m^2 quadrats per treatment plot. All current-year growth of herbage in the quadrat area was clipped to ground level, bagged, and later dried and weighed.

Composition of dominant species and groups of minor species in the current-year herbage was determined in each treatment by using a dry-weight-rank method (Jones and Hargreaves 1979). With this method, the 3 most abundant species in each quadrat (25 x 100 cm) were given a rank of 1, 2, or 3 with 1 indicating the most abundant. If any species accounted for more than 85% of the total, it was given both the ranking 1 and 2. If a quadrat did not contain 3 species, the dominant species received rank 1 and the second species received ranks 2 and 3. Multiplication factors of 70, 21, and 9 were then used to calculate the percent composition from the rankings (Gillen and Smith 1986). A single, trained observer collected all dry-weight-rank data. On each sampling date, 100 randomly located

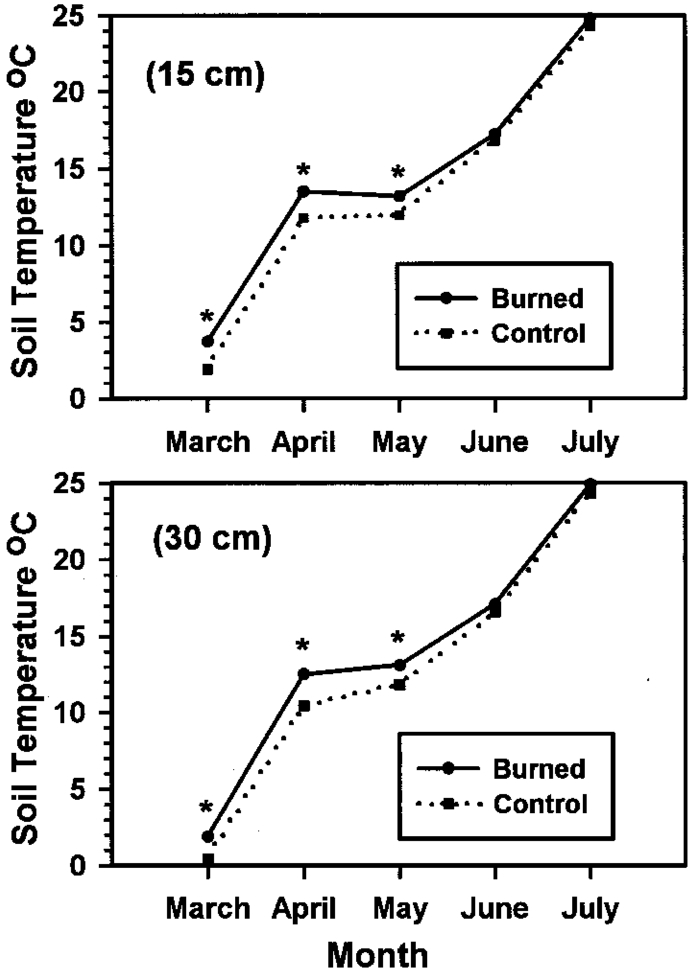

Fig. 1. Spring and early summer soil temperatures during 1996 at 15 and 30 cm depths for the burn treatment (previous fall) and control. * Within months, treatment means differ significantly ($P < 0.05$).

quadrats were ranked in each of the burn and control plots. Because there was minimal or no warm-season species growth at the time of the May sampling, dry-weight-rankings in May 1996 were based on dominant individual cool-season grass species. Sampling that occurred in June through August ranked dominant warm-season grass species individually and minor warm-season and all cool-season grasses as groups. Forbs and sedges also were ranked as groups.

Analysis of variance procedures (SAS Institute Inc. 1985) were used to evaluate treatment effects on soil temperature, herbage standing crop, and percent composition for each individual species or species group. The 3 cooperating-ranch study sites were considered replications and the 3 burn and control paired-plots at each replication were designated as the experimental units. Soil temperature data were collected only in 1996 and model components for that analysis included treatment and replication. Weight of herbage standing crop components (cool- and warm-season grasses, sedges and forbs) was determined by multiplying percent composition for those components by total herbage weight. Analysis of herbage standing crop and percent composition was conducted by year and sampling month and model components included treatment and replication. All differences discussed are significant at the $P \leq 0.05$ level unless otherwise noted.

Results and Discussion

Soil Temperature

Through the beginning of the 1996 growing season (March through May), soil temperatures under the burn treatment were an average of 1.6°C higher at both 15 and 30 cm depths compared to the control (Fig. 1). By June, however, these differences were no longer significant. The small increase in spring soil temperature apparently had no effect on standing crop production up to the May sampling date (Table 3). Wright and Bailey (1982) reported soil temperatures on several grassland types to average about 5° C higher following spring burns. Our observed increase in soil temperature was less, probably because in the 7 months since the burn had occurred, wind and water erosion and leaching had nearly removed all blackened ash from the soil surface.

Species Composition

Species composition sampling conducted in May 1996 (first growing season after the fires) ranked dominant cool-season grass species individually and other herbage components as groups. Needleandthread, prairie junegrass, and sedges were the 3 species having the highest percentage composition (Table 1). Percentage composition of sedges was significantly higher under the burn treatment

Table 1. Percentage composition for species and species groups for the burn treatment and control, May 1996.

Species/species group	Burn	Control
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Cool-season grasses		
Prairie junegrass	15	20
Needleandthread	33	34
Scribner panicum	5	7
Western wheatgrass	2	2
Other cool-season grasses	1	1
Total cool-season grasses	56	64
Warm-season grasses	5	8
Sedges	33[a]	20[b]
Forbs	6	8

[ab]Treatment means for each species or group with unlike letters differ significantly ($P < 0.05$).

Table 2. Percentage composition for species and species groups for the burn treatment and control in August 1996, 1997, and 1998.

Species/species group	1996 Burn	1996 Control	1997 Burn	1997 Control	1998 Burn	1998 Control
	(%)					
Warm-season grasses						
Blue and hairy grama	2	1	2	1	2	3
Little bluestem	8[a]	47[b]	20[a]	51[b]	42	49
Prairie sandreed	19	14	15[a]	8[b]	7	7
Sand bluestem	6	4	8	4	5	4
Switchgrass	8	5	8	7	9	6
Other warm-season grasses	1	1	1	2	2	1
Total warm-season grasses	44[a]	72[b]	54[a]	73[b]	67	70
Cool-season grasses	33[a]	19[b]	32[a]	16[b]	25	23
Sedges	5[a]	1[b]	4[a]	2[b]	3	2
Forbs	18[a]	8[b]	10	9	5	5

[ab]Within years, treatment means for each species or group with unlike letters differ significantly ($P < 0.05$).

(33%) compared to the control (20%). Treatment plots did not differ in composition for any of the other species or groups in May 1996. Bragg (1998) reported that sedge response in the growing season following a September burn was variable depending on the site aspect. However, during the second and third growing seasons following the burn, sedges declined, indicating that they may be adversely affected by burning (Bragg 1998). Wright (1971), in a burning mortality comparison between needleandthread and squirreltail [*Sitanion hytstrix* (Nutt.) J.G. Smith], reported that needleandthread mortality was higher because of a greater density of dead plant material within the bunch. This caused burn temperatures to be higher for a longer period of time. At the time of the fire in our study, spring growth of needleandthread was mature and dry, but some new fall growth (4 to 6 cm) was present. This may have reduced heat within needleandthread bunches.

Percentage composition data of the peak standing crop (August) during the first (1996), second (1997) and third (1998) growing seasons after the fires are shown in Table 2. Percentage composition of several individual species or species groups differed between the burn treatment and control during 1996 and 1997.

The percentage composition of little bluestem was significantly less under the burn treatment compared to the control in 1996 (39 units) and 1997 (31 units), but not in 1998 (Table 2). The percentage composition of blue and hairy grama, prairie sandreed, sand bluestem, and switchgrass did not differ between treatments in August 1996. The percentage composition of prairie sandreed was higher under the burn treatment in 1997 but similar to the control in 1998. Because of less little bluestem, percentage composition for the total warm-season grass group also was less in the burn treatment compared to the control in 1996 and 1997. Our visual observations that were made on little bluestem tussocks indicated that there were relatively few tussocks that were completely killed and had no new tillers emerging. In most cases, the burned tussocks had from 5 to 20 new tillers emerging compared to unburned tussocks that contained from 75 to as many as 140 tillers. Over time, little bluestem produces a dense canopy of dead tillers that also limits availability of current-year's growth to grazing animals. This canopy produces an intense fire around the growing points of a bunchgrass when it burns (Wright 1971). The extent of little bluestem mortality is likely related to fuel load and heat, both of which can vary between tussocks. Anderson et al. (1970) also reported a decrease in little bluestem basal cover with 20 March burning compared to 1 May and hypothesized that with the drier conditions in March, little bluestem was more susceptible to injury. Pfeiffer and Steuter (1994) reported a 90% reduction in bunchgrass standing crop (primarily little bluestem) in the growing season following a late-July burn. On hilltops and sites with a south aspect, Bragg (1998) reported less canopy cover of little bluestem on plots burned the previous September compared to an unburned control. During the second and third growing seasons following the burn, canopy cover of little bluestem increased on hilltop sites but not south aspect sites. Our observed increase of little bluestem in burned plots during 1997 and 1998 appeared to be the result of recruitment of new tillers within the partially thinned tussocks. Although no measurements were made, an increase in individual tiller size also would contribute to the overall increase.

The percentage composition of cool-season grasses and sedges was significantly greater under the burn treatment compared to the control in August 1996 and 1997, but not in 1998 (Table 2). This difference was present for sedges when sampling was conducted in early May 1996, but not for the cool-season grass group (Table 1). On this range type, the majority of cool-season grass growth occurs from May through June. With removal of dormant and dead plant material in the burn treatment, cool-season species would have had full access to sunlight and possibly, less competition for soil water in 1996 and 1997 as a result of the mortality of little bluestem.

The percentage composition of forbs was greater under the burn treatment (18%) compared to the control (7%) during 1996, but no differences were detected in 1997 or 1998 (Table 2). Of the forb species, visual observations indicated that annual sunflower (*Helianthus annuus* L.), plains sunflower (*H. petiolaris* Nutt.), and to a lesser extent, stiff sunflower [*H. rigidus* (Cass.) Desf.] were more abundant under the burn treatment compared to the control. Spotted spurge (*Euphorbia maculata* L.) and Missouri spurge (*E. missurica* Raf.) were 2 other annual species that also

Table 3. Current-year herbage standing crop for the burn treatment and control in the first growing season (1996) following the fall wildfires.

Component	May Burn	May Control	June Burn	June Control	July Burn	July Control	August Burn	August Control
	($g\ m^{-2}$)							
Cool-season grasses	10	13	28	29	51[a]	33[b]	48[a]	27[b]
Warm-season grasses	1	1	9[a]	31[b]	35[a]	82[b]	64[a]	101[b]
Sedges	6	4	12[a]	6[b]	6[a]	1[b]	8[a]	2[b]
Forbs	1	2	6	4	22[a]	9[b]	26[a]	10[b]
Total	18	20	55	70	114	125	146	140

[ab]Within months, treatment means with unlike letters differ significantly ($P < 0.05$).

were observed to be more abundant under the burn treatment. Bragg (1998) reported an average 36% canopy cover of forbs on plots burned the previous September compared to an average 25% canopy cover of forbs in control plots. Stiff sunflower, Missouri spurge, and western fleabane (*Erigeron bellidiastrum* Nutt.) were forb species that Bragg (1998) described as exhibiting a fire-positive response during either first or second growing season following a September burn.

Herbage Standing Crop

During 1996, the first growing season after the burn, there were no significant treatment differences in total current-year herbage standing crop on any of the sampling dates (Table 3). Total standing crop averaged 19, 63, 120, and 143 g m^{-2} in May, June, July, and August, respectively. However, differences were present for 2 of the herbage components in June and for all 4 herbage components in July and August. In June, standing crop of sedges was greater and standing crop of warm-season grasses was less under the burn treatment compared to the control. During July and August, standing crop of cool-season grasses, sedges, and forbs was greater and standing crop of warm-season grasses less under the burn treatment compared to the control. The lower standing crop for the warm-season grass group was primarily attributable to less little bluestem under the burn treatment (Table 2). Pfeiffer and Steuter (1994), also working on sands range sites, found no difference in total August standing crop between burn (previous late July) and control treatments. They observed a decline in the bunchgrass component and an increase of forbs. Morrison et al. (1986) reported 16% greater August standing crop on a burn treatment compared to a control.

Total herbage standing crop during 1997 averaged 92 g m^{-2} in June and 142 g m^{-2} in August with no significant difference between the burn treatment and control (Table 4). Similar to 1996, there were standing crop differences for the herbage components with greater yield of cool-season grasses and sedges and less yield of warm-season grasses under the burn treatment compared to the control. Forb standing crop was greater under the burn treatment during June but similar between treatments during August.

Total herbage standing crop averaged 185 g m^{-2} in August 1998 with no difference between treatments (Table 4). There also were no treatment differences for any of the herbage components. The warm-season grass component of the August standing crop under the burn treatment increased each year with 64, 78, and 123 g m^{-2} being present in 1996, 1997, and 1998, respectively. This increase is attributable to the recovery and increase in percent composition of little bluestem (Table 2).

Table 4. Current-year herbage standing crop for the burn treatment and control in the second (1997) and third (1998) growing season following the fall wildfires.

	June[1]		August	
Component	Burn	Control	Burn	Control
	(g m^{-2})			
1997				
Cool-season grasses	52[a]	33[b]	48[a]	23[b]
Warm-season grasses	21[a]	45[b]	78[a]	101[b]
Sedges	6[a]	2[b]	5[a]	3[b]
Forbs	17[a]	8[b]	15	12
Total	96	88	146	139
1998				
Cool-season grasses	—	—	46	42
Warm-season grasses	—	—	123	133
Sedges	—	—	5	4
Forbs	—	—	9	9
Total	—	—	183	188

[1] Sampling did not occur in June 1998.
[a b] Within months, treatment means with unlike letters differ significantly ($P < 0.05$).

Management Implications

A late growing-season burn did not reduce August standing crop of total herbage the following growing season on sands range sites. Cool-season grasses, sedges, and forbs increased with fire to offset a decline in little bluestem. Little bluestem exhibited a marked recovery during the second and third growing seasons after the burn. The positive response of forbs to burning was generally evident for only the first growing season following the burn.

A primary question posed by Sandhills ranchers and land managers is to what extent their grazing management should change following wildfires that occur in the late growing-season or when vegetation is completely dormant. Because of the loss of residual plant cover and litter, wind and water erosion are possible. Grazing management that includes reductions in stocking rate along with a delay in the start of grazing should enhance the accumulation of residual plant material and litter formation. Although our study found no reduction in standing crop on sand range sites, productivity of choppy sands range sites following a burn is reduced (Bragg 1978, 1998). Thus, because most Sandhills pastures contain a mosaic of sandy, sands, and choppy sands range sites, it is likely that the overall livestock carrying capacity of a pasture will be reduced. Additionally, increases in unpalatable forbs would likely increase grazing pressure on more desirable species.

Burning may also result in changes in grazing behavior that could complicate grazing management decisions. Patterns of grazing distribution, for example, may be different in burned than in unburned areas. Preference and relative palatability of individual plant species and corresponding degree of plant use also may change following a burn. Pfeiffer and Steuter (1994), for example, reported heavy use and further reduction of little bluestem when bison grazed the growing season following a burn.

Further studies are needed to completely address the effects of burning on the vegetation, soil, and animal components of Sandhills rangeland. Specifically, the evaluation of burning and grazing interaction effects is an area of study where additional information is needed.

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