ABOVEGROUND BIOMASS IN TALLGRASS PRAIRIE: EFFECT OF TIME SINCE FIRE.

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Abstract. Previous research on the Konza Prairie Research Natural Area (KPRNA) has indicated that the interval between fires may influence the magnitude of biomass production responses to fire. To test this hypothesis, we estimated total aboveground biomass (grass+forbs+current year dead biomass) in burned watersheds that varied in fire history from 20 years of annual spring burning to fire exclusion for 18 years, and in an unburned watershed. In addition, we measured tiller density of big bluestem (*Andropogon gerardii*), the dominant grass of Konza Prairie. Tiller density was generally greater (19%) in annually burned sites, but biomass production was significantly higher in watersheds that had been protected from fire for >10 years (557 ±33 g/m^2) relative to annually burned sites (422 ±10 g/m^2). The increased production response to fire in sites previously unburned for several years was attributed to the maintenance of high forb biomass in the year of the fire coupled with a significant increase in graminoid biomass in relation to unburned sites.

INTRODUCTION

Drought and fire are known to exert direct control on patterns of net primary production in the tallgrass prairie (Collins and Wallace 1990). Over a 17-year period, peak aboveground biomass on the Konza Prairie Research Natural Area (KPRNA) has ranged from <200 g/m^2 to 700 g/m^2. Annually burned lowlands are usually the most productive sites while unburned uplands are usually the least productive (Abrams et al. 1986). During this 17-year period, aboveground total biomass in annually burned sites averaged 482 g/m^2 (SE=24) in the lowlands and 386 g/m^2 (SE=19) in uplands. In unburned sites, total biomass averaged 341 g/m^2 (SE=19) in lowlands and 349 g/m^2 (SE=23) in the uplands. In contrast, biomass of forbs was greater in unburned sites (Abrams et al. 1986).

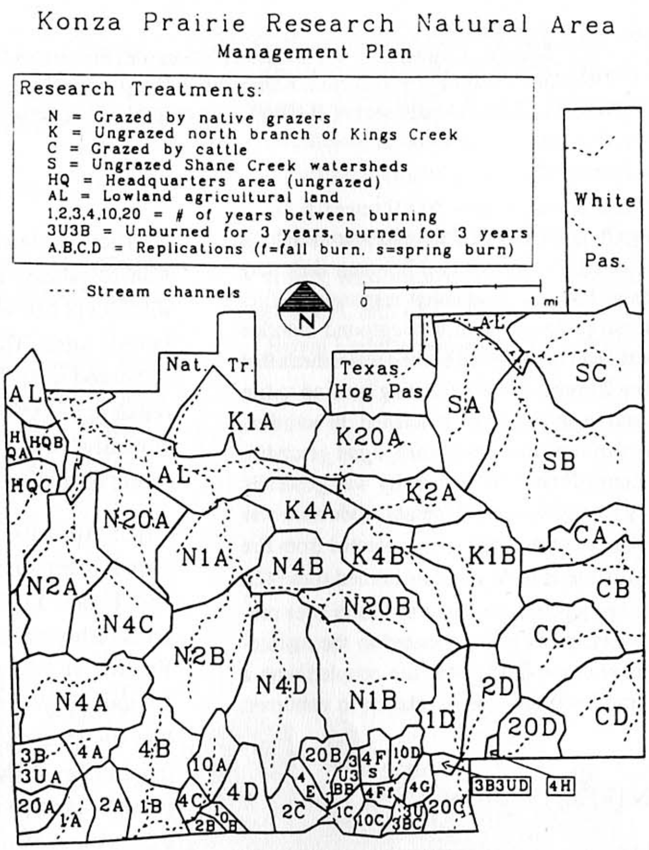
A variety of factors are influenced by fire that result in increased aboveground biomass in tallgrass prairie (Knapp and Seastedt 1986). Perhaps the most important function of a spring fire is the removal of old detrital biomass (Knapp and Seastedt 1986). This detrital layer reduces light available to emerging shoots, results in leaves developing "shade characteristics", keeps soil temperature cool in the spring, and, as a consequence, production on unburned sites is less than on burned sites. Many studies on KPRNA have documented this fire induced increases in aboveground biomass (Abrams et al. 1986, Briggs et al. 1989, Hulbert 1988, Knapp and Seastedt 1986, Seastedt 1985, Seastedt et al. 1991). In addition, Seastedt et al. (1991) reported that post-fire production responses to fertilizer (N) in sites with a history of infrequent fire was reduced relative to responses in annually burned sites. This suggests that N accumulates in soils of unburned sites. Thus, fire in an infrequently burned site will result in a significantly greater biomass response, relative to annually burned sites, because neither nitrogen or energy will limit production.

On 05 April 1991, a wildfire (a prescribed fire that escaped) burned over 2160 ha (5335 acres) of KPRNA (62% of the site; Figure 1). This wildfire burned watersheds (catchment units) whose fire histories varied from those protected from fire for 18 years to those annually burned for >20 years (Figure 1). We used this wildfire to evaluate the hypothesis that the interval between fires (fire history) influences the magnitude of the production response to fire. Below, we present estimates of peak aboveground biomass and also, tiller densities of big bluestem (*Andropogon gerardii*; the dominant grass of KPRNA) from 17 watersheds included in this wildfire. In addition, we estimated peak aboveground biomass from one watershed that has been unburned since 1971.

METHODS

Konza Prairie Research Natural Area is representative of the Flint Hills, a dissected upland with chert-bearing limestone layers. The ridges are usually flat with shallow, rocky soils, whereas the larger and wider valleys have deep permeable soils. The steep-sided hills are characterized by exposed Permian limestone and shale strata that prevented cultivation. Elevation on KPRNA ranges from 320 m to 444 m, with most of the land in the range of 366 m to 427 m. This native tallgrass prairie is dominated by big bluestem, little bluestem (*A. scoparius*), and switch grass (*Panicum virgatum*; Freeman and Hulbert 1985).

An experimental plan initiated in 1971 (Hulbert 1973) placed different watersheds (catchment units) under a variety of prescribed spring burning (mid-April) regimes ranging from annual, 2-, 4-, and 10-year intervals to long-term unburned sites. (Figure 1). Most watersheds have either Florence cherty clay loam soils on the broad, nearly level uplands or lowland Tully silty clay loam soils sites (Jantz et al. 1975). While portions of the site have been grazed by cattle or bison, only



ANALYSIS OF 05 APRIL 1991 WILDFIRE

WATERSHED	LAST YEAR BURNED	YEARS SINCE LAST BURN
001C*	1990	1
001D*	1990	1
002C	1989	2
002D*	1990	1
004E*	1987	4
004F*	1989	2
004G	1988	3
004H	1990	1
010C*	1981	10
010D*	1986	5
020B*	1973, (75)	18
020C*	(72-77, 1980)	11
020D*	1980	11
033B*	1989	2
033C*	1989	2
033D	1990	1
N20A	1990	1
N20B*	1980	11
N01A	1990	1
N01B*	1990	1
N02B*	1990	1
N04B	1989	2
N04D*	1988	3
K20A	1980, (85)	11
K01B	1990	1
K02A	1990	1
K04A	1989	2
K04B	1988	3
C20A	1980, (83)	11
C01A	1990	1
C02A	1989	2
C02B	1990	1
S03A	1986	5
S03B	1990	1
S03C	1989	2

() Partial Burn

* = Aboveground biomass was estimated from this watershed

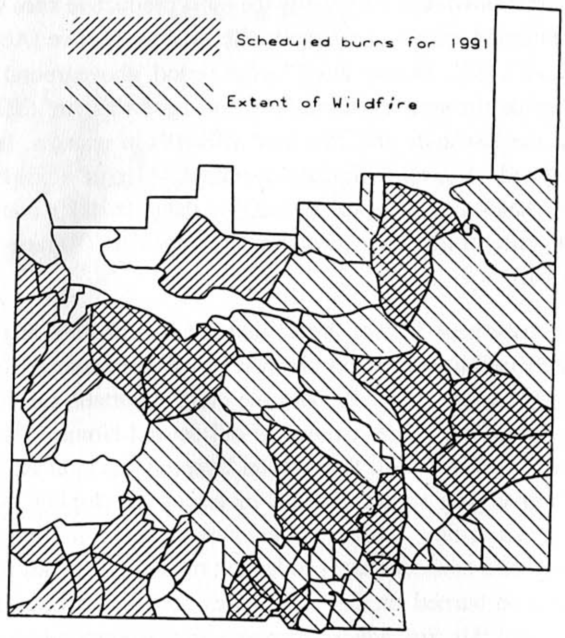


Figure 1. **1a. Konza Prairie Research Experimental Design showing fire intervals.**
1b. The area burned on Konza Prairie by the wildfire of 05 April 1991.

Table 1. Peak mean (SE) aboveground biomass (g/m$^{2)}$ on tallgrass prairie watersheds with different burn regimes. Values with the same letter are not significantly different at P<0.05 using Duncan's multiple range test.

YEARS SINCE LAST FIRE	TOTAL ABOVEGROUND BIOMASS (g/m^2)	GRASS (g/m^2)	Forbs (g/m^2)
1-2 (320)*	422 (10.3) C	359 (9.7) A	63 (4.0) C
3-5 (160)*	441 (15.4) CB	352 (13.4) A	116 (10.4) B
6-12 (160)*	493 (18.5) B	325 (16.7) A	141 (11.3) B
>12 (40)*	557 (33.3) A	310 (25.1) A	248 (29.4) A
Unburned (20)*	455 (30) B	226 (22.3) B	190 (30) B

* = number of 0.1 m^2 plots sampled

data obtained from watersheds ungrazed for at least 12 years are reported here.

To estimate peak aboveground biomass in 17 watersheds, 680 0.1 m^2 quadrats (20 per soil type from each watershed; soil type=Florence and Tully) were harvested in mid-August 1991 at sites with various burning histories (Figure 1). In addition, 20 0.1 m^2 quadrats were harvested from an unburned watershed (unburned for >20 years). This protocol is adequate to sample aboveground biomass and to detect the experimental effect of fire in this biome (Briggs and Knapp 1986). Detailed methodology for sampling the aboveground components are given in Abrams et al. (1986) but briefly, plant material was separated into graminoid and forb material (including a minor woody plant component), oven-dried at 60 C for 48 hr, and weighed to the nearest 0.1g.

Tiller density of big bluestem was measured on the uplands and lowlands of six watersheds that were burned during the wildfire in 1991. The watersheds included two burned annually for >10 years, two burned every four years, and two unburned for >10 years (Figure 1). Eighty random samples per fire history treatment were measured four times throughout the growing season.

For statistical analysis of aboveground biomass data, watersheds were grouped based upon past fire history. Groups were 1) watersheds burned annually or every 2-years for the past five years (N = 320 quadrats); 2) watersheds last burned 3-5 years before 1991 (N = 160 quadrats); 3) watersheds last burned 6-12 years before 1991 (N = 40 quadrats); 5) the unburned watershed (N=20 quadrats). These groups were selected based on results from Seastedt et al. (1991). ANOVA (P <0.05) on total, grass and forb biomass was conducted using PC-SAS (GLM Procedure, SAS, 1981). ANOVA with the least significant difference (LSD) method was used for pairwise comparison of tiller density data.

RESULTS AND DISCUSSION

On watersheds burned annually or biennially, total peak aboveground biomass was not significantly different from watersheds burned for the first time in 3-5 years (Table 1). However, on sites burned for the first time in 6-12 years, total peak aboveground biomass was significantly higher than watersheds burned at least biennially. The greatest biomass response was measured in watersheds burned for the first time in >12 years (Table 1). Peak grass biomass was not significantly different between fire history groups, but was significantly higher than in the unburned watershed. Forb biomass, however revealed a strong response to fire history (Table 1). A significant (P <0.001) difference in total, grass, and forb biomass was detected between upland and lowland soil types, thus a separate analysis was used for each soil type.

On upland sites, peak total aboveground biomass was not significantly different between watersheds burned at least biennially and watersheds burned for the first time in 3-5 years (Figure 2). On watersheds burned for the first time in 6-12 years, peak aboveground biomass was significantly higher than in watersheds burned at least biennially, but

Table 2. Big bluestem (*Andropogon geradii*) tiller densities per m^2 (mean and SE) from watersheds that differed in the years they were last burned. Values with the same letter are not significantly different at P<0.05 using LSD.

BURN HISTORY	MAY	JUNE	JULY	AUGUST
BURNED ANNUALLY	782 (32.5) A	1013 (30.5) A	1022 (29.4) A	989 (26.8) A
BURNED EVERY 4 YEARS	642 (29.9) B	972 (33.8) AB	964 (35.2) A	926 (25.1) AB
UNBURNED >10 YEARS	550 (31.7) C	906 (29.7) B	948 (30.9) A	866 (24.9) B

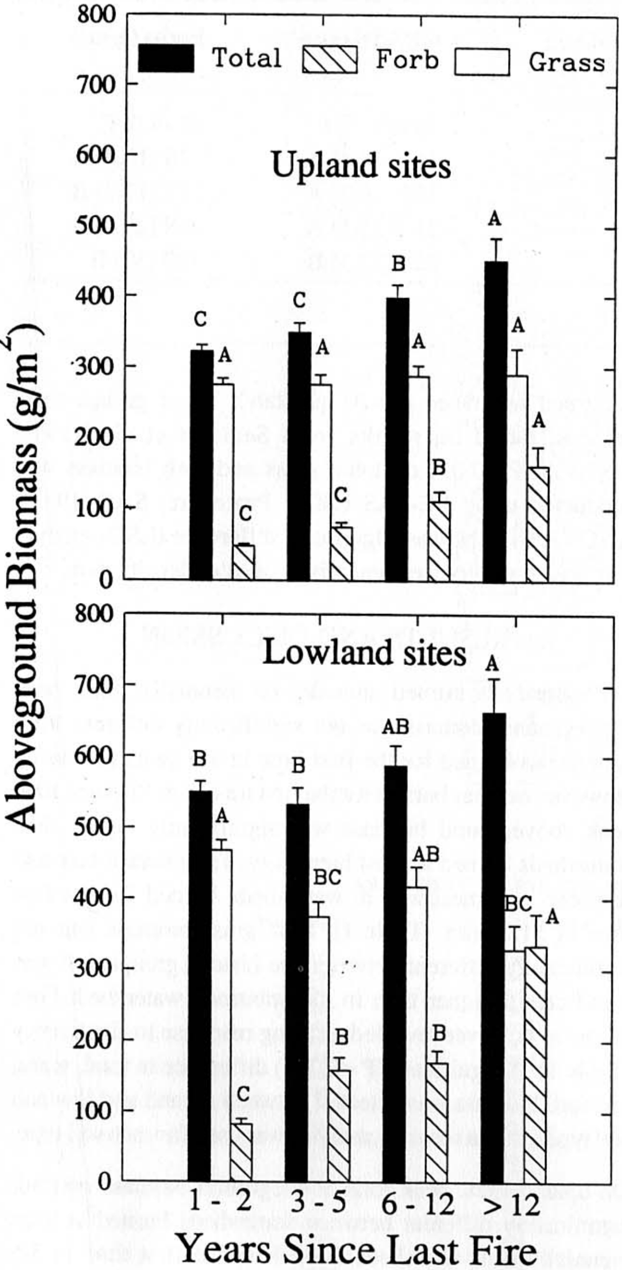


Figure 2. Peak above ground biomass (+SE of the mean) of watersheds on Konza Prairie Research Natural Area in 1991 differing in year since last burn. Bars with same letters are not significantly different at P<0.05.

lower than watersheds burned for the first time in 12 years. No significant difference between fire history groups was detected in grass biomass, but forb biomass was significantly higher on sites previously unburned for >6 years (Figure 2).

On lowland sites, biomass was greater than upland sites in all four groups, but the pattern of difference among groups was similar to upland sites in total aboveground biomass (Figure 2). However, peak grass biomass showed a negative response to time since last fire, as grass biomass decreased with increased time since last fire (Figure 2). Even so, grass biomass in watersheds unburned for >12 years was greater than in unburned sites. As in upland sites, forb biomass increased with increasing interval since last fire (Figure 2).

Tiller densities of big bluestem varied across the watersheds ranging from a low of 550 tillers per m^2 in May on watersheds unburned for >10 years to over 1012 tillers per m^2 on annually burned watersheds (Table 2). During all four measurement dates, densities of tillers were higher on annually burned watersheds compared to watersheds burned less frequently (Table 2). In previously unburned watersheds, tiller densities increased over the growing season, a pattern not seen in the annually burned sites.

Abrams et al. (1986) reported that biomass of gramminoids was 40% lower and forb biomass was 200-300% greater in unburned than in annually burned sites. Our data are consistent with this (Table 1). The lack of a significant difference in post-burn grass biomass between sites previously unburned vs. those annually burned in this study suggests that graminoids responded rapidly in these previously unburned sites, as did tiller density (Table 1). Moreover, the maintenance of high forb biomass after fire indicates that one year of fire is not sufficient to significantly decrease the importance of forbs in these communities. Thus, maximum levels of biomass in sites burned for the first time in several years can be attributed to the large graminoid response coupled with the presence of high forb biomass (Table 1, Figure 2). This is likely a nonsustainable phenomenon (Seastedt and Knapp 1993) since continued burning would reduce forb biomass and increase N limitations (Seastedt et al. 1991).

The 1991 wildfire may had different effects on the grassland vegetation compared to a prescribed fire. Fire temperature during a spring burn is highly variable in tallgrass prairie with headfires usually hotter than backfires (Gibson et al. 1990). In addition, areas that have not been burned for many years may have hotter fires than areas burned annually. However, in an earlier study on Konza Prairie, maximum fire temperatures did not differ significantly between sites burned annually and sites burned for the first time in 15 years (Gibson et al. 1990). Bidwell et al. (1990) found that in an Oklahoma grassland, peak aboveground biomass of tallgrasses was greater on headfired plots (typical of our wildfire) than on backfired plots, while the opposite occurred for forb peak aboveground biomass. We believe that the responses we report are not due to the type of fire (wildfire as opposed to a prescribed burn), as the total aboveground biomass on the sites which had burned annually for >17 years had similar production values to years when they had been burned during prescribed fires (17 year mean 434 ±24 g/m^2 vs. 422 ±10 g/m^2 during this wildfire).

CONCLUSION

In conclusion, tallgrass prairies are subject to considerable spatial and temporal variation in factors influencing NPP (fire, drought, grazing, etc.). Previous studies have shown that infrequent fires may maximize species diversity of plants and insects (Gibson and Hulbert 1987, Evans 1984). Data from this study suggest that aboveground biomass may also be maximized under these conditions.

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