Short Communication

Vegetation Responses to Season of Fire in Tallgrass Prairie: A 13-Year Case Study

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ABSTRACT

Fire regulates vegetation composition of fire-dependent grasslands in North American tallgrass prairies. We measured the vegetation response to prescribed fire seasonality by burning in two-month increments every two years, from 2004 to 2015, west of Stillwater, Oklahoma, USA. Fire exclusion or burning in any season led to an in increase in woody plant cover ranging from 18% to 63%, except for September through October, which showed no increase. Tallgrass cover increased with September through December burn treatments. Forb cover decreased with burning from January through April, but was highest in the September through October treatment. These vegetation responses suggest that land managers, policy makers, and researchers should consider the benefits of burning outside of the traditional late-winter to early-spring window, providing that they have the ability to increase the number of burn days and reduce temporal concentrations of smoke.

RESUMEN

El fuego regula la composición de los pastizales fuego-dependientes de las praderas de pastos altos de Norte América. En este trabajo medimos la respuesta de la vegetación a quemas prescritas realizadas bimestralmente durante todas las estaciones del año, desde 2004 a 2015, al oeste de Stillwater en Oklahoma, Estados Unidos. La exclusión del fuego o las quemas realizadas en cualquier estación llevaron a un aumento de la cobertura de arbustos, cuyo rango varió entre el 18% y el 63%, con excepción de los meses de septiembre y octubre, los cuales no mostraron ningún incremento. La cobertura de pastos altos se incrementó con los tratamientos de quema realizados desde septiembre hasta diciembre. La cobertura de hierbas no gramíneas decreció con las quemas de enero a abril, mientras que la cobertura más alta de éstas se registró con las quemas de setiembre y octubre. Estas respuestas de la vegetación sugieren que los gestores de recursos, decisores políticos, e investigadores, deberían considerar los beneficios de quemar por fuera de la ventana de prescripción tradicional del invierno tardío y la primavera temprana, siempre que tengan la posibilidad de incrementar el número de días de quema y reducir las concentraciones temporales de humo.

Keywords: disturbance ecology, grasslands, plant functional group, plant succession

Citation: Weir, J.R., and J.D. Scasta. 2017. Vegetation responses to season of fire in tallgrass prairie: a 13-year case study. Fire Ecology 13(2): in press.

INTRODUCTION

Fire is a regulating ecological disturbance for grasslands in the Great Plains of North America (Anderson 2006). These grasslands are dependent on regular fire to prevent woody plant encroachment that can lead to juniper (*Juniperus* L. spp.)-dominated woodland in as little as 40 years (Briggs *et al.* 2002). As this transition from grassland to woody-dominated state occurs, herbaceous forage biomass, livestock production, and native wildlife habitat are negatively impacted (Limb *et al.* 2010). In the Great Plains, prescribed fires are almost exclusively conducted in late winter to early spring, primarily for livestock production (Weir 2011). By burning only during this narrow time frame, prescribed fire use can be limited significantly and create smoke management issues (Kansas Department of Health and Environment 2010, Weir 2011). This narrow seasonality of burning also poorly replicates historical pre-European fire regimes (Towne and Craine 2014).

Most fire studies in the region have been concerned with loss of grass production and increase in forbs, but research indicates that season-of-burn effects are highly variable (Engle and Bidwell 2001; Towne and Craine 2014, 2016). Engle and Bidwell (2001) noted that little research on late growing-season fire in tallgrass prairie had been done, and Towne and Craine (2016) confirmed that more research is necessary. We empirically tested the seasonality effects of prescribed fire on tallgrass prairie. Our objectives were to: (1) quantify changes to plant functional groups relative to fire seasonality, and (2) derive ecological and management implications to guide effective prescribed fire applications across seasons.

METHODS

Fourteen 20 m × 30 m plots were established on the Oklahoma State University Research Range 13 km west of Stillwater, Oklahoma, USA. Prior to the study, two fires burned the entire site in February 1991 and March 1996. Each plot was marked with three permanently established transects, mid-point and 5 m to each side, oriented on the long axis of the plot. Vegetation data was collected in the late growing season at 10 random points along each transect. Plant functional group composition using cover classes for tallgrasses, other grasses, forbs, legumes, and woody plants was estimated in 2003 (baseline) and then following fire treatments in 2005, 2008, 2010, 2014, and 2016. We randomly applied seven treatments to each of the two replications. The treatments were fire applied every two years during 1) January to February (Jan-Feb), 2) March to April (Mar-Apr), 3) May to June (May-Jun), 4) July to August (Jul-Aug), 5) September to October (Sep-Oct), 6) November to December (Nov-Dec), and 7) the control (No Burn; Figure 1). The plots were burned in 2004, 2006 to 2007, 2008 to 2009, 2010 to 2011, 2012 to 2013, and 2014 to 2015, with the same fire treatment applied to the same plot each time.

For analyses of vegetation, we used plot as the experimental unit. As an experimental study with only two replications across space and six iterations of each fire season treatment (i.e., every two years) during the 13-year study period, we consider this a long-term case study. We calculated the 2003 and 2016 means for each plant functional group and presented the mean from the two replications of each fire seasonality treatment. For woody plant cover, we used linear least squares regression to de-

No burn	Nov-Dec	Jan-Feb	Jul-Aug	Mar-Apr	May-Jun	Sep-Oct
Burn date	**Burn date**	**Burn date**	**Burn date**	**Burn date**	**Burn date**	**Burn date**
7 Apr 2009*	14 Dec 2004	14 Jan 2004	24 Aug 2004	29 Mar 2004	27 May 2004	1 Oct 2004
	21 Nov 2006	29 Jan 2007	10 July 2006	2 Apr 2007	5 Jun 2007	29 Sep 2006
	13 Nov 2008	3 Feb 2009	23 July 2008	14 Apr 2009	27 May 2009	8 Oct 2008
	10 Dec 2010	25 Feb 2011	4 Aug 2010	30 Mar 2011	1 Jun 2011	16 Sep 2010
	14 Nov 2012	31 Jan 2013	20 Sept 2012	26 Mar 2013	3 Jun 2013	20 Sep 2012
	2 Dec 2014	30 Jan 2015	18 Aug 2014	10 Apr 2015	12 Jun 2015	17 Oct 2014
Sep-Oct	**May-Jun**	**Jul-Aug**	**Jan-Feb**	**No burn**	**Nov-Dec**	**Mar-Apr**
Burn date	**Burn date**	**Burn date**	**Burn date**	**Burn date**	**Burn date**	**Burn date**
1 Oct 2004	27 May 2004	24 Aug 2004	14 Jan 2004		14 Dec 2004	29 Mar 2004
29 Sep 2006	5 Jun 2007	10 Jul 2006	29 Jan 2007		21 Nov 2006	2 Apr 2007
8 Oct 2008	7 Apr 2009*	23 Jul 2008	3 Feb 2009		13 Nov 2008	14 Apr 2009
16 Sep 2010	1 Jun 2011	4 Aug 2010	25 Feb 2011		10 Dec 2010	30 Mar 2011
20 Sep 2012	3 Jun 2013	20 Sep 2012	31 Jan 2013		14 Nov 2012	26 Mar 2013
17 Oct 2014	12 Jun 2015	18 Aug 2014	30 Jan 2015		2 Dec 2014	10 Apr 2015

Figure 1. Layout of plots with burn treatments (i.e., Jan-Feb) and actual dates fires were applied to each (burn date) in native prairie west of Stillwater, Oklahoma, USA, from 2004 to 2014. Asterisk (*) denotes plot was accidentally burned by wildfire on that date.

termine if woody plant cover change was correlated with time in each seasonal treatment based on the coefficient of determination (r^2), a *P*-value for fit linear trendlines, and the slope of significant trendlines to predict annual increases.

RESULTS

Tallgrass cover was lower during the last sample period of the study in the no burn (−50%), May-Jun (−7%), and Jul-Aug (−22%) treatments, and did not change in the Jan-Feb or Mar-Apr treatments (Table 1). However, the Sep-Oct (6%) and Nov-Dec (14%) treatments had significantly higher tallgrass cover. Cover of other grasses was lower in all treatments by the 2016 sample period. Forb cover was higher at the conclusion of the study in the no burn (9%), May-Jun (12%), Jul-Aug (11%), Sep-Oct (14%), and Nov-Dec (3%) treatments, but lower in Jan-Feb (−8%) and Mar-Apr (−4%) treatments. Legume cover increased in the no burn (6%), Mar-Apr

Table 1. Plant functional group starting (2003) and ending (2016) cover relative to fire treatments every two years. Values are the mean of the two spatial replications per treatment. Values marked with a positive sign (+) remained neutral or increased, and those with a negative sign (–) decreased..

Timing	Tallgrass	Other grass	Forbs	Legumes	Woody plants
No fire	–70% to 20%	–19% to 16%	+1% to 10%	+1% to 7%	+4% to 67%
Jan-Feb	+58% to 58%	–16% to 4%	–15% to 7%	+1% to 1%	+11% to 40%
Mar-Apr	+60% to 60%	–15% to 5%	–9% to 5%	+1% to 4%	+14% to 51%
May-Jun	–51% to 43%	–17% to 14%	+4% to 16%	–2% to 1%	+21% to 41%
Jul-Aug	–64% to 42%	–12% to 6%	+4% to 15%	+2% to 2%	+12% to 31%
Sep-Oct	+56% to 62%	–18% to 10%	+5% to 19%	–3% to 2%	+13% to 12%
Nov-Dec	+54% to 68%	–19% to 4%	+6% to 9%	+1% to 4%	+16% to 34%

(3 %) and Nov-Dec (3 %) treatments, but did not change in the Jan-Feb or Jul-Aug treatments. May-Jun (−1 %) and Sep-Oct (−1 %) treatments showed slight decreases in legume canopy cover.

Total woody plant cover increased dramatically with no burn (63 %), and even with fire: Jan-Feb (29 %), Mar-Apr (37 %), May-Jun (20 %), Jul-Aug (19 %), Nov-Dec (18 %), with the only exception being the Sep-Oct (−1 %) treatment (Table 1). The relationship between time and woody plant canopy cover was significantly and positively correlated for the no burn, Jan-Feb, Mar-Apr, and May-Jun fire treatments ($P < 0.01$ and $r^2 \geq 0.39$ in all treatments; Figure 2). The slope of these relation-

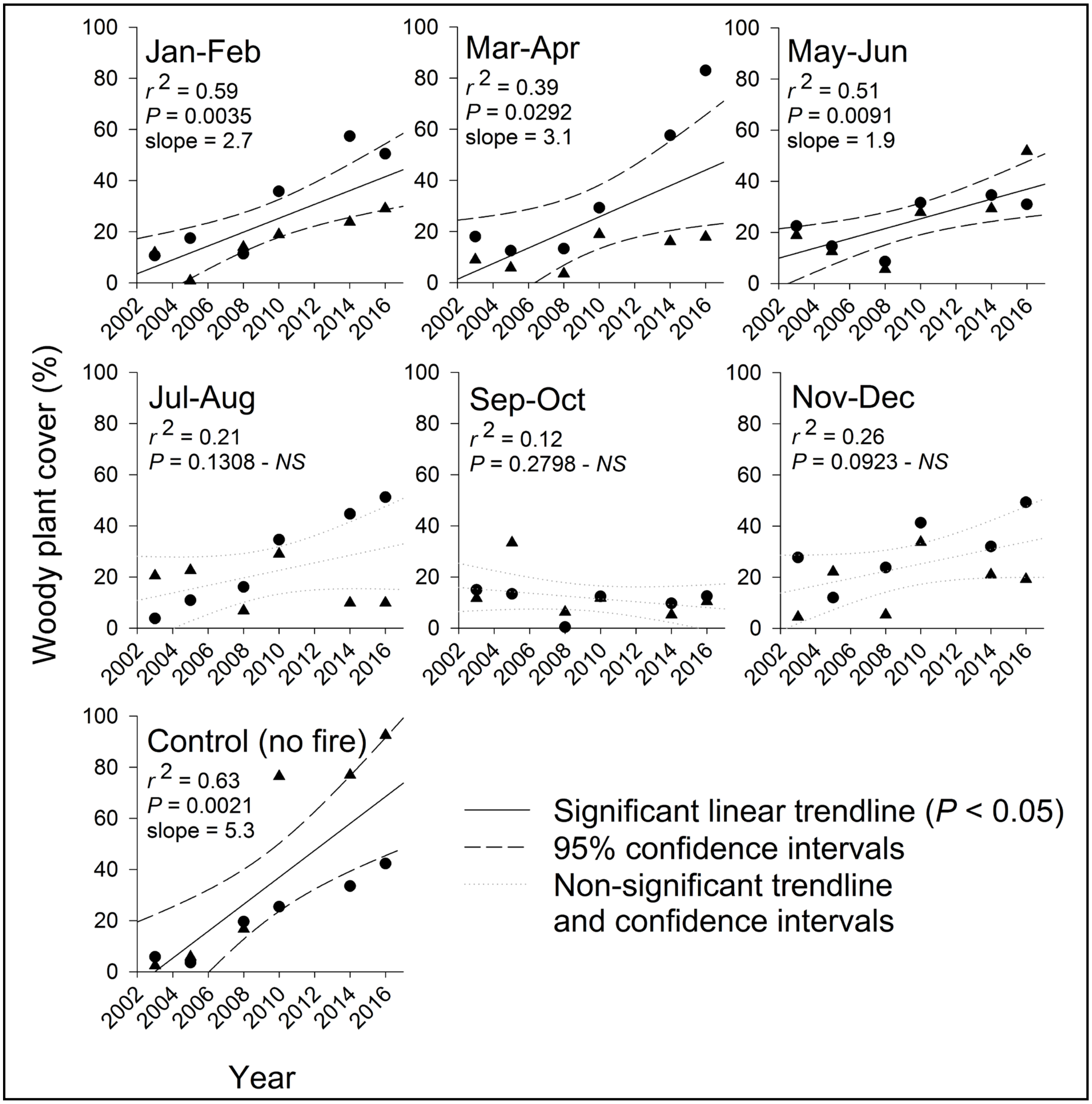

Figure 2. Relationship between woody plant cover and time as influenced by season of burning in native tallgrass prairie west of Stillwater, Oklahoma, USA, from 2004 to 2016. Symbols represent the two spatial replications per treatment. NS = not significant.

ships indicates that each year absolute woody plant canopy cover increases 1.9% to 5.3%. However, for the Jul-Aug, Sep-Oct, and Nov-Dec treatments, this relationship was very poorly correlated and non-significant ($P > 0.05$ and $r^2 \leq 0.26$ in all treatments; Figure 2).

DISCUSSION

The results from our 13-year small plot study indicate that burning later in the year appears to have positive effects on mitigating woody plant encroachment, increasing forb diversity, reducing exotic grasses, and increasing native tallgrass species. Moreover, frequent burning in a very narrow late-winter to early-spring window may not actually reduce or limit woody plant encroachment and can reduce forb diversity. These results challenge the current burning paradigm that late winter and early spring are the most effective times to burn to maintain tallgrass prairie in the Great Plains. Other studies using fire during the spring and summer found that repeated burning during this time did not reduce the cover or frequency of any woody species, just as our study found (Engle and Bidwell 2001, Towne and Kemp 2008). Also, the potential benefit of burning later in the year on flowering forbs and tallgrasses has implications for biodiversity, particularly for pollinators and wildlife habitat (Towne and Kemp 2008, Howe 2011).

Many fire managers are concerned about not having enough burn days during the traditional burn season (Roberts *et al.* 1999, Weir 2011). More burn days gives land managers increased opportunities to safely and effectively conduct prescribed burns. Burning in other seasons will potentially increase the number of available burn days and ultimately increase the potential number of hectares on which fire is restored. This is supported by historic accounts of Native Americans burning in the fall (Stewart 2002). In the oak regions that border the southern Great Plains, timber was historically, and likely more effectively, burned following leaf fall (Stewart 2002, Weir and Limb 2013). Finally, Stambaugh *et al.* (2009) reported that 97% of the fire scars from 1712 to 2006 occurred from September to March in southwest Oklahoma.

Our 13-year case study demonstrates that conducting burns outside of the traditional late-winter to early-spring paradigm is not detrimental and can even be valuable to the overall plant community. Along with these ecological benefits, burning year around can increase the number of burn days, allowing for more burns to be conducted. Spreading the burn season out can also reduce smoke impacts to urban areas that are caused by only burning during one time of the year. This study suggests that land managers, policy makers, and researchers should all consider the benefits of burning outside of the traditional burn season window.

ACKNOWLEDGEMENTS

Appreciation is extended to staff and students who assisted with burning, and also for the support from the Oklahoma Agricultural Experiment Station and Cooperative Extension Service.

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