Effects of Prescribed Fire on Soil Carbon Pools and Nutrient Flux in Oak Woodlands of the Missouri Ozark Highlands

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Introduction

- Prescribed fire is commonly used as a tool in the Ozark Highlands to meet a variety of forest management objectives, including the restoration and maintenance of Oak (*Quercus* spp.) woodlands.
- Forest productivity relies heavily on nutrient cycling associated with forest floor and soil organic matter decomposition.
- Decreases in soil quality from disturbance could adversely impact forest productivity; thus, it is important to evaluate the sustainability of prescribed fire use.
- Few studies have measured the effects of fire on soil physical and chemical properties in this region (Ponder et al., 2009, Rhoades et al., 2004).
- Commonly observed after a fire event are changes in soil organic carbon, nitrogen, nutrient flux (Certini, 2005) and changes in soil aggregates (Mataix-Solera et al., 2011). These potential changes are of concern for low nutrient status forest soils in the Ozark Highlands.
- Also uncertain is the minimal fire-free period required for soil quality to return to pre-burn levels.

Objectives

- To quantify changes in soil carbon stocks and pools, nutrient concentrations, soil pH, and aggregate size distribution over time, and evaluate the time required for soil properties to return to pre-burn levels.
- To monitor nutrient flux and potential nutrient loss through the soil profile, and identify the time required for available nutrient concentrations to return to pre-burn levels.

Experimental Design and Site Description

- **Joint Fire Science Project (JFSP)** study sites are located in southeast Missouri and are managed by the Missouri Department of Conservation.

Timeline:

2002 - JFSP study initiated (no fire for prior 30 years)

2003 - First prescribed burn

2005 - Second prescribed burn

2015 - Third prescribed burn

- In addition to the original **Burn (B)** and **Control (C)** sites, the current study initiated **New Burn (NB)** sites on exposed slopes. These NB sites were burned in 2015 for the first time in recent history.
- Each treatment unit is approximately 2 ha each.
- Soils at the study sites are **Ultisols** and **Alfisols** and contain large quantities of coarse fragments (Table 1) and reduced nutrient content (Meinert, 1997, Nigh and Schroeder, 2002).

Table 1. Soil texture classes, clay and sand content, percent coarse fragments (v/v), and bulk density of the fine soil fraction (ρ_f) at three depths for each treatment.

Treatment	Depth (cm)	Texture	Clay (g/kg)	Sand (g/kg)	% coarse (v/v) (avg. ± s.d.)	ρ_f (g cm^{-3}) (avg. ± s.d.)
	0-10	Silt Loam	7.9	34.0	25.2 ± 6.0	0.83 ± 0.28
Control	10-20	Silt Loam	8.0	31.0	22.4 ± 9.7	1.05 ± 0.30
	20-30	Silt Loam	9.4	28.9	36.9 ± 11.4	1.34 ± 0.43
	0-10	Silt Loam	9.2	36.0	33.4 ± 8.5	0.78 ± 0.14
Burn	10-20	Silt Loam	9.8	33.2	16.1 ± 4.9	0.82 ± 0.18
	20-30	Silt Loam	11.1	33.4	31.8 ± 10.6	1.83 ± 0.39
	0-10	Silt Loam	8.1	29.5	33.4 ± 10.8	0.80 ± 0.17
New Burn	10-20	Silt Loam	8.8	27.0	13.53 ± 2.5	0.92 ± 0.25
	20-30	Silt Loam	9.7	25.8	26.4 ± 3.3	1.78 ± 0.29

Figure 2. Photos and illustrations of the cation and anion PRS™ probes (Western Ag. Innovations Inc., Saskatoon, SK, Canada) used for *in situ* monitoring of soil nutrient flux.

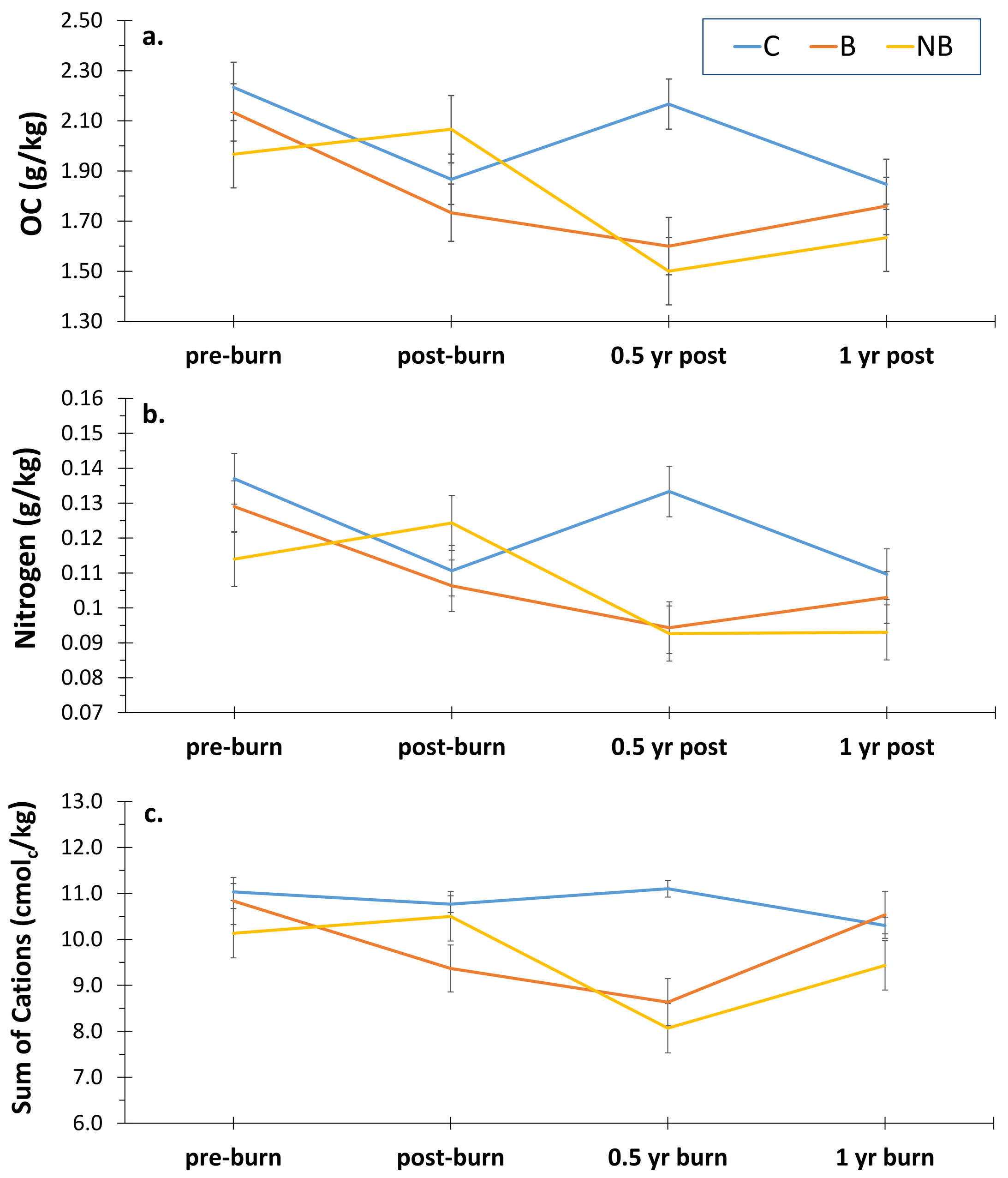

Figure 1. Graphs depicting the change in (a) organic carbon (OC), (b) nitrogen, and (c) sum of cations between bulk soil samples collected pre-burn, post-burn, 0.5 yr. post-burn, and 1 yr. post-burn at the 0-10 cm depth on control sites (C), sites burned multiple times in recent history (B), and sites that were burned for the first time in recent history (NB). Error bars represent the standard error of the means.

Table 2. Table of p-values (n=36, df = 3,18) comparing three treatments (trt) over four sampling events (time) and the treatment by time interaction (n=36, df = 6,18)) in the bulk soil at the 0-10 cm depth. P-values in bold denote statistically significant effects at α = 0.05.

Source	Analyte ------ p-values ----- Carbon (g/kg)	Nitrogen (g/kg)	pH_{H2O}	Sum Cations (cmolc/kg)
trt	0.7659	0.7176	0.6964	0.3608
time	**<.0001**	**0.0291**	**0.0064**	**0.0211**
trt*time	**0.0338**	0.0558	0.5122	**0.0419**

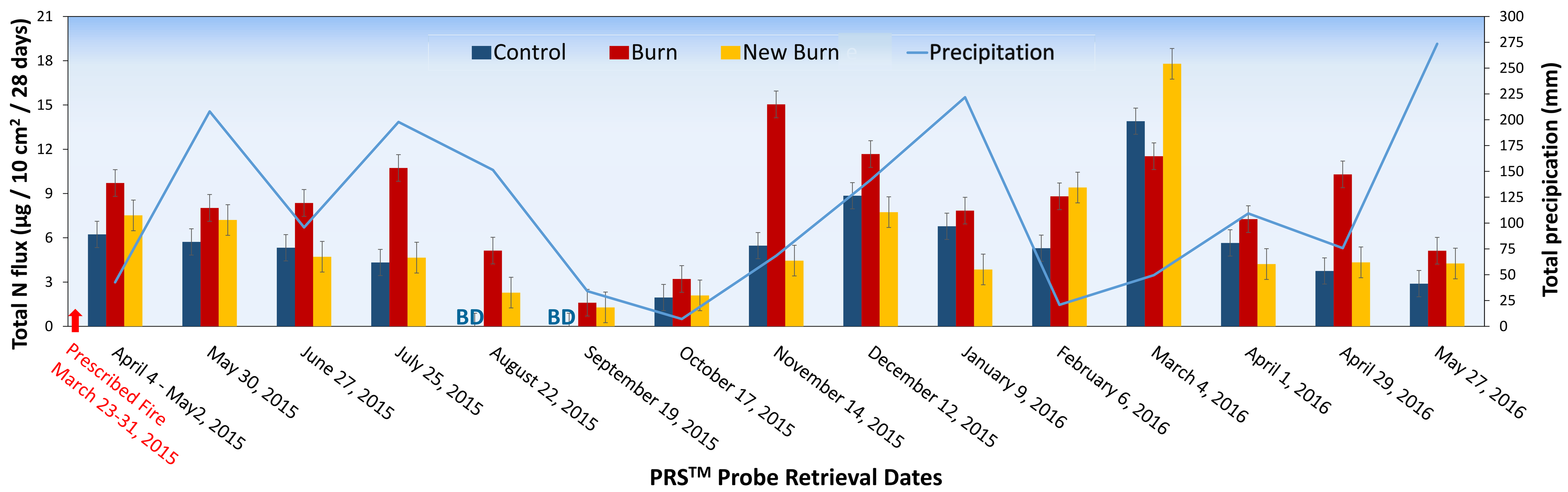

Figure 3. Graph depicting the total nitrogen (NO_3^- and NH_4^+) flux in soil solution for the 0-10 cm depth at control sites (Control), sites burned multiple times in recent history (Burn), and sites that were burned for the first time in recent history (New Burn). Post-burn sampling with PRS™ probes (Western Ag. Innovations Inc., Saskatoon, SK, Canada) began April 4, 2015 and is continuous at four week intervals. Error bars represent 95% confidence intervals. Total precipitation corresponds with each burial period. BD = Below detection levels

Sampling and Analyses

Bulk soil sampling and analyses:

- Bulk soil samples were collected pre-burn (Jan 2015), directly post-burn (April 2015), 0.5 yr. post-burn (Oct 2016), and 1 yr. post-burn (April 2016) at **0-10 cm, 0-20 cm, and 20-30 cm depths**. Sampling at 6 month intervals will conclude with a final collection at 2 years post-burn.
- Soils were analyzed for **particle size determination** and a suite of **chemical properties** using standard methods of analysis (Burt, 2004) (Fig. 1, Table 1, Table 2).
- **Bulk density** (**ρ_d**) was measured at three depths using the foam method (Muller and Hamilton, 1992) (Table 1).
- Analyses in progress include: **Total organic carbon** (by combustion); **active carbon** (Lucas and Weil, 2012); **aggregate size distribution** (Elliot, 1986).

Soil solution:

- *In situ* monitoring of **nutrient flux** using **Plant Root Simulator probes (PRS™;** Western Ag. Innovations Inc., Saskatoon, SK, Canada) at **10 and 30 cm depths** at four week intervals (Fig. 2, Fig. 3).
- Monitoring with PRS™ probes was initiated 1 yr. pre-burn and will conclude 2 yrs. post-burn.

Statistical Analysis:

- **GLIMMIX procedure** (SAS version 9.4, SAS institute, Inc., Cary, NC) (Table 2)
- Result means are compared using Tukey's honestly significant difference (HSD) test at α = 0.05.

Observations

Bulk soil analyses at 0-10 cm (Fig. 1):

- The **avg. OC content** measured immediately post-burn in Control sites was 14% less than the pre-burn values (p=0.03); however, the avg. OC content measured in Burn and New Burn units was 24% and 25% less at 0.5 yr. post-burn when compared to pre-burn measurements (p= <0.001 and 0.003, respectively).
- The **avg. N content** measured in Burn and Control units was 18% and 19% less immediately post-burn than pre-burn (p= 0.02 and 0.01, respectively). New Burn plots showed significantly less avg. N content at 1 yr. post-burn relative to the immediate post-burn measurements (p=0.04).
- The **avg. sum of cations** measured immediately post-burn and 0.5 yr. post-burn in Burn plots was 14% and 20% less than the pre-burn average (p= 0.03 and 0.01, respectively). However, at 1 yr. post-burn, the avg. sum of cations significantly returned to pre-burn levels (p=0.72). The avg. sum of cations within New Burn sites followed similar trends as Burn sites.

Acknowledgements

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