EFFECTS OF WILDFIRES AND LIMING OF PINE-OAK-HEATH COMMUNITIES IN THE LINVILLE GORGE WILDERNESS, WESTERN NORTH CAROLINA

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ABSTRACT

Linville Gorge Wilderness (LGW) is a Class I area in the southern Appalachian Mountains, western North Carolina. Over the last 150 years, LGW has been subject to several wildfires, varying in intensity and extent (Newell and Peet 1995). In November 2000, a wildfire burned 4000 ha in the wilderness; the fire ranged in severity across the northern portion of the wilderness from low severity in coves to high severity along ridges and bluffs (Reilly and others 2006). In May 2007, the Pinnacle wildfire burned ca. 2000 ha in the southern portion of the wilderness. A large portion of the Pinnacle fire overlapped the area previously burned in 2000, resulting in much of the central section of LGW being burned twice in less than 7 years. In addition, dolomitic lime was aerially applied at a rate of 1120 kg ha^{-1} on the most severely burned area. We hypothesized that liming the most severely burned area would accelerate the restoration of acidic, nutrient depleted soils by adding basic cations, balancing soil pH, reducing soil and soil solution Al, and subsequently increase ecosystem productivity. We sampled vegetation (composition, biomass, and foliar nutrients) and soil nutrients in five treatment areas in LGW over a 2-year period following the most recent wildfire. The treatment areas were: severely burned twice (2000 and 2007) plus dolomitic lime application (2xSBL); moderately burned twice plus lime (2xMBL); severely burned twice, no lime (2xSB); moderately burned once (2000), no lime (1xMB); and an unburned and unlimed reference area (REF).

All wildfire burned sites experienced overstory mortality (>300 stems ha^{-1}). There were no live overstory trees on 2xSBL, and 2xSB had a larger number of dead trees than all other sites. The large number of dead pines on all sites, including the reference, was due in large part to a southern pine beetle (*Dendroctonus frontalis* Zimm.) outbreak in 1999-2001. The three areas impacted by the recent wildfire had little to no live pine in the overstory. Overstory biomass was lower on the severely burned areas (2xSBL and 2xSB) than the other treatments, with no significant change between 2008 and 2009 (Fig. 1). By 2009, understory density was higher on 2xSBL than the other treatments (Fig. 2a), with higher numbers of tree species (Fig. 2b). We found no differences in shrub density among burned treatments, and only 2xSB had higher shrub density than REF (Fig. 2c). As expected, ericaceous (heath) species sprouted after fire, and their density increased between 2008 and 2009 for all recently burned treatments.

We found no differences in foliar nitrogen (N) concentration among treatments for either evergreen or deciduous species (Table 1). Evergreen foliar calcium (Ca) was greater on 2xMBL and REF than the severely burned sites (2xSBL and 2xSB); whereas deciduous foliar Ca and phosphorus (P) were greater on 2xMBL than 2xSBL, 1xMB and REF (Table 1).

With few exceptions, we found significant date, treatment, date x treatment interaction effects for soil exchangeable cations for both shallow (0-10 cm

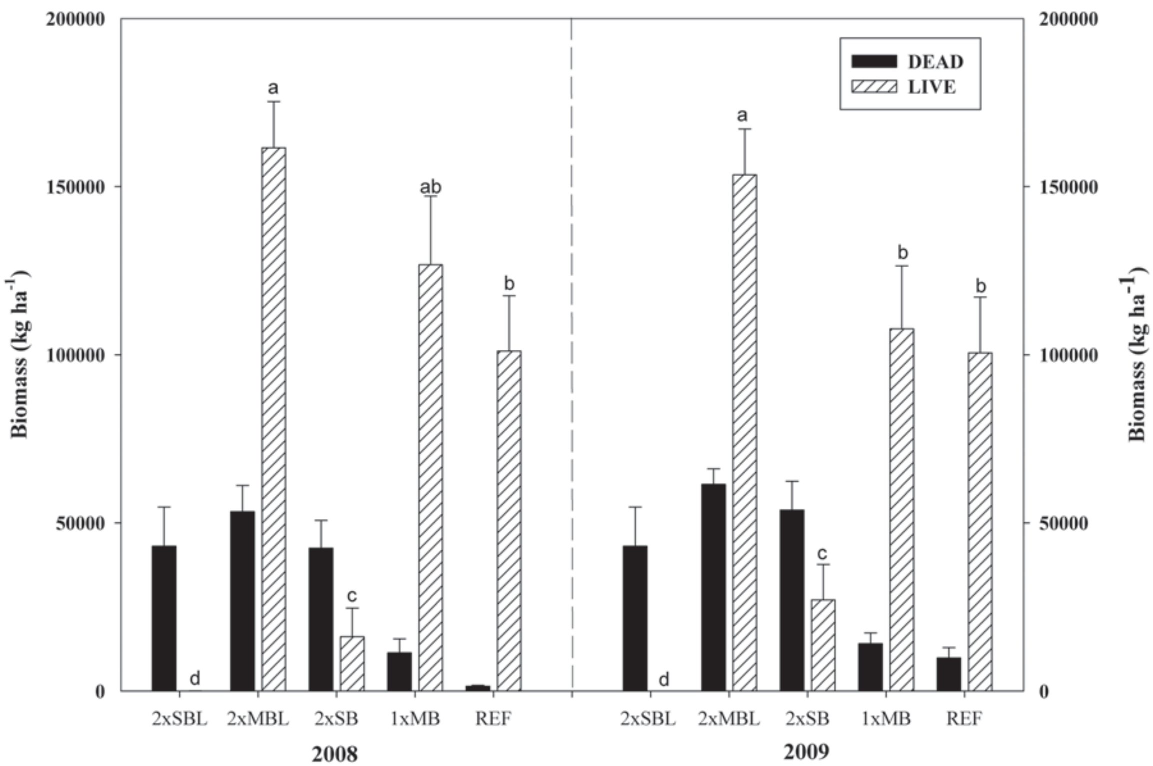

Figure 1.—Overstory (≥ 5.0 cm diameter at breast height [d.b.h.]) biomass with standard error bars of live and standing dead trees for the five treatment areas the first (2008) and second (2009) growing seasons after wildfire in Linville Gorge Wilderness, western North Carolina. The treatments were severely burned twice (2000 & 2007) plus dolomitic lime application (2xSBL); moderately burned twice with lime (2xMBL); severely burned twice, no lime (2xSB); moderately burned once (2002), no lime (1xMB); and an unburned and unlimed reference area (REF). Bars with different letters denote significant (α≤0.05) differences among treatments within a year.

depth) and deep (10-30 cm depth) soils (Table 2). Soil exchangeable Ca^{2+} had a significant treatment effect, but no date or date x treatment interaction effects (Table 2). Soil Ca^{2+} was greater on 2xMBL and 2xSBL than 2xSB, 1xMB, and REF for shallow soil, and greater on 2xMBL than 2xSBL for deep soil (Table 2). Soil extractable aluminum (Al^{3+}) was less on 2xSBL than 2xSB, 1xMB, and REF, which resulted in higher Ca/Al ratios on 2xSBL and 2xMBL than 2xSB, 1xMB, and REF.

Wildfires are landscape-scale disturbances and have the potential to significantly impact biogeochemical processes by altering pools and fluxes of carbon and nutrients (Debano and others 1998, Knoepp and others 2005). The magnitude and duration of these responses depends on the interactions among preburn conditions, burn severity, postfire precipitation regime, topography, soil characteristics, and vegetative recovery rate (Robichaud 2005). We expected that the effects of the most recent wildfire and lime application would be observed over a 2-year period, possibly longer, as Ca and Mg leach into the soil where it can be taken up by the recovering vegetation (Elliott and others 2002, Knoepp and Swank 1997). In our study, the moderately burned site with lime application had the highest soil and foliar Ca suggesting that the lime application was subsequently taken up by vegetation.

In contrast, the severely burned site with lime had greater soil Ca but lower foliar Ca than the moderately burned site even though both sites received lime application. Soil Al was lowest on 2xSBL, suggesting that the lime addition did improve the soil Ca/Al ratio since it was higher on this site than the others. Al^{3+} increased and Ca/Al ratio decreased over time for both the shallow and deep soil depths (Table 2). Thus, the lime addition did improve the soil Ca/Al ratio, but the response was transitory. Soil Ca/Al ratios remain well below the toxicity threshold <1.0 (Cronon and Grigal 1995) on all treatment areas in LGW.

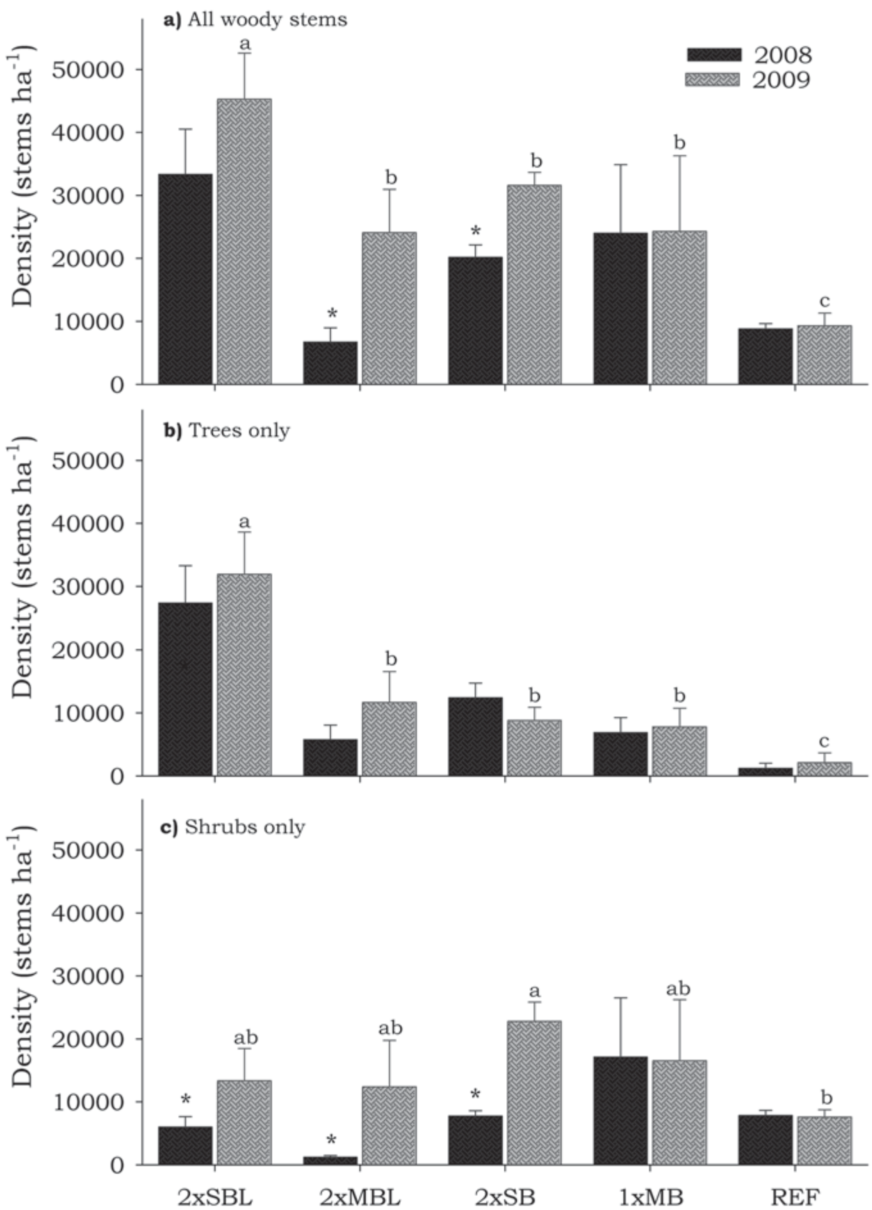

Figure 2.—Understory (shrubs and trees <5.0 cm d.b.h.) density with standard error bars: a) all woody species, b) trees only, and c)shrubs only for the five treatment areas the first (2008) and second (2009) growing seasons after wildfire in Linville Gorge Wilderness, western North Carolina. Treatment labels are the same as in Figure 1. Bars with different letters denote significant (α≤0.05) differences among treatments within a year. Asterisk denotes significant (α≤0.05) difference between years within a treatment.

Table 1.—Nutrient concentrations (with standard errors in parenthesis) of evergreen and deciduous leaf tissue for the five treatment areas: severely burned twice (2002 and 2007) plus dolomitic lime application (2xSBL); moderately burned twice plus lime (2xMBL); severely burned twice, no lime (2xSB); moderately burned once (2002), no lime (1xMB); and an unburned and unlimed reference area (REF).

	2xSBL	2xMBL	2xSB	1xMB	REF
N (percent)					
Evergreen	0.779 (0.032)	0.961 (0.021)	0.877 (0.032)	0.961 (0.064)	0.923 (0.052)
Deciduous	1.696 (0.067)	1.775 (0.132)	1.553 (0.059)	1.639 (0.057)	1.712 (0.042)
Ca ($\mu g\ g^{-1}$)					
Evergreen	6687 b (373)	10214 a (1001)	7180 b (313)	8878 ab (646)	10163 a (506)
Deciduous	4927 b (470)	6697 a (158)	5503 ab (560)	5164 b (510)	5014 b (556)
P ($\mu g\ g^{-1}$)					
Evergreen	736 (33)	780 (18)	707 (28)	670 (48)	739 (68)
Deciduous	1506 ab (36)	1612 a (53)	1445 ab (42)	1249 c (29)	1357 bc (24)
Al ($\mu g\ g^{-1}$)					
Evergreen	52 (6)	59 (5)	47 (4)	169 (65)	193 (92)
Deciduous	91 b (30)	104 ab (21)	138 ab (9)	166 a (28)	84 b (11)

Notes: Values followed by different letters are significantly different ($p < 0.05$) among treatments (SAS 2002-2003).

Table 2.—Mean soil chemistry (with standard errors in parenthesis) for the five treatment areas in the Linville Gorge Wilderness, western North Carolina, USA. Treatment labels are the same as in Table 1. All values are in $cmol_c\ kg^{-1}$ except for Ca/Al molar ratio.

	2xSBL	2xMBL	2xSB	1xMB	REF
0-10 cm soil depth					
Nitrogen	0.107 b (0.021)	0.164 a (0.011)	0.143 ab (0.012)	0.145 ab (0.005)	0.139 ab (0.005)
NO_3–N	0.0009 (0.0004)	0.0003 (0.0003)	ND†	ND	ND
NH_{4+}-N	0.118 (0.021)	0.105 (0.022)	0.070 (0.005)	0.104 (0.011)	0.072 (0.005)
HPO_4^{2-}	0.236 ab (0.009)	0.250 a (0.015)	0.195 b (0.008)	0.241 ab (0.014)	0.251 a (0.010)
Ca^{2+}	7.322 ab (0.502)	9.616 a (1.662)	1.854 c (0.363)	4.009 b (0.630)	0.626 c (0.059)
Al^{3+}	76.36 c (6.234)	167.55 a (8.232)	124.00 b (6.404)	110.09 b (4.752)	109.40 b (7.700)
Ca/Al	0.102 a (0.006)	0.072 ab (0.017)	0.015 c (0.003)	0.037 bc (0.006)	0.006 c (0.001)
10-30 cm soil depth					
Nitrogen	0.046 b (0.009)	0.070 a (0.004)	0.078 a (0.006)	0.062 ab (0.003)	0.060 ab (0.003)
NO_3–N	ND	ND	ND	ND	ND
NH_{4+}-N	0.040 b (0.005)	0.044 b (0.003)	0.052 a (0.003)	0.053 a (0.003)	0.038 b (0.002)
HPO_4^{2-}	0.111 b (0.013)	0.142 ab (0.005)	0.143ab (0.008)	0.136 ab (0.009)	0.162 a (0.014)
Ca^{2+}	0.956 b (0.038)	1.519 a (0.251)	0.574 bc (0.146)	0.606 bc (0.063)	0.218 c (0.015)
Al^{3+}	57.83 c (4.982)	116.57 a (4.868)	87.55 b (6.530)	76.42 bc (3.719)	81.11 b (2.747)
Ca/Al	0.018 a (0.001)	0.016 a (0.003)	0.006 bc (0.001)	0.009 b (0.001)	0.003 c (0.0002)

†ND = samples below the detection limits of our methods. Values within a soil depth followed by different letters are significantly different ($p < 0.05$) among sites (SAS 2002-2003). Values were averaged across time; and then, mean values and standard errors were based on the five plots per treatment area ($n = 5$).

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