1B.3 CHANGES IN NUTRIENTS AND BIOMASS IMMEDIATELY AFTER A LOW-INTENSITY PRESCRIBED FIRE IN AN UNEVEN-AGED LOBLOLLY PINE STAND

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1. INTRODUCTION

Dormant season, low-intensity fires have been applied at an irregular interval (1-4 years) for the past 20 years within three uneven-aged loblolly pine (*Pinus taeda* L.) stands on the Crossett Experimental Forest in southeastern Arkansas. These stands have been used to quantify the impacts of fire interval on loblolly pine regeneration (Cain and Shelton 2002) and alteration of nutrient regimes by repeated prescribed fires. In this study, both nutrients and mass of the forest floor and understory vegetation were measured before and immediately after a prescribed fire conducted on January 4, 2002.

2. METHODS

The study was located in the West Gulf Coastal Plain of southeastern Arkansas. Site index for loblolly pine is 26.5 m at 50 years, which is above average when compared to other areas across the southern US (Shultz 1997). One- ha plots within three stands were used for sample collection and measurement. Each 1-ha plot contained a 0.35-ha isolation strip to decrease influences from outside the plot (Figure 1).

Samples of the forest floor (O_i and O_{e+a}) and understory vegetation (< 1.5 cm in groundline diameter) were collected before and after the prescribed fire. A total of 30 understory and forest floor samples were collected on systematically spaced subplots within the 0.65-ha plots. Subplot size was respectively 0.1 m^2 and 1.0 m^2 for the forest floor and understory vegetation (Figure 1).
Forest floor and understory samples along each row within a plot were composited for further processing. Samples were dried, weighed, ground to pass a 1-mm sieve, and analyzed for macronutrient concentrations. Paired t-tests were used to test for significant differences (α=0.05) between pre-fire and post-fire mass, nutrient concentrations, and nutrient contents.

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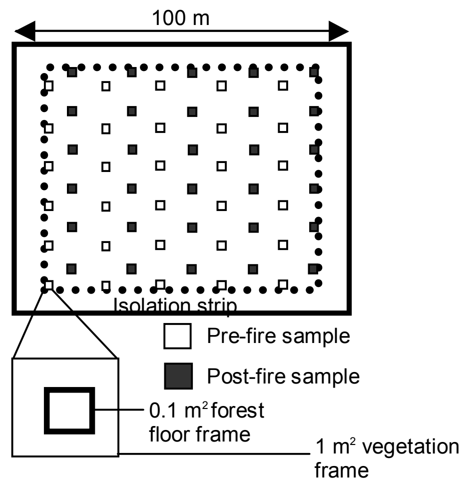

Figure 1. Pre- and post-fire plot location in each of the three stands in the Crossett Experimental Forest in southeastern Arkansas.

3. FIRE AND WEATHER ATTRIBUTES

The prescribed fire for all the stands in this investigation was applied and completed on January 4, 2002. Ignition times were 1100 to 1130 for stand one, 1200 to 1230 for stand two, and 1300 to 1315 for stand three. All 1-ha plots were burned using a ring ignition pattern that started with a backing fire, followed by two flanking fires, and ending with a head fire.

Both the weather and available fuel conditions accounted for low intensity fires. Weather conditions during burning included an ambient air temperature that increased from 4.4 °C at 1100 to a high of 8.3 °C at 1330. Relative humidity concurrently decreased from 35 to 25% during this same period. Wind speed averaged 7 kph, with gusts between 12-17 kph prevailing from the southeast. Average fuel loads were 2.2 Mg ha^{-1} across the plots. Moisture content of the dead understory vegetation and the upper forest floor layer averaged 25% across the plots. Five cm of rain fell within 2 days after the prescribed fire. Post-fire samples were collected between January 7-21, 2003.

4. CHANGES IN MASS POST-FIRE

A significant loss of mass occurred in both the forest floor and understory vegetation as a result of the fire. The greatest losses occurred in the forest floor. Average post-fire organic matter content of the forest floor was 55% less than pre-fire values. The mean mass of forest floor organic matter decreased from 1,060 g m^{-2} prior to the fire to 473 g m^{-2} after the fire (Figure 2). The mass of understory vegetation also decreased. Mean mass of the understory vegetation was reduced from 242 g m^{-2} to 170 g m^{-2}, which was a 30% decline. A total of 668 g m^{-2} was lost from the sum of the two components due to the fire; this was a 50% loss in mass from these combined components.

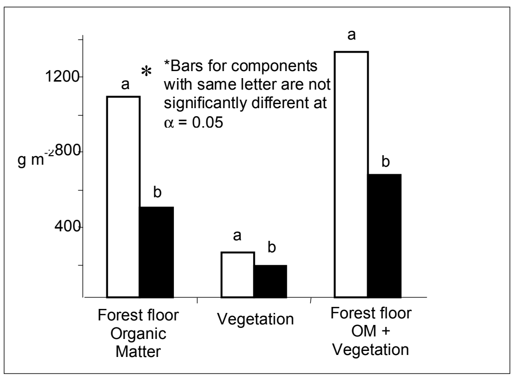

Figure 2. Mass of the forest floor, understory vegetation, and combined components prior to and after a low-intensity prescribed fire in three uneven-aged loblolly pine stands in Crossett Experimental Forest in southeastern Arkansas. White and black bars indicate pre- and post-fire, respectively.

5. CHANGES IN NUTRIENTS POST-FIRE

Concentrations for all nutrients were higher in the forest floor than the understory vegetation. For the forest floor, concentrations for N, P, Ca, Mg, and S significantly increased, while K significantly decreased. There was no significant change in C.

Proportional increases in nutrient concentrations after burning ranked in the following order: P>Ca>Mg>N>S.

The fire significantly increased understory vegetation concentration of C but decreased concentration of N, K, Mg, and S. Concentrations of P and Ca did not significantly change. The decrease in concentration of nutrients of the understory vegetation were ranked as follows: K>S>Mg≈N.

Nutrient contents of both the forest floor and understory were decreased by the fire (Table 1). This reduction in nutrient content was mostly attributed to the loss of forest floor and understory mass, since concentrations generally increased in the forest floor and the decreases within the understory were minimal. The losses of K from the forest floor and the understory vegetation were greater than any other nutrient. A total of 1.46 g m^{-2} or 61% of the K in these two components was lost. P and Ca had the lowest losses, which ranged between 25-29% of pre-fire amounts.

Table 1. Nutrient contents in the forest floor and understory vegetation prior to and after the prescribed fires in three uneven-aged loblolly pine stands on the Crossett Experimental Forest in southeastern Arkansas.

	Nutrient	Collection Period	Mean (g m^{-2})	Standard Deviation	P-value
Forest Floor	C	Pre	538	161	<0.001
		Post	247	75	
	N	Pre	7.89	2.93	0.004
		Post	5.07	1.42	
	P	Pre	0.41	0.16	0.030
		Post	0.31	0.08	
	K	Pre	1.08	0.34	<0.001
		Post	0.32	0.10	
	Ca	Pre	7.12	2.33	0.005
		Post	5.04	1.12	
	Mg	Pre	1.13	0.34	0.001
		Post	0.73	0.16	
	S	Pre	0.84	0.29	0.001
		Post	0.49	0.13	
Understory Vegetation	C	Pre	105	37	0.003
		Post	76	17	
	N	Pre	1.43	0.68	0.001
		Post	0.80	0.20	
	P	Pre	0.11	0.04	0.003
		Post	0.08	0.02	
	K	Pre	1.30	0.44	<0.001
		Post	0.60	0.18	
	Ca	Pre	1.31	0.53	0.025
		Post	0.97	0.28	
	Mg	Pre	0.25	0.10	<0.001
		Post	0.13	0.04	
	S	Pre	0.18	0.07	<0.001
		Post	0.09	0.03	

6. DISCUSSION

A total of 587 g m^{-2} of forest floor organic matter was lost due to the fire. This loss is similar to losses found by other studies of low-intensity fires in the southeastern region and stands with low fuel loadings (Binkley 1986, Hough 1981, Lewis 1974). Estimated forest floor losses from these studies were respectively 650 g m^{-2}, 651 g m^{-2}, and 597 g m^{-2}. The similarity in loss of forest floor from all of these studies illustrates the importance of weather, fuel conditions, and fuel loading on fire intensity and fuel consumption (DeBano and others 1998).

In our study, mass losses from the forest floor were greater than understory vegetation losses. Similar results have been reported by other researchers (Hough 1981). This relationship is directly related to the amount of mass available for burning during the dormant season (Pyne and others 1996). While plant and leaf senescence from the understory and overstory during the dormant season adds material to the forest floor, the mass of the understory vegetation declines. In addition, the horizontal arrangement of the leaves, needles, and twigs in the forest floor, compared to the vertical arrangement of understory vegetation, provides a greater surface area for ignition (DeBano and others 1998).

Observed changes in forest floor nutrient concentrations in our study were similar to those reported by Lewis (1974) in loblolly-longleaf pine stands in South Carolina. The observed changes of K in our study were almost identical to those observed by Lewis (1974). However, Ca and Mg changes were substantially different; Lewis (1974) observed an 83 and 81% reduction in Ca and Mg, respectively, while both Ca and Mg increased in our study. Reasons for these different results may involve the method in which nutrient concentration changes were measured or differences in nutrient levels of forest floor or understory vegetation.

Results from this study show that the loss of forest floor C content is proportionately related to the quantity of mass loss that occurs with the fire. This is similar to the observations by Mroz and others (1980) and Hough (1981). Although Hough (1981) also reported a strong relationship between the loss of forest floor N content and mass, this study failed to demonstrate a similar relationship.

Losses in nutrient content from this study were within the lower range of losses reported by Allen (1964), Christensen (1977), Grier (1975), Harwood and Jackson (1975), Wells and others (1979). While estimates of N loss from the forest floor reported by these researchers ranged from 2 to 90 g m^{-2}, losses in N from our study averaged 3.4 g m^{-2} for the forest floor and understory vegetation combined. Losses in Ca from our study for these combined components averaged 2.4 g m^{-2} and were at the lower end of the range of Ca losses (0.4-10.0 g^{2}) reported in the literature. Losses in P after burning for this investigation were again low (0.10 g m^{-2}) when compared with these previously mentioned studies (0.10 – 10 g m^{-2}).

The greatest proportional losses for the forest floor and understory occurred for K. Interestingly, average loss of K from the forest floor in our study was 0.76 g m^{-2}, which is within the lower end of K losses (0.4-28.2 g m^{-2}) reported by the previously mentioned studies in the southern US.

One possible reason that low losses of nutrients occurred in these uneven-aged was the high moisture contents of the forest floor and understory vegetation as well as the extremely low fuel loading. Although mass losses were similar to Hough (1981) and Binkley (1986), nutrient losses may have been lower due to initial nutrient content.

7. CONCLUSIONS

The immediate effects of prescribed burning in uneven-aged pine stands are the reduction of forest floor and understory vegetation mass as well as the redistribution of nutrients near the soil surface. Nutrient concentrations generally increased in the forest floor while concentrations in understory vegetation decreased. The combined changes in mass and concentrations resulted in a consistent loss in nutrient content from the forest floor and understory vegetation. However, these losses were at the lower end of the range of losses reported by other studies in the southern US.

Comparison of nutrient concentrations in live pine foliage and mineral soils have indicated that 20 years of prescribed fire applied at a 1-4 year interval did not have a deleterious effect on the availability of soil nutrients or nutrient cycling. The minimal losses in nutrients reported from the fire in 2002 help to explain why nutrient regimes within these stands have not been significantly altered. Although burning does not appear to reduce nutrient availability within these stands, fire must be applied judiciously in uneven-aged pine stands to maintain adequate pine regeneration. Burning creates favorable seedbeds for loblolly pine regeneration and reduces competing non-pine vegetation. However, burning will also kill pine regeneration before it reaches fire-tolerant size classes. Thus, fire may be used as a remedial silvicultural treatment when no regeneration is present. Once adequate pine regeneration becomes established, burning should be discontinued until the regeneration reaches fire-tolerant sizes.

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