IMPACTS OF LONG-TERM PRESCRIBED FIRE ON DECOMPOSITION AND LITTER QUALITY IN UNEVEN-AGED LOBLOLLY PINE STANDS

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Abstract—Although fire has long been an important forest management tool in the southern United States, little is known concerning the effects of long-term fire use on nutrient cycling and decomposition. To better understand the effects of fire on these processes, decomposition rates, and foliage litter quality were quantified in a study investigating uneven-aged loblolly pine (*Pinus taeda* L.) management and prescribed fire in the Upper Coastal Plain of southern Arkansas. A portion of the study area had been burned on a 2 to 3-year cycle since 1981 while another portion of the study area had not been burned. Decomposition rates were determined by placing litterfall from each area into litterbags, installing these bags in the field within each area, and monitoring the litterfall weight loss over a 10-month period. Decomposition potential was determined using a cotton strip assay method. Foliar litter quality was evaluated by determining C, N, P, K, Mg, and Ca concentrations for samples collected from both treatments. Decomposition rate and potential were not significantly different in the burned and unburned areas. However, burning significantly affected foliar litter quality by increasing K, Ca, and Mg concentrations, but decreasing C. Decomposition rates and/or mass loss were significantly higher for foliar litterfall collected from the burned than unburned areas 0.5 months following placement of litterbags in the field.

INTRODUCTION

In the southern pine belt of the United States, the dependence of the pine forest upon fire is well documented (Barnes and others 1998, Wade and Lunsford 1989). Although fire has been considered a damaging agent with few benefits in the past, it is now apparent that fire can be important in the maintenance and establishment of forests (Barnes and others 1998). Today, the use of prescribed fire has become a well-accepted silvicultural practice. Prescribed fire is often used to reduce fuels; prepare sites for regeneration; dispose of logging debris; improve wildlife habitat; manage for competing vegetation and disease; improve aesthetics, access, and grazing; perpetuate fire dependent species; and to manage for endangered and other species (Wade and Lunsford 1989). Fuel burned by prescribed fires may include dead trees, logs, slash, needles, leaves, and other litter (McCullough and others 1998).

The effects of fire on forest ecosystems are complex and can be beneficial or detrimental depending on fire intensity, stand structure, and community composition (Barnes and others 1998). Positive benefits of fire can include increased nutrient uptake, accelerated tree growth, enhanced nutrient cycling (Clinton and others 1996), and improved nutrient availability (Shoch and Binkley 1986, Wade and Lunsford 1989). Negative effects of prescribed fire may include damage to the forest floor and organic matter, nutrient loss, soil erosion, decreased soil aeration and penetrability, and vegetation injury or mortality (Wade and Lunsford 1989).

Because prescribed fire is an important part of southern pine management, it is essential to determine how frequent application of fire over long periods of time alters forest ecosystem processes. One such process that could be altered by fire is organic matter decomposition. Decomposition and oxidation of litterfall, as well as the subsequent mineralization of nutrients contained in the litterfall, regulate the accumulation of organic matter and account for a substantial amount of the nutrients that are cycled in forest ecosystems (Fogel and Cromak 1977). With this in mind, we superimposed a litter decomposition study within an ongoing investigation of the silvicultural effects of fire in uneven-aged loblolly pine (*Pinus taeda* L.) stands in southeastern Arkansas. The objectives of our study were to determine: (1) if pine foliar litterfall on burned areas decomposes at a different rate than litterfall on unburned areas, (2) if pine foliar litterfall collected from burned areas decomposes at a different rate than litterfall collected from unburned areas, and (3) if decomposition potential is different between burned and unburned areas. These objectives were accomplished by examining pine litterfall decomposition, cotton tensile strength loss, and foliar nutrient contents.

METHODS

Study Area

The study was located in the Crossett Experimental Forest in Ashley County, Arkansas, at 32° 02' N mean latitude and 91° 56' W mean longitude. The study area is 53 m above mean sea level with nearly level topography. Annual precipitation averages 140 cm. Soils are predominantly Bude and Providence silt loams (fine-silty, mixed, thermic, Glossaquic

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and Typic Fragiudalfs, respectively) that have an impervious layer at a depth of 50-100 cm, which impedes internal drainage and root growth (Gill and others 1979). Soil reactivity varies from medium acid to very strongly acid. Site index for loblolly pine is 27 m at age 50 (Cain 1993).

Treatments

Starting in the late 1930's, the study sites were managed using uneven-aged silviculture with single-tree selection and the complete exclusion of fire (Cain 1993). After the late 1960's, no harvesting, burning or vegetative control was performed until 1980. The following treatments were initiated in January of 1981 and consisted of: 1) an unburned control, 2) an irregular winter burn [every 2-3 years], 3) a winter burn every 5 years, and 4) a winter burn every 10 years (Cain and others 1998). The treatments were installed in each of the three 16-ha compartments. Four contiguous 1-ha plots comprised a 4-ha burn treatment in each compartment. Each 1-ha plot had an interior measurement plot of 0.65 ha that was surrounded by a 10-m wide isolation strip. For the purposes of this study, only the unburned control and irregular burn treatments were used. In 1992, the unburned control plots were treated with a broadcast application of Arsenal AC™ herbicide (1.7 kg a.i.) in 113 liters of water/ha using skidders. The most recent burn on the irregular burned treatment was conducted in October 1998.

All measurements occurred in the interior 0.65-ha plot located within a selected 1-ha plot in a treatment. Each of the selected 1-ha plots has been maintained at a residual pine basal area of 14 m^2/ha using single-tree selection on a six year harvesting schedule since 1980. Thus a total of six plots were used in the study, one unburned control and one irregularly burned plot in each of the three compartments. Within each of the measurement plots, three 4 x 4 m subplots were located. Vegetation within each of the 4 x 4 m subplots was trimmed to ground level in three strips (approximately 40 cm wide) for litterbag installation.

Litterbags

The litterbag method (Melillo and others 1982, Lockaby and others 1995) was utilized to measure decomposition rates on both treatments. Each nylon litterbag was 30 cm x 30 cm with a mesh size of 5 mm on the top and 2 mm on the bottom. In the fall of 1999, pine foliar litterfall was collected from all plots within the two treatments. The litter was air dried, mixed by treatment, and stored for later use in litterbags.

One set of litterbags was filled with 20 g of air-dried pine foliar litter collected from the burned treatments and a second set of litterbags was filled with 20 g of air-dried pine foliar litter collected from the unburned control treatment. Litterbags from both sets were placed on the forest floor surface in each of the trimmed strips located in each subplot on February 28, 2000. One litterbag from each set (foliage collected from the unburned and irregular burned treatments) was collected from each subplot after 0.5, 1, 2, 5, 7, and 10 months. Litterbags were transported in plastic bags to the laboratory, where all foreign material was removed. Litter was dried at 70° C for 48 hours and weighed. Loss on ignition from each sample was determined by heating the litter to 375° C for 16 hours. These values were then used to give a corrected (ash free) mass. The corrected mass, which is free from contamination by mineral soil, was used for statistical analysis. In addition, a correction factor was applied to adjust the initial air-dried weight of the litter to an oven-dried basis.

Cotton Strip Assay

A cotton strip assay (Latter and Howson 1977, Latter and Walton 1988, Butterfield 1999) was used to evaluate decomposition potential in the burned and unburned treatments. This technique is useful in assessing decomposition potential because the cloth is a uniform substrate and allows for examination of decomposition potential at different depths. In both April and July of 2000, sets of five 12 x 30 cm sheets of burial cloth manufactured by Shirley Dyeing and Finish Ltd. (Sagar 1988) were buried on each subplot to a depth of 25 cm using methods described by Latter and Howson (1977). After 30 days of incubation, the sheets were removed for analysis. In the laboratory, strips were cut and frayed to a width of 1 cm at each of four depths (3-5, 7-10, 12-15, and 21-24 cm). Tensile string was determined for each strip using a Scanpro Alwetron TH-1 tensile strength tester. Strips were equilibrated in a climate-controlled room at 50 percent relative humidity and 20° C for 2 weeks prior to strength testing. The tensile strengths of strips from incubated sheets were subtracted from the tensile strengths of strips cut from control sheets that had been installed in the soil and immediately removed at the start of each incubation period. The use of the control sheets adjusted for the loss of tensile strength during installation and removal. The difference of these two values divided by the control strip tensile strength gave percent tensile strength loss for the incubated strips. Reduction of tensile strength calculated in this way reflects oxidation of carbon through decomposition.

Litter Quality

Several studies have used litter quality as a variable to assess decomposition rates (Fogel and Cromak 1977, Taylor and others 1989). Initial quality of loblolly pine litterfall was assessed for each treatment. Seven subsamples of the litter collected from each treatment were dried, ground, and analyzed for macronutrient concentrations. Concentrations of P, K, Ca, Mg, and S in the litterfall were determined using inductance coupled plasma (University of Arkansas, Soil Test Laboratory, 1990) after a perchloric acid digestion (Alder and Wilcox 1985). N and C concentrations were determined by combustion using a LECO CN2000 analyzer.

Statistical Design

Corrected mass loss from the litterbags was analyzed using ANOVA with a split-plot through space and time design with compartment as the blocking factor. The cotton strip data were analyzed using ANOVA with a split-split plot design. The litter quality data was analyzed using a paired t-test. All tests were done with a significance level at a = 0.05.

RESULTS AND DISCUSSION

After 10 months, there was no statistical evidence that 20 years of prescribed fires had significantly altered decomposition rates at these sites (figure 1). The corrected mass loss of the pine litterfall did not significantly differ between the

Table 1—Initial nutrient concentration of foliar litter collected from irregular burned and unburned treatments in three uneven-aged loblolly pine stands in Crossett, AR

Nutrient	Source	Mean Concentration (pct)	Standard Error
C	Burned	47.8 a[a]	0.083
	Unburned	48.2 b	0.104
N	Burned	0.43 a	0.006
	Unburned	0.43 a	0.012
P	Burned	0.26 a	0.001
	Unburned	0.27 a	0.002
K	Burned	0.13 a	0.004
	Unburned	0.11 b	0.007
Ca	Burned	0.36 a	0.006
	Unburned	0.33 b	0.011
Mg	Burned	0.09 a	0.002
	Unburned	0.08 b	0.003
S	Burned	0.04 a	0.001
	Unburned	0.04 a	0.001

[a] Concentrations for a given nutrient followed by the same letter are not significantly different at a = 0.05.

burned and unburned treatments for any of the collection dates. However, corrected mass of the litterfall was consistently lower on average in bags collected from the unburned than the burned treatment. Differences in corrected mass between the treatments were less than 2.2 percent for all collection periods.

Similar to the corrected mass loss of litter in the bags, cotton tensile strength loss (decomposition potential), did not significantly differ between the burned and unburned treatments for a given incubation period or depth (figure 2). Cotton tensile strength loss varied among incubation periods and depths but showed no consistent trends between treatments. Variation due to depth and incubation period (April or July) was generally much greater than variation between treatments (figure 2).

In contrast, corrected mass from litterbags containing pine litterfall from the irregular burned treatment was significantly lower than litterbags containing pine litterfall collected from the unburned treatment (figure 3). At the 0.5-month collection period, litterfall collected from the irregular burned treatment had lost 56 percent more mass than litterfall collected from unburned areas. After this time, mass of the two litterfall sources remained significantly different throughout the 10 months. The difference in mass between the two sources remained at approximately the same levels detected after ½ months. These results suggest that long-term prescribed fire can indirectly affect mass loss, and perhaps decomposition. The litterfall collected from the burned areas either decomposed faster or experienced rapid leaching after only 2 weeks. This suggests that there is an inherent difference in nutrient concentration, chemical composition, or possibly physical characteristics between the litterfall sources and that these differences need to be quantified.

Nutrient analysis of the collected litter showed no significant differences for N, P, S, or C/N ratios (table 1). However, litterfall collected from the burned treatment contained significantly higher concentrations of K, Ca, and Mg but lower concentrations of C than in litterfall from the unburned treatments. These differences, although small, may explain a portion of the initial differences in corrected mass loss in litterfall from the two treatment areas. It is also possible that differences in physical characteristics or soluble sugar contents of the litterfall contributed to the initial difference in weight loss. Examining nutrient contents in combination

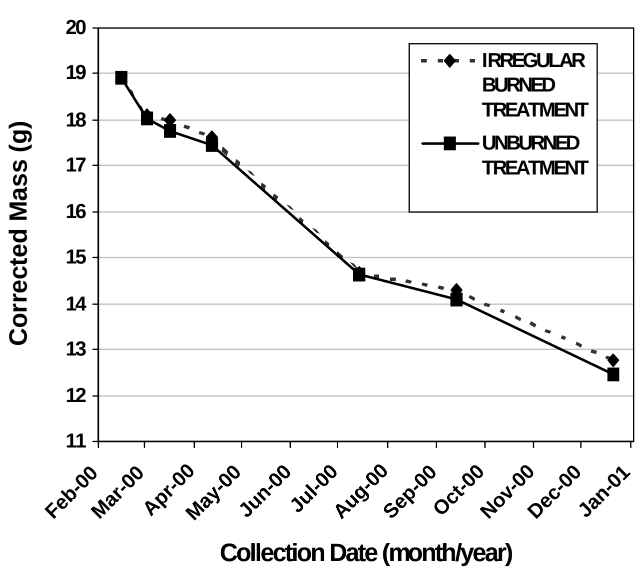

Figure 1—Corrected mass loss of decomposing foliar litter placed in irregular burned and unburned treatments in three uneven-aged loblolly pine stands in southeastern Arkansas.

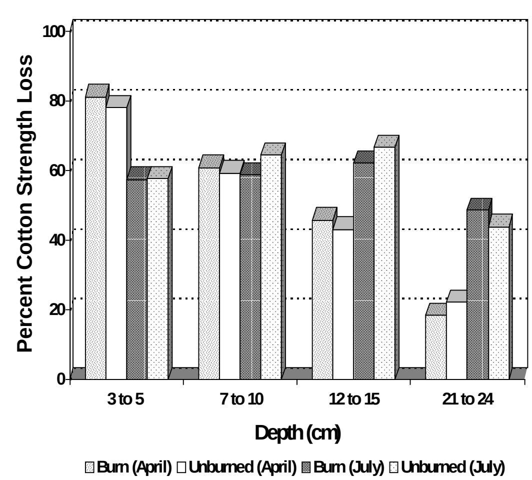

Figure 2—Percent cotton tensile strength loss over 30-day periods in April and July 2000 in irregular burned and unburned treatments in three uneven-aged loblolly pine stands in southeastern Arkansas.

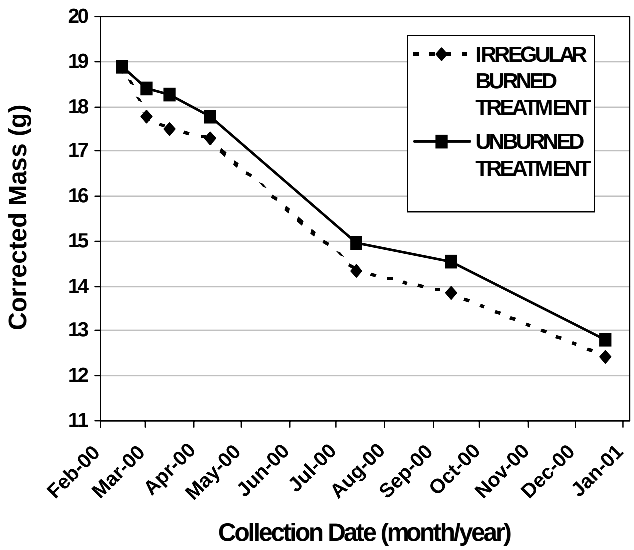

Figure 3—Corrected mass loss of decomposing foliar litter collected from irregular burned and unburned treatments in three uneven-aged loblolly pine stands in southeastern Arkansas.

with cellulose, lignin, or soluble sugar concentrations could have provided a better explanation of the corrected mass loss, but, we did not perform those analyses.

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