FUEL LOADING IN THE SOUTHERN APPALACHIAN MOUNTAINS MAY BE A FUNCTION OF SITE QUALITY AND DECOMPOSITION RATES

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Abstract—Fuel distribution in the Southern Appalachian Mountain region was measured on 1,008 study plots that were stratified by topographic position (aspect and slope position). Few fuel differences occurred among topographic positions indicating that fuel accumulation is no greater on highly productive sites than on less productive sites. Litter was slightly higher on undisturbed upper slopes than on lower slopes but woody fuels showed no significant differences. Rhododendron (*Rhododendron* spp.) and mountain laurel (*Kalmia latifolia*) were less common than expected occurring on 25 and 42 percent of sampled plots, respectively. The lack of significant differences among topographic positions for woody fuels suggests that varying inputs associated with site productivity are balanced by varying decomposition rates.

INTRODUCTION

Fire, both lightning and human caused, has played a significant role in the evolution of plant communities in the Southern Appalachian Mountains (Van Lear and Waldrop 1989). Fire exclusion policies on public lands likely reduced the diversity of these mountains and may have altered fuel loads. The dynamic nature of forest structure resulting from the succession of fire-dependent pine-hardwood communities to hardwood-dominated stands, as well as an abundant ingrowth of flammable understory species such as mountain laurel (*Kalmia latifolia*) makes it necessary to measure and update fuel load estimates frequently (Harrod and others 2000, Vose and others 1999). Fuel loads are a particular concern in this region because the numbers of retirement communities and single homes multiply each year.

Prediction of fuel loading in the Southern Appalachian Mountains can be as complex as the mountains themselves, because fuels may be closely associated with site quality and forest cover type. Studies by Iverson and others (2003), Kolaks and others (2004), and Waldrop and others (2004) suggest that fuel loads are controlled by the varying inputs associated with different species and productivity levels across the landscape while Abbott and Crossley (1982) discussed the impacts of varying decomposition rates at different site types. At any given time since disturbance, loading of fuels is a function of inputs from dying or broken vegetation minus losses from decay.

Although some data exist, there is limited documentation of fuels across the diverse topography of the region. In addition, past work has not covered the range of inherent variability. Thus our specific objective was to determine fuel loading by type across a range of combinations of aspect and slope positions in the Southern Appalachian Mountains.

METHODS

We designed this study to provide an exhaustive dataset of fuel loading in the Southern Appalachian Mountains because of the limited documentation of these fuels, the diverse topography of the region, and our perception that variability would be high among combinations of aspect and slope position. Therefore, we selected study sites in four States representing much of the range in elevation and topography of the region. We sampled one study area of 10 square miles in each State: South Carolina, Georgia, North Carolina, and Tennessee. Study sites included: the Sumter National Forest in northwestern South Carolina, the Chattahoochee National Forest in northeastern Georgia, the Nantahala National Forest in western North Carolina, and the Great Smoky Mountains National Park in southeastern Tennessee.

Plot locations were generated randomly within each 10-square-mile study area and were stratified by slope position and aspect using ArcView GIS software. We defined topographic position as a combination of slope position and aspect and assumed that tree productivity and, thus, fuel loading would be greater on more productive sites. Fifty plots each were located on middle slopes and lower slopes on northeast (325° to 125°) and southwest (145° to 305°) aspect. An additional 50 plots were located on ridgetops, the driest of all sites, for a total of 250 plots in each of the 4 study areas (1,000 total). Additional plots were included when necessary to give adequate representation of all slope position/aspect combinations. The resulting dataset had measurements from 1,008 plots.

Dead and down woody fuels were surveyed using Brown's (1974) planar intersect method along three 50-foot transects arranged with a common starting point and with the outer two transects 45° apart. Orientation of the middle transect in each set was determined randomly. We recorded numbers of 1- and 10-hour fuels (zero to 0.25 inch in diameter and 0.25 to 1.0 inch in diameter, respectively) crossing the transect plane along the first 6 feet of each transect. Along the first 12 feet of each transect, we recorded the number of 100-hour fuels (1.0 to 3.0 inches in diameter) crossing the transect plane. All fuels >3.0 inches in diameter, at the point where they crossed

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the transect plane, were classified as 1,000-hour fuels and were counted along the entire length of each transect. One thousand-hour fuels were recorded by diameter, type (hardwood or softwood), and decay class (solid or rotten). These counts were converted to weights using Brown's (1974) equations and specific gravity estimates for southern species by decay class developed by Anderson (1982). At the 12-, 25-, and 40-foot marks along each of the three transects we measured litter depth (O_i and O_e layers) and height of dead and down woody fuel. Litter depth was converted to weight using equations for pine and hardwood litter developed by Waldrop and others (2004) and Phillips and others (2006).

The center transect became the midline of a 50- by 44-foot vegetation plot with each side of the plot extending 22 feet from it. All trees taller than 4.5 feet were recorded within the entire plot, identified by species, and assigned to a 2-inch diameter class. On one-half of each plot, we visually estimated percent cover of ericaceous shrubs, primarily rhododendron (*Rhododendron* spp.) and mountain laurel.

Fuel loads were analyzed by analysis of variance using topographic position as the independent variable. Dependent variables included weights of litter, 1-, 10-, 100-, and 1,000-hour fuels plus cover of live fuels, predominantly mountain laurel and rhododendron. Mean separation was by linear contrast. All differences were considered significant at $\alpha = 0.05$.

RESULTS

Composition of major species groups on the 1,008 plots measured in this study was similar across topographic positions (table 1). Total basal area averaged 128 square feet per acre across all plots; it was greatest on lower slopes and decreased toward the ridges. Oak (*Quercus* spp,) was the dominant species group followed pines (*Pinus* spp.). The most common oak species included chestnut oak (*Q. prinus*), scarlet oak (*Q. coccinea*), and northern red oak (*Q. rubra*). Chestnut oak and scarlet oak were most common on dry sites and northern red oak was most common on moist sites. White pine (*P. strobus*) was the most common pine throughout all study sites and was more common on northeastern slopes than on southwestern slopes.

Downed woody fuels showed few differences in fuel loading across aspect/slope position plots (table 2). The only observed differences occurred in the litter layer. The litter on the 1,008 sample plots tended to be heaviest along the ridges and decreased going downhill on both southwest and northeast slopes, suggesting that decomposition exceeded leaf litter inputs on the wetter sites. Even though this difference among site types was significant, the relative differences were small. There was approximately 8 percent less litter on northeast lower slopes (1.68 tons per acre) than on ridges (1.83 tons per acre). There were no significant differences among slope/aspect combinations for loading of 1-, 10-, 100-, and 1,000-hour fuels or average fuel bed depth. These data should be considered preliminary because analyses of impacts such as disturbance or cover type are not yet complete. However, these findings closely agree with those of Kolaks and others (2003) indicating that down woody fuels are uniformly distributed across slopes and aspects.

Another component of fuels in eastern hardwood systems that must be considered is live fuel cover, particularly from ericaceous shrubs. Waldrop and Brose (1999) and Phillips and others (2006) indicate a strong relationship of fire intensity to a cover of mountain laurel. In this study, both mountain laurel and rhododendron were missing from most measured plots but occurred in thick clumps where they were found. Mountain laurel was found at all aspect/slope position combinations but was significantly more abundant on southwest upper slopes (table 2). Wildfires that might

Table 1—Basal area by major species or species groups and topographic position on 1,008 study plots in the Southern Appalachian Mountains of South Carolina, Georgia, North Carolina, and Tennessee

Species or group	Northeast lower	Northeast upper	Ridge	Southwest upper	Southwest lower	All plots
	------ *square feet per acre* ------					
Maples	14.8	11.8	16.6	10.4	10.9	12.9
Hickories	3.9	3.5	4.8	7.4	4.4	4.8
Yellow-poplar	6.5	10.9	16.6	13.5	10.5	12.1
Pines	29.6	32.2	15.3	19.6	35.7	26.5
Oaks	44.9	43.6	32.7	34.9	42.3	39.7
Hemlock	7.4	3.5	10.0	7.4	3.5	6.4
Understory	14.8	9.2	12.6	18.7	11.3	13.3
Other overstory	11.8	12.2	10.9	11.3	14.8	12.2
Total basal area	133.7	126.9	119.5	123.3	133.4	127.9

Table 2—Fuel characteristics by slope position and aspect in the Southern Appalachian Mountains of Tennessee, North Carolina, Georgia, and South Carolina

Slope/ Aspect	Litter	1-hour	10-hour	100-hour	1,000-hour	Fuel height	Mountain laurel	Rhododendron
	tons per acre					*inches*	*percent*	
Northeast								
Lower	1.68 a	0.32	0.91	3.8	24.0	4.3	10.6 a	37.0 c
Northeast								
Upper	1.82 b	0.30	0.91	3.5	18.0	4.6	13.6 a	19.7 b
Ridge	1.83 b	0.29	1.04	4.2	16.2	4.6	13.1 a	6.1 a
Southwest								
Upper	1.75 ab	0.30	0.97	3.7	17.3	4.3	21.0 b	6.8 a
Southwest								
Lower	1.70 a	0.29	0.92	3.4	18.3	4.1	15.6 a	15.4 b

Means followed by the same letter within a column are not significantly different at the 0.05 level.

occur could reach dangerous intensities if they burned uphill on dry southwest slopes and ran into thickets of mountain laurel. Rhododendron was also present at all slope/aspect combinations, but it was more common at lower slope and northeast-facing plots.

DISCUSSION AND CONCLUSIONS

This paper provides a preliminary analysis of an extensive dataset. An important component of fuel loading, disturbance, has yet to be considered. Wildfires, insects, diseases, wind, and ice temporarily increase the rate of fuel input by breaking limbs and felling trees.

An objective of this study was to determine if fuel loading varied by topographic position. We assumed that different species composition and productivity levels associated with slope position and aspect would create different fuel loads. For many fuel variables, there was no difference in loading across topographic positions. Litter weights varied significantly among slope/aspect positions but weights of 1-, 10-, 100-, and 1,000-hour fuels and fuel height did not vary. This result was surprising because of the large sample size used for analysis (1,008 plots). The result gives support to the conclusions of Kolaks and others (2003) and Waldrop (1996) who described the dynamics of fuel inputs and outputs of Southern Appalachian ecosystems. Both studies suggested that the differences in fuel inputs, associated with site quality at different topographic positions, were balanced by differing decomposition rates. Productive sites tend to have higher decomposition rates (Abbot and Crossley 1982), thus removing the higher fuel inputs sooner. The balance between inputs and decomposition deserves additional study in the Southern Appalachian region.

ACKNOWLEDGMENTS

This study could only be conducted through a generous grant from the U.S. Joint Fire Science Program, Boise, ID. We are grateful to the dedicated professionals who spent countless hours hiking to plots and measuring fuels in some of the most remote regions of the Southern Appalachian Mountains. Among these professionals are Mitchell Smith, Charles Flint, Gregg Chapman, Horace Gambrell, Ross Phillips, Laura Zebehazy, and Shane Welch.

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