PRELIMINARY FUEL CHARACTERIZATION OF THE CHAUGA RIDGES REGION OF THE SOUTHERN APPALACHIAN MOUNTAINS

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Abstract—Many areas of the southern Appalachian Mountains contain large amounts of dead and/or ericaceous fuel. Fuel information critical in modeling fire behavior and its effects is not available to forest managers in the southern Appalachian Mountains, and direct measurement is often impractical due to steep, remote topography. An existing landscape ecosystem classification (LEC) model was used as the basis for a characterization of fuel complexes in the Chauga Ridges region in South Carolina. We hypothesized that LEC site units have distinct fuel assemblages. Fuels were characterized using discriminant analysis, which yielded an overall 54 percent success rate of 275 randomly located plots. *Rhododendron maximum* L. biomass, *R. minus* Michx. ground cover, *Vaccinium* L. spp. ground cover, duff depth, and 1,000-hour fuel loading were discriminating fuel characteristics of xeric, intermediate, submesic, and mesic site units. Disturbance was not addressed in this analysis, but future work will address its effect on fuel complexes of LEC site units.

INTRODUCTION

The use of prescribed fire is becoming increasingly widespread in the southern Appalachians for various silvicultural objectives. Fuel loading information is not readily available, however. Fuel models and other resources traditionally used by fire managers are broad generalizations or specific to some southeastern fuel types but not others (e.g. Deeming and others 1972, Johansen and others 1976, Anderson 1982). These resources assume a homogeneous fuel complex and do not account for large and live ericaceous fuels. Such information is necessary for accurate prediction of fire behavior and developing prescriptions but is not currently available. Direct measurement is impractical since many areas are remote and very steep. Resource managers seek alternative means to obtain fuel loading information.

Landscape ecosystem classification (LEC) was proposed to characterize fuel complexes in the southern Appalachians. Resulting LEC site units are productively similar, the expressive result of soils, vegetation, and topography, and recur predictably on the landscape (Barnes and others 1982, Jones and Lloyd 1993). Site units support distinctive vegetation assemblages and structural attributes. Therefore, fuel complexes should change predictably across an environmental gradient. This paper summarizes preliminary results from work in the Chauga Ridges to determine whether Hutto and others (1999) LEC site units support distinctive fuel types and amounts.

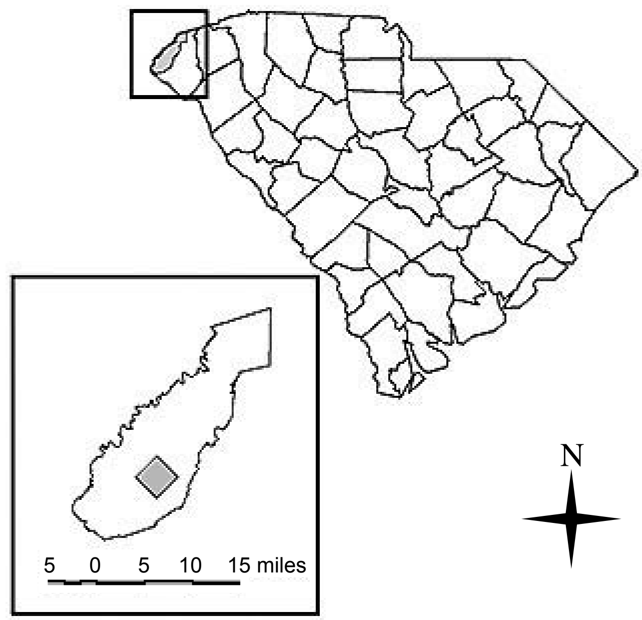

Figure 1—County map of South Carolina with shaded Andrew Pickens Ranger District, Sumter National Forest, Oconee County. Inset = location of 10 square-mile research area in the Chauga Ridges region of the southern Appalachian Mountains.

METHODS

Study Area

This study was conducted in a 10-square mile area on the southern portion of the Andrew Pickens Ranger District, Sumter National Forest, Oconee County, SC (fig. 1). The region is named after the Chauga River which bisects and drains the majority of the area. Short, steep slopes trend southwest to northeast with the Brevard Fault Zone, a narrow band of low-grade metamorphic rock. Climate, soils, and topography of the Chauga River watershed are ultimately influenced by this zone (Tobe and others 1992). Elevations in the study area range from 1,000 to 1,900 feet.

The 10-square mile sampling area contained 275 plots located randomly within 5 strata. The plots represented various seral stages of forest development and disturbance regimes. The stratification was by aspect and relative slope position and was intended to provide near-equal representation of four LEC site units.

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Landscape Ecosystem Classification

Each plot was classified by LEC site unit using methods developed by Hutto and others (1999). Certain variables known to influence or used to gauge relative moisture availability were involved in the classification. Environmental variables duff depth, slope gradient, landform index (McNab 1993), distance to bottom, and terrain shape index (McNab 1989) were measured. Values were entered into a discriminant function developed by Hutto and others (1999). Equation results indicated which of four LEC site units were most indicative of relative moisture availability. Possible site units included xeric, intermediate, submesic, and mesic.

Fuel Sampling

Dead woody fuels were sampled using Brown's (1974) planar intersect method and recorded in 1-, 10-, 100-, and 1,000-hour time-lag size classes: 0.00 to 0.25 inch, 0.25 to 1.00 inch, 1.00 to 3.00 inches, and 3.00+ inches, respectively.

Three 50-foot transects originated at each plot center. The center transect was stretched from plot center at a randomly generated azimuth. Two transects were stretched from plot center +22° and -23° from the center transect forming a 45° angle. Fuels in the 1- and 10-hour class were tallied along the first 6 feet of each transect. Fuels in the 100-hour class were tallied along the first 12 feet of each transect. Fuels in the 1,000-hour class were recorded by species, diameter, and decay state (sound or rotten) along the entire length of each 50-foot transect. Litter (Oi), duff (Oe and Oa), and fuel-bed depth were measured at three equally spaced points along each transect. Fuel counts were converted to tons per acre using equations given by Brown (1974). Fuel weights, litter, duff, and fuel-bed depth were averaged across the three transects.

Live ericaceous fuels were sampled within a 22-foot by 50-foot (0.01 ha) plot. Height, basal diameter, and crown dimensions were measured for *Kalmia latifolia* L., *Rhododendron maximum* L., and *R. minus* Michx. Biomass was calculated for *K. latifolia* and *R. maximum* using allometric equations given by Monk and others (1985). Crown dimensions were used to calculate ground cover for *R. minus* as no biomass equations were available. Ground cover was estimated for *Vaccinium* L. spp.

Statistical Analysis

Fuel variable means of LEC site units were compared using analysis of variance. Multivariate analysis of variance (MANOVA) was used to test for overall differences among site types based on the entire vector of fuel variables. Pairwise comparisons among LEC site units were evaluated based on Hotelling's T^2 statistic. Differences were considered significant at $\alpha = 0.05$ in both univariate and multivariate analysis of variance. Stepwise discriminant analysis was used to identify fuel variables that best define the fuel complexes of LEC site units.

RESULTS AND DISCUSSION

Analysis of variance for overall differences among LEC site units resulted in significant differences in 1,000-hour fuel loading, duff depth, *R. maximum* biomass, and *Vaccinium* spp. ground cover (table 1). Fine fuels, litter depth, fuel-bed depth, *K. latifolia* biomass, and *R. minus* ground cover did not vary among LEC site units. Multivariate analysis of variance provided additional evidence of overall differences in fuel complexes among LEC site units (T^2=0.70, p<0.0001). Rejection of the multivariate hypothesis justified subsequent procedures to identify discriminating fuel variables. Of the 275 total plots, 148 were correctly resubstituted in stepwise discriminant analysis yielding a success rate of 54 percent. In cross-validation, a more stringent test of the discriminating ability of the discriminant function, 143 plots were correctly classified yielding a success rate of 52 percent.

In discriminant analysis, maximum separation among LEC site units was given by the following fuel variables: 1,000-hour fuel loading, duff depth, *R. maximum* biomass, *R. minus* ground cover, and *Vaccinium* spp. ground cover (table 1). Mesic site units had greater 1,000-hour fuel loading than intermediate and xeric site units. Submesic site units had greater 1,000-hour fuel loading than xeric site units. We attributed higher concentration of large fuels at moist sites to both up-rooting of trees with more shallow root systems and breakage and

Table 1—Fuel variable means and standard deviations of landscape ecosystem classification site units in the Chauga Ridges region of the southern Appalachian Mountains. Means within a row followed by the same letter are not significantly different among site units at α = 0.05

Fuel variable	Xeric (n=68) Mean	SD	Intermediate (n=168) Mean	SD	Submesic (n=15) Mean	SD	Mesic (n=24) Mean	SD
1-hour (*T/ac*$^{-1}$)	0.24a	0.01	0.23a	0.01	0.22a	0.03	0.29a	0.02
10-hour (*T/ac*$^{-1}$)	1.21a	0.08	1.04a	0.05	0.98a	0.18	1.18a	0.14
100-hour (*T/ac*$^{-1}$)	2.36a	0.17	1.92a	0.13	1.79a	0.42	1.88a	0.33
1,000-hour (*T/ac*$^{-1}$)[a]	11.06c	2.66	12.85bc	1.69	23.47ab	5.66	29.21a	4.47
K. latifolia (*T/ac*$^{-1}$)	1.12a	0.34	1.01a	0.22	1.91a	0.73	1.23a	0.58
R. maximum (*T/ac*$^{-1}$)[a]	0.06b	0.18	0.13b	0.12	0.75b	0.39	2.51a	0.31
R. minus groundcover (*%*)[a]	4.05ab	1.62	2.06b	1.03	1.22b	3.44	9.46a	2.72
Vaccinium spp. groundcover (*%*)[a]	11.33a	1.77	3.93b	1.13	0.13b	3.77	0.00b	2.98
Fuel-bed depth (*inches*)	3.25a	0.37	2.88a	0.23	3.11a	0.78	3.93a	0.62
Duff depth (*inches*)[a]	1.21a	0.06	0.89b	0.04	1.00ab	0.13	0.87b	0.10
Litter depth (*inches*)	1.60a	0.08	1.57a	0.05	1.72a	0.16	1.88a	0.13

[a] Fuel variable was discriminating of LEC site units.

abscission of large wood material from trees on these productive sites. These results are consistent with those documented by Rubino and McCarthy (2003), Spies and others (1988), and Waldrop (1993).

Models of southeastern fuel complexes rarely address large fuel particles. The right combination of fuel moisture and fire intensity and residence time is necessary in order for large fuels to be consumed. In periods of drought, large fuels are more likely to be consumed and could greatly influence fire behavior and effects (Hungerford and others 1991). Additionally, a silvicultural objective may be to eliminate these large fuels. For example, where insect activity has killed much of the residual overstory, forest managers may rely on fire to remove fuel loads resulting from tree fall. In such cases, models addressing large fuels are necessary.

Duff thickness of xeric site units was significantly greater than that of other site units. Mesic site units had significantly thinner duff but were not different from submesic and intermediate sites. These results are similar to Hutto and others' (1999) observations in xeric and mesic sites but do not follow the same pattern of decreasing thickness along the moisture gradient. We attribute this to thick duff encountered beneath eastern hemlock (*Tsuga canadensis* L. Carr) and *R. maximum* in alluvial submesic site units. These results are consistent with Abella and others' (2003) findings in mesic hemlock-*Rhododendron* LEC site units in the Jocassee Gorges.

Duff is not generally targeted in prescribed burning operations nor does fire typically reach intensities necessary for consumption of all duff material. However, duff thickness is commonly used to index fire severity. Thick duff on xeric sites helps protect surface soil during fire events. Thin duff on mesic and submesic sites renders these sites more susceptible to soil detriment and/or loss in the event of high-severity fire (Hungerford and others 1991).

Typically a wet habitat-preferring species, *R. maximum* biomass on mesic sites was significantly greater than that of other site units. There were no additional significant differences in *R. maximum* biomass among site units. These results are similar to those obtained by Monk and others (1985), Baker and Van Lear (1998), and Vandermast and others (2002).

R. minus ground cover in mesic site units was significantly greater than in submesic and intermediate site units. There were no additional significant differences in *R. minus* ground cover among site units. Like *R. maximum*, moist and shaded conditions are ideal for *R. minus*, but the species also tolerates drier conditions. Abella (2002) noted that *R. minus* was commonly found on north-facing upper slopes in the Jocassee Gorges.

Vaccinium spp. ground cover in xeric site units was significantly greater than in intermediate, submesic, and mesic site units. There were no additional significant differences in *Vaccinium* spp. ground cover among site units. Xeric ridgetops contain *Vaccinium* spp. in highest abundance. Oak and pine species contribute foliage that, when dropped amid stems of *Vaccinium* spp., creates a deep, aerated and highly flammable litter layer. Like *K. latifolia*, the foliage of *Vaccinium* spp. contains volatile resins that lead to erratic fire behavior. Ericaceous shrub strata are potential ladders for fire into elevated fuels.

SUMMARY AND CONCLUSIONS

The need for prescribed burning in the southern Appalachians is well-substantiated, and its use is becoming increasingly widespread. Traditional resources do not adequately represent the mosaic of fuel complexes, the ericaceous fuel component, or large fuel particles. Resource managers require such information in prescribing management and predicting fire's behavior and effects. Direct measurement of fuel is impractical given remote areas and steep topography.

Fuel variables that best define fuel complexes included: 1,000-hour fuel loading, duff depth, *R. maximum* biomass, *R. minus* ground cover, and *Vaccinium* spp. ground cover. Fine woody and litter fuels and *K. latifolia* levels were similar across site units. *K. latifolia* exhibited a ubiquitous growth habit and covered an average of 16 percent of the sampled land area.

The fuel complex of xeric sites is characterized by thick duff and abundant *Vaccinium* spp. Xeric sites also lack *R. maximum* and generally have lesser 1,000-hour fuel loading. Xeric sites may contain moderate densities of *R. minus*. Intermediate sites have moderately thin duff and contain less *Vaccinium* spp. than xeric sites. Intermediate sites may be least likely to contain the dense ericaceous thicket characteristic of the southern Appalachians of any LEC site unit.

Submesic sites are characterized by moderately thick duff and contain greater 1,000-hour fuel loading than both intermediate and xeric sites. Submesic sites contain greater *R. maximum* than intermediate and xeric sites but do not contain densities as high as mesic sites. The fuel complex of mesic sites is characterized by thin duff and high densities of both *R. minus* and *R. maximum*. Both submesic and mesic sites are characterized by the absence of *Vaccinium* spp. Like submesic sites, mesic sites contain high 1,000-hour fuel loading.

Disturbance was not addressed in this analysis. Future work will address the effect of episodic disturbance on the fuel complexes of LEC site units. Landscape ecosystem classification site units are expected to exhibit different burning characteristics and susceptibilities to fire effects.

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