FUEL DYNAMICS ACROSS SOUTHERN APPALACHIAN LANDSCAPES

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Abstract—This study was conducted in Rabun County, GA, on the Warwoman Wildlife Management Area to measure the annual accumulations and decomposition of leaf litter, fine woody fuel, and total fuel loadings on undisturbed sites across different topographical positions in the Southern Appalachian Mountains. There were five "treatments" used in this study, representing five topographic positions: ridge tops, middle, and lower slopes on northeast (325 to 125 degrees) and southwest (145 to 305 degrees) aspects. Ten plots (replicates) were established at each topographic position for a total of 50 plots. Results suggested that there were few differences in accumulation and decomposition of leaf litter, 1-, 10-, and 100-hour fuels among different topographical positions. The only exception was coarse woody debris, which had significantly more on northeast facing slopes (26.6 tons/ha) compared to all other slope positions (10.8 tons/ha). Ericaceous shrubs were present on 74 percent of plots and could have influenced the results.

INTRODUCTION

For approximately 70 years, fire has been suppressed in Southern Appalachian ecosystems, and the result of fire exclusion has been a buildup of fuels and an expansion of ericaceous shrubs such as mountain laurel (*Kalmia latifolia*) and rhododendron (*Rhododendron maximum*) (Vose 2000). These increases, coupled with an increasing human population, have increased the probability of intense, severe fires. Mountain laurel and rhododendron can burn intensely resulting in mixed severity or even stand replacement fires (Stanturf and others 2002). Harrod and others (2000) suggest that reductions in fire frequency through active fire suppression and changing patterns in land uses have resulted in a decrease in fire frequency, thus increasing stand densities. The result has been a less diverse and productive understory. In addition, an increase in canopy density and decreasing grass cover have combined to shift the disturbance regime from frequent low-intensity surface fires to infrequent but catastrophic crown fires (Harrod and others 2000).

The Southern Appalachian Mountains have diverse topography, which produces a complex mosaic of site types. Each site type is affected by soil and topography (slope, slope position, elevation, and aspect), which influence temperature, light, and moisture (Graham and McCarthy 2006, Waldrop and others 2007). These variables produce drastically different fuel conditions that change both temporally and spatially. The fuel dynamics of this area can be as complex as the mountains themselves. Rubino and McCarthy (2003) stated that stand composition varies drastically with topographic gradient resulting in different edaphic climaxes that can be found within close proximity of one another. This mosaic of vegetative communities can change fuel characteristics over very short distances (<100 meters) with changing microclimate (Graham and McCarthy 2006).

There is a need to understand how hardwood fuels are distributed across Southern Appalachian landscapes to give fire planners the knowledge to apply appropriate silvicultural treatments to obtain desired management objectives. There have been several studies examining fuel loads in the Southern Appalachian Mountains and central hardwood region including fuel loading in the central hardwood region (Kolaks and others 2003), evaluation of coarse woody debris (CWD) and forest vegetation (Rubino and McCarthy 2003), and forest floor fuel dynamics in mixed-oak forest (Graham and McCarthy 2006). These studies yielded useful information about fuel loadings in these ecosystems enabling fire planners to use the data directly for fire planning or in fire behavior modeling, but none of these studies analyzed how accumulations and decomposition of fuels differed across differing topographical gradients (Waldrop and others 2007). Graham and McCarthy (2006) stated that varying microclimates resulting from highly dissected landscapes produce very different fuel conditions dependent on slope position, percent slope, and slope aspect, all of which affect moisture. Moisture in turn influences both the productivity (inputs) and decay (loss) rates of fuel on these sites.

In a recent study, fuels on disturbed and undisturbed sites in the Southern Appalachian Mountains, Waldrop and others (2007) measured fuel loadings on 1,008 plots of which 705 were undisturbed. Total basal area for undisturbed sites averaged 29.1 m^2/ha and was higher on lower slope positions and decreased towards the ridge tops. Litter was heavier on ridge tops and decreased downhill in both the northeast and southwest slopes, suggesting that decomposition exceeded leaf litter inputs on the more mesic sites. This study found there was 12 percent less litter on northeast lower slopes (3.8 tons/ha) than on ridge tops (4.2 tons/ha). There were significantly less 1-hour fuels on ridge top positions (0.6 tons/ha) as compared to the other slope positions (0.7 tons/ha).

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There were also no significant differences in 1,000-hour fuel loadings on undisturbed sites, though there was on average more 1,000-hour fuels on northeast lower slopes (44 tons/ha) as compared to other slope positions (35 tons/ha). There was more mountain laurel on southwest slopes and rhododendron was most common on northeast lower slopes.

Previous studies suggest that differing decomposition rates balance the loading of downed woody fuels across topographic gradients (Abbott and Crossley 1982, Graham and McCarthy 2006, Kolaks and others 2003, Waldrop and others 2007). However, inputs and decay rates of leaf litter and fine and coarse woody fuels have never been measured across differing topographic gradients. The overall objective of this study was to measure inputs and decomposition rates of leaf litter and fine and coarse woody fuels across a topographic gradient in the Southern Appalachian Mountains.

METHODS

Study Site

The study measured a portion of the study sites used by Waldrop and others (2007) in the Warwoman Wildlife Management Area (WMA), occupying approximately 6397 ha, within the Chattooga River Ranger District of the Chattahoochee National Forest, Rabun County, GA. The WMA is characterized by short, steep slopes with elevations ranging from 244 to just over 1036 m. The average temperature and precipitation during the study period for the area was 12.5 °C and received on average 172.8 cm of precipitation (National Oceanic and Atmospheric Administration 2008). The long-term average precipitation (100-year average, 1907 to 2007) was 127.3 cm annually (National Oceanic and Atmospheric Administration 2008).

Waldrop and others (2007) reported red oak species were the most common species in the overstory on the WMA followed by yellow pines, and then all other understory species. Red oak species account for 25 percent of the total basal area while white oak species, including chestnut oak, occupy only 6 percent of the total basal area. This was surprising because chestnut oak is considered a dominant species present on the drier upper slope positions in the Southern Appalachian Mountains.

Experimental Design

This study used a completely randomized design, with a subset of plots established by Waldrop and others (2007). There were 50 plots chosen at random, 10 replicates from each “treatment.” This subset of plots was used to measure the input/accumulation and decomposition (loss) of fuels across differing landscape gradients in the current study. Waldrop and others (2007) defined topographic position as a combination of slope position and aspect, and assumed that tree productivity and, thus, fuel loadings would be greater on more productive sites. The five “treatments” consisted of topographic positions including ridge tops, middle slopes, and lower slopes on northeast (325 to 125 degrees) and southwest (145 to 305 degrees) aspects. Ten plots (replicates) were established at each topographic position for a total of 50 plots.

Litter Trap Design and Sampling Procedures

In most litter and woody detritus decay studies, a litter bag of some type is used. However, Binkley (2002) used a method previously described as a litter “sandwich.” In the litter sandwich method one piece of screen (with 2- or 3-mm openings) was first fastened to a stable frame (small wooden pieces 5 by 5 cm work well), then, after the major litter fall period, another piece of screen was placed on top of the freshly fallen litter. This pattern of fresh litter fall and new screen application can be continued for as long as the study is designed to last. This design mimics the natural dynamics of the forest floor; in addition it alleviates the problem of excluding soil micro- and macrofauna. Samples can easily be cut from the layers of screen at designated intervals without disturbing other material. Five 1-m^2 litter-trap sandwiches were placed at each of the 50 study plots, for a total of 250 litter traps, prior to the major leaf fall in September 2005.

January 2006 was designated as the end of leaf fall and sampling began in February 2006. The end of year 2 sampling started in January of 2007. Sampling took place every 3 months and consisted of a 10-cm^2 subsample cut from within each litter trap, for a total of 5 samples per plot and 250 samples per sample period. During sampling the litter traps were emptied and the material was sorted into different fuel categories, litter (including acorns and bark); pine cones; 1- (zero to 0.64 cm), 10- (0.64 to 2.5 cm), 100- (2.5 to 7.6 cm), and 1,000-hour fuels (>7.6 cm). All sorting was conducted in the field. The separated materials were weighed and divided equally among the five traps (the total mass of material was divided by five) at each point. The material was divided into the five litter traps because, in most cases, there was too much litter to place into a single litter trap. All 10- and 100-hour fuels were placed into litter trap 1, because the quantities were not sufficient to place them into all five litter traps and be able to collect subsamples in subsequent sampling periods. After the material was redistributed, a screen was placed on top of the material and loosely (care was taken not to compress the material) stapled to the wooden frame forming the sandwich. After screens were stapled on top of the 5 litter traps, a 10-cm^2 subsample was cut from a random location within each trap; the location was the same for all 250 litter traps.

A 4- by 20-m (80 m^2) grid was established in a randomly assigned azimuth to sample CWD (>7.62 cm in diameter). Each piece of CWD was painted so it would not be remeasured in subsequent sampling periods. Each of the CWD grid plots was surveyed during the resampling periods; approximately every 3 months for a total of nine sampling periods.

The process of sorting and weighing fuels was repeated after the litter fall of 2006. The final sampling period started in December of 2007. At that time, there were only 212 traps intact and viable to sample. Others were destroyed by wildlife, mostly just after mast fall.

Data Analysis

Data from this study were analyzed in three major components: (1) accumulation/production (input of leaf litter and fine woody fuels), (2) loss (decay) of leaf litter and fine woody fuels, and (3) total fuel loadings across the topographical gradients. To obtain an accurate assessment of the five slope and aspect positions and differences associated with the material collected, a one-way analysis of variance was conducted (SAS Institute 2002) with differences considered significant at $\alpha = 0.05$, and a linear contrast was performed to compare the mean of northeast slopes (the slope positions that should have been the more mesic) to the mean of all other slope positions. Mean separation was determined by Fisher's protected least significant differences. A matched pair t-test was conducted on the means for leaf litter, 1- and 10-hour fuels collected in years 2005 and 2006, to determine if there were differences in the quantity of material collected between the 2 years.

RESULTS

Accumulation and Production

There were no significant differences in accumulations of leaf litter, 1-, 10-, and 100-hour fuels detected among slope and aspect position for either of the 2 years (2005 or 2006) (fig. 1). There were significant differences in the quantity of litter, 1- and 10-hour fuels produced between the 2 years. More litter was produced in 2006 than 2005 ($P = 0.0172$), but there were more 1- and 10-hour fuels produced in 2005 than 2006 ($P = 0.0172$ and 0.0434). In addition, 2005 produced more 100-hour fuels than 2006; no 100-hour fuels were collected in 2006.

One possible reason that the 2006 collection had more leaf litter than 2005 was the litter traps were not placed in the field until August of 2005. The leaves that had fallen earlier in 2005 were not recovered and placed into the litter traps. There were more 1- and 10-hour fuels collected in 2005 than in 2006; this could have been caused by major wind events or possible damage from a major ice storm in December of 2005. The high variance within each treatment for both 2005 and 2006 was caused by high variability from plot to plot. This variability and lack of significant differences can possibly be attributed to the presence of ericaceous shrubs. In combination, mountain laurel and rhododendron were present on 37 of 50 (74 percent) plots in this study. There could be strong influences on the input of fuel material with either or both of the ericaceous shrub species because both are composed of heavy volatile chemicals that weigh proportionally more than leaves produced by other species (Clinton 2002). These differences in specific leaf weights among species were ignored in previous studies when determining litter fuel loading. In addition there can be a 20-percent reduction in available water to plants and decomposers under rhododendron thickets (Clinton 2002).

Analysis of CWD data showed significant differences in CWD loading between the northeast facing slopes and all other slope positions (fig. 2). There were no significant differences between slope and aspect positions for CWD. Subsequent linear contrast showed there was a significant difference between the mean of northeast facing slopes as compared to the mean of all other slope positions ($P = 0.0042$).

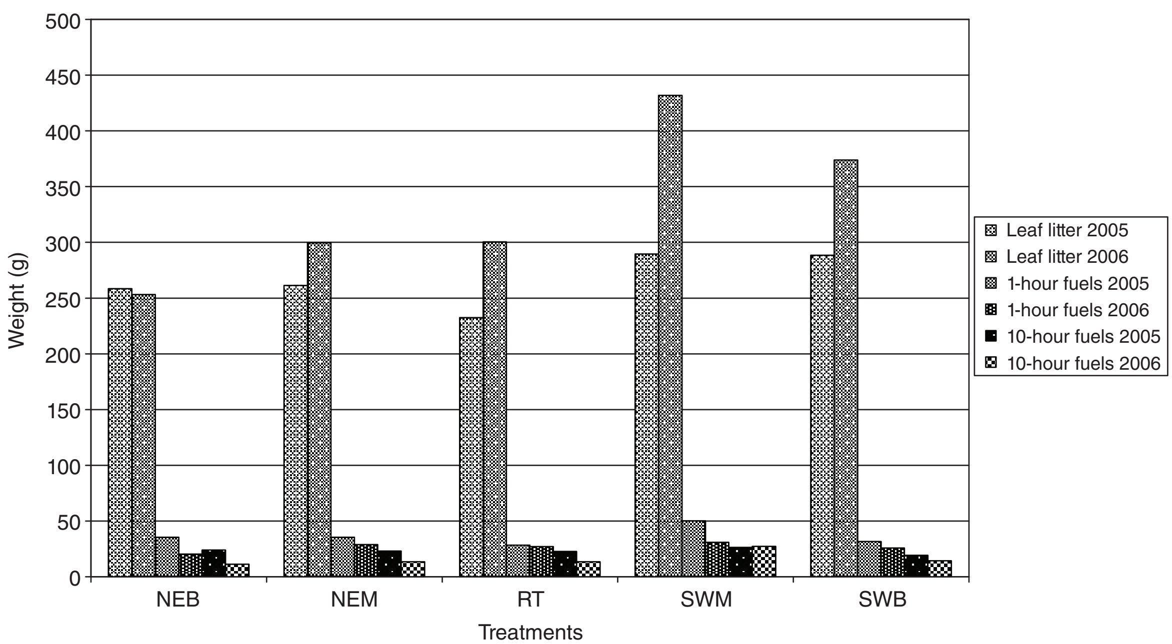

Figure 1—Mean accumulations of leaf litter and fine woody fuels for 2005 and 2006. (NEB = northeast bottoms, NEM = northeast midslopes, RT = ridgetops, SWM = southwest midslopes, and SWB = southwest bottoms)

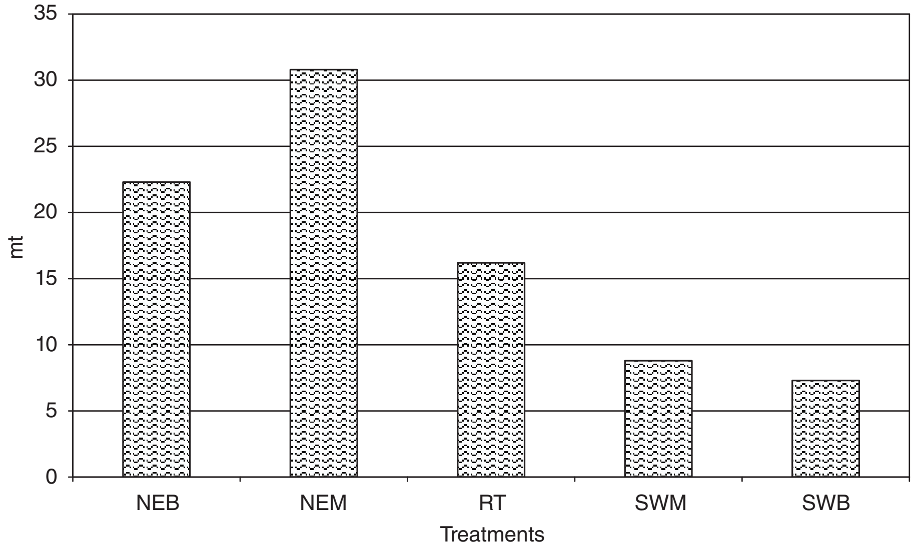

Figure 2—Initial 2005 coarse woody debris survey. (NEB = northeast bottoms, NEM = northeast midslopes, RT = ridgetops, SWM = southwest midslopes, and SWB = southwest bottoms)

It was not expected to find significant differences for total fuel loadings across the topographical gradient. There were no differences detected in the quantity of material collected in the litter traps among slope and aspect positions, and therefore, there should not have been detectable differences in total fuel loadings among the same slope and aspect positions. There was, though not significant, more leaf material collected on southwest slope positions (3.5 tons/ha) as compared to northeast slope positions (2.4 tons/ha), and the 1-, 10-, and 100-hour fuels are virtually identical across all treatments.

Decomposition

The 2005 leaf litter, 1-, 10-, and 100-hour fuels (material that had been in the field for 2 years) were not significantly different among slope positions or aspect. Similarly, the 2006 leaf litter, 1- and 10-hour fuels (material that had been in the field for 1 year) had no significant differences among slope positions or aspect (fig. 3). It was expected that on the more protected sites (northeast slopes and lower southwest slopes) there would be smaller remaining masses, indicating more loss through decay. These sites hold more moisture and therefore should have faster turnover times as compared to drier site types. However, that pattern was not observed. Ericaceous shrubs could have had an effect on decay. These tightly closed canopies act to keep the microsite moist and cool, and it is well accepted that both moisture and temperature are two of the main driving forces in the decay process (Clinton 2002). However, Nilsen and others (2001) reported that although it is moist under a rhododendron canopy, there is 20 percent less water available to plants and decomposers due to evapotranspiration by rhododendron. In this study, there was a greater abundance of rhododendron (40 percent) and mountain laurel (54 percent) than the findings reported by Waldrop and others (2007), at 25 and 42 percent, respectively. This could have biased the study findings to lower decay rates than are actually found on the same slope and aspect positions without ericaceous shrubs. The dense closed canopy and higher evapotranspiration rates associated with rhododendron, combined with the high acid and lignin content found in rhododendron leaves, create conditions that are suboptimal for decomposers, thereby slowing the decomposition process. Another possible influence on decay in this study was infiltration of fine roots into the layers of litter traps. Mass of fine roots present at the time the material was removed from within the litter traps could not be estimated; however, there were many samples from the more mesic sites that had a substantial quantity of fine roots, based on visual observations.

CONCLUSION

Significant differences in accumulation and decomposition were not detected for leaf litter, 1-, 10-, and 100-hour fuels among the five different slope position and aspect combinations for either year sampled. The results support findings from previous studies. The overall mean for leaf litter accumulations was 299.4 g/m^2 which fall within the range of 291 to 785 g/m^2 reported in other studies. Mean accumulation of woody material was 104.3 g/m^2 just below means of 106.9 and 107.6 g/m^2 reported in previous studies.

Northeast facing lower slopes had significantly greater 1,000-hour fuels than other topographic positions (26.6 and 10.8 tons/ha, respectively). This supports findings of Waldrop and others (2007), who reported finding 44 tons/ha on northeast facing slopes and 35 tons/ha for all other slope positions, and Kolaks and others (2003), who reported 8.4 tons/ha on protected slopes and 3.9 tons/ha on unprotected slopes.

Further study is needed, with study plots biased against ericaceous shrub species, to validate input and decay

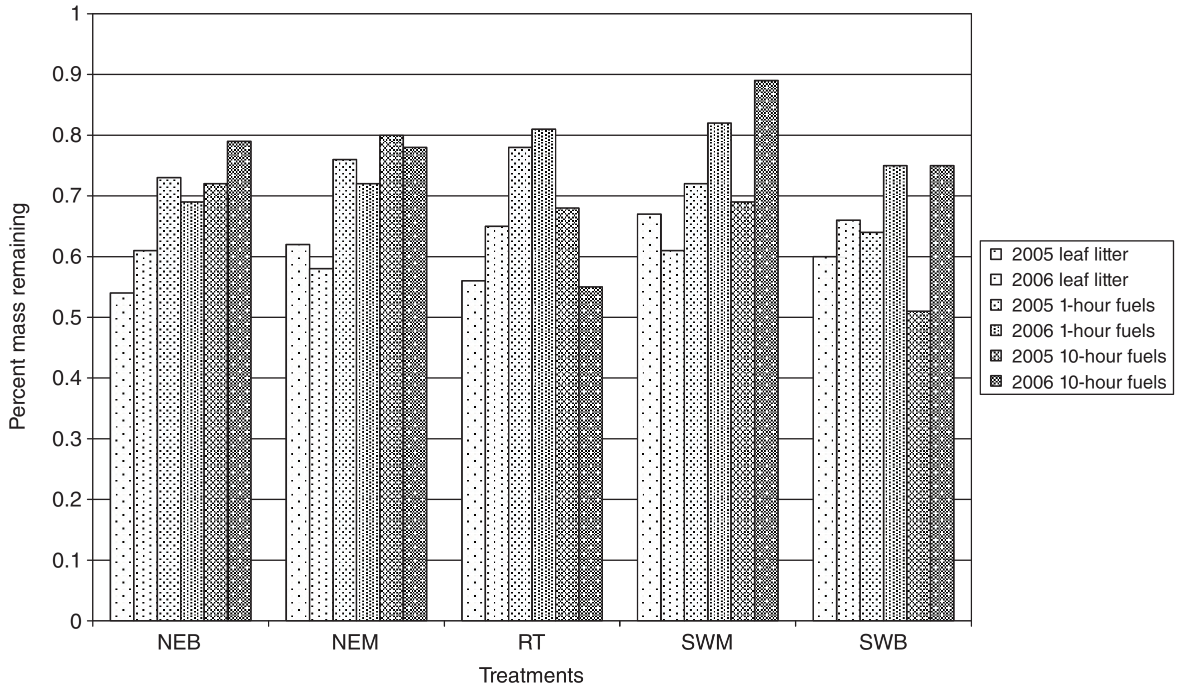

Figure 3—Percent mass remaining for leaf litter, 1- and 10-hour fuels 2005 and 2006. (NEB = northeast bottoms, NEM = northeast midslopes, RT = ridgetops, SWM = southwest midslopes, and SWB = southwest bottoms)

differences over different landscape positions in the Southern Appalachian Mountains. By biasing against these species, a more diversified species composition could be captured in the litter traps and the influence of ericaceous shrub species could be eliminated or greatly reduced.

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