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Changes in vegetation structure and composition in response to fuel reduction treatments in the South Carolina Piedmont

R.J. Phillips *, T.A. Waldrop

Ecologist and Supervisory Research Forester, USDA Forest Service, Southern Research Station, Clemson, SC, United States

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Abstract

Fuel reduction treatments are helpful to restore ecosystem structure and function to forests that historically sustained frequent, low-intensity fires. But the impacts of these treatments on Piedmont forests are not well understood. We examined the effects of prescribed burning, thinning, and a combination of burning and thinning on community composition of *Pinus taeda*/*Pinus echinata* forests in the South Carolina Piedmont to identify changes in community structure and species composition. Overstory basal area was reduced across all treatments. The combination of thinning and burning resulted in a substantial increase in sapling density, whereas the burn-only decreased slightly after 3 years. Seedling density for all tree species increased across all treatment units during the same time span. In addition, cover of grasses and forbs increased in the burn-only and thin + burn treatments. Treatments appeared to affect understory life forms differently with the burn-only treatment encouraging forb cover while the thin + burn treatment promoted shrub and graminoid abundance. Non-metric multidimensional scaling (NMS) indicated rapid changes in understory composition for the burn-only and thin + burn treatments, whereas the thin-only treatment showed a more gradual shift over time. Published by Elsevier B.V.

Keywords: Prescribed fire; Thinning; *Pinus taeda*; South Carolina Piedmont; Species richness; Non-metric multidimensional scaling

1. Introduction

The southeastern Piedmont is a unique transitional region between the pine forests of the Coastal Plain and the hardwood forests of the Appalachian Mountains. In the past, fire functioned as an integral part of ecosystem development in the southern United States as Native Americans used burning to hunt, maintain prairies and grasslands, improve wildlife habitat, and clear land for agriculture (Van Lear and Waldrop, 1989; Williams, 1989; Silver, 1990; DeVivo, 1991; Carroll et al., 2002). The forests were characterized by an open, herbaceous understory with widely spaced trees and fire was observed throughout the landscape (Silver, 1990). Fire continued to be used as a tool for land management up until the 1900s when the federal government enacted the Clarke–McNary Act, which encouraged fire suppression by providing funding for such activities (Williams, 1989; Wade et al., 2000). Although prescribed fire was touted as a method to help reduce fuels in southern forests following major wildfires in the 1930s and 1950s (Stanturf et al., 2002), most forest land in the southeastern Piedmont is owned by non-industrial private landowners (Bechtold and Ruark, 1988) and remains unmanaged. Relatively little information is available on the effects of prescribed fire and fuel reduction treatments on vegetation in the southeastern Piedmont region.

Disruption of the fire cycle as well as other factors (e.g., farming and subsequent land abandonment, timber harvesting) has led to forests with less spatial heterogeneity, greater stem densities, and therefore, increased fuel loads. In South Carolina approximately 5000–6000 fires occur each year burning an average of 12,000 ha (South Carolina Forestry Commission, http://www.state.sc.us/forest/fire.htm). Since 1970, catastrophic wildfires (those over 400 ha) have occurred at the rate of one per year in South Carolina. Because of the high degree of urban/wildland interface in the region, fires of this size usually destroy homes, businesses, or other private property.

Fire-sensitive, shade-tolerant species are becoming established changing community composition (Halls and Homesley, 1966; Cowell, 1998) and altering nutrient cycling and decomposition rates in addition to other ecosystem functions (Lockaby et al., 1995). Fuel reduction techniques have been

* Corresponding author at: 233 Lehotsky Hall, Clemson, SC 29634-0331, United States. Tel.: +1 864 656 0674; fax: +1 864 656 1407.
E-mail address: rjphillips@fs.fed.us (R.J. Phillips).

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proposed to help restore stand structure and function to forests that traditionally experienced low-intensity fires with short return intervals (Mutch, 1994; Covington, 1995; Moore et al., 1999). Previous studies have documented the effects of silvicultural treatments on different vegetative components of *Pinus taeda* and *Pinus echinata* communities, but none have examined the effects of several different fuel reduction treatments on the entire vegetation community over time.

This work is a part of the National Fire and Fire Surrogate (FFS) study (http://www.fs.fed.us/ffs), which is evaluating the long-term effects of fuel reduction treatments (prescribed burning, mechanical treatment, prescribed burning + mechanical) on ecosystem structure and function at 13 sites across the U.S. (Weatherspoon, 2000). The study sites represent a variety of forest types that historically sustained frequent low-intensity surface fires which currently have greater stem densities and increased fuel loading as a result of long-term fire suppression. At the Southeastern Piedmont site the primary goals were to re-establish stand structure and composition characteristic of fire-adapted communities. We compared the effectiveness of dormant-season prescribed burns, thinning from below, and the combination of thinning and prescribed burning to achieve these goals while supporting stand management for timber production, wildlife habitat, and recreation.

We hypothesized that the combination of thinning and burning would have the greatest impact on stand structure and composition by reducing basal area and density for the overstory and midstory, and thus elicit the greatest increase in understory abundance. Intermediate levels of stand change and understory response were expected for the burn-only and thin-only treatments.

2. Methods

2.1. Study site

The study site is located on the Clemson Experimental Forest in Anderson, Oconee, and Pickens Counties, South Carolina. The forest, essentially reclaimed farm land, supported subsistence agriculture until the 1930s, which greatly reduced the land's productivity, as most of the topsoil was removed. Reforestation programs begun during the Great Depression and harvesting since that time have resulted in second- or third-growth timber on most of the forest. The dominant forest type is *P. taeda* and *P. echinata* with a mixture of oaks (*Quercus*), hickories (*Carya*), and other hardwoods.

Elevation ranges from 200 to 300 m. Topography is a factor of past erosion, ranging from rolling hills to moderately steep slopes. Most soils on the Clemson Experimental Forest are Ultisols, predominantly of the Cecil–Lloyd–Madison association (fine, kaolinitic, thermic Typic Kanhapludult), with moderate to extremely severe erosion (Herren, 1975). Entisols and Inceptisols are present but not abundant.

Average annual temperature and precipitation are 15.3 °C and 138 cm, respectively. Growing season (May–September) temperatures average 23 °C and precipitation during those months totals 54 cm. Drought conditions were prevalent in the southeast from 1999–2001, where deficits in annual precipitation greater than 43 cm for 2000 and 37 cm for 2001 were recorded (NCDC: Annual Climatological Summary, http://cdo.ncdc.noaa.gov).

2.2. Treatments

Thinning and burning levels were prescribed that would reduce fuels and follow standard silvicultural practices for managed stands in the Piedmont. Our prescription for thinning was to reduce basal area to 18 m^2/ha by removing small, merchantable-sized trees and diseased or insect-infested trees first, and cutting other trees as necessary to provide the target residual basal area. Residual tree spacing following treatment was approximately 6 m. Thinning treatments occurred in the winter of 2000–2001. Non-merchantable material was left on-site.

Prescriptions for the burn-only treatment were moderate-intensity fires resulting in some mortality of large overstory trees, whereas low-intensity fires were prescribed for the thin + burn treatment to kill saplings and small diameter overstory trees. Prescribed burns were conducted on three consecutive days for the burn-only treatment units in April 2001; ambient temperatures ranged from 22 to 30 °C, relative humidity (RH) was between 42% and 56%, and wind speeds varied from 4 to 10 km/h. The thin + burn treatment units were burned 1 year later (March 2002) to allow the slash to fully cure; ambient temperatures were 18–20 °C, RH 22–56%, and winds from 4 to 7 km/h. For all burns we used strip head fires spaced approximately 10 m apart. Observed flame lengths for both the burn-only and thin + burn units were 0.5–2.0 m. Maximum fire temperature was measured using heat-sensitive paint applied to ceramic tiles hung 0.8 m above the ground along the center-line of the vegetation plots (n = 5/plot). We recorded maximum temperatures of 253–399 °C in the burn-only plots and 177–253 °C in the thin + burn plots.

2.3. Field sampling

Twelve treatment units were selected on the basis of stand size, tree size distribution, and management history. Stands at least 14 ha in size were selected in order to allow for a 10-ha sampling area plus a buffer (approximately 20 m) to reduce edge effects. Tree size was used as a blocking factor to reduce variability, with blocks defined as: block 1—pulpwood-sized trees (dbh 15–25 cm); block 2—a mixture of pulpwood- and sawtimber-sized trees (dbh >25 cm); and block 3—sawtimber-sized trees. None of these areas had been thinned during the past 10 years and none had been burned (wild or prescribed) in at least 5 years.

Ten 0.1 ha vegetation plots (20 m × 50 m) were systematically placed every 200 m within each treatment unit using permanently marked, geo-referenced locations that had previously been established on a 50 m × 50 m grid. The direction of the long axis of each plot was randomly assigned one of the four cardinal directions (N, S, E, W). Each vegetation plot was subdivided into ten 10 m × 10 m subplots, five of