

EFFECTS OF FUEL-REDUCTION TECHNIQUES ON VEGETATIVE COMPOSITION OF PIEDMONT LOBLOLLY-SHORTLEAF PINE COMMUNITIES: PRELIMINARY RESULTS OF THE NATIONAL FIRE AND FIRE SURROGATE STUDY

Ross J. Phillips, Thomas A. Waldrop, Gregg L. Chapman, Helen H. Mohr, Mac A. Callaham, and Charles T. Flint, Jr.¹

Abstract—As part of the National Fire and Fire Surrogate (NFFS) Study, prescribed burning, thinning, and a combination of burning and thinning were conducted in loblolly (*Pinus taeda* L.) and shortleaf pine (*P. echinata* Mill.) communities in the Piedmont of South Carolina to test the effectiveness of these treatments for fuel reduction. Treatment implementation resulted in an overall reduction of overstory basal area from 28 to 19 m² ha⁻¹, with the largest reduction (10.8 m² ha⁻¹) occurring in the thin-plus-burn treatment. Stem densities decreased by 6332 stems ha⁻¹ in the burn-only treatment, 3330 stems ha⁻¹ in the thin-only treatment, and 5288 stems ha⁻¹ for the thin-plus-burn treatment. Percent cover of understory vegetation differed significantly between burned plots (burn-only and thin-plus-burn) and unburned plots (thin-only and control). Nonmetric multidimensional scaling indicated three distinct vegetative groups. Identification of distinctive communities created by fuel-reduction treatments will help explain changes that may occur in other components of the NFFS Study, such as fuels, fire behavior, and wildlife habitat.

INTRODUCTION

In forests which historically had short fire-return intervals, several factors over the last century; e.g., fire suppression, farm abandonment, climate change, and past timber harvests, have led to forests that have less spatial heterogeneity, a greater abundance of small-diameter trees, and greater fuel loading (Abrams and McCay 1996, Arno and others 1997, Gilliam and Platt 1999). These changes have resulted in an increased likelihood of wildfire, as well as deterioration of forest health. Fuel reduction can be accomplished through mechanical treatments, burning, or a combination of mechanical treatments and burning, but information about the consequences of these treatments on ecosystem health is lacking (Sierra Nevada Ecosystem Project 1996).

The National Fire and Fire Surrogate (NFFS) Study was established to investigate the ecological, economic, and social consequences of fuel-reduction techniques on vegetation, fuels and fire behavior, wildlife, pathogens, insects, soils, and economics and utilization in these forests with frequent low-severity fire regimes. National sampling protocols have been developed and are followed at all study sites, allowing both regional and national comparisons.

This paper examines changes in vegetation composition resulting from fuel-reduction techniques on one of 13 study sites within the national NFFS. This study site is located in the southeastern Piedmont within a loblolly (*Pinus taeda* L.)-shortleaf (*P. echinata* Mill.) pine community. Results presented here are from the first year following treatment implementation.

METHODS

The study site is located at the Clemson Experimental Forest in the Piedmont physiographic province of South

Carolina. The experimental forest covers approximately 7100 ha and is managed by the university for teaching, research, timber production, and recreation purposes. The area is characterized by rolling hills with moderate-to-severe erosion, and soils are primarily of the Cecil-Lloyd-Madison association (Sorrells 1984). Elevation ranges from 200 to 300 m.

Within the Clemson Experimental Forest, 12 treatment areas were selected based on forest type, stand size, stand age, and management history. Loblolly and shortleaf pine communities at least 14 ha in size (comprised of a 10-ha treatment area and a surrounding 20-m buffer) were located using aerial photos and were randomly selected to receive one of four treatments (control, burn-only, thin-only, thin-plus-burn). Treatment areas were blocked by stand age: block 1 consisted of pulpwood-size trees with diameter at breast height (d.b.h.) of 15 to 25 cm, block 3 contained sawtimber-size trees > 25 cm d.b.h., and block 2 had a mix of pulpwood- and sawtimber-size trees. All treatment areas were selected so that time since last thinning or burning was > 10 and > 5 years, respectively.

Ten 0.1-ha sample plots were established within each treatment area. These plots measured 20 by 50 m and were further subdivided into ten 10- by 10-m subplots. Trees (> 10 cm d.b.h.), saplings (< 10 cm d.b.h. and > 1.4 m tall), and shrubs (> 1.4 m tall) were sampled on half of the subplots. D.b.h., status (live, standing dead, dead and down, or harvested), and incidence of beetles or disease were recorded for all trees. Saplings were tallied based on status (live or dead) and size class (class 1—< 3 cm d.b.h., class 2—3 to 6 cm, class 3—6 to 10 cm). Percent cover for each shrub species was estimated within each subplot.

Two 1- by 1-m quadrats were established within each subplot for sampling herbaceous and woody vegetation

¹ Ecologist, Research Forester, Biological Technician, Forester, Research Ecologist, and Biological Technician, USDA Forest Service, Southern Research Station, Clemson, SC 29634, respectively.

Citation for proceedings: Connor, Kristina F., ed. 2004. Proceedings of the 12th biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-71. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 594 p.

< 1.4 m tall. Within these quadrats, percent cover was estimated for each species using the following cover classes: 1 = < 1 percent, 2 = 1 to 10 percent, 3 = 11 to 25 percent, 4 = 26 to 50 percent, 5 = 51 to 75 percent, 6 = > 75 percent. Treatment means for basal area, stem density, and percent cover of understory species were analyzed using analysis of variance (ANOVA) with $\alpha = 0.05$.

Implementation of the thinning treatment occurred during the winter of 2000–01. The thinning prescription included selective removal of small, merchantable-sized trees and diseased or insect-infested trees. Other trees were harvested as necessary to achieve the target residual basal area of 18 m² ha⁻¹.

Burning occurred in April 2001 and March 2002 for the burn-only and thin-plus-burn treatments, respectively. The prescription for the burn-only treatment called for moderate-intensity surface fires which would result in some overstory mortality. Air temperatures for these fires ranged between 22 and 30 °C with light S. to SW. winds, relative humidity (RH) values between 42 and 56 percent, and 1- to 2-m flame lengths. Strip head fires were used to burn blocks 1 and 2, while a flanking fire technique was used for block 3. For the thin-plus-burn treatments, the prescription was for a low-intensity fire that would kill most of the smaller stems and reduce the midstory. Air temperatures ranged from 18 to 28 °C with light winds from the SE. to SW. RH was between 42 and 55 percent with 1-m flame lengths. Strip head-firing techniques were used for all three blocks.

Nonmetric multidimensional scaling (McCune and Mefford 1999) was used to examine differences in vegetation composition due to treatment effects. Data for shrubs, herbaceous species, and woody vegetation < 1.4 m tall were combined into a single matrix. Rare species, defined as those occurring in only one or two quadrats, were removed from the dataset, and an outlier analysis was performed. Nine quadrats identified as outliers were removed prior to ordination. A secondary matrix also composed of data for shrubs, herbaceous species, and woody vegetation was added into the analysis to examine species correlations with respect to the primary and secondary axes. Ordinations were performed using the “slow and thorough” setting and Sorensen (Bray-Curtis) distance measure in the “auto-pilot” mode to identify the appropriate dimensionality, choose the best solution for each dimension, and test for statistical significance.

RESULTS AND DISCUSSION

Overstory and Midstory Vegetation

Treatments reduced overall basal area from 28 to 19 m² ha⁻¹. The largest decrease in basal area was evident in the thin-plus-burn treatments (10.8 m² ha⁻¹), while the burn-only and thin-only treatments were reduced by 6.2 m² ha⁻¹ (fig. 1). The recent southern pine beetle (*Dendroctonus frontalis* Zimmerman) outbreak in the Southeast influenced mortality rates in both the control plots and burn-only plots. Within one control area, southern pine beetle killed 75 percent of the pines. Burning appeared to weaken the trees, making them more susceptible to pine beetle infestation and mortality. Boyle and others (in press) present southern

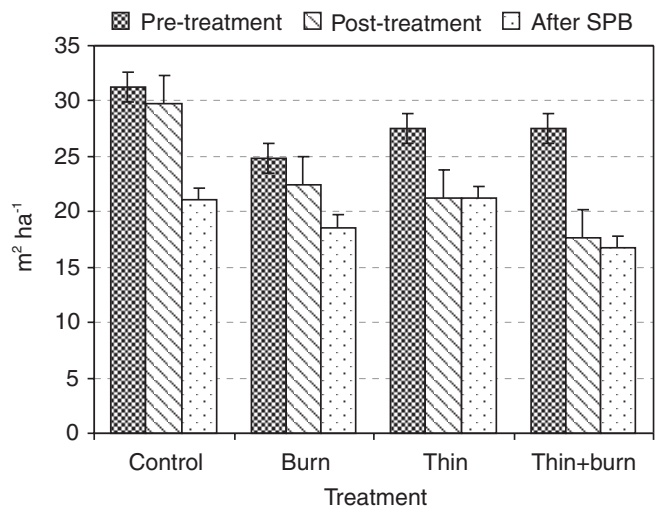


Figure 1—Basal area of overstory trees (d.b.h. > 10 cm) by treatment before and after treatment implementation and southern pine beetle (SPB) effects.

pine beetle impacts for this study. Basal area reduction due to pine mortality was 4.7 m² ha⁻¹ in the burn-only treatment, 5.6 m² ha⁻¹ in the thin-only treatment, and 9.4 m² ha⁻¹ in the thin-plus-burn treatment. Hardwood basal area was reduced 1.5 m² ha⁻¹ for the burn-only, 0.6 for thin-only, and 1.4 for thin-plus-burn treatments.

Significant reductions in stem densities were evident for the burn-only, thin-only, and thin-plus-burn treatments. The burn-only treatment experienced the largest change in stem density, with density decreasing from 10 192 to 3860 stems ha⁻¹ (fig. 2). Most individuals removed were from the 6- and 12-cm d.b.h. classes, which were primarily composed of hardwood species. There was a 70-percent decline in hardwood stems and a 90-percent decline in pine stems in the smallest size class in the burn-only treatment areas. After burning, all stems present in the 6-cm d.b.h. class were hardwood sprouts, except for a few pines in a single subplot that did not completely burn. Stem density in the

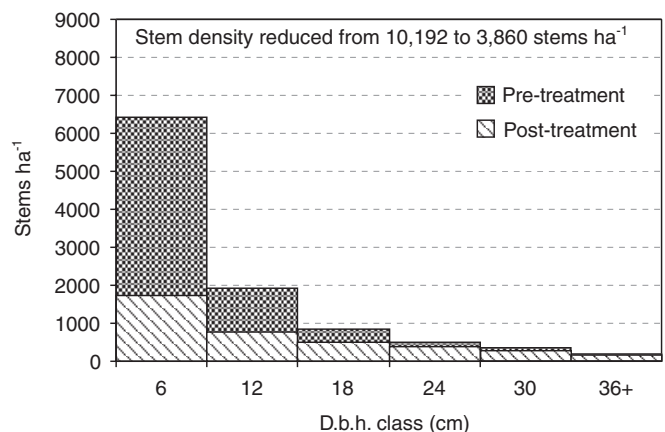


Figure 2—Density of trees before and after treatment in burn-only sample plots.

12-cm d.b.h. class was reduced by about 50-percent, with a 68-percent decrease in hardwood stems and a 47-percent decline in pines. Larger d.b.h. classes also showed some mortality. This treatment had the desired effect of removing some of the overstory as well as significantly reducing the midstory component.

Stem density in the thin-only treatment decreased from 12 536 to 9206 stems ha⁻¹ (fig. 3). Number of stems in the 6-cm d.b.h. class dropped from 8870 to 6272 stems ha⁻¹. Hardwood saplings in this size class declined 29 percent, and pine stems were reduced by 32 percent. The number of stems in the 18 to 36+ cm d.b.h. class was reduced by 30 percent, opening the overstory while leaving a fairly dense midstory.

Overall stem density for the thin-plus-burn treatment declined from 10 350 to 5062 stems ha⁻¹ (fig. 4). Stems in the 6-cm d.b.h. class were reduced from 6464 to 3026 stems ha⁻¹ (hardwoods declined 51 percent and pines were reduced by 88 percent). For the 12-cm d.b.h. class, stem density was reduced by half, from 1654 to 850 stems ha⁻¹. The thin-plus-burn and burn-only treatments had about the same number of individuals in the 6-cm d.b.h. class prior to treatment. Prescriptions for a more intense understory fire

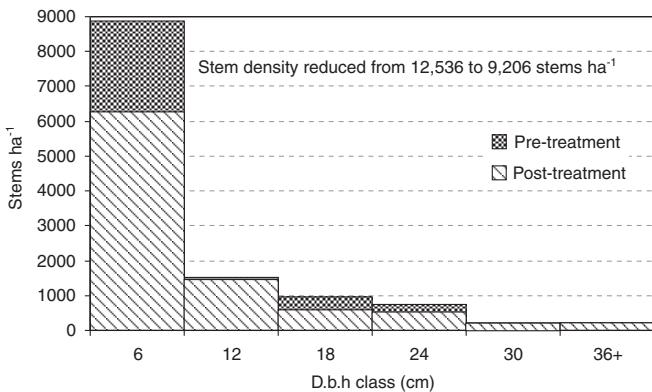


Figure 3—Density of trees before and after treatment in thin-only sample plots.

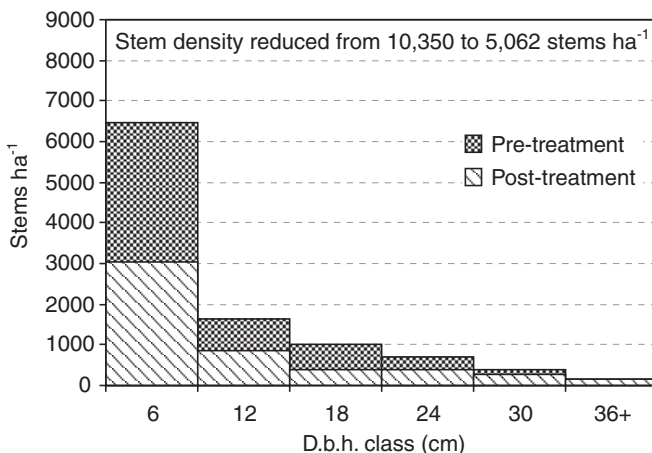


Figure 4—Density of trees before and after treatment in thin-plus-burn sample plots.

in the burn-only treatments reduced stem density in the smallest size class more than the thin-plus-burn treatment. Significant reductions in both the overstory and midstory were achieved in the thin-plus-burn treatment.

Understory Vegetation

Cover of different vegetative life forms < 1.4 m tall varied significantly between burned plots (burn-only, thin-plus-burn) and unburned plots (control, thin-only) (fig. 5). Burn-only plots had significantly greater coverage of forbs, grasses, and trees and less coverage of shrubs and vines than did control plots. The hot fires used for our burn-only treatment reduced overstory basal area and removed significant portions of the midstory, which increased the amount of light reaching the forest floor. They also provided an adequate seedbed for germination of early seral species including fireweed [*Erechtites hieracifolia* (L.) Raf.], other composites, and tree of heaven [*Ailanthus altissima* (Mill.) Swingle]. These burns stimulated sprouting in all hardwoods, particularly oaks (*Quercus* spp.) and hickories (*Carya* spp.).

Compared with untreated controls, the thin-only treatment significantly decreased shrubs, slightly increased forbs and vines, and slightly decreased graminoids and trees (fig. 5). The lack of significant increases in forbs and graminoids and a slight overall reduction in percent cover were unexpected, but were similar to reports by Scherer and others (2000) and Miller and others (1999). Our results may indicate a time lag as understory cover responds to changes in the overstory and/or soil disturbance from thinning machinery (Thomas and others 1999).

In addition to changes in overstory and midstory structure, treatments changed the structure of the forest floor (Waldrop and others, in press). Burning resulted in uniform disturbance of the forest floor, removing the majority of fresh litter and some duff throughout the treatment areas. Disturbance from thinning was more variable, ranging from areas with exposed mineral soil to others with no forest floor disturbance. At least some of the changes in understory vegetation composition can be attributed to these changes in stand and forest floor structure.

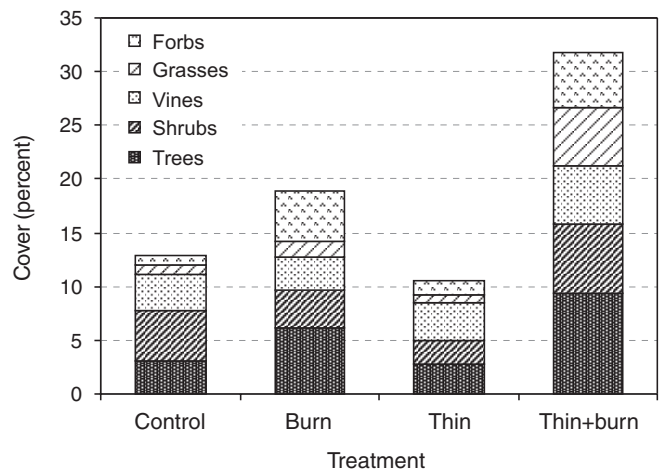


Figure 5—Percent cover of life-form classes for 1-m² quadrats.

Thinning and burning significantly increased cover of all life-form classes (fig. 5). Overstory and midstory components were significantly reduced, increasing the amount of light reaching the forest floor. In combination with burning, this increase in light availability appears to improve the effects of physical disturbance caused by harvesting machinery.

Ordinations showed three main groupings (fig. 6): (1) thin-plus-burn plots cluster toward the upper end of both axis 1 and axis 2; (2) burn-only plots are located midway along axis 1 and at the upper end of axis 2; and (3) thin-only and control plots are dispersed along the mid to lower ends of both axis 1 and axis 2. The primary axis appears to be a treatment effect on species richness with a group of plots, primarily controls, with the lowest species richness values on far left. Moving across this axis to the right, the thin-only plots and burn-only plots occupy the same relative space on the primary axis. Those plots at the far right represent thin-plus-burn plots with the highest species richness. Variation along the secondary axis indicates an association with disturbance intensity. Some thin-only plots received severe disturbance, which exposed bare soil, while others were left virtually untouched, thus accounting for the wide dispersion of these plots along axis 2.

Monitoring of changes will continue in subsequent years to determine whether separation between burned and unburned plots continues. We will also examine whether the thin-only plots show differences from the controls. The future trajectories of these communities will depend upon incidence of disturbance (insects, disease, additional fires)

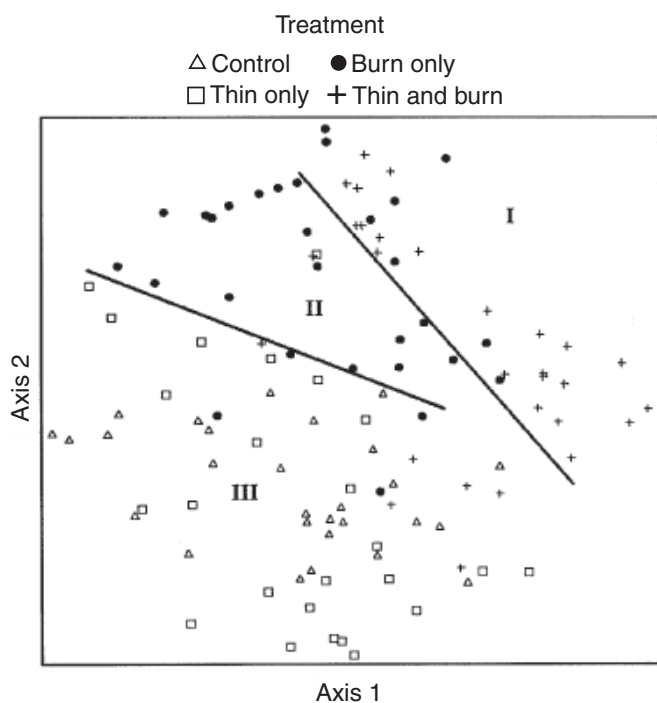


Figure 6—Nonmetric multidimensional scaling ordination for understory vegetation and percent shrub cover.

over the next few years. Identification of distinct communities created by fuel-reduction treatments will help to explain changes in other components of the NFFS Study; e.g., fuels, fire behavior, and wildlife habitat.

ACKNOWLEDGMENTS

This is Contribution Number 33 of the NFFS Project, funded by the U.S. Joint Fire Science Program. The authors express their gratitude to the graduate students and summer interns for all their hard work in the field. We specifically thank Sandra Rideout for her input and technical assistance.

LITERATURE CITED

- Abrams, M.D.; McCay, D.M. 1996. Vegetation-site relationships of witness tress (1780-1856) in the presettlement forests of eastern West Virginia. *Canadian Journal of Forest Research*. 26(2): 217-224.
- Arno, S.F.; Smith, H.Y.; Krebs, M.A. 1997. Old growth ponderosa pine and western larch stand structures: influences of pre-1900 fire and fire exclusion. Res. Pap. INT-RP-495. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 20 p.
- Boyle, M.F., II; Hedden, R.L.; Waldrop, T.A. [In press]. Impact of prescribed fire and thinning on host resistance to the southern pine beetle: preliminary results of the National Fire and Fire Surrogate Study. In: Connor, K.F., ed. Proceedings of the 12th biennial southern silvicultural research conference. Gen. Tech. Rep. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station.
- Gilliam, F.S.; Platt, W.J. 1999. Effects of long-term fire exclusion on tree species composition and stand structure in an old-growth *Pinus palustris* (longleaf pine) forest. *Plant Ecology*. 140(1): 15-26.
- McCune, B.; Mefford, M.J. 1999. PC-ORD. Multivariate analysis of ecological data. Version 4. Gleneden Beach, OR: MjM Software Design. 237 p.
- Miller, D.A.; Leopold, B.D.; Conner, L.M.; Shelton, M.G. 1999. Effects of pine and hardwood basal areas after uneven-aged silviculture treatments on wildlife habitat. *Southern Journal of Applied Forestry*. 23(3): 151-157.
- Scherer, G.; Zabowski, D.; Java, B.; Everett, R. 2000. Timber harvesting residue treatment. Part II: understory vegetation response. *Forest Ecology and Management*. 126: 35-50.
- Sierra Nevada Ecosystem Project. 1996. Summary of the Sierra Nevada ecosystem project report. Wildl. Resour. Cent. Rep. 39. Davis, CA: University of California, Centers for Waters and Wildland Resources. 22 p.
- Sorrells, R.T. 1984. The Clemson Experimental Forest: its first fifty years. Clemson, SC: Clemson University College of Forest and Recreation Resources. 46 p.
- Thomas, S.C.; Halpern, C.B.; Falk, D.A. [and others]. 1999. Plant diversity in managed forests: understory responses to thinning and fertilization. *Ecological Applications*. 9(3): 864-879.
- Waldrop, T.A.; Glass, D.W.; Rideout, S. [and others]. [In press]. An evaluation of fuel reduction treatments across a landscape gradient in Piedmont forests: preliminary results of the National Fire and Fire Surrogate Study. In: Connor, K.F., ed. Proceedings of the 12th biennial southern silvicultural research conference. Gen. Tech. Rep. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station.