

THE NATIONAL FIRE AND FIRE SURROGATE STUDY: VEGETATION CHANGES OVER 11 YEARS OF FUEL REDUCTION TREATMENTS IN THE SOUTHERN APPALACHIAN MOUNTAINS

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Abstract—At the Appalachian site of the National Fire and Fire Surrogate Study, prescribed burning was repeated three times and chainsaw felling of shrubs was done twice between 2002 and 2012. Goals were to reduce fuel loading and to promote restoration of an open woodland community. Chainsaw felling created a vertical fuel break, but the effect was temporary, and no restoration goals for other vegetation were achieved. Prescribed burning opened the canopy only slightly and supported graminoids and oak regeneration for a short time after each burn. The combination of mechanical and burning treatments provided open canopies and removed the shrub layer. Graminoid cover increased and oak regeneration was abundant the year after treatment, but both decreased as sprouts of competing shrubs and trees overtopped them. The burn-only and mechanical-plus-burn treatments show promise for eventually creating an open woodland community. However, treatments may need to be repeated numerous times to reach that goal.

INTRODUCTION

Management of forests in the southern Appalachian Mountains is as difficult as the region is complex. The region is one of the most biologically significant in the United States. Covering over 80 million acres, the Appalachian Plateau, Ridge and Valley Province, and the Blue Ridge Mountains include portions of NC, SC, TN, GA, AL, VA, and KY. The region has high ecosystem diversity because of its wide variety of land types, soils, precipitation levels, and disturbance histories. Some areas have the fastest growing wildland-urban interfaces in the United States; ecosystems are changing and losing key ecological functions because of fire exclusion, and managers have only recently begun to establish guidelines for ecosystem restoration using fire.

The Appalachian region has the largest cluster of public lands east of the Rocky Mountains—and the greatest need for fire management. Prescribed fire is used to restore the historical woodland character of pine-oak and oak-hickory forests. Appalachian hardwood ecosystems were developed by a broad array of natural disturbances, but the role played by natural and anthropogenic fire has not been appreciated until recent years (Brose and others 2001, Waldrop and others 2007). In some areas, prescribed burning is not possible, such as along the wildland/urban interface. Mechanical treatments may prove to be an acceptable surrogate for fire, but little information is available.

In 2000, a team of Federal, State, university, and private scientists and land managers designed the Fire and Fire Surrogate (FFS) study, an integrated national network to address the need for many types of information. The national network included 12 sites on Federal and State lands extending from Washington to Florida. At each site, impacts of fuel reduction treatments were studied on a broad array of variables, including flora, fauna, fuels, soils, forest health, and economics (see Youngblood and others 2005 for a description of the national study). Treatments were designed to restore ecosystems by re-establishing an ecosystem process (fire), stand structure (mechanical fuel reduction), or both. Changes in stand structure can alter ecosystem components such as vegetative diversity (Hutchinson 2006), fire behavior and return interval (Phillips and others 2006), and soil processes (Boerner and others 2008).

Most FFS sites were abandoned after reporting impacts that occurred within 1 year after treatment. However, managers at the FFS site in the southern Appalachian Mountains have been able to continue the prescribed burning treatment on a 3- to 5-year rotation. The primary management objective is to reduce wildfire severity by reducing live and dead fuels. Secondary objectives are to increase oak regeneration and to improve wildlife habitat by increasing cover of grasses and forbs. It may be possible to obtain each of these goals by restoring this community to the open woodland habitats once common

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in these regions (described in syntheses by Stanturf and others 2002 and Van Lear and Waldrop 1989). Fire and mechanical treatments at the southern Appalachian FFS site were designed to restore stand structure to an open woodland condition.

At the southern Appalachian FFS site, two fires and one mechanical treatment over a 6-year period achieved few management objectives, and the need for repeated treatment was evident. Mechanical treatment altered stand structure by eliminating vertical fuels within the shrub layer, but without prescribed burning, this treatment added litter and fine woody fuels that increased several measures of simulated fire behavior (Waldrop and others 2010). Prescribed burning promoted abundant regeneration of hardwood and shrub sprouts (Waldrop and others 2008), but there was no increase in understory species richness or grass cover (Phillips and others 2007). The combined mechanical and burning treatments had not prescribed fires during the first burn that killed some overstory trees, resulting in increased amounts of woody fuels on the forest floor. However, the impact of those fuels was short-lived because this treatment was the most effective at reducing all measures of fire behavior and advancing restoration objectives (Waldrop and others 2010). Understory diversity and grass cover increased for 1 year after each burn but did not persist, as mountain laurel sprouts became competitive (Phillips and others 2007).

The numerous variables measured in the first years of the study strongly indicated that repeated entries of fire and/or mechanical treatments were necessary to reach fire protection, restoration, and wildlife management objectives. This paper examines the impacts of a third fire and a second mechanical treatment to vegetation and forest structure.

METHODS

The Southern Appalachian Mountains site of the FFS study is located in Polk County, NC, on the Green River Game Land, which is managed for wildlife habitat, timber, and other resources by the North Carolina Wildlife Resources Commission. Elevations range from 1100 to 2500 feet. Forests of the study area were 80 to 120 years old, and showed no indication of past agriculture or recent fire. Forest composition is mixed-oak with pitch pine (*Pinus rigida*) and Table Mountain pine (*P. pungens*) on xeric ridges and eastern white pine (*P. strobus*) in moist coves. A dense layer of ericaceous shrubs—mostly mountain laurel (*Kalmia latifolia*) and rhododendron (*Rhododendron maximum*)—is found throughout. Soils are primarily Evard series (fine loamy, oxidic, mesic Typic Hapludults). These are moderately deep, well-drained, mountain upland soils (Keenan 1998).

The experiment was designed as a randomized complete block with three replicate blocks composed of four factorial treatment units. Individual treatment units were 25 to 30 acres in size. All treatment units were surrounded by buffer zones of approximately 10 to 25 acres, and both the treatment unit and its corresponding buffer received the experimental treatment. These treatment units were designed to include all prevailing combinations of elevation, aspect, and slope. However, these conditions varied within experimental units (treatment areas) and could not be separated for analysis. A 164- by 164-foot grid was established in each treatment unit to measure fuels. Grid points were permanently marked and georeferenced. Ten sample plots of 0.25 acres each were established at randomly selected grid points within each treatment unit to measure vegetation.

Treatments were selected to alter stand structure in a manner to reduce fuels, improve density of oak regeneration, and improve habitat for some wildlife species by reducing shrub cover and increasing herbaceous density. Factorial treatments were randomly allocated among treatment units within a site, and all treatment units were sampled through the pretreatment year (2001). Treatments consisted of prescribed burning (B), mechanical fuel reduction (M), a combination of mechanical treatment and prescribed burning (MB), and an untreated control (C). M involved creating a vertical fuel break by chainsaw-felling all tree stems >6 feet tall and <4 inches diameter at breast height (dbh) as well as all stems of ericaceous shrubs, regardless of size. This treatment was accomplished between December 2001 and February 2002. Prescribed fires were applied in B and MB units during March 2003 and again in March 2006. B and MB plots were burned for the third time in winter 2011. Chainsaw felling of small trees and shrubs was completed in early 2012 (January to February) in M units only. The objectives of prescribed burning were to remove vertical fuels and create a few snags. All fires were burned with a spot-fire technique.

Vegetation and fuels data were collected before treatment (2001) and at various years after treatment, depending on the date the treatment was completed. B plots were measured in 2003 (1 year after burning), 2005 (3 years after burning), 2006 (1 year after the second burn), 2011 (1 year before the third burn) and 2012 (1 year after the third burn). M plots were measured in 2002 (1 year after felling), 2004 (3 years after felling), 2006 (5 years after felling), 2011 (1 year before the second felling), and 2012 (1 year after the second felling). MB plots were measured in 2002 (1 year after felling), 2003 (1 year after burning), 2005 (3 years after burning), 2006 (1 year after the second burn), 2011 (1 year before the third burn and second felling), and 2012 (1 year after the third burn and

second felling). C plots were measured every year from 2001 through 2006 and again in 2011 and 2012.

Vegetation data were collected on the 0.25-acre sample plots. Each plot was 164 by 66 feet in size and divided into 10 subplots, each 33 by 33 feet in size. All trees 4 inches dbh or larger were measured in five subplots at each sample date. For each tree, the tree number, species, dbh, and status (i.e., standing live or dead) were recorded. Shrubs >3.3 feet tall were measured on five 33- by 33-foot subplots using ocular estimates of the percentage of area covered by the crowns of each shrub species. Herbaceous cover was estimated for each species in 20 subplots, 3.3 by 3.3 feet in size, within each 0.25-acre plot.

Litter and duff depth and mass were determined by destructively sampling the forest floor at each of the 36 grid points and in the center of each 0.25-acre plot. A square wooden frame with sides 3.3 feet long was used along with a cutter to collect each sample by layer (L and F/H), and each layer was bagged separately. After careful removal of the frame, each layer was measured on each side of the sampled area. Each sample was then washed to remove soil and rocks and dried to a constant weight in an oven set at 185 °F. Litter and duff samples were then weighed in the laboratory.

The down dead-woody fuels were measured before and after treatment using the planar intercept method described by Brown (1974). Three 50-foot transects were established approximately 6 feet from each grid point in a randomly selected direction. This method produced a total of over 70,000 feet of fuel transects.

Analysis of treatment effects on vegetation and fuels was conducted using repeated-measures analysis of variance, with treatment and year modeled as fixed effects and block as a random effect. To account for differences among years, we interpreted significant treatment and (or) treatment-by-year interactions ($\alpha = 0.05$) as evidence of treatment effects, and we made post hoc comparisons using linear contrasts. Because much of the data did not meet the assumption of normality, it was necessary to use data transformations to normalize the distributions. Logarithmic and square root transformations were used in these analyses.

RESULTS

Through 11 years of post-treatment measurement, basal area in C and M treatment areas is gradually increasing as trees grow; there have been no significant differences in basal area between these two treatment areas at any time (fig. 1). The B treatment resulted in the death of a few trees in 2003, and more trees died each year after, especially after the second burn. Basal area (BA) was

significantly lower in B units than in C and M units every year. However, basal area in B units was high throughout the measurement period, remaining near 120 square feet per acre or more. Overstory BA was most affected by the MB treatment. The initial burn was very hot, with flame heights of 10 to 15 feet, because of heavy residual fuels from the mechanical treatment. Some trees died in MB plots during every year after the initial burn. Basal area in these treatment areas was significantly lower than in all other treatment areas during every year. Over time, BA reduced from 119 to 82 square feet per acre in MB plots and may continue to decline with delayed mortality after each burn (Yaussy and Waldrop 2010).

Canopy openness was significantly greater in both B and MB treatment areas than in C areas each year (fig. 2). The MB treatment created the most open canopy by far, and openness there did not change after the initial treatment, remaining at about 29 percent. Even though surviving trees were likely filling open space, delayed mortality was sufficient to prevent canopy closure. In the B areas, openness was greater than in M areas the first year after treatment, but there were no significant differences in any later year, possibly because trees in B areas grew faster from a fertilizing effect of fire and less competition. Openness did not differ significantly between M and C areas at any time. Both M and C areas had increased openness over time, which was attributed to ice storms that occurred in 2005 and 2009 and to mortality of individual trees from unknown sources.

All active treatments reduced shrub cover the first year after treatment, and it remained significantly lower than in C plots throughout the study period (fig. 3). With time, however, shrub cover increased in the M (from 1 to 9 percent) and MB (from 0 to 7 percent) treatments as stump sprouts grew into the minimum size class for measurement. Shrub cover remained at about 4 percent in B plots until the third fire. In the 11th year after initial treatment, the third burn and second mechanical treatment reduced shrub cover to approximately 1 percent in M, B, and MB treatment areas.

Ground cover was reduced by the B and MB treatments the first year after burning, but was not affected by the M treatment without fire (fig. 4). Over time, ground cover in the B and M treatment areas was low and at about the same amount as measured in C plots. Ground cover in MB areas remained significantly higher than in C areas beyond the first year after the initial treatment. Burning and mechanical treatments during the 11th year significantly reduced ground cover in all active treatment areas. At that time, ground cover was significantly higher (40 percent) in MB areas than in all other areas. Ground cover reduced to 24, 23, and 19 percent in C, B, and M areas, respectively; these differences were not significant.

The goal of increasing cover of graminoids was not successful in any of the treatment areas. Although the MB treatment areas had significantly more cover than in other treatment areas, the total was never more than 2 ½ percent (fig. 5). In MB areas, graminoid cover decreased between the second and third burns; the 6 years between these burns was sufficient for shrubs, tree sprouts, smilax, and other plants to grow tall enough to shade out grasses and sedges.

Numbers of oak seedlings and sprouts were stimulated by burning but not by chainsaw felling. Numbers in M areas never differed from those in C areas (fig. 6). However oak regeneration significantly increased after the first burn in B and MB areas and remained significantly higher than in M and C areas throughout the study. A decline in oak numbers that occurred during the 6-year period between the second and third burns suggests the need for more frequent burning. That suggestion is supported by the large increase in oak numbers that occurred immediately after the third fire in B and MB areas.

DISCUSSION AND CONCLUSIONS

Each fuel reduction treatment changed stand structure differently, resulting in different degrees of success in achieving restoration goals. After three burns and two mechanical treatments, none of the treatment areas exhibited all of the characteristics of the target open woodland community.

Chainsaw felling of small trees and shrubs (M) left a dense canopy with little change in canopy openness. The treatment did reduce the shrub layer cover for 7 years; most sprouts did not grow back into the shrub layer (>3 feet) during that time. However, shrub cover increased greatly through year 11. A second treatment in the 11th year reduced the shrub cover to almost zero percent. None of the target variables showed a positive response to this change in structure with the possible exception of fire behavior. Without a shrub layer there was a vertical fuel break, especially after 8 to 10 years, as felled decomposed stems were flat on the ground. Even though there was a reduction in the cover of shrubs, there was not a positive response in forest floor vegetation, graminoid cover, or oak regeneration. This treatment left an intact overstory and forest floor. The best practical use of mechanical shrub felling may be for reducing fuels where prescribed burning is difficult or impossible. Even frequent use of this treatment is unlikely to produce our restoration goals.

Prescribed burning alone produced a two-storied stand structure, similar to that of the mechanical only treatment. The first burn essentially removed the shrub layer, and subsequent burns were frequent enough to keep it low. The canopy layer was thinned somewhat, but basal area

remained high and openness was low. Ground cover, graminoid cover, and oak regeneration increased for a short period after each of the first two fires but declined by the time of the next burn. The structure of the burn-only plots was closer to that of open woodlands than it was before burning, but the restoration objective was not met. An initial burn of high intensity followed by more frequent prescribed burning may be necessary to open the overstory and to maintain gains in graminoid cover and oak regeneration.

The combination of mechanical and burn treatments produced immediate and large reductions to basal area, shrub cover, and ground cover. Stand structure in these areas was closest to the desired open woodland condition, with a 40 percent reduction in basal area and 30 percent canopy openness. However, understory shrubs, tree sprouts, and herbaceous plants quickly claimed the open forest floor and prevented successful growth of graminoids and oaks. These results agree with the substantial body of literature stating restoration will require numerous fires occurring more frequently than every 3 years.

Even though the stand structures produced in this study largely did not support desired objectives for most variables, progress was observed after prescribed burning, particularly when burning was done in combination with chainsaw felling of the shrub layer. With frequent burning, the MB areas may eventually support an open woodland community. These areas have an open canopy and improved wildlife habitat. Frequent burning will be needed for fuel reduction and spread of graminoids and oaks.

The Appalachian site of the National Fire and Fire Surrogate continues to be an important source of information about fire effects in this region, where prescribed fire is relatively new and little research is available. The study remains active with current efforts to continue treatments and follow their impacts on vegetation, fuels, soils, herpetofauna, and avifauna.

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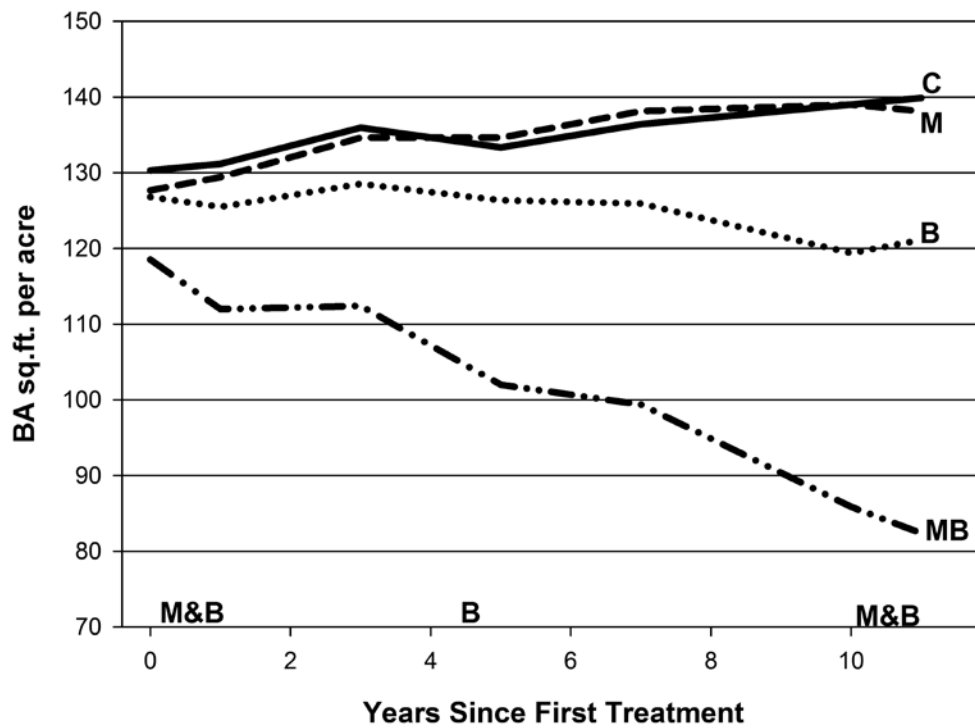


Figure 1—Change in basal area over the number of years since the first treatment. Letters by each line represent the treatment (C=untreated control, B=burn only, M=mechanical only, MB=combined mechanical and burn treatments). Letters along the X axis show the timing of each treatment.

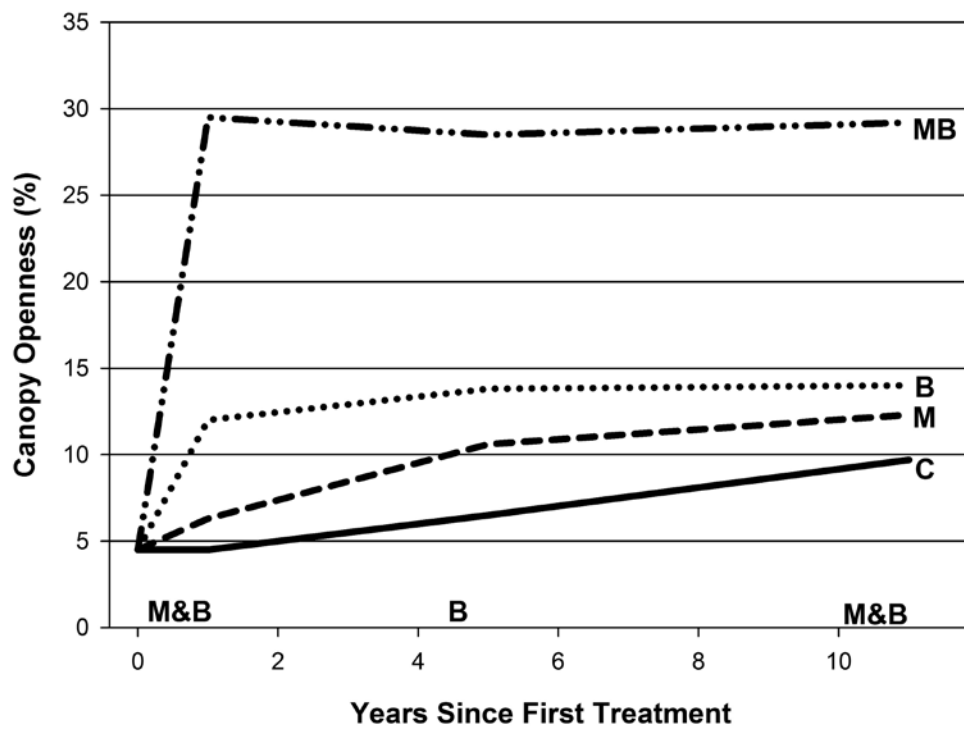


Figure 2—Change in canopy openness over the number of years since the first treatment. Letters by each line represent the treatment (C=untreated control, B=burn only, M=mechanical only, MB=combined mechanical and burn treatments). Letters along the X axis show the timing of each treatment.

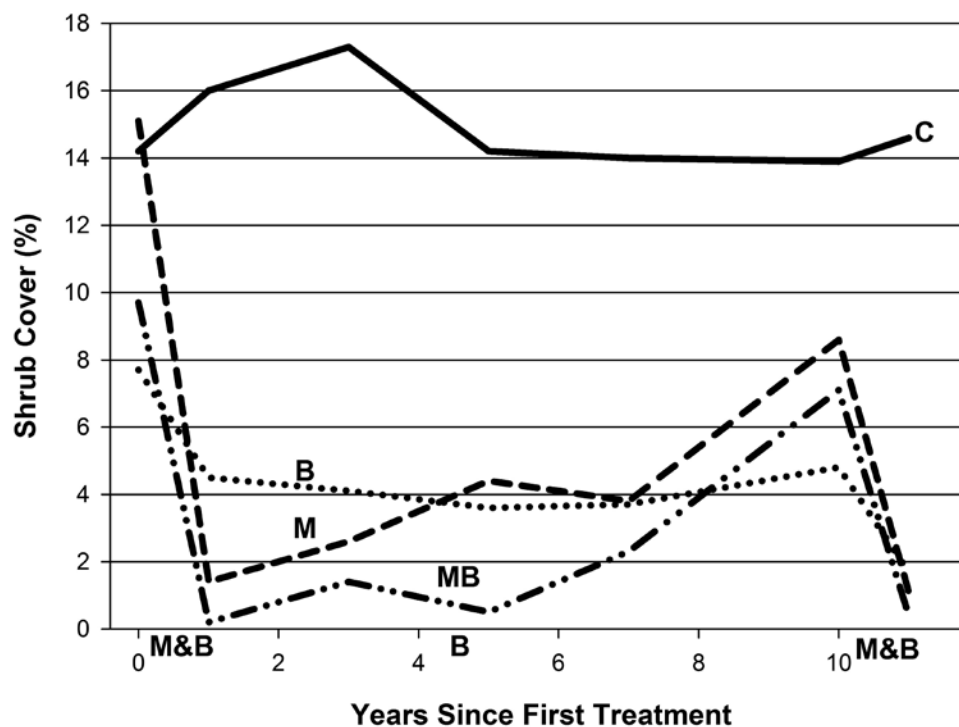


Figure 3—Change in shrub cover over the number of years since the first treatment. Letters by each line represent the treatment (C=untreated control, B=burn only, M=mechanical only, MB=combined mechanical and burn treatments). Letters along the X axis show the timing of each treatment.

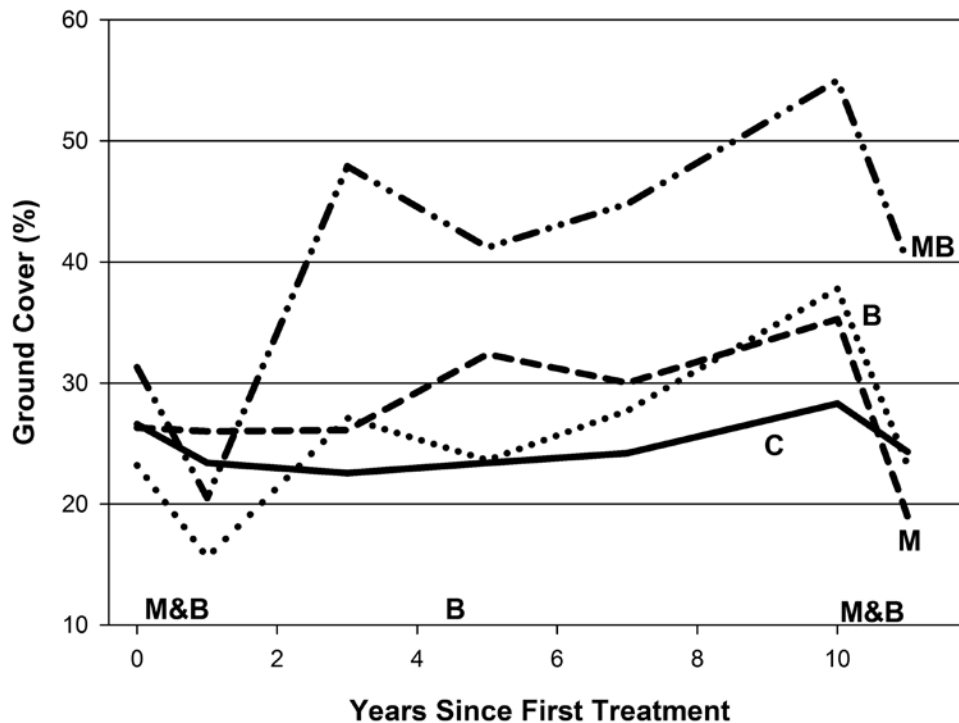


Figure 4—Change in ground cover over the number of years since the first treatment. Letters by each line represent the treatment (C=untreated control, B=burn only, M=mechanical only, MB=combined mechanical and burn treatments). Letters along the X axis show the timing of each treatment.

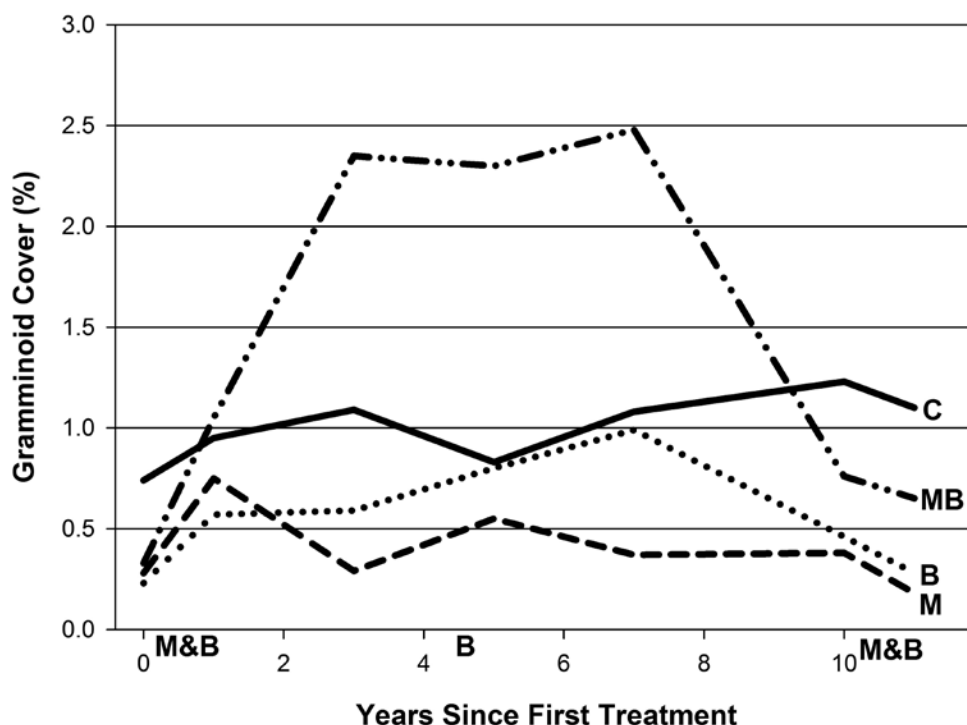


Figure 5—Change in Gramminoid cover over the number of years since the first treatment. Letters by each line represent the treatment (C=untreated control, B=burn only, M=mechanical only, MB=combined mechanical and burn treatments). Letters along the X axis show the timing of each treatment.

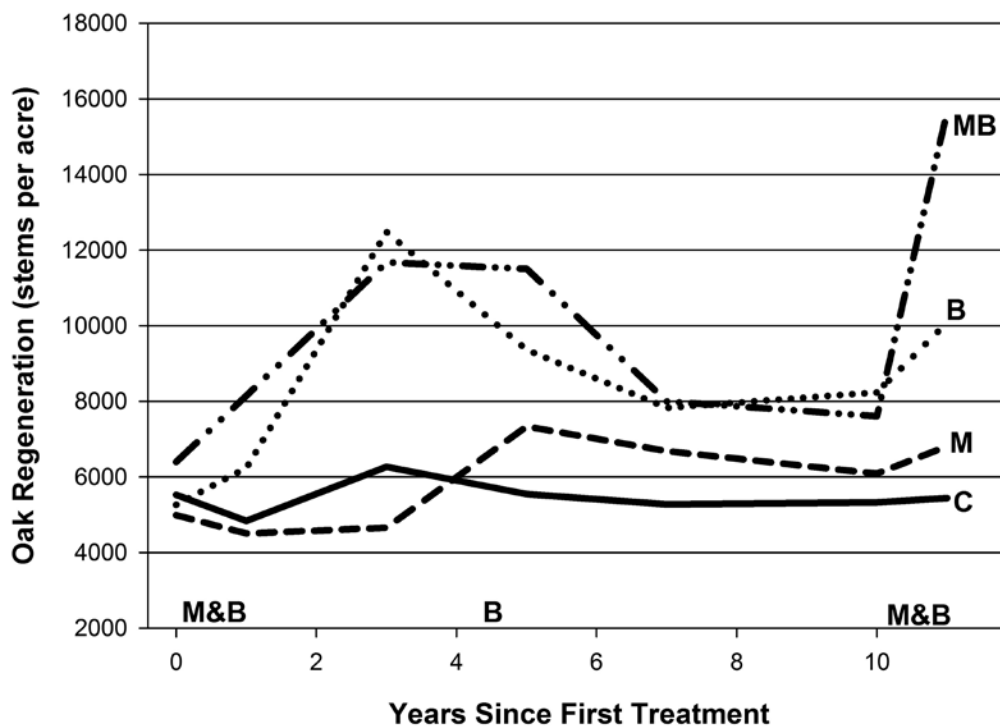


Figure 6—Change in density of oak regeneration over the number of years since the first treatment. Letters by each line represent the treatment (C=untreated control, B=burn only, M=mechanical only, MB=combined mechanical and burn treatments). Letters along the X axis show the timing of each treatment.