Using Fire to Restore Pine/Hardwood Ecosystems in the Southern Appalachians of North Carolina

**James M. Vose[1], Wayne T. Swank[1], and Barton D. Clinton',
Ronald L. Hendrick[2] and Amy E. Major[2]**

'*USDA Forest Service, Southern Forest Experiment Station, Coweeta Hydrologic Laboratory
3160 Coweeta Lab Rd., Otto, NC 28763*
Tel. (704) 524-2128; Fax (704) 369-6768

[2]*School of Forest Resources, University of Georgia, Athens, GA 30602*

Introduction

In the southern Appalachians, mixed pine/hardwood ecosystems occupy the most xeric sites (i.e., south/west aspect ridge sites). They are typically comprised of varying proportions of pitch pine (*Pinus rigida*), virginia pine (*Pinus virginiana),* and/or shortleaf pine (*Pinus echinata)* and a mixture of hardwoods, including scarlet oak (*Quercus coccinea),* chestnut oak (*Quercus prinus*)*,* and red maple (*Acer rubrum*). Mountain laurel *(Kalmia latifolia), an* evergreen ericaceous shrub, is a major component of these ecosystems. While the pine/hardwood ecosystem is limited in extent (e.g.,<5% of the landscape in the southern Appalachians), it is a unique vegetation type that provides important habitat for both flora and fauna.

The pine component of many of these pine/hardwood ecosystems is in a serious state of decline. Smith (1991) determined that 98% of the pine/hardwood stands at the Coweeta Hydrologic Laboratory in western North Carolina have little or no remaining live pine. Smith's study showed that pine has been declining since the early 1970's; however, a major loss of pine occurred in the mid 1980's. This loss is coincident with a severe drought in the region (Swift et al. 1989) which weakened trees and caused widespread and severe southern pine beetle infestations.

The initial origin of many mixed pine/hardwood stands in the Southern Appalachians is largely a result of past agricultural activities which created microsite conditions conducive to pine regeneration (i.e., mineral soil, limited competition) (Whittaker 1956, Nicholas and White 1984). However, many of these stands are located on sites which could not be cultivated due to steep topography and poor soils and fire has been advanced as the major factor determining their origin. In either case, the maintenance of pine/hardwood ecosystems is hypothesized to depend on intense wildfiies (Barden and Woods 1976). Because pine/hardwood sites are typically dry, hot, and contain substantial quantities of flammable fuels (Vose and Swank 1993), natural or human-caused fires have the potential for the high intensity fire necessary for pine regeneration (Barden and Woods 1976).

Fire suppression has limited the role of either human-caused or natural fires in perpetuating these ecosystems. While fuel loads in these stands are currently substantial (due to pine mortality and large amounts of mountain laurel), fire suppression efforts will continue to limit the extent of intense wildfires in these ecosystems, even during dry conditions. As an alternative, silvicultural treatments may have equal success in regenerating these stands. Over the past 10 to 20 years, some of these degraded pine/hardwood stands have been chainsaw felled, burned, and planted to white pine (*Pinus strobus*) in an attempt to increase overall site productivity (Swift et al. 1993). Previous studies have shown that this treatment also increases the density of other pine species more typical of the site (i.e., *Pinus rigida, P. Virginia, and P. echinata)* (Vose et al. 1994). However, imposing these treatments is expensive (e.g., $ 200 per hectare) and there are some uncertainties about long-term effects on site productivity because of the amount of organic matter and associated nitrogen these fires consume (Vose and Swank 1993). As an alternative, we have initiated research on the use of prescribed "stand replacement" fires to restore degraded pine/hardwood stands. In this application, the objective of the fire is to produce a high intensity fire (i.e., a simulated wildfire) sufficient to produce seedbed conditions for pine seed germination and reduce mountain laurel vigor to allow for seedling establishment. This approach has only recently been applied in the southern Appalachians and very little is known about ecosystem responses to this prescription.

Our objective is to compare the effectiveness of the fell and burn method with stand replacement techniques for restoring pine/hardwood ecosystems in the southern Appalachians of North Carolina. This is accomplished by comparing pine regeneration and overstory composition among an unburned reference site, a 13-yr-old fell and burn site, a 25-yr-old wildfire site, and a stand replacement fire site. We also briefly compare the effects of burning on aboveground nitrogen (N) pools.

Approach

We use data and results from three studies to accomplish our objectives. To assess the effectiveness of the fell and burn vs. stand replacement burning on pine regeneration and stand composition, results from Vose et al. (1994) are used to compare pine seedling and sapling densities of a 13-yr old fell and burn treated stand, a 25 yr-old stand originating after a wildfire, and a unburned reference stand. To compare the effects of the two burning techniques on aboveground N pools, we use data from Vose and Swank (1993) for the fell and burn treatment and preliminary data from the stand replacement burn described below. Methods of measurement and overall study design for both studies are described in Vose et al. (1994), Swift et al. (1993) and Vose and Swank (1993).

Several studies of ecosystem responses to stand replacement burning have been initiated on a 200 ha study site in the Nantahala National Forest in Western North Carolina. Specifically, studies include measures of vegetation response, changes in mass and nutrient pools, fire characterization, effects on forest floor insects, and small mammal responses. In this paper, we report preliminary data on fire characterization, pine regeneration, overstory composition, and changes in nitrogen pools. We located permanent plots in ridge, mid-slope, and lower slope positions and measured species composition (overstory and seedlings) and mass of humus, forest floor, and downed wood before and after burning. Mass loss was converted to nitrogen (N) loss using the N to mass loss ratios presented in Vose and Swank (1993). Fire intensity (1 m aboveground) was determined using heat sensitive paint (OMEGA marker; temperature range of 50 to 800 "C) applied to ceramic tiles co-located with each mass consumption measurement plot. In this paper, we only use data from the ridge plots because this is the topographic position where the pine/hardwood ecosystem type is dominant.

Description of Burning Techniques

The fell and burn treatment was developed by Abercrombie and Sims (1986) for pine/hardwood ecosystems in the mountain region of South Carolina. As originally conceived, merchantable products are removed and all other vegetation felled in the spring after leaf-out, followed by a mid-summer burn which consumes slash and sprouting vegetation. In our study examining nutrient pool responses (Vose and Swank 1993). vegetation was felled in the early summer of 1990, no merchantable products were removed (due to low volume), and the sites were not burned until September 1990. Three sites (approximately 5 ha each) were chosen for study. Averaged across all sites, pre-bum fuel loadings were 11, 23, and 138 Mg ha-' for litter, humus, and downed wood, respectively.

Sites were burned in mid-September using headfiies ignited at the lower cutting boundary. Mean peak flame temperature was 7 12 °C (Swift et al. 1993) and fuel consumption was 85, 8, and 55 % for litter, humus, and downed wood, respectively (Vose and Swank 1993). The burning resulted in a relatively uniform consumption of fuels across the study areas.

The stand replacement fire was conducted in April, 1995, prior to leaf expansion of most tree species. The fire was ignited by helicopter, with strip head fires applied at lower slope (i.e., riparian zone) and mid-slope positions. The fire moved rapidly upslope into the ridge position. Prior to lighting the headfires, a backfire was set along the ridgeline to provide a firebreak. Creeks and a paved road provided fire breaks on all other sides of the burned area. Pre-burn fuel loadings in the ridge position were 5, 20, and 16 Mg ha^{-1} for litter, humus, and downed wood, respectively. Standing vegetation biomass was not directly measured; however, typical values for sites of similar stocking and species composition is approximately 150 Mg ha-'. Peak flame temperature ranged from 80 to > 800 °C, resulting in a mosaic of fire intensities throughout the ridge and entire study area (Figure 1). Average fuel consumption in the ridge plots was 42, 4, and 25 % for litter, humus, and downed wood, respectively. Very little (< 10%) of the standing vegetation was consumed in the fire.

Pine Regeneration

Both the fell and burn and stand replacement fires resulted in increased pine regeneration (Figure 2). For the 13-yr-old fell and burn treatment and the 25-yr-old wildfire treatment, seedling and sapling densities (excluding planted white pine) of approximately 1000 per ha' represent a lo-fold increase over the unburned reference stand. Substantially more seedlings were present prior to burning on the stand replacement site (i.e., 1000 per ha-l) and burning resulting in a 5-fold increase in the first summer after burning. By September, seedling mortality had decreased seedling density to 3-fold greater than pre-burn. These results indicate that the stand replacement fiie stimulated pine seedling germination. The much greater pre-bum seedling density and post-fire seedling density was probably related to the large number of live pine in the overstory on the stand replacement burn site (see next section). The increased germination is attributed to improvement of microsite characteristics for pine seed germination on the ridge (i.e., reduced litter layer). We also observed a large number of cones on the forest floor which opened and released seed after the fire (pitch pine produces both serotinous and non-serotinous cones). The differences in seedling density between the fell and burn, wildfire, and stand replacement burning cannot be directly compared because of the differences in years since treat-
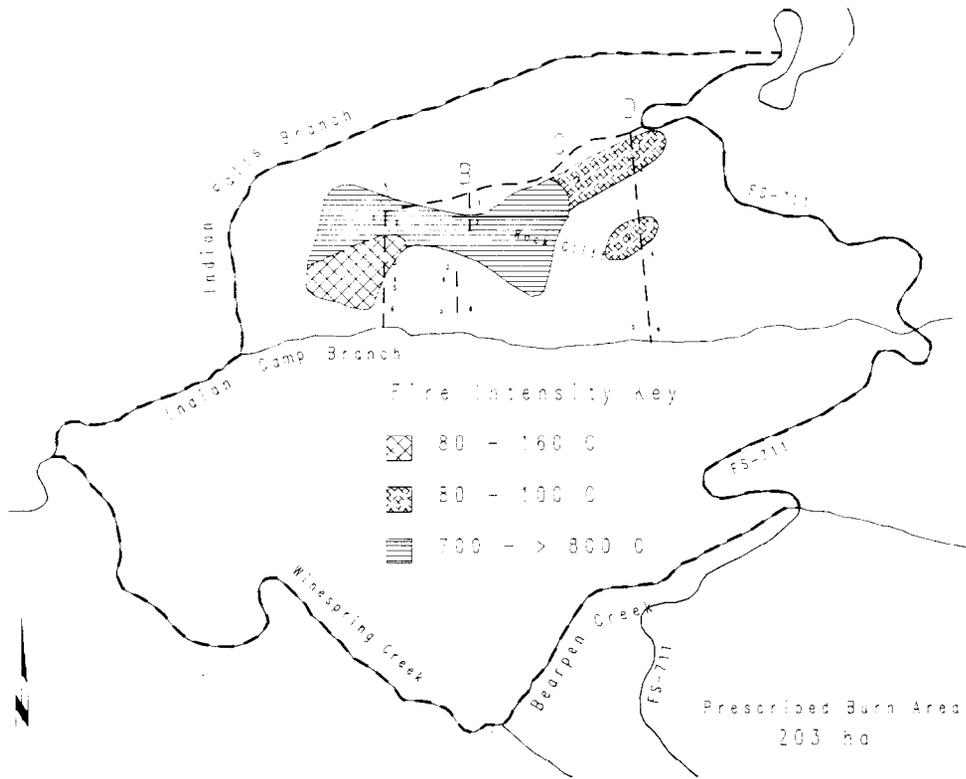
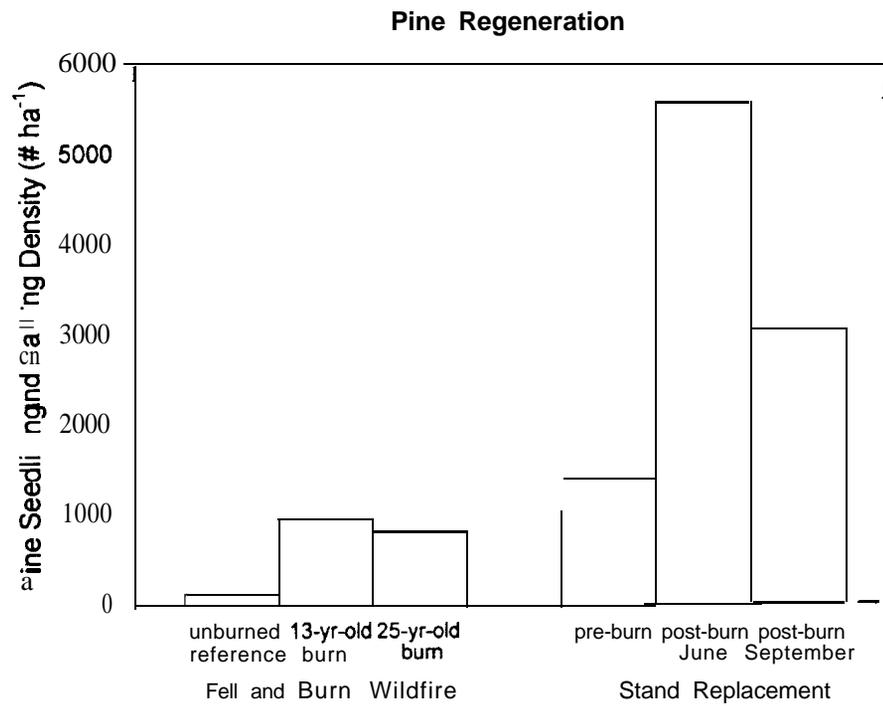Figure 1. Fire intensity across prescription area.

Pine Regeneration

Figure 2. Pine seeding and sapling (<10 cm dbh) density(#ha^{-1}) response to fell burn, wildfire, and stand replacement burning. Stand replacement burning represents the response in the first year after burnmg.

ment. However, it appears that the stand replacement fire has the potential to equal or exceed pine regeneration success with the fell and burn treatment, and to mimic regeneration after wildfire. Reduced vigor of mountain laurel (i.e., mountain laurel biomass was reduced by 70 % after burning), which is a major competitor for light and perhaps other resources, should improve the establishment success of the pine **seedlings.** We will continue to follow the successional dynamics of the stand to assess the longer term responses.

Overstory Composition

The stand replacement site had an overstory composition similar to the fell and burn treatment site and the wildfire site prior to and after burning (Figure 3). For example, in all three stands, pine comprised more than 70 % of the total overstory density. The site chosen for stand replacement burning was purposely selected to include a substantial live pine overstory to provide a seed source for regeneration. Hence, the high density of both pre-bum and post-burn seedling densities reflects the greater availability of seed in stands which have a sub-

stantial live pine component. In stands of this type, the primary effect of stand replacement fiie on the site will be to perpetuate pine in the overstory. The overstory composition in the reference stand was markedly different, with pine comprising only 20 % of the overstory density. This overstory composition is typical of most pine/hardwood communities in the southern Appalachians, where the pine have declined substantially due to drought related insect infestations. In this case, fires are required to reintroduce, rather than perpetuate, the pine component.

Effects on Aboveground Pools

Nitrogen is the most commonly limiting nutrient in forest ecosystems. The responses to burning on aboveground N pools are an indicator of the severity of fire effects. There were substantial differences in the effects of the two burning treatments on aboveground N pools (Figure 4). In terms of total pools (excluding soils), losses from the fell and burn treatment were four-fold higher than from the stand replacement burn (i.e., 300 vs 75 kg ha^{-1} for fell and burn and stand replacement **fires,** respectively). The primary reason for the high N losses
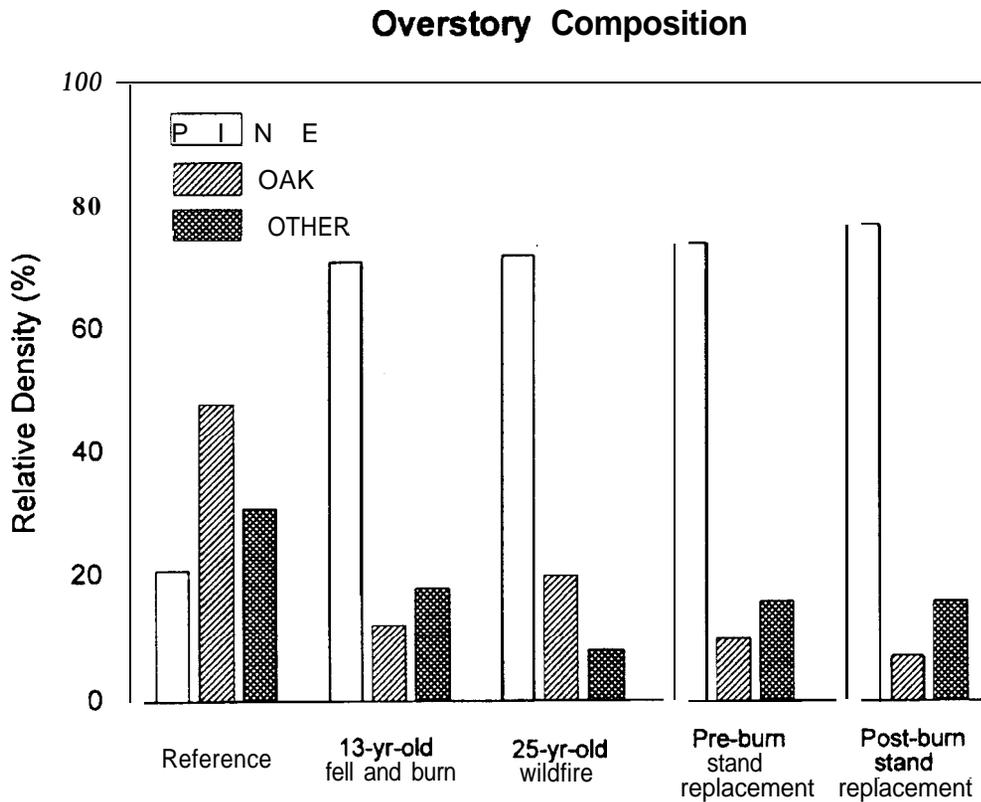

Overstory Composition

Figure 3. Overstory composition by fire type and major species groups.
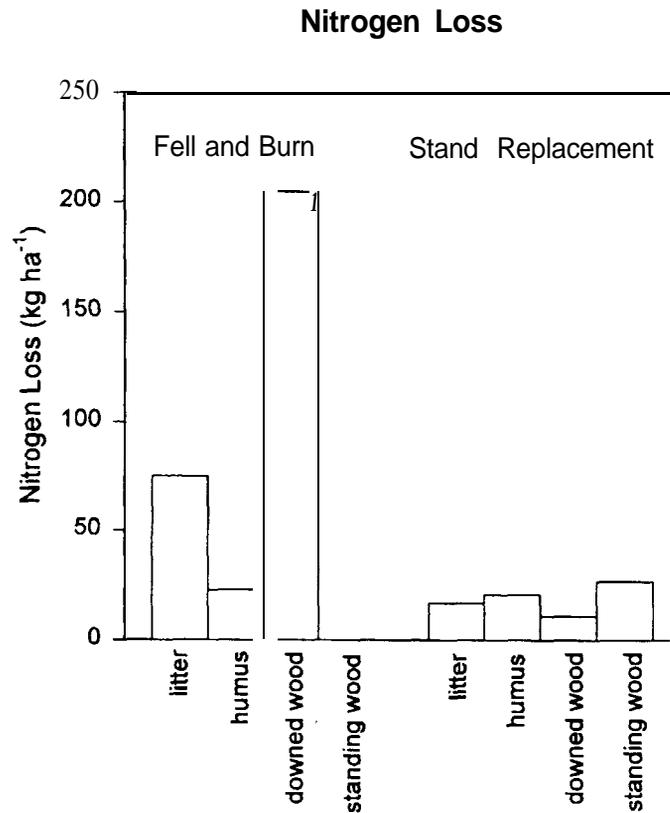
Nitrogen Loss

Figure 4. Losses of N (kg ha^{-1}) by pool type and fire type. Standing wood loss is zero in fell and burn and estimated in stand replacement.

on the fell and burn treatment is that cutting and curing the vegetation increases the downed wood pool size and consumption. While most of the N contained in wood is relatively unavailable, there are potential long-term implications for reduced productivity. Much less N is lost in stand replacement fires because standing, living vegetation is only partially consumed by the fire. While many of these trees may subsequently die, the N contained in the woody tissue will be recycled within the ecosystem.

Management Implications

Our preliminary results indicate that both the fell and burn treatment and the stand replacement treatment increase pine regeneration and create a mix of species comparable to wildfire derived communities. However, there are several advantages, disadvantages, and unknowns associated with the treatments. The primary advantages of the fell and burn treatment are that fires are easy to control and prescribe, products can be removed, and planting of either yellow pines or white pine can be used to supplement the natural pine regeneration. Disadvantages include high cost, uniform effects across the stand, and potentially

high N losses. For the stand replacement fires, advantages include lower N losses, lower cost, and creation of a mosaic of effects in response to variation in fire intensity and severity across the site. The primary disadvantages are the difficulty in applying the prescription (i.e., selecting burning conditions to avoid the fire escaping) and the limited opportunity for additional management in terms of product removal and planting. There are also several unknowns common to both treatments. For example, what are the long-term effects ? In particular, will the vigor of mountain laurel be sufficiently reduced to allow establishment ? Similarly, are there enough pine seedlings to adequately perpetuate or re-introduce the pine component in these systems? What is the appropriate return interval ? For the stand replacement fires, a major question remains about the effectiveness of the treatment in stands without a significant live pine component. Pitch pine seeds remain viable in the litter for about one year, so seed pools will decline rapidly as the pine overstory dies. Hence, a key question is whether a large scale stand replacement burn (i.e., 100 ha), such as conducted here, will have an adequate seed supply from surrounding areas to adequately re-establish pine on the site.

References

Abercrombie, J.A., Jr.. and D.H. Sims. 1986. Fell and burn for low cost site preparation. For. Farmer. 46:14-17.

Barden, L.S. and F.W. Woods. 1976. Effects of fire on pine and pine-hardwood forests in the southern Appalachians. For. Sci. 22:399-403.

Nicholas, N.S. and P.S. White. 1984. The effect of southern pine beetle on fuel loading in yellow pine forests of Great Smoky Mountains National Park. USDI National Park Service, Research/Resource Management Report SER-73. Gatlinburg, TN. 3 1 pages.

Smith, R.N. 1991. Species composition, stand structure, and woody detrital dynamics associated with pine mortality in the southern Appalachians. M.S. Thesis. University of Georgia, Athens, GA. 163 pages.

Swift, L.W. Jr., JB. Waide, and D.L. White. 1989. Refinements in the Z-T method of extreme value analysis for small watersheds. P. 60-65 In Proceedings of the Sixth Conference on Applied Climatology, Charleston, SC March 7-10, 1989. American Meteorological Society, Boston, MA.

Swift, L.W. Jr., K.J. Elliott R.D. Ottmar, and R.E. Vihnanek. 1993. Site preparation burning to improve southern Appalachian pine-hardwood stands: fire characteristics and soil erosion, moisture, and temperature. Canadian Journal of Forest Research 23: 2242-2254.

Vose, JM. and W.T. Swank. 1993. Site preparation burning to improve southern Appalachian pine-hardwood stands: aboveground biomass, forest floor mass, and nitrogen and carbon pools. Canadian Journal of Forest Research 23: 2255-2262.

Vose, J.M., W.T. Swank, and B.D. Clinton. 1994. Fire, drought, and forest management influences on pine/hardwood ecosystems in the southern Appalachians. pages 232-238 In Proceedings of the 12th Conference on Fire and Forest Meteorology, October 26-28. 1993. Jekyll Island, GA.

Whittaker, R.H. 1956. Vegetation of the great Smoky Mountains. Ecol. Mono. 26: 1-80.