BURNING IN SOUTHERN APPALACHIAN LOGGING SLASH--

EFFECTS ON RESIDUAL VEGETATION AND REGROWTH[1/]

S. J. Danielovich, D. H. Van Lear,
S. K. Cox, and M. K. Augspurger[2/]

Abstract.--An intense site-preparation burn was applied during late summer following harvest of a mature mixed pine-hardwood stand in the Southern Appalachian Mountains of South Carolina. On plots where residual trees were left standing, burning top-killed 64 percent of the residual hardwood basal area. Frequency of top-kill increased with decreasing stump diameter. Height of competing sprouts one year after burning was reduced by about 0.15 m, but number of sprouts of the hardwood coppice tended to increase on burned plots where residuals were felled. Above-ground biomass of herbaceous vegetation on burned plots was twice that on unburned plots in the first year after treatment. Results suggest that felling residuals prior to burning, rather than attempting to kill standing residuals with fire, may provide more favorable long-term growth conditions for the new stand. Additional research on effects of intense site preparation burning on ecosystem responses is warranted.

Keywords: prescribed fire, pine-hardwood stands.

INTRODUCTION

The high cost of cultural activities is a serious obstacle to management of low-quality pine-hardwood stands in the Southern Appalachians (McGee 1982). If conversion to pure pine or stands with a large pine component is desired, substantial costs are required to remove or reduce logging debris and control vegetative competition. Pure pine stands are difficult to establish on cutover hardwood-occupied lands, due primarily to the tenacity of hardwood root stocks. Such sites may best be managed as mixed pine-hardwood stands (Sims et al. 1981, Zahner 1982).

Planting pines on cutover hardwood or mixed pine-hardwood sites is difficult without site preparation to reduce logging debris. Broadcast burning is increasingly used in the Southern Appalachians as a low-cost site preparation method for establishment of mixed pine-hardwood stands. The U.S. Forest Service currently fells residual stems on the Sumter National Forest after leaf-out in late May and burns in July or August after foliage has sufficiently cured to carry the fire.

Under-burning in pine stands is effective in top-killing small hardwood stems up to about 6 cm in diameter (Ferguson 1961, Langdon 1981a). However, little information is available regarding effects of high-intensity site-preparation burns on larger residual stems. If broadcast burning of logging debris would kill stems and crowns of standing residuals, the felling of such stems would be unnecessary. Information is also lacking concerning response of woody sprouts and herbaceous vegetation to high intensity burning in the mountains. This paper reports on vegetative response to intense site preparation burning in the Southern Appalachians.

[1/] Paper presented at the Sixth Central Hardwood Forest Conference, Knoxville TN, February 24-26, 1987.

[2/] Former graduate assistant, professor, and agricultural science associates, respectively, Department of Forestry, Clemson University, Clemson, SC 29631.

METHODS

Study Area

The study site was located in Oconee County, S.C., on the Sumter National Forest in the Southern Appalachians. The region is transitional between the central deciduous forest and the prevailingly evergreen forests of the Southeast and lies within the Oak-Pine region as described by Braun (1950). A series of coves, slopes, and ridges yielding relatively steep terrain characterizes the general topography of the area. Elevation is about 600 m above sea level.

Merchantable timber was commercially harvested on 17 ha of the study area in the fall of 1983. Commercial timber harvest was followed by firewood cutting in which most of the large cull hardwood trees were removed. The harvested stand was of poor quality and averaged 22 m^2/ha of basal area (71% hardwood and 29% pine). Major hardwood overstory species were scarlet (Quercus coccinea Muenchh.), white (Q. alba L.), northern red (Q. rubra L.), southern red (Q. falcata Michx.), black (Q. velutina Lam.), blackjack (Q. marilandica Muenchh.), chestnut (Q. prinus L.), and post (Q. stellata Wangenh.) oaks. Mid- and understory hardwoods were red maple (Acer rubrum L.), blackgum (Nyssa sylvatica Marsh.), dogwood (Cornus florida L.), sourwood (Oxydendron arboreum L.), persimmon (Diospyros virginiana L.), and black cherry (Prunus serotina Ehrh.). Yellow-poplar (Liriodendron tulipifera L.), hickories (Carya spp.), and sassafras (Sassafras albidum Nutt.) are frequent in the oak-pine region but were not abundant in the harvested stand. Shortleaf pine (Pinus echinata Mill.) was the major pine overstory species.

Slopes ranged from 21 to 43 percent with southerly and northerly aspects and lengths averaging 70 m. The predominant soil was the Evard series, a fine-loamy, oxidic, mesic Typic Hapludult (SCS 1983) formed in residuum weathered from granite, gneiss and schists. Minor inclusions of colluvial soil were present at the toe of slopes. The soil profile indicated past agronomic use and previous erosion losses.

Study Design

Twelve 900 m^2 (.09 ha) plots were established following harvest. Four replications of three treatments were established in a randomized complete block design. Each block occupied an area of uniform slope and aspect. Treatments were:

(A) Clearcut, residuals felled, no burn (control),
(B) Clearcut, residuals standing, summer burn, and
(C) Clearcut, residuals felled, summer burn.

Burning Methods

Prescribed burning was conducted on August 24, 1984, about 1 week after a soaking rain. Burning began at 12:00 EDT when air temperature was 28°C, relative humidity 47%, and winds northerly at about 6.4 kmph. Moisture content of 10-hour time-lag fuels (Brown et al. 1977) was 10% on the harvested area when burning began. Fire lines had been plowed around control plots in each of the four blocks where fire exclusion was necessary. In addition, a pumper truck was available to wet down control lines. Backfiring began on ridges and was followed by strip headfiring, which allowed the fire to burn in strips towards the edges of the clearcut. Flame length averaged 0.5-1.5 m, but numerous hot spots occurred in slash piles producing flame heights from 6-10 m. Burning was completed at 5 p.m.

Field Methods

Residual unmerchantable stems standing after clearcutting and firewood cutting were felled after leaf-out in early June 1984 on the entire clearcut area, with the exception of treatment B plots. Trees left standing on each of the four replicates of treatment B were marked with aluminum tags and recorded by species and stump diameter. In May 1985, 9 months after burning, all residual stems in treatment B plots were categorized by their response to fire:

1. Minimal damage - little if any noticeable treatment effects after leaf-out.
2. Severe damage - sparse leaf development and/or shoot growth at branch tips, generally accompanied with profuse epicormic sprouting along stem.
3. Top-killed - stem indicated complete cessation of visual growth processes.

Individual stumps from winter-cut merchantable and spring-cut residual stems were randomly selected and tagged on treatment A and C plots prior to burning. Total number of sprouts and height and ground-line diameter of the dominant sprout from each sprout clump were tallied by species the following spring.

Species composition and density of hardwood regeneration on treatment areas were sampled in 1 x 20 m transects perpendicular to the contour of the slope. Total number and heights of stems in strip plots were inventoried before burning and early in the following growing season. Herbaceous and perennial vegetation was clipped from ten 1 m^2 randomly located quadrates/plot in August 1985. Vegetation was oven-dried at 70°C and weighed to estimate biomass.

Statistical Analysis

Statistical computations were performed using Statistical Analysis System (SAS) package programs (SAS 1985). Analysis of variance procedures and orthogonal contrasts (Little and Hills 1978) were used to test for differences in composition and quantity of regeneration and herbaceous biomass. Differences were considered significant at the 5 percent level of confidence.

RESULTS AND DISCUSSION

Effects on Vegetation

Treatment effects on residual stems, hardwood regeneration and ensuing perennial and herbaceous vegetation are presented. No information on growth of planted white pine seedlings is presented since this species characteristically exhibits slow growth the first year.

Residual Stems

Density of unmerchantable trees following commercial clearcutting and firewood cutting was 281 stems/ha totaling 3.89 m^2/ha of basal area (Table 1). Miscellaneous hardwood species, consisting primarily of red maple, dogwood, and sourwood, accounted for 53.7 percent of the residual basal area. Red and white oak groups comprised 18.3 and 22.9 percent of the residual basal area, respectively. Mean diameter of residual stems at stump height was 13.4 cm.

Nine months after burning, 64 percent of the total residual stem basal area on treatment B plots was top-killed (Table 1). About 19 percent of the residual stem basal area was minimally affected by burning and may remain an undesirable component of the new stand. An additional 17 percent of the residual basal area was severely damaged, but the final status of these trees is uncertain. Mortality rates may increase over time. Toole (1961) found that fire damaged trees in the floodplain of the Mississippi River died over a five-year period, with greatest mortality during the third year.

Top-kill was more prevalent in the smaller diameter classes, and less successful as diameter increased (Fig. 1). Perala (1974) found similar results after clearcutting in an aspen-mixed hardwood forest in Minnesota. Top-kill of residu trees by fire is generally considered to depend primarily on destruction of the cambium near the ground line, which can be accomplished by attaini a lethal temperature of 54-60°C (Hare 1965). High-intensity fires may also cause mortality by damaging branch tips and by defoliation.

Although these high intensity fires did not kill all standing residuals, they markedly improv the plantability of the site. Woody slash residu was reduced by 38 and 30 percent on treatments B and C, respectively (Danielovich 1986). Most of this reduction occurred in small to medium branch biomass. Large branches and boles of felled residuals were not consumed but did not interfere with the hand-planting of pine seedlings.

The long-term influence of standing residual trees on growth of regenerated pine stands can be severe. Coastal Plain studies indicate that pine growth can be doubled by controlling large overtopping hardwoods at time of regeneration (Langdon 1981b). Overtopping trees can be expected to have adverse effects in developing mixed pine-hardwood stands in the mountains also.

Table 1.--Basal area and density of residual stems on treatment B plots following harvest and their response to burning.

Species Group	Residual Basal Area	Density	Damage 1/		
			Minimal	Severe	Top-killed
	m^2/ha	stems/ha	m^2/ha		
Hickory	.20	17	.00	.04	.19
Miscellaneous	2.09	164	.50	.43	1.31
Red oak	.71	47	.04	.00	.62
White oak	.89	53	.19	.19	.35
Total	3.89	281	.73	.66	2.47

1/ The sum of basal area by damage classes does not exactly equal preburn residual basal area because of different measurement times and rounding errors.

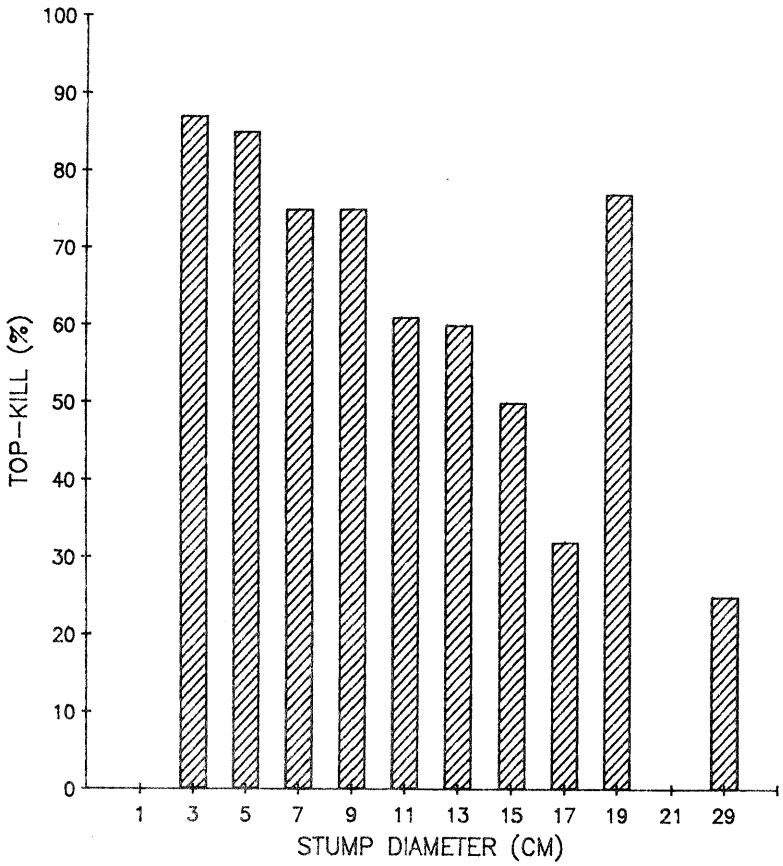

Figure 1.--Top-kill of residual stems by diameter class (cm) at 15 cm above ground following broadcast burning in the Southern Appalachians.

Since about 36% of the residual tree basal area remained alive on treatment B plots after one year, results of this study suggest that felling residual trees prior to burning is preferable over attempts to kill standing residuals with fire. In addition, residuals felled after full leaf-out provide the cured fuels which help carry the fire through the green herbaceous and woody sprout vegetation. Without cured fuels, it would be necessary to burn under much drier conditions, which may cause increased erosion and site damage in steep terrain.

Hardwood Regrowth

Regrowth consisted of seedlings, root suckers and stump sprouts, the latter being by far the most abundant. Regeneration counts tallied one year after burning ranged from 33,000 to 52,130 stems/ha (Table 2). Treatment A (control) averaged 35,290 stems/ha, while the burn treatments (B & C) were 33,000 and 52,130 stems/ha, respectively. Average number of stems on treatment C (residuals felled and burned) was higher than on treatment B (residuals left standing and burned) due to prolific sprouting of stumps of felled residuals.

The 1.5 fold increase in number of sprouts on Treatment C plots over control plots suggests that burning tended to stimulate sprouting. Perala (1974) and Waldrop et al. (1985) reported increases in stem counts after clearcutting and burning. Apparently inhibition of suppressed basal buds at or below the root collar is removed when stool and epicormic sprouts developing higher on the stump are killed by fire. Prolific basal sprouting is often observed when trees are girdled, which results in cessation of auxin control over suppressed basal buds. Although not measured in this study, origin of most sprouts developing after burning is from the root collar or below (Augspurger et al. 1987), a distinct advantage in producing quality hardwood sprouts. Sprouts which form higher on the stump often develop rot and are not well anchored, rendering them poor candidates for crop trees on long rotations (Roth and Sleeth 1939).

One year after burning, individual stem heights averaged 0.85 m in control plots and 0.70 m and 0.71 m in burn treatments B and C, respectively, (Table 2). Height responses of regeneration differed among species groups.

Table 2.--Average density and height of hardwood regeneration and biomass of perennial and herbaceous vegetation on a clearcut site in the Southern Appalachians one year after burning.

Treatment	Hardwood Regeneration Density	Hardwood Regeneration Height	Biomass of Perennial and Herbaceous Vegetation
	stems/ha	m	T/ha
(A) Control	35,290	.85	1.45
(B) Residuals standing-Burn	33,000	.70	2.65
(C) Residuals felled-Burn	52,130	.71	2.91
Std. error	4,960	.03	.21
Contrasts	F-values (1,6) df		
A vs C	5.78	.15	.84
A vs B + C	7.46[1/]	13.35[1/]	28.22[1/]

[1/] Significant at the 5 percent level.

White oak sprouts were 0.25 m shorter on burned plots while heights of red oak sprouts did not differ between burned and control plots. Height of the miscellaneous hardwood group on burned plots was 0.27 m shorter than that on control plots. Although height reduction was slight, this initial reduction may benefit establishment and subsequent growth of planted pine seedlings. Measurements over the next five years will be needed to substantiate this speculation. Many mixed pine-hardwood stands averaging 4 to 6 years old have been established on the Sumter National Forest using these burning and planting methods, and few have required release of the planted pine seedlings (Abercrombie and Sims 1986).

Reduction in height of competing vegetation on burned plots is due to a shorter growing period rather than an inhibitive response to burning. Burning was conducted in August. Therefore, stems in burned plots were much younger than those in unburned plots. Since only a small decrease in height due to burning was found, rate of growth after burning may actually have been stimulated. Accelerated growth after burning has been reported and may be caused by improved soil fertility from ash or by sterilization effects from soil heating (Raison 1979).

Number of sprouts from stumps of merchantable trees one year after treatment averaged 12.1, 12.3, and 15.2 for control, treatment B, and treatment C, respectively. Stumps from residual stems, harvested in early June, remaining after harvest had 7.7 sprouts/stump on control plots and 20.8 on treatment C plots. There were no residual stems on treatment B. Although total number of sprouts reported here is high (Table 2), most sprout clumps will thin to one or two individual stems within the next two decades.

Burning earlier in the summer when root reserves are low and tops are more readily killed may be more effective in reducing sprout vigor than the late summer burn used in this study. Goebel et al. (1967) noted that spring burning was twice as effective as late summer burns in top-killing understory hardwoods in the upper Piedmont, but heights of sprouts were not measured. Potential adverse effects on ground-nesting wildlife must be considered if burning is conducted before the end of June.

Burning many harvested areas during the summer when fuel and weather conditions are ideal is logistically difficult using present ground firing techniques. Aerial ignition promises to be a technological breakthrough that could allow many areas to be burned in a short time when fuel and weather conditions are ideal.

Perennial and Herbaceous Vegetation

Biomass of perennial and herbaceous vegetation on burned plots (2.65 and 2.91 T/ha) was about two-fold greater than that on control plots (1.45 T/ha) (Table 2). Major perennial species included blackberry (Rubus occidentalis L.) and southern lowbush blueberry (Vaccinium vacillians Torrey), while major herbaceous species were fireweed (Epilobium angustifolium L.), and lespedeza (Lespedeza spp.). Species present in lesser amounts were bracken fern (Pteridium aquilinum (L.) Kuhn), pokeweed (Phytolacca americana L.), several taxa from the grass family (Poaceae), greenbrier (Smilax spp. L.), and tickseed (Coreopsis spp. L.).

Other investigators have also documented increases in herbaceous vegetation following high-intensity fires (Cushwa et al. 1969). Fire apparently creates a better seedbed for perennial and herbaceous vegetation and stimulates germination of seed already present in the duff. The fibrous root system and dense above-ground biomass of this early successional vegetation helps protect soils in steep terrain from erosion and also conserves nutrients (Cox and Van Lear 1985).

SUMMARY AND CONCLUSIONS

Intense burning prior to pine interplanting was successful in top-killing a majority (64 percent of the basal area) of residual stems left standing after clearcutting. However, long-term effects of surviving residual hardwood trees on growth of the new pine-hardwood stand may be detrimental. Numbers of sprouts were not significantly affected by burning, although number of sprouts on Treatment B plots was 1.5 times greater than that on control plots. Overall height of sprout regeneration was reduced by 0.15 m. Burning earlier in the summer (but after wildlife nesting) may be more effective in controlling sprout vigor than late summer burns. Perennial and herbaceous vegetation increased tremendously within the first year after burning, an ecological response important in conserving site nutrients and stabilizing the soil.

The major benefits of summer broadcast burning are the improved plantability of the site and the increased ease of monitoring quality of the planting job. Habitat for many wildlife species will be improved as a result of increased food and cover provided by the herbaceous vegetation and prolific sprouting. First-year benefits from hardwood sprout competition control were not demonstrated, although such an effect may become apparent later.

Felling of leafed-out residuals prior to burning eliminates competition from overhead trees as the new stand develops. In addition, the presence of cured fuels facilitates high intensity burns within a few days following a soaking rain, thereby minimizing potential soil damage from erosion (Danielovich 1986). Therefore, the current Forest Service practice of felling leafed-out residuals prior to burning is recommended over attempting to kill these residuals with high-intensity fires.

LITERATURE CITED

Abercrombie, J. A. and D. H. Sims, Jr., 1986. Fell and burn for low-cost site preparation. Forest Farmer. 46(1):14-17.

Augspurger, M. K., S. K. Cox, D. H. Van Lear, and D. R. Phillips. 1987. Regeneration of hardwood coppice following clearcutting with and without prescribed fire. In D. R. Phillips (ed.) Fourth Biennial Southern Silvicultural Research Conference Proc. Nov. 4-6, 1986. Atlanta, GA. (In press).

Braun, E. L. 1950. Deciduous forests of eastern North America. MacMillan Publishing Co., Inc. NY.

Brown, J. K., J. A. K. Snell, and D. L. Bunnell. 1977. Handbook for predicting slash weight of western conifers. USDA For. Serv. Gen. Tech. Rep. INT-37. 35 p.

Cox, S. K. and D. H. Van Lear. 1985. Biomass and nutrient accretion on Piedmont sites following clearcutting and natural regeneration of loblolly of pine. p. 501-506. In (E. Shoulders, ed.). Third Southern Silvicultural Research Conference Proc. Nov. 7-8, 1984, Atlanta, GA.

Cushwa, C. T., E. Czuhai, R. W. Cooper, and W. H. Julian. 1969. Burning clearcut openings in loblolly pine to improve wildlife habitat. Ga. For. Res. Pap. 61.

Danielovich, S. J. 1986. High intensity site preparation burning after clearcutting in Southern hardwoods - effects on residual vegetation and soil erosion. M.S. Thesis, Dept. of Forestry, Clemson Univ., Clemson, SC. 67 p.

Ferguson, E. R. 1961. Effects of prescribed fires on understory stems in pine-hardwood stands of Texas. J. For. 59:356-359.

Goebel, N. B., E. V. Brender, and R. W. Cooper. 1967. Prescribed burning of pine-hardwood stands in the upper Piedmont of South Carolina. Clemson Univ., Dept. of Forestry, For. Res. Series No. 16. 22 p.

Hare, R. C. 1965. Contribution of bark to fire resistance of southern trees. J. For. 63:248-251.

Langdon, O. G. 1981a. Some effects of prescribed fire on understory vegetation in loblolly pine stands. p. 143-153. In G. W. Wood (ed.). Prescribed Fire and Wildlife in Southern Forests. Proc. of a Symposium. The Belle W. Baruch Institute of Clemson University. Georgetown, SC. 170 p.

Langdon, O. G. 1981b. Natural regeneration of loblolly pine: A sound strategy for many forest landowners. South. J. Appl. For. 5(4):170-176.

Little, T. M. and F. J. Hills. 1978. Agricultural experimentation. Design and analysis. John Wiley and Sons, NY.

McGee, C. E. 1982. Low-quality hardwood stands. USDA For. Ser. Gen. Tech. Rep. SO-40. 22 p.

Perala, D. A. 1974. Prescribed burning in an aspen-mixed hardwood forest. Can. J. For. Res. 4:222-228.

Raison, R. J. 1979. Modification of the soil environment by vegetation fires, with particular reference to nitrogen transformations: a review. Plant and Soil 51:73-108.

Roth, E. R. and B. Sleeth. 1939. Butt rot in unburned sprout stands. USDA Tech. Bul. 684. 43 p.

SAS. 1985. SAS User's Guide: Statistics. Version 5 Edition. SAS Institute Inc. Cary, NC. 956 p.

SCS. 1983. Evard series. National Cooperative Soil Survey Established Series Description Sheet. USDA Soil Conservation Service, Fort Worth, TX.

Sims, D. H., C. E. McGee, J. Galloway, and B. Richman. 1981. Mixed pine-hardwood stands - a low cost operation for reforestation. For. Farmer 40:10-11,16-17.

Toole, E. R. 1961. Fire scar development. Southern Lumberman 203:111-112.

Waldrop, T. A., E. R. Buchner, and J. A. Muncy. 1985. Cultural treatments in low-quality hardwood stands for wildlife and timber production. p. 493-500. In E. Shoulders, ed. Proceedings Third Biennial Southern Silvicultural Research Conference, Atlanta, GA. USDA For. Serv. Gen. Tech. Rep. SO-54.

Zahner, R. 1982. Productivity and benefits of young hardwoods in mixed pine-hardwood stands. pp. 84-91. In Proceedings Tenth Annual Hardwood Symposium of the Hardwood Research Council. Cashiers, NC.