INTERMEDIATE CUTTING IN MIXED UPLAND OAK STANDS ON THE WESTERN HIGHLAND RIM, TENNESSEE, AFTER A QUARTER OF A CENTURY

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Abstract—In 1973 and 1974, a study was established at Stewart State Forest (SSF) and Lewis State Forest (LSF) to evaluate Roach and Gingrich's "Even-Aged Silviculture for Upland Central Oaks" on the Western Highland Rim. Harvesting to the "B-level" of the stocking guide primarily removed cull and low-quality stems. Basal area was reduced from 110 to 80 square feet per acre at SSF and from 99 to 75 square feet per acre at LSF. Although there were no differences between uncut and cut plots before harvest at either state forest, density, basal area, volume and value were significantly higher on the uncut plots immediately after harvest and also at 10 and 26/27 years, except for number of merchantable trees at age 26/27. Current value of the sawtimber and of all merchantable trees was not significantly different between uncut and cut plots. After a quarter of a century, the number of saplings decreased substantially on both the cut and uncut plots at both state forests. At SSF, at least 90 percent of the saplings were undesirable timber species or understory species; at LSF, nearly 70 percent were undesirable.

INTRODUCTION

The Western Highland Rim (WHR) in Tennessee encompasses nearly 4.5 million acres in all or parts of 20 counties. More than half of it is forested. Adoption of sound silvicultural practices progressed slowly in this area, and past abuses, such as heavy, repeated cuttings for charcoal production and logging to small diameters for crossties and lumber, made the trees in many stands poor indicators of site quality and potential productivity (Clatterbuck 1991). Although some sites are too poor for profitable timber production, there is substantial area where productivity could be improved with good silvicultural practices, including intermediate stand treatments.

Silvicultural guides for upland central hardwoods developed by researchers at the U.S. Department of Agriculture, Forest Service's Northeastern, North Central, and the former Central States Forest Experiment Stations were thought to be generally applicable to the mixed oak forests of the WHR. Roach and Gingrich (1968) summarized information on hardwood silviculture in Agriculture Handbook 355, "Even-Aged Silviculture for Upland Central Hardwoods". It synthesized even-aged silvicultural prescriptions for a broad array of stand structures, densities, and species mixtures for three site classes based on black oak (*Quercus velutina*) site index with the objective to "..grow full yields of the highest value products the site can produce in a relatively short time." This objective was compatible with the need for improvement in WHR forests for maximum volume and quality lumber production.

This study was established in 1973 and 1974 to test the local applicability of Roach and Gingrich's guide to silviculture for upland central hardwoods. Specific objectives of this study were to determine the effects of intermediate treatments on number of stems, stand basal area, volume, and quality of growing stock by species group.

STUDY SITES

Warm, humid summers and mild winters characterize the climate on the WHR. The average temperature ranges from about 40 °F in the winter to about 80 °F in the summer. The mean annual precipitation is about 45 inches. The wettest months of the year are January through March (Smalley 1980).

Site and stand criteria included: (1) topography typical of the WHR [slopes of 30 to 60 percent and relief of 200 to 600 feet]; (2) upland oak stands [oak (*Quercus* spp.) comprising at least 50 percent of the basal area] that were fully stocked; (3) medium to good sites [site index at least 55 feet for black oak].

As originally conceived, this study was to be established at six to eight locations. However, only two were established because of budgetary constraints. The two locations are Lewis State Forest (LSF), near Hohenwald, TN, and Stewart State Forest (SSF), near Erin, TN.

Both study areas are located on cherty, gently sloping to steep, north slopes classified as Landtype 5 according to Smalley's (1980) land classification system for the WHR. Landtype 5 has moderately deep to deep cherty silty and clayey soils that are well drained to somewhat excessively drained with a relatively high soil-water supply, and that are strongly acid with moderate to moderately low fertility. Estimated site indices (base age 50) for natural stands are 70 for upland oaks, 90 for yellow-poplar (*Liriodendron tulipifera*), and 75 for loblolly pine (*Pinus taeda*).

Stewart State Forest

Plots on SSF range from 400 to 500 feet in elevation. The age of the overstory, at establishment, averaged 71 years with a few trees over 100 years old. Seventy-five percent of sawtimber trees were white oak (*Q. alba*), northern red oak (*Q. rubra*), and black oak. Ten percent were yellow-poplar,

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and 10 percent were hickories (*Carya* spp.). Minor sawtimber species included sugar maple (*Acer saccharum*), scarlet oak (*Q. coccinea*), and chinkapin oak (*Q. muehlenbergii*). About 75 percent of sawtimber trees were classified as acceptable, and 25 percent were unacceptable growing stock, as defined by Roach and Gingrich (1968).

Forty-five percent of the pole-sized trees were hickories, 29 percent were white and northern red oaks, and 6 percent were blackgum (*Nyssa sylvatica*). Minor species included white ash (*Fraxinus americana*), sugar maple, yellow-poplar, black cherry (*Prunus serotina*), black oak, scarlet oak, sourwood (*Oxydendrum arboreum*), flowering dogwood (*Cornus florida*), cucumbertree (*Magnolia acuminata*), American hornbeam (*Carpinus caroliniana*), eastern hophornbeam (*Ostrya virginiana*), and American elm (*Ulmus americana*). About 27 percent of poles were acceptable, 53 percent were unacceptable, and 20 percent were culls.

Of the sapling-sized trees, only about 10 percent were of desirable sawtimber species: hickories, white ash, white oak, yellow-poplar, and black cherry. Other timber or understory species present included eastern hophornbeam, flowering dogwood, blackgum, eastern redbud (*Cercis canadensis*), sassafras (*Sassafras albidum*), American hornbeam, sourwood, and American beech (*Fagus grandifolia*).

Lewis State Forest

Plots on LSF range in elevation from 860 to 920 feet. The age of the overstory, at establishment, averaged 59 years but ranged from 44 to 80 years with a few trees over 100 years. Of the sawtimber trees, 52 percent were scarlet and white oak, 24 percent were southern red oak and black oak, and 8 percent were yellow-poplar. Minor species included northern red oak, post oak (*Q. stellata*), hickories, and blackgum. About 62 percent of sawtimber-sized trees were rated as acceptable, 12 percent as unacceptable, and 26 percent as culls.

Forty-four percent of the pole-sized trees were white oak, 10 percent were scarlet oak, and 8 percent were black oak. Minor species included hickories, yellow-poplar, northern red oak, southern red oak (*Q. falcata*), chestnut oak (*Q. prinus*), post oak, blackgum, sourwood, flowering dogwood, sweetgum (*Liquidambar styraciflua*), and sassafras. About 76 percent of poles were rated as acceptable, 15 percent as unacceptable, and 9 percent as culls.

Eighty-five percent of the sapling-sized trees were white oak, hickories, flowering dogwood, and blackgum. Minor species included sugar maple, sassafras, northern red oak, post oak , chestnut oak, and yellow-poplar.

METHODS

Four plots, ranging in size from 0.87 to 1.26 acres, were established at each state forest. Two plots were randomly selected for treatment in 1974 and 1975, whereas two plots served as controls.

The basis for determining the cut was Roach and Gingrich's (1968) stocking guide. The basal area removed was equal to the difference between the basal area of the initial inventory and the "B-Level" of the stocking guide, which is the minimum density required for full site utilization, or about 58 percent of full stocking. Two to three square feet of basal area were reserved for expected loss of trees due to damage from logging.

All culls and some unacceptable growing stock trees [diameter at breast height (d.b.h.) > 4.5 inches] were removed in the cut and, at SSF, a few relics were also removed. Merchantable trees were felled, skidded off the plot, and utilized whereas unmerchantable trees were injected with an herbicide. A light fire burned at SSF after the initial inventory but before the first growing season after treatment; damage was confined to understory plants.

Stand inventories were conducted in each plot prior to treatment. The initial inventory consisted of 100-percent tally of growing stock trees. Data collected included d.b.h., species, and rating of trees as acceptable, unacceptable, or cull growing stock according to Roach and Gingrich's guide. Each tree was assigned a consecutive number and tagged with that number for use throughout the study. Ingrowth trees were determined at each subsequent inventory, tallied, tagged, assigned a continuing consecutive number for that plot, and their species and d.b.h. determined. On the cut plots, numbers of cut trees were noted to allow calculation of "after cut" values. D.b.h. of live trees was measured 3, 5, 10, and 26 or 27 years after the cut.

A note concerning the periods after harvest: LSF was cut in 1974 and SSF was cut in 1975. We measured both state forests in 2002; thus, LSF was measured 27 years after harvest and SSF was measured 26 years after harvest. This one-year difference after a quarter of a century should have little impact on the results.

Originally, 6 to 21 trees were selected per plot for detailed measurement and use in estimating volume. In the most recent measurement, bark thickness at breast height, diameter outside bark (d.o.b.) at the top of the first log, and height to a 4-inch d.o.b. or height to the end of merchantable material and d.o.b. at that point, were measured. These data were used to develop local volume equations that were then used to estimate volume of all trees in the study for all inventories.

Sawtimber and total values were based on delivered prices for West Tennessee in the 4th Quarter 2001 Tennessee Forest Products Market Report (Tennessee Department of Agriculture, Forestry Division 2001). Hardwood pulpwood was quoted at $56.26 per cord, mixed hardwood sawtimber at $127 per thousand board feet (MBF) (Doyle log rule), and oak sawtimber at $357 per MBF (Doyle log rule). Doyle prices were converted to International ¼ inch by multiplying the price by 0.61. The conversion factor for pulpwood was 85 cubic feet per cord.

Twelve or 15 1/100-acre sample plots were systematically located in each plot. At each measurement, saplings (1.0 to 4.5 inches in d.b.h.) were measured to a 10th of an inch.

Stand characteristics available were density (trees per acre, trees > 0.9 inches in d.b.h.), basal area (square feet

per acre, trees > 0.9 inches in d.b.h.), stand volume (cubic feet per acre to 4-inch d.o.b., trees > 4.5 inches in d.b.h.), and sawtimber volume [board feet (International ¼ inch) per acre to 8-inch d.o.b., trees > 11.5 inches in d.b.h.).

Statistical analyses were conducted using SAS Version 7.0 at an error level of alpha = 0.05 to indicate significant differences. Analysis of variance (PROC GLM) was used to detect treatment differences between state forests and between treatments for each variable. Significant differences among means were detected using F-tests; comparison of means was made using Duncan's Multiple-Range Test.

RESULTS

First, the conditions at each measurement at SSF will be compared with those at LSS, and then the cut plots will be compared to the uncut plots. No comparison of cut plots and uncut plots at individual state forests will be made because treatment/location interactions were not significant.

SSF had significantly fewer trees than LSF throughout the study (table 1). SSF had significantly more basal area until the last measurement when there was no difference. This same trend was also found for stand volume. For sawtimber volume, SSF had more than LSF over the entire period since treatment.

Before harvest, the uncut plots were not significantly different from the cut plots (table 2). After harvest, the cut plots had significantly less timber than the uncut plots, except at the last measurement, when trees per acre, stand value, and sawtimber value were no longer different between cut

Table 1—Stand characteristics for Stewart State Forest and Lewis State Forest on the Western Highland Rim, TN, averaged over cut and uncut plots, before, immediately after, and 10 and 26/27 years after an intermediate cut

Stand characteristic	Location	Time of measurement			
		Pre-cut	Post-cut	10 years	26/27 years
Trees[a] (*per acre*)	SSF	154*[b]	129*	122*	116*
	LSF	199*	177*	167*	146*
Basal area[a] (*ft² per acre*)	SSF	98*	83*	97*	111
	LSF	78*	67*	84*	107
Volume[a] (*ft³ per acre*)	SSF	4,942*	4,187*	4,875*	5,624
	LSF	3,900*	3,340*	4,185*	5,406
ST volume[c]	SSF	11,703*	9,612*	13,475*	17,628*
	LSF	4,342*	3,423*	6,491*	12,781*

SSF = Stewart State Forest; LSF = Lewis State Forest.

[a] For merchantable trees (d.b.h. > 4.5 inches).

[b] A * indicates significant difference between state forests for time of measurement at α = 0.05.

[c] Sawtimber volume in board feet (International ¼ inch) per acre, trees >11.5 inches d.b.h.

Table 2—Stand characteristics for cut and uncut plots averaged over Stewart State Forest and Lewis State Forest on the Western Highland Rim, TN, before, immediately after, and 10 and 26/27 years after an intermediate cut

Stand characteristic	Treatment	Time of measurement			
		Pre-cut	Post-cut	10 years	26/27 years
Trees[a] (*per acre*)	Uncut	174	174*[b]	158*	135
	Cut	179	133*	130*	127
Basal area[a] (*ft² per acre*)	Uncut	88	88*	100*	114*
	Cut	89	63*	80*	104*
Volume[a] (*ft³ per acre*)	Uncut	4,376	4,376*	5,042*	5,766*
	Cut	4,466	3,151*	4,017*	5,264*
ST volume[c] (*bd ft per acre*)	Uncut	8,184	8,184*	11,700*	16,105*
	Cut	7,861	4,851*	8,266*	14,304*
Value[d] (*$*)	Uncut	1,989	1,989*	2,669*	3,424
	Cut	1,927	1,234*	1,895*	3,063
ST value[e] (*$*)	Uncut	1,517	1,517*	2,171*	2909
	Cut	1,432	870*	1,478*	2,585

[a] For merchantable trees (d.b.h. > 4.5 inches).

[b] A * indicates significant difference between treatments for time of measurement at α = 0.05.

[c] Sawtimber volume in board feet (International ¼ inch) per acre.

[d] Value per acre for sawtimber and pulpwood.

[e] ST value is value per acre for sawtimber only.

and uncut plots. Of note is the more rapid increase in stand characteristics for the cut plots as compared to the uncut plots.

Results by growth component provide insight into where the growth occurred. For stand volume, mortality on the uncut plots exceeded that on the cut plots (table 3). For the first decade, it was about a third more, whereas for the 10-year to 26/27-year period, it was about twice that on the cut plots. Ingrowth on the uncut plots was slightly less than that on the cut plots for both periods. Similarly, growth of the surviving trees was slightly less on the uncut plots than on the cut plots.

For the sawtimber trees, mortality on the uncut plots was similar to that on the cut plots during the first decade (table 4). From 10 years to 26/27 years after treatment, mortality on the uncut plots was about three times that on the cut plots. Ingrowth on the cut plots was about 30 percent more than on the uncut plots during the first decade and about 40 percent more from 10 years to 26/27 years. Growth on the surviving trees in the cut plots was only about 75 percent of that on the uncut plots during the first decade and about 90 percent from 10 years to 26/27 years. The slower growth on survivors on the cut plots was surprising.

Trees per acre and stand basal area for both uncut and cut plots were plotted on the stocking chart (fig. 1). Here initial, 10-year, and 26/27-year values are shown. Two trends are evident. First, the cut plots had very little mortality relative to the uncut plots. Second, the cut plots have not attained the stocking of the uncut plots, but the cut plots should soon match the uncut plots, given their current growth rate.

Comparing species of merchantable trees initially with species 26/27 years after treatment, there was little change in the proportion of basal area for each species. At SSF

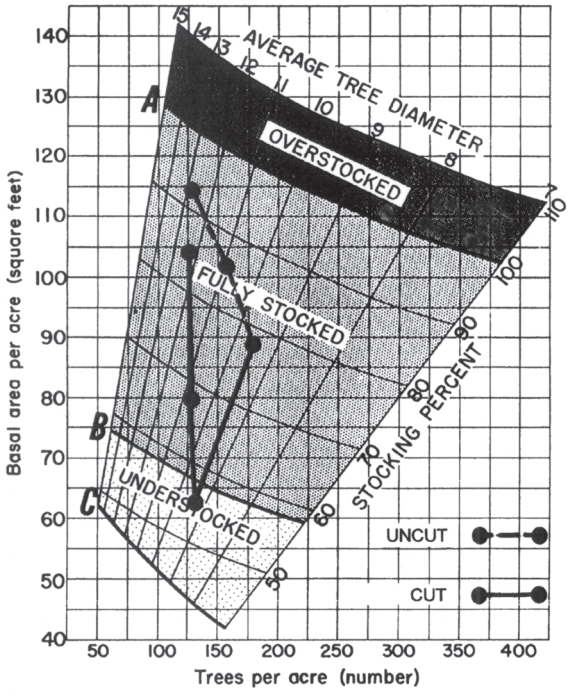

Figure 1—Graph of uncut and cut plot means on stocking chart (Roach and Gingrich 1968) before cut and immediately after, 10 years after, and 26/27 years after an intermediate cut in mixed oaks averaged over Stewart State Forest and Lewis State Forest, Western Highland Rim, TN.

uncut plots, white oak had the most basal area, followed by hickory, northern red oak, and black oak (table 5). On the cut plots, northern red oak was followed by white oak, hickory, black oak and yellow-poplar. Most of the major species increased in basal area. Mostly white oak, northern red oak, hickory, and black oak were harvested. White oak,

Table 3—Stand volume (cubic feet per acre, merchantable trees, d.b.h. > 4.5 inches) growth components for cut and uncut plots averaged over Stewart State Forest and Lewis State Forest on the Western Highland Rim, TN, for two periods after an intermediate cut

		Cut to 10 years			10 years to 26/27 years			
Treatment	Post-cut volume	Mort.	Ingrowth	Survivor growth	Mort.	Ingrowth	Survivor growth	Final volume
Uncut	4,376	485	78	1,057	853	71	1,522	5,766
Cut	3,180	357	90	1,105	420	99	1,567	5,264

Table 4—Sawtimber volume [board feet (International ¼ inch per acre), d.b.h. > 11.5 inches] and growth components for cut and uncut plots averaged over Stewart State Forest and Lewis State Forest on the Western Highland Rim, TN, for two periods after an intermediate cut

		Cut to 10 years			10 years to 26/27 years			
Treatment	Post-cut volume	Mort.	Ingrowth	Survivor growth	Mort.	Ingrowth	Survivor growth	Final volume
Uncut	8,184	567	1,316	2,709	1,880	1,813	4,532	16,105
Cut	4,907	511	1,744	2,125	625	2,617	4,007	14,305

Table 5—Stand basal area (square feet per acre) for merchantable trees (d.b.h. > 4.5 inches) by species or species group for cut and uncut plots at Stewart State Forest and Lewis State Forest on the Western Highland Rim, TN, before and 26/27 years after an intermediate cut

Location	Time of measurement	Treatment	Species or species groups					
			White oak	Northern red oak	Black oak	Yellow-poplar	Hickories	Other species
SSF	Initial	Uncut	30.12	16.65	14.80	7.46	21.11	7.79
		Cut	19.57	26.25	15.08	12.73	16.07	7.56
	26 years	Uncut	39.52	20.18	10.12	14.19	24.22	8.47
		Cut	29.17	26.92	6.71	19.52	17.40	6.13
Location	Time of measurement	Treatment	White oak	Southern red oak	Black oak	Scarlet oak	Yellow-poplar	Other species
LSF	Initial	Uncut	26.61	5.37	6.40	9.17	5.60	11.15
		Cut	29.72	6.86	9.17	13.68	5.18	15.20
	27 years	Uncut	44.05	7.78	6.87	25.48	16.00	14.60
		Cut	47.49	6.45	6.90	15.44	14.60	9.91

SSF = Stewart State Forest; LSF = Lewis State Forest.

northern red oak, yellow-poplar, and hickory increased in basal area during the subsequent quarter of a century. However, black oak decreased in basal area on both the uncut and cut plots.

At LSF, there was little change in the proportion of basal area by species (table 5). White oak had the most basal area, and scarlet oak, yellow-poplar, southern red oak, and black oak were additional major components. Here, the harvest was concentrated in white oak, red oaks, and hickory. All species added basal area whether on the cut plots or on the uncut plots. White oak grew faster on the cut plots.

Saplings were grouped into desirable sawtimber species, other sawtimber, and understory woody species. No differences were found in number of stems per acre either before the cut or at 26/27 years. As with merchantable trees, differences were found between state forests. At LSF, there were considerably fewer seedlings of desirable sawtimber species and understory species, whereas other sawtimber species were about the same (table 6). The only species or species group that increased in number was sweetgum. At SSF, saplings in all categories decreased in number. The only species in large number at age 26 years was sugar maple, which accounted for about three-quarters of the total of other sawtimber species.

IMPORTANT FINDINGS

1. Although uncut plots and cut plots initially had the same cubic-foot volume, the cut plots still contained about 500 cubic feet per acre less than the uncut plots.

Table 6—Number of saplings (stems 1.0 to 4.5 inches d.b.h.) per acre by species or species group for cut and uncut plots at Stewart State Forest and Lewis State Forest on the Western Highland Rim, TN, before and 26/27 years after an intermediate cut

Location	Time of measurement	Treatment	Species or species groups						
			White oak	Red oak group	Yellow popar	Hickory	Sweetgum	Other ST species	Understory species
SSF	Initial	Uncut	8.3	0	4.2	25.0	0	291.7	379.2
		Cut	8.3	0	4.2	4.2	0	283.3	404.2
	26 years	Uncut	0	0	8.3	8.3	50.0	212.5	141.7
		Cut	0	0	58.3	0	12.5	175.0	170.8
LSF	Initial	Uncut	211.6	38.3	6.7	163.4	0	85.9	217.5
		Cut	183.4	16.7	0	163.4	0	80.0	193.4
	27 years	Uncut	38.3	0	13.3	15.0	99.2	21.7	140.0
		Cut	26.7	0	20.0	46.7	76.7	6.7	100.0

ST = sawtimber; SSF = Stewart State Forest; LSF = Lewis State Forest.

Board-foot volumes on cut plots had about 1800 board feet per acre less volume than uncut plots.

2. Both stands added cubic-foot and board-foot volume at rapid rates, but more of the growth was added to acceptable quality trees on cut plots than on uncut plots.
3. The intermediate cut increased the percentage of acceptable sawtimber and poles, particularly in the oaks, by removing the culls and some of the unacceptable trees.
4. Mortality, mostly oaks, greatly affected the growth of the uncut plots and cut plots at both state forests. More cubic-foot volume and board-foot volume were lost to mortality and less gained from ingrowth on uncut plots than on cut plots. Survivor growth was less on uncut plots than on cut plots for cubic-foot volume, whereas uncut plots had more board foot survivor growth than cut plots.
5. There was little net ingrowth of saplings to poles because the cuts were implemented at either state forest.
6. The number of saplings was substantially less on both the cut and uncut plots at both state forests after a quarter of a century. At SSF, 90 percent or more of the saplings were undesirable timber species or understory species; at LSF, nearly 70 percent were undesirable. Many of the undesirable saplings should now be deadened.
8. The intermediate cut at both state forests failed to promote advance reproduction of oaks. Evidently, the openings were not sufficiently large to produce the microenvironment necessary for oak regeneration.
9. Despite the complicating effects of oak mortality, the data show that middle-aged mixed oak stands on cherty north slopes do respond to stand density control, and that the proportion of acceptable quality trees can be substantially increased by an intermediate cut using Roach and Gingrich's basal area guide.
10. Although the cut plots have not yet achieved the basal area or volume of the uncut plots, Roach and Gingrich's recommendations for intermediate stand management remain sound silvicultural advice for WHR mixed oak stands, i.e., remove culls and unacceptable growing stock and concentrate growth on acceptable growing stock. Whether this removal can be an economical operation will depend on markets and volume and value of trees marked for removal.

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