DEFERMENT CUTTING IN CENTRAL APPALACHIAN HARDWOODS: AN UPDATE

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ABSTRACT

This paper summarizes research results on deferment cutting, a silvicultural practice that promotes a two-age stand structure, as it has been applied in central Appalachian hardwoods on the Monongahela National Forest (MNF) since 1979. Ten-year results from experimental cuts that were applied from 1979 to 1983 indicated that 89% of residual trees survived, 76 to 100% of the survivors maintained their initial grade depending on species, and d.b.h. growth increased for most species. Reproduction that developed following the experimental cuts included a wide variety of desirable commercial species, similar to that observed after clearcutting. Forest managers on the MNF began making operational deferment cuts as an alternative to clearcutting in 1991, and 20 stands were surveyed in 1996 to assess the condition of residual trees and the early development of reproduction. These results indicated that 92% of residual trees had survived, and grade reductions were minimal for most species. Reproduction was well distributed and consisted of many commercial species in each of the three forest cover types studied. Preliminary guidelines for applying deferment cutting to meet specific management objectives also are discussed.

INTRODUCTION

Deferment cutting is designed to regenerate a variety of high-quality hardwood species and promote a two-age stand structure for aesthetic, wildlife habitat, and other non-timber benefits. Basal area is reduced enough so that it resembles a seed-tree or shelterwood practice in that some overstory trees are retained while all other trees are cut (Fig. 1). However, in deferment cutting the residual trees are not cut once the reproduction becomes established as would be the case in even-age practices. Instead, the harvest of the residual trees is deferred until new reproduction is between 40 and 80 years old, generally one-half to a full sawtimber rotation. The result is a two-age stand structure. Once the two-age stand structure is established, deferment cuts can be repeated at intervals of 40 to 80 years to maintain this condition for many years. Silviculturists also use terms such as clearcutting with reserves or irregular shelterwood to describe practices that promote a two-age stand structure.

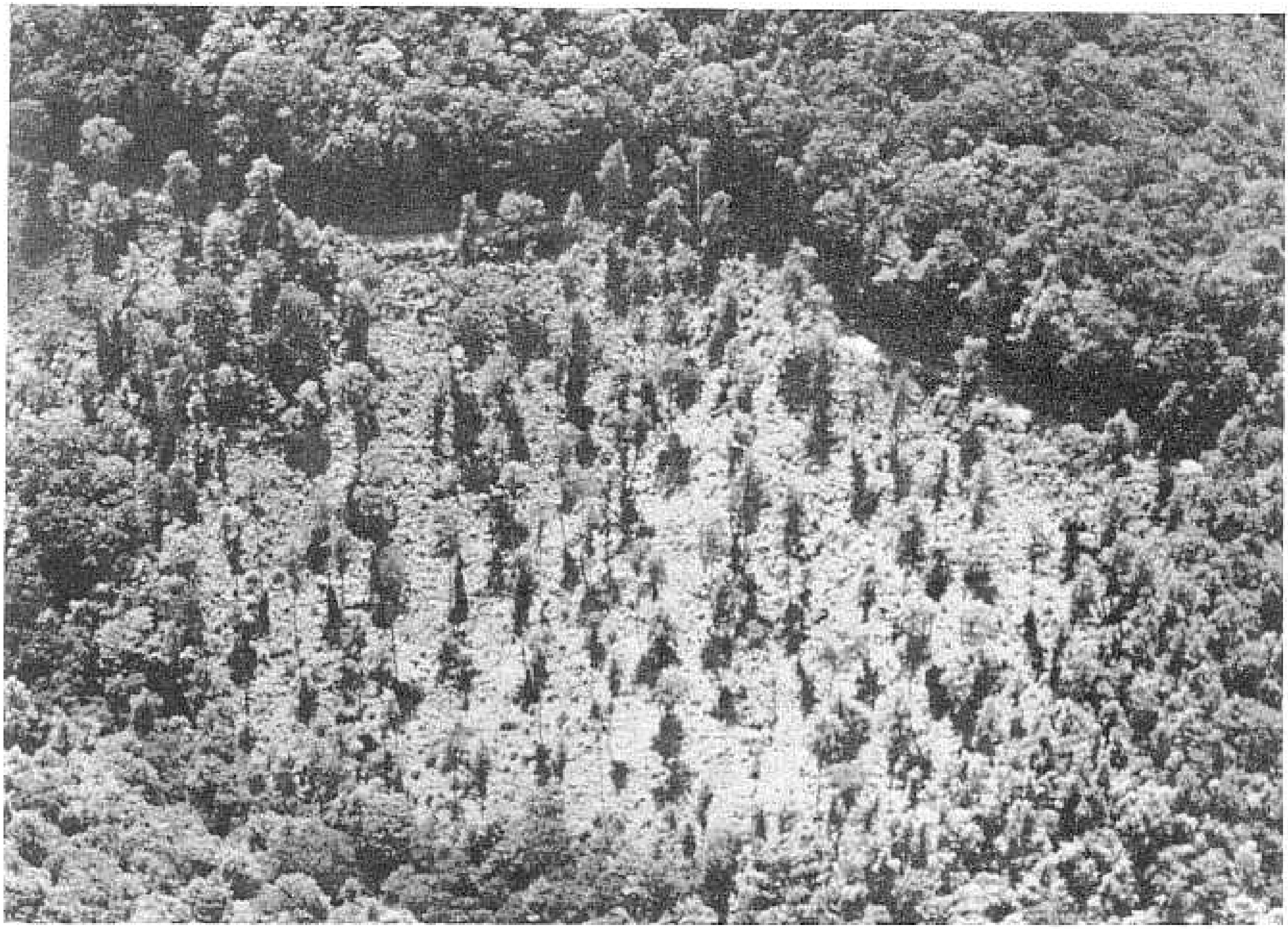

Figure 1. Three years after deferment cutting in central Appalachian hardwoods. The residual stand contained 13 desirable codominant trees per acre, the remaining merchantable sawtimber trees were removed, and all other stems 1.0 inch d.b.h. and larger were cut to prepare the site for new reproduction.

Silvicultural systems that promote a two-age stand structure have been initiated on national forests, state forests, industrial forests, and to a lesser degree on nonindustrial private forests in many eastern states. A similar practice called "insurance silviculture" was applied in Pennsylvania to retain a seed source in the event of a regeneration failure (Bennett and Armstrong 1981). In most cases, two-age silvicultural methods were employed to regenerate a variety of species, particularly those that are shade-intolerant, and to mitigate the perceived negative visual impacts of clearcutting. Similar to clearcut stands, natural regeneration that follows two-age regeneration methods includes a variety of both shade-tolerant and shade-intolerant commercial hardwoods (Miller and Schuler 1995). Unlike clearcutting, however, the presence of residual overstory trees improves aesthetics and maintains a more diverse vertical stand structure that may benefit certain wildlife species (Pings and Hollenhorst 1993). As the new reproduction develops beneath the large overstory residuals, the stand has two distinct height strata. These strata provide a diverse habitat for songbirds that forage in high canopy trees (Wood and Nichols 1995), as well as those that require a brushy cover characteristic of a young even-age stand (DeGraaf et al. 1991). Deferment cutting also provides an opportunity to retain species that produce hard mast for wildlife food.

Though wildlife habitat and aesthetic issues also are important, this report focuses on two aspects of stand development after deferment cutting: 1) growth and development of the residual trees, and 2) abundance and species composition of reproduction that develops after cutting. This paper summarizes research results on deferment cutting as it has been applied in central Appalachian hardwoods on the Monongahela National Forest (MNF) since 1979. A brief history of deferment cutting on the MNF is presented, followed by a summary of published reports on specific silvicultural implications of this practice. In addition, results are presented from a recent study of 20 operational deferment cuts applied in stands throughout the MNF since 1991.

HISTORY OF DEFERMENT CUTS ON THE MONONGAHELA

During the 1970's, forest managers on the MNF began considering alternative regeneration methods in response to public criticism of clearcutting. An employee of the USDA Forest Service visited Europe and learned of deferment cutting, a practice used to manage larch, pine, and oak-beech stands (Kostler 1956; Troup 1966) to improve the aesthetics of even-age practices that remove the overstory over a relatively short interval. In 1979, an experimental deferment cut was applied on the Greenbrier Ranger District in cooperation with Northeastern Forest Experiment Station scientists at Parsons, West Virginia. Five additional experimental deferment cuts were applied on the Cheat and Marlinton Ranger Districts and the Fernow Experimental Forest by 1983. These study sites, which range from 10 to 15 acres, have since provided preliminary silvicultural information on deferment cutting for forest managers who are interested in alternatives to clearcutting.

After the experimental deferment cuts were applied, the study sites served as valuable demonstration areas where students and forest managers from the forest industry and various public agencies were able to see applications of two-age silviculture. As these two-age stands developed through the 1980's, preliminary reports were published on residual tree growth and the development of regeneration (Smith 1988; Smith et al. 1989). In addition, forest managers on the MNF were able to visit these stands over the course of several growing seasons to monitor the progress of the new reproduction and to evaluate their potential as an alternative to clearcutting.

In 1990, a team was organized on the MNF to define and evaluate possible alternatives to clearcutting. This team included experts from many disciplines: wildlife biology, landscape architecture, silviculture, and forestry research. Two-age management was included as a viable alternative for regenerating shade-intolerant species and improving aesthetics. The first deferment cuts, averaging 15 acres, were applied on the Potomac and Greenbrier Ranger Districts in 1991. These stands also served as demonstration areas for managers from other districts. From 1991 through 1996 clearcutting was the prescribed silvicultural treatment on a declining number of acres, while two-age cuts were prescribed on an increasing number of acres. For example, regeneration treatments were prescribed on an average of 1,500 acres/year on the MNF since 1990. The proportion of acres on which clearcutting was prescribed declined from 98 to 45 percent from 1990 to 1995. In most cases, two-age regeneration treatments were prescribed instead of clearcutting, and this trend is expected to continue.

In 1995, personnel from the MNF, the Northeastern Forest Experiment Station (Parsons, WV), and Northeastern Area State and Private Forestry (Morgantown, WV) collaborated on a Marker Training Workshop. Silviculturists and marking crews from each ranger district attended a two-day training session that focused on proper residual stand stocking levels and criteria for selecting leave-trees to meet various management objectives. This workshop included hands-on marking exercises in various forest cover types. In preparing for this workshop, the concerns of district silviculturists, specialists from non-timber disciplines, and administrators on the forest were included in the marking guidelines. As a result, timber marking became more consistent throughout the forest, and marking crews were better prepared to implement the intended prescriptions.

The process of evaluating deferment cuts and improving application methods on the MNF is continuing. The aesthetics of deferment cutting were compared to other silvicultural methods (Pings and Hollenhorst 1993). A study of songbird density and nesting success in two-age stands was conducted from 1992-1996 (Wood and

Nichols 1995; Miller et al. 1995). Logging economics and product market options also have been investigated (Miller and Baumgras 1994; Baumgras et al. 1995). New studies are planned to test shelterwood treatments that increase the proportion of oak regeneration that develops before and after deferment cuts are applied.

STUDY AREAS

Study areas are located in north-central West Virginia. The topography consists of low valleys dissected by northeast-southwest ridges. Elevation ranges from 1,800 to 3,600 feet above sea level. In general, soils are medium textured and well drained, derived from sandstone and shale with occasional limestone influence. The average soil depth exceeds 3 feet. Annual precipitation ranges from 40 to 59 inches and is well distributed throughout the year. The growing season averages 145 frost-free days.

The initial stands were unmanaged second-growth Appalachian hardwoods with age ranging from 75 to 90 years that became established after heavy logging in the early 1900's. Periodic fire was common throughout the region as the stands became established until about 1920. Chestnut blight also killed many large trees during the 1930's and resulted in some patchy reproduction before and during World War II. Forest cover types included beech-cherry-maple, mixed Appalachian hardwoods, and mixed oaks. Stand size ranged from 10 to 35 acres.

EXPERIMENTAL DEFERMENT CUTS

The experimental deferment cuts were applied by retaining 12 to 15 codominant trees per acre and cutting all other stems 1.0 inch diameter breast height (d.b.h.) and larger (Smith and Miller 1991). Residual trees were marked to achieve an average residual stocking of 20 ft^2/acre. In general, trees with the greatest potential value as high-quality sawtimber and veneer products were chosen as leave trees using the following criteria:

Species — northern red oak, black cherry, yellow-poplar,
Crown class — dominant or codominant,
Vigor — no evidence of epicormic branches or other signs of decline,
Risk — no disease, low forks, shallow roots, or other risk factors,
Quality — current or potential high-quality butt log, and
Spacing — residual trees well-distributed throughout the stand.

Sawtimber cut-trees were skidded tree-length in three stands using a wheeled skidder and in one stand using a truck-crane cable system. All other cut-trees were left on the site. Each harvest operation was completed by a three-person logging crew, instructed to take special care to avoid damage to the few residual trees.

Species, d.b.h., crown class, crown width, total height, merchantable height (to the nearest 8-foot half log), tree grade (Hanks 1976) and number of epicormic branches were recorded for each residual tree. Live epicormic branches at least 1 foot long were counted by 8-foot bole sections to the top of the second 16-foot log. Residual trees also were examined to assess logging damage, and the length and width of sapwood wounds were recorded.

Reproduction data were obtained at permanent sample points located along systematic grids in each stand. At each point, small reproduction (1.0 foot tall to 0.99 inch d.b.h.) was tallied within a 1/1000-acre circular plot, and large reproduction (1.0 inch d.b.h. and larger) was tallied within a 1/100-acre circular plot. For small reproduction, stem counts and heights were recorded for each species observed on a plot. For large reproduction, species, d.b.h., stem origin, quality, and crown class were recorded for each stem observed on a plot. Trees with the potential to become sawtimber crop trees in the future were classified as good. Trees with low forks, crooked or leaning stems, or evidence of low vigor were classified as poor. Data for residual trees and reproduction surveys were recorded before and after treatment, followed by remeasurements 2, 5, and 10 years later.

Data from four experimental stands were summarized to provide information on residual tree development and reproduction 10 years after treatment. Although deferment cutting was applied in six stands, the residual trees in one stand were selected for wildlife habitat characteristics and tree quality was not an objective, and one stand had not reached the tenth year of development when the data were summarized. Thus, this summary of results is based on four stands in which residual tress were chosen to satisfy timber production objectives. Species composition before treatment included yellow-poplar, northern red oak, chestnut oak, hickory, black cherry, white oak, basswood, white ash, American beech, red maple, and sugar maple. Initial basal area averaged 127 ft^2/acre and merchantable volume averaged 15.9 Mbf/acre (Table 1). The deferment cuts removed 84 percent of basal area and 78 percent of board-foot volume. Basal area in the residual stands averaged 20.2 ft^2/acre in 13.8 high-quality, codominant trees/acre, while residual volume averaged 3.5 Mbf/acre. Species composition in the residual stands was dominated by northern red oak, yellow-poplar, black cherry, and white oak. During the 10-year period after treatment, residual stand basal area increased at a rate of 0.6 ft^2/acre/year to an average of 26.6 ft^2/acre. Net volume growth was 140 bf/acre/year, with volume averaging 4.9 Mbf/acre after the study period.

Table 1. Summary per-acre data for four central Appalachian hardwood stands before and 10 years after experimental deferment cutting.[a]

	Number of trees		Basal area		Volume			Average d.b.h.	
Stand	5.0-10.9[b]	11.0+	5.0-10.9	11.0+	5.0-10.9	11.0+	11.0+	5.0-10.9	11.0+
	—No./acre—		—Ft2/acre—		—Ft3/acre—		Bf/acre[c]	—Inches—	
					SI 70 - 26.9 acres				
Initial	111	74	36.4	94.5	641	2,378	14,187	7.7	15.3
Cut	110	61	35.7	77.2	627	1,937	11,511	7.7	15.2
Residual	1	13	0.7	17.3	14	441	2,676	9.9	15.9
After 10 yrs.	0	12	0.0	22.4	0	581	3,706	0.0	18.6
					SI 80 - 23.3 acres[d]				
Initial	76	68	24.2	99.2	452	2,671	17,824	7.6	16.3
Cut	76	55	24.1	76.5	448	2,050	13,362	7.6	16.0
Residual	0	13	0.1	22.7	4	621	4,462	9.6	17.6
After 10 yrs.	0	13	0.0	31.4	0	880	6,359	0.0	21.0

[a]From Miller et al. (1995).
[b]Inches d.b.h.
[c]International 1/4-inch rule.
[d]Data combined for two stands on each northern red oak site index.

D.b.h. growth

Generally, residual trees after deferment cutting exhibited faster diameter growth compared to control trees in uncut stands over the 10-year study period, although growth response varied by individual species (Table 2). Deferment trees were free-to-grow with an average crown growing space of 20 feet to adjacent residual tree crowns after treatment (Miller and Schuler 1995). Control trees also were codominant, but they had crown competition on all sides during the study period. For each species tested, released trees had greater average d.b.h. growth than control trees, although for black cherry (P=0.48) and chestnut oak (P=0.13) the difference was not significant.

D.b.h. growth of released trees was 45 to 134 percent faster than controls, led by white oak, yellow-poplar, basswood, and red oak. White oak, chestnut oak, red oak and basswood grew faster the second 5 years compared to the first 5 years after treatment. For yellow-poplar, deferment trees grew faster during the first 5 years after treatment, although growth during the second 5 years continued to exceed that of controls.

Table 2. Ten-year d.b.h. growth for central Appalachian hardwoods released by deferment cutting versus unreleased controls.

Species	Treatment	Number of trees	Initial d.b.h.	10-year d.b.h. growth	P[a]
			———inches———		
White oak	Release	59	14.5	2.89	<0.01
	Control	14	19.6	1.02	
Chestnut oak	Release	12	14.4	2.18	0.13
	Control	6	17.2	1.57	
Northern red oak	Release	200	16.7	3.34	<0.01
	Control	58	19.9	1.92	
Yellow-poplar	Release	193	17.8	3.65	<0.01
	Control	46	17.3	1.95	
Black cherry	Release	66	14.2	2.30	0.48
	Control	47	16.9	2.21	
Basswood	Release	18	15.1	2.93	<0.01
	Control	9	18.6	1.47	

[a]P = probability of a larger F; analysis of covariance means adjusted for initial d.b.h.

Survival and quality of residual trees

There were 667 residual trees within the four study areas. After 10 years, 89 percent of residual trees had survived. A total of 6 trees (1 percent) were destroyed or removed due to inadvertent damage during logging. After logging, 22 trees (3 percent) died within two years, and an additional 38 trees (6 percent) died between the second and the fifth years. Mortality after the fifth year was greatly reduced; only an additional 7 trees (1 percent) died between the fifth and the tenth years. Mortality was greatest for black cherry (over 20 percent), least for yellow-poplar (less than 5 percent). The cause of mortality was equally distributed between blowdown and exposure.

Epicormic branching increased for all species within two years after treatment. Between the second and tenth years there was no significant increase in the number of epicormic branches on the butt 16-foot log sections (Miller 1996). Epicormics continued to increase on the second 16-foot log section for black cherry, red oak, and yellow-poplar. The net effect on quality was that an average of 12 percent of residual trees exhibited a reduction in tree grade due to new epicormic branches over the 10-year study period (Table 3). Of the grade reductions observed, white oak (24 percent), black cherry (23 percent), basswood (17 percent), and northern red oak (12 percent) were most susceptible, while less than 1 percent of yellow-poplar trees had lower grades due to epicormic branching.

Table 3. Average number of epicormic branches and change in butt-log grade for residual trees 10 years after deferment cutting.[a]

Species	Number of trees	Initial d.b.h.	Number of epicormics Initial	10-years	Change in butt-log grade Reduced	None	Improved	Grade loss due to epicormics
		Inches			Number of trees (percent)			
White oak	59	14.4	0.64a[b]	2.61a	16(27)	22(37)	21(36)	14(24)
Chestnut oak	12	14.4	0.00b	0.00b	1(8)	2(17)	9(75)	0
Northern red oak	200	16.7	0.03b	1.62b	25(12)	103(52)	72(36)	24(12)
Yellow-poplar	190	17.8	0.01b	0.26b	9(5)	137(72)	44(23)	2(1)
Black cherry	66	14.2	0.00b	2.58a	14(21)	24(36)	28(42)	15(23)
Basswood	18	15.1	0.11b	2.89a	3(17)	6(33)	9(50)	3(17)
All species	545	16.2	0.09	1.37	68(12)	294(54)	183(34)	58(11)

[a]From Miller (1996).
[b]Values in columns followed by the same letter are not significantly different ($p > 0.01$) using Tukey-Kramer HSD.

Logging operations resulted in bark wounds (exposed sapwood) on about one-third (32 percent) of residual deferment trees; 16 percent had wounds less than 50 in^2, and 16 percent had larger wounds. The remaining 68 percent of residual trees had no wounds. Most of the wounds were located on the lower portions of the bole, caused by skidding logs too close to residual trees. Over 95 percent of logging wounds that were less than 50 in^2 in size callused over and were closed within 10 years after logging (Table 4). Based on the observed rate of healing over a 10-year period it appears that larger wounds up to 200 in^2 in size will close within 15 to 20 years after logging (Smith et al. 1994).

Table 4. Bark wounds (exposed sapwood) that callused and closed 5 to 10 years after logging.[a]

Species	Number of wounds	Number (percent) closed at 5 years	Number (percent) closed at 10 years
		Wounds ≤ 50 in.^{2}	
White oak	6	4(67)	6(100)
Chestnut oak	1	1(100)	1(100)
Northern red oak	18	7(39)	18(100)
Yellow-poplar	13	10(77)	13(100)
Black cherry	4	2(50)	2(50)
Basswood	3	2(67)	3(100)
Total	45	26(58)	43(96)
		Wounds > 50 in.^{2}	
White oak	22	0	4(18)
Chestnut oak	4	0	1(25)
Northern red oak	15	0	4(27)
Yellow-poplar	9	1(11)	5(56)
Black cherry	4	0	1(25)
Total	54	1(2)	15(28)

[a]From Smith et al. (1994)

Reproduction

Before deferment cutting, small reproduction averaged 3,019 stems/acre, with 50 percent in shade-tolerant species (maples and American beech), 37 percent in shade-intolerant species (black cherry and yellow-poplar), and 13 percent in intermediate-shade-tolerant species (oaks and white ash). Over 80 percent of survey plots had at least one stem of a commercial hardwood species present, and over 60 percent of survey plots had sugar maple or American beech present.

Two years after harvest, small reproduction in the study areas averaged 9,100 stems/acre of commercial species composed of 60 percent seedling-origin stems. There also were over 14,000 stems/acre of noncommercial woody species. Over 95 percent of survey plots contained one or more stems of a commercial species. Five years after harvest, the canopy of the new age class developing beneath the residual overstory had not closed. Large reproduction at five years included over 300 stems/acre of commercial species and 100 stems/acre of noncommercial species.

After 10 years, the canopy of the new age class developing beneath the deferment trees was nearly closed, and codominant trees averaged 35 feet tall. Large reproduction included 991 stems/acre of commercial species, with 448 good, codominant stems/acre exhibiting the potential to become high quality crop trees in the future (Table 5) (Miller and Schuler 1995). On excellent growing sites (site index 80) northern red oak reproduction was sparse, averaging only 10 potential crop trees/acre (Table 5). Other codominant, commercial species reproduction included a variety of both shade-tolerant and shade-intolerant species distributed over 74 percent of the stand area.

OPERATIONAL DEFERMENT CUTS

In 1996, data were collected on 20 two-age stands on the MNF that had received deferment cuts two to five growing seasons prior to the study. This survey was conducted to assess current conditions and the implications of deferment cutting on future species composition and wood product quality. Thus, changes in residual tree quality and reproduction presented here are preliminary results for the first two to five years after treatment and do not necessarily represent the long-term implications of this practice. Data collected for residual trees included species, d.b.h., crown class, number of epicormic branches on the bottom two 16-foot logs, size of wounds, and tree grade (Hanks 1976). Initial tree grade was estimated based on visible tree characteristics minus new wounds and new epicormic branches that were deemed to have resulted from recent logging. Data collected for reproduction included species and height for each woody stem on 0.001-acre plots located along systematic grids in each stand. There were an average of 30 plots per stand.

Survival and quality of residual trees

A total of 768 individual trees representing nine commercial species were evaluated for tree grade, epicormic branches, and logging damage. An average of 8 percent of residual trees had died since the stands were cut. In general, deferment cutting did not result in significant changes in grade in the first 2 to 5 years after treatment. Among large sawtimber (17.0 inches d.b.h. and larger) 11, 8, and 3 percent of white oak, black cherry, and northern red oak, respectively, exhibited grade reductions due to logging wounds or epicormic branches. Large sawtimber of other species did not exhibit grade reductions. Among small sawtimber (11.0 to 16.9 inches d.b.h.) grade reductions were more common compared to large sawtimber (Table 6). The development of epicormic branches was most prevalent on white oak. Suppressed and intermediate trees developed more epicormic branches and had more reductions in tree grade compared to codominant and dominant trees. Considering all of the 20 stands, 45 percent of residual trees were wounded during logging, 21 percent of trees had severe wounds larger

Table 5. Summary of reproduction of commercial species 10 years after deferment cutting in four central Appalachian hardwood stands.[a]

Species	Total	Codominant	Good Codominants[b]
	No. stems/acre		
		SI 70	
Black cherry	392	316	220
Beech	110	59	35
Red maple	105	63	47
Northern red oak	86	54	45
Black birch	77	54	52
Sugar maple	50	26	13
Chestnut oak	48	32	22
Yellow-poplar	44	21	16
Other	87	48	38
Total	999	673	488
		SI 80	
Yellow-poplar	383	206	190
Sugar maple	136	49	40
Black birch	85	50	46
Beech	65	20	10
Red maple	45	19	12
Basswood	36	9	9
Northern red oak	31	11	10
White ash	29	10	6
Other	172	91	84
Total	982	465	407

[a]From Miller and Schuler (1995)

[b]Good trees were characterized by straight stems, vigorous crowns, no low forks, no disease, etc. These trees were viewed as potential high-quality crop trees in the future.

than 100 in^2, and 24 percent had smaller wounds. The remaining 55 percent of residual trees were not wounded. However, the number of trees wounded and the severity of wounds was related to the months in which logging occurred (Fig. 2). Logging damage was greatest during the spring (March-June) and least during the dormant season (November-February).

Reproduction

Stands were grouped by three forest cover types before regeneration results were summarized: beech-cherry-maple at the higher elevations in the Allegheny mountains, mixed Appalachian hardwoods in the coves of the Allegheny Mountains, and mixed oaks in the Ridge and Valley province east of the Allegheny Front. Most of the reproduction present on the survey plots was less than 1.0 ft tall (Table 7). In the beech-cherry-maple stands, reproduction was dominated by American beech, black cherry, and the birches, though many other species also were present. The mixed Appalachian hardwood stands contained the greatest diversity of species, though

Table 6. Percent of trees reduced in grade due to logging wounds or epicormic branching after deferment cutting.[a]

	Small sawtimber (12-16 inches d.b.h.)				Large sawtimber (18 inches d.b.h. and larger)			
Species	n	Number of trees	%	95% CI[b]	n	Number of trees	%	95% CI
Yellow-poplar	23	1	4	<1-34	11	0	0	0-46
Black cherry	59	3	5	<1-11	38	3	8	1-22
Northern red oak	43	2	5	<1-19	32	1	3	<1-16
White oak	19	0	0	0-20	9	1	11	<1-48
Chestnut oak	22	0	0	0-11	15	0	0	0-33
Sugar maple	61	4	7	<1-12	20	0	0	0-17
Red maple	49	1	2	<1-12	10	0	0	0-49
White ash	41	4	10	<1-18	20	0	0	0-17
American basswood	17	0	0	0-26	3	0	0	0-71

[a]Data from 20 stands on the MNF where operational two-age cutting was applied.
[b]Confidence interval.

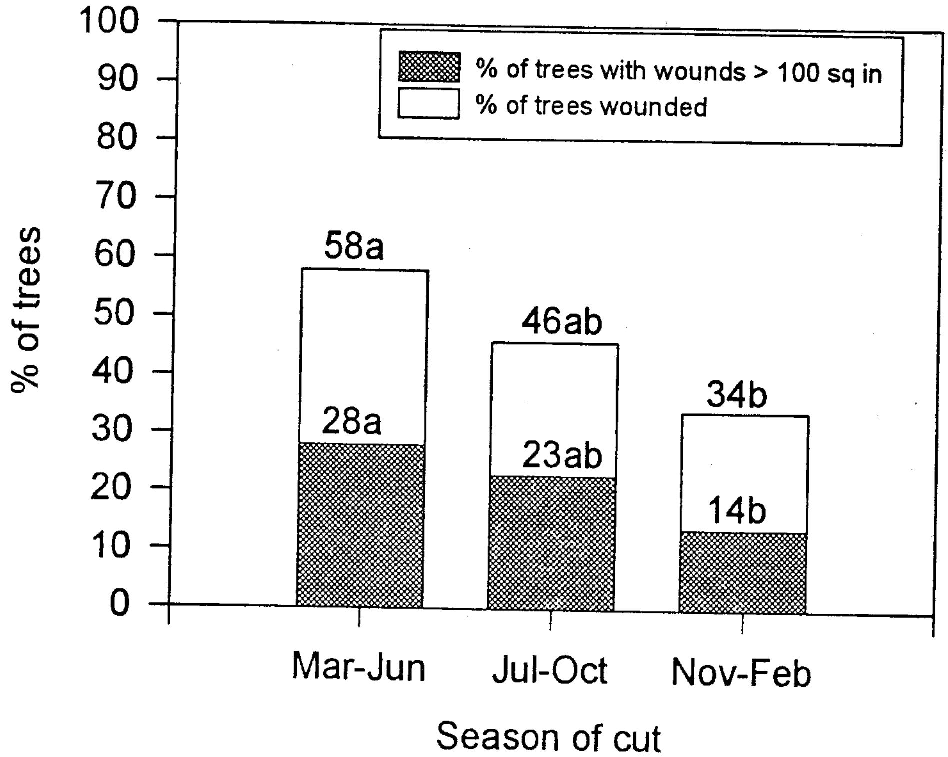

Figure 2. Mean percent of residual trees with logging wounds. For bars of the same shade, means followed by the same letters are not significantly different (P>0.10) using Tukey-Kramer HSD.

birches, maples, black cherry, and white ash were most abundant. Reproduction in the mixed-oak stands was dominated by red and sugar maple, birches, and northern red oak. These results are consistent with other studies of two-age and even-age regeneration practices (Trimble 1973; Miller and Schuler 1995; Beck 1986).

The total number of noncommercial stems was relatively small, representing only 5, 12, and 28 percent of stems present in the beech-cherry-maple, mixed Appalachian hardwood, and mixed oak cover types, respectively. Noncommercial stems included striped maple, dogwood, pin cherry, sassafras, serviceberry, and American hornbeam. These stems are not expected to interfere with the growth and development of commercial species (Miller and Schuler 1995).

Currently, the data indicate these stands areas have adequate density and distribution of desirable reproduction. However, it is too soon to predict the eventual species composition. As these stands continue to develop, the trees in the new age class will form a height stratum distinct from the larger overstory trees left after logging. Stems present when data were collected will compete for crown position until the canopy of the new age class closes from 10 to 15 years after logging. Trees that attain a codominant position at crown closure will determine the species composition of these stands for many years to come (Trimble 1973).

SUMMARY AND RECOMMENDATIONS

Experience with deferment cutting since 1979 indicates that desirable reproduction can be established and will develop into an acceptable new crop for sustained production of many forest benefits. The species composition

Table 7. Summary of small and large reproduction present 2-5 years after deferment cutting by forest cover type.[a]

	Beech-Cherry-Maple		Mixed Appalachian Hardwoods		Mixed Oaks	
Species[b]	Very small[c]	Small[d]	Very small	Small	Very small	Small
	number of stems/acre (% of plots stocked)					
Birches	8,464(62)	1,989(31)	3,502(39)	2,324(24)	2,886(25)	137(9)
Maples	1,717(50)	641(16)	1,116(39)	516(19)	2,259(50)	556(14)
Red oaks	9(1)	3(1)	410(24)	203(11)	582(18)	100(7)
White oaks	0(0)	0(0)	80(8)	254(1)	103(6)	140(3)
Am. beech	2,268(55)	4,591(63)	83(4)	162(4)	20(1)	0(0)
Black cherry	6,357(68)	3,825(44)	820(25)	466(14)	40(2)	45(2)
Hemlock	68(3)	0(0)	0(0)	4(1)	0(0)	0(0)
White ash	38(3)	30(1)	829(22)	499(12)	30(30)	0(0)
Yellow-poplar	404(12)	70(4)	3,271(35)	62(3)	367(13)	18(2)
Am. basswood	0(0)	0(0)	4(1)	12(1)	0(0)	0(0)
Others	305(16)	68(5)	185(14)	396(17)	299(16)	520(20)
Total	19,628	11,217	10,300	4,898	6,586	1,516

[a]Data from 20 stands on the MNF where operational applications of deferment cutting were applied.
[b]Birches include sweet and yellow birch; maples include red and sugar maple; red oaks include northern red, scarlet, and black oak; white oaks include white and chestnut oak; others include blackgum, aspen, and cucumbertree.
[c]Very small reproduction = all stems < 1.0 ft in height
[d]Small reproduction = stems ≥ 1.0 ft in height and < 1.0 inch d.b.h.

includes a wide variety of shade-intolerant and shade-tolerant species that is similar to that observed after clearcutting (Trimble 1973; Beck 1968; Miller and Schuler 1995). Cultural practices such as crop-tree release can be applied to stems in the new age class once the canopy closes to favor the growth and development of the most desirable stems such as northern red oak.

Residual basal area in experimental deferment cuts applied between 1979 and 1983 averaged 20 ft^2/acre. In more recent operational deferment cuts applied on the MNF since 1991, residual basal area averaged 39 ft^2/acre. While residual trees in the experimental deferment cuts were potential high-quality sawtimber, residual trees in the operational deferment cuts also included mast and den trees to help meet wildlife habitat objectives. In practice, deferment trees may be selected by many criteria to help the forest manager achieve a wide range of objectives.

Where residual tree quality is a concern avoid leaving trees in weaker crown positions or trees that show evidence of stress before treatment. For most species, the strong codominants will not suffer grade reductions after deferment cutting. To reduce logging damage, try to employ a reliable logger and conduct operations during the dormant season from November through January. To reduce windthrow, avoid leaving trees above skid roads close to the cut bank where roots are disturbed.

To meet regeneration goals, residual basal area should range from 20 to 40 ft^2/acre. However, if small sawtimber or poles are retained, maximum residual basal area will be reduced to allow for crown expansion as the overstory trees mature. It also is important to cut all stems 1.0 inch and larger other than the desired residual trees. Cutting these stems during logging eliminates low shade that interferes with regeneration and provides suitable growing conditions for the valuable shade-intolerant species.

Two-age regeneration harvests should be applied no more frequently than one-half the recommended sawtimber rotation for local conditions. In the central Appalachians, economic sawtimber rotations are 90, 80, and 70 years for northern red oak SI 60, 70, and 80, respectively. As a result, two-age harvests could be applied every 40 to 50 years. A concern with relatively frequent harvests is that many large poles and small sawtimber need to be cut at short intervals in order to provide adequate light for regeneration of a new age class. At age 40, even-aged stands in the region contain 75 to 100 codominant stems per acre, with an average d.b.h. of only 10 inches. To maintain a two-age stand structure, 20 to 30 of the best codominant trees need to be retained to reach maturity, while the remaining trees will be cut. A disadvantage of short cutting intervals is that many cut trees will be removed at a time when their potential growth and value increase are at a maximum.

As two-age regeneration methods are employed to meet emerging forest management objectives, additional research is needed to better understand the implications of this practice. It is important to define linkages among plant and animal communities that may be affected by maintaining two vertical strata of woody vegetation over extended periods of time. For example, additional studies are needed to determine the relationship between stand density and structure on game and nongame wildlife communities. And because the forest is always changing, more research is needed to define the susceptibility of residual trees to attacks by insects and pathogens over much longer time periods. This practice may also affect product options in the future. Residual trees grow rapidly after deferment cutting and such growth rates may influence product quality and utilization options.

Due to differences in the timing and frequency of harvest cuts, economic returns from silvicultural alternatives are seldom directly comparable on the basis of returns from a single entry. However, estimates of harvesting costs and roundwood values indicate that implementing deferment cuts versus conventional clearcuts can reduce net cash flows from the initial regeneration cuts by 459 to 1,171 dollars/acre, or 18 to 26 percent, depending on site quality and roundwood price levels (Miller and Baumgras 1994; Baumgras et al. 1995). These revenue reductions were estimated for fully stocked stands at age 80 years, and reflect the assumption that the deferment cutting residual trees were low-risk, dominants and codominants. These residual trees can make significant contributions to economic returns from future harvests, but diminish short term returns to provide the desired non-timber amenities.

Two-age methods show promise for application in the central Appalachian hardwood region. With additional information from long-term observations, this practice and its many potential variations may provide forest managers with an ecosystem management tool for the future.

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APPENDIX. Names of species used in this report.

Common name	**Scientific name**
American basswood	*Tilia americana* L.
American beech	*Fagus grandifolia* Ehrh.
Yellow birch	*Betula alleghaniensis* Britton
Sweet birch	*Betula lenta* L.
Northern red oak	*Quercus rubra* L.
Chestnut oak	*Quercus prinus* L.
Scarlet oak	*Quercus coccinea* Muenchh.
Black oak	*Quercus velutina* Lam.
White oak	*Quercus alba* L.
Black cherry	*Prunus serotina* Ehrh.
Yellow-poplar	*Liriodendron tulipifera* L.
Sugar maple	*Acer saccharum* Marsh.
Red maple	*Acer rubrum* L.
Blackgum	*Nyssa sylvatica* Marsh.
Aspen	*Populus grandidentata* Michx.
Cucumbertree	*Magnolia acuminata* L.
Striped maple	*Acer pensylvanicum* L.
Dogwood	*Cornus florida* L.
Pin cherry	*Prunus pensylvanica* L. f.
Sassafras	*Sassafras albidum* (Nutt.) Nees.
Serviceberry	*Amelanchior arborea* (Michx. f.) Fern.
American hornbeam	*Carpinus caroliniana* Walt.

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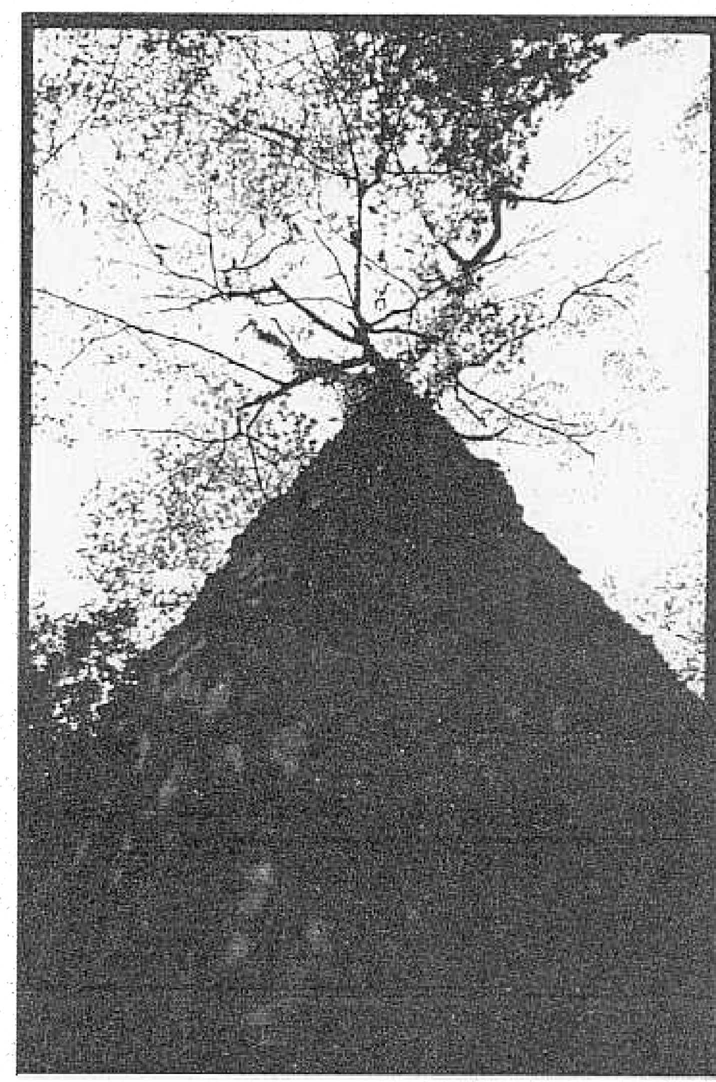

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