DIAMETER-LIMIT CUTTING in Appalachian Hardwoods: *BOON or BANE?*

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BOON OR BANE?

DIAMETER-LIMIT CUTTING is widespread and is applied in a great many ways, often without appreciation of its advantages and disadvantages and without an understanding of its effects on subsequent stand development. Although the technique has advantages, unless applied carefully, it can have long-lasting adverse effects on sawtimber production. The latest results of studies of diameter-limit cutting on the Fernow Experimental Forest, near Parsons, W. Va., shed additional light on its use as a silvicultural tool for sawtimber production.

Varied Applications

When diameter-limit cutting is intended as a valid forestry measure, an attempt is made to set a diameter that will result in harvesting only trees that are more-or-less financially mature. Theoretically at least, a well-stocked stand of trees is left to occupy the site and to provide for similar future cuts at more-or-less equal intervals on a sustained-yield basis.

Diameter-limit cuts are sometimes applied as one-shot treatments. In such cases, the implied intention is to adopt a more intensive type of forest practice in the future. Such cuts may be made to recover the purchase price of forest land in one cutting, or to condition a second-growth stand that contains a number of large old residuals from a previous cutting. The latter application—to harvest the residuals—is typical in Appalachia.

Another use, and perhaps the most common one, is to set a diameter limit that will roughly separate the trees it pays to harvest from those on which the operator loses money. A limit thus set both facilitates appraisal work and guides the fallers in leaving submarginal trees. In this application, many hardwood sawtimber operators use a 14-inch stump diameter limit. This method of cutting is almost always applied on someone else's land—or if on one's own land, is applied through ignorance—with little or no thought to long-term value or productivity.

Past Research

A number of observers have written about the results of diameter-limit cutting, based on theoretical grounds and on short-period research.

Hutnik (1958) made a 5-year report on diameter-limit cuts made in mixed hardwood stands on medium sites on the Fernow Experimental Forest. He said that the big advantage of diameter limit cutting is simplicity of application, but that cutters still require the same supervision as on a marked stand. Another advantage is that returns per unit volume can be greater, because—unless the diameter is set very low—no low-value small trees are handled. Hutnik pointed out that,

> both of these advantages are most important in the first cut. Thereafter, the disadvantages begin to show. Compared to the selection system, growth following a diameter-limit cut is considerably less. Dense young stands are not thinned; areas supporting large trees are completely cut-over; dying small trees are not salvaged; trees of the highest vigor tend to be cut first, while trees of low vigor remain in the stand; slow-growing species tend to be left and fast-growing species cut; the smaller, low-quality trees are left; and there is no control over reproduction. Thus, not only is the total amount of growth less, but also the value per unit of growth is less.
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> Some of the disadvantages already cited could be resolved by changes in the method of management. A flexible diameter limit could be made where desirable trees just above the limit are left and undesirable trees below the limit are cut. Also the diameter limit could be varied with species, site and stand size. But every step taken in this direction increases the amount of management and more closely approaches the selection system.

Blum and Filip (1963), writing about diameter limit cutting in northern hardwoods on the Bartlett Experimental Forest in New Hampshire, came to conclusions similar to those of Hutnik.

Trimble (1961), from a 10-year study of a diameter-limit cut on an excellent site in West Virginia, reached similar conclusions and observed that special caution should be exercised in judging the early results of diameter-limit cutting. He felt that it is unlikely the effects of this type of management will be fully expressed until at least two cuts have been made.

Smith's (1962) discussion of selection thinning bears on the effect of diameter-limit cutting on the stand. He writes (parenthetical comments are mine):

> In selection thinning, dominant trees are removed in order to stimulate the growth of the trees of the lower crown classes. (This is, in effect, the way diameter-limit cuts work). The same kind of vigorous trees that are favored in crown and low thinning are the very ones that are likely to be cut in selection thinning. It is obvious then that selection thinning is suitable only for rather limited purposes and, if not carefully used, readily degenerates into high-grading . . . Selection thinning, by removing numerous dominants, may reduce the investment more but it usually reduces the growth in value as well . . . Selection thinnings have little place in hardwood management except as initial corrective action in elimination of rough dominants from young stands. (This corresponds to setting diameter-limits to harvest old residuals).

Hart (1964), writing of his 9-year experience with diameter-limit cutting in mixed hardwood—spruce-fir plots in Maine, said: ". . . Diameter-limit cutting results in uneven stocking. And it tends to remove many vigorous trees above the limit while leaving defective and poor-vigor trees below the limit."

FERNOW RESEARCH

Data recently available from areas on the Fernow Experimental Forest cut one and two times by the diameter-limit method, when compared to data from selection-cut and clearcut areas, provide the basis for confirming, modifying, and extending earlier observations on this method of cutting. This should facilitate making more rational judgments about using diameter-limit cutting for the production of sawtimber.

The diameter-limit-cut areas had minimum cutting diameters between 15.5 and 17.0 inches and averaged 16.6 inches. The clearcut stands were harvested to 5 inches d.b.h. In the selection-cut stands, individual trees were marked for cutting throughout the d.b.h. range above 11 inches, so trees below sawlog size were ignored. Cuts were 15 to 20 years apart for the diameter-cut areas and about 10 years apart for the selection-cut areas.

Stand Composition

The distribution and density of the tree canopy after cutting affect the relative abundance of tolerant species versus intolerant species among stems of reproduction. One of the most frequently observed disadvantages of diameter-limit cutting is that it provides no control of spacing and so results in a clumpy stand with clearcut and partially-cut areas interspersed with overly-dense areas. This was the situation on all of the diameter-limit stands studied on the Fernow.

Where a mixture of hardwood species exists, such cutting favors reproduction of intolerant species in the large openings and tolerant species in the lightly-cut areas. In this respect, such cutting should be intermediate between single-tree selection cutting and clearcutting; the former should result in a higher proportion of tolerant species, and the latter should produce more intolerants. Observations of reproduction 7 to 20 years after logging on areas cut in all three ways on the Fernow showed this to be the case (table 1).

All three types of cutting resulted in abundant and well-distributed reproduction of commercial species (Trimble and Hart 1961 and Wendel and Trimble 1968).

If lower diameter limits had been designated for cutting (for example, 14 inches d.b.h. instead of 17 inches), we would have expected to find more intolerants in the reproduction and, probably, more of the new stems would have been sprouts.

Another disadvantage of diameter-limit cutting: Because small-size stems are ignored, species composition is not controllable

Table 1.—*The effect of cutting practice on the proportions of tolerant versus intolerant reproduction*

Type of cutting	No. of areas	Total acreage	Site index (for oak)		Number of 1- to 5-inch stems in—		Stump sprouts as a proportion of total reproduction
			Range	Average	Intolerant[1] species	Tolerant[2] species	
	No.	*Acres*	*Ft.*	*Ft.*	*Weighted Pct.*	*Weighted Pct.*	*Pct.*
Clearcut	9	110	61 - 77	70	37	27	58
Diameter-limit	5	151	59 - 75	69	18	62	18
Selection	7	198	59 - 82	71	5	78	18

[1]Red oak (*Quercus rubra* L.), *yellow-poplar* (*Liriodendron tulipifera* L.), black cherry (*Prunus serotina* Ehrh.), white ash (*Fraxinus americana* L.), black locust (*Robinia pseudoacacia* L.), sassafras (*Sassafras albidum* (Nutt.) Nees).

[2]Beech (*Fagus grandifolia* Ehrh.), sugar maple (*Acer saccharum* Marsh.), red maple (*Acer rubrum* L.).

below the minimum cutting diameter. Undesirable species, such as beech, may gradually increase in number until they form the bulk of the stand growing across the cutting threshold. (No such trend is yet discernible on the Fernow.)

Quality

Two measures of quality were used to compare results of diameter-limit cutting with selection cutting: (1) proportion of stand volume in cull trees, and (2) log quality of the stand.

(Not enough cuts have been made for scaling defects to be correlated with the cutting system. However, in the diameter-limit system, the fact that the small poorly-formed and partly-rotten trees are left to grow predestines future cuts to higher scaling deductions than in selection cutting.)

Cull Trees.—In general, the custom is to kill culls down to the minimum diameter limit considered for cutting. This means that some sawtimber culls are usually left where diameter limits are above 11 inches.

In applying the selection system of sawlog management on the Fernow, culls above 11 inches d.b.h. were killed. In the diameter-limit cutting areas, only those culls were killed that were larger than the minimum cutting diameter of 17 inches.

The data taken after the first cuts showed that diameter-limit cutting reduced the original cull tree volume 85 percent (obviously most of the original cull-tree volume was in trees above 17 inches d.b.h.). The selection cutting reduced cull tree volume by 99 percent (table 2).

These figures are merely indicative and do not necessarily characterize diameter-limit cuts. To illustrate the possible extremes, a 12-inch-stump diameter cutting would take all sawtimber-size cull trees; in contrast, in a stand cut to a 17-inch limit where all original sawtimber cull trees were between 11 and 17 inches, no culls would be killed.

Grapevine damage is a big factor on medium and better sites when stands are cut heavily. Grapevines are intolerant; and once cut out of trees, they do not grow back unless the stand is opened up drastically. Under the selection system, stand improvement

Table 2.—*Cull tree volume in the sawtimber-stand*

Method of cutting	Total acreage	Cull tree volume in sawtimber trees		Reduction
		Before cutting	After cutting	
	Acres	*Pct.*	*Pct.*	*Pct.*
Diameter-limit	237	8.5	1.3	84.7
Single-tree-selection	179	15.0	.1	99.3

measures generally include cutting grapevines, and in most cases they are inhibited from regrowing by the shade of the canopy. However, under diameter-limit cutting, where big holes are left in the canopy and where, customarily, little stand improvement is done, grapevines proliferate and may reduce future timber growth rates and log quality.

Log Quality.—Log grade indicates the relative quality of the lumber in the tree. Since hardwood values are so highly correlated with timber quality, log grades strongly reflect profitability. Log grades 1 and 2 (Ostrander and others 1965) are the money makers, and they provide a useful yardstick by which to judge the success of a forestry practice.

On the Fernow, log grades were sampled on several areas to determine the effects of both diameter-limit and selection cutting on the proportion of the different log grades (table 3). In interpreting the meaning of grade changes, the conditions of the stands and nature of the treatments must be kept in mind. All of the stands were vigorous, middle-age, second growth, and contained varying proportions of old large residuals.

In the diameter-limit cutting, the diameter limits were so set (at 17 inches d.b.h.) that the first cut took most of the old residuals and little else. Many of these old trees were partly defective, and this resulted in low average grade yield in the first cut.

The second cut in these stands took the faster-growing trees of the second growth. These were good quality trees with a lot of log-grade-1 material (the minimum-sized tree that can have a

Table 3.—*Proportion of sawtimber volume in the better log grades*

Area no.	Size	Proportion of sawtimber in log grades 1 and 2					
		Stand after cutting			Harvested trees		
		1st cut	2nd cut	3rd cut	1st cut	2nd cut	3rd cut
	Acres	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
DIAMETER - LIMIT CUTTING							
27A	34	—	34	—	—	58	—
9A	53	7	42	—	30	58	—
8A	5	19	23	—	47	60	—
9	81	8	44	—	33	58	—
Weighted average		8	41	—	32	58	—
SELECTION CUTTING							
WS5A	78	27	53	—	6	38	—
WS5B	12	38	56	—	12	35	—
7C	20	—	51	—	—	51	—
19B	11	30	45	—	30	52	—
8C	5	24	40	58	26	34	45
Weighted average		28	52	58	10	41	45

grade 1 butt log is 16 inches d.b.h.). Grade yield of the second cut was thus much higher than the first; second cuts averaged about 58 percent in grades 1 and 2 logs compared to 32 percent for the first cut. We predict that the next cut will show a drop in grade from the second cut. This cut will be composed of (1) slow-growing individuals of intolerant species that have passed many years in partly submerged positions (and, therefore, will be more subject to degrade through epicormic branching) and (2) of slower-growing species, the beech component of which will be low grade (Trimble 1965).

The selection-cut stands, because they were cut on a different basis, exhibited a different pattern of grade development. While the diameter-limit cuts were in essence high grading, the selection cuts built up stand grade by taking the poor trees first. After the second cut, the residual selection stands averaged 52 percent in log grades 1 and 2, while the diameter-limit stands averaged only

41 percent in these grades. Part of the difference is due to the fact that more large trees were left in the selection stands.

Grade yield of the selection-cut areas improved steadily, from 10 percent in log grades 1 and 2 for the first cut to 41 percent for the second cut. However, after two cuts, the selection-cut yield still does not equal the yield of 58 percent in log grades 1 and 2 from the diameter-limit second cut.

We predict that grade yields of the third cuts under the two systems will be more nearly equal; and that, in subsequent cuts, the selection system will provide higher grade yields. (Moreover, by then, a real difference in scaling deduction should be showing up in favor of the selection system.)

Growth

Diameter-limit cutting contains three potential sources of loss of merchantable timber growth: (1) loss in cull-tree volume and in volume of scaling deductions in merchantable logs (discussed previously), (2) mortality of trees below the cutting diameter, and (3) loss due to understocking.

Diameter-limit cutting makes no provision for salvaging dead trees below the designated cutting diameter. Sawlog-size trees that die before they reach the minimum cutting diameter are lost to harvestable growth; in comparison, most of this growth is harvested in selection cutting. The situation is accentuated when species that mature at small size make up an appreciable part of stands. Cutting to a higher uniform minimum diameter means that most of the volume of such species is lost.

Cutting stands below full site occupancy is another source of growth loss. Because of the inherent lack of control over density and spacing, this can easily happen in diameter-limit cuttings. Our growth data seem to indicate that this is happening on the Fernow diameter-cut study areas (table 4).

It appears that these stands were cut well below full site occupancy for both board foot and cubic foot growth; the growth rate for the first 5 years after logging was below the annual rates for longer measuring periods, indicating that, as stocking increased, growth rate increased. The growth rate ratios indicate

Table 4.—*Growth of sawtimber*

Area	Oak site index	Diameter limit	Basal area after 1st cutting in trees over 5 inches d.b.h.	Basal area after 1st cutting in trees over 11 inches d.b.h.	Annual per acre growth in 1st 5 years of study period		Basal area at end of 5 years in trees over 5 inches d.b.h.	Basal area at end of 5 years in trees over 11 inches d.b.h.	No. of years from 5th year to end of period	Annual per acre growth from 5 years to end of study period		Annual growth for 1st 5 years as percent of growth in the second-period	
No.	*Ft.*	*In.*	*Ft.*	*Ft.*	*Bd. ft.*[1]	*Cu. ft.*[2]	*Ft.*	*Ft.*	*Yrs.*	*Bd. ft.*	*Cu. ft.*	*Bd. ft.*	*Cu. ft.*
					DIAMETER-CUTTING AREAS								
27-A	70	16.5	57	23	277	54	66	31	13	377	69	73	78
27-B	66	16.5	64	26	275	53	73	35	14	406	70	68	76
8-B	78	15.5	42	22	349	61	54	32	15	534	90	65	68
26-B	65	13.5	66	14	239	50	75	23	15	456	—	52	—
					SELECTION-CUTTING AREAS								
8-C	78	—	54	41	467	87	70	55	15	369	72	127	121
16-A	77	—	90	50	477	51	97	65	12	577	85	83	60
8-C	78	—	58	42	551	95	76	58	15	459	81	120	117
13[3]	76	—	102	68	494	87	95	65	15	329	57	150	153
21[3]	74	—	93	43	251	58	86	40	15	272	48	92	121

[1]Measured by the International ¼-inch kerf rule to an 8-inch top d.i.b. in trees over 11.0 inches d.b.h.
[2]Measured to a 4-inch top d.i.b. on all trees over 5.0 inches d.b.h.
[3]These two stands were cut lightly several times in the first 5 years; this accounts for the fact that basal areas are lower after 5 years than after the first cut.

that board foot growth was reduced more than cubic foot growth.

When the same type of comparison was made for a number of selection cut areas, i.e., growth comparisons between the 5-year post-logging period and the longer later period, on the average, no growth increase occurred. This adds further proof that the diameter-limit cut areas were understocked. (The decreased growth in the second period for the selection cut areas is probably related to increasing stand age and reduction of ingrowth rather than to a stocking factor.) A comparison of the post-cutting basal areas between the two types of cutting shows that stocking for diameter cutting areas was much less than for selection cutting areas (table 4).

We conclude that diameter-limit cutting, as practiced on the study areas, has resulted in a growth loss after the first cutting that will never be made up. It is logical to expect that this same type of growth loss will be repeated after similar diameter-limit cuts.

Sawlog growth is undoubtedly quite low for a long period after the common 12- and 14-inch-stump diameter cuts. This results in either an extremely long period between profitable cuts or subsequent harvests of small trees with low-grade logs, or probably both.

Eventually, the Fernow diameter-limit cuts should provide—for one specified kind of diameter-limit cutting—a sawlog growth comparison with selection-cuts where defective trees are eliminated, potential mortality is recovered, and residual sawtimber stands more fully occupy the site. Because of differences between the original stands in species composition, in cull tree volume, and in stand structure, two more cuts will probably be required to establish growth rates representative of the two cutting practices.

Value of Cuts and Residual Stands

In general, cutting big trees results in low unit costs of logging, if the trees are not too big for easy handling and if the harvests are heavy enough to minimize the impact of such fixed costs as road work and transporting equipment. Also, other things being equal, big trees are more valuable because they have higher grade and produce better lumber. Thus cutting to a high minimum diameter is characterized by high monetary returns per thousand board feet. This has been true with 17-inch diameter-limit cutting on the Fernow. If the minimum diameter was set at 20 to 24 inches on the better sites, the return per thousand board feet would be even higher.

On the other hand, very heavy per-acre cuts (such as 14-inch stump-diameter cuts)—which take most or all of the merchantable trees, but not the submarginal ones—are characterized by returns that are higher per acre, but lower per thousand board feet.

Initial selection cutting in unmanaged sawtimber stands, unless deliberate high grading, usually returns less per thousand board feet and less per acre than diameter-limit cuts. This is especially true when the costs for selection marking are considered.

These are generalized relationships that apply to first cuts in average unmanaged sawtimber stands. Many factors may cause them to vary including the minimum diameter limit; the marking guides used for selection cutting; stand variables such as species composition, distribution of stem sizes, stand volumes, and cull-tree frequency; and whether or not stand improvement treatments are subsequently applied.

Theoretically, after a number of cuts, the relative value of the harvests under the two practices can be expected to change. Because of stand deterioration under the usual diameter-limit cutting and stand improvement under a good selection system, the value of future cuts should be greater under the selection system.

Conclusions

For a number of reasons, which have been discussed in this paper, diameter-limit cutting is not recommended as a method of repeatedly harvesting hardwood stands. When diameter limits are set low, periods between cuts are too long or only small trees are available in the recuts. When the diameter limit is set high, the potential silvicultural disadvantages of the system are postponed, that is, a long period of time will pass before they show up. This is especially true if the diameter limit is set to conform with stand conditions and to approximate financial maturity.

Another drawback to diameter-limit cutting is that, with many crews, supervision costs are high. This is especially true if a high minimum diameter is designated.

A number of modifications can be made in diameter-limit cutting to improve its performance and soften the impact of its poor features. These include killing culls below the minimum diameter, different diameter limits for different species to conform to their physiological and financial maturity sizes, and setting diameter limits based on stand inventories so as to leave a residual stand that fully occupies the site. However, as pointed out by Hutnik, when these steps are taken the advantages of diameter-limit cutting, that is, cheapness and ease of application, are partially lost.

In many cases, cutting to a diameter limit has immediate short-range economic advantages. Moreover, if it is done right—such as making only one diameter-limit cutting and setting the limit high so as to remove only old residuals—it should have no adverse long-range silvi cultural effect on the stand.

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