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Distribution-Of-Cut Guides For Thinning In Allegheny Hardwoods: A Review

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Abstract

Distribution-of-cut guidelines describe the amount of stand density to be removed from broad size classes of trees to attain a target residual stand density and stand structure. Current guides for thinning Allegheny hardwoods recommend that 75 percent of the cut relative stand density be taken from below the average stand diameter and 25 percent from above. These guides are well suited for maximizing production of wood volume and stand worth in 50-year-old stands. In 70-year-old stands, previously thinned or not, wood production is maximized by distributing the cut so that the entire cut is from below the average stand diameter. Stand worth is maximized at 25 to 50 percent cut from below. Current guides for thinning 70-year-old Allegheny hardwoods are a compromise between the two at 75 percent cut from below. Only at this percentage is black cherry retained at sufficient levels to fully regenerate a site.

Guides for thinning Allegheny hardwood stands are keyed to controlling both stand density and stand structure. Cuttings that control only stand density can have highly variable results on growth, yield, and regeneration. Particularly in stratified, even-age mixtures, a cut that leaves 60 percent relative stand density can be a silvicultural thinning from below, a high-grade, a single-tree selection cut, or another variation. It is the distribution of trees remaining in each size class that determines the stand structure. The only way to specify a cut that will achieve the desired management objective is to control both stand structure and density.

A broadly used thinning schedule for maximizing production of high-quality veneer and sawtimber from Allegheny hardwoods (Marquis 1986, 1994b) is based on the results of field studies and simulation experiments. The stand-structure aspects of this schedule are applied using distribution-of-cut (DOC) guides which describe the amount of stocking to be removed from different size classes to reach a target residual stand density with the desired residual structure. The cut is allocated among tree-size classes by first defining an appropriate point of centrality, usually an average stand diameter closely related to the size of main crown-canopy trees, and then removing certain proportions of trees above and below this point. The value of structure guides is that thinning prescriptions and marking instructions can be developed and applied consistently.

DOC guides for thinning Allegheny hardwoods were first developed by Roach (Roach 1977) and later modified by Marquis based on “unpublished results of numerous computer simulations in Allegheny hardwood stands of varying species composition and age” (Marquis and others 1992:11). Contemporary DOC guides for thinning Allegheny hardwoods include the recommendation that 75 percent of the cut relative stand density be taken from below the average stand diameter and 25 percent from above for a wide range of stand conditions and thinning prescriptions (Marquis 1986, 1994b). Resulting stand structures from such cuts move the stand in the direction that thinning theory suggests it should go (Marquis 1986, 1994a,b). However, there is little published verification that stand structures resulting from thinning achieve a particular management objective. Marquis and Ernst (1991) field tested some of the effects of stand structures, but results are limited to the first 10 years' response in a 50-year-old stand.

The objectives of this study were to: 1) describe the development and use of DOC guides for thinning Allegheny hardwoods, and 2) examine the effects of distributions of cut on wood volume production and stand worth in both 50- and 70-year-old Allegheny hardwoods, previously thinned or not. To achieve the first objective, we reviewed the nearly 25-year history of DOC guide development in Allegheny hardwoods. To achieve the second objective, we conducted simulation experiments.

History of Distribution of Cut Guidelines

The history of DOC guidelines for Allegheny hardwoods can be divided into two periods—the 1970's, which centers around Roach's work, and the 1980's, the period bounded by Marquis' work.

The 1970's

In the early 1970's, Roach developed a DOC guideline that directed that two-thirds of the cut basal area be taken from below the average stand diameter and one-third from above (Roach 1977). Roach treated each stand as two populations of trees: shade-tolerant (sugar maple and beech) and shade-intolerant (black cherry-white ash-yellow poplar or CAP). Red maple, birch, and other species of intermediate shade tolerance were nominally present in his studies. The tolerant population, which naturally follows an inverse J-shape diameter distribution, was thinned to create a more normal distribution. The CAP population, which naturally follows a bell-shaped distribution, was thinned to become flatter and shifted to the larger diameter classes. The diameters around which Roach thinned were the quadratic stand diameter (QSD) of the entire CAP population (1.0 inch and larger in d.b.h.) for the CAP population, and the QSD of the "other" species in the stand for the tolerant population.

It should be noted that Roach's experience with stand-structure manipulations predated his work in Allegheny hardwoods, extending back to the 1940's with studies on the Kaskaskia Experimental Forest in Illinois (Marquis 1994b). During the 1970's, when lecturing on his experiences with partial cutting on the Kaskaskia, Roach noted that practitioners, including contemporary practitioners, often ended up "playing hob with stand structure without realizing it, and especially without realizing the consequences" (Marquis 1994b:257). Roach's early experiences with stand structure were translated into broad DOC guidelines in the silviculture guides for upland central hardwoods, that is, cut primarily from below to enhance the presence of a fully stocked crop (Gingrich and Roach 1968). But it was not until his stocking guide for Allegheny hardwoods was published (Roach 1977) that stand structure and DOC guidelines were outlined in detail. We surmise that Roach's recommendation that two-thirds of the cut basal areas be taken from below the average stand diameter was a "best guess." It was during the 1980's that DOC guidelines began to be objectively rooted in experimentation.

The 1980's

Marquis (1994a:30) presented a series of graphs portraying the natural development of stand structure in uncut plots measured over 60 years. His analysis provided theoretical support for DOC guides. The graphs showed two important trends: (1) distribution of the shade-tolerant population slides down and to the right and develops a hook in the lower diameter classes over time, and (2) the distribution of the CAP population flattens and moves to the right over time.

During the 1980's, the focus of distribution of cut shifted from basal area to relative stand density. The ensuing rule described that 75 percent of the cut relative stand density should be from below the average stand diameter and 25 percent from above (Marquis 1986, 1994b). The 75/25 ratio using density is equivalent to the two-thirds/one-third ratio using basal area. Working with density units allows direct calculations of residual density without the trial and error required with basal-area units (Roach 1977), and computations of relative stand density, unlike those of basal area, recognize the different growing-space requirements of the various species in the mixture.

Marquis changed the stand diameter from which to distribute the cut from QSD of two different populations of trees to one medial stand diameter for the entire stand. The total amount of cut in broad size classes of trees is about the same with both the Roach and Marquis approaches, but the intent of the cut is different. Marquis' approach focuses on creating a single normal distribution that features the biggest and best codominant and dominant trees. Roach's approach centers on creating two normally distributed populations, one with codominant-dominant trees and one with suppressed and intermediate trees.

The diameter around which the cut is distributed in the Marquis approach is the medial stand diameter, defined as the "average of the diameter or size-class midpoints, weighted by the proportion of basal area in that size class" (Marquis and others 1992:52). Marquis (1991) demonstrated the utility of the medial stand diameter, commenting that it is "far more useful for stand management than more traditional average diameters such as the arithmetic mean or the quadratic mean diameter, as it better reflects the size of the crop trees and is less influenced by small understory trees" (Marquis and others 1992:52). Two medial stand diameters are used to distribute the cut during thinnings. For stands in which the cut is not completely merchantable, i.e., some of the cut would have to occur in nonmerchantable stems (saplings) to achieve residual stocking of 60 percent of relative stand density, the medial diameter of the entire stand (stems ≥ 1.0 inch d.b.h.) is used to distribute the cut. This type of thinning is referred to as a combined thinning—a combination of noncommercial and commercial cutting (Marquis and Ernst 1991).

In a commercial thinning, i.e., where all of the cut is from merchantable trees, the medial stand diameter of the

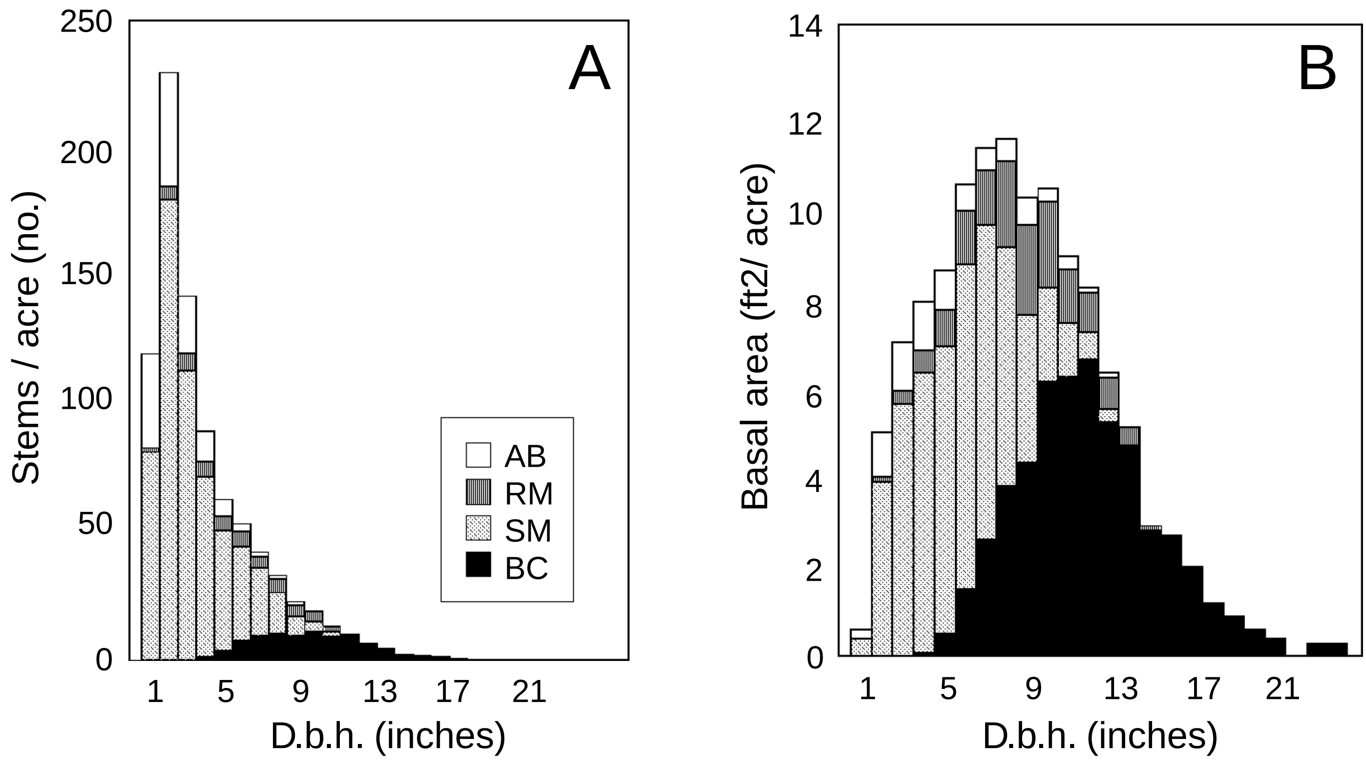

Figure 1.—Distribution of number of stems (A) and basal area (B) by 1-inch diameter (at breast height) class for a typical 50- to 55-year-old Allegheny hardwood stand (after Nowak 1996). AB = American beech; RM = red maple; SM = sugar maple; BC = black cherry.

merchantable trees only (d.b.h. ≥ 5.5 inches) is used to distribute the cut. A variant of commercial thinning—the thin-harvest—uses the same diameter but the distribution of cut is focused on removing individually mature, large, high-risk stems and stems in the pole-size class (5.5 to 11.4 inches d.b.h.).

During the 1980's, it was recognized that there was no single residual structure that was appropriate for optimizing sawtimber and value production in all stands. The solution was to recommend a variety of thinnings in stands of varying age, species composition, and stand structure: precommercial thinning, combination thinning, commercial thinning, and thin-harvest. Each thinning has a different goal for residual stand structure. From a practical standpoint, this is the most important change to Roach's guide. Marquis avoided the recommendation that precommercial cutting in the sapling class be included in all thinnings, which was a stumbling block for many practitioners because of the high cost of marking and cutting nonmerchantable trees. Marquis also recognized the economic advantage of harvesting some of the mature individuals as the stand approached maturity.

Simulating Distribution of Cut Effects

Creating Treatment Effects

The simulator in SILVAH—the silvicultural analysis, prescription, and simulator program for Allegheny hardwoods (Marquis and Ernst 1992)—was used to project growth of typical Allegheny hardwoods with different distributions of cut. SILVAH accurately projects stand growth in Allegheny hardwoods (Schuler and others 1993). Five distributions of cut were tested: 0, 25, 50, 75, and 100 percent of relative stand density cut from below (CFB). Preliminary simulation runs showed that important DOC effects occurred at intervals of 25 percent. Simulated treatments generally were within the range of data used to build SILVAH, which included data from thinning experiments that varied both in stand density and structure. Also, all of the growth equations in the SILVAH simulator include a relative diameter variable (ratio of tree diameter to the quadratic mean diameter of the stand), which allows the simulator to accurately predict growth for trees in different stand structures (Marquis 1991; Hillebrand and others 1992). Residual relative stand density was set at 60 percent and stand development was simulated for 20 years after treatment.

Hundreds of preliminary simulations were run with a variety of Allegheny hardwood stands. DOC effects generally were insensitive to differences in species composition and stumpage prices, but did vary with age. Therefore, we report simulation runs using one initial set of stand parameters that described tree-size and species distribution for a typical 50-year-old Allegheny hardwood stand (Fig. 1). This stand is the average of twenty-three 2-acre treatment plots from a long-term thinning study (Nowak 1996).

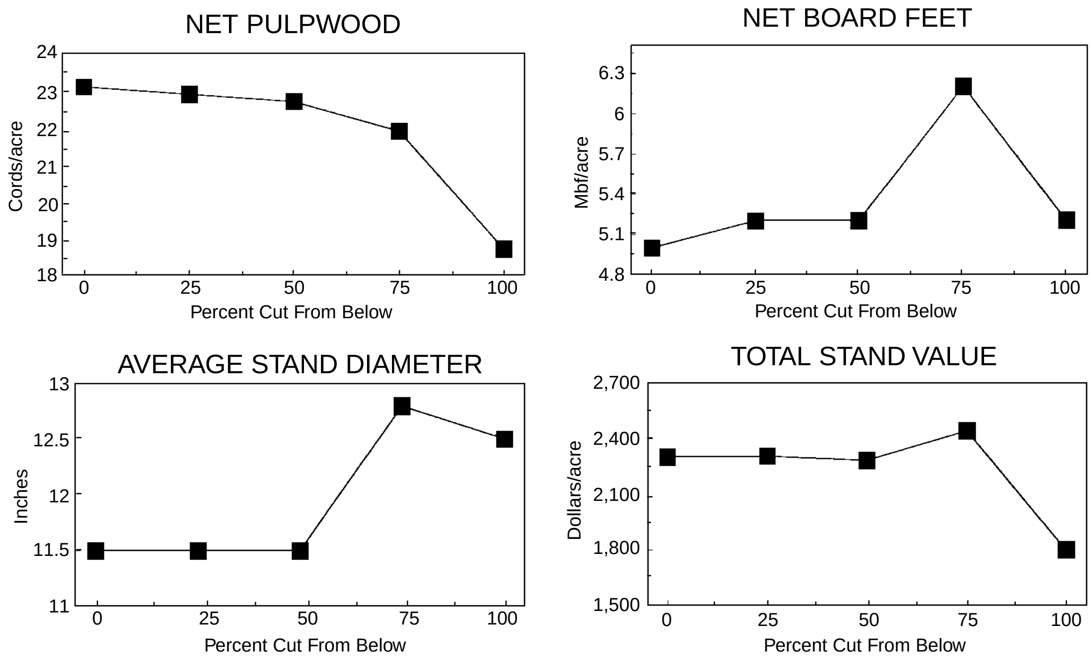

Figure 2.—Simulated wood volume, stand diameter, and value production over a 20-year thinning interval in not previously thinned 50-year-old Allegheny hardwoods. The percent cut-from-below values are distribution-of-cut treatments applied at the beginning of the thinning interval.

Two stand histories and two stand ages were combined to create three stands with these histories:

1) Not previously thinned, age 50 (NPT50).

2) Not previously thinned, age 70 (NPT70).

3) Previously thinned at age 50 using a 75-percent cut from below, age 70 (PT70).

The NPT70 and PT70 stands were created by simulating the development of the NPT50 stand for 20 years. In the NPT50 stand, all treatments distributed the cut around the total medial stand diameter for all stems ≥ 1 inch d.b.h. The 75/25 treatment means that 75 percent of the cut came from trees smaller than the mean stand diameter and 25 percent from trees larger than the stand diameter. This treatment is the currently recommended (by SILVAH) combination commercial/precommercial cut for young stands with > 20 ft^2 of sapling basal area. The 100-percent treatment takes all of the cut from below the average stand diameter and, therefore, likely would be a precommercial cut. The 0-percent treatment, which takes all of the cut from trees larger than the average stand diameter, would be a severe high-grade, as would the 25- and 50-percent treatments.

In the 70-year-old stands, the cut is distributed around the medial stand diameter of merchantable trees only (≥ 5.5 inches d.b.h.). The 75-percent treatment is identical to the commercial thinning recommended by SILVAH in this age stand. The 100-percent treatment still would be a commercial thinning, but all of the cut would be in small trees, probably all pulpwood. Again, the 0- and 25-percent cuts would represent varying degrees of high-grades, while the 50- and 75-percent cuts would be somewhat similar to the thin-harvest for stands approaching maturity currently recommended by SILVAH.

Calculating Dependent Variables

SILVAH was used to generate four dependent variables over each 20-year thinning interval: net pulpwood production, net board foot-volume production, medial merchantable stand diameter, and total stand worth. Value for calculating total stand worth is derived in SILVAH by assigning a fixed dollar-per-cord ($5) value for pulpwood (5.5 to 10.5 inches d.b.h.) and adding this to the sawtimber value. Sawtimber (≥ 10.5 inches d.b.h.) values were calculated using stumpage values for northwestern Pennsylvania (Nolley 1995). SILVAH uses a series of algorithms and correction factors to adjust these values for individual-tree quality, grade, defect, and conversion costs (cost of harvesting and transporting a log), in combination with the SETS procedure[1] (Mendel and others 1976). Income gained from a thinning treatment was compounded for each thinning interval at 5-percent rate of return and added to the end-of-period stand value to derive a total stand worth. Costs associated with stand preparation such as inventory and marking were not included. These costs likely are not constant among DOC treatments. We ran a series of simulations with a variety of assumed costs and stumpage prices and found no significant effect on DOC

[1] Hillebrand, J. 1991. **NE model: volume and value comparisons of various models.** Unpublished report on file at USDA Forest Service, Northeastern Forest Experiment Station, Warren, PA.

effects. Therefore, we present only analyses with one set of stumpage prices and no assumed costs.

Results and Discussion

The 75-percent CFB treatment in the NPT50 stand produced more net board feet and more large trees (high stand diameter) than the other treatments (Fig. 2). These results are consistent with those of Marquis and Ernst (1991) from a 10-year field thinning trial in 50- to 55-year-old Allegheny hardwoods. They found that sawtimber production was 66 percent lower at a 0-percent CFB treatment and 23 percent lower at a 100-percent CFB compared to a conventional combined thinning with a 75-percent CFB. Recalculating their results for value, we found that stand worth was 10 percent lower at 0-percent CFB treatment and 36 percent lower at 100-percent CFB compared to a 75-percent CFB.

The 75-percent CFB treatment in the NPT50 stand produced a higher total stand worth (Fig. 2). Stand value generally increases as stands pass from a pole-sawtimber stage to a sawtimber stage, from 50 to 70 years. During this period it is important to keep enough good growing stock to take advantage of value increases associated with increased tree size fostered by thinning. Value continues to increase with increased tree size through the small sawtimber class as trees pass from 10-, 13- and 16-inch d.b.h. thresholds, corresponding to changes in tree grade. Average stand diameter for the 50-year-old stand was 8.5 inches. For cherry alone it was 11.5 inches. In this type of stand, the high-grade treatments (0-, 25- and 50-percent CFB) removed nearly all of the sawtimber and, concomitantly, a large portion of the cherry before it reached critical threshold diameters (Table 1). The small amount of dollars gained by the high-grade treatments did not equal the gain in value that the trees might have achieved if left in the stand for 20 more years. Compared with the 75-percent CFB treatment, 100-percent CFB must have resulted in insufficient stimulation of good growing stock to have it move as quickly into the larger size classes.

These results are consistent with current guidelines. The 75-percent treatment, currently recommended for combination thinning, is better than all of the other treatments in these mixed-species, 50-year-old stands. Strictly precommercial thinning (100-percent CFB) has a devastating effect on economic returns, which supports previous caution in recommending precommercial thinnings (Marquis 1994b).

For the 70-year-old stands, previously thinned or not, net pulpwood and board-foot production and stand diameter were greatest at 100-percent CFB (Figs. 3-4). Stand worth peaked at 50- and 25-percent CFB for the NPT70 and PT70 stands, respectively, though there was little difference in PT70 treatment from 0- to 50-percent CFB.

As stands age and approach maturity, management objectives become more important in determining the appropriate residual stand structure. For 70-year-old stands with an objective of maximizing production of high-quality sawtimber volume, thinnings that remove trees primarily from below the average stand diameter might be appropriate. If maximizing economic return is a more important objective, some cutting in mature individuals would be required. This is not unlike the thin-harvest prescription available in SILVAH, which describes cutting large trees (23.5 inches d.b.h.) that are financially mature, coupled with a thorough cutting of pole-size trees (Marquis and others 1992).

High-grade cuts (0- and 25-percent CFB treatments) are economically attractive in older stands, though their use may have adverse consequences for regeneration. In stratified forests such as Allegheny hardwoods, heavy cuts from above selectively remove fast growing, high-value species. In our simulations, the basal area of black cherry was reduced by 89 and 89 percent in the NPT70 stand and 57 and 67 percent in the PT70 stand for the 0- and 25-percent CFB treatments, respectively (Table 1). Most of the residual black cherry in these treatments was poletimber in lower crown positions. At least 25 to 30 ft^2/acre of well-distributed, mature, codominant-dominant black cherry are needed to distribute seed across an area (Horsley and others 1994). In the high-grade treatments, the 0- and 25-percent CFB, black cherry was reduced well below this critical level (Table 1).

Table 1.—Distribution of residual basal area (ft^2/acre) among tree-size classes and in black cherry for different cut-from-below (CFB) treatments

	Tree-size class[a]			
CFB treatment	Sapling	Pole	Sawtimber	Total black cherry
Not Previously Thinned (age 50)				
Uncut	29.1	64.9	27.2	49.7
0	28.5	34.4	1.8	15.5
25	23.0	42.2	1.8	18.1
50	19.2	48.0	1.8	20.0
75	11.9	50.6	15.8	33.7
100	0	61.6	27.2	48.0
Not Previously Thinned (age 70)				
Uncut	17.8	60.6	87.8	81.4
0	17.8	46.7	0	9.0
25	17.8	46.7	0	9.0
50	17.8	35.8	19.5	21.2
75	17.8	21.8	50.0	43.9
100	17.8	3	87.8	70.6
Previously Thinned (age 70)				
Uncut	10.8	48.4	63.0	58.7
0	10.8	47.9	13.9	19.6
25	10.8	43.1	22.8	25.3
50	10.8	38.7	31.3	30.7
75	10.8	31.9	46.1	42.6
100	10.8	23.2	63.0	54.3

[a] Saplings: 1.00 to 5.49 inches d.b.h.; pole: 5.50 to 11.49 inches d.b.h.; sawtimber: ≥ 11.50 inches d.b.h.

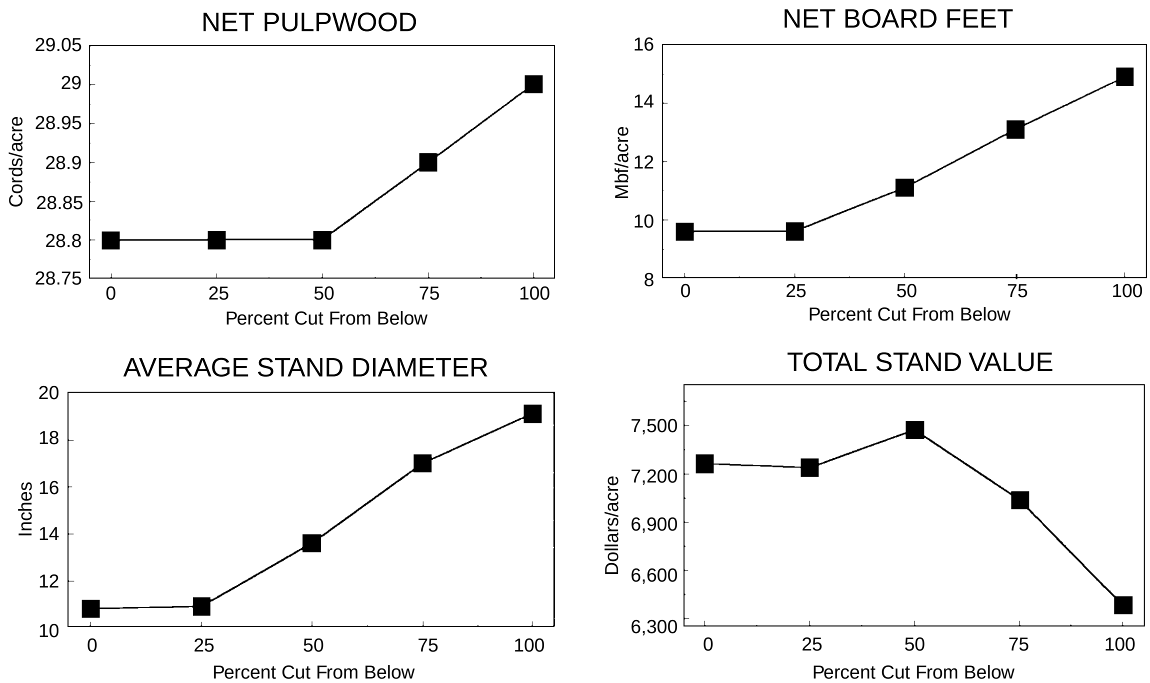

Figure 3.—Simulated wood volume, stand diameter, and value production over a 20-year thinning interval in not previously thinned 70-year-old Allegheny hardwoods. The percent cut-from-below values are distribution-of-cut treatments applied at the beginning of the thinning interval.

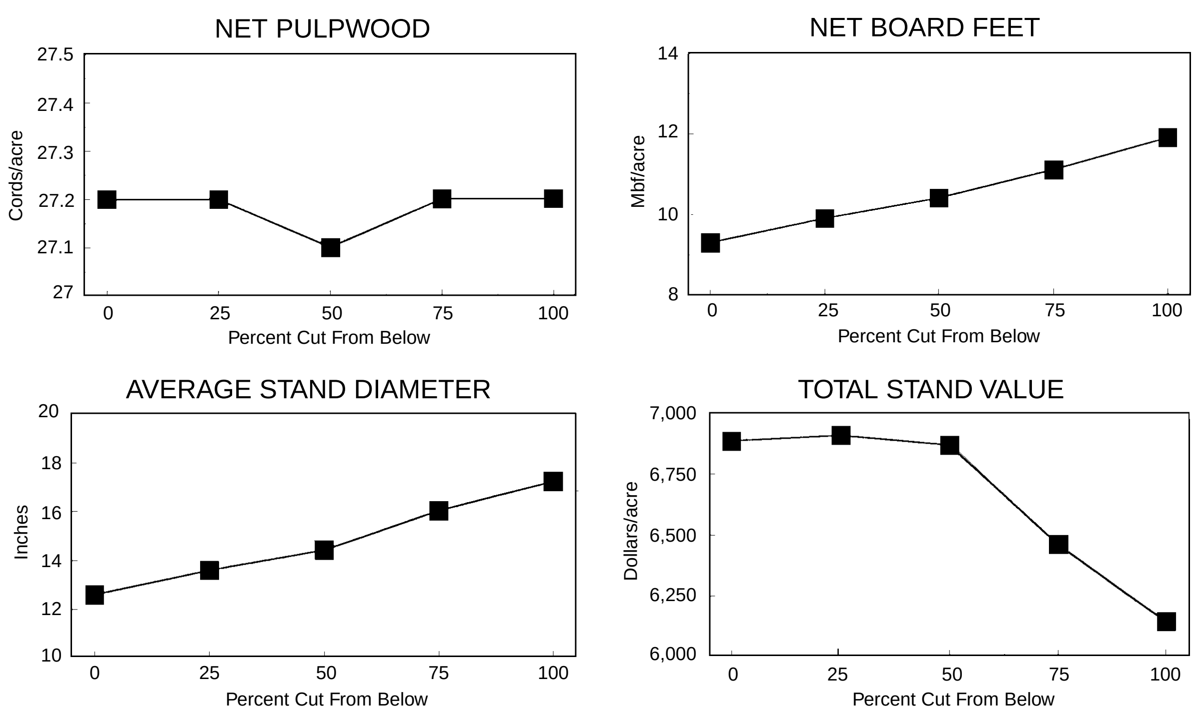

Figure 4.—Simulated wood volume, stand diameter, and value production over a 20-year thinning interval in previously thinned, 70-year-old Allegheny hardwoods. The percent cut-from-below values are distribution-of-cut treatments applied at the beginning of the thinning interval.

Summary

Guidelines for distributing the cut when thinning Allegheny hardwoods describe that 75 percent of the cut relative stand density be taken from below the average stand diameter and 25 percent from above. Simulation results from this study support the continued use of these guidelines in 50-year-old Allegheny hardwoods when the goal of thinning is maximizing sawtimber volume and stand worth. Fiber production was maximized at 0-percent CFB. In 70-year-old stands, thinned or unthinned, simulations showed that pulpwood and sawtimber yields are maximized when 100 percent of the cut is from below the average stand diameter, but that stand worth is maximized at 50-percent CFB or less. For black cherry, seed source was found at levels adequate to fully regenerate an area only at the 75- and 100-percent CFB. The current guide for thinning 70-year-old Allegheny hardwoods with a 75-percent CFB treatment is a compromise between maximizing wood production and stand worth while maintaining regeneration options.

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