THE EFFECT OF SILVICULTURAL THINNING ON TREE GRADE DISTRIBUTIONS OF FIVE HARDWOOD SPECIES IN WEST VIRGINIA

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ABSTRACT

It is well established that silvicultural thinning can increase tree growth and wood volume utilization in hardwood stands, but the effects on tree quality and value are less clear. This study measured the effect of silvicultural thinning on tree grades over a period of 12 to 15 years for 803 black cherries *(Prunus serotina,* Ehrh.), 424 northern red oaks *(Quercus rubra,* L.), 180 red maples *(Acer rubrum,* L.), 235 trees in the white oak group (Q. spp.), and 494 yellow-poplars *(Liriodendron tulipifera,* L.). Grade distributions of trees >9.6 and > 12.6 in. diameter at breast height (DBH) for black cherry, northern red oak, and yellow-poplar improved after thinning due to the removal of lower quality trees and the increased growth and the retention of high-quality, large-diameter residual trees. Red maple and the white oaks showed no improvement after thinning due to poor overall initial quality. Trees grouped by species, quality, and growth categories did not exhibit a significant increase or decrease in grade due to thinning. However, black cherry and yellow-poplar appeared to increase in grade due to silvical properties such as early branch pruning and fewer epicormic branches. Analysis of grade distributions for groups of species did not produce the same results as analyzing individual species. Mixed-species datasets may obscure species-specific effects of thinning, and species composition may have an appreciable effect on test results.

INTRODUCTION

Si1vicultural thinning is a forestry practice that is designed to allocate site resources to desirable trees such that growth, quality, and. value of the residual stand is increased after thinning. In general, trees selected for removal are of poorer quality and are less valuable species than those remaining. Numerous field trials have demonstrated that thinning increases tree growth and increases wood volume utilization. However, it is not clear if reductions in stand density associated with thinning treatments have measurable effects on important factors such as epicormic branching and residual tree quality.

Tree quality can be measured using guidelines established by the USDA Forest Service (Table 1). Tree grades incorporate tree size, quality defects, and volume-reducing defects in the tree that directly influence the grade and quantity of lumber sawn from the tree. Several studies have quantified the percentage of trees in each grade for different species and size classes (Myers et al. 1986, Yaussy 1993, Prestemon 1998).

Table 1. USDA Forest Service tree grading rules a (Hanks 1976).

			Clear Cuttings		
Tree Grade	DBH[b] (in.)	Maximum Cull Deduction	Combined Length (ft.)	Minimum Length per Cutting (ft.)	Number of Cuttings
3	≥9.6	50[c]	6	3	unlimited
2	≥12.6	9[d]	8	5	1 or2
1	≥15.6	9	10	7	1 or2

a Based on the best 12-foot section of the second worst grading face of the butt 16-foot log.

b 9.6, 12.6, and 15.6 inches represent the lower thresholds of the 10-, 13-, and 16-inch DBH classes, respectively.

c Trees with >50 percent cull deduction are considered below grade (BG). In this study, trees <9.6 in. DBH were not graded and were not included in the BG category.

d Fifteen percent crook and sweep or 40 percent total cull deduction are allowed in grade 2 if the tree otherwise has the size and surface characteristics to qualify for grade 1.

There have been few studies that measure the effects of cutting practices on tree grade distributions of important Appalachian hardwood species. In West Virginia, most timber harvests on private lands are classified as diameter-limit cuts in which all merchantable trees above a certain size are removed. Valuable species such as red oaks (mainly northern red oak, Quercus *rubra,* L.), yellow-poplar *(Liriodendron tulipifera,* L.), white oak (Quercus *alba,* L.), chestnut oak (Quercus *prinus,* L.), and maples *(Acer spp.)* are preferentially cut (Fajvan et al. 1998). Unlike silvicultural thinning, diameter-limit cutting maximizes immediate timber revenues but does not attempt to maintain or improve species composition or tree quality. Research throughout the northeastern United States has shown that over several years, harvest practices such as diameter-limit cutting produce stands of lower quality and less total value than do silvicultural thinnings (Erickson et al. 1990, Niese et al. 1995, Strong et al. 1995, Sendak et al. 2000). Data are now available from several long-term thinning studies to evaluate the effect of silvicultural thinning on residual tree quality.

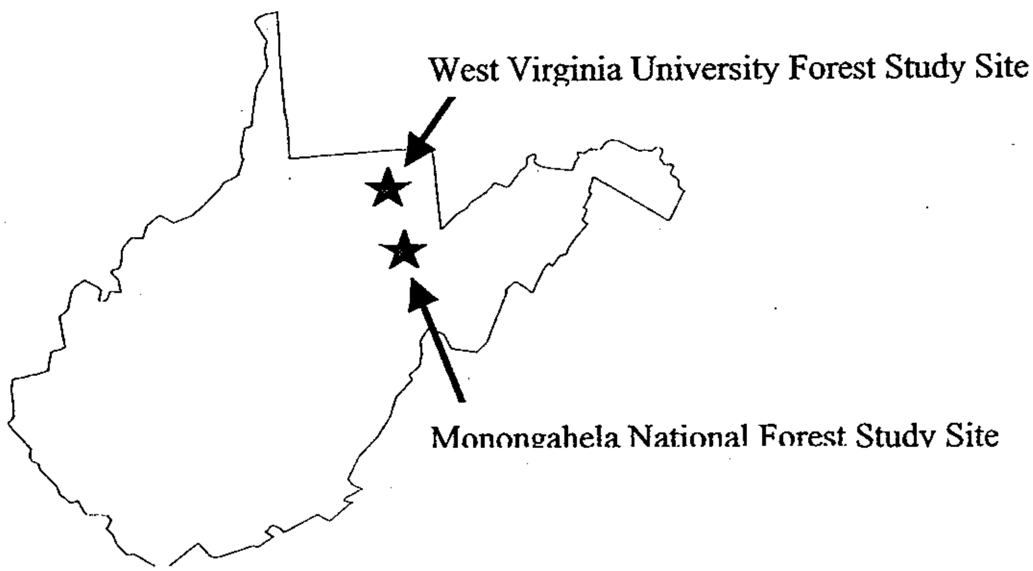
OBJECTIVES

- To compare the effects of silvicultural thinning on USFS tree grade distribution for five important Appalachian hardwood species.
- To analyze tree grade changes over time for five quality and growth categories, and when differences were found, to further analyze the data to find likely causes.
- To analyze tree grade distributions for a mixed-species group and compare these results to single-species analyses.

STUDY SITES AND FIELD MEASUREMENTS

Two West Virginia sites were used (Figure 1). The first study area is located on the Monongahela National Forest (MNF) within the Loop Road Research Area in northern Pocahontas county (38°41' N, 79°43' W) (MNF site and study descriptions from Miller 1997): Elevation ranges from 3,542 to 3,621 feet on a southwest aspect. The landforms include mostly ridgetops and sideslopes where slopes range from 5 to 20 percent.

Figure 1. West Virginia study site locations.



Treatments were applied during 1981 in unmanaged, 60-year-old, even-aged stands. These stands originated following heavy timber cutting of the original forests around 1920. When the study began, the overstory was predominantly black cherry (Prunus serotina, Ehrh.) with some white ash (Fraxinus americana, L.)and red maple (Acer rubrum, L.). Site index for black cherry is 75 feet at a base age of 50 years. The MNF study area was divided into four thinning treatment areas: 45 percent relative density (RD), 60 percent RD, 75 percent RD, and an uncut control. Relative density was measured according to published stocking equations (Roach 1977). Six permanent 0.5-acre plots were established for each of the thinning treatment levels and five plots were established as controls. In 1986, the "trees were graded using USDA Forest Service rules (Table 1). In 2000, each tree was graded a second time using the same rules. Additional butt-log variables collected included diameter at breast height (DBR); number of epicormic branches, limbs, dead branches, and overgrowths; percent rot and sweep; and potential [future] grade.

A total of 803 black cherry trees were included in the analysis.

The second study area is located on the West Virginia University Forest (WVU) in northern Monongalia and Preston counties (40° 00' N, 79°50' W). Elevation of the study area ranges from 1,600 to 2,300 feet. (WVU site and stand history descriptions are from Graves et al. 2000.) Similar to most stands in the region, the WVU study area has undergone many disturbances within the past 150 years: periodic partial cuttings, fires, chestnut blight, and gypsy moth defoliation. On mesic lower slopes, the current forest consists of yellow-poplar, northern red oak, and black cherry, with lesser amounts of red maple, sweet birch *(Betula lenta.* L.), and white oak. Drier ridgetops are dominated by chestnut oak and scarlet oak *(Quercus coccinea,* Muenchh.) with smaller amounts of red maple. Site indices for northern red oak and yellow-poplar ranged from 65 to 80.

The WVU stands are part of a larger study established to measure the effect of thinning on gypsy moth defoliation-induced mortality. In 1989, five 60-year-old stands were thinned to 60 percent RD with an emphasis on reducing species susceptible to defoliation (oaks). Five stands served as controls. Within each stand, measured trees are located on 20 0.1 ""acre permanent plots. Trees were graded in 1989 and again in 2000 using USDA Forest Service rules. Four species groups provided sufficient sample sizes for analysis: northern red oak (424 trees), red maple (180 trees), white oak group (235 trees: 185 chestnut oaks, 50 white oaks), and yellow-poplar (494 trees).

DATA ANALYSIS

Two major factors influence tree grade: size class (DBH) and stem quality (Table 1). The analysis was designed to help separate differences in tree grade due to one or both of these factors as well as silvicultural treatment and tree species.

Two types of analysis were conducted for each species. The first analysis summarized the 2000 grade distribution based on size class and thinning treatment. Counts of trees by thinning treatment and grade were determined for 3 size classes: >9.6 in. DBH, >12.6 in. DBH, and >15.6 in. DBH. These classes represent the minimum DBH for tree grades 3, 2, and 1, respectively. The counts of trees in each size/treatment/grade combination were tested using a Pearson Ch^2 test. A significant result ($p<0.05$) indicates that the grade distributions among the treatments are not equal for that size class. The percentage of trees in each category is presented for ease of interpretation.

A second analysis for each species summarized grade changes among three quality classes (Maximum, Below, and Small) and two growth classes (Increase and Same). Maximum quality trees were in the maximum grade for that DBH at the time of original grade measurement (1986 or 1989), while Below quality trees were graded below the maximum due to cull or lack of clear cuttings. Small trees were too small to be graded originally (9.6 in. DBH).

Trees in the Increase growth class increased in DBH between grade measurements (1986-2000 or 1989-2000) to meet DBH requirements for at least the next higher grade. Trees in the Same growth class did not increase enough in size to meet the next higher grade, although they did grow. Trees that were large enough to be grade I at both measurements are also included in this class. Five quality/growth categories resulted: Maximum/Increase, Maximum/Same, Below/Increase, Below/Same, and Small/Increase.

For each quality/growth category, trees were grouped according to their grade change between measurements: (1) Increase, (2) Same, or (3) Decrease.

Trees in the Maximum/Increase and Below/Increase categories were classified according to whether they increased grade (positive response) or failed to increase or decreased grade (negative response). Trees in the Maximum/Same category did not increase grade because they did not increase in DBH; therefore, these trees either had the same grade (positive response) or decreased in grade (negative response). Trees in the Below/Same category either (I) increased grade or maintained grade (positive response) or (2) decreased grade (negative response). Trees in the Small/Increase category were grouped by whether they made maximum grade (positive response) or less than maximum grade (negative response) since they were too small to have an initial grade. Pearson Chi^2 tests were performed on tree counts in each quality category where sample sizes permitted.

A Chi^2 test was performed only if all expected values were greater than 1 and no more than two values were near 1 (Snedecor and Cochran 1989). Tests were not performed if sample sizes were very small (<10 trees per treatment). When Chi^2 tests were significant ($p<0.05$), asterisks were placed on values that contributed most to the Chi^2 statistic based on examination of standardized residuals of each cell value (observed-expected/SQR expected) (SYSTAT 1992).

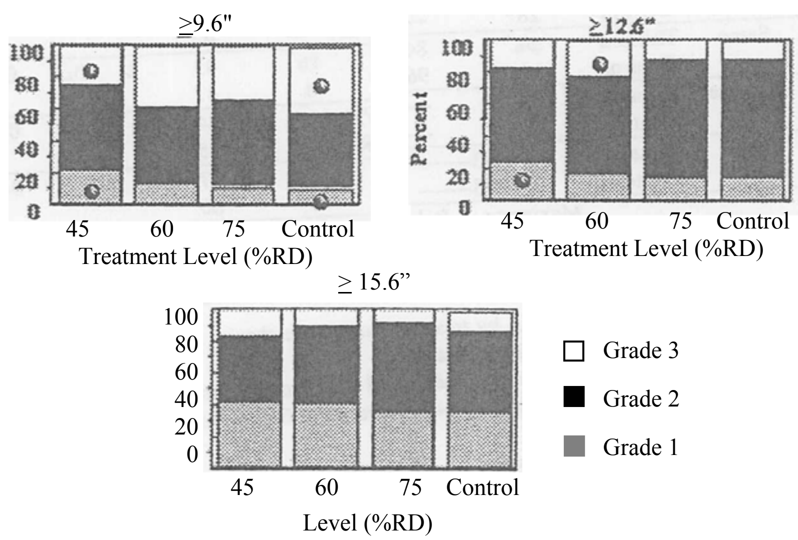
RESULTS AND DISCUSSION

Black Cherry

The USFS tree grade distribution of black cherry by size class and treatment is presented in Figure 2. For trees >9.6 in. DBH, there was a higher than expected percentage of grade 1 trees in the 45 percent RD thinning and fewer than expected grade 1 trees in the control plots. There are three likely causes for this difference. In the 45 percent and 60 percent RD thinnings, many trees were removed during thinning, leaving mostly large diameter residuals. These larger trees are the only trees meeting size requirements to be grade 1. Secondly, trees in the heavy thinnings grew more quickly than those in the control plots (Miller 1997), allowing more grade 2 and 3 trees to grow large enough to be grade L Third, thinning removed lower quality trees. In the >12.6-in. DBH class, there were more grade 1 trees in the 45 percent RD treatment and more grade 3 trees in the 60 percent RD treatment than would be expected due to similar causes.

Only one quality/growth class of black cherry showed a significant effect of thinning (Table 2). In the Maximum/Same category, 8 percent more trees decreased grade in thinned stands compared to controls. Trees that decreased in grade had much higher amounts of cull (33-34 percent) than trees that increased in grade (8 percent). Trees with >10 percent cull (rot + sweep/crook) cannot attain grade 1 and rarely attain grade 2. Trees in the control plots that decreased in grade also appeared to have higher amounts of defects, which reduced the number and lengths of clear cuttings.

Figure 2. Percent of black cherry trees in each USFS tree grade by size class (> 9.6 in., > 12.6 in., and> 15.6 in. DBH) and treatment level in 2000. When the overall Chi[2] had a p-value <0.05, an asterisk (*) denotes values contributing most to the Chi' statistic.



Red Maple

Thinning did not have a significant effect on the grade distribution of red maple at the WVU Forest study site when analyzed by either size class or quality and growth classes (Table 3). Red maple was generally of very low quality at both measurements and frequently had large amounts of defect and cull. These quality and volume defects prevented changes in grade due to thinning, even when growth was measurably increased. The grade distributions by size class were not significantly different because few high quality trees existed to serve as residuals during thinning. Less than 1 percent of red maples attained grade 1 under either treatment and 1832 percent were below grade.

Table 2. Percent of black cherry trees changing grades by quality class, growth class, and treatment from 1986-2000.

Quality Class	Growth Class	Treat-ment	Grade Change: Increase	Same	Decrease	# Trees	df	Chi^2	D-value[a]
Maximum	Increase	Thinned	61	----39----		289	1	0.1	0.7403
		Control	63	----37-----		79			
Maximum	Same	Thinned	N/a[b]	89	11*	144	1	5.3	0.0211
		Control	N/a	97	3*	99			
Below	Increase	Thinned	75	----25----		20	-	-	[c]
		Control	0	---100---		4			
Below	Same	Thinned	---94---		6	84	1	05	0.4744
		Control	---89---		11	19			
			Maximum	Below Maximum					
Small	Increase	Thinned	94	---6---		50	--	--[c]	--
		Control	100	---0---		15			

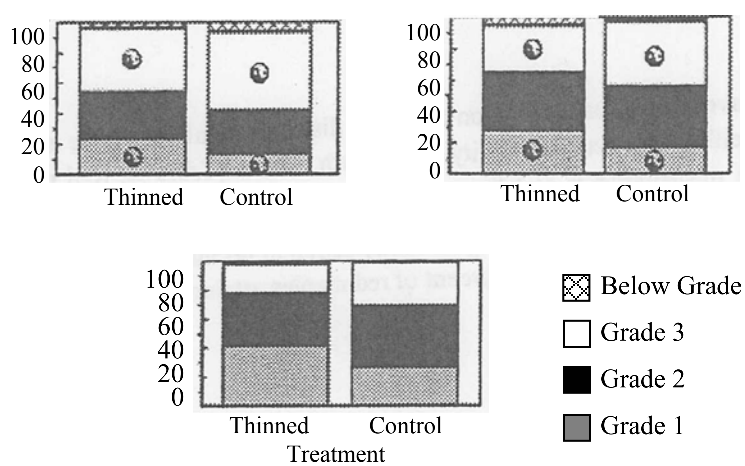
[a]Pearson Chi^2 tests were performed on tree counts by treatment and grade change. When the overall Chi^2 had a p-value <0.05, asterisks (*) denote values contributing most to the Chi^2 statistic.
[b]N/a = not applicable. Trees that were in the maximum grade could not increase in grade without additional DBH growth.
[c]Chi^2 tests were not performed on the Below/Increase category due to small sample size and the Small/Increase category due to an expected value <1.

Table 3. Percent of red maple trees changing grades by quality class, growth class, and treatment from 1989-2000 at the WVU Forest study site.

Quality Class	Growth Class	Treat-ment	Grade Change: Increase	Same	Decrease	# Trees	df	Chi2	p-value[a]
Maximum	Increase	Thinned	47*	----53----		68	1	5.3	0.0212
		Control	28*	----72----		65			
Maximum	Same	Thinned	n/a[b]	84	16	45	1	3.3	0.0682
		Control	n/a	96	4	47			
Below	Increase	Thinned	21	----79----		24	1	0.8	0.3761
		Control	32	----68----		25			
Below	Same	Thinned	-93-		7	27	1	1.8	0.1746
		Control	-98-		2	60			
			Maximum	Below Maximum					
Small	Increase	Thinned	86	-14--		22	1	0.6	0.4230
		Control	78	---22----		41			

[a]Pearson Chi^2 tests were performed on tree counts by treatment and grade change. When the overall Chi^2 had a p-value <0.05, asterisks (*) denote values contributing most to the Chi^2 statistic.
[b]n/a = not applicable. Trees that were in the maximum grade could not increase in grade without additional DBH growth.
[c]Chi2tests were not performed on the Maximum/Same, Below/Increase, or Below/Same categories due to small sample sizes.

Figure 3. Percent of northern red oak trees in each USFS tree grade by size class (>9.6 in., >12.6 in., and >15.6 in. DBH) and treatment level in 2000. When the overall Chi^2 had a p-value <0.05, an asterisk (*) denotes values contributing most to the Chi^2 statistic.



Northern Red Oak

The grade distribution of northern red 03k at the WVU Forest study site differed between, the thinning treatment and control plots for trees >9.6 and >12.6 in. DBH (Figure 3). There were 10 percent more grade 1 trees in thinned stands for the >9.6-inch size class and 11 percent more grade 1 trees in thinned stands for the >12.6-inch DBH class. In addition, there were 14 percent more grade 1 trees in thinned stands for the >15.6inch DBH class. The differences are likely due to larger residual trees, higher growth rates in the thinned stands, and removal of poorer grade trees, similar to the results for black cherry.

Northern red oak trees at the WVU Forest study site in the Maximum/Increase category were affected by thinning (Table 4) with 19 percent more trees in thinned stands increasing grade than in the control stands. Trees that increased in grade had very little cull (2-4 percent) and fewer butt-log defects than 'did trees that failed to increase in grade. Trees that maintained or lost grade had higher initial amounts of cull (8-9 percent) that increased to 10-12 percent at the second measurement. Trees with > 10 percent cull were not likely to improve in grade, similar to results for the black cherry Maximum/Same category.

Table 4. Percent of northern red oak trees changing grades by quality class, growth class; and treatment from 1989-2000 at the WVU Forest study site.

Quality Class	Growth Class	Treat-ment	Grade Change: Increase	Same	Decrease,	# Trees	df	Chi^2	p-value[a]
Maximum	Increase	Thinned	47*	--53--		68	I	5.3	0.0212
		Control	28*	---72--		65			
Maximum	Same	Thinned	n/a[b]	84	16	45	1	3.3	0.0682
		Control	n/a	96	4	47			
Below	Increase	Thinned'	21	-----79---		24	1	0.8	0.3761
		Control	32	---68-----		25			
Below	Same	Thinned	-93--		7	27	1	1.8	0.1746
		Control	--98---		2	60			
			Maximum	Below Maximum					
Small	Increase	Thinned	86	----14--		22	1	0.6	0.4230
		Control	78	-22-		41			

a Pearson Chi^2 tests were performed on tree counts by treatment and grade change. When the overall Chi^2 had a p-value <0.05, asterisks (*) denote values contributing most to the Chi^2 statistic.

b n/a = not applicable. Trees that were in the maximum grade could not increase in grade without additional DBH growth.

Table 5. Percent *of* white oak group trees changing grades by quality class, growth class, and treatment from 1989-2000 at the WVU Forest study site.

Quality Class	Growth Class	Treat-ment	Grade Change: Increase	Same	Decrease	# Trees	df	Chi^2	p-value[a]
Maximum	Increase	Thinned	43*	-----57------		23	1	0.1	0.7244
		Control	39*	-----61------		31			
Maximum	Same	Thinned	n/a[b]	96	4	27	1	0.3	0.5952
		Control	n/a	93	7	45			
Below	Increase	Thinned	17	-----83-----		6			c
		Control	0	----100----		6			
Below	Same	Thinned	------83-----		17	12	1	0.1	0.7659
		Control	-----79---		21	24			
			Maximum	Below Maximum					
Small	Increase	Thinned	84	-------16-------		31	1	0.5	0.4784
		Control	90	-------10-------		30			

a Pearson Chi^2 tests were performed on tree counts by treatment and grade change. When the overall Chi' had a p-value <0.05, asterisks (*) denote values contributing most to the Chi^2 statistic.

b n/a = not applicable. Trees that were in the maximum grade could not increase in grade without additional DBH growth.

c A Chi^2 test was not performed on the Below/Increase category due to small sample size.

White Oak Group

The grade distribution of trees in the white oak group at the WVU Forest study site was not significantly affected by thinning and showed the least variability of the five species between thinned stands and the controls. Similar to red maple, trees in the white oak group were very low in initial quality and were not appreciably changed by thinning. In addition, white oaks often show poor pruning of limbs on the lower bole (Dale and Sonderman 1984) and they develop epicormic branches following thinning, which preclude the clear cuttings required of grade 1 and 2 trees.

Yellow-Poplar

The grade distribution of yellow-poplar at the WVU Forest study site was affected by thinning for the >9.6inch and > 12.6-inch DBH classes (Figure 4), similar to both black cherry and northern red oak. There were 13 percent more grade 1 trees in thinned treatments than in the controls for the >9.6-inch DBH class and 12 percent more grade 1 trees in thinned treatments for the > 12.6-inch DBH class. Thinning did not affect the grade distribution of yellow-poplar when grouped by quality/growth category (Table 6).

Figure 4. Percent of yellow-poplar trees in each USFS tree grade by size class (>9.6 in., >12.6 in., and >15.6 in. DBH) and treatment level in 2000. When the overall Chi2had a p-value <0.05, an asterisk (*) denotes values contributing most to the Chi2statistic.

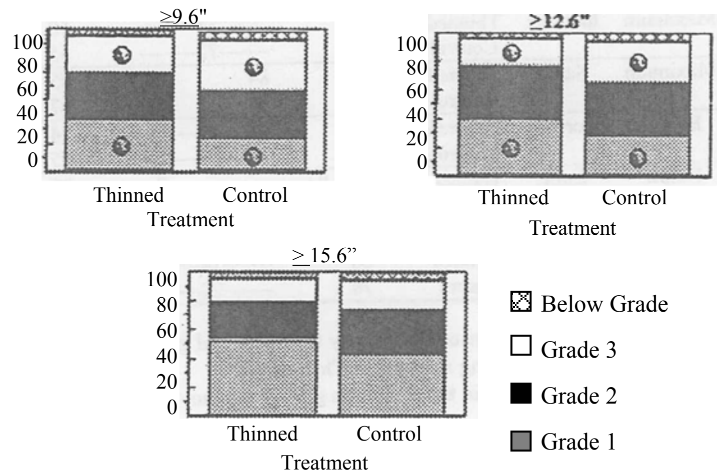


Table 6. Percent of yellow -poplar trees changing grades by quality class, growth class, and treatment from 1989-2000 at the WVU Forest study site.

Quality Class	Growth Class	Treat-ment	Grade Change: Increase	Grade Change: Same	Grade Change: Decrease	# Trees	df	Chi^2	p-value[a]
Maximum	Increase	Thinned	63	----37----		56	1	2.0	0.1549
		Control	49	----51----		55			
Maximum	Same	Thinned	N/a[b]	89	11	83	I	0.5	0.4602
		Control	N/a	85	15	89			
Below	Increase	Thinned	30	---70---		10	I	0.3	0.5925
		Control.	21	---79---		19			
Below	Same	Thinned	----93-		7	67	I	0.2	0.6825
		Control	-----91-----		9	97			
			Maximum	Below Maximum					
Small	Increase	Thinned	100	------0------		8			
		Control	80	----20----		10			

a Pearson Chi2tests were performed on tree counts by treatment and grade change. When the overall Chi2had a p-value <0.05, asterisks (*) denote values contributing most to the Chi2 statistic.

b n/a = not applicable. Trees that were in the maximum grade could not increase in grade without additional DBH growth.

c A Chi2test was not performed on the Small/Increase category due to small sample size.

COMPARISONS AMONG SPECIES

In general, thinning increased the percentage of grade 1 trees and decreased the percentage of grade 3 trees in the >9.6-inch or >12.6-inch DBH size classes when high-quality, large-diameter trees were favored as residuals (e.g., black cherry, northern red oak, and yellow-poplar). There was no significant effect of thinning for these size classes when large-diameter, high-quality trees were not selected as residuals or were unavailable (e.g., red maple and the white oak group). No species showed a significant thinning effect for trees in the > 15.6-inch size class. Thus the benefits of increased tree growth and wood volume utilization that result from thinning, were not offset by reductions in tree quality.

However, there appears to be appreciable differences in grade changes among species. In the Maximum/Increase category, 49-63 percent of black cherries and yellow-poplars increased grade, while 14-47 percent of northern red oak, red maple, and the white oak group increased grade. This difference is likely due to the silvical properties of each species, such as shade intolerance, branch pruning, susceptibility to decay, and tendency to form epicormic branches (Bums and Honkala 1990). Black cherry and yellow-poplar are both shade-intolerant species that usually prune lower branches at an early age, resulting in a clear lower bole and a higher butt-log grade.

COMPARISON WITH OTHER STUDIES

Direct comparison of our results with other studies is difficult. No other studies were found that tracked the grade distributions of individual tree species in response to silvicultural thinning. Two recent studies (Strong et at 1995, Sendak et al. 2000) compared the grade distributions of mixed-species stands in response to silvicultural treatments and found that the percentage of better grade trees, as well as the mean tree grade, improved in silvicultural treatments compared to diameter-limit cutting or controls. These results are consistent with our analysis by size class and species, in which increased size and quality of residual trees significantly improved the grade distribution in thinned stands.

The above studies used mixed-species datasets for two reasons: (I) to increase sample sizes for analysis, or (2) initial grade data were not separated by species. An important question is: does combining species into one dataset mask the effect of thinning on individual species?

A test was conducted to quantify whether analysis of mixed-species data affected test results. The counts of trees in each quality/growth category were combined for the four species in the WVU Forest dataset: northern red oak, red maple, white oak group, and yellow-poplar (1,333 trees). The results of the, analysis are presented in Table 7.

Four of the quality/growth categories did not have significantly different tree grade distributions between thinned and control stands and had p-values (0.77-0.93) appreciably higher than the species-level tests. The Maximum/Increase category was significantly affected by thinning, while northern red oak, red maple, and yellow-poplar showed similar effects when analyzed individually.

One possible reason for discrepancies between mixed-species and individual-species results is that mixed-species datasets obscure quality differences among species. The species composition of trees in the mixed-species Maximum/Increase group is presented in Table 8. Yellow-poplar comprised 41-45 percent of trees that increased grade and 25 percent of trees that failed to increase grade. Red maple comprised 5-9 percent of trees that increased grade and 16-17 percent of trees that failed to increase grade. Yellow-poplar is generally of better grade than red maple, regardless of treatment (Myers et at 1986). These results suggest that the species composition of mixed-species datasets may have a major effect on the significance of test results and may produce results that differ markedly from species-level analyses.

Table 7. Percent of northern red oak, red maple, white oak group, and yellow-poplar trees changing grades by quality class, growth class, and treatment from 1989-2000 at the WVU Forest study site.

Quality Class	Growth Class	Treat-ment	Grade Change: Increase	Same	Decrease	# Trees	df	Chi^2	p-value[a]
Maximum	Increase	Thinned	50*	-------50-------		169	1	8.3	0.0040
		Control	35*	-------65--------		172			
Maximum	Same	Thinned	N/a[b]	90	10	163	1	0.0	0.9254
		Control	N/a	89	11	205			
Below	Increase	Thinned	24	------- 7 6--------		51	1	0.0	0.9051
		Control	25	------- 7 5-------		53			
Below	Same	Thinned	-----91------		9	117	1	0.1	0.7678
		Control	------92-----		8	197			
			Maximum	Below Maximum					
Small	Increase	Thinned	76	-------24--------		97	1	0.1	0.7726
		Control	78	-------22--------		109			

a Pearson Ch^2 'tests were performed on tree counts by treatment and grade change. When the overall Chi' had a p-value <0.05, asterisks (*) denote values contributing most to the Chi^2 statistic.

b N/a = not applicable. Trees that were in the maximum grade could not increase in grade without additional DBH growth.

Table 8. Species composition of trees in the Maximum/Increase category for four species at the WVU Forest study site.

Quality Class	Growth Class	Treatment	Tree Species[a]	Grade Change: Increase	Same/Decrease
Maximum	Increase	Thinned	n (# of trees)	---85---	---84---
			NRO (%)	38	43
			RM (%)	9	17
			WO (%)	12	15
			YP (%)	41	25
		Control	n (# of trees)	---60---	---112---
			NRO (%)	30	42
			RM (%)	5	16
			WO (%)	20	17
			YP (%)	45	25

a Species key: NRO = northern red oak, RM = red maple, WO = white oak group, and YP = yellow-poplar.

PRELIMINARY CONCLUSIONS

- For mixed-species forests, thinning significantly increased grade of high-quality trees, 50 percent compared to only 35 percent in unthinned stands.
- Silvicultural thinning effects on tree grade differ by species. Black cherry, northern red oak, and yellowpoplar showed significant improvements in grade distributions for trees >9.6 and >12.6 inches DBH. Red maple and the white oak group showed no significant effects of thinning.
- Improvements in grade distributions from thinning are dependent on the selection of high-quality, large diameter residual trees.
- Trees that have, or are likely to develop, > 1 0 percent cull rarely improve in grade regardless of growth rate or silvicultural thinning.
- High-quality, slow-growing black cherries decreased grade 8 percent more often in thinned stands compared to controls. High-quality, fast-growing northern red oaks increased grade 19 percent more often in thinned stands compared to controls. Thinning did not significantly affect the grade of other species and quality/growth categories.
- Analysis of grade distributions for groups of species does not produce the same results as analyzing individual species. Mixed-species datasets may obscure species-specific effects of thinning, and species composition may have an appreciable effect on test results.

FUTURE WORK

- Verify these results with additional datasets in Pennsylvania, Ohio, and Kentucky.
- Develop probability distributions for tree grade changes for important hardwood species.
- Evaluate genetic variation in stem quality for northern red oak provenance plantations in Ohio. Evaluate how faster radial growth due to thinning affects veneer log quality.

REFERENCES

Burns, R.M.; Honkala, RH., tech. coords. 1990.Silvics of North America. Volume 2. Hardwoods. Agricultural Handbook 654. U.S. Department of Agriculture.

Dale, M.E.; Sonderman. D.L. 1984. Effect of thinning on growth and potential quality of young white oak crop trees. Res. Pap. NE-539. U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station: 12 p.

Erickson, M.D.; Reed, D.D.; Mroz, GD. 1990~ Stand development and economic analysis of alternative cutting methods in northern hardwoods: 32-year results. Northern Journal of Applied Forestry. 7: 153-158.

Fajvan, M.A.; Grushecky, S.T.; Hassler, C.C. 1998. The effects of harvesting practices on West Virginia's wood supply. Journal of Forestry. 96(5): 33-39.

Graves, A. T.; Fajvan, M.A.; ~v1iller, G VI. 2000. The effects of thinning on snag and cavity tree abundance in an Appalachian hardwood stand. Canadian Journal of Forest Research. 30: 1214-1220.

Hanks, L.F. 1976. Hardwood tree grades for factory lumber. Res. Pap. NE-333. U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station: 81 p.

Miller, G W. 1997. Stand dynamics in 60-year-old Allegheny hardwoods after thinning. Canadian Journal of Forest Research. 27: 1645-1657.

Myers, J.R.; Miller, GW.; Wiant, Jr., H.V.; Barnard, '1.E. 1986. Butt-log grade distributions for five Appalachian hardwood species. Res. Pap. NE-RP-590. U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station: 4 p.

Niese, J.N.; Strong, T.F.; Erdmann, GG 1995. Forty years of alternative management practices in secondgrowth, pole-size northern hardwoods. II. Economic evaluation. Canadian Journal of Forest Research. 25: 1180-1188.

Prestemon, J.P. 1998. Estimating tree grades for southern Appalachian natural forest stands. Forest Science. 44(1): 73-86.

Roach, RA. 1977. A stocking guide for Allegheny hardwoods and its use in controlling intermediate cuttings. Res. Pap. NE-277. U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station.

Sendak, P.E.; Leak, W.E.; Rice, w.E. 2000. Hardwood tree quality development in the White Mountains of New Hampshire. Northern Journal of Applied Forestry. 17(1): 9-15.

Snedecor, GW.; Cochran, W.G 1989. Statistical methods. 8th ed. Ames: Iowa State University Press. 503 p.

Strong, T.F.; Erdmann, GG; Niese, J.N. 1995. Forty years of alternative management practices in secondgrowth, pole-size northern hardwoods. I. Tree quality development. Canadian Journal of Forest Research; 27: 1645-1657.

SYSTAT. 1992. SYSTAT for windows: statistics, version 5 ed. SYSTAT, Inc., Evanston, Ill.

Yaussy, D.A. 1993. Method for estimating potential tree-grade distributions for northeastern forest species. Res. Pap. NE-670. U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station: 12 p.

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