DEVELOPMENT AND QUALITY OF REPRODUCTION IN TWO-AGE CENTRAL APPALACHIAN HARDWOODS -- 10-YEAR RESULTS

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Abstract: Silvicultural practices that promote two-age stand structures have the potential to meet a wide range of forest resource goals. Such practices can overcome perceived disadvantages associated with clearcutting and still provide sustainable yields of desirable timber products and other woodland benefits. Forest managers need information on stand development following two-age harvests to develop prescriptions that meet diverse landowner objectives over long planning periods. Species composition, distribution, and stem quality of commercial hardwood reproduction were evaluated in four central Appalachian hardwood stands 10 years after a two-age regeneration harvest. Regeneration harvests cut all stems 1.0 inch d.b.h. and larger except for 12 to 15 codominant residual trees/acre comprising 17 to 25 ft^2 basal area/acre. After 10 years, codominants in the regenerated stand exhibited similar species composition, abundance, distribution, stem size, and quality as that previously reported for clearcuts in similar stands. Competition from the much taller residual trees in the older age class apparently has no effect on the 10-year development of the new age class. Forest managers can use the information provided to determine if two-age silvicultural practices applied in similar stands have the potential to meet specific stand management goals.

INTRODUCTION

Two-age management in central Appalachian hardwoods has the potential to provide a variety of aesthetic, habitat, and timber production benefits that may satisfy a wide range of land management objectives. Such practices involve leaving 15 to 20 codominant residual trees per acre, and perhaps some flowering shrubs or den trees for aesthetics and wildlife, and cutting all other stems 1.0 inch diameter breast height (d.b.h.) and larger. After cutting, two-age stands initially resemble those following a seed-tree cut. However, in two-age stands the codominant residual trees are retained for many years, often as long as a second rotation. The presence of a few codominant residual trees greatly improves aesthetics compared to that in clearcut stands (Figure 1).

Light conditions on the forest floor following a two-age cut are similar to those expected after traditional clearcutting or seed-tree practices, and result in regeneration of a variety of both shade-intolerant and shade-tolerant species (Smith and others 1989). As new reproduction becomes established and grows beneath the residuals, the vertical structure of the stand includes two distinct height strata. These strata provide a diverse habitat, particularly for migratory bird species that forage among the crowns of mature hardwoods (Nichols and Wood 1995). A brushy cover characteristic of young even-aged stands is present for many years, thus providing cover and food for a variety of wildlife species.

Logging operations in second-growth hardwoods to develop two-age stand structures are economical in most Appalachian markets (Miller and Baumgras 1994). To maintain a two-age stand structure, regeneration harvests are conducted at minimum intervals equal to one-half the length of a typical even-age rotation. In the central Appalachians, where economic rotations for sawtimber production are approximately 60 to 80 years, two-age harvests can be applied at least every 40 years. Preliminary results indicate that two-age regeneration practices can provide sustainable yields of desirable commercial timber products and other woodland benefits.

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Figure 1. A two-age central Appalachian hardwood stand 5 years after a regeneration harvest.

This report summarizes 10-year results on the quality and development of natural regeneration resulting from two-age harvests in four central Appalachian hardwood stands. Although diameter growth of the residual codominant trees is stimulated by removal of surrounding competitors, height growth of mature residual trees increases very little (Smith and Miller 1991). Similar to even-age stands, a new age class becomes established and grows rapidly in both total height and d.b.h. for many years. An earlier report described the application methods and summarized preliminary 5-year results for two stands (Smith and others 1989).

STUDY AREAS

Four study areas were established in cooperation with the Monongahela National Forest on two ranger districts and on the Fernow Experimental Forest in north-central West Virginia. Stand size ranged from 10.2 to 14.8 acres. Two stands were located on each of two northern red oak site classes, site index (SI) 70 and 80 at base age 50 years. The stands were uncut, second-growth central Appalachian hardwoods with an average age of about 75 years that became established after heavy logging in the early 1900's. Periodic fire was common throughout the study area as the stands became established, though no fires have occurred in these areas in the last 50 years. Chestnut blight also killed some large trees during the 1930's and resulted in patchy reproduction before and during World War II.

In general, soils on the study areas are medium-textured and well-drained, derived from sandstone shale with occasional limestone influence. The average soil depth in the general area exceeds 3 feet. However, the Olson Tower stand is on a Cookport silt loam soil with a fragipan at a depth of about 20 inches, resulting in shallow-rooted trees and problems with soil compaction on skid trails and log landings. Annual precipitation averages 59 inches and is well distributed throughout the year. The growing season averages 145 frost-free days.

METHODS

Regeneration harvests were applied in the four stands by retaining 12 to 15 codominant trees per acre and cutting all other stems 1.0 inch d.b.h. and larger (Table 1). In selecting the residual trees, the goal was to leave a residual basal area of approximately 20 ft^2/acre. Residual trees were selected using the following criteria:

Species -- northern red oak (*Quercus rubra* **L.**), yellow-poplar (*Liriodendron tulipifera* **L**), black cherry (*Prunus serotina* **L.**),
Crown class -- dominant or codominant,
Vigor -- no evidence of epicormic branches or other sign 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.

Logging operations to remove merchantable sawtimber (11.0 inches d.b.h. and larger) were conducted between 1980 and 1983. Nonmerchantable stems were felled and left on the site. A truck-crane cable system was used to log the Fish Trough stand and a portion of the Shavers Fork stand. Wheeled skidders were used in the Riffle Creek and Olson Tower stands, and the remaining portion of the Shavers Fork stand.

Reproduction data were obtained before logging, and at 2, 5, and 10 years after logging from 172 permanent sample points located along systematic grids throughout the four study areas. At each point, a 1/1000-acre and 1/100-acre circular plot were used to sample small and large reproduction, respectively. Small reproduction was defined as woody stems at least 1 foot tall and less than 1.0 inch d.b.h. Large reproduction was defined as woody stems 1.0 inch d.b.h. and larger. Species, d.b.h., stem origin, quality, and crown class were recorded for each tree observed on a plot. Tree quality was based on the potential of individual trees to become sawtimber crop trees in the future. Trees with straight, clean boles, well-developed crowns, and no evidence of potential problems were classified as good. Trees with low forks, crooked or leaning stems, or evidence of low vigor were classified as poor.

RESULTS

Before harvest, small reproduction varied in terms of species composition and total number of stems per acre among the four stands (Table 2). On SI 70, shade-tolerant species such as sugar maple (*Acer saccharum* **Marsh.**), red maple (*Acer rubrum* **L.**), and American beech (*Fagus grandifolia* **Ehrh.**) accounted for 79 percent of small reproduction in

Table 1.--Summary per-acre data for four central Appalachian hardwood stands before and after a two-age regeneration harvest

	Number of trees		Basal area		Volume			Average d.b.h.	
Stand	5.0-10.9	11.0+	5.0-10.9	11.0+	5.0-10.9	11.0+	11.0+	5.0-10.9	11.0+
	---- No./acre ----		---- ft^2/acre ----		---- ft^3/acre ----		Mbf/acre[a]	----- Inches ----	
				SI 70					
Riffle Creek - 14.8 acres									
Initial	120.2	68.6	41.3	87.7	741	2,202	12,932	7.9	15.3
Cut	118.9	57.4	40.6	70.9	727	1,773	10,305	7.9	15.0
Residual	1.3	11.2	0.7	16.8	14	429	2,627	9.9	16.6
Olson Tower - 12.1 acres									
Initial	100.5	79.9	30.4	102.9	519	2,593	15,721	7.4	15.4
Cut	99.2	65.9	29.7	84.9	505	2,138	12,987	7.4	15.4
Residual	1.3	14.0	0.7	18.0	14	455	2,734	9.9	15.4
				SI 80					
Fish Trough - 13.1 acres									
Initial	48.9	72.2	16.5	112.7	316	3,058	20,630	7.9	16.9
Cut	48.7	58.1	16.4	88.0	314	2,379	15,697	7.9	16.7
Residual	0.2	14.1	0.1	24.7	2	679	4,933	9.6	17.9
Shavers Fork - 10.2 acres									
Initial	110.6	63.4	34.1	81.9	626	2,175	14,221	7.5	15.4
Cut	110.2	50.7	33.9	61.8	621	1,627	10,363	7.5	15.0
Residual	0.4	12.7	0.2	20.1	5	548	3,858	9.6	17.0

[a]International 1/4-inch rule.

the Riffle Creek stand, and shade-intolerant black cherry accounted for 87 percent of small reproduction in the Olson Tower stand. On SI 80, small reproduction in the Fish Trough stand was mostly sugar maple and American beech (84 percent), and mostly American beech and white ash (*Fraxinus americana* L.) (74 percent) in the Shavers Fork stand.

The distribution of small reproduction before harvest was typical of second-growth central Appalachian hardwood stands on good growing sites (Trimble 1973). In general, more than 80 percent of the survey plots had at least one seedling or sprout of a commercial species present. For the Olson Tower stand, 69 percent of the survey plots had at least one black cherry stem present before harvest. For the other stands, more than 60 percent of the survey plots had at least one sugar maple or American beech seedling present before harvest.

Table 2.--Summary of small reproduction[a] of commercial species before and 2 years after a two-age regeneration harvest

Before cut		After 2 years		Before cut		After 2 years	
Species	No./acre	Species	No./acre	Species	No./acre	Species	No./acre
			SI 70				
	Riffle Creek				Olson Tower		
Beech	1,575	Red maple	1,170	Bl. cherry	4,311	Bl. cherry	9,600
S. maple	745	Beech	1,170	Beech	467	Beech	844
Red maple	340	Ch. oak	957	Basswood	67	R. maple	689
Red oak	255	S. maple	532	Others	112	S. maple	200
Bl. cherry	128	Red oak	489	--	--	Bl. birch	178
White oak[b]	128	Bl. cherry	298	--	--	Red oak	44
Ch. oak	106	Sassafras	234	--	--	Others	133
Others	105	White ash	128	--	--	--	--
--	--	Others	64	--	--	--	--
Total	3,382	Total	5,042	Total	4,957	Total	11,688
			SI 80				
	Fish Trough				Shavers Fork		
S. maple	833	S. maple	2,033	Beech	1,200	Y-poplar	3,600
Beech	300	Y-poplar	1,733	White ash	520	Beech	2,300
Wh. ash	167	Beech	1,433	S.maple	380	Red oak	2,000
Others	116	Sw. birch	467	Red oak	40	White ash	1,640
--	--	Bl. cherry	433	Others	180	S.maple	700
--	--	Elm	167	--	--	Bl. cherry	220
--	--	Others	100	--	--	Others	1,800
Total	1,416	Total	6,366	Total	2,320	Total	12,260

[a]Small reproduction includes woody commercial species 1.0 feet tall to 0.9 inches d.b.h.
[b](*Quercus alba* L.).

Two years after harvest, small reproduction in the study areas averaged 9,100 commercial stems per acre composed of 60 percent seedling-origin stems (Table 2). On SI 70, red maple, American beech, black cherry, and sugar maple were the most abundant species. Yellow-poplar, American beech, and sugar maple were the most abundant species on SI 80. In the Riffle Creek and Shavers Fork stands, there were 489 (17 percent were sprouts) and 2,000 (65 percent were sprouts) northern red oak stems per acre, respectively (Table 2). Some northern red oak was present in these stands before harvest.

Five years after harvest, the canopy of the new age class developing beneath the residual overstory trees had not closed. For large reproduction 1.0 inch d.b.h. and larger, species composition and number of stems per acre varied among the four stands (Table 3). In the Olson Tower stand, reproduction was dominated by black cherry, averaging 200 stems per acre. The Riffle Creek stand also had more than 200 stems per acre, distributed among a variety of species including chestnut oak (*Quercus prinus* L.), red maple, yellow-poplar, northern red oak, and American beech. Large reproduction in stands on the more productive sites was dominated by yellow-poplar, basswood (*Tilia americana* L.), cucumbertree (*Magnolia acuminata* L.), and sugar maple. The Shavers Fork stand had more than 350 yellow-poplar stems per acre, mostly of seedling origin.

Table 3.--Summary of large reproduction[a] of commercial species 5 years and 10 years after a two-age regeneration harvest

After 5 years		After 10 years		After 5 years		After 10 years	
Species	No/acre	Species	No/acre	Species	No/acre	Species	No/acre
			SI 70				
	Riffle Creek				Olson Tower		
Ch. oak	62	Beech	179 (51)[b]	Bl. cherry	200	Bl. cherry	744 (130)
Red maple	53	Bl. birch	145 (36)	Others	18	Red maple	71 (25)
Y-poplar	43	Red maple	138 (32)	--	--	Red oak	42 (20)
Red oak	26	Red oak	128 (31)	--	--	Beech	38 (10)
Beech	15	Ch. oak	96 (31)	--	--	Others	38 (12)
Others	41	Sug. maple	89 (27)	--	--	--	--
--	--	Y-poplar	87 (40)	--	--	--	--
--	--	Bl. cherry	55 (20)	--	--	--	--
--	--	Others	145 (41)	--	--	--	--
Total	240	Total	1,062 (94)	Total	218		933 (130)
			SI 80				
	Fish Trough				Shavers Fork		
Basswood	70	Y-poplar	310 (88)	Y-poplar	352	Y-poplar	434 (72)
Sugar maple	57	Sug. maple	273 (70)	Cucumber	53	Beech	94 (19)
Y-poplar	33	Bl. birch	103 (39)	Sug. maple	16	Bl. birch	74 (17)
Other	70	Basswood	93 (74)	Red maple	16	Red maple	64 (28)
--	--	Others	221 (53)	Others	57	Sug. maple	54 (16)
--	--	--	--	--	--	Red oak	44 (16)
--	--	--	--	--	--	Others	208 (41)
Total	230	Total	1,000 (117)	Total	494	Total	972 (89)

[a] Large reproduction includes woody commercial species 1.0 inches d.b.h. and larger.
[b] Standard error of estimated mean.

Ten years after harvest, the abundance of large reproduction under the residual overstory trees was uniform among the four study areas averaging more than 990 stems per acre. Although not present in large numbers at 5 years, black birch (*Betula lenta* L.) had become a notable competitor in three stands 10 years after treatment (Table 3). For stands on SI 70, black cherry, American beech, red maple, black birch, and northern red oak were the predominant species. On SI 80, yellow-poplar, sugar maple, red maple, and black birch were predominant species. In an earlier study of regeneration resulting from the seed-tree method, stands on site indices 70 and 80 had more than 1,200 and 1,700 stems per acre, respectively, 12 years after harvest (Smith and others 1976). Data from the two-age stands reported here indicate that stand development is similar to that observed for even-age practices where overstory trees are removed during or soon after the regeneration harvest.

Codominant stems present at the time of crown closure have an important impact on species composition and quality of future crop trees developing in the new age class. In general, crown closure among the new age class was nearly complete at 10 years, though the Olson Tower stand had patchy areas where reproduction was lacking due to soil compaction. On SI 70, the Riffle Creek and Olson Tower stands averaged about 700 codominant commercial stems per acre 10 years after two-age harvests were applied (Table 4). More than 70 percent of the codominant stems were classified as good quality with the potential to become crop trees in the future (Figure 2). While the number and quality of codominant stems was similar for the two stands on SI 70, species composition was more variable in the Riffle Creek stand. On SI 80, the Fish Trough and Shavers Fork stands averaged 493 codominant stems per acre with more than 85 percent classified as good quality with the potential to become crop trees in the future. Species composition of good, codominant stems was similar in these two stands. Yellow-poplar, black birch, sugar maple, and cucumber were the predominant species 10 years after harvest.

In general, approximately one-half of the commercial reproduction in a codominant crown position after 10 years originated as seedlings among the four study areas (Table 4). Sprout-origin stems accounted for 62 percent of codominant stems in the Shavers Fork stand where yellow-poplar was most abundant. The Olson Tower stand, dominated by black cherry, had only 37 percent sprout-origin stems.

Table 4.--Summary of codominant commercial stems 10 years after a two-age harvest

Stand	Site index	Codominants	Sprout-origin codominants	Sprouts
		No. stems/acre		Percent
Riffle Creek	70	612	308	50
Olson Tower	70	735	276	37
Fish Trough	80	486	203	42
Shavers Fork	80	458	284	62

Height growth of codominant reproduction in the two-age stands was also similar to that observed in even-aged stands in the study area . Height of reproduction in the two-aged stands was measured in 1994, when new reproduction in the study stands ranged from 11 to 15 years old (Table 5). Total height of reproduction in the Olson Tower stand averaged 29 feet and was based on 11-year-old seedling-origin black cherry. Codominant reproduction in the remaining stands had reached 40 feet tall by age 15. By comparison, seedling-origin yellow-poplar and black cherry stems averaged 30 to 35 feet tall (Lamson and Smith 1989), and sprout origin yellow-poplar, black cherry, red maple, and red oak averaged 37 feet tall (Lamson 1983) in 12-year-old clearcuts on SI 70.

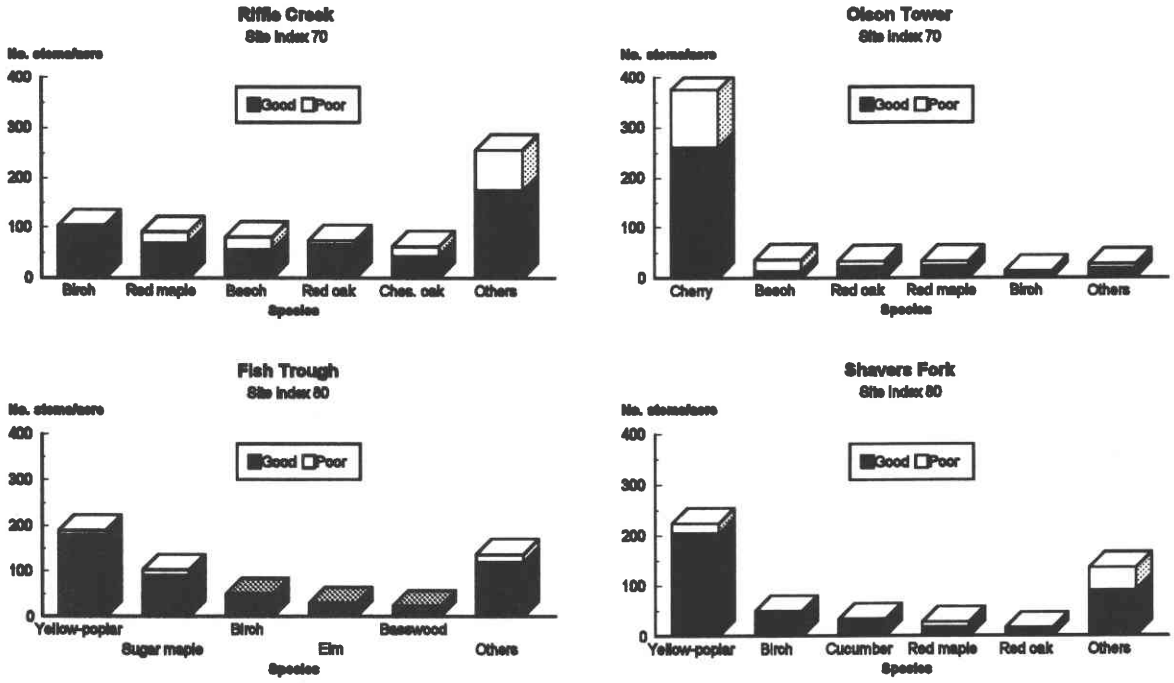

Figure 2. Distribution of codominant reproduction by stand and stem quality 10 years after a two-age harvest .

Table 5.--Average total height of codominant reproduction in two-age central Appalachian hardwood stands

Stand	Site index[a]	Age	Total height
		Years	Feet
Riffle Creek	70	15	42
Olson Tower	70	11	29
Fish Trough	80	14	42
Shavers Fork	80	13	40

[a]Northern red oak site index base age 50 years.

DISCUSSION

Similar to reproduction following clearcutting, the two-age regeneration harvest as applied in this study promoted the development of a variety of commercial hardwood species. For the new age class developing beneath the larger trees, light conditions were suitable for the development of desirable shade-intolerant and shade-tolerant species. In general, yellow-poplar, black cherry, black birch, sugar maple, red maple, and American beech were the most abundant species in a codominant crown position after 10 years. Some good quality, codominant northern red oak stems also were present, though the stands on SI 80 averaged less than 10 stems per acre.

At low residual stocking levels similar to the study stands, reproduction in the new age class can be expected to continue to develop without competition from the larger overstory trees for many years. The residual basal area in 12 to 15 overstory trees/acre ranged from 17.5 to 25.8 ft^2/acre in the four stands reported here. After 10 years, the crowns of residual overstory trees were still widely spaced with approximately 20 feet of growing space between adjacent trees. Crown expansion among the overstory residual trees was negligible after 10 years, and reproduction in the new age class should have ample growing space to allow shade-intolerant species to reach merchantable size classes in the future.

Large reproduction (1.0 inch d.b.h. and larger) also included noncommercial species such as serviceberry (*Amelanchier arborea* **(Michx. f.) Fern.**), striped maple (*Acer pensylvanicum* **L.**), pin cherry (*Prunus pensylvanica* **L. f.**), flowering dogwood (*Cornus florida* **L.**), and American hornbeam (*Carpinus caroliniana* **Walt.**) 10 years after harvest. On SI 70, noncommercial reproduction averaged 250 stems per acre with 160 stems per acre in a codominant crown position. On SI 80 stands, noncommercial reproduction averaged 340 stems per acre, with 96 stems per acre in a codominant crown position. Although noncommercial species can inhibit the growth of neighboring timber crop trees, they do provide food and cover for wildlife and some have showy flowers that enhance the aesthetics of two-age stands in the spring. However, data from this study indicate that an adequate number of timber crop trees can develop in the presence of noncommercial hardwoods.

Similar to even-age practices, light conditions following a two-age regeneration cut enhance the development of wild grapevines on good growing sites. In an earlier study of even-aged stands, grapevines were found growing in 48 to 74 percent of trees 1.0 inch d.b.h. and larger after 12 growing seasons (Smith and others 1976). Although some vines are beneficial to wildlife, stem quality and growth of commercial trees can be reduced when too many vines are present. Vines matted in trees result in crown damage by ice and snow storms in the dormant season, and slow growth because of shading during the growing season. In this study, wild grapevines (*Vitus* **spp.**) were present in all stands 10 years after harvest. In the Shavers Fork stand, 58 percent of commercial trees had at least one vine in the crown. The Riffle Creek and Fish Trough stands each had 25 percent, and the Olson Tower stand had less than 1 percent of commercial trees with vines. Grapevines were cut at ground line after 10 growing seasons to control spreading. This operation required 0.8 to 1.8 man-hours/acre to cut from 70 to 270 vines/acre, respectively.

Residual overstory trees in the four study areas are scheduled for another two-age harvest when the new age class is 80 years old. At that time, the two-age harvest method will be applied again, leaving 12 to 15 trees per acre from the new age class, and cutting all other trees 1.0 inch d.b.h. and larger. To improve the composition, spacing, and quality of the new age class, some potential crop trees in the 10-year-old age class should be released using a crown-touching technique (Lamson and Smith 1989). Such early cultural treatments will improve the value and marketability of two-age harvests in the future.

SUMMARY

The development and quality of natural hardwood reproduction following a two-age regeneration harvest can be summarized by several key observations.

- Leaving 12 to 15 residual overstory trees per acre and cutting all other trees 1.0 inch d.b.h. and larger resulted in hardwood reproduction similar to that expected after clearcutting.
- Two years after harvest, small reproduction (1.0 foot tall to 0.9 inch d.b.h.) averaged 9,100 commercial hardwood stems per acre, composed of 60 percent seedling-origin stems.
- Five years after harvest, large reproduction (1.0 inch d.b.h. and larger) averaged more than 300 commercial hardwood stems per acre, and the canopy had not closed.
- Ten years after harvest, large reproduction averaged 990 commercial hardwood stems per acre, with 574 stems per acre (58 percent) in a codominant crown position.
- Codominant trees averaged 30 to 40 feet tall after 10 growing seasons, and the canopy of the new age class was nearly closed.
- From 70 to 85 percent of codominant reproduction after 10 growing seasons was considered good quality with the potential to become timber crop trees.
- Ten years after harvest, species composition of the new age class was variable, including shade-intolerant species such as yellow-poplar, black cherry, northern red oak, chestnut oak, and black birch, and shade-tolerant species such as American beech, red maple, and sugar maple.
- Large reproduction in a codominant crown position also included serviceberry, striped maple, pin cherry, flowering dogwood, and American hornbeam.
- After 10 growing seasons, residual overstory trees left to form the older age class were still free-to-grow, with an average of 20 feet of growing space between adjacent crowns.
- Reproduction in the new age class is expected to develop for many years without serious competition from the residual overstory trees.

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