20 Years of INTENSIVE UNEVEN-AGED MANAGEMENT

: Effect on Growth, Yield, and Species Composition in Two Hardwood Stands in West Virginia

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RESULTS AFTER 20 YEARS

IN 1948 A STUDY of uneven-aged forest management, with individual tree-selection cuttings, was begun on two 31-acre stands of Appalachian hardwoods in West Virginia. Now, after 20 years, these stands are beginning to show how this kind of management affects growth, yield, and species composition.

The stands are located on the Fernow Experimental Forest near Parsons, West Virginia, one of the outdoor laboratories of the Northeastern Forest Experiment Station, USDA Forest Service. Elevation is about 2,600 feet. Average rainfall is about 59 inches. Soils are well-drained, of medium texture, and 3 to 4 feet deep.

Both stands had been first cut for sawlogs about 40 years before the study was begun. In that cutting, defective trees, below sawlog-size stems, and unmerchantable species were left. So the 1948 stand was made up of two distinct groups of trees: the old growth left from the original logging, and the second growth that came in afterward.

Both areas have average site indexes (for oak) of 75 feet (*Trimble and Weitzman 1956*). Both areas have sites ranging from dry ridge tops to moist stream bottoms; both were fairly typical in 1948 of stand conditions in the northern Appalachian region, though they represented two different stages in the recovery of cut-over, burned-over forest land. Cutting was followed by fire on both areas, but stand 1 appeared to have suffered more severely, possibly because it was closer to an old logging railroad. The stand in 1948 still reflected this past damage.

The results of the first 10 years of this study have been published as an economic analysis *(Mitchell and Webster 1961)*. This report deals with the effects of one type of management (and of the maturation of the stand) over a 20-year period. And from this record, predictions can be made about the future developments of the two areas.

METHODS

A 100-percent inventory was made of each stand in 1948. Inventories were repeated in 1958 and 1968. All trees over 5.0 inches d.b.h. were tallied by 2-inch d.b.h. (diameter breast high) classes. Local volume tables were made as a basis for estimating board-foot and cubic-foot volumes. Board feet were computed according to the International 1/4-inch kerf rule for trees over 11.0 inches d.b.h. to an 8-inch top i.b. (inside bark). Cubic-foot volumes were computed for trees over 5.0 inches d.b.h. to a 4-inch top i.b.

Log grade in sawtimber-size trees was sampled, using the grades developed by the USDA Forest Service, Forest Products Laboratory, and following the definitions published by Ostrander and others *(1965)*.

RESULTS

Harvest Cuttings

For the first 10 years of the study, a cutting was made annually in some part of each stand, as a farmer might cut his woodlot. During the second 10 years, cuttings were made every 2 years in each stand. All together 15 cuttings were made in each area. All cut volumes used in this report are based on marked-tree tallies.

Most of the cuttings produced only sawtimber; some produced only pulpwood; a few produced both sawlogs and pulpwood. Over the 20-year period, stand 1 produced a harvest of 2.4 thousand board feet of sawlogs per acre and 190 cubic feet (inside bark), or 2.7 cords (at 70 cubic feet per cord) of pulpwood per acre (table 1). Stand 2 produced 5.2 thousand board feet of sawlogs per acre and 104 cubic feet or 1.5 cords of pulpwood per acre. Pulpwood came mostly from trees in the 5- to 11-inch d.b.h. range; tops and limbs of harvested sawtimber trees were utilized to only a slight extent.

The cutting was heavier during the first 10 years, when emphasis was placed on cleaning up the stand as rapidly as possible.

Table 1.—*Material harvested per acre*

Stand number	Board feet[1]			Cords[2]		
	1949-58	1959-68	Total	1949-58	1959-68	Total
1	2,000	430	2,430	1.54	1.18	2.72
2	3,750	1,420	5,170	1.07	.40	1.47

[1] International ¼-inch kerf rule, to an 8-inch top i.b. in trees over 11.0 inches d.b.h.

[2] At 70 cubic feet per cord, computed to a 4-inch top i.b. in trees 5- to 11-inches d.b.h. If cubic feet had been computed outside bark, 80 cubic feet per cord would have been used.

During this period, most of the old-growth trees were cut. During the second 10 years, the cutting was lighter, since the main effort was directed toward building up the stocking.

Growth

Growth data were computed for the two 10-year periods, then combined for the 20-year record (table 2). Only merchantable trees were used; most cull trees were killed during the first year of the study. Growth figures include the cuttings as well as changes in the stand. Stand ingrowth is included; mortality is excluded.

Board-foot growth, computed for the period for trees over 11.0 inches d.b.h., averaged 256 feet per year for stand 1, and 361 feet for stand 2. Annual *cubic-foot* growth was computed for all trees over 5.0 inches d.b.h. For stand 1 it averaged 48 cubic feet and for stand 2 it averaged 62 cubic feet. Annual *basal-area* growth was 2.08 square feet for stand 1 and 2.28 square feet for stand 2.

Ingrowth accounted for a high percentage of board-foot growth over the 20-year period; 45 percent for stand 1 and 32 percent for stand 2 (table 2). For cubic-foot growth the percentage of ingrowth was lower: 8 percent for each stand. For both stands, and for both board-foot and cubic-foot growth, ingrowth percentage was higher in the first 10-year period than in the second.

Table 2.—*Periodic annual growth rates per acre*

Item	Board-foot growth[1]			Cubic-foot growth[2]			Basal-area growth[3]		
	1949-58	1959-68	Average	1949-58	1959-68	Average	1949-58	1959-68	Average
Stand 1:									
Net growth	228	284	256	48.6	48.0	48.3	2.16	2.00	2.08
Percent ingrowth	50	40	45	11	4	8	—	—	—
Stand 2:									
Net growth	402	319	361	69.4	54.1	61.8	2.57	2.00	2.28
Percent ingrowth	36	28	32	8	7	8	—	—	—
Average									
Net growth	315	302	308	59.0	51.0	55.0	2.36	2.00	2.18
Percent ingrowth	43	34	39	10	6	8	—	—	—

[1] International ¼-inch kerf rule, to an 8-inch top i.b. in trees over 11.0 inches d.b.h.
[2] In trees over 5.0 inches d.b.h., to a 4-inch top i.b.
[3] For trees over 5.0 inches d.b.h.

Sawtimber Quality

Timber quality was measured by a combination of three yardsticks: (1) the volume of the cull trees in the stand, (2) defective material in merchantable trees, and (3) the grade of the logs in merchantable trees. A cull sawtimber tree was defined as a tree over 11.0 inches d.b.h., which does not contain at least one 16-foot log having 50 percent or more merchantable volume.

Total inventories gave us the volume in cull trees; scaling records in these and similarly treated stands provided an estimate of volume reduction due to scaling defects; and sample tree grading during the inventories yielded an estimate of log grade in the sawtimber stand.

Over the 20 years, in stand 1 volume per acre in cull trees dropped from 746 board feet to 68, a reduction from 14 percent to less than 1 percent (table 3). In stand 2, the reduction was from 1,353 to 42 board feet, or from 13 percent to less than ½ percent of sawtimber volume.

A study made in these and other similar stands showed that after repeated selection cutting we can expect scaling deductions on merchantable trees to drop below 5 percent of sawtimber volume *(Trimble 1965a)*. These deductions include cull logs in merchantable trees, and crook, sweep, shake, and rot in merchantable logs.

Factory log grades 1 and 2 are the money makers. Twenty years of management—and of increasing stand diameter—have raised the percentage of merchantable sawtimber volume in the stand in these two grade classes from 19.2 to 51.4 for stand 1 and from 29.7 to 58.9 for stand 2 (table 4).

Table 3.—*Per-acre volumes, merchantable and cull*

Stand number	1948				1968			
	Merch. volume	Cull tree volume	Total volume	In cull trees	Merch. volume	Cull tree volume	Total volume	In cull trees
	Bd. ft.	*Bd. ft.*	*Bd. ft.*	*Pct.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Pct.*
1	4,611	746	5,357	13.9	7,296	68	7,364	0.9
2	9,227	1,353	10,580	12.8	11,274	42	11,316	0.4

Table 4.—*Percentage of sawtimber volume, by log grades*

Date	Log grade 1	Log grade 2	Log grade 3	Log grades 4 and 5	Log grade 6 (cull log)
		STAND 1			
1948	11.0	8.2	52.7	23.3	4.8
1958	11.7	14.9	39.6	32.1	1.7
1968	27.1	24.3	39.6	8.3	0.7
		STAND 2			
1948	10.7	19.0	38.0	26.8	5.5
1958	25.8	21.1	38.8	13.4	0.9
1968	35.6	23.3	33.9	6.9	0.3

Species Composition

Typical of Appalachian hardwood stands, both stands are composed of a great number of species. In 1948, 21 commercial species grew in stand 1 and 24 grew in stand 2. Many of these occurred so infrequently or were of such low value that they were of little economic importance. During the 20-year period there was little change in the total number of species, but their relative frequency in the stand changed appreciably (table 5).

From previous work in this area we expected that, on these sites, uneven-aged management with selection cutting would result in an increase of shade-tolerant species such as the maples and beech *(Trimble 1965b)*. These species reproduce and the seedlings can develop under the canopy conditions produced by uneven-aged management. Typically this trend would be accompanied by the diminution of such shade intolerants as black cherry and yellow-poplar. These species cannot thrive under canopy.

These expectations were borne out by the record. In 1948, beech, red maple and sugar maple made up 13.5 percent of the 5- to 11-inch stems in stand 1 and 16.6 percent in stand 2. In 1968, the percentages had increased to 25.3 and 32.3. Meanwhile, yellow-poplar and black cherry, which in 1948 made up 15.1 percent of the 5- to 11-inch stems in stand 1 and 21.8 percent in stand 2 dropped to 8.8 and 6.1 percent. Most of the 5- to 11-inch stems had grown into the sawtimber size class after 20 years,

Table 5.—*Species composition, twelve most numerous species*

	5- to 11-inch trees				Trees over 11 inches			
	1948		1968		1948		1968	
	Species in numerical order	Percent of total stand	Species in numerical order	Percent of total stand	Species in numerical order	Percent of total stand	Species in numerical order	Percent of total stand
				STAND 1				
1.	Red oak	18.3	Sweet birch	20.6	Beech	22.8	Red oak	36.0
2.	Sweet birch	17.6	Red oak	13.0	Red oak	21.2	Yellow-poplar	23.8
3.	Yellow-poplar	12.1	Red maple	11.0	Yellow-poplar	17.8	Beech	6.0
4.	Black locust	6.6	Beech	9.4	Black cherry	6.6	Chestnut oak	5.8
5.	Red maple	6.6	Yellow-poplar	7.2	Sugar maple	5.3	Black cherry	5.4
6.	Beech	5.2	Fraser magnolia	5.7	Sweet birch	4.1	Red maple	4.2
7.	Sassafras	5.1	Cucumbertree	5.5	Chestnut oak	4.1	Sweet birch	3.5
8.	Cucumbertree	4.6	Sugar maple	4.9	Black gum	4.1	Cucumbertree	3.1
9.	Chestnut oak	4.1	Chestnut oak	4.7	Red maple	3.4	Fraser magnolia	2.5
10.	Black cherry	3.0	Black locust	3.0	Cucumbertree	2.2	Sugar maple	1.9
11.	White ash	2.4	Serviceberry	2.6	Hickory	1.9	Basswood	1.7
12.	Sugar maple	1.7	White ash	2.4	Basswood	1.2	White ash	1.7
	Sum of 12	87.3		90.0		94.7		95.6
				STAND 2				
1.	Yellow-poplar	18.0	Sweet birch	13.0	Yellow-poplar	23.3	Yellow-poplar	31.2
2.	Red oak	12.9	Red maple	12.5	Beech	12.6	Red oak	20.0
3.	Sweet birch	8.4	Sugar maple	10.9	Red oak	11.4	Basswood	8.8
4.	Beech	8.0	Sassafras	9.8	Sugar maple	7.7	Beech	6.7
5.	Basswood	7.6	Red oak	9.1	Basswood	7.2	Black cherry	5.7
6.	Red maple	6.1	Beech	8.9	Sweet birch	6.3	Chestnut oak	4.5
7.	Sassafras	5.6	Basswood	6.4	Black cherry	6.0	Hickory	3.5
8.	Yellow-poplar	4.4	Yellow birch	5.9	Chestnut oak	5.1	Sugar maple	2.9
9.	Black cherry	3.8	Yellow-poplar	4.9	Hickory	4.0	Red maple	2.9
10.	White ash	3.2	Fraser magnolia	3.5	White oak	3.7	White ash	2.5
11.	Cucumbertree	3.1	Cucumbertree	3.1	Black locust	2.3	White oak	2.4
12.	Black locust	2.9	Hickory	2.7	Yellow birch	2.3	Sweet birch	2.2
	Sum of 12	8.40		90.7		91.9		93.3

and there were few, if any, replacements. On both areas in 1968 sweet birch became the most numerous species in the 5- to 11-inch stand. The undesirable Fraser magnolia was not represented in the 5- to 11-inch stand in 1948, but 20 years later it made up 6.6 and 3.2 percent of the small stems in stands 1 and 2. This increase was the result of vigorous stump sprouting by this species.

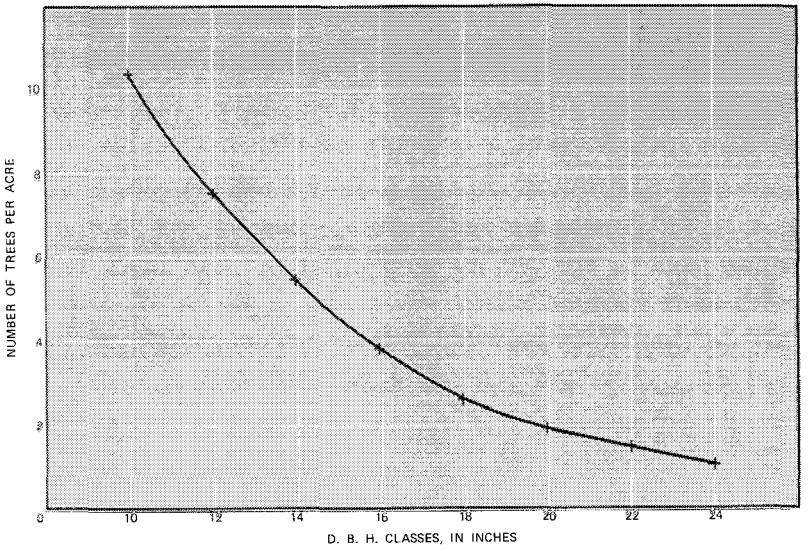
The effect of the silvicultural system has not in 20 years greatly affected the composition of the stand now over 11.0 inches d.b.h. These trees came in after a clearcutting 60 to 65 years ago. It will be another 20 years or so before the species composition of the sawtimber stand strongly reflects the current program of periodic individual tree-selection cuttings. However, one definite effect of management to date is the decline of beech sawtimber. Because of its typically poor quality, it has been marked heavily for removal. Sugar maple sawtimber was also heavily marked during the 20-year period because most of it was old growth.

Diameter Distribution

In a stand managed under the uneven-aged system, one of the goals is to harvest approximately equal volumes in more-or-less equally spaced cuttings. This requires that a fairly consistent diameter distribution be maintained. It requires also that this distribution be so balanced that sufficient numbers of trees grow into the higher d.b.h. classes.

De Liocourt devised a method that has been used to accomplish this objective, and it is described by Meyer et al. *(1961)*. A. "Q", or proportional relationship between number of trees in different diameter classes, defines an inverse J-shaped curve (fig. 1). For example, using a Q of 1.4 with 2-inch diameter classes means that the stand should contain 1.4 times as many trees in each decreasing d.b.h. class; that is, the 16-inch class should have 1.4 times as many trees as the 18-inch class, etc. In actual practice —marking a stand to leave a given Q—the diameter classes are usually combined into 4- to 6-inch classes. Determination of stand-structure guides involves not only picking a suitable Q, but also deciding what basal area to leave and the maximum-size tree to leave.

Figure 1.—J-shaped curve illustrating a "Q" of 1.4.



The average Q's for the two stands in 1948 and 1968 were as follows:

	Computed Q	
Stand	*1948*	*1968*
1	1.9	1.7
2	1.5	1.5

During the 20 years of management, tree size has increased, as indicated by the increasing number of stems in the sawtimber-size d.b.h. classes (table 6). Average d.b.h., including all sound stems over 5.0 inches d.b.h., has increased as follows:

	Average d.b.h., by years		
Stand	*1948 (inches)*	*1958 (inches)*	*1968 (inches)*
1	8.5	8.8	9.7
2	9.9	10.1	10.3

Table 6.—*Number of living trees per acre, by 2-inch d.b.h. classes*

D.b.h. class (inches)	Stand 1			Stand 2			Planned residual stand of the future[1]
	Before first cut, 1948	Cut or killed 1948-68	Trees after last cut, 1968	Before first cut, 1948	Cut or killed 1948-68	Trees after last cut, 1968	
6	86.0	27.2	50.6	49.8	10.2	48.2	26.6
8	51.0	12.0	37.4	31.5	7.1	28.0	19.0
10	28.2	6.0	27.6	23.4	5.8	17.0	13.6
12	15.8	4.5	21.0	16.2	5.2	14.6	9.7
14	8.4	3.6	13.9	11.3	4.9	12.1	6.9
16	4.0	2.7	8.6	7.1	3.4	9.0	4.9
18	2.8	1.8	4.6	5.1	3.3	6.0	3.5
20	2.2	2.0	2.0	3.1	2.0	3.8	2.5
22	1.1	1.0	1.1	2.2	1.4	2.4	1.8
24	.6	.2	.4	1.5	1.4	1.3	1.3
26	.3	.2	.3	.8	.7	.7	.9
28	.1	.1	.2	.4	.4	.3	—
30	.03	.1	.06	.2	.4	.4	—
32	—	—	—	.1	.2	—	—
34	—	—	—	.03	.06	.1	—
36	.03	.03	—	.06	.06	—	—
38	—	—	—	.03	.03	—	—
Total	200.6	61.4	167.8	152.8	46.6	143.9	90.7

[1] Goal of management is based on: Maximum size tree = 26 inches d.b.h.; Q = 1.4; basal area in trees over 5.0 inches d.b.h. = 65 square feet.

DISCUSSION & CONCLUSIONS

Twenty years of record, although detailed, is far from a satisfactory predictive base from which to postulate on the detailed behavior of these and similar stands when they fully reflect the silvicultural system practiced. However, considering the over-all lack of stand data from long-term studies, and in view of the fact that the results of this study parallel findings from other large-area studies on the Fernow Experimental Forest, we feel that certain conclusions about long-range implications are warranted.

We feel that a growth rate of 300 board feet per acre can be maintained in stands on this site quality during the period of converting to a fully managed uneven-aged condition. In cubic volume of wood, exclusive of bark, the stands can produce 55 to 60 feet, not including top and limb wood. When the volume in tops and limbs is included, and computations are based on volumes outside bark, we estimate annual production of about 1¼ cords per acre.

Previous studies on the Fernow indicate that this growth rate can be maintained on a wide range of residual stocking, possibly going as low as 65 square feet per acre (in trees over 5.0 inches d.b.h.) with a Q of 1.3 to 1.5 and a maximum-size leave tree of about 26 inches *(Trimble 1968)*. A residual stand tailored to such specifications would contain about 32 trees of sawtimber size and about 59 trees between 5 and 11 inches d.b.h. (table 6). This stand would contain about 6,665 board feet. This is less than either stand is now carrying.

The indicated growth rate should produce a per-acre harvest of approximately 3 thousand board feet every 10 years, plus 3 to 6 cords of pulpwood.

Indications are that the future stabilized stands will provide a sawlog cutting that will be composed about 60 percent of log grades 1 and 2.

On this site, the future stand will be composed primarily of the maples, beech, and sweet birch. Sugar maple will predomi-

nate in the sawtimber sizes, and sweet birch will possibly account for the greatest volume in the pulpwood-size stand.

It should be stressed that the species composition of a forest stand reflects the quality of the site, silvical characteristics of the species indigenous to the area, and the silvicultural system used to manage the stand. Strong interrelationships operate between these factors, particularly the second two. For example, and as described previously, shade-tolerant species such as sugar maple are favored by uneven-aged systems, in contrast to intolerant yellow-poplar, which cannot develop satisfactorily under an individual tree-selection cutting program. Species preferences of the forest manager, expressed through marking practices, may drastically alter the natural development of stand composition under any silvicultural system. While the characteristics of beech favor its development as a strong component in an uneven-aged system, it will generally be discriminated against in marking because of its undesirable characteristics such as poor log quality and slow growth, and thus will be relegated to the position of a minor stand component.

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