STAND STRUCTURE AND SPECIES COMPOSITION CHANGES IN A BEECH-MAPLE STAND IN EAST TENNESSEE

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ABSTRACT

Stand structure and species composition changes brought about by harvesting in a northern hardwood outlier community in the Ridge and Valley Province of East Tennessee were presented through analysis of an experiment initiated by TVA in 1938.

The uneven-aged structure of the original stand was not altered significantly by light harvesting except that really large, over-mature stems were eliminated. The remaining sawtimber stems provided typical structure of an uneven-aged stand. However, heavy harvesting did bring about structure differences such that two separate age classes were recognizable. These conditions hinted toward more even-aged silviculture.

Species composition changes were apparent following any degree of harvesting, but they were more noticeable in the heavily cut plots. The aggressive yellow-poplar had partially replaced the sugar maple and American beech through silvicultural practices of crown release and regeneration. Pole-sized yellow-poplar grew quite well after release with some trees reaching dominant crown class status and exhibiting radial growth of greater than ½ inch. Other yellow-poplar stems approaching sawtimber status were shown to have originated from seed following the first perturbation in 1938. Continued silvicultural practices to favor the yellow-poplar will continue to reduce the uneven-aged structure of the original stand.

INTRODUCTION

It is somewhat rare to have the opportunity to study a forest stand with the research history of Beech Island. This community of beech-maple (Fagus grandifolia Ehrh.-Acer saccharum L.) overlooks Norris Lake from a northern aspect. Although they are more characteristic of northern environments, the beech-maple communities in east Tennessee comprise some 300,000 acres in the Tennessee Valley.

Research began in the Beech Island stand in 1938 when the Tennessee Valley Authority initiated an experiment to determine the most advantageous sawtimber stocking density for these outlier northern hardwood communities. Growth inventories were maintained from that time until 1974 when the study was terminated. Although the original objectives did not address these possibilities, our purpose is to relate the composition and structure changes that occurred within this community as a result of harvesting.

Although the stand was not in primeval condition prior to the initiation of treatments in 1938, disturbances had been minimal. An occasional, large chestnut stump attested to an earlier harvesting that was a salvage cut rather than a growth regulating cut. There was no evidence that the stand had been commerically logged or intensively managed. Only those practices that would now be labeled as highgrading had been done.

Into this environment TVA introduced an experiment using a series of one-acre plots to test for the most favorable stocking density for maximum sawtimber production. Treatment residual densities approximated 1,500 board feet per acre (hereafter called maximum harvest) and 6,000 board feet per acre (hereafter called minimum harvest). Skidding was done by mules, thereby minimizing erosion. Damage to the residual stand was minimal during cutting in 1938 and in 1958 when the second experimental harvest occurred. However, the 1975 post-experimental harvest was accomplished with heavy equipment, and the stand character was drastically changed.

STAND STRUCTURE CHANGES

The Original Stand

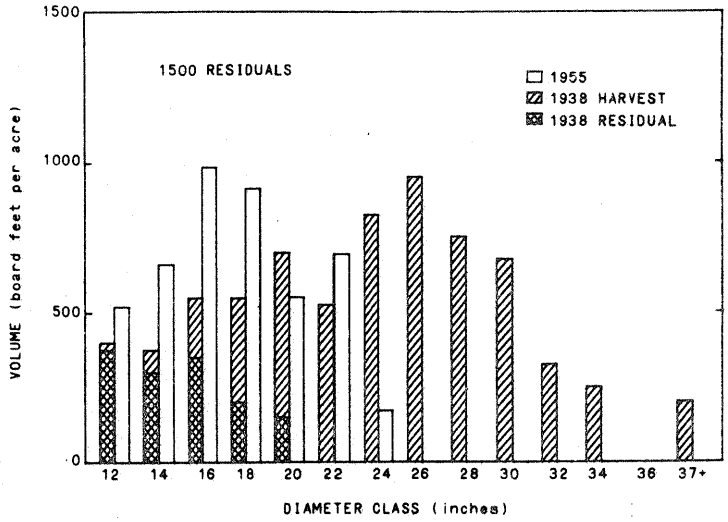
Species composition of the original stand was given only as a list of trees, with sugar maple and beech predominating. There was some yellow-poplar (*Liriodendron tulipifera* L.), but only scattered trees of several other species. There were some species in the understory that lacked potential to develop into canopy trees, but no mention was made of reproduction, in the 1938 inventory.

Sawtimber volume by diameter class is presented in Figure 1. Mean volume of the original stand was 9,368 board feet per acre with tree ages up to 250 years. Mean sawtimber diameter in 1938 was 24 inches, but it ranged from 12 to 40 inches. The stand was clearly over-mature and uneven-aged with large sawtimber stems predominating in the upper canopy. Plots were chosen for harvesting treatments by an unknown (at least in 1978) scheme that may have been something other than random. Plots chosen for maximum harvest did not appear to originally support enough volume to be allocated into the minimum harvest treatment. Ramifications of this plot selection are speculative, but noteworthy, at this time.

The Residual Stand-1938

Volume removed in 1938 is shown in Figure 1. Volume was harvested from each sawtimber diameter class on the minimum harvest treatments. Essentially a few trees were harvested from the entire range of sizes available. With the exception of the 34 inch class, no diameter class was eliminated from the stand. Thereby, stand structure on the minimum harvest plots based on volume remained nearly unchanged after treatments were applied in 1938.

The harvest from the maximum harvest plots eliminated those diameter classes above 20 inches, but it only slightly affected the 12 to 16 inch classes. Structure of these plots was changed drastically, because all the big trees were removed. It appeared that all or most of the dominants were removed from the canopy and that those few 20 inch trees left were probably co-dominants at best. Therefore, a few co-dominants and intermediates or even suppressed trees were all that remained of the original canopy on the maximum harvest plots. We can only imagine the amount of exposure afforded the forest floor, but we can safely speculate that it was substantial.



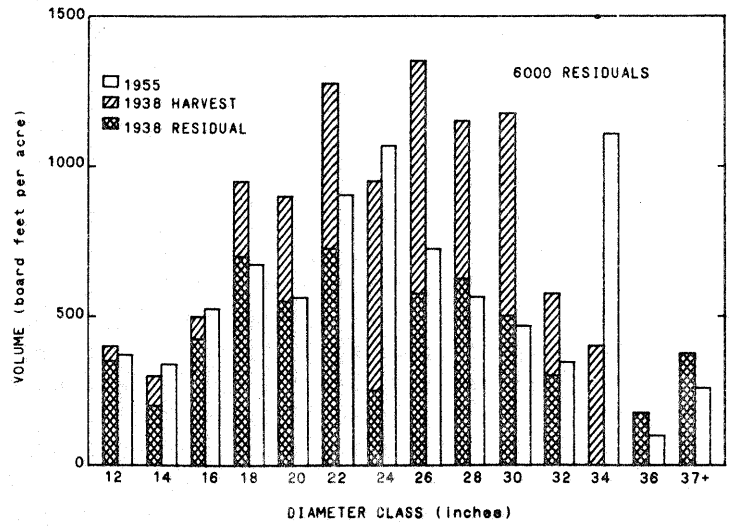


Figure 1. Volume per acre of the residual stand in 1938 and the new stand in 1955 for the minimum removal (6000 residuals) and maximum removal (1500 residuals) treatments.

Since no mention of nor provisions for advanced reproduction were made in the original study, we must conclude that seedlings and saplings were not a concern in 1938 nor were they anticipated as a result of treatment. It is not totally irresponsible conjecture that some seedlings could have become established in response to seedbed preparation as a consequence of logging plus the availability of seed sources.

The New Stand-1955

Minimum Harvest Plots: Volume growth of the stands during the period 1938 to 1955 is found in Figure 1. Volume growth into the small diameter classes on the minimum harvest plots was negligible. The volume of the 12 to 22 inch classes increased very little during this 17 year growth period. The treatment in 1938 was not sufficient to allow signigicant release for these smaller diameter classes. Any openings created in the canopy were closed quickly, thereby discouraging release of the subordinate trees into canopy positions. Similarly, any seedlings that may have become established experienced severe competition.

Maximum Harvest Plots: Growth responses on the maximum harvest plots were considerably different than those on the minimum harvest plots. Volume growth in all diameter classes was substantial with doubling and tripling of the 1938 volume in the 14 through 22 inch classes. Since the largest trees were eliminated in 1938, plenty of crown release was provided to the residuals. Their response was overwhelming. Volume growth in the 12 and 14 inch classes was sufficient to recognize ingrowth into those classes. Stems in the pole class were also released and they subsequently grew into the sawtimber classes.

There was ample evidence of reproduction on these plots in 1955. Release in 1938 was considerable and yellow-poplar was already in the stand, providing a seed source. Sapling counts showed 21 yellow-poplar stems per acre in the 1 through 4 inch classes; sugar maple and beech were more numerous, especially in the 1 inch class.

The Residual Stand-1958

The stand was harvested again in 1958 using a selective criterion because there was still uneven-aged structure. Some of the larger trees were cut in an attempt to improve the vigor of the stand and other trees were cut to release the residuals, thereby constituting a thinning. Skidding was again done by animals, thereby causing minimal disturbances to the forest floor.

Minimum Harvest Plots: On the minimum harvest plots, the 1958 residual stand had sawtimber in each diameter class from 12 to 26 inches (Fig. 2). Maximum volume occurred in the 18 inch diameter class with approximately 1,200 board feet. Both the 14 and 16 inch classes contained approximately 1,000 board feet. Through the first growing cycle and the second harvest, the uneven-aged structure had been maintained. Species composition changes were less clear due to the ingrowth of stems into the sawtimber classes, but sugar maple and beech continued to dominate the canopy.

Maximum Harvest Plots: In the maximum harvest plots, sawtimber volumes in 1958 were represented in the same diameter class range as the minimum harvest plots. Maximum volume also occurred in the 18 inch class, but there was only about one half the volume in this class as found in the same class on the minimum harvest treatments. There was very little difference in the volume of the 12 through 22 inch classes on the maximum harvest plots; if the smaller diameter classes had the same volume as the larger classes, there had to be many more small stems.

Although species composition was not recorded, there were 50 percent more sawtimber stems on these plots in 1955 than on the minimum harvest plots. Such could only come about by significant release of pole-size stems of fast growing species, like yellow-poplar. Although sugar maple stems showed some growth increase after release, they were not capable of such rapid ingrowth. Neither was there enough time for the reproduction to reach sawtimber size during this first growing cycle.

Figure 2 revealed a 1958 stand that had started to lose its uneven-aged structure. After two harvests, the large trees were gone from the maximum harvest plots, and there was a tremendous ingrowth of smaller stems. Very few stems were 20 inches or larger, rather a large number of small stems had moved into the sawtimber class. Such diameter distribution is more characteristic of an even-aged stand than an uneven-aged one.

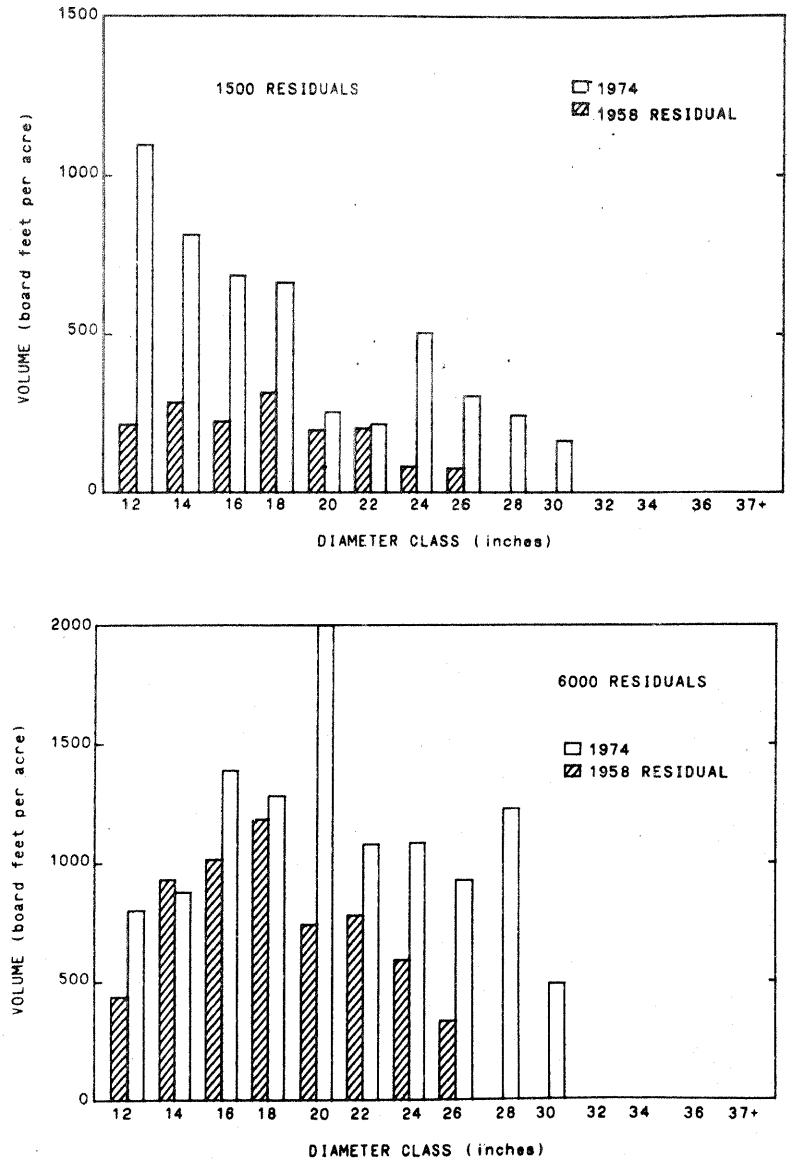


Figure 2. Volume per acre of the residual stand in 1958 and the new stand in 1974 for the minimum removal (6000 residuals) and maximum removal (1500 residuals) treatments.

The New Stand-1974

Minimum Harvest Plots: On the minimum harvest plots, volume occurred in all sawtimber diameter classes from 12 to 30 inches in 1974. Maximum volume was in the 20 inch class (2,000 board feet); the 16 to 28 inch classes contained approximately 1,000 board feet each.

Several changes had occurred that reflect growth responses to treatment. In the 1958 residual stand, the 14 to 18 inch classes had the largest volumes, and through inference the largest number of trees. These were newly released (from 1938) trees that had renewed crowns and they were ready to take a dominant place in the canopy. They did, for the 16 to 20 inch classes had the most volume in 1974.

There were also a few large trees in the 1958 stand, i.e., 24 to 26 inches. These trees were already dominants and growing well. They continued to grow well, for the 1974 volume chart clearly showed considerable volume in the 28 inch diameter class. The 12 inch diameter class doubled volume during the second growing cycle (1958-1974). Such growth was possible due to ingrowth into the sawtimber class. If the 1938 release had been more complete; ingrowth could have helped the 14 inch class. However, the 14 inch class showed a decrease in volume between 1958 and 1974 indicating more outgrowth than ingrowth.

The net effect was that the uneven-aged structure was maintained on these plots, albeit some spread in size classes was occurring. Selection silviculture, carefully applied, would maintain some form of uneven-aged structure and probably a mixture of species. Sugar maple poles responded somewhat to release, thereby maintaining dominance in the canopy; there were 45 to 50 stems per acre of sugar maple reproduction in the one inch class. Sugar maple seedlings formed green carpets in some areas.

Yellow-poplar will maintain itself within these plots also. Buckner and McCracken (1978) reported that yellow-poplar was just as much a part of the climax as it was a pioneer species. Future removals of a few large trees from these plots, complete with scarification of the forest floor, will assure some yellow-poplar in the stand. Even-aged silviculture will not be required for yellow-poplar to remain in the stand.

The Maximum Harvest Plots: The maximum harvest plots (Figure 2) had sawtimber volume in each diameter class from 12 to 30 inches in 1974. The 12 inch class had maximum volume at 1,100 board feet followed by the 14, 16 and 18 inch classes in decreasing order, respectively.

Some management responses were clearly evident in 1974. By 1958 the stand had been intensively thinned twice in 20 years. There were nearly equal volumes in the 12 through 22 inch classes. Being cognizant of the relationships between diameter distribution and volume as affected by tree sizes, we can infer that there were a few more stems in the 12 inch class than in the 22 inch class. However, the differences may not have been large.

The residual trees in 1958 had survived the scrutiny that comes with intensive thinning. Undesirable trees were removed in 1938, therefore the 1958 thinning probably was designed to favor those trees with good crowns, capable of excellent growth following their release. In other words, 20 years of intensive selection had helped change the growth potential of this stand such that intensive management objectives could now come to fruition.

By 1974, the stand showed growth responses to intensive management, especially in a changed stand structure. The uneven-aged structure of the original stand had been altered in that two age classes were now apparent within the sawtimber class. The more vigorous, larger stems in the 1958 stand were now 24 to 30 inches in diameter, and they comprised a recognizable portion of the 1974 stand. Those stems released and/or regenerated in 1938 have responded to management such that they now comprised a recognizable portion of the stand too. The age and size of these stems were less than the 1938 residuals, but there were many of them.

Assuming 24 merchantable feet to a 10 inch top, the volume (Scribner) of an average tree in the 12 inch class would be 60 board feet. Therefore at least 18 stems per acre were necessary to attain the 1,100 board feet per acre measured in 1974. Such a large number of stems that originated following the perturbation in 1938 constituted a significant and recognizable portion of the stand. Instead of an uneven-aged stand that presented a somewhat balanced structure, the new stand assumed a more even-aged character, complete with all of the management ramifications thereof.

SPECIES COMPOSITION

The species composition of the original stand was not recorded, except as a listing of the more important sawtimber trees. Some records were kept on sawtimber stems that were left after the 1938 treatments were applied, so their performance is known. However, by 1974 enough of them had been cut or died, such that they no longer dominated the canopy on many plots. To report species composition, exclusively with these data would be to report only a portion of the story.

Although one of the stated objectives of the original study was not to change the species composition of the stand, such changes were apparent by 1974. Changes occurred because some species responded to release better than others and new dominants materalized in a few years. Some species were able to regenerate following the heaviest cuttings, thereby causing additional changes in species composition of the canopy.

It is our contention that yellow-poplar dominance has been increased within the managed stand, thereby bringing about a partial species conversion, especially on those plots that had been heavily cut. The silviculture mechanisms were (1) through excellent height and diameter growth after crown release, and (2) through vigorous growth of seedlings and saplings into the canopy, i.e., regeneration occurred in the openings created by logging. The northern hardwood component has been diminished but not eliminated by management. Sugar maple was capable of good growth following release and many stems did just that. Sugar maple reproduction was almost always present to fill large openings in a canopy. Further intensive management, in the magnitude of the maximum removal treatment will increase the proportion of yellow-poplar in the stand, thereby increasing overall stand vigor and stand value, and decreasing the dominance of the northern hardwoods.

Species Response To Treatments

Sawtimber growth resulting from the treatments applied in 1938 and 1958 was not particularly revealing when analyzed by species. There are several plausible reasons why species composition changes were just becoming manifest in 1974.

The old growth stand was over-mature and slow growing. There was limited vigor, either as a stand or as individual trees. Therefore, any cutting would first have the desirable effect of removing trees of the poorest vigor, within criteria of the stocking density treatments and experimental objectives. After the second cutting, nearly all the large, low-vigor trees, regardless of species had been removed. Now species growth differences could be seen from under the mask of compounding competition.

Secondly, the silvical characteristics of the species in the stand are quite different, especially since the northern hardwoods are on the fringe of their range. Once the dominant trees became something other than old-growth, these differences could be seen, e.g., on one treatment, yellow-poplar averaged 242 board feet per acre per year and sugar maple only averaged 65 board feet per acre per year. There were about twice as many yellow-poplar stems as sugar maple stems, which means each yellow-poplar was growing twice as much volume as sugar maple.

Crown Release Of Existing Stems: One mechanism by which species differences and canopy dominants could appear was through release of existing stems. The growth increase of sugar maple sawtimber during the second growing cycle was significantly increased by the 1938 release on the maximum harvest plots. In addition to increased growth on existing sawtimber stems, considerable stems from the pole class grew into the sawtimber class.

The largest growth increase following crown release occurred with yellow-poplar. It was possible shortly after the 1975 harvest to trace growth patterns on some of the yellow-poplar stumps. Stumps from some treatments were measured for average diameter (at stump height and not breast height) at the times of release.

One stump, chosen at random but situated within a maximum harvest plot was 30 inches in diameter in 1975. The growth spurts that accompanied crown release were quite apparent, even before measurements confirmed that the tree was 20 inches in diameter in 1958 and 13.3/4 inches in diameter in 1938. This tree had been a weak co-dominant at best in the 1938 stand, but growth following crown release had been maximized. It was growing well and a dominant when harvested in 1975. The 1974 diameter growth was 5/8 inches and during some years, diameter growth exceeded one inch. Because sugar maple and other northern hardwoods were unable to match this rapid growth, species composition of the canopy was changing. There were many more large yellow-poplar stumps in the stand and there were still plenty of yellow-poplar in the canopy.

Response to crown release on the minimum harvest plots by yellow-poplar had not been so dramatic. One 19 inch co-dominant in 1975 had only grown 4 inches in diameter since 1958. Diameter growth following the 1938 release had been good; the tree grew from 5½ inches to 15 inches during the first 20 years of the experiment. A 32 inch dominant yellow-poplar on another minimum harvest plot had managed to overtop its sugar maple neighbor after the 1958 harvest. Subsequent diameter growth of 10 inches by 1975 with some annual increments approximating 1 inch attested to the growth capacity of yellow-poplar in comparison to northern hardwoods in the same stand. This tree was 43 years old when the experiment was implemented in 1938.

Regeneration: The second mechanism by which species composition of the stand has been changed was through regeneration on the maximum removal plots. It was possible to obtain some stem cross-sections within 2 inches of the ground from one of the maximum harvest plots. Two sugar maples were analyzed. Both were about 45 years old, therefore they were present as advanced reproduction when the experiment started in 1938. The smaller stem was ½ inch in diameter and the larger stem was 1 inch in diameter when released in 1938. The smaller stem had only attained a diameter of 5 inches at the ground line by 1974. It was still growing under intense competition, and it did not respond to release in 1958.

The larger stem was 9 inches at the ground line in 1974, and it had responded to the 1938 and 1958 releases. Release following the 1938 harvest was evident in the doubling of annual ring width at 9 years of age. By the time of the second release, diameter at the ground line was 5 inches and progressing toward 9 inches at harvest. Crown release of this stem had been adequate to promote good growth for sugar maple advanced reproduction. Although it was felled just before it reached sawtimber status, this tree demonstrated that ingrowth from advanced reproduction into the sawtimber class was plausible on the maximum harvest plots.

Ingrowth into the sawtimber class was also found to be possible for trees originating as seedlings after the 1938 harvest. One yellow-poplar stem that was sacrificed during road building was analyzed at the ground line. At 20 years of age the stem was 6 inches in diameter and diameter growth had occurred in a typical sigmoid pattern. Competition had become noticable before the 1958 harvest and when the tree was felled in 1975 it was again experiencing a decreasing diameter growth trend. Nonetheless, it had attained a diameter of 11 inches in 36 years. Assuming this tree had escaped its untimely death in 1975, there was every reason to believe that rapid growth would have occurred again after crown release. Certainly those yellow-poplar stems previously discussed had the size of this tree as a base upon which to accumulate exceptional growth increments.

SUMMARY

Although the original experimental objectives were not addressed in this discussion, to some extent they were answered anyhow: any cutting in a northern hardwood outlier stand in this part of the Ridge and Valley Province of the Great Valley of Tennessee is going to have its greatest impact by initiating and maintaining the more vigorous yellow-poplar within the stand.

Species conversion was not mentioned in 1938, however, we have presented two silvicultural mechanisms by which yellow-poplar increased its stem frequency and importance within these northern hardwood stands:

1. Those yellow-poplar stems that had been impeded by competition from neighboring species exhibited exceptional growth after crown release.

2. Heavy cutting favored yellow-poplar reproduction, many of which have grown into the sawtimber class from seedlings within 40 years.

There is every reason to encourage the growth of yellow-poplar in these stands. Volume increments on a 30 inch stem that result from diameter growth of up to 1 inch per year are significant returns on anybody's investment. When do these yellow-poplar dominants slow enough in annual value increments to justify harvest? That question wasn't answered here, nor did we intend to, but such possibilities should delight any silviculturist.

LITERATURE CITED

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