# Managing Appalachian Hardwood Stands Using Four Regeneration Practices—34-Year Results

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*ABSTRACT. Adjacent Appalachian hardwood stands in West Virginia established on excellent growing sites were managed for a 34-year period using four regeneration practices. These practices included a commercial clearcut, 15.5-in diameter-limit, and two single-tree selection practices. An uncut area was maintained as a control. Stand development, growth response, and some stumpage revenue data were summarized for each treatment. At 34 years after the initial treatments, the commercial clearcut stand had the greatest variety of tree species for future management. This stand was dominated primarily by yellow-poplar and black locust. Selection and 15.5-in diameter-limit treatments promoted sugar maple on these excellent sites. Stand quality improved through management. After 34 years, the control area was worth $1,554/ac, and an intensively managed selection area was worth $1,214/ac, but the control area contained twice the sawtimber volume. Other preliminary value comparisons indicate that landowners benefit from some type of management compared to doing no management.*

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## WHAT WAS DONE

In 1949, four 5-ac cutting practice areas were established on the Fernow Experimental Forest near Parsons, WV. Each 5-ac area was assigned one of four management practices—commercial clearcutting, 15.5-in diameter-limit, and two single-tree selection cutting practices. The purpose was to demonstrate the effect of these management practices on central Appalachian hardwood stands. All of the initial harvest cutting treatments were applied during the 1949–50 dormant season. Since then, treatments in the diameter-limit and selection areas have been applied periodically. In 1956, an additional 5-ac undisturbed forest stand adjacent to the study area was set aside as a control area. In this article, we discuss stand growth and development and summarize tree quality and stumpage returns during the ensuing 34-year period.

This study lacks the design and replication needed for statistical analyses. Also, the treatment areas are relatively small (5 ac), and further observation is advisable before any long-term economic comparisons can be made among treatments. However, this study has been underway long enough and remeasurements have been frequent enough to indicate stand development trends that can be expected when applying these treatments.

The 5-ac plots were established on an area with site index 80 for red oak (Schnur 1937), which is an excellent hardwood growing site. Soils were Belmont silt loam derived from limestone with a soil depth of more than 3.5 ft. The area typically receives about 58 in of precipitation annually, and the length of the growing season is usually 120 to 140 frost-free days.

In 1949, the study areas were composed of 40- to 45-year-old second growth hardwoods, residuals left from the high-grade logging that occurred between 1905 and 1910, and scattered sapling and poletimber trees that replaced American chestnut trees that died during the 1930s (Trimble 1961).

## PLOT TREATMENTS

### Commercial Clearcut (CC)

In 1949 all commercial trees 5.0 in diameter breast height (dbh) and larger were cut; the understory trees less than 5.0 in dbh were not cut. No cultural practices such as cull removal or grapevine control have been applied to the stand and none are planned. The next commercial clearcut is scheduled for the fall of 2019.

### Diameter-Limit (DL)

All trees larger than 15.5 in dbh were cut in 1949 and again in 1968 on a 20-year cutting cycle. Cull trees larger than 15.5 in dbh were girdled or felled. No cutting or cultural work was done in the stand below 15.5 in dbh. However, during each harvest cut, grapevines were cut near groundline throughout the stand.

### Uneven-age Management—Selection (S)

The goal in this single-tree selection practice is to manage for quality products from sawtimber-size trees only. A 10-year cutting cycle is used, and only trees 11.0 in dbh and larger are marked for cutting or designated as culls. At each harvest cut, cull trees more than 11.0 in dbh are girdled or felled, and grapevines are cut near groundline. Residual tree goals are to grow trees to a maximum size of 32 in dbh and to retain a residual basal area of 65 ft$^2$/ac in trees 11.0 in dbh and larger using a quotient, "q," of 1.3 (Smith and Lamson 1982). The stand has been cut four times in 34 years (1949, 1958, 1968, 1978).

### Uneven-age Management—Selection (SP)

The goal in this single-tree selection practice is to manage for quality products from sawtimber-size trees and to periodically harvest selected trees in the poletimber stand for cordwood or fuelwood. At each cutting period, trees 5.0 in dbh and larger are selected for cutting, and cull trees are girdled or felled. Residual tree goals are to grow trees to a maximum size of 32 in dbh and to retain a residual basal area of 85 ft$^2$/ac in trees 5.0 in dbh and



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larger using a "q" of 1.3. Near the beginning of the study period a 5-year cycle was used but the timber volume harvested using the 5-year cycle was not economical. In 1968, the cutting cycle was changed to 10 years. The stand has been cut five times (1949, 1958, 1963, 1968, and 1978).

### Control or Unmanaged

This area with similar site and stand conditions was not treated but was used for comparison with the treated areas. Initial measurements were taken in 1956, 6 years after the initial measurements in the four treated areas.

## METHODS

Periodic inventories have been done to monitor stand growth and yield, species composition, stand value, and tree quality. A 100% stand inventory of all trees 5.0 in dbh and larger is made, usually every 5 years. A butt-log grade sample is taken of the sawtimber trees. Random 1/100-ac plots are used to sample stems 1.0 to 4.9 in dbh and random 1/1000-ac plots are used to sample stems 1.0 ft tall to 0.9 in dbh. Volumes (Int. ¼-in) were determined for sawlog-size trees to an 8.0-in diameter inside bark (dib) top and cubic-foot volumes to a 4.0-in dib top. Tree grade, based on grade of the butt log, and tree-log height (nearest 8 ft) were used to estimate the percent of volume by grade class for each treatment. This provided an estimate of stand-quality development as did stand value computations. All logs were scaled and graded at a log deck. Stumpage revenues received from the sale of all wood products during the 34-year period were summarized.

After the 1983 stand inventory, stumpage was appraised for all trees 5.0 in dbh and larger for each study area following procedures used by the Monongahela National Forest for timber sale appraisals. Sawtimber stumpage price per thousand board feet was determined for each species, and these values included an estimate of tree quality. The appraisal also allowed for temporary skid road construction as needed for the control and commercial-clearcut areas. Black locust poles 6 to 10 in dbh used for posts were appraised for a stumpage value of \$3.91 per cunit (100 $ft^3$) while other pole-size hardwoods were appraised using a stumpage value of \$1.50 per cunit. Also, each 1,000 board feet (mbf) of sawlog volume was considered to have 40 $ft^3$ of poletimber material in tops. Another stand quality estimate was the percent of board-foot volume in factory tree (log) grades 1 and 2 (Hanks 1976). This estimate indicates change in stem quality and ultimate value. In general the higher portion of volume in log grades 1 and 2, the more valuable the stand.

Stumpage revenues from the actual sale of all wood products were summarized. The total amount of dollars (present net worth in 1983) made from each treatment and the control was determined by assuming that the stumpage received at each cutting period was invested at a 6% interest rate compounded annually.

Total merchantable stand production was determined by including the volume from periodic harvests plus the difference between the residual merchantable stand volume in 1949 and merchantable stand volume present 34 years after the initial treatment. Periodic annual growth was determined for a 34-year period for the treated stands and a 28-year period for the control area.

Stand data for each treatment were summarized in four stem groups by size classes:

Seedlings—stems 1.0 ft tall to 0.9 in dbh
Sapling—1.0 to 4.9 in dbh
Poletimber—5.0 to 10.9 in dbh
Sawtimber—11.0 in dbh and larger

## RESULTS

### Stand Data

*Commercial clearcut* Except for tree size, the 34-year-old commercial clearcut stand is similar to the 1949 pretreatment stand (Fig. 1, Table 1). After 34 years, 151 merchantable pole and sawtimber trees per acre were present for a basal area of 96 $ft^2$ with a volume of 10,350 bf. Yellow-poplar, black locust, and sugar maple were the main sawtimber and poletimber species present throughout the study period. Currently, the commercial clearcut area has 49 sawtimber trees per acre dominated by yellow-poplar.

At this time, the understory sapling and seedling stems are of little importance in this clearcut stand; but the status of the understory will be more important just prior to the next clearcut. However, sugar maple and sweet birch were the dominant species in the understory 34 years after the stand was cut.

The commercial clearcut area is now similar in stand development to the control area 30 to 40 years ago. In another 40 years this commercial clearcut area, with the exception of the old residuals, will be similar in species composition to the current control area. Yellow-poplar and black locust now dominate the control area.

*Diameter-limit (15.5 in dbh+)* Thirty-four years after the initial diameter-limit treatment, pole and sawtimber stems were similar to pretreatment conditions—132 trees/ac, basal area of 91 $ft^2$, and a volume of 10,735 bf (Table 1). Also, the residual basal area after the initial treatment was nearly 40 $ft^2$/ac for the poletimber (17 $ft^2$) and sawtimber (22 $ft^2$) stand. Sugar maple and yellow-poplar were the predominant sawtimber species, both before treatment and 34 years later. However, in the poletimber stand, sugar maple is replacing yellow-

Figure 1. Commercial clearcut 34 years after treatment.

**Table 1. Merchantable stand per acre data before and 34 years after treatment.**

| Harvest treatment[a] and size class[b] | Before treatment | | | | After 34 years | | | |
|---|---|---|---|---|---|---|---|---|
| | No. stems | Basal area (ft²) | Volumes: Cubic feet | Volumes: Board feet | No. stems | Basal area (ft²) | Volumes: Cubic feet | Volumes: Board feet |
| *Commercial clearcut* | | | | | | | | |
| Seedlings | 1,500 | | | | 2,280 | | | |
| Saplings | 42 | 1.5 | — | | 358 | 12.5 | | |
| Poles | 98 | 34.0 | 655 | | 102 | 34.0 | 645 | |
| Sawtimber | 40 | 61.4 | 1,655 | 10,290 | 49 | 61.8 | 1,635 | 10,350 |
| Totals | | 96.9 | 2,310 | 10,290 | | 108.3 | 2,280 | 10,350 |
| *Diameter-limit* | | | | | | | | |
| Seedlings | 1,740 | | | | 4,306 | | | |
| Saplings | 40 | 1.0 | | | 340 | 11.0 | — | |
| Poles | 69 | 25.3 | 495 | | 81 | 26.8 | 505 | |
| Sawtimber | 48 | 69.6 | 1,865 | 11,605 | 51 | 63.9 | 1,695 | 10,735 |
| Totals | | 95.9 | 2,360 | 11,605 | | 101.7 | 2,200 | 10,735 |
| *Selection (S)* | | | | | | | | |
| Seedlings | 2,440 | | | | 6,722 | | | |
| Saplings | 50 | 1.0 | | | 244 | 8.0 | | |
| Poles | 50 | 18.6 | 370 | | 83 | 27.0 | 510 | — |
| Sawtimber | 52 | 77.3 | 2,080 | 12,535 | 45 | 75.6 | 2,055 | 13,150 |
| Totals | | 96.9 | 2,450 | 12,535 | | 110.6 | 2,565 | 13,150 |
| *Selection (SP)* | | | | | | | | |
| Seedlings | 4,240 | | | | 4,417 | | | |
| Saplings | 22 | 1.0 | | | 190 | 5.5 | | |
| Poles | 63 | 23.6 | 470 | | 49 | 16.7 | 320 | — |
| Sawtimber | 54 | 75.2 | 2,015 | 12,245 | 41 | 77.3 | 2,120 | 13,925 |
| Totals | | 99.8 | 2,485 | 12,245 | | 99.5 | 2,440 | 13,925 |
| *Control* | | | | | | | | |
| Seedlings | 896 | — | — | — | 1,250 | — | — | — |
| Saplings | 479 | 8.0 | — | — | 309 | 10.5 | — | — |
| Poles | 93 | 31.4 | 600 | — | 56 | 17.6 | 325 | — |
| Sawtimber | 64 | 84.8 | 2,855 | 14,110 | 74 | 141.3 | 3,890 | 26,025 |
| Totals | | 124.2 | 3,455 | 14,110 | | 169.4 | 4,215 | 26,025 |

[a] Stand data include 34-year information for all cutting treatments and 28-year information for the control treatment.
[b] Seedlings 1 ft tall to 0.9 in dbh; saplings 1.0 to 4.9 in dbh; poles 5.0 to 10.9 in dbh; sawtimber 11.0 in dbh and larger.

poplar and black locust. Also, cull tree volumes were about 85 ft³/ac both before treatment and 34 years later.

Initially and 34 years later, about 75% of the sapling stems and about 50% of the seedling stems were sugar maple (Table 1). Though some black cherry seedlings are present, these stems are not growing into the sapling or poletimber stand.

*Selection (S-sawtimber only)* After 34 years and four periodic cuts, the current stand data are similar to pretreatment conditions. Volume per acre was about 13,000 bf, while basal area averaged more than 100 ft² (Table 1). In 1949, the selection (S) stand had a larger hickory sawtimber component than the clearcut or diameter-limit areas. More than half of the sawtimber trees were hickory. After 34 years, sugar maple and hickory dominate the sawtimber stand, but sugar maple is replacing the hickory as indicated by both the sawtimber and poletimber species composition. In 1949, hickory, sugar maple, and yellow-poplar were the major poletimber species and 34 years later, two-thirds of the poletimber trees were sugar maple. There are no cull sawtimber trees in this stand after 34 years, and because culls were not treated in the poletimber stand, the number of cull poletimber trees has not changed much during 34 years.

No changes in species composition for seedling and sapling stems were evident during the study period as sugar maple dominated, accounting for 80% of the sapling stems and 65% of the seedlings.

*Selection (SP-sawtimber and poletimber)* After 34 years, the 49 pole and 41 sawtimber trees per acre totalled 94 ft² of basal area (Table 1). Initial sawtimber volume was 12,245 and after five periodic cuts, the volume had increased to 13,925 bf/ac.

Before treatment, the 54 sawtimber trees per acre were mainly hickory and yellow-poplar. After 34 years, 41 sawtimber trees were dominated by yellow-poplar and sugar maple. Yellow-poplar, sugar maple, and hickory were the main poletimber species in the stand before treatment, but sugar maple dominates the current poletimber stand, accounting for 70% of these stems. In 1949, the two selection areas (S, SP) had similar pole and sawtimber stand data, though hickories were more numerous in the selection (S) area. After 34 years of management, the selection (SP) stand had about 40% fewer poletimber trees per acre than the selection (S) area (Fig. 2). Sugar maple dominated the sapling and seedling stems before the initial treatment and 34 years later, accounting for 65 to 75% of the stems (Table 1).

*Control* Pretreatment volume and basal-area data were higher for the control area than the other treatment areas because the control area was established in 1956, 7 years after the other treated areas. At that time, the merchantable pole and sawtimber trees had a basal area of 116 ft²/ac and a volume of 14,110 bf (Table 1). After 28 years, basal area for the pole and sawtimer trees was 159 ft²/ac with a volume of 26,025 bf. Yellow-poplar and black locust have generally been the most abundant sawtimber species. However, after 28 years, more than 40% of the poletimber trees were sugar maple.

During the study period, sugar maple and beech dominated the seedling and sapling stems in the control area and accounted for at least 80% of the available stems. If no additional silvicultural practices or stand disturbance occurs on the control area, the future sawtimber stand will eventually be dominated by the tolerant sugar maple and beech.

**Figure 2. Single-tree selection after 34 years of managing poles and sawtimber trees for five cutting periods.**

## Growth

For the commercial clearcut area, the annual merchantable stand production averaged 607 bf/ac/yr during the 34-year study period. Volume production for trees 5.0 in dbh and larger averaged 135 ft$^3$/ac/yr. Total stand volume harvested and produced during the 34-year period was 20,640 bf/ac (Table 2). Stand production for the diameter-limit area averaged 772 bf or 126 ft$^3$/ac/yr. Total board foot volume harvested and produced during the 34-year period averaged 26,240/ac. Annual merchantable stand production for the selection (S) area where only sawtimber trees were managed averaged 603 bf or 105 ft$^3$/ac/yr during the 34-year study period. And the total volume produced by the (S) stand during the 34-year period was 20,510 bf/ac (Table 2). For selection (SP) area where management was done in both poletimber and sawtimber trees, the stand production data were similar to the selection (S) area, 615 bf or 105 ft$^3$/ac/yr and 20,915 bf/ac.

Finally, the annual stand production in the unmanaged or control area for the 28-year period averaged 426 bf or 27 ft$^3$/ac/yr. The total volume produced was 11,915 bf (Table 2).

## Value

Stumpage revenues from periodic harvests during the study period and stand values for each treatment are summarized in Table 3. For the two selection and possibly the diameter-limit practices, values in the table illustrate some of the potential revenues available as second-growth stands with some old residuals are converted to uneven-age management units. Similarly, values for the clearcut and control areas indicate some of the changes associated with even-aged stands, at different stages and with different stand development histories, when no cultural practices are applied. However, the preliminary comparisons in Table 3 indicate cash flows and stand value changes only for a particular period of time. A complete economic analysis would include all future cash flows associated with periodic cutting cycles or rotations for the appropriate harvest practice. Further observation is advisable before long-term economic comparisons can be made among the treatments, but some important trends in stand value development are apparent after 34 years.

While stand stumpage values were virtually equal among the four treated areas before treatment, there was a wide range in stand values 34 years later. Stand values in 1949 before treatment averaged \$115/ac, and differences among areas were less than \$9/ac. In 1983, stand values among the treatments ranged from \$527.48 to \$1,213.96/ac, a difference of nearly \$690/ac (Table 3). Part of the reason for these value differences is that the individual harvest cutting practices had different influences on species composition and average tree diameter in each treatment area. Also, the periodic harvests associated with a particular cutting practice left each area in a unique stage of development. For example, the 1983 data for the two selection areas were collected in the middle of a 10-year cutting cycle after 4 or 5 periodic cuts. The diameter-limit area data were collected in the fifteenth year of a 20-year cutting cycle after 2 periodic cuts. And data from the commercial clearcut area were collected at approximately midway in a 70-year rotation. Thus, stand values measured before and after 34 years of management do not provide a valid economic comparison among all the treatments.

The information in Table 3 provides a "snapshot" of the first 34 years of management and does not show the long-term economic impact of each alternative. As additional periodic harvests influence the species composition and periodic yields available, the cash flows associated with future harvests will be affected. Once the stands reach a state where periodic yields and revenues are more or less equal and perpetual, a valid economic com-

**Table 2. Total merchantable stand production per acre during study period.**

| | | | | | Stand production[b] | |
|---|---|---|---|---|---|---|
| Treatments[a] | Postlogging volume | End volume | Difference | Cut volume | Periodic production | Periodic annual production |
| | | ........ board feet[c] ........ | | | | |
| CC | 0 | 10,350 | 10,350 | 10,290 | 20,640 | 607 |
| DL | 3,275 | 10,735 | 7,460 | 18,780 | 26,240 | 772 |
| S | 6,515 | 13,150 | 6,635 | 13,875 | 20,510 | 603 |
| SP | 6,895 | 13,925 | 7,030 | 13,885 | 20,915 | 615 |
| C | 14,110 | 26,025 | 11,915 | 0 | 11,915 | 426 |
| | | ........ cubic feet[d] ........ | | | | |
| CC | 0 | 2,280 | 2,280 | 2,310 | 4,590 | 135 |
| DL | 890 | 2,200 | 1,310 | 2,960 | 4,270 | 126 |
| S | 1,355 | 2,565 | 1,210 | 2,345 | 3,565 | 105 |
| SP | 1,430 | 2,440 | 1,010 | 2,575 | 3,585 | 105 |
| C | 3,455 | 4,215 | 760 | 0 | 760 | 27 |

[a] Data are 34-year information for all cutting treatments and 28-year information for the control.
[b] Harvest cut volume plus stand increment (difference between residual stands or 1949 or 1956 and 1983).
[c] Board-foot volume-Int. ¼-in log rule.
[d] Includes trees 5.0 in dbh and larger.

**Table 3. Stand stumpage values and compounded values of periodic harvests for four harvest cutting practices and a control over a 34-year period.**

| Treatment | Stand stumpage before treatment | Periodic harvest values | | 1983 Value | |
|---|---|---|---|---|---|
| | | Total[a] | Compounded[b] | Stand[c] stumpage | Total[d] treatment |
| | | ..................... $/acre .... | | | |
| Commercial clearcut | 110.95 | 110.95 | 804.50 | 527.48 | 1,331.98 |
| Diameter-limit | 113.60 | 495.65 | 1,588.88 | 797.10 | 2,385.98 |
| Selection (S) | 117.75 | 259.15 | 699.37 | 889.42 | 1,588.79 |
| Selection (SP) | 119.35 | 471.00 | 872.00 | 1,213.96 | 2,085.96 |
| Control | 148.70 | 0 | 0 | 1,553.72 | 1,553.72 |

[a] Sum of stumpage payments received from periodic harvests during the study period.
[b] Value of stumpage payments from periodic harvests compounded at 6% annual interest for the appropriate number of years to the end of 1983.
[c] Minimum acceptable stumpage for poletimber and woods-run sawtimber derived from Hardwood Market Report (Lemsky 1983).
[d] Total treatment value includes stand value in 1983 plus compounded value of periodic harvests.

parison among the treatments can be made. This comparison should be possible when the commercial clearcut area is harvested for the second time in year 2019.

Net stumpage revenues from periodic harvests were used to determine the present value of each harvest cutting practice up to 1983 (Table 3). Stumpage payments were compounded to the end of 1983 at an assumed rate of 6% annual interest. The compounded value of harvest revenues was greatest in the diameter-limit area, $1,589/ac followed by the selection (SP) area, $872/ac. If 1983 stand values are added to the compounded value of periodic harvests, the diameter-limit and selection (SP) practices continue to rank highest among the five treatments in this study.

Tree quality, as measured by percent of residual stand volume in trees with butt-log grade 1 or 2, increased in each area over the 34-year study period (Table 4). In general, butt-log grades improved with diameter growth, so some of the increase in stand quality resulted from trees growing into minimum diameter classes needed for the better grades. For example, residual stand volume in grades 1 or 2 increased from 20 to 51% in the control area where no harvests or cultural practices have been applied. Similarly, nearly 38% of volume in the commercial clearcut areas was in grades 1 or 2 in 1983, even though no cultural practices have been applied since the area was treated in 1949.

In the areas where periodic harvests were made, the greatest improvement in stand quality occurred in the selection (SP) area, where selected trees are removed down to 5.0 in dbh. Also, the SP area had the highest percent of volume in trees with grade 1 or 2 butt logs and the highest stumpage price per unit of volume relative to all 5 treatment areas after 34 years (Table 4). Only the SP practice affords an opportunity to enhance species composition and improve tree quality in the poletimber stand. Poletimber stems are not included in the cut in the diameter-limit and selection (S) areas, thus allowing more poor-quality stems and low-value species to develop into sawtimber trees. As a result, the diameter-limit area, where no cutting is done below 15.5 in dbh, had the lowest percentage of stand volume in grades 1 or 2 after 34 years.

## DISCUSSION

All harvest treatments but the commercial clearcut favored the development of sugar maple for all stem size classes. Due to periodic harvests in the diameter-limit and selection areas, species such as yellow-poplar, black locust, and white ash were being replaced by sugar maple faster than those trees in the control area. Openings created at each cutting cycle in the harvested areas allowed some regeneration of intolerant species, but development into the sapling and poletimber classes is not occurring.

Sugar maple will continue to develop as the dominant species in the diameter-limit and selection treatments. Fortunately sugar maple is a high value tolerant species in the study area. Regenerating a desirable tolerant species is critical when using partial cutting practices.

After five periodic cuts in the selection (SP) area, the residual stand is close to the desired residual tree goals established for this selection treatment. That is, the marking crew is able to mark nearly all the surplus trees without overcutting. At the next 10-year cutting period in 1988, we expect to reach these established selection goals. We are probably at least two cutting cycles from attaining similar goals for the selection (S) area.

After 34 years and four to five cutting periods, sustained yield seems feasible for the selection practices. Periodic annual merchantable stand production ranged from 603 to 615 bf/ac. When the initial cut volumes were excluded from stand production, the periodic annual growth for the selection areas ranged from 426 to 458 bf/ac (72 to 74 ft$^3$). Since roads are established, a harvest of 3,000 to 4,000 bf/ac using a 10-year cutting cycle is a realistic goal. However, once the stands become dominated by tolerant species in the sawtimber stands, residual tree guidelines and periodic harvest volumes will need revision.

For the 15.5-in diameter-limit treatment used in this study, periodic harvest yields averaging 8,000 bf/ac per 20-year cutting cycle are realistic for at least a 60-year period. During the 34-year study period annual merchantable stand production averaged more than 770 bf/ac and periodic annual growth was 527 (83 ft$^3$). However, as tolerant species, with lower volumes per tree, replace the intolerants, this information should change. Though not done in this study, a shorter cutting cycle provides a better opportunity to salvage mortality and quality losses due to logging damage. A higher dbh diameter-limit would also increase the potential dollar return by allowing more trees to increase in butt-log grade (Smith et al. 1979, Trimble et al. 1974). In this instance, the 15.5-in dbh diameter-limit is the minimum for butt logs to become grade 1. The diameter-limit cutting practice could also be improved by removing undesirable trees in the pole and small sawtimber stand during periodic harvests. Although treating these trees below the indicated diameter-limit is a major change from the intent of the diameter-limit treatment, removing undesirable trees can improve future stand quality.

**Table 4. Comparison of tree quality changes over a 34-year period.**

| Treatment | Residual stand volume in trees with butt-log grade 1 or 2 | | | Stumpage price |
|---|---|---|---|---|
| | 1949 | 1983 | Change | |
| Commercial clearcut | 0 | | 37.5 | |
| Diameter-limit | 19.5 | | 24.5 | |
| Selection (S) | 24.0 | | 23.5 | |
| Selection (SP) | 22.5 | | 33.0 | |
| Control | 20.0 | | 31.0 | |

In the control area, merchantable stand production averaged 426 bf/ac/yr. During the 34-year period, the control area produced a total of 12,000 bf/ac, while the selection and commercial clearcut areas produced about 21,000 bf and the diameter-limit area produced 26,000 bf/ac. At this point, indications are that management is better than no management.

Forest managers question managing poletimber trees by selection cutting when small-product markets are not available. On better sites, managers should consider the removal of some undesirable poletimber trees. Future stand tree quality will improve and growth will be distributed on more desirable stems. Also, the removal of low-value trees should improve the probability of growth and survival of higher value trees.

Although the selection (S) and control areas provided the landowner with similar potential returns over the study period, the selection (S) area initially contained a large component of low-value hickory. The hickory contributed little to periodic harvest revenues and in 1983, the remaining hickory contributed little to the current stand value. However, as the hickory is eliminated in future harvests, the selection (S) area will have better quality and more valuable sawtimber trees than the control area. The result will be increased revenues from the selection (S) area and greater potential returns compared to those from the control area.

The economic benefits of stand management are clear when comparing the 1983 stumpage appraisal for the control and selection (SP) areas. Merchantable stems in the control, or unmanaged area, were appraised at $1,554/ac, while in the selection (SP) area, the most intensively managed stand during the study period, stumpage was appraised at $1,214/ac. The difference in stand value is small considering the control area contained nearly twice the merchantable volume (26,025 compared to 13,925 bf/ac) at the end of the study period. After five periodic harvests, the average stumpage price in the SP area was $87.20/mbf compared to $59.70/mbf in the control area, reflecting improvements in stem quality and species composition resulting from management (Table 4). The stand improvements brought about by periodic harvests and the revenues they generate are two significant benefits of managing hardwood stands instead of allowing Mother Nature to do it for us.

Periodic harvests usually result in some damage to a portion of the residual stand. Damage is usually concentrated in the saplings, but an adequate number of undamaged stems remain for future stand development. Wounds to larger trees are not cause for concern with short cutting cycles because wounded trees can be harvested before losses in value occur (Lamson et al. 1985).

Information from this study should be helpful to forest land managers applying harvest practices in Appalachian hardwood stands. Trends in stem development as a result of these harvest practices are clear. Likewise, some modifications of the practices are suggested. Though economic comparisons among stand treatments should not be made, early indications are that landowners can make money managing good hardwood sites.

## APPLICATION OF 34-YEAR RESULTS

1. For these study conditions, sustained yields of 3,000 to 4,000 bf/ac every 10 years using a single-tree selection practice seem possible for at least 7 cutting periods when trying to change an even-aged stand to an uneven-aged stand. Of course the real test for sustained yield is when tolerant species dominate the stand and dbh is an indicator of stem age.
2. If poletimber markets are not available, managers should consider removing (felling) undesirable poletimber trees when using the selection practice on the better sites. Future stand quality will improve and future growth will be concentrated on the more desirable stems.
3. For the diameter-limit practice, sustained yields of 8,000 bf/ac every 20 years seem possible for at least 4 cutting cycles or a 60-year period.
4. If a diameter-limit treatment is used, we recommend increasing the diameter-limit to at least 18 in dbh. This allows butt logs to become at least a possible grade 1 and increases the potential dollar return.
5. We recommend that when applying the diameter-limit treatment consider the removal of undesirable trees in the pole and sawtimber stand below the threshold diameter specified in the treatment. When possible fell these trees.
6. For the diameter-limit, control, and two selection practices, there was an increase in the number of sugar maple and a decrease in the number of yellow-poplar trees in the poletimber size class. Sugar maple dominated seedling and sapling size classes throughout the study period for all treatments.
7. For partial cutting practices, regeneration of a desirable tolerant species is necessary for sustained yield. Without the presence of a merchantable tolerant species, continued commercial harvests are not possible.
8. Though not planned, the commercial clearcut area could be thinned to provide stumpage revenues before the final harvest. An economical cut was available during the 34-year study period.
9. Some form of management is better than no management. During the 34-year period the managed areas produced 75% to 117% more volume per acre than the unmanaged areas. Also, managed stands provide periodic revenues, and management can improve future stand quality. □

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