COMPARING PARTIAL CUTTING PRACTICES IN CENTRAL APPALACHIAN HARDWOODS

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Abstract: Variations of diameter-limit and perhaps single-tree selection harvesting are used to regenerate and manage central Appalachian hardwood sawtimber stands. In practice, these methods differ in terms of cut rules, control of stand structure, and cultural treatment of immature stems. Preliminary information is provided to compare the effect of two differing harvest practices on the residual stand--species composition, tree quality, stand structure, and return on residual stand value. Data were obtained from second-growth central Appalachian hardwood stands managed under a given harvesting practice for 30 to 40 years. Results indicate that, for the short term, many single-tree selection goals may be achieved with an easy-to-apply diameter-limit harvest of mature trees. Economic considerations for practical application and potential long-term impacts of each harvesting method are discussed.

INTRODUCTION

Partial harvest practices, such as diameter-limit cutting and single-tree selection cutting, can be used to manage and regenerate central Appalachian hardwood stands. Appropriately applied, single-tree selection is classical unevenage management, while diameter-limit cutting is mentioned often when discussing unevenage management because it also involves periodic partial harvests. What are the on-the-ground differences between a high minimum diameter-limit and single-tree selection? These two practices differ in terms of cut rules, control of residual stand structure, and culture of immature growing stock. Selection represents more intensive silviculture by virtue of its strict control of stand structure, while diameter-limits simply remove all stems over a given size-class. Do these practices lead to residual stands with distinct characteristics and different implications for long-term management?

This paper provides additional information for comparing selection and high-minimum diameter-limit practices. Key factors affecting both economic returns and sustained yield are compared for second-growth stands managed under each harvesting method for 30 years. Comparisons are based on changes in: species composition, tree quality, residual stand structure, and return on residual stand value. Finally, economic considerations for applying these harvesting methods over extended planning periods are discussed.

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Repeated partial harvests over long periods can influence species composition and quality of merchantable products. Intolerant species have difficulty developing under partial shade maintained by periodic partial harvests. So, even a stand initially composed of largely intolerant species will regenerate to more tolerant species over time. How do selection and diameter-limit practices differ in their influence on species composition?

Partial harvest practices may also have some affect on product quality. For example, selection practices afford an opportunity to culture immature stems by removing undesirable stems and providing available growing space to trees of better potential grade. By contrast, diameter-limit harvests commonly make no removals below a specific d.b.h. size-class, so this practice provides little direct influence on quality of the residual trees. How do selection and diameter-limit practices differ in their influence on product quality?

Forest managers should make provisions for sustained yield of wood products when applying a partial harvest practice over long periods of time, say 100 years or more. Single-tree selection, as applied in these stands, controlled residual basal area (RBA), largest diameter tree (LDT), and diameter distribution quotient (q-factor) to provide for long-term sustained yield (Smith and Lamson 1982). The diameter-limit practice did not have residual stand targets as in the selection practice. As applied in this study, the d.b.h. cutting limit was 17.0 inches, relatively high for most eastern hardwood markets. The higher limit allows trees to become large enough for grade 1, the highest sawtimber grade, before harvest. How do selection and diameter-limit practices differ in their ability to establish desirable regeneration following each harvest and provide a sustained yield of wood products?

Each factor discussed has an important influence on financial returns from timber production using a partial harvest management system. Frequency and value of periodic revenues are directly related to growth characteristics and product quality of the species which regenerate following each harvest. In addition, within a particular species group, individual tree quality plays an equally important role in determining the unit value of merchantable products sold each cutting cycle. And finally, a harvest practice must provide for sustained yield or else periodic revenues may be interrupted in the future, requiring costly, unexpected stand reestablishment. How do selection and diameter-limit practices compare in terms of potential rate of return?

The information presented here provides a basis for evaluating partial harvest practices. The preliminary results shed light on the returns possible during transition from a second-growth evenaged stand to an unevenaged stand in which periodic yields are regular. Trends observed also indicate the likely species composition, tree quality, and regeneration potential for stands managed over long periods with partial harvest practices. Information regarding the transition period and clues about the character of the future stand make it possible to estimate the long-term returns possible from selection and diameter-limit practices.

In summary, the information presented here can help the forest manager evaluate two types of partial cutting practices and decide which practice is best suited to management objectives.

DATA

Data were obtained from stands located on the Fernow Experimental Forest near Parsons, West Virginia. The study area receives about 55 inches of precipitation annually, distributed evenly throughout the year. Stands compared in this study are located on site index 70 for northern red oak (*Quercus rubra* L.). Management began in the early 1950's when the second-growth stands were about 45 years old. Some old residuals from the early logging in 1905 and some stems resulting from regeneration following death of the American chestnut in the 1930's were present in the study area when the first partial harvests were made. The study stands contained three age classes when management began.

Stand data were obtained from 100 percent cruises taken every 5 years and before each harvest. Small reproduction consisted of any woody species from 1.0 foot tall to 0.99 inches d.b.h., tallied on 1/1000-acre plots randomly located throughout the study areas. Large reproduction was composed of any woody species 1.0 to 4.9 inches d.b.h., tallied on 1/100-acre plots randomly located throughout the study areas. Sawtimber quality was measured using U.S. Department of Agriculture, Forest Service log grades on a random sample of trees measured during the periodic inventories. Current (at the time of harvest) average stumpage prices for each species group were used to determine harvest and residual stand values.

TREATMENTS

In this study, diameter-limit cutting was applied using 17.0 inches as the minimum cutting diameter. Harvests were planned on a 15-year cutting cycle. Two diameter-limit areas totalling 87 acres have been cut three times since the early 1950's. Cultural practices such as vine control were applied throughout the stand before logging, but culls and undesirable growing stock below the 17.0-inch diameter limit were not cut. Cut trees were marked during the 100 percent inventory, thus relieving the logging contractor of the responsibility of measuring d.b.h.

Single-tree selection was applied according to guidelines described by Smith and Lamson (1982). In this study, selection stands were marked to achieve a residual basal area of 65 sq ft per acre (including trees 5.0 inches d.b.h. and larger) with a largest tree of 26 inches d.b.h. and a q-factor of 1.3. Marking was controlled by cut ratios for each 2-inch-diameter class, 11.0 inches d.b.h. and larger. Vines and culls were cut during each harvest operation. Harvests are planned on a 10-year cutting cycle. Since the early 1950's, two selection areas totalling 54 acres have been cut three and four times, respectively.

Data from two control areas totalling 83 acres also were included to detect changes not related to the cutting treatments. Control areas were unmanaged over the study period and received no vine control or cull treatments.

RESULTS AND DISCUSSION

In general, both selection and diameter-limit practices provided adequate regeneration to continue making periodic harvest cuts for at least an additional 40 years. Development of advance regeneration also was favorable for continued management using these harvest methods. The first 40 years of applying partial harvest practices promoted the establishment of tolerant species. Moreover, evidence from surveys of small and large reproduction indicated that continued partial harvests eventually will eliminate intolerant species, and, that sugar maple (*Acer saccharum* Marsh.), red maple (*Acer rubrum* L.), and American beech (*Fagus grandifolia* Ehrh.) will dominate harvest volume as long as these practices are continued.

The first three or four cutting cycles in managing second-growth hardwoods using partial harvest practices resulted in economical, commercial harvests which provided periodic income. The early cutting cycles also provided valuable clues about the nature of periodic income in the distant future. Results from the initial 30 years of management may improve the reliability of growth and value projections for the next several cutting cycles and beyond.

Initial Harvests

The study areas were 45-year-old second-growth stands when partial harvests were first applied in the 1950's. In single-tree selection stands, initial harvests removed old residuals, undesirable species, and high-risk trees throughout merchantable size-classes. In diameter-limit stands, no attempt was made to condition smaller merchantable growing stock, but some merchantable trees below the 17.0-inch d.b.h. cut limit were removed for roads and incidental damage.

Stand data for the initial harvest treatments are presented in Table 1. Planned cutting cycles were 15 years and 10 years for the diameter-limit and selection practices, respectively. Periodic annual merchantable volume growth is expected to be about 350 bd ft/acre, so periodic harvests could range from 3000 to 5000 board feet per acre, depending on the cutting cycle. Eventually, periodic harvests will equal periodic growth, but as exhibited in this study the initial cuts may exceed growth as old residuals are removed.

Initial harvest treatments removed 25 to 42 trees per acre. Cut trees averaged 16 inches d.b.h. in the diameter-limit, 14 inches d.b.h. in the selection stand. Harvest volume in the selection stand was slightly higher due to removal of several large old residuals and some removals in small sawtimber to achieve residual stand goals. Note that residual stands from both treatments were similar following the initial partial harvests. This initial similarity helped clarify the effect of cutting practices as the stands developed over the next 30 to 40 years. Once the old residuals were harvested, a review of subsequent harvests clarified actual differences between diameter-limit and selection practices.

Table 1.--Stand data for initial partial harvests in 45-year-old second-growth Appalachian hardwoods, 5.0 inches d.b.h. and larger.

Treatment	Stand	No. trees/a	BA/ac	Bd ft/ac	Cu ft/ac
Control	Initial	156	98	9,200	2,200
D-Limit	Initial	158	89	7,900	1,950
	Cut	25	33	4,900	840
	Residual	133	56	3,000	1,110
Selection	Initial	144	91	8,800	2,040
	Cut	42	44	5,700	1,070
	Residual	102	47	3,100	970

Later Harvests

The diameter-limit stands were harvested two additional times: 17 years and 32 years after the initial harvest. Selection stands also were harvested two additional times: 15 years and 25 years after the initial harvest. Cutting cycles were slightly longer after the initial harvest to allow the stands to rebuild growing-stock volume following the relatively heavy initial harvests. However, the time between the second and third cuts was equal to the desired cutting cycle: 15 years for diameter-limit and 10 years for selection. Data collected at these third harvests can be compared because these stands have been under management for about the same length of time. Trends are beginning to develop and harvests will be made on a regular cycle in the future. The comparison also sheds light on stand changes that occur during the transition to long-term unevenage management.

Table 2 contains stand data for the third diameter-limit and selection harvests. Note that harvest volume is roughly equal to periodic growth, although the diameter-limit harvest is still a little heavy. Both practices removed about twenty trees per acre, but cut trees in the diameter-limit averaged 17 inches d.b.h. compared with 14 inches d.b.h. in selection. Once again, the residual stands to begin the growth period before the next harvest were similar. Stocking in the diameter-limit stand was slightly lower than in the selection stand, but the cutting cycle was longer and harvests were heavier and less frequent than in this selection practice.

Stand data presented in Tables 1 and 2 indicate only slight differences between the treatments. And the difference in cutting cycle length may be the primary cause of slight dissimilarities at this point in the transition period. Because the stands were similar to begin with, and both have been cut three times, it is not surprising that the stands are similar after 30 years.

Table 2.--Stand data for partial harvests after 30 years of management, 5.0 inches d.b.h. and larger.

Treatment	Stand	No. trees/ac	BA/ac	Bd ft/ac	Cu ft/ac
Control	Recruise	132	151	19,900	3,720
D-Limit	Recruise	163	110	11,600	2,500
	Cut	19	31	5,300	790
	Residual	144	79	6,300	1,710
Selection	Recruise	171	107	10,200	2,400
	Cut	21	22	2,900	540
	Residual	150	85	7,300	1,860

At this point, it may be helpful to examine changes in species composition, tree quality, and stand structures to enhance the comparison of these practices. After all, timber sale revenues and sustained yield are influenced greatly by these factors over time. Changes occurring now, in the transition period, will affect profitability and feasibility of these practices in the future. A closer look also may reveal important modifications needed to improve the effectiveness of these harvesting systems in achieving landowner goals.

Changes in Species Composition

Preliminary evidence indicates that harvest revenues in the future will be based primarily on sales of sugar maple stumpage. The species diversity characteristic of evenage second-growth stands is giving way to commercial tolerant species such as sugar maple, American beech, and red maple. The merchantable growing stock (11.0 inches d.b.h. and larger) after 30 years of management under a partial harvest system still contains valuable intolerant species such as black cherry (*Prunus serotina* Ehrh.) and yellow-poplar (*Liriodendron tulipifera* L.), as well as northern red oak, white ash (*Fraxinus americana* L.), and other species of intermediate tolerance. Three harvest cuts have removed larger sawtimber trees and provided growing space for advance regeneration present in the 1950's to develop into the sawtimber trees present today (Figure 1). In fact, the species composition in merchantable sawtimber size-classes has changed very little over the study period. There are a few more sawtimber trees per acre in all treatment areas including control, but in general, changes in merchantable species composition will not be evident for several more cutting cycles.

A slight increase in the proportion of tolerant species is evident in the poletimber in each treatment area (Figure 2). Under full shade of the control area and partial shade of the managed stands, intolerant species are not replacing established intolerant poles as they grow into sawtimber sizes. In the diameter-limit stands, however, some intolerant species are

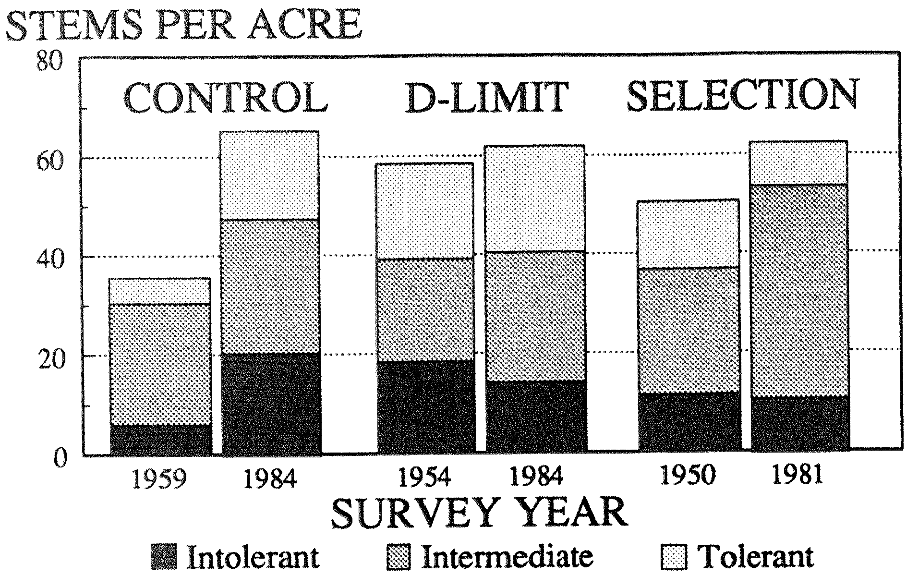

Figure 1. Species composition of sawtimber by tolerance.

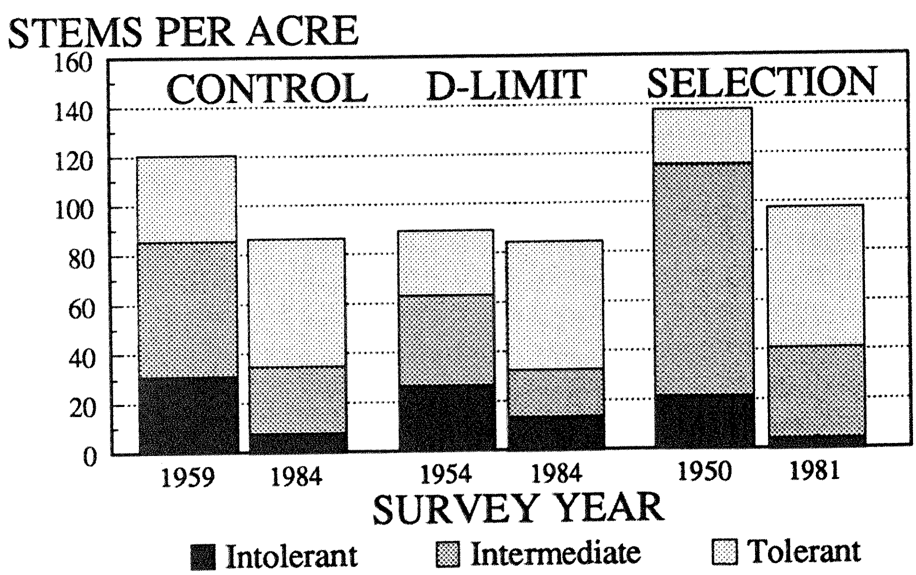

Figure 2. Species composition of poletimber by tolerance.

developing in the poletimber classes. In the selection stands, an effort is made to distribute the cut evenly throughout the stand, if possible. Openings large enough for intolerants to flourish are less likely in selection practices than in diameter-limits. Still, a small proportion of the stand will have some intolerant species develop for either practice, but more intolerants will develop under a diameter-limit practice.

Surveys of large reproduction indicate a decrease in the total number of saplings per acre in all treatments, with the vast majority of advance reproduction made up of tolerant sugar maple in these study areas (Figure 3). Although intolerant species made up a minor part of large reproduction at the beginning of the study when the canopy was closed, only the diameter-limit stands showed an increase in the proportion of intolerant species over the study period.

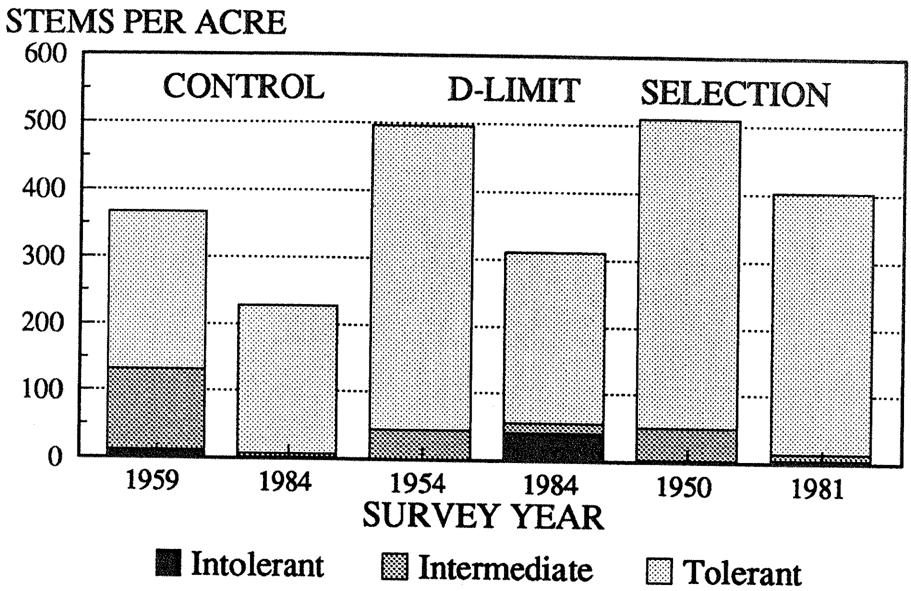

Figure 3. Species composition of large reproduction by tolerance.

Trees were aged in the study area to determine when regeneration was established. Intolerant poles in the treated areas were less than 40 years old, indicating they were established as a result of the partial regeneration harvests made since management began. Only the smaller (1 to 2 inches d.b.h.) tolerant saplings became established as a result of management. Other tolerant poles were probably small saplings in the understory when the first cuts were made in the 1950's.

Small reproduction contained a minor component of intolerant species after 30 years of management. Diameter-limit stands contained the most intolerant reproduction, about 500 stems per acre (Figure 4). Selection stands contained over 5,000 sugar maple seedlings per acre at the 30-year survey, almost twice as many as the control or diameter-limit areas. Although surveys of small reproduction show that regeneration is established after every partial cut, they do not indicate adequately the future stand composition (Trimble 1973). Some intolerants like black cherry can be tolerant when small and young, but without adequate light, they lose their early tolerance and die before they become part of the large reproduction. So, high counts of intolerants in the small reproduction do not indicate a component of merchantable intolerants in the distant future.

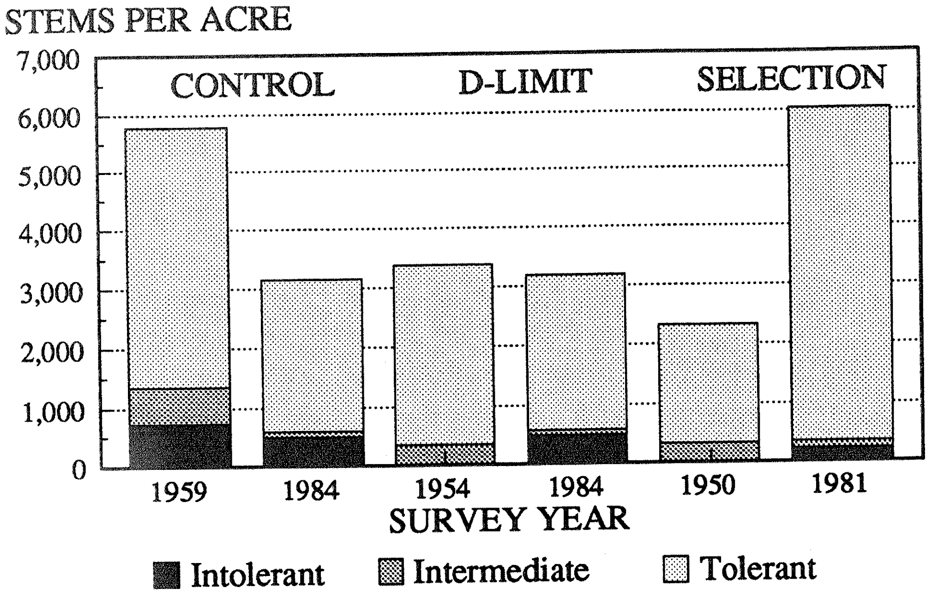

Figure 4. Species composition of small reproduction by tolerance.

Without question, continued application of partial harvest practices will lead to stands made up of tolerant commercial species if they are present and can be regenerated at each harvest. Results indicate, also, that diameter-limit cutting may allow more intolerants to become established compared to selection practices. The longer cutting cycle with a heavier, less frequent harvest is a major reason why the diameter-limit areas contained more intolerants. Also, removal of clumps of mature trees also created favorable light conditions for intolerants to develop. Forecasting species composition in the distant future is often difficult, but trends indicate that sugar maple will dominate these stands. Some intolerants will continue to play a minor role. In comparing the practices, diameter-limit stands will be composed of 10 to 20 percent intolerants, black cherry, and yellow-poplar in the study area, while selection stands will be 5 to 10 percent intolerants. The actual impact of the intolerant component will depend on how stumpage prices compare with sugar maple prices at each of the partial harvests. If the intolerant species is black cherry, the added revenue may give diameter-limit a slight advantage over selection, other things equal. If the intolerant species is yellow-poplar, the practices may provide similar returns because sugar maple and yellow-poplar prices differ only slightly in many markets. Thus, there may be no incentive to choose diameter-limit cutting to favor development of some additional intolerants if they are not high-value species.

Changes in Tree Quality

An important difference between selection and diameter-limit management is the cultural treatment of immature stems. Selection harvests remove some trees from all merchantable diameter classes. The main objective in cutting throughout a range of d.b.h. classes is to control stand structure, but selection also cultures immature merchantable stems. So in addition to controlling numbers of stems, the selection practice affords an opportunity to influence quality of the residual stand. Diameter-limit, on the other hand, disregards stand structure and tree quality development in stems smaller than the cut limit.

Samples of butt-log grade taken during preharvest cruises provided a basis for comparing the effects of selection and diameter-limit cutting on stand quality development. Some improvement in grade is due to trees growing into larger size-classes where grade rules are more forgiving of surface defects. Total board foot stand volume in grades 1 and 2 (highest sawtimber grades) increased by about 10 percent in unmanaged stands over a 25-year period (Figure 5). Diameter-limit areas had a similar increase in stand quality over a 30-year period, but there was a slight decrease in quality between the 15- and 30-year sample. Apparently, quality in the diameter-limit areas may fluctuate as it does in an unmanaged area because trees below the cut limit are not improved through periodic harvests.

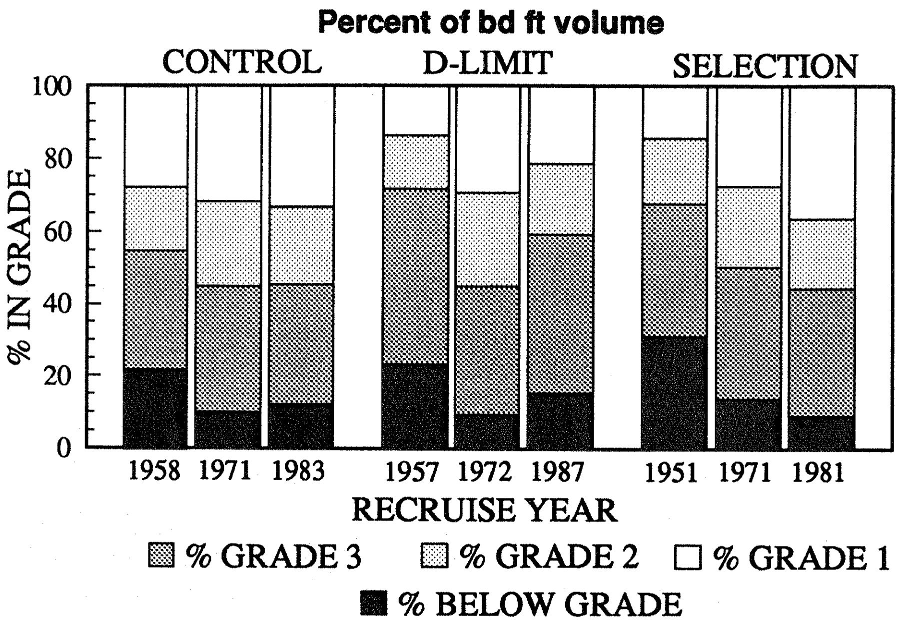

Figure 5. Distribution of sawtimber by volume by butt-log grade.

In selection stands there was a distinct improvement in quality over 30 years. These stands were cut three times, continually reducing the proportion of volume in trees below sawlog grade. Most of the quality improvement was from an increasing proportion of volume in grade 1 and a decreasing proportion of volume below grade. Proportion of volume in grades 2 and 3 remained relatively stable.

Each harvest removed trees of lower grade, leaving behind trees with the greatest potential for making grade 1. As the chosen residual 12- and 14-inch trees grow into larger d.b.h. classes, the percent of volume in grade 1 or 2 increases. Because the number of 12- and 14-inch d.b.h. trees is fairly stable under selection management and these classes are too small for grade 1, it is understandable that the percent of volume in grades 2 and 3 is fairly stable also. Percent of volume in grade 1 increases as stands are converted to unevenage management because the larger sawtimber growing stock is made up of "best" trees favored at each periodic harvest.

Volume in grades 1 and 2 increased by 35 percent in selection areas and only 15 to 20 percent in the diameter-limit areas. For the next three or four periodic harvests, selection areas will yield 15 to 20 percent more grade 1 and 2 sawtimber volume than diameter-limit areas. Stumpage prices and sale revenues will reflect the higher quality products. As stands under both management systems are converted to predominantly unevenaged tolerant species, grade differences will be more predictable because grade variations among various species groups will be eliminated.

For projecting grade distributions for managed unevenaged stands, Table 3 contains an unbiased estimate of sugar maple butt-log grade distribution. Data were obtained from grade samples taken in stands managed under single-tree selection for 30 years or more, each stand cut from 3 to 5 times. Proportions of trees in each grade by diameter class can provide an estimate of tree quality for repeated selection harvests. Note that well over half of the residual trees in a managed stand are in grades 1 and 2.

Table 3.--Butt-log grade distribution for sugar maple in managed selection stands.

D.b.h.	No. Trees	% Grade 1	% Grade 2	% Grade 3	% Below Grade
12	32	-	-	91	9
14	29	-	52	45	3
16	31	39	35	23	3
18	29	55	31	14	0
20	30	44	23	33	0
22	37	41	32	27	0
24	41	51	17	27	5
26 plus	99	48	26	24	1
Total	328				

Changes in Residual Stand Structure

Providing for sustained yield is an important consideration when applying partial harvests over long planning horizons. Selection harvests are planned with a goal residual stand in mind, primarily to ensure enough trees in smaller diameter classes to continue periodic harvests in the near future. In addition, residual basal area goals are set to ensure adequate regeneration after each harvest and to provide continual recruitment of trees for the distant future.

In the central Appalachians, partial harvests using an 18-inch diameter-limit have not created deficit d.b.h. classes which could lead to disruptions of regular periodic yield. Prior to the most recent harvest, both diameter-limit and selection stands had stand structures similar to the original stand structures when management had begun 30 years earlier (Figure 6). There were adequate numbers of trees in each merchantable d.b.h. class to meet a residual stand goal suitable for sustained yield.

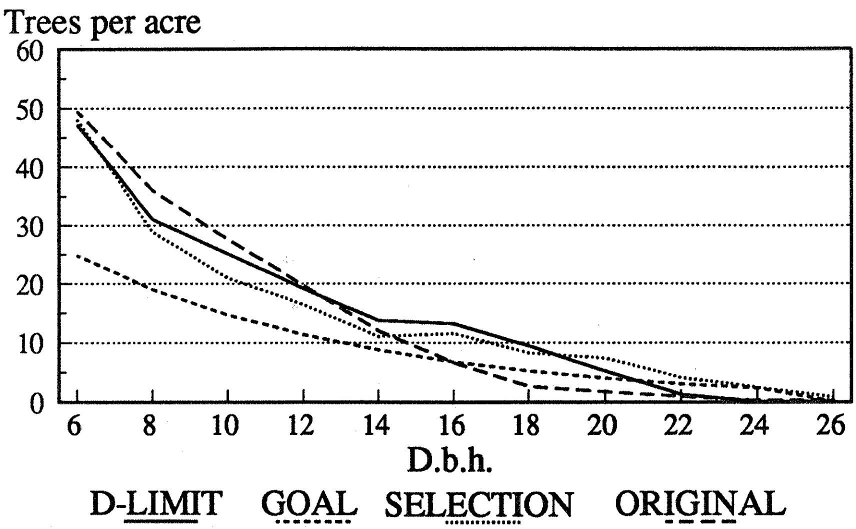

Figure 6. Stand structure before most recent harvest.

Selection harvests were made to achieve gradually a residual stand goal, so it is not surprising that after four harvests stand structure is very near the goal (Figure 7). There is still a small surplus in the 16- to 18-inch d.b.h. classes, reflecting a conservative attitude toward marking in the early periodic harvests, before marking guidelines were fully evaluated. Future harvests will bring the residual stand closer to the goal because preliminary results indicate that it is adequate for regeneration and sustained yield, and retaining surplus trees is no longer warranted.

Forest managers may question the feasiblity of diameter-limit cutting because the cut rule does not ensure that sustained yield conditions can be maintained over time. A review of residual stand structures revealed that diameter-limit areas met some of the residual stand targets used to practice selection even though periodic harvests were not explicitly planned to do so. For example, the diameter-limit areas had a residual basal area of 79 sq ft per acre, similar to the selection practice. In addition, the residual stand structure had adequate numbers of trees in each d.b.h. class to meet a stand structure goal for a q-factor equal to 1.3 (Figure 7). So, the diameter-limit stands appear to provide adequate regeneration and tree recruitment throughout merchantable diameter classes to continue the practice for at least three or four cutting cycles in the future. Although a 17.0-inch d.b.h. cut limit was

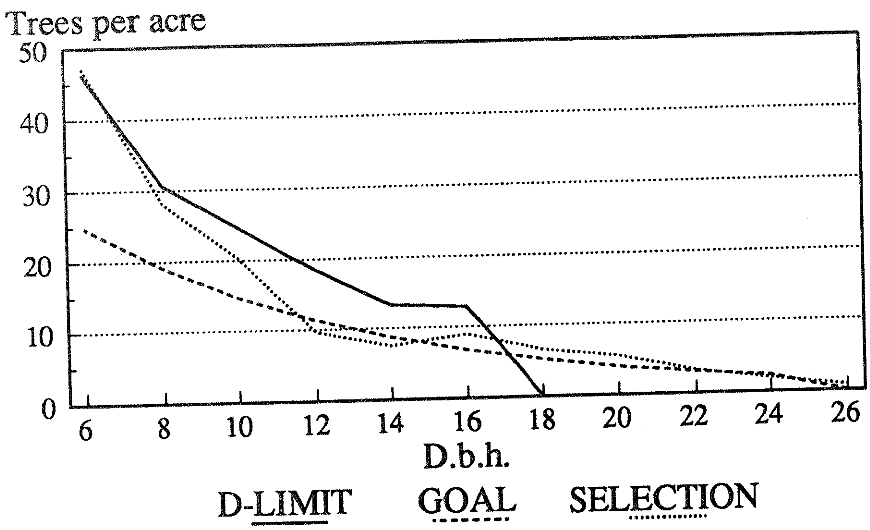

Figure 7. Stand structure after most recent harvest.

appropriate for the stands studied, a higher limit may be needed in some stands to avoid overcutting. Still, residual basal area goals can be achieved using either selection or diameter-limit practices.

Both partial harvest practices examined here have brought about adequate regeneration and recruitment of smaller trees to meet sustained yield guidelines over the first 40 years of application. Preliminary results indicate that these practices can be used for up to 80 years, allowing six to eight periodic commercial timber sales. Further study will define in more detail implications of partial harvest practices over even longer periods. For now, forest managers can apply partial harvest practices so long as a desirable tolerant species is present and can be regenerated after each periodic harvest. Later, adjustments may be needed to account for changes in species composition that are certain to occur.

Return on Residual Stand Value

Actual stumpage revenues from selection and diameter-limit harvests were used to compute periodic rates of return during the study period. For computing real returns, stumpage values at the time of each harvest were adjusted for inflation using Producer's Price Index for all commodities. Inflation averaged 3.7 percent during the study period.

The two-diameter-limit cutting areas earned an average 9.8 percent market rate of return and a 5.9 percent real rate of return. These rates were competitive with other long-term investments available during the same period. Earnings in the two single-tree selection areas averaged 10.0 percent market rate of return and 6.1 percent real rate of return. Selection areas earned slightly higher average returns because one area was harvested four times compared to three times in other treatment areas. The additional payoff helped boost average rate of return. For the control stand, where no harvests were made, earnings averaged an 8.3 market rate of return and a 4.4 real rate of return.

Managed stands provided higher earnings than the control stand mainly because periodic partial harvests reduce the time required to receive income. Periodic annual board-foot-volume growth was about the same for each of the three treatments, 370 to 400 board feet per acre. Thus, the main reason for higher average earnings in managed stands is the more frequent harvest income. Comparing single-tree selection and diameter-limit cutting, as applied in this study, earnings were about the same over the first 30 years of management.

SUMMARY

Partial harvest practices can help meet a range of management objectives. Evidence indicates that commercial sales 10 to 15 years apart can provide periodic timber income for 80 years or more without adverse effects on residual growing stock. In visually sensitive areas, these practices provide a continuous cover of trees while growing and harvesting timber products.

Each practice has important advantages and disadvantages. Single-tree selection improves tree quality and affords explicit control of residual stocking for sustained yield. Selection can be more difficult to apply, in practice, because it requires marking by cut ratios and accurate counts of cut and leave trees during marking. Yield from selection harvests is distributed among small and large sawtimber, thus increasing the unit harvesting costs and reducing stumpage value compared to diameter-limits.

Diameter-limit cutting is very easy to apply. Harvest volume is in relatively large trees (18 inches d.b.h. and larger) so harvesting costs are lower than for selection cutting, other things equal. Stands observed in this study did regenerate following each harvest, and residual stand structure was adequate for sustained yield even though no attempt was made to achieve a given residual stocking. The greatest drawback of diameter-limit cutting is the lack of influence on the quality of immature merchantable trees. The quality of trees growing into larger sizes classes is left to chance.

Trimble, Mendel, and Kennell (1974) suggested a compromise between single-tree selection and diameter-limit cutting for managing hardwood stands using a partial cutting practice. Mature trees are harvested using a flexible diameter-limit based on financial performance of residual trees. In addition, merchantable immature growing stock receives an improvement cut at each periodic harvest. Residual basal area guidelines are used to adjust the minimum d.b.h. cut limits for mature trees to provide for sustained yield. This method offers the simplicity of diameter-limit cutting in the field--each species has its own minimum d.b.h. cut limit. It also offers the intensity of selection management--the forest manager can control residual stand stocking and quality better.

Partial cutting practices, if properly applied, can earn competitive returns on residual growing stock while providing the nonmarket benefits of continuous forest cover. In this study, average annual volume growth was 370 to 400 bd ft per acre for selection and diameter-limit, respectively. Harvests of periodic stand growth in the future will yield 3,000 to 5,000 bd ft per acre every 10 to 15 years, varying only slightly with each cutting cycle. Using local stumpage prices near the study area, periodic income will be $250 to $500 per acre depending on the length of the cutting cycle.

Assuming observed trends continue in the study stands, real (net of inflation) return on residual stand value will be 5.4 percent for diameter-limit and 4.9 percent for selection. These rates compare favorably with alternative investments available to forest landowners. This is not to say that diameter-limit cutting is more profitable in all cases. But once again, diameter-limit cutting (with a high minimum d.b.h. limit) and single-tree selection as applied in this study, are similar.

Results from this study indicate that partial cutting practices have merit, and diameter-limit cutting achieves many of the residual stand goals of single-tree selection. Selection did result in improved stand quality. However, the diameter-limit practice earned a similar rate of return and may earn a higher rate of return in the future because periodic timber sales are made up of mostly larger trees. Both practices established desirable regeneration following each harvest, and had enough residual trees to provide for sustained yield. Diameter-limits also promoted the development of some valuable intolerant species, although, in general either practice will lead to a stand of mostly tolerant species over time.

A high minimum-diameter-limit appears to be a much easier method for applying partial cutting management in central Appalachian hardwoods than single-tree selection. The observable effects on development of the residual stand and economic benefits were similar in this study. If diameter-limit practices are used, trees should be allowed to reach minimum requirements for a grade 1 butt log (16 inches d.b.h.). A higher minimum d.b.h. cutting limit is recommended--at least 17.0 inches as applied in this study.

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