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Financial Aspects of Partial Cutting Practices in Central Appalachian Hardwoods

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Abstract

Uneven-aged silvicultural practices can be used to regenerate and manage many eastern hardwood stands. Single-tree selection methods are feasible in stands where a desirable shade-tolerant commercial species can be regenerated following periodic harvests. A variety of partial cutting practices, including single-tree selection and diameter-limit cutting have been used for 30 years or more to manage central Appalachian hardwoods on the Fernow Experimental Forest near Parsons, West Virginia. Results from research of these practices are presented to help forest managers evaluate financial aspects of partial cutting practices. Observed volume growth, product yields, changes in species composition, and changes in residual stand quality are used to evaluate potential financial returns. Also, practical economic considerations are discussed for applying partial cutting methods.

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Cover Photo: A central Appalachian hardwood stand on site index 80 for northern red oak after four 10-year, periodic, single-tree selection regeneration cuts.

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Introduction

Interest in applying uneven-aged silvicultural practices in eastern hardwood stands has grown in recent years, mostly in response to public opposition to the esthetic effects of clearcutting. Critics of clearcutting suggest that applying single-tree selection or related management practices, which involve periodic partial cutting operations, might provide a suitable compromise: continued utilization of timber resources without complete removal of the overstory trees. It is important to remember that partial cutting methods influence key economic factors: stand growth, volume yields, tree quality, species composition, and returns on residual stand value. This paper provides information on these factors derived from central Appalachian hardwood stands that have been managed using either single-tree selection or diameter-limit cutting over a 30- to 40-year period.

In many cases, the decision to practice uneven-aged silviculture in a particular stand is based on nonmarket management objectives such as esthetics or wildlife. Management goals may require a more-or-less continuous cover of overstory canopy trees to satisfy other goals, but economic objectives still apply. Given that single-tree selection is the desired silvicultural method, why not apply this practice so that it is economically efficient? This paper also provides guidelines for evaluating financial returns from several variations of single-tree selection.

Finally, information is provided on other aspects of partial cutting practices that may be helpful in understanding the impacts of periodic cuts on financial returns. Economic considerations such as logging damage, management of nonmerchantable trees, and improvement of diameter-limit cutting are all discussed.

Data

Data were obtained from stands located on the Fernow Experimental Forest near Parsons, West Virginia. The study area receives approximately 55 inches of precipitation each year, distributed evenly throughout the year. Stands are located on sites ranging in site index from 60 to 80 feet for northern red oak (base age 50 years). 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 when the first partial cuts were made. As a result, the stands under study contained three age classes when management began in the early 1950's, although most trees were 45 years old at that time.

Merchantable stand data were obtained from 100 percent inventories taken every 5 years and before each periodic cut, while data on reproduction were obtained from fixed-area sample plots. Seedling reproduction consisted of woody species 1.0 foot tall to 0.99 inches diameter breast height (d.b.h.), tallied on randomly located 1/1000-acre plots. Sapling reproduction consisted of wood species 1.0 to 4.9 inches d.b.h., tallied on 1/100-acre plots. Poletimber consisted of commercial species 5.0 to 10.9 inches d.b.h., and sawtimber consisted of commercial species 11.0 inches d.b.h. and larger. Sawtimber quality was estimated using U.S. Forest Service log grades on a random sample of trees measured during periodic inventories (Rast et al. 1973). Stumpage values were estimated using Tree Value Conversion Standards (DeBald and Dale 1991).

Review of Single-Tree Selection

Thinnings, improvement cuts, diameter-limit cutting, and even "high-grading" have been confused with selection practices. While all of these practices are a form of partial cutting that may lead to establishment of regeneration, they are *not* true single-tree selection. In true selection practices, the objective is to maintain a given number of residual trees per acre throughout a range of d.b.h. classes over time. In other practices, the harvested material usually is from larger sawtimber-sized diameter classes and residual number of tree goals are not used to ensure sustained yield.

In order to evaluate financial benefits of uneven-aged management, it is important to review selection procedures and identify factors used to control periodic harvests. Based on stand characteristics and management objectives, a residual stand goal is established in terms of residual basal area (RBA), largest diameter residual tree (LDT), and q-value, which defines how residual trees are distributed among diameter classes (Smith and Lamson 1982). Once a goal is established, trees are harvested from diameter classes in which there are excess trees, that is, more than enough to meet residual stand goals (Fig. 1). Financial returns are affected by frequency of periodic cuts and the volumes removed, so it is important that the forest manager define residual stand goals that are economical and in harmony with landowner objectives.

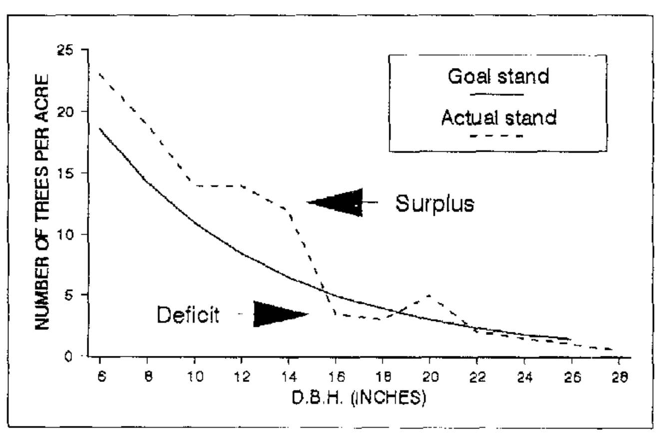

Figure 1.—An example of a residual-stand structure goal compared to actual stand structure from cruise data.

Periodic Product Yields and Income

From a practical financial point of view, uneven-aged stand management practices are periodic sales of merchantable products. In order to provide for a sustained yield of products and sale income, periodic cuts should remove no more than periodic stand growth. Removing too much volume at any periodic cut might delay or reduce harvests in the future. For example, in central Appalachian hardwood sawtimber stands, average annual volume growth (International 1/4-inch rule) can be estimated by northern red oak site index as follows:

SI 60	200 bd ft/acre
SI 70	300 bd ft/acre
SI 80	400 bd ft/acre

This means that on site index 70, selection cuts feasibly could remove approximately 3,000 board feet per acre every 10 years, or 4,500 board feet every 15 years, or 6,000 board feet every 20 years. Actual stand growth will vary, but these guidelines are useful for planning initial harvests in previously uncut stands.

The cutting cycle (number of years between partial cuts) depends on site productivity, average merchantable volume growth per acre, and minimum sale requirements in local markets. For roaded areas in the Appalachians, harvests averaging a minimum of 2,500 board feet per acre usually are acceptable. So, in most managed stands, the minimum cutting cycle is 10 to 15 years, depending on site index. Longer cutting cycles may be used if needed, particularly on large forests where labor resources are limited.

Observed periodic yields. Single-tree selection has been applied in central Appalachian hardwood stands since the early 1950's on the Fernow Experimental Forest. Selection stands on site index 70 have been cut four times on a 10-year cutting cycle using the following residual stand goals:

RBA = 65 ft^2 (5.0 inches d.b.h. and larger)
LDT = 26 inches d.b.h.
q-value = 1.3

Figure 2 illustrates the relationships among initial, cut, and residual stand volume for the first four periodic cuts in a previously unmanaged Appalachian hardwood stand. The first periodic cut in this stand resulted in relatively heavy volume removals per acre to condition the stand and remove many large old residual trees left following the original logging of the early 1900's. Later harvests removed roughly one-third of the merchantable volume. Note that residual stand and harvest volumes have been increasing since management began in 1955.

The most recent cut. Recall that selection harvests should remove volumes equal to periodic growth. In one stand on the Fernow, a recent harvest in 1990 removed 3,700 board feet per acre. The harvest removed an average of 17 trees per acre that averaged 16.7 inches d.b.h. Over 50 percent of the cut volume and value was from northern red oak and other medium shade-tolerant species (Table 1). Only 7 percent of the stumpage revenue cut was from more shade-tolerant species such as red maple and sugar maple. Stumpage income was nearly $500 per acre. However, it is unreasonable to assume that this stand will provide such a level of income for all future cutting cycles.

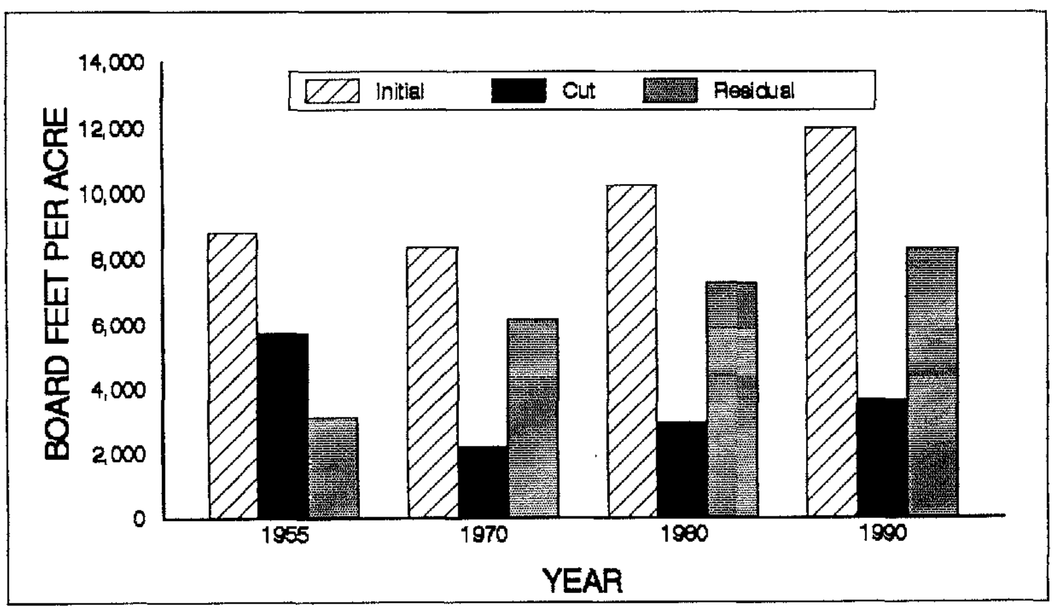

Figure 2.—Volume per acre for four selection harvests in Appalachian hardwoods.

Table 1.—Species composition of 4th selection cut on site index 70

Species	Bd ft/acre	$/acre
Black cherry	750	186
Other intolerants	150 (24%)	2 (38%)
Red oak	1,200	235
Intermediates	775 (54%)	39 (55%)
Sugar maple	480	27
Red maple	270	9
Other tolerants	75 (22%)	1 (7%)
Total	3,700	499

As future cuts remove valuable shade-intolerant and medium shade-tolerant species from the sawtimber-size classes, less valuable shade-tolerant species will replace them. Thus, to evaluate single-tree selection over long planning horizons, the value of future harvests must be estimated based on future species composition and growth rates. Trees present in the initial unmanaged stand have influenced cut volumes and value for many years since the effects of continued uneven-aged management are just beginning to show.

Selection Favors Regeneration of Shade-Tolerant Species

In previously unmanaged stands, there may be a diversity of commercial sawtimber species present when the first selection cuts are applied. An important impact of repeated partial cuts using a single-tree method is that shade-tolerant species eventually will dominate future stands. Light conditions created by removing a few scattered trees every 10 to 20 years are not conducive to development of intolerant species such as black cherry and yellow-poplar. Intolerant seedlings may germinate and grow for a few years, but as the canopy closes between periodic cuts, they simply die due to insufficient light. Shade-tolerant species, such as sugar maple and red maple, however, survive and slowly grow in the understory between cuts and then replace overstory trees removed in future cuts.

The first few selection cuts in a previously unmanaged stand are used to improve stand quality by removing poor quality and high-risk trees, as well as cut excess desirable trees to achieve residual stand goals. Once poor trees are removed, the next few selection cuts are composed of sawtimber-sized trees that were part of the stand when management began, plus poletimber from the initial stand stimulated to grow into merchantable size classes. Selection stands on the Fernow Experimental Forest indicated that as many as 6 to 8 cuts (approximately 80 years) may be needed before species composition of the harvest becomes predominantly shade-tolerant species.

Changes in future species composition are much more apparent in the seedling- and sapling-size classes. Figure 3 illustrates a slow but steady change in species composition for second-growth Appalachian hardwoods managed using a single-tree selection practice. Small reproduction predominantly was sugar maple, but some intolerant black cherry and medium-tolerant species were present (Fig. 3, upper graph). Note that an adequate number of seedlings needed for sustained yield were established following each periodic cut.

Intolerant and medium shade-tolerant seedlings did not, however, develop into sapling-size classes. There was a steady decline in the number of saplings per acre, but only the second survey in 1970 contained a significant number of shade-intolerant saplings (Fig. 2, middle graph). This could be explained by the relatively heavy initial harvest 15 years earlier. Closure of the canopy was delayed, allowing ample light for some intolerant seedlings to survive and develop. Later inventories following lighter cuts showed very few intolerant species developing in the sapling-size class. The data clearly indicate that as periodic cuts continue, the future stand predominantly will be sugar maple on this site.

In poletimber-size classes, intolerant and medium-tolerant species were present but gradually diminishing (Fig. 3, lower graph). in 1990, poletimber trees were found to be more than 40 years old, indicating they were present when management began in the 1950's. As poletimber trees grow into sawtimber, they, too, will continue to be replaced by sugar maple.

Species Composition Affects Volume and Value

In general, tolerant species have lower volume growth rates and lower product values than intolerant and medium-tolerant species even though d.b.h. growth rates are similar (Smith and DeBald 1975). A comparison of five important Appalachian hardwood species at 24 inches d.b.h. illustrates a wide range of volume and value per tree (Table 2). Volume differences primarily are related to merchantable height on a given site index, while value differences are related to volume, log quality, and price of lumber products.

Table 2.—Average volume and tree value for 24-inch d.b.h. Appalachian hardwood sawtimber on site index 70

Species	Bd ft/tree	$/tree
Yellow-poplar	662	45
Black cherry	573	211
Red oak	527	145
Sugar maple	541	50
Red maple	538	40

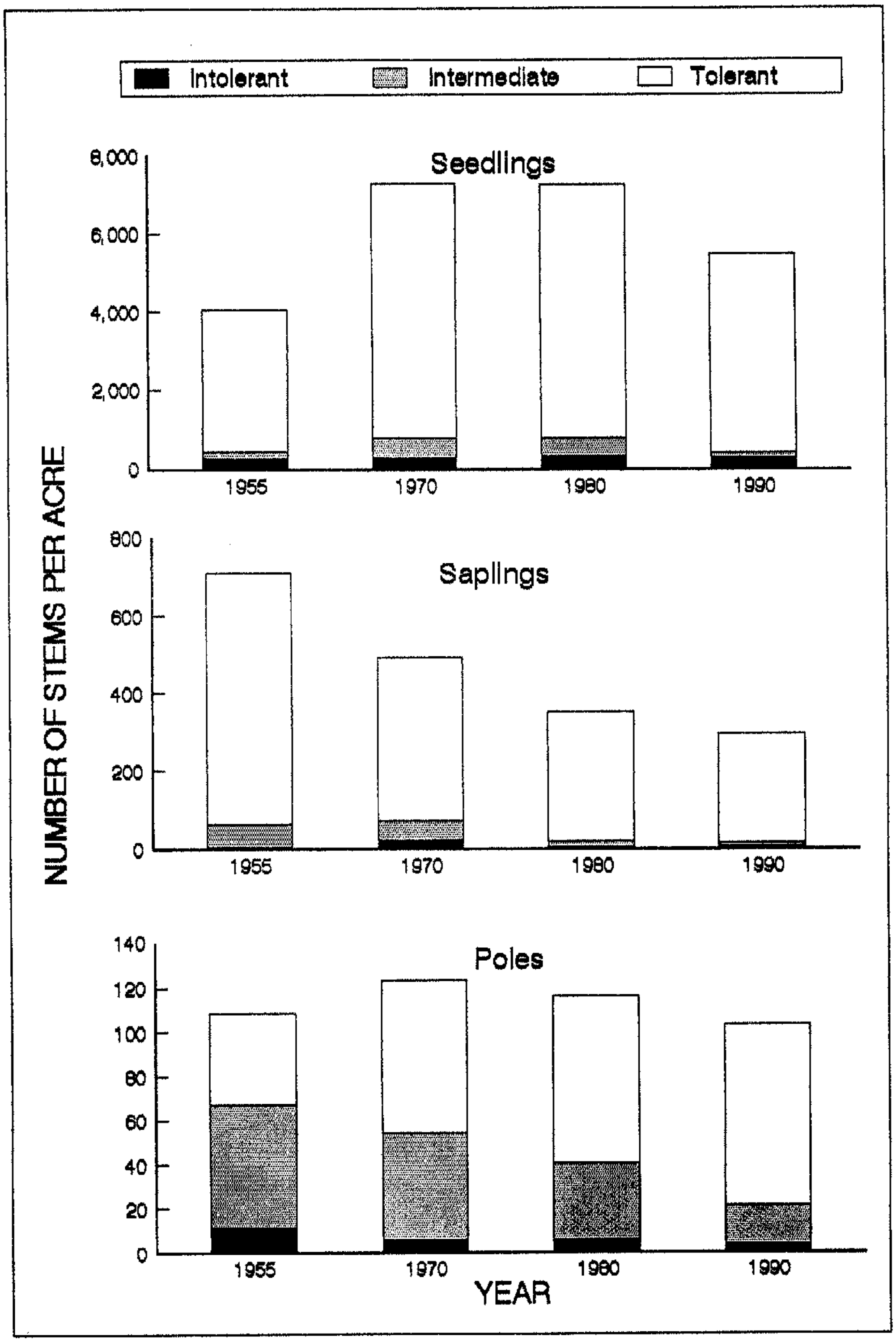

Figure 3.—Species composition in an Appalachian hardwood selection stand.

In managed selection stands, less than 50 percent of sawtimber-sized sugar maple trees will qualify for grade 1 butt logs, the highest sawlog grade (Table 3). By contrast, nearly 60 percent of yellow-poplar trees will qualify for grade 1 butt logs once d.b.h. exceeds 22 inches (Myers et al. 1986). Grade differences are even greater for red maple (Table 4), for which only approximately 25 percent of trees qualify for grade 1 butt logs. Thus, practicing single-tree selection brings about changes in species composition that, in turn, affects potential product quality and periodic income from harvests.

Once species composition changes are complete, periodic income will be derived from sales of primarily sugar maple stumpage on good sites (site index 70) and primarily red maple on fair sites (site index 60). As a result, periodic income will be reduced drastically compared to the mix of species harvested in the initial cuts as the stand is being converted to uneven-aged management. Recall that the most recent harvest generated nearly $500 per acre. In the future, periodic income (in constant dollars) could be from $150 to $225 per acre, depending on site index and its effect on species composition and cutting cycle. This reduction occurs mainly because harvests will be composed of the less valuable tolerant species, instead of other species that cannot develop under shaded conditions maintained by single-tree selection.

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
		Percent			
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+	99	48	26	24	1
Total	328				

Table 4.—Butt-log grade distribution for red maple in managed selection stands.

D.b.h.	No. trees	Grade 1	Grade 2	Grade 3	Below Grade
		Percent			
12	69	–	–	67	33
14	48	–	35	55	10
16	52	19	29	48	4
18	52	33	25	42	0
20+	80	24	26	48	2
Total	301				

Economic Considerations

When a desirable, commercial tolerant species can be regenerated at each periodic cut, single-tree selection has been demonstrated to be a practical management alternative. In central Appalachian hardwoods, partial cuts over the past 40 years have resulted in adequate regeneration to satisfy sustained yield objectives. After four cutting cycles, residual stand structure is about the same as when management began in the mid 1950's (Fig. 4). Thus, it is reasonable to expect that at least four more periodic cuts are possible in the future. With continued periodic establishment of desirable reproduction, partial cutting practices can be continued indefinitely. Economic considerations and suggestions for improving the efficiency of partial cutting practices are discussed in the following sections.

Competitive returns. On the Fernow Experimental Forest, partial cutting practices involving diameter-limits and variations of single-tree selection earned competitive rates of return on residual stand value (Smith and Miller 1987; Miller and Smith 1991). Other studies have shown that partial-cutting practices can earn from 4 to 6 percent real rates of return (McCauley and Trimble 1972; Reed et al. 1986).

Partial cutting also allows the landowner to retain many management options. Hunting and recreation opportunities usually remain intact under partial cutting and residual timber improves the esthetic value of the forest property. If the landowner decides to sell both land and timber, the residual timber will attract a range of potential buyers. Standing timber also is a form of savings the landowner can withdraw later if needed.

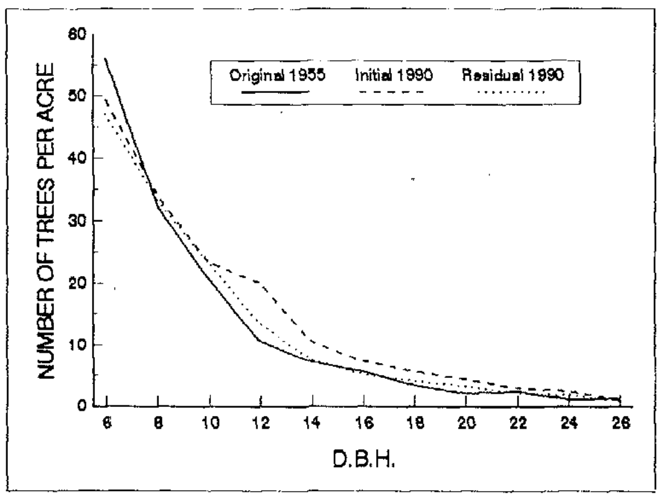

Figure 4.—Stand structure in an Appalachian hardwood selection stand on red oak site index 70 before and after four periodic cuts.

Logging damage. Foresters usually are concerned about logging damage to residual stems when using partial cutting practices, particularly when cutting cycles are relatively short, say 10 to 15 years. Damage to saplings is of concern because the future stand is strongly dependent on this source of regeneration. Skinned stems on residual poletimber and small sawtimber trees also is a concern because there is the potential for lower quality and value if such wounds degrade butt logs in the future.

A recent study of logging damage in single-tree selection stands indicated that periodic harvests leave an adequate number of undamaged stems to produce good timber crops in the future (Lamson et al. 1985). Damage usually is heaviest in the sapling-size classes, but there were over 270 undamaged saplings per acre after three or four periodic cuts (Table 5). Similarly, over 100 poletimber and over 30 sawtimber trees per acre were not damaged by periodic cuts. As a result, residual stands contained enough undamaged trees to meet residual stand goals for selection.

Of the trees that did suffer exposed-sapwood wounds, the majority of them will not be degraded in the future. Wounds to potential crop trees were concentrated near the stump portion of the butt log. Also, trees with large wounds (100 in^2 or more) or wounds above stump height can be removed in future cuts before any loss in grade occurs due to rot. Smaller wounds tend to heal before grade reductions occur.

To reduce logging damage, logging equipment should be confined to skid roads as much as possible. Fender trees along skid roads help ensure that the load stays in the road and away from residual trees. Skidding shorter log lengths also reduces damage. Spring logging when bark slips off easily certainly should be avoided in partial cuts. Good loggers who have demonstrated the ability to conduct responsible partial cutting operations are well known in local markets. Conscientious operators can save the landowner money in the future by protecting residual trees and streams, even if they offer slightly lower stumpage prices to compensate them for extra care given to the residual stand. Contracting with a reputable logger may provide this extra care.

Table 5.—Per-acre logging damage by diameter class during the third or fourth cut using individual-tree selection practices

	Number				Basal area (sq ft)				Board feet
	inches d.b.h.								
Item	1.0-4.9	5.0-10.9	11.0+	Total	1.0-4.9	5.0-10.9	11.0+	Total	11.0+
Initial stand	427	137	59	623	14.4	43.8	73.9	132.1	10,344
Marked trees	0	6	19	25	0.0	2.3	24.4	26.7	3,306
Residual stand[a]	427	131	40	598	14.4	41.5	49.5	105.4	7,038
Logging Damage — Residual stand									
Destroyed	40	5	2	47	1.0	1.3	1.3	3.6	167
Bent or leaning	28	4	1	33	0.8	1.1	0.6	2.5	73
Net residual stand[b]	359	122	37	518	12.6	39.1	47.6	99.3	6,799
Exposed sapwood	58	17	4	79	2.1	5.4	5.6	13.1	795
Broken crown branches	29	4	1	34	1.7	2.0	0.9	4.6	123

[a]Residual stand = initial stand minus marked trees.
[b]Net residual stand = residual stand minus destroyed trees minus bent or leaning trees.

Managing poletimber. Where markets are not available for poletimber products, partial cuts usually include only sawtimber trees. However, stand quality and value of future harvests can be improved if periodic selection cuts include cutting cull and undesirable poletimber, even if they are cut and left in the woods. Managing unmerchantable poletimber in single-tree selection results in cutting 15 to 20 additional trees per acre (Smith and Miller 1987). The benefits of cutting some undesirable poletimber include slight improvements in species composition and spacing of residual trees, plus improvements in average log quality of trees growing into sawtimber-size classes in the future. In one study on the Fernow, a selection stand managed for both sawtimber and poles (SP) was worth 33 percent more than a similar stand managed only for sawtimber (S) over a 34-year study period (Table 6). Growing space that would otherwise have been occupied by undesirable poles was redistributed to desirable poles and advanced regeneration.

Improving diameter-limits. Diameter-limit cutting is by far the most common partial cutting practice in eastern hardwoods. Buyer and seller transact sales with this practice because short-term profits are greatest with diameter-limit cutting, not considering impacts on stand value that often are delayed for decades (McCay and Lamson 1980; Smith and Miller 1987). If diameter-limit cutting is used, there are several ways to improve on the more traditional 14-inch stump diameter or 12-inch d.b.h. cut used in most Appalachian hardwoods in the past. Raise the minimum cut diameter to at least 16 inches d.b.h. (higher if possible) to allow trees to reach the minimum size required for grade 1 butt logs (Smith et al. 1979). For an 18-inch d.b.h. sugar maple, grades 1, 2, and 3 correspond to a value ratio of 7:4:1, meaning a tree with butt log grade 1 is 7 times more valuable than one with a grade 3 butt log. Thus, it is beneficial to raise minimum cut diameters so that merchantable products have the highest potential value.

Diameter-limits also can be improved by managing poletimber, as discussed above for selection, and merchantable sawtimber below the minimum cut d.b.h. When comparing a 17.0-inch diameter-limit practice (where no management below the cutting limit was done) to a single-tree selection practice (where all merchantable trees are managed) the impact on residual stand quality is remarkable. Over a 30-year period, selection stands showed a steady increase in the percent of residual stand volume in grade 1 trees (Fig. 5). Selection stands also showed a decreasing amount of volume in trees below sawlog grade. By contrast, diameter-limit stands did not show trends of improving quality and exhibited quality fluctuations very similar to unmanaged stands over time. Trimble et al. (1974) suggested a modification of diameter-limit cutting using financial maturity guidelines for individual species by site index. This practice also includes residual basal area guidelines to ensure sustained yield and an improvement cut below minimum-cut d.b.h. limits to promote higher quality stands in the future.

Table 6.—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: Total[a]	Periodic harvest values: Compounded[b]	1983 value: Stand stumpage[c]	1983 value: 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	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.

Economic selection goals. Residual stand goals used to practice single-tree selection can affect financial performance. Leaving too much basal area can limit growth of individual trees and reduce their earning power. Growing trees beyond their financial maturity diameters can reduce returns because space occupied by larger trees is not available for smaller trees that are capable of increasing in value at a much faster rate. The q-value used to distribute trees among size classes also is important because it affects recruitment into larger diameter classes and overall financial performance of the stand. Selecting the most efficient combination of RBA, LDT, and q-value is the key to maximizing returns.

Returns from single-tree selection usually are maximized using a largest-diameter residual tree (LDT) of 20 to 22 inches d.b.h. (Martin 1982; Miller 1991). However, landowners often desire larger residual trees to satisfy esthetics or wildlife objectives. For various LDT goals, the q-value for residual stand structure should be adjusted to take full advantage of the available growing space and earning power of the stand (Miller 1991). For example, if LDT is 26 inches d.b.h., RBA should be approximately 80 ft^2 per acre (5.0 inches d.b.h. and larger), and the q-value should be 1.3 to maximize present value of the stand (Table 7). For other LDT goals, similar adjustments in q-value and RBA are required to maximize financial performance. Landowner objectives usually determine LDT, and then other residual stand goals for selection (RBA and q-value) can be derived using information in Table 7 to maximize present value of the managed stand.

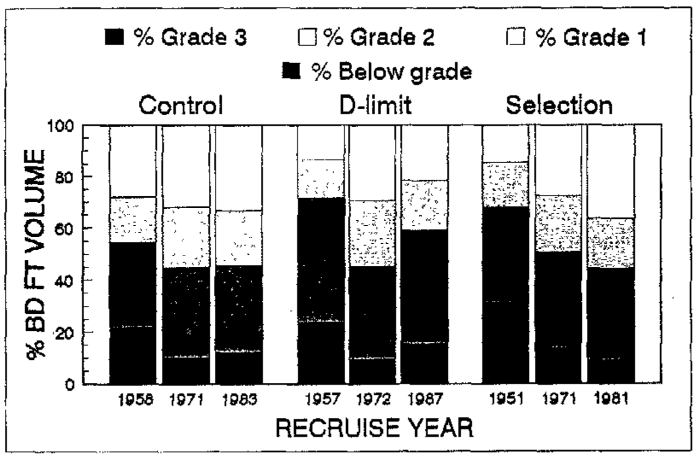

Figure 5.—Percent of board-foot volume per acre in trees of various butt-log grades.

Table 7.—Maximum NPV and optimal RBA for combinations of q-value and LDT on a 10-year cutting cycle

LDT		q-value 1.2	1.3	1.4	1.5	1.6
-- in --		ft²/acre, $/acre				
20	BA[a]	75	67	60	55	50
	NPV[b]	404	362	325	294	269
22	BA	80	72	64	57	52
	NPV	388	361	323	292	268
24	BA	81	77	67	59	54
	NPV	349	354	321	291	267
26	BA	83	80	69	61	55
	NPV	271	308	295	276	258

[a]BA includes all residual trees 5.0 inches d.b.h. and larger.
[b]NPV based on 4 percent real discount rate.

Summary

Uneven-aged stand management is feasible where a desirable shade-tolerant species can be regenerated at each periodic cut. Does it pay? Studies have shown that selection practices earn competitive rates of return (Miller and Smith 1991; Smith and Miller 1987). How does it compare to even-aged stand management practices? In general, uneven-aged stand management is considered because landowner objectives call for a partial cutting practice that leaves a more-or-less continuous cover of overstory trees. Thus, uneven-aged silvicultural practices often are chosen because they are the only feasible means of satisfying objectives, not because they might be financially superior to another practice.

Once the decision has been made to apply uneven-aged silvicultural practices in a particular stand, the forest manager then tries to set stand goals and plan periodic cuts to maximize potential financial performance. Managing poletimber, reducing logging damage, and evaluating a range of stand structure goals are a few of the more important ways to improve partial cutting practices. The information provided here focuses on quantifying the financial impact of various management options so that managers can develop efficient and practical cutting strategies that meet a range of objectives.

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Uneven-aged silvicultural practices can be used to regenerate and manage many eastern hardwood stands. Single-tree selection methods are feasible in stands where a desirable shade-tolerant commercial species can be regenerated following periodic harvests. A variety of partial cutting practices, including single-tree selection and diameter-limit cutting have been used for 30 years or more to manage central Appalachian hardwoods on the Fernow Experimental Forest near Parsons, West Virginia. Results from these research areas are presented to help forest managers evaluate financial aspects of partial cutting practices. Observed volume growth, product yields, changes in species composition, and changes in residual stand quality are used to evaluate potential financial returns. Also, practical economic considerations for applying partial cutting methods are discussed.

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