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PRACTICING UNEVEN-AGE MANAGEMENT: DOES IT PAY? SOME ECONOMIC CONSIDERATIONS

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Abstract

Unevenage silvicultural practices can be used to regenerate and manage many eastern hardwood stands. Single-tree cutting methods are feasible in stands where a desirable shade tolerant commercial species can be regenerated following periodic harvests. A variety of partial harvest 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.

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 aesthetic effects of clearcutting. Critics suggest that applying single-tree selection, or related management practices which involve periodic partial stand harvest operations, might provide a suitable compromise -- continued utilization of timber resources without complete removal of the overstory trees. It is important to remember, however, that partial cutting methods, depending on the way they are applied, influence key economic factors -- stand growth, volume yields, tree quality, species composition, and returns on residual stand value. This paper provides information on each of these factors derived from central Appalachian hardwood stands managed using single-tree selection or diameter-limit cutting over a 30 to 40 year period.

In many cases, the decision to practice uneven-age silviculture in a particular stand is based on non-market management objectives such as esthetics or wildlife. Objectives call for 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 which may be helpful in understanding the impacts of periodic cuts on financial returns. Economic considerations such as logging damage, management of nonmerchantable trees, and improving diameter-limit cutting are discussed.

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 are located on site index 60 to 80 for northern red oak. 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. As a result, the study stands contained three age classes when management began.

Merchantable stand data were obtained from 100 percent cruises taken every 5 years and before each periodic cut. Small reproduction consisted of woody species from 1.0 foot tall to 0.99 inches d.b.h., tallied on randomly located 1/1000-acre plots. Sapling reproduction consisted of woody species 1.0 to 4.9 inches d.b.h., tallied on 1/100-acre plots. Sawtimber quality was measured 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 referred to as selection practices. While all of these practices are a form of partial cutting which in some cases may lead to establishment of regeneration, they are not genuine single-tree selection. In selection practices, the objective is to maintain a given number of residual trees per acre throughout a range of sawtimber and occasionally poletimber diameter classes. In other practices, the harvested material is usually 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 -- more than enough to meet residual stand goals (Figure 1). Financial returns are affected by periodic cuts, so it is important that the forest manager define residual stand goals that are economical and in harmony with landowner objectives.

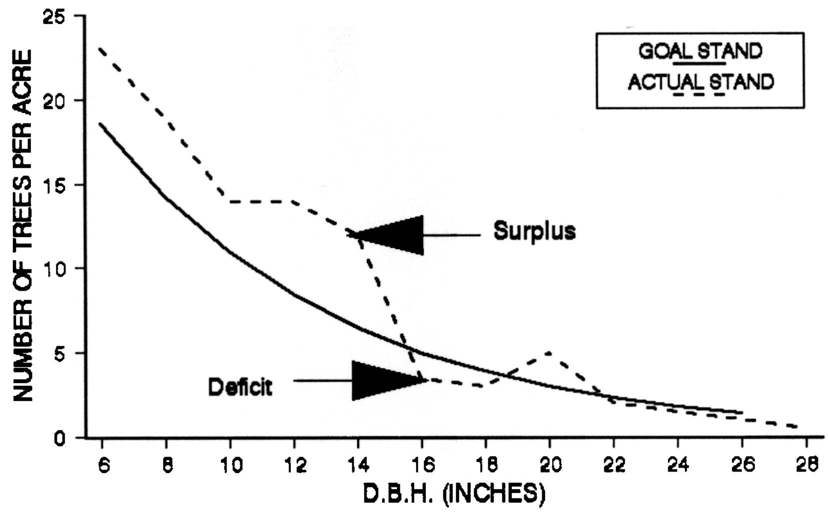

Figure 1. Example of residual stand structure goal compared to actual stand structure from cruise data.

Periodic Product Yields and Income

From a practical financial point of view, uneven-aged stand management practices are simply 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 (Int. 1/4-inch rule) can be estimated by northern red oak site index as follows.

SI 60	200 BF/ACRE
SI 70	300 BF/ACRE
SI 80	400 BF/ACRE

This means that on site index 70, selection cuts could feasibly remove about 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 hartvests 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 are usually acceptable. So, in most managed stands, the minimum cutting cycle is 10-15 years depending on site index. Longer cutting cycles may be used if needed, particularly on large forests where manpower is 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 near Parsons, West Virginia. Selection stands on site index 70 have been cut 4 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 example 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 volume has been increasing since management began in 1955.

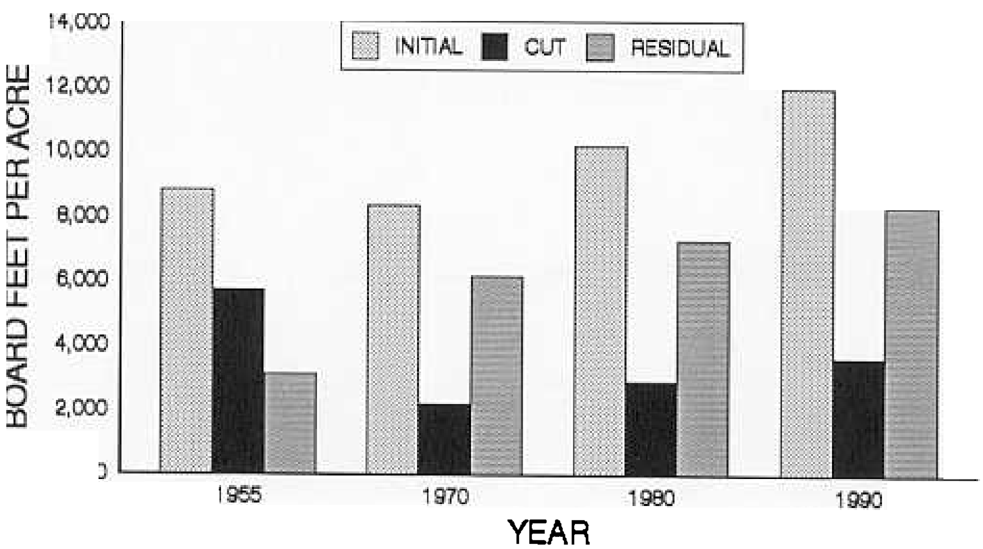

Figure 2. Volume per acre for four selection harvests in Appalachian hardwoods.

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 which averaged 16.7 inches d.b.h. Over 50 percent of the cut volume and value was from red oak and other medium shade tolerant species (Table 1). Only 7 percent of the stumpage revenue cut was from shade tolerant species such as red maple and sugar maple. Stumpage income was nearly $500 per acre. However, it is unreasonable to assume this stand will provide this level of income for all cutting cycles in the future.

Table 1. Species composition and per acre volume and value of fourth (1990) selection cut (SI 70).

Species		Board feet per acre	Dollars per acre
Black cherry		750	186
Other intolerants		150	2
	Subtotal	900(24%)	188(38%)
Red oak		1,200	235
Intermediates		775	39
	Subtotal	1975(54%)	274(55%)
Sugar maple		480	27
Red maple		270	9
Other tolerants		75	1
	Subtotal	825(22%)	37(7%)
Total		3,700	499

As future cuts remove valuable intolerant and medium 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 Tolerant Regeneration

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 will eventually dominate future stands. Light conditions created by removing a few trees here and there 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. Tolerant species such as sugar maple and red maple, however, survive and 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 or 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 which 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 may be needed before species composition of the harvest is mostly 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 (1.0 foot tall to 0.99 inches d.b.h.) was predominantly tolerant sugar maple, but some intolerant black cherry and medium-tolerant species were present (Figure 3, upper graph). Note that an adequate number of seedlings needed for sustained yield were established following each periodic cut.

Intolerant and medium-tolerant species did not, however, develop into sapling size-classes (1.0 to 4.9 inches d.b.h.). 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 (Figure 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 surveys 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 will be predominantly tolerant sugar maple on this site.

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

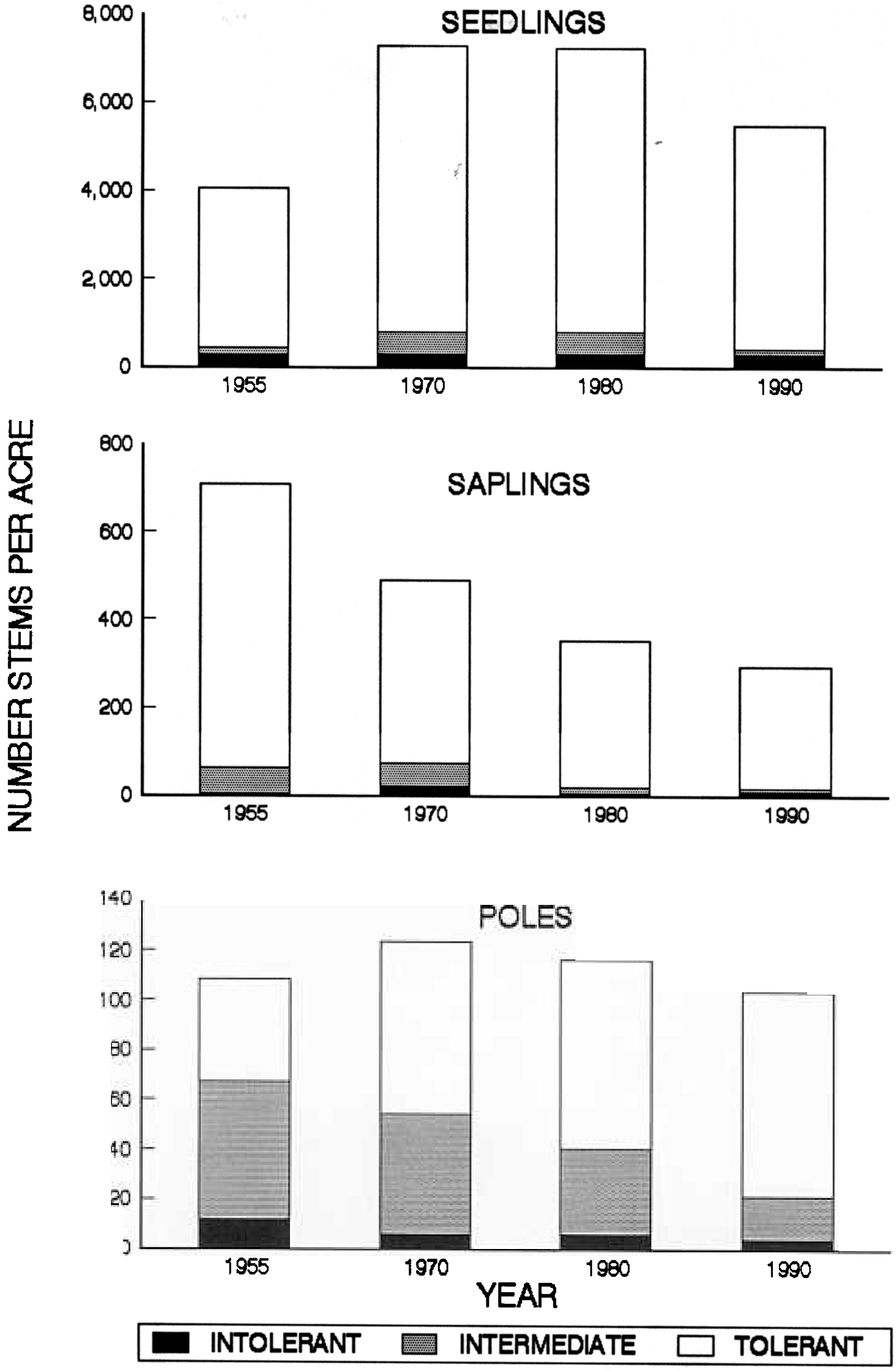

Figure 3. Species composition in an Appalachian hardwood selection stand.

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 are primarily 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. Volume and average tree value for 24-inch d.b.h. Appalachian hardwood sawtimber.

Species	Volume/Tree	Value/Tree
	board feet	dollars
Yellow-poplar	662	45
Black cherry	573	211
Red oak	527	145
Sugar maple	541	50
Red maple	538	40

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 about 25 percent of trees qualify for grade 1 butt logs. Thus, practicing single-tree selection brings about changes in species composition, which in turn affects potential product quality and periodic income from partial harvests.

Once species composition changes are complete, periodic income will be derived from sales of mostly sugar maple stumpage on good sites (site index 70) and mostly red maple on fair sites (site index 60). As a result, periodic income will be drastically reduced compared to the mix of species harvested in the initial cuts as the stand is being converted to unevenaged management. Recall that the most recent harvest generated nearly $500 per acre. In the future, periodic income 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 which can not develop under shady conditions of single-tree selection.

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

D.b.h.	No. trees	Grade	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
	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
	80	24	26	48	2
Total	301				

Economic Considerations

When a desirable, commercial tolerant species can be regenerated at each periodic harvest, 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 satsify sustained yield objectives. After four cutting cycles, residual stand structure is about the same as when management began in the mid 1950's (Figure 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.

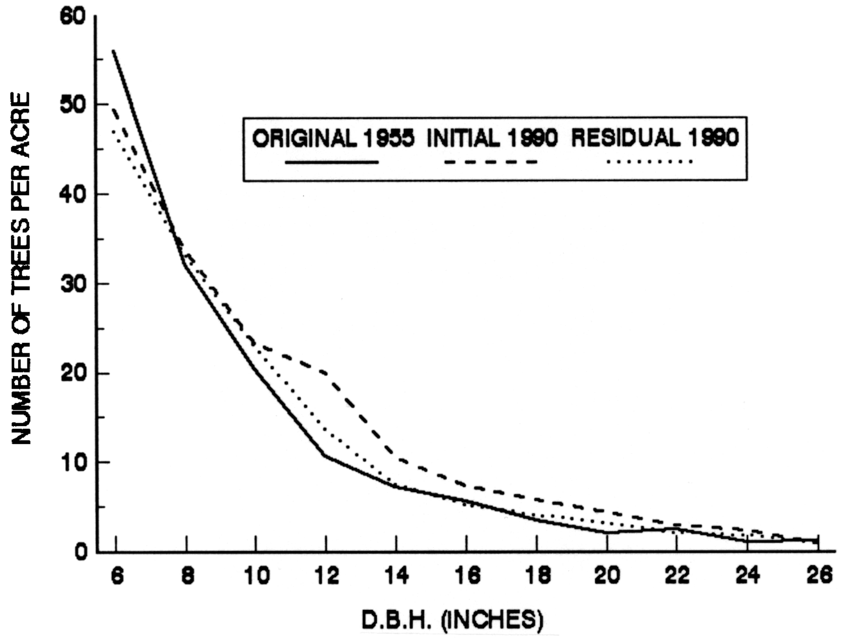

Figure 4. Stand structure in Appalachian hardwood stand before and after four selection cuts.

Competitive returns. On the Fernow Experimental Forest, partial harvest 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 is also a form of savings the landowner can withdraw later if needed.

Logging damage. Foresters are usually 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 vegitation. Skinned stems on residual poletimber and small sawtimber trees is also a concern because there is the potential for lost 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 is usually 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 or wounds above stump height can be removed in future cuts before any loss in grade due to rot occurs. Smaller wounds tend to heal before grade reductions occur.

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

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+
	----number of trees-				----------ft ^{2}--				--bf--
Initial	427	137	59	623	14.4	43.8	73.9	132.1	10,344
Marked trees	0	6	19	25	0	2.3	24.4	26.7	3,306
Residual[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[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

aResidual stand = initial stand minus marked trees.

bNet residual stand = residual stand minus destroyed trees minus bent or leaning trees.

To reduce logging damage, logging equipment should be confined to skid roads as much as possible. Fender trees along skid roads help to ensure 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 should certainly be avoided in partial harvest cuts. Good loggers who have demonstrated the ability to conduct responsible partial harvest 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. Try to contract with a good logger.

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 simply 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 poles and sawtimber was worth 33 percent more than a similar stand managed for only sawtimber 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 advance 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 terms are greatest with diameter-limit cutting, not considering impacts on stand value which are often 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 1,2,3 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 can also 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 (Figure 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		1983 Value	
		Total[a]	Compounded[b]	Stand Stumpage[c]	Total[d] Treatment
	----------------------dollars/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	,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 there financial maturity diameters can reduce returns because space occupied by larger trees is not available for smaller trees capable of increasing in value at a much faster rate. The q-value used to distribute trees among size classes is also 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 are usually maximized using a largest diameter residual tree (LDT) of 20 to 22 inches d.b.h. (Martin 1982; Miller 1990). 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 1990). For example, if LDT is 26 inches d.b.h., RBA should be about 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.

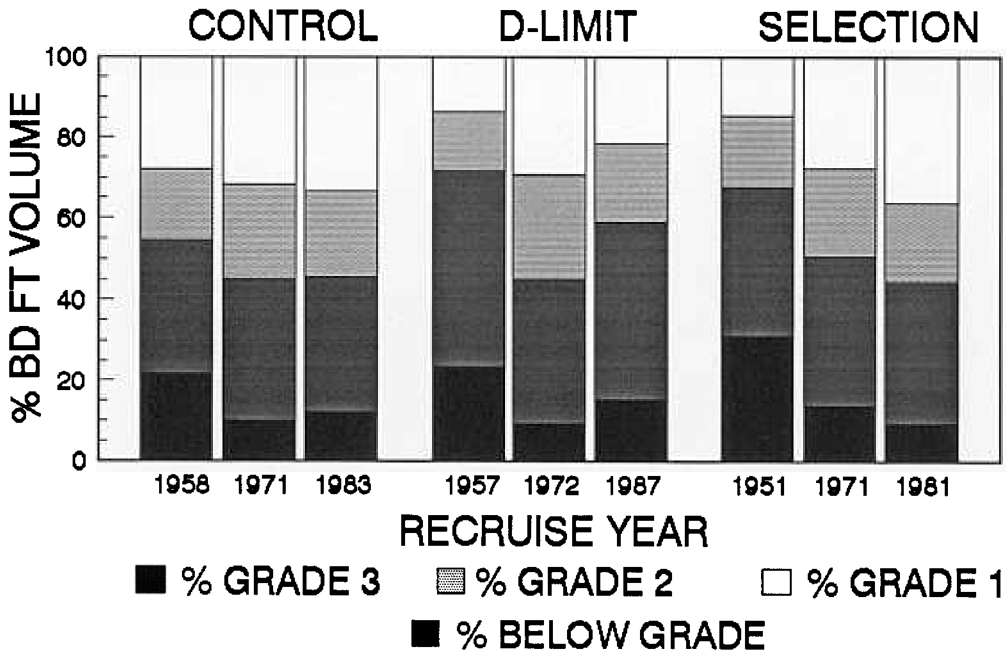

Figure 5. Percent of volume per acre in trees of various butt-log grades.

Summary

Uneven-aged stand management is feasible where a desirable 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-age stand management is considered because landowner objectives call for a partial cutting practice which leaves a more or less continuous cover of overstory trees. Thus, uneven-age silvicultural practices are often 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 practice uneven-age management 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.

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

		q-value				
LDT		.2	1.3	1.4	1.5	1.6
inches		----- ft²/acre, $/acre ---				
20	BA[a]	75	67	60	55	50
		404	362	325	294	269
22	BA	80	72	64	57	52
		388	361	323	292	268
24	BA	81	77	67	59	54
		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.

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