Careful thinning can preserve amenities and increase yield

L.G. Brace and D.J. Stewart

Eastern white pine is both commercially and aesthetically valuable. In a test area, the hardwood overstory was removed and shelterwood silviculture initiated by a careful wheeled-skidder operation which preserved amenity values. Results indicated that an efficient operator would still make a profit on such an operation, and that the forest owner would realize a net return because of future sawlog gains.

In 1971, a 300-acre commercial timber-harvesting operation was carried out at the Petawawa Forest Experiment Station, near Chalk River, Ont., with Consolidated Bathurst Ltd. as the prime contractor. The entire operation was done using wheeled skidders. Its main aim was to increase the growth and yield of white pine (*Pinus strobus* L.) for sawlogs over the next 20 to 30 years by releasing suppressed pine from the hardwood overstory. Harvesting entailed removal of large volumes of pulpwood suitable for kraft pulping, as well as some sawlog material (Table 1). In general, improvement cutting was

TABLE I. Description of stands cut (pre-treatment estimates).

			Total volume		% of cut			$\bar{x}$	$\bar{x}$	
Stand no.	Ac.	Total age[1]	Pre-cut (cunits/ac)	cut (cunits/ac)	Hdwd pulp	Swd pulp	Sawlog	Skidding dist. (ft)	Vol. per tree (cu ft)	% Stand cut
				Two-storied[2] (uniform shelterwood)						
101	47.4	60 — 85	36.7	20.2	64.2	13.0	22.8	600	12	55
102	24.2	60 — 80	31.9	21.8	44.3	20.8	34.9	400	11	68
129	8.4	50 — 75	30.5	14.3	69.8	11.3	18.9	800	7	47
201	26.9	50 — 80	30.1	22.2	85.8	8.9	5.3	600	11	74
202	34.0	50 — 83	22.0	15.0	85.9	4.3	9.8	750	5	68
205	25.0	60 — 85	29.4	17.7	80.0	8.8	11.2	550	8	60
208	7.8	60 — 85	22.4	16.4	64.9	25.6	9.5	700	6	73
209	13.2	55 — 90	34.1	21.2	82.6	14.2	3.3	750	8	62
301	9.4	55 — 80	26.9	16.2	67.5	11.6	20.9	600	5	60
Total	196.3									
Avg.	21.8	55 — 80	30.2	18.9	72.1	11.8	16.1	600	9	63
				Single-storied (uniform shelterwood)						
128	33.0	80	35.6	18.2	29.3	22.0	48.7	600	25	51
204	21.4	70	30.5	14.6	39.5	30.1	30.4	650	14	48
302	19.4	75	28.3	15.6	17.0	34.2	48.8	600	14	55
Total	73.8									
Avg.	24.6	80	32.2	16.5	29.0	27.6	43.4	600	19	51
				Single-storied (strip shelterwood)						
123	21.0	75	31.2	10.4	17.3	45.3	37.4	1000	8	33
207	6.9	80	36.0	12.0	22.6	23.7	53.7	700	8	33
346	14.7	75	36.3	12.1	12.0	45.8	42.2	600	7	33
Total	42.6									
Avg.	14.2	80	33.7	11.2	16.3	42.0	41.7	800	8	33

[1]First of two figures is age (in years) of understory softwood, second figure is age of overstory hardwood.
[2]Characterized by white pine and varying amounts of red pine and white spruce occurring on an understory aged 30 to 70 yr., 16 to 60 ft. tall, 4 to 12 in. d.b.h. and 25 to 50% live crown.

applied as a means of implementing shelterwood silviculture in the future. The operation was conducted as a research project in applied silviculture, according to a rigorous experimental design which will allow statistical testing of treatment effects.

Eastern white pine is a commercial timber species for which there is continuing demand, but shrinking supply and decreasing quality. An increase in the supply of quality sawlogs in the near future would be desirable. Yet more than simply providing additional wood is involved: the commercial range of white pine stands lies within the area of increasing urban influence (Gould, 1966), with consequent increasing demand for amenity uses such as camping, hunting, fishing and sightseeing; and white pine itself is an important component of the landscape from an aesthetic point of view. Under such circumstances, planned multiple use becomes something more than a popular phrase.

In order to successfully combine present and future timber production and amenity uses on a given forest property, the silvicultural and logging systems employed must be compatible, and tailored to management objectives. This report will cover:

1. The effects of improvement cutting on white pine sawlog yield.
2. The impact of logging damage caused by wheeled skidders during closely-supervised logging.
3. Logging efficiency and profitability under restrictions imposed upon the operator by the requirements of preshelterwood improvement cutting.
4. Costs and returns to the forest owner.
5. Impact on amenity values.

The forest owner's point of view presented most closely resembles that of a provincial government department managing Crown forest land.

STANDS AND TREATMENTS

Stands

In central and eastern Canada there are extensive areas of mixed stands of softwoods and intolerant hardwoods aged 50 to 80 years in which white pine is a major component. In the Upper Ottawa Valley commonly associated species include red pine (*Pinus resinosa* Ait.), white spruce (*Picea glauca* (Moench) Voss), aspen (*Populus grandidentata* Michx. and *Populus tremuloides* Michx.) and white birch (*Betula papyrifera* Marsh). Hardwoods, especially aspen, are of generally low quality by age 50 and becoming decadent by age 80, whereas white pine retains its potential for rapid growth beyond age 50 provided suppression has not been severe (Horton and Bedell, 1960).

Two-storied and single-storied stands are intermingled in the pine mixedwood forest, and should be managed as a unit. Of the two types, two-storied stands with a well-developed pole-sized white pine understory beneath a birch and aspen overstory appear to offer the best prospects for release treatments to increase the supply of quality sawlogs in a short time (Buckman and Lundgren, 1962; Brace, 1968). Table 1 shows the size and nature of stands treated in the current study.

Soils were mainly dumped tills, ranging in moisture from dry to fresh (Hills, 1959), and slopes ranged from 0 to 24%.

Silvicultural System

Shelterwood silviculture was considered the system which would best serve the long-term objectives of wood production and amenity use, for the following reasons:

1. Shelterwood is known to be suitable for the regeneration and growth of quality white pine (Scott, 1958; Horton and Bedell, 1960).
2. Shelterwood is particularly effective in controlling the white pine weevil (*Pissodes strobi* Peck).
3. Uniform shelterwood is considered second only to the selection system in terms of site protection and aesthetics (Smith, 1962). On a rating scale of effects of silvicultural system on water, wildlife forage and aesthetics, shelterwood is preferable to seed tree and clearcutting (Shearer, 1971).
4. Application of uniform shelterwood requires a market for hardwood and softwood pulp, particularly hardwood pulp.

These attributes were considered sufficient to offset the real, or theoretical, disadvantage owing to:

1. Risk of excessive damage to residual trees by mechanized logging.
2. Increased costs of planning, supervision, roads, and reduced logging production in comparison to clearcut and seed tree systems (Shearer, 1971; Wiksten, 1966; Horton and Bedell, 1960). Rather, these extra costs *must be considered in terms of the benefits of shelterwood for growth and regeneration of quality pine, and compatibility with demands for amenity.*

Accordingly, the cutting treatment applied was *the first step* towards establishing a form of extensive shelterwood silviculture on the area (Smith, 1962).

Nature of the Cut

The cut, shown in Table I, can be described as timber stand improvement and was applied as follows:

1. Two-thirds of the area consisted of two-storied stands which offered good opportunities for accelerated sawlog production. These were converted to pure pine stands, suitable for subsequent management by uniform shelterwood, by removing overstory hardwoods for pulp, and diseased and low-quality pine for pulp and small sawlogs, thereby affording full over-head release to the understory pine.
2. Hardwood pulp and softwood pulp and sawlogs were cut from the single-storied mixedwood stands, providing residual pine with increased growing space and initiating uniform shelterwood management.
3. The strip-shelterwood system (cutting alternate chain-wide strips) was established in pure pine stands which were too dense or insufficiently windfirm to be marked and cut by uniform shelterwood.

Logging System

The tree-length wheeled-skidder system was used in this operation. The wheeled-skidder has proved itself as a logging machine in areas with varied topography, soil conditions, stand composition, tree size and quality (McCraw and Hallett, 1970). Skidders or similar machines can be expected to remain useful in the future because full mechanization is unlikely to be

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practicable under such diverse conditions (Zasada, 1969; Weetman, 1966; Silversides, 1972).

Tree-length logging is more economical than log-length because of reduced skidding time per turn, larger load sizes and reduced bucking costs. It also provides increased control of roundwood product manufacture and quality by concentrating bucking at a central landing, a distinct advantage in mixed forests characterizing the area under study. The main disadvantages of tree-length logging with wheeled skidders are the risk of killing or damaging residual trees, and necessarily large landings which are aesthetically undesirable.

Planning the Operation

Following an operational cruise, stands to be logged were delineated. Roads were located to avoid unnecessary disturbance of streams and lakeshores and areas of special interest for educational, historical, and aesthetic reasons, such as remnant old-growth stands and evidence of pioneering activities. Road building specifications required pre-felling and removing wood from rights-of-way before bulldozing, and extra gravelling to improve road appearance and provide all-weather access for recreational and other users.

A detailed logging plan was prepared for the area. A variety of feasible skid trail and landing layouts was considered for each stand, and skidder production for each layout was computed using the equations of McCraw and Hallett (1970). The most efficient layout for each stand was thereby determined for a wheeled-skidder operation. The plan took into account layout requirements for two-storied stands which dictated parallel skid trails at about 150-foot intervals. A map of logging layout for each stand was then produced, and necessary roads built.

Landing specifications were included in the logging plans for each stand. Landings averaged 100 by 250 ft. Specifications required pre-felling and removing wood before bulldozing. Landings were located in three different ways to demonstrate opportunities to control their visual impact on recreational users while maintaining operational efficiency. In some cases they were located with the long axis along the road, giving maximum visual impact, in others they were "tipped" into the stands with the short axis on the road, and in others they were hidden entirely to eliminate visual impact.

FIELD PROCEDURES

Job Organization

The prime contractor employed two jobbers to do the cutting. The jobbers employed a total of seven 3-man crews, organized in the conventional manner for tree-length skidder operations with three men per skidder — one felling, one operating the machine, and the third on the landing. Skidders were all in the 75 to 100 hp range. The truck haul for the job varied from 60 to 80 miles one way.

Crew Supervision and Training

A logging inspector-supervisor was employed full time on the job. The two-storied stands were prepared for cutting first, with the following special requirements:

1. Layout and cutting of skid trails was decided in consultation with the supervisor, before cutting commenced.
2. Cutting proceeded from the back of the stand toward the landing, providing progressive openings for directional felling and maintaining the borders of main skid trails uncut for as long as possible, thereby providing protection of desired growing stock against skidding damage.
3. Skidders were confined to specified skid trails.
4. All possible precautions were taken to avoid killing or damaging white and red pine residual trees 3 in. d.b.h. and larger.

After skid trails were prepared, on-the-job training in prescribed felling and skidding techniques was carried out, requiring an average of three supervisor-days per crew for initial training and follow-up.

The supervisor kept daily records of man and machine-hours and machine maintenance and repair costs. He also supervised product manufacture on the landing, and scaled and compiled the sawlog cut by stand and landing. As pulpwood was scaled at the mill, it was necessary to supervise trucking closely in order to keep records of the origin of each load by stand and landing.

This operation required about twice the amount of supervision normally provided on conventional logging operations.

Logging Damage Appraisal

A system of 67 0.3-acre plots was located randomly throughout the area to assess the kind and amount of logging damage attributable to felling and skidding operations. These were measured concurrently with the operation, and gave the supervisor guidelines for crew performance.

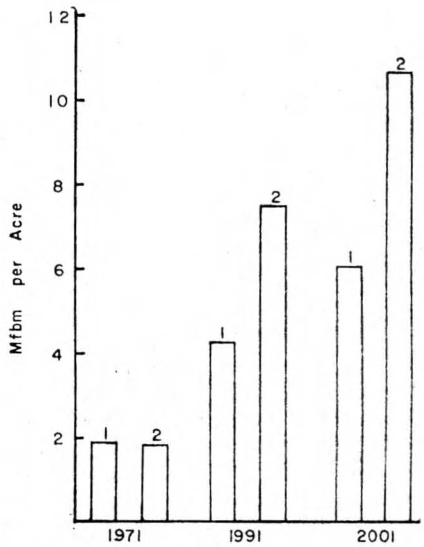

Fig. 1. Effects of treatment on sawlog yield — two-storied mixedwoods.

RESULTS AND DISCUSSION

Silviculture

Sawlog Yield in Two-Storied Mixedwoods: Figure 1 illustrates expected gains in sawlog yield over 20 and 30 years, following conversion of two-storied mixedwoods to pure pine stands. Indicated yield gains are approximately 3200 fbm per acre in 20 years, and 4600 fbm per acre in 30 years, illustrating the potential of such stands to grow if released after age 50.

Growth predictions were made using stand table projection (Husch, 1963). Growth data were obtained from Smithers, 1954; Berry, 1959; Buckman and Lundgren, 1962; and Brace, 1968, and from a 3-year pilot study near the Petawawa Forest Experiment Station.

A growth study has been established on the area to follow actual developments in treated stands and adjacent untreated control stands.

Single-storied stands, which occupied about one-third of the study area, are not expected to provide sawlog yield gains. However, individual tree growth was accelerated, quality was improved by

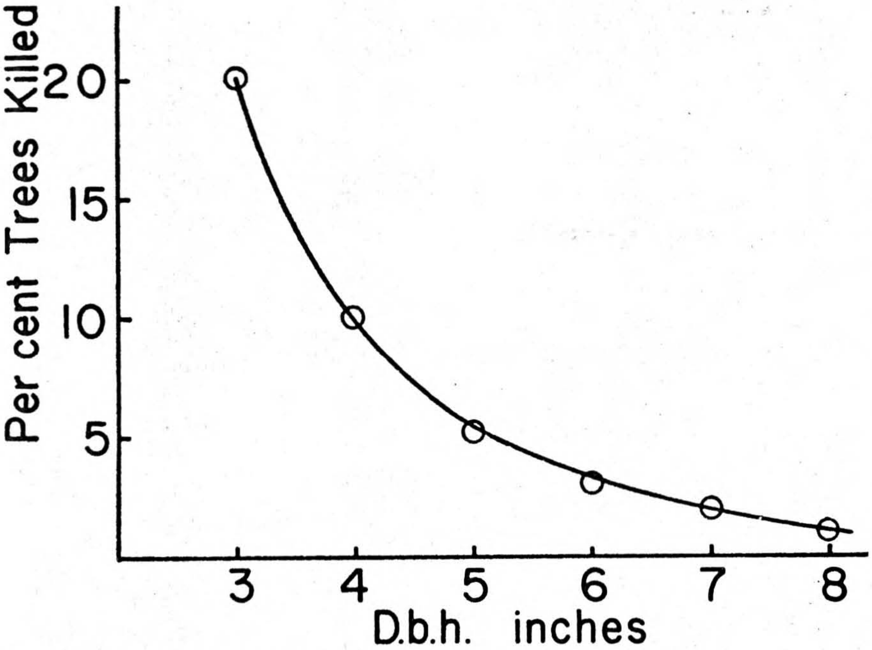

Fig. 2. Residual softwoods killed by felling and skidding.

cutting, and the stands prepared for regeneration.

Logging Damage: The nature and implications of stand damage caused by the various logging operations, to be reported in detail elsewhere, are dealt with briefly here. Figure 2 shows the percentage of residual pine killed by felling and skidding tree-lengths during the logging operation. Felling accounted for two-thirds of the fatalities. Mortality in small sizes is of little concern for sawlog yield in the present rotation, but is of concern for continued application of the tree-length wheeled skidder logging system in future removal cuts after regeneration has become established as advance growth. If dense regeneration is obtained (in the order of 5000 or more saplings per acre at the time of the first removal cut), it should be possible to employ the tree-length system during removal cuttings under the uniform shelterwood system — providing planning, layout, training and supervision are adequate. Winter logging for first removal has been recommended to help reduce damage (Horton and Bedell, 1960).

Figure 3 summarizes logging damage in general, for two-storied mixedwoods cut as previously specified. About 60% of all non-fatal damage was caused by skidding, and the majority of such damage was the removal of bark from the lower 3 feet of tree stems. About 7% of non-fatal damage will affect butt log quality in the current rotation, but the total effect on sawlog quality is expected to be less than 5% and will be offset by in-

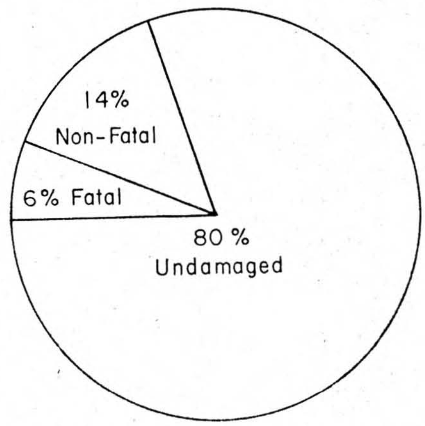

Fig. 3 Logging damage — number soft-wood residual trees 3 in. +

creased sawlog quality resulting from cutting of low-grade and diseased trees.

It is estimated that logging damage was reduced by at least 50% by employing the methods and procedures described above.

Operations

Table II shows costs, returns and logging profit for individual and combined jobbers. Jobbers operated on an hourly wage basis.

Production and profit: Jobber I was about 33% less productive in terms of cunits per skidder hour than Jobber 2, as shown in the "actual" column of Table II. The difference reflects mainly the lack of experience and lower efficiency of Jobber 1, and the somewhat better logging chance of Jobber 2.

Average actual profit was 5.1 and 16.3% for Jobbers 1 and 2 respectively. Average profit was over 1% greater in two-storied than in single-storied stands, primarily because of the heavier cut in two-storied stands (Table I).

Data for both jobbers were combined in order to obtain production and profit results applicable to the range of stand conditions encountered, as jobbers did not operate in a comparable range of conditions. Total costs and profits were affected by these differences. For a low efficiency estimate, the wage rates of Jobber 2 were set at those of Jobber 1, and the skidder production rate of Jobber 2 was reduced by 30%, the observed production difference between jobbers on *equal* logging chances. The reverse procedure was used for a high-efficiency estimate.

The average skidder production of the actual operation was 1.7 cunits/hr and average profit was 10.5%. A highly efficient operation over the entire area would have resulted in a production rate of 2.0 cunits/hr and a profit of

TABLE II. Logging costs and returns to operator at three levels of efficiency[1].

	Jobber 1			Jobber 2			Jobbers 1 and 2		
	Actual	High eff.	Low eff.	Actual	High eff.	Low eff.	Actual	High eff.	Low eff.
Total wood prodn. (cunits)	2540	2540	2540	2334	2334	2334	4874	4874	4874
Skidder prodn. (cunits/hr)	1.4	1.8	1.4	2.1	2.1	1.5	1.7	2.0	1.4
Total cost/cunit, $	24.83	22.60	24.83	22.08	22.08	23.30	23.51	22.35	24.09
Gross returns/cunit, $	26.16	26.16	26.16	26.38	26.38	26.38	26.27	26.27	26.27
Net return/cunit, $	1.33	3.56	1.33	4.29	4.29	3.08	2.75	3.91	2.17
Profit %[2]	5.1	13.6	5.1	16.3	16.3	11.6	10.5	14.9	8.3

[1]a) Costs include all labor and machine costs for landing construction, felling, skidding, bucking, piling, loading and hauling, office overhead and camp costs. All equipment rental at going industrial rates. Office overhead was 25% of wages, and camp costs $0.50 per cunit.
b) Returns are based on the value of scaled volume by product, delivered to the prime contractor.
c) Pay rates were $2.25 per hr. for jobber 1, and $2.75 per hr. for Jobber 2.
[2]Profit is net return as a % of gross return.

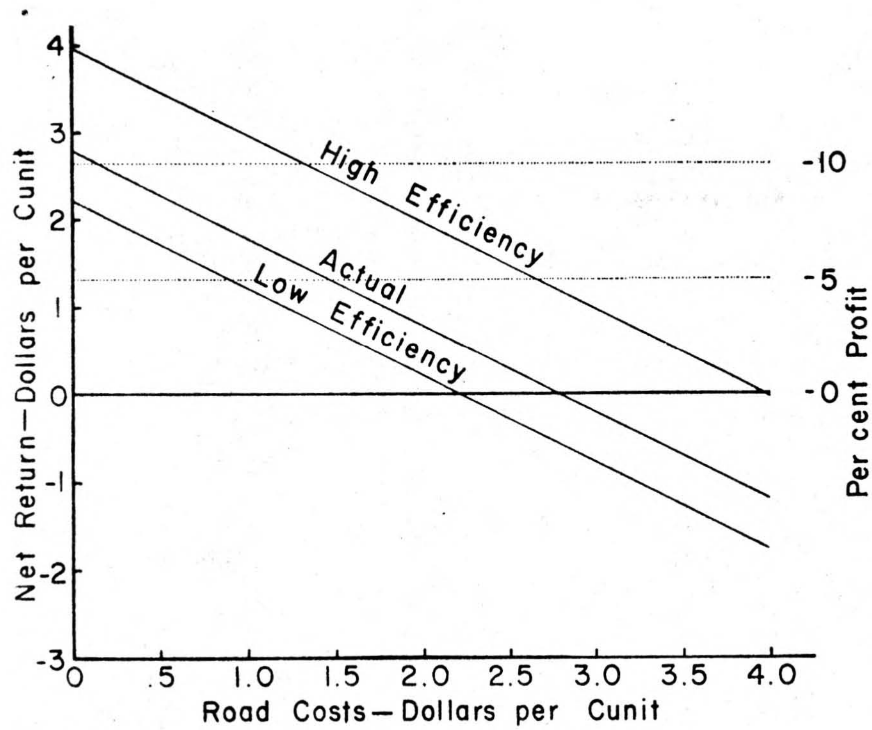

Fig. 4. **Effect of road costs** on returns to the logging operator.

14.9%, and a low efficiency operation would have resulted in a production rate of 1.4 cunits/hr. and a profit of 8.3%.

Production Estimates for Planning: Skidder production estimates made for the logging plan using the equations of McCraw and Hallett (1970) proved to be 27% high for Jobber 1, 12% high for Jobber 2 and 20% high for the entire job. Such equations are useful for preparing logging plans where relative operability of different stands must be evaluated, and experience in their use could be expected to reduce errors of estimation. They are particularly useful in planning for logging in stands for which actual production experience is lacking.

Production Penalty: It is possible to compare average production for highly efficient crews on this operation with rates for piece-work crews not working under the restrictions of shelterwood, to determine the "production penalty" attached to combining wheeled-skidder logging with improvement cutting. The average production of a highly efficient crew in these operations was 2 cunits/hr. Average production in partial cutting without restrictions on logging damage could be expected — based on local experience, data from companies operating in similar stands and calculations using equations of McCraw and Hallett, 1970 — to average 2.5 cunits. Thus the production penalty is probably in the order of 0.5 cunits per hour or 20%, raising skidder production costs from $6.98 to $8.72 per cunit. This penalty reflects extra time taken in felling, choking and skidding to reduce damage to residual trees, and the small average volume of trees removed (Table I). The costs of prefelling and removing wood from landings before bulldozing, which was considered as part of the production process, were offset by returns from wood salvaged on landings, so had no appreciable effect on production costs.

Road Costs: Although road costs in the research area were not assessed against the operator, it is possible, using Fig. 4, to demonstrate their effect on profit in such an operation. Net returns and profit for the operation as carried out are shown where the "actual" return line intersects the Y-axis. Considering the location and character of the logging chance, road construction and maintenance costs for logging purposes alone would be about $2.00 per cunit. In that case, if the operator were building the road, an inefficient operator could expect to make less than 1% profit; about 3% would be earned by a mixture of efficient and inefficient opera-

TABLE III. Costs and returns to owner.

Stand	Ac.	Cost[1] $/ac.	Gross return[2] $/ac.	Net return[3] $/ac.	Net return[4] $/ac.	Net return[5] $/ac.	Cut cunits/ac.	Cost $/cunit	Gross return $/cunit
			Two-storied — converted to uniform shelterwood						
101	47.4	48.32	52.29	3.97			18.03	2.68	2.90
102	24.2	49.18	78.54	29.36			19.44	2.53	4.04
129	8.4	34.94	34.05	— .89			12.80	2.73	2.66
201	26.9	50.65	24.07	—26.58			20.93	2.42	1.15
202	34.0	33.82	22.81	—11.01			13.42	2.52	1.70
205	25.0	45.07	29.00	—16.07			15.76	2.86	1.84
208	7.8	46.81	25.61	—21.20			14.72	3.18	1.74
209	13.2	53.96	21.62	—32.24			18.80	2.87	1.15
301	9.4	46.88	40.19	— 6.69			14.56	3.22	2.76
Total	196.3								
Wtd Mean		45.50	39.11	— 6.39	27.81	27.86	17.04	2.68	2.28
			Single-storied- converted to uniform shelterwood						
128	33.0	42.53	91.79	49.26			16.42	2.59	5.59
204	21.4	43.86	49.01	5.15			13.21	3.32	3.71
302	19.4	43.05	75.42	32.37			14.07	3.06	5.36
Total	73.8								
Wtd Mean		43.05	75.08	32.03	32.03	32.03	14.87	2.92	4.98
			Single-storied — converted to strip shelterwood						
123	21.0	27.90	40.79	12.89			9.27	3.01	4.40
207	6.9	35.17	62.22	27.05			10.82	3.25	5.75
316	14.7	35.18	53.05	17.87			10.96	3.21	4.84
Total	42.6								
Wtd Mean		31.59	48.49	16.90	16.90	16.90	10.10	3.12	4.77
Grand Mean		43.03	48.88	5.85	27.32	27.35	15.58	2.80	3.26

[1]Cost items are planning, cut layout, marking, crew training, supervision and scaling.
[2]Return from stumpage.
[3]No allowance for sawlog yield gain resulting from treatment in two-storied stands.
[4]Discounting 20-year yield gain of 3240 fbm/ac. at 5%, assuming sawlog value in 1991 of $28.00/M fbm.
[5]Same for 30-year yield gain of 4626 fbm/ac, using sawlog value of $32.00/M fbm.

tors such as those actually employed, and an efficient operator could make about 8% profit. The job would therefore be feasible for an efficient operator but marginal for others.

The actual costs of multi-purpose roads built on the project area were in excess of $4.00 per cunit, more than double conventional logging road costs. These costs reflect additional expenditures in planning, location, pre-felling, and wood removal, gravelling and post-cut cleanup, and if charged against the logging job alone, make it uneconomical (Fig. 4).

Forest Owner

Costs and Returns: Table III shows costs and returns per acre to the forest owner both with, and without, considerations of sawlog yield gains resulting from pine release in two-storied mixedwoods. Costs reflect all actual costs of planning, stand layout, marking, training, supervision and scaling on the job, at current pay rates for forest technicians. Gross returns reflect stumpage only. Cost of planning ($0.97 cunit) and crew training and supervision ($0.92) on this operation are approximately double the costs of these activities on a mechanical partial cutting operation where no restrictions are imposed on logging damage.

With no consideration for returns resulting from future gains in sawlog yield from two-storied stands converted by release cutting, net returns ranged from a gain of $29.36 to a loss of $32.34 per acre, averaging a loss of $6.39 per acre for all two-storied stands combined. A treatment cost of $6.39 per acre is comparable to the cost of release by aerial application of herbicides, a possible alternative where access or market conditions preclude cutting treatments.

When the effects of the cutting treatment on returns from future gains in sawlog yield are considered, the average net return for 20 and 30 year periods into the future is calculated to be almost $28.00 per acre (Table III), which compares favorably to returns of about $32.00 from uniform shelterwood cutting in single-storied stands, and $17.00 for strip shelterwood in single-storied stands where no major sawlog yield increase is expected as a result of cutting.

Amenity Uses

Table IV shows an estimate of the extra costs incurred specifically to achieve the silviculture objective and to accommodate amenity uses. These extra costs, in this project, were assigned to the forest owner and the logging operator. In the estimate, it is assumed that the forest owner absorbs all road costs, and that costs of road building to satisfy amenity uses would be double conventional logging road costs.

The forest owner absorbed all extra costs related *directly* to accommodating amenity uses. The extra landing costs were incurred in post-logging cleanup. The logging operator experienced no extra costs because of pre-felling and wood-removal before bulldozing landings. Thus, reduced visual impact of landings can apparently be achieved at no extra over-all cost. Over 80% of the extra costs incurred directly to initiate shelterwood silviculture were borne by the logging operator in the form of increased skidder production costs. The successful implementation of shelterwood silviculture goes a long way in itself to accommodating amenity uses.

The decision to manage a property for combined timber production and specific amenity uses such as fishing, hunting, camping and sightseeing should be made *before* plans for any single use are drawn up. There is no question that development of a road system and logging plan for an area may adversely affect opportunities for other uses, and that costs incurred during logging, to facilitate other uses, may make logging uneconomic.

The success achieved in combining timber production and amenity uses in this project can be judged by visiting the area, which is readily accessible. The field demonstration is supplemented by an audio-visual presentation.

CONCLUSIONS

Improvement cutting using wheeled skidders was employed as a means of establishing shelterwood silviculture in a pine-mixedwood forest area. The results can be summarized as follows:

1. Sawlog yield gains expected from converted two-storied mixedwood stands are about 3200 and 4600 fbm per acre for 20 and 30 years respectively following treatment, thus achieving a major silvicultural objective. Such silvicultural opportunities deserve consideration in planning mixedwood management.

2. Logging damage resulting from the wheeled-skidder system was limited to 20% of the number of residual trees in the stands by careful planning, training and crew supervision. Damage should have no appreciable impact on the yield and quality of sawlogs in the next 20 to 30 years, and the logging system, as applied, should be compatible with the shelterwood silvicultural system in terms of damage even at later removal-cut stages.

3. Efficient operators can make a profit in stands such as those logged at today's logging costs and market prices.

4. Crews, once trained, can operate with only a 20% reduction in logging production compared to cutting operations with no restriction, on logging damage.

5. Road costs are a main determinant of logging economics. Additional road costs to accommodate uses other than timber production can easily be double those built for logging alone, and should somehow be borne by the users who benefit if timber production is to be economic in such stands.

TABLE IV. Extra costs of implementing shelterwood silviculture and accommodating amenity uses, $/cunits.

	Forest owner		Logging operator	
Extra cost item	Silviculture	Amenity	Silviculture	Amenity
Planning, crew training and supervision	$0.94	—	—	—
Roads	—	2.00	—	—
Landings	—	0.15[1]	—	—
Skidder Production	—	—	1.74	—
Total	0.94	2.15	1.74	—

[1]Only significant landing cost increase was post-cutting cleanup, which is estimated here from incomplete data and is included in overall road cost estimates elsewhere in this report.

6. The forest owner will experience approximately a doubling of planning and training and supervision costs in employing the silvicultural and logging systems as done here, compared to partial cutting operations with no restrictions on logging damage. However, a positive net return is anticipated even for treated two-storied stands because of future sawlog yield gains.

7. Amenity values can be preserved and timber production increased on the same pine mixedwood area, using wheeled skidder logging techniques combined with improvement cutting, if adequate planning, crew training and supervision are employed.

8. Specific estimates of extra costs incurred in initiating shelterwood silviculture and accommodating amenity uses are presented in this report. Extra costs for accommodating amenity uses are mainly associated with road planning construction, and clean-up, and minor costs with clean-up of landings.

9. The project area is readily accessible for yield visits; and serves as a demonstration of treatment results.

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