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Costs of Logging Thinnings and a Clearcutting in Appalachia Using a Truck-Mounted Crane

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Abstract

Four timber cutting treatments—three levels of thinning and a clearcutting —were applied on 60-year-old mountain stands of Allegheny hardwoods. The stands were logged by a three-man crew using chain saws and a truck-mounted crane. Logging operations were studied, and production rates determined for tree-length logs decked at roadside. Work efficiency and productivity of the logging crew were somewhat higher on the thinning operations than on the clearcut.

Labor, equipment, and road construction costs were determined and applied to production rates. Comparison of logging costs among the four cutting treatments showed that the cost of wood decked at roadside was less for thinnings than for clearcutting. Silvicultural and environmental considerations of truck-crane logging are discussed.

Acknowledgment

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Introduction

Eastern hardwood forests abound with wood. However, most of the wood and growth occurs in poletimber and small sawtimber stands, many of which are overstocked. Silviculturists recommend that many of these stands be thinned to improve the quality and size of residual trees and to salvage trees that would die. The increased yield and growth would help meet the Nation's demand for fiber and wood energy, which is projected to more than double by the year 2000.

Because of a lack of markets for small roundwood, thinning of eastern hardwood forests has not been a common management practice. Recent studies (Huyler 1982, Wartluft and Sarles 1982) of two conventional harvesting systems have shown that thinning operations for energy wood in mountain hardwoods are economically marginal. This paper reports logging production rates and costs for thinning and clearcutting operations conducted in the central Appalachians using a somewhat unconventional harvesting system—the truck-mounted crane.

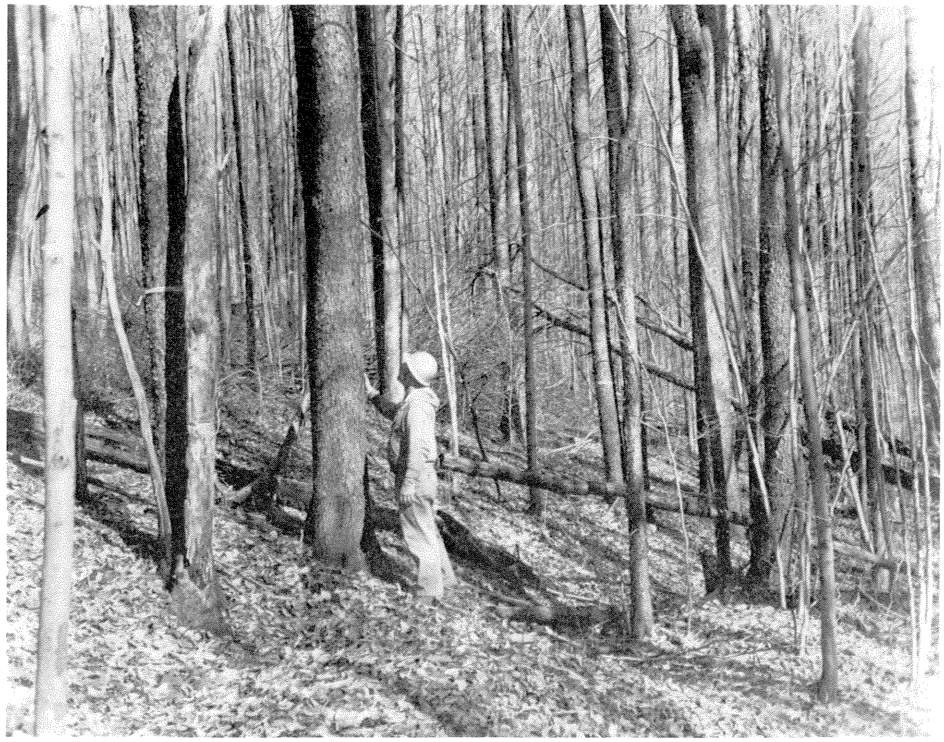

Figure 1.—Overstocked stand of Allegheny hardwoods on Middle Mountain (elevation 3,700 feet) in the Monongahela National Forest, Pocahontas County, West Virginia.

The Study

The harvesting study was conducted on a 60-year-old stand (red oak site index 70) of Allegheny hardwoods located at 3,700 feet on Middle Mountain in the Greenbrier District of the Monongahela National Forest, Pocahontas County, West Virginia. The timber, mainly black cherry and maple, was even aged and overstocked (Fig. 1) with an average of 759 stems (≥ 1 inch) per acre, averaging 6.2 inches dbh (diameter at breast height) (Table 1).

Table 1.—Stand data for thinned and clearcut blocks of Allegheny hardwoods, Pocahontas County, West Virginia, before cutting

Treatment	Block size	Average number of trees/acre ≥ 1.0 inch dbh	Basal area/acre	Mean dbh[a]
	Acres		*ft²*	*Inches*
Thinning				
75-percent-level[b]	4.0	609	168.5	7.1
60-percent-level[b]	4.0	732	166.5	6.5
45-percent-level[b]	4.0	788	158.0	6.1
Clearcut	2.0	908	149.9	5.5
Overall	14.0	759	160.7	6.2

[a]Diameter at breast height of tree of average basal area.
[b]Stocking level of residual stand.

Three blocks of four acres each, laid out side by side on a mid-slope location, were thinned to residual stocking levels of 45, 60, and 75 percent in accordance with Roach's (1977) prescriptions for Allegheny hardwoods. A fourth block of 2 acres, located on a flattened ridgetop, was clearcut. Although the stands of timber on the harvested blocks were fairly comparable and suitable for our harvesting study, there were differences. For example, the number of trees per acre ranged from 609 on the 75-percent block to 908 on the clearcut block. Basal area per acre and size of the average tree, however, were highest on the 75-percent block and lowest on the clearcut (Table 1).

Harvesting was done by a three-man crew of experienced loggers using chain saws for felling and a truck-mounted crane for yarding tree-length logs to cold decks at the woods road (Fig. 2). The crane, mounted on a 20-ton, rubber-tired crane carrier, required a 12-foot-wide, graded truck road on which to operate.

Figure 2.—Truck-mounted crane used to yard tree-length logs from thinned and clearcut blocks. Maximum yarding distance on slopes was 450 feet.

From the thinned blocks, the loggers removed trees (merchantable in local markets) 6.0 inches dbh and larger (Fig. 3). The average dbh of the cut trees ranged from 9.2 to 10.5 inches; the average cubic volume of wood and bark ranged from 13.2 to 17.4 cubic feet per stem. The average number of trees and tonnages cut per acre ranged from 71 trees (24 tons) for the lightest thinning to 117 trees (52 tons) for the heaviest (Table 2).

On the clearcut block, 258 merchantable trees averaging 9.1 inches dbh and 13.4 cubic feet in volume were harvested. Total tonnage of logs removed per acre was 89 tons (Table 2). In addition to cutting the merchantable trees, the feller, in the course of his work, felled and lopped nonmerchantable saplings and poles $\geq$ 1.0 inch dbh.

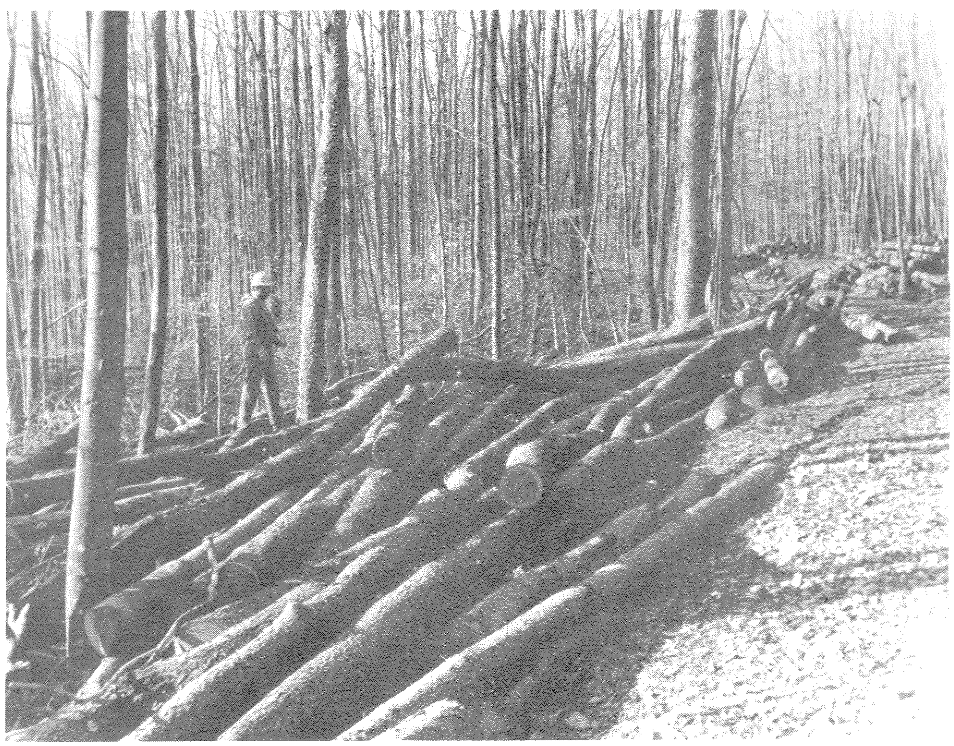

Figure 3.—Typical assortment of tree-length logs removed in thinnings on Middle Mountain.

Table 2.—Harvest data for merchantable trees cut from thinned and clearcut blocks of Allegheny hardwoods, Pocahontas County, West Virginia

Treatment	Average number of trees/acre ≥6.0 in. dbh	Average basal area	Mean dbh[a]	Average merchantable length[b]	Average merchantable volume[c]	Harvest/acre		
		ft²/acre	*Inches*	*Feet*	*ft³*	*ft³*	*Cords*[d]	*Tons*[e]
Thinning								
75-percent-level[f]	71	33.1	9.2	36.0	13.2	937	10.2	24.1
60-percent-level[f]	102	57.0	10.1	37.1	15.7	1,601	17.4	41.2
45-percent-level[f]	117	70.2	10.5	37.9	17.4	2,039	22.2	52.5
Clearcut	258	115.9	9.1	37.9	13.4	3,455	37.6	89.0

[a]Diameter at breast height of tree of average basal area.
[b]Average length to a 4-inch top dob, or to the limit of merchantability.
[c]Volume of tree-length logs, including bark, calculated using top and butt dob's and merchantable length in the formula for frustum of a cone.
[d]92 cubic feet of wood plus bark per cord.
[e]Determined by applying Timson's (1975) weight/volume ratios for Appalachian hardwoods.
[f]Stocking level of residual stand.

Work measurement studies were conducted to determine felling and yarding production rates and worker efficiency. Each discrete work activity in the tree-felling and yarding cycles was timed using snapback stopwatches. Work delays were also timed and causes noted. Tree and log measurements (Fig. 4) were taken and recorded. Merchantable volumes of trees and tree-length logs were calculated using the frustum-of-a-cone formula. Tree and log weights were computed by applying Timson's (1975) weight/volume ratios for Appalachian hardwoods.

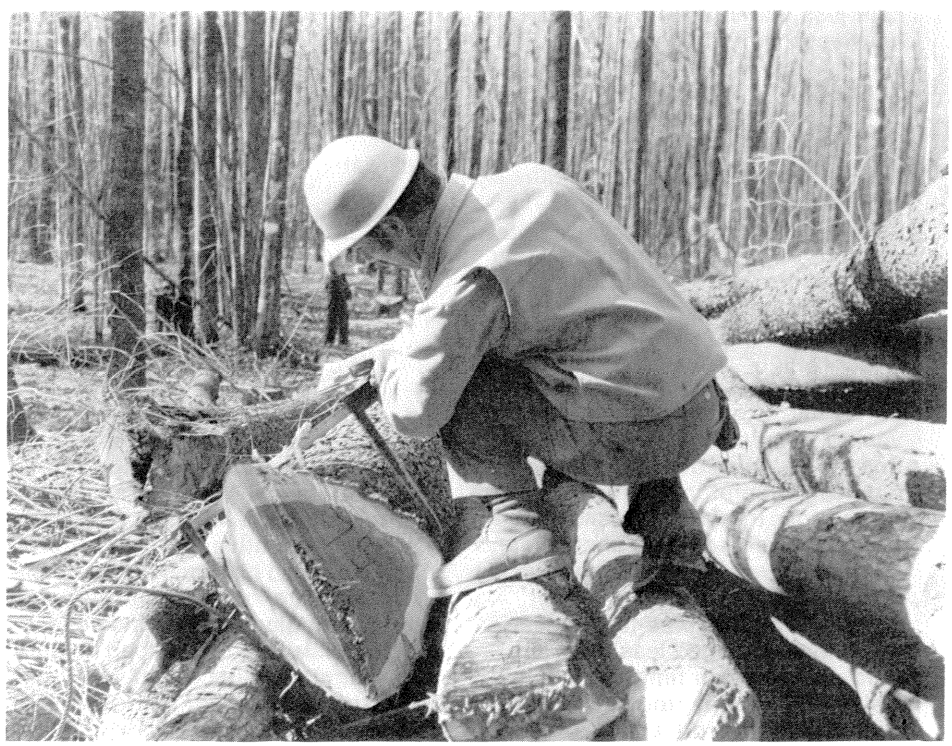

Figure 4.—Measuring tree-length logs at the landing.

Production Rates

Felling

Mean felling production rates (based on productive time) were estimated for each of the four harvests from the tables developed by Sarles and others (in press). These rates were related directly to the average merchantable volume (Table 2) of the cut trees.

To account for nonproductive time, which was caused by various delays, we calculated the worker efficiency factor for each cutting operation. The product of the efficiency factor times production rate per productive hour (PPH) was the production rate per scheduled hour (PSH) (Table 3). The lower efficiency factor for clearcutting was mainly due to nonproductive time used to cut saplings. Even with more than usual assistance from the chokersetter, the feller's daily output was about 24 percent less than his performance in the heaviest thinning.

Yarding

The truck-mounted crane yarded logs using two different techniques and sets of hardware. For distances greater than 100 to 150 feet, logs were yarded using three or four wire-rope chokers. Anywhere from two to four logs per turn were yarded to the log deck at roadside. Logs within 100 to 125 feet or less of the deck were yarded singly using log tongs (Fig. 2). For each setting of the truck crane, part of the logs on the strip being harvested were yarded using chokers, and part were yarded using log tongs. (Of 315 yarding turns that we timed on the four treatment blocks, 48 percent were yarded using chokers, and 52 percent were yarded using tongs.)

Tong yarding was fast—mean turn times averaged less than one-third of mean turn times for chokers (Table 4). This was understandable because yarding distances and load weights were considerably less for tong yarding than for choker yarding.

Table 3.—Hourly and daily mean production rates for felling, limbing, and topping tree-length logs

Treatment	Production rates per productive hour	Efficiency factor	Production rates per scheduled hour	Production rates/day (8 hours)
	Tons	*Percent*	*Tons*	*Tons*
Thinning				
75-percent-level[a]	10.9	63	6.9	55
60-percent-level[a]	11.7	60	7.0	56
45-percent-level[a]	12.8	60	7.7	62
Clearcut	11.2	53	5.9	47

[a]Stocking level of residual stand.

Table 4.—Adjusted mean productive times per turn for truck-crane yarding in thinning and clearcutting operations

Treatment	Mean turn times		
	Chokers[a]	Tongs[b]	Combined[c]
	Minutes		
Thinning			
75-percent-level[d]	4.89	1.44	3.09
60-percent-level[d]	5.09	1.40	3.17
45-percent-level[d]	5.72	1.50	3.53
Clearcut	6.05	1.62	3.74

[a]Adjusted to yarding distance of 225 feet, load weight of 1,962.5 pounds, and 2.5 logs per turn.
[b]Adjusted to yarding distance of 80 feet, load weight of 785 pounds, and 1.0 log per turn.
[c]Adjusted using weighting factor of 0.48 for chokers and 0.52 for tongs.
[d]Stocking of residual stand.

Combining the dissimilar turn times for choker and tong yarding to arrive at an overall production rate representative of the truck-mounted crane presented a challenge. So, we modeled productive time per turn for (1) chokers and (2) tongs as functions of one or more independent variables from a variable pool that included yarding distance, slope, load volume and weight per turn, number of logs per turn, mean weight per log, and a number of other functions and interactions. For choker and tong yarding, an analysis of covariance indicated that individual models were required for each of the four cutting treatments—eight regression models in all. The variables—in various combinations—that gave the best fit for choker yarding models were yarding distance, load weight per turn, number of logs per turn, mean weight per log, and the interaction of yarding distance and mean weight per log. The variables that gave the best fit for tong yarding models were yarding distance and the interaction of yarding distance and load weight per turn.

To compare yarding production rates among the four cutting treatments, mean productive times per turn for choker and tong yarding were adjusted (using the appropriate regression model) to selected values:

	Tongs	*Chokers*
Yarding distance, feet	80	225
Load weight per turn, pounds	785	1,962.5
Number of logs per turn	1.0	2.5
Mean weight per log, pounds	785	785
Proportion of total turn, percent	52	48

Mean production rates in tons PPH were calculated for each cutting treatment using the combined adjusted mean turn time (Table 4) and mean load weight per turn as follows:

$$\text{Production rate in tons PPH} = \frac{60 \text{ minutes}}{\text{combined adjusted mean turn time, minutes}} \times \frac{\text{mean load weight, pounds}}{2{,}000 \text{ pounds}}$$

For example, the mean production rate for the medium thinning was calculated as follows:

$$\begin{aligned}\text{Production rate in tons PPH} &= \frac{60 \text{ minutes}}{3.17 \text{ minutes}} \times \frac{1{,}350.2 \text{ pounds}}{2{,}000 \text{ pounds}} \\ &= 18.93 \text{ turns per hour} \times 0.675 \text{ tons per turn} \\ &= 12.8 \text{ tons per hour}\end{aligned}$$

Mean production rates PPH for each cutting treatment are given in Table 5. (Tables of mean production rates PPH for a range of yarding distances, turn weights, and numbers of logs are available for each operation from the authors.) Efficiency factors for yarding on each cutting treatment are also given. Mean production rates PSH were calculated as the product of production rate PPH times the efficiency factor. Yarding output per 8-hour day is the product of mean production rate PSH times 8 (Table 5).

Table 5.—Hourly and daily mean production rates for yarding tree-length logs

Treatment	Production rates per productive hour	Efficiency factor	Production rates per scheduled hour	Production rates/day (8 hours)
	Tons	*Percent*	*Tons*	*Tons*
Thinning				
75-percent-level[a]	13.1	52	6.8	54
60-percent-level[a]	12.8	50	6.4	51
45-percent-level[a]	11.5	55	6.3	50
Clearcut	10.8	43	4.6	37

[a]Stocking of residual stand.

Investment and Costs

Equipment for the logging system used in this study included two new chain saws, a used truck-mounted crane, and a new pickup truck. The capital invested in these machines totaled $25,646 in 1982 (Table 6). Compared to other combinations of new felling and skidding equipment—some costing as much as $200,000—the investment in this system can be considered very moderate.

The cost to own and operate the machines, plus wages and fringe benefits for the three crew members, was $31.58 an hour (Tables 7 and 8). This system operating cost was converted to cost per ton harvested by dividing $31.58 by the tonnage yarded to the road per scheduled hour (Table 5). For the lightest to the heaviest thinnings, the respective costs per ton were $4.64, $4.93, and $5.01. And for the clearcut, the cost was $6.87 per ton (Table 9).

Road building costs are highly variable depending on the terrain, soil and rock conditions, construction standards, and so on. For this study we estimated road costs using Kochenderfer and Wendel's (1980) data for an operation similar to ours. Based on their tractor time of 57 hours per mile to bulldoze and construct drainage dips and 1982 machine and labor rates ($45 per hour for a D-6), we figured that a newly constructed woods road, 12 feet wide with most grades 10 percent or less, would cost approximately $3,000 per mile. This amount includes an allowance for three 20-foot culverts, but no gravel.

With roads spaced at 350-foot intervals, the truck-mounted crane can log, uphill, approximately 42.4 acres per mile of road. Thus, cost of the woods road at $3,000 per mile converts to $70.75 per acre. Dividing $70.75 by tons harvested per acre on each cutting (Table 2), road costs per ton were $0.79 for the clearcut and $2.94, $1.72, and $1.35, respectively, for the lightest to the heaviest thinnings (Table 9).

Table 6.—Equipment prices and other assumptions used to compute hourly machine costs

Item	Price (1982)	Economic life	Scheduled hours/year	Utilization factor
	Dollars	*Years*	*Number*	*Percent*
Chain saw	646	2	1,800	53 to 63[a]
Chain saw (spare)	646	2	1,800	20
Truck-mounted crane (used)	15,240	5	1,800	43 to 55[a]
Pickup truck (for crew, tools, parts, and fuel)	9,114	3	2,000	25

[a]Varied among the four operations studied.

Table 7.—Hourly machine rates for equipment

Item	Fixed[a]	Variable[b]	Total
	Dollars		
Chain saw	0.195	1.001[c]	1.196
Chain saw (spare)	.195	.339	.534
Truck-mounted crane (used)	2.360	2.840[c]	5.200
Pickup truck	1.740	1.290	3.030
Totals	4.490	5.470	9.960

[a]Fixed cost based on scheduled hours per year includes depreciation, 13-percent cost of capital, insurance, and taxes.
[b]Variable cost based on actual operating hours includes fuel, lubricants, filters, tires, chains and bars, maintenance, and repairs.
[c]Average variable cost for thinnings and clearcutting.

Table 8.—Hourly labor costs

Job	Wage	Fringe benefits[a]	Total
	Dollars		
Crane operator	6.50	2.02	8.52
Feller	5.50	1.70	7.20
Chokersetter	4.50	1.40	5.90
Totals	16.50	5.12	21.62

[a]In West Virginia, estimated at 31 percent for Social Security, Workmen's Compensation, and Unemployment Insurance.

Table 9.—Logging costs per ton for tree-length logs decked at roadside using a truck-mounted crane harvesting system

Treatment	System operating cost	Road cost	Total logging cost
	Dollars per ton		
Thinning			
75-percent-level[a]	4.64	2.94	7.58
60-percent-level[a]	4.93	1.72	6.65
45-percent-level[a]	5.01	1.35	6.36
Clearcut	6.87	.79	7.66

[a]Stocking of residual stand.

After the operating and road costs for the truck-mounted crane system were determined and converted to dollars per ton, the cutting treatments were compared on a cost basis. Total logging cost for tree-length logs decked at roadside was lowest ($6.36 per ton) for the 45-percent-level thinning and highest ($7.66 per ton) for the clearcut. The cost per ton for the 45-percent-level thinning was $0.29 less than the 60-percent-level thinning, $1.22 less than the 75-percent-level thinning, and $1.30 less than the cost of the clearcutting (Table 9).

Discussion

Most loggers and foresters would not expect the cost of logging the clearcutting to be more than the cost of logging the thinnings. Is there an explanation? If so, it must be either in costs or productivity of the harvesting system.

Costs

Two principal costs were involved in logging the four cuttings: hourly operating costs and road construction costs. As has been shown in tables 7 and 8, hourly operating costs for equipment and labor were the same for the truck-mounted crane system regardless of cutting operation.

When comparing the equipment machine rates of this system to other systems that might have been used, the hourly rate ($5.20) for the used truck-mounted crane is an important factor. This reasonable cost for a cable yarder contributed significantly to the low-cost performance of all cutting treatments. By comparison, the hourly rate for a used rubber-tired cable skidder might be 2 or 3 times as much. For example, if a used rubber-tired cable skidder (90-hp class) at $10.56 per hour had been used, operating costs per ton (assuming the same crew size and production rates) would have increased 15 percent, and more roads would have been required.

Productivity

For the purposes of this study, productivity was equated with the amount of wood in tree-length logs yarded and decked at roadside landings per scheduled hour. Two components in this determination were: production rate per productive hour and the efficiency factor. Each component was affected to some degree by characteristics of the sites, the stands, and the cutting treatments. For example, we found that the flatness of the clearcut block had a detrimental effect. It took the chokersetter longer to pull out the cable over flat ground than on the downhill slopes where gravity provided assistance. This showed up as a 35 percent longer out-haul time per 100 feet of yarding distance. Log hookup times were also 35 percent longer on the clearcut block because of the increased amount of slash on the ground from cutting more trees per acre. The slowup in out-haul and hookup times accounted for much of the increase in yarding turn times for clearcutting and, hence, in the lower production rate per productive hour.

The single biggest reason, however, for reduced productivity on the clearcut operation was the reduced efficiency of the crew as reflected in nonproductive delays. Delay time per turn for clearcutting averaged 4.7 minutes—57 percent more than the average delay time of 3.0 minutes per turn for thinnings. The most significant reasons for delays in clearcutting were: work other than yarding (2.07 minutes per turn) and hangups (1.18 minutes per turn). Both of these related directly to the larger number of trees cut per acre and the increased amount of slash and number of stumps that hampered yarding (Fig. 5). Work other than yarding included time lost while the chokersetter assisted the feller with directional felling, hung-up trees, and cutting nonmerchantable saplings and poles. It also included time working on the landing to make room to deck the increased number of logs coming off the clearcut block.

Silvicultural Considerations

To comply with the clearcutting prescription, all saplings (1.0 to 5.5 inches dbh) had to be felled and lopped. This work, classed as a stand regeneration operation, usually is not considered as a part of logging. More and more, though, loggers are removing saplings on clearcuts as part of their harvesting contracts. Many saplings are destroyed by logging and do not have to be felled, and, with intensive utilization practices, larger saplings are often harvested for whole-tree chipping.

Sometimes, however, loggers are compensated for slashing the nonmerchantable material. If so, two methods of payment seem to be practiced: an allowance applied against the cost of stumpage, or a direct payment on an acreage basis. The latter is used more when the operation is conducted after harvest.

Figure 5.—Heavy slash on clearcutting block was one cause of reduced yarding production and efficiency.

Miller (1984) determined costs for reducing sapling basal area in thinned cherry-maple stands. It cost almost $15.00 per acre to remove 20 square feet of basal area. To remove 25 square feet of saplings on a clearcut, the cost would be proportionately more, or about $19.00 per acre. Spread over the total 89 tons harvested from the clearcut, the cost of sapling reduction would be $0.21 per ton. Allowances of $0.40 to $0.80 per ton (depending on stand and terrain conditions) were used in the past by one firm for compensating logging contractors. If we select an allowance midrange of these three figures, $0.50 per ton ($44.50 per acre), logging cost for clearcutting reduces to $7.16 per ton, a cost in line with those for the thinnings.

Logging Damage

Damage to trees in the residual stand is always a concern when logging, especially in thinnings where the residual stems are expected to increase in value for future harvests. Lamson and Miller (1982) determined logging damage of residual dominant and codominant trees in the same cherry-maple stands discussed in this report. Blocks logged with the truck-mounted crane suffered less damage than stands logged with a rubber-tired cable skidder. Only 5 percent or less of the residual dominant and codominant trees on blocks logged with the truck crane were classed as high risk trees for the respective 75, 60, and 45 percent thinning operations. With the rubber-tired skidder, 7, 13, and 22 percent of the number of stems were classed as high risk trees for the respective 75, 60, and 45 percent thinning operations. On steep terrain, the truck-mounted crane reduces residual stand damage because of increased lift of the logs and greater operator control over yarding through use of the 25-foot swing boom.

Environmental Concerns

Visual impacts of logging—road scars on hillsides, damaged trees, and muddy streams—arouse public feelings against timber harvesting. Compared to wheeled-tractor logging, the truck-mounted crane "walks" relatively lightly on the land. Timber stand damage is lessened, and fewer roads and landings are required for truck-crane logging. Disturbance of soil and streams due to roads, landings, and stream crossings is reduced (Kochenderfer 1977).

Soil erosion is minimized since truck-crane logging harvests 2 to 3 times more acreage per mile of constructed road compared to wheeled-tractor logging. Sediment production from a truck-crane logged watershed was similar to yields summarized for undisturbed forest plots and small watersheds in the Eastern United States. Soil disturbance was minimized by taking necessary precautions with road building and critical stream channel areas (Kochenderfer and Wendel 1980).

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Investigates the effects of thinning and clearcutting on the cost of logging using a truck-mounted crane for yarding and chain saws for felling. Work measurement studies of the harvesting operations were conducted on three 4-acre blocks of timber marked for thinning and on a 2-acre clearcut. Worker efficiency and productivity were higher for thinning than for clearcutting. Reasons for the difference are discussed. Comparisons of logging costs among the four cuttings showed that the cost of wood delivered to roadside was less for logs removed from the thinned blocks than from the clearcut. Silvicultural and environmental aspects of truck-crane logging are discussed.

ODC 666

Keywords: Logging costs; thinning; clearcutting; cable yarding; time study; production rates; Allegheny hardwoods

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