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Harvester Productivity for Row Thinning Loblolly Pine Plantations

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SUMMARY

Two tree harvesters currently being used to thin southern pine plantations were evaluated to determine the effects of stand characteristics on machine productivity. Production rates for row thinning loblolly plantations are presented by stand age, site index, and stand density.

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INTRODUCTION

Plantation thinning has been a focus for mechanization efforts in southern timber harvesting over the past decade. This attention has stemmed from anticipated increases in thinning requirements—due to extensive planting under the Soil Bank Program and by forest industry—and unfavorable trends in labor supply and wage rates. Also, relative uniformity of tree size and of spacing in plantations favors mechanical row thinning.

As harvesting systems become more capital-intensive, however, it becomes increasingly important to match machines and timber if harvesting costs are to be kept in line. Costs will soar if expensive equipment is used where its productivity is impaired. Rapidly escalating capital costs can make new machines uneconomical in many types of stands. Therefore, it is important to know the costs of operating alternative mechanized thinning systems and the ways stand characteristics and thinning specifications affect them. Production rates for key machines are necessary to derive these costs. Such rates allow users to apply current dollar values to estimate probable operating costs.

In this study, productivity of two types of tree harvesters currently used for row thinning loblolly pine plantations was evaluated. The objective was to determine the effects of stand characteristics on machine productivity. The results, together with those from a previous study (Anderson and Granskog 1974), provide basic productivity information for the principal types of tree harvesters being used to thin pine plantations in the South.

MACHINES

Tree harvesters may be classified into three general types by the form of their output—shortwood, tree-length, and full-tree. Machines studied for this report were representative of the tree-length and full-tree types. During data collection, shortwood harvesters were not being utilized to row thin loblolly pine plantations.

The tree-length harvester was a Timberjack RW-30,[1] which had been modified to include some of the improvements designed into the newer model TJ-30 (fig. 1). The machine can handle trees with stump diameters not exceeding 14 inches. In a processing cycle, an articulated felling arm severs the tree and lifts it back to a horizontal position on the delimbing assembly. The delimbing head/boom has a 33-foot delimbing stroke,[2] which can be extended 9 to 10 feet by advancing or lowering the felling arm. When delimbing is completed, the tree is topped and deposited in a carrier on the side of the machine. A cord of stems can be accumulated before being dumped on the ground.

The full-tree harvester was a Melroe Bobcat 1075 Feller Buncher (fig. 2). This machine was equipped with a 16-inch capacity shear and an accumulator arm. In operation, two arms hold the tree while it is severed at ground level, and the accumulator arm allows several small trees to be gathered before the stems are deposited on the ground.[3] Severed trees are carried and piled until the desired bunch size is created.

PROCEDURES

Data Collection

Production data were obtained through time studies of machines in ongoing thinning operations in central Alabama and Tennessee. Operating conditions were similar in each case; terrain was flat to slightly rolling, and undergrowth was light to moderate. All data for each machine were taken by the same experienced operator.

[1]Mention of trade names is solely to identify equipment used and does not imply endorsement by the U.S. Department of Agriculture.

[2]The operator on the observed machine shortened the basic delimbing stroke by positioning the delimbing head near the base of the crown of the incoming tree, so needless processing of the clear stem was eliminated.

[3]The accumulator on the observed machine was used only with 5-inch dbh or smaller trees because of the difficulty of maneuvering with multiple stems of larger size.

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Time and output measurements were obtained on plots installed in rows to be cut. Plots were line segments selected to cover a range of tree diameters and spacing intervals. Segment length was limited by the extent of uniformity of the tree diameters and intervals between trees.

Twenty-seven sample plots were harvested by the tree-length machine and 30 by the full-tree harvester. For each plot, the following information was recorded before cutting:

1. Length of segment from the first tree to be cut to the first tree beyond the segment, measured to the nearest tenth of a foot.
2. Dbh of each tree, measured to the nearest tenth of an inch.
3. Total height of each tree, measured to the nearest foot.

During harvesting of the trees on a plot, total time required was measured from the moment the first tree was sheared until the first tree beyond the segment was sheared. Times were recorded to the nearest hundredth of a minute. In addition, log lengths and top diameters were measured after the tree-length harvester had completed processing trees on a plot.

Analysis

Estimating equations were developed from the measurements taken with each harvester. The object was to relate the time required to harvest a specified length of plantation row to the characteristics of the trees cut.

A stepwise regression procedure was used to select the best prediction equation. The dependent variable was time, expressed in minutes per hundred feet of

Figure 1.—*Timberjack RW-30 tree-length harvester.*

plantation row. Other data were also converted to a hundred-foot basis. Independent variables tested for significance were:

1. Number of trees.
2. Average dbh.
3. Average of the dbh squared.
4. Total length of stems cut.
5. Total length of stems cut/average of the dbh squared.
6. Average of the dbh squared/average dbh.

Total tree heights and sum of log lengths were used as two alternative measures of total length of stems cut, depending on the form of output from the harvester.

Resulting equations for the harvesters are shown in table 1, together with measures of goodness of fit. For the tree-length machine, variable 4—total length of merchantable stems—was the single significant variable, indicating the delimbing function explained most of the variation. Other differences, such as tree weight, did not significantly affect this machine within the range of diameters harvested. Number of trees was a single significant variable for the full-tree machine, but this was rejected in favor of variables that included measured tree characteristics. In the absence of variable 1, variables 5 and 6 were found to be significant for the full-tree harvester. Variable 5 was highly correlated with the number of trees, and variable 6 is a measure of dispersion of tree size around the mean. All variables were significant at the one percent level.

Table 1.—*Estimating equations*

Harvester	Equation	R^2	SE
Tree length	$Y = 1.373 + .01135(\Sigma L)$	.89	.62
Full-tree	$Y = -3.622 + .278(\Sigma H - \frac{\Sigma D^2}{N}) + .614(\frac{\Sigma D^2}{\Sigma D})$	.81	.83

Y = Time per 100 feet in minutes.
D = Dbh in inches.
H = Tree height in feet.
L = Log length in feet.
N = Number of trees.

The equations apply to productive time only. Therefore, allowance must be made for downtime, idle time, and turn-around time, depending on the method of operation.

PRODUCTIVITY

To determine how productivity will vary in different plantations, the equations were used with stand structure and yield data to calculate hourly production rates for each machine.

Detailed stand structures for unthinned loblolly pine plantations were obtained from Lenhart and Clutter (1971), which provides diameter, height, and yield in-

Figure 2.—*Melroe Bobcat 1075 feller-buncher.*

formation by stand age, site index, and density. Tables were chosen for plantation ages 15 and 20 years, a range which covers the preferred age for a first commercial thinning. Site indexes of 60 and 70 at 25 years were selected since they represent the preponderance of loblolly pine sites. Densities ranged from 500 to 1,000 trees per acre for each age and site index.

For each density class, intervals between merchantable trees within rows were calculated for plantations spaced 6 and 8 feet between rows. Merchantable trees were limited to those in the 4-inch diameter class and larger, and tree lengths and volumes were computed to a 3-inch top diameter. Stand characteristics for each situation were then used with the estimating equations to obtain the processing times per hundred feet of row.

Processing times for the various stand situations were used to calculate potential hourly output. It was assumed that the harvesters would be working in a 40-acre tract with rows 1,320 feet long, using grapple skidders as supporting equipment. To limit skidding distance, the harvesters would cut half of the row with butts facing one way and half facing the other. They would do this by entering a row from one end, cutting 660 feet, returning to the end of the row, and then entering the next row to be removed. Thus, an allowance for return time, an integral part of the operation, was made in computing hourly output.

Potential output in cords per hour for the tree harvesters in plantations with 6- and 8-foot spacing between rows is shown in figures 3 through 6. For both machines, productivity increases as both stand age and site index rise. These increases reflect volume gains due to larger average stand diameters and a larger number of merchantable trees. Output is also greater in both instances with 8 feet between rows rather than 6 feet. For a given density, this reflects closer within-row spacing, or less travel time, as well as more room to maneuver. For each site index and stand age, tree size declines as stand density increases; therefore, machine productivity also drops, although less so for the tree-length harvester than the full-tree machine.

Different production levels for the harvesters result from the amount of processing done by each machine. Although expressed in cords, output from each harvester is in a different form.

The production rates shown represent hourly output at 100 percent machine utilization. As such, they stress variation as stand conditions change. To obtain realistic production levels for a specified time period, the productivity figures should be adjusted for the probable utilization rate. The appropriate percentage deduction from the hourly rates charted depends upon machine availability records and operating procedures where the machine will be employed.

COSTS

In the absence of stable prices, harvesting cost figures quickly become outdated. However, the production rates presented in physical terms allow users to apply current dollar values to estimate costs for each machine.

Harvester costs per cord can be estimated by calculating an hourly machine cost for current prices and dividing by the hourly output of the machine for a selected plantation situation. For example, suppose the cost of row thinning a 20-year-old plantation with site index 60 and containing 800 trees in rows 8 feet apart is desired for the tree-length harvester. Figure 4 shows the potential hourly output for this stand to be 6.6 cords. Applying a 75 percent utilization factor indicates an hourly production rate of 4.9 cords. Assume an hourly machine cost of $30 has been derived using current prices and wages. Dividing the $30 hourly machine cost by the 4.9 hourly output reveals an estimated $6.12 harvester cost per cord.

Since the output from each harvester is in a different stage of production, costs per cord are not directly comparable. However, the harvesters can be compared by considering them as a part of systems that carry wood to a common delivery point (Granskog 1978).

Evaluating the harvesters on a systems basis takes into account the supporting equipment and labor needed with each type of harvester. Since harvester

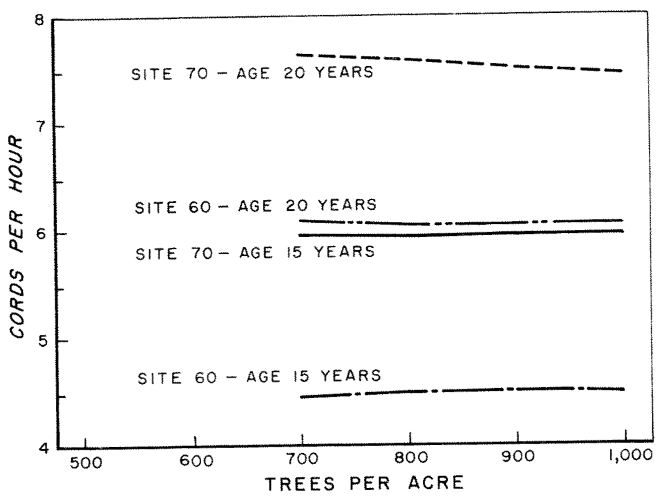

Figure 3.—*Potential hourly output of the tree-length harvester with rows 6 feet apart.*

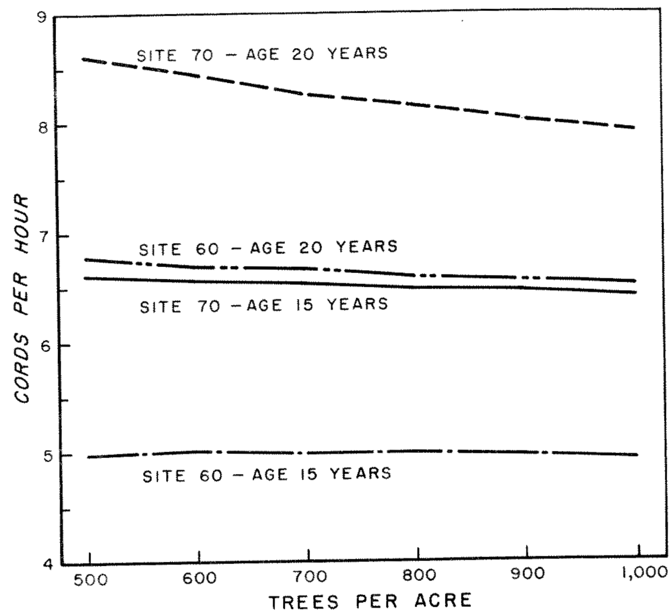

Figure 4.—*Potential hourly output of the tree-length harvester with rows 8 feet apart.*

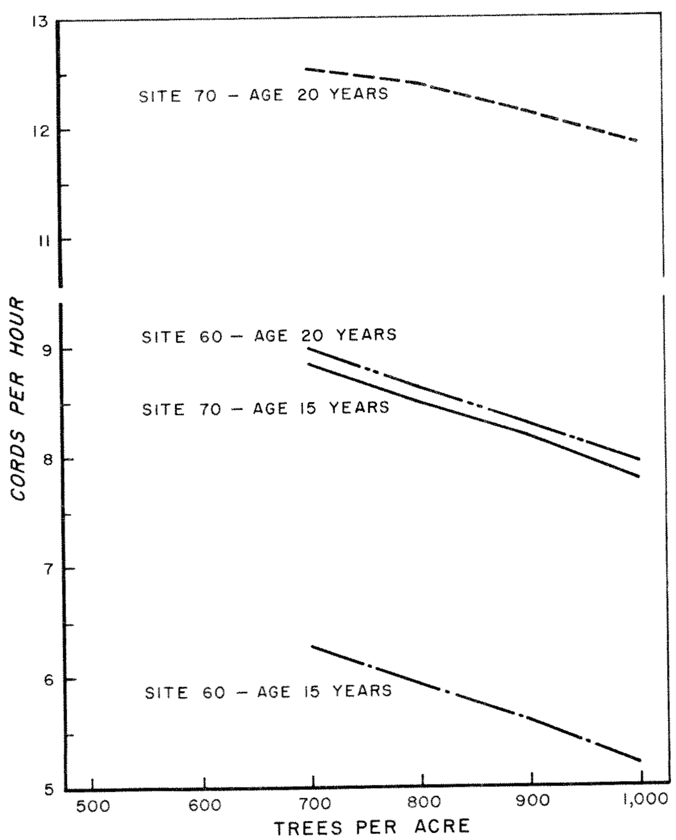

Figure 5.—*Potential hourly output of the full-tree harvester with rows 6 feet apart.*

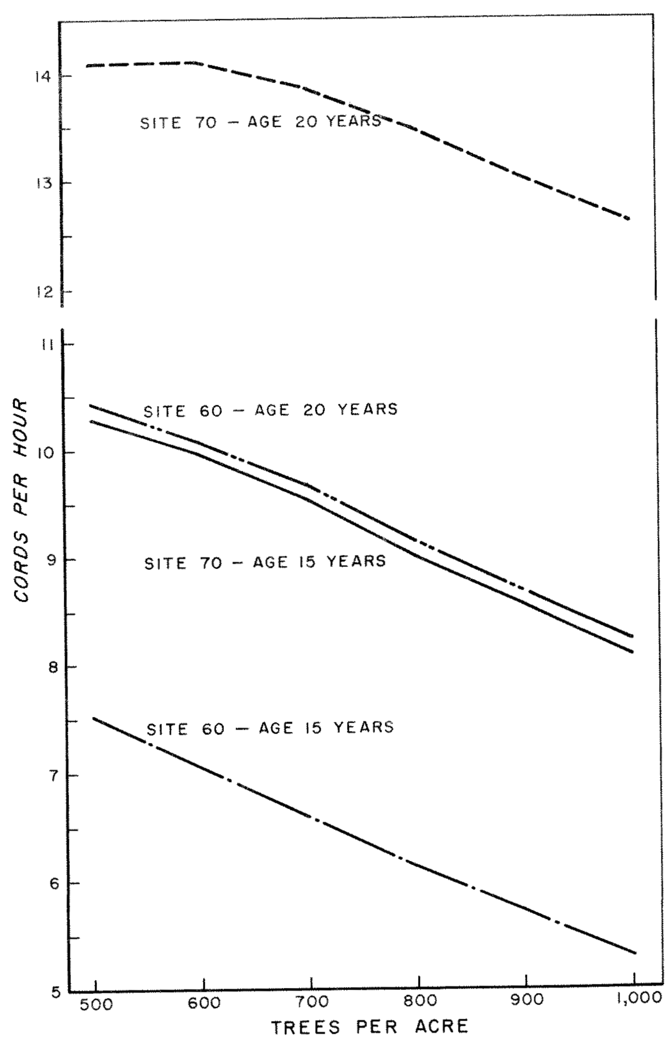

Figure 6.—*Potential hourly output of the full-tree harvester with rows 8 feet apart.*

production will control the output rate for the total system, comparing productivity rates for supporting equipment and labor to harvester output rates will determine the number of units needed. Hourly costs computed for all units can then be combined to obtain hourly system costs. These system costs are divided by hourly system outputs (utilization adjusted harvester production rates) to derive comparable harvesting costs.

DISCUSSION

This study determined production rates for two types of tree harvesters being used to row thin loblolly pine plantations. As noted earlier, a previous study (Anderson and Granskog 1974) provided the same information for three types of harvesters operating in slash pine plantations. Machines representative of two harvester types—tree-length and full-tree—were covered in both reports.

Even between machines of the same type, comparisons of production rates should be made carefully because of different operators and differences in stand characteristics between species for a given site, age, and density. In spite of these limitations, some distinction in production patterns within each type was evident because of variation in machine design.

The design of the tree-length harvester previously observed row thinning slash pine plantations required processing the full length of the tree stem. In contrast, the design of the tree-length machine studied in this report enabled the operator to eliminate needless processing of the clear stem. As a result, there was less decline in production for the latter machine as tree size declined. (In some instances, the operator merely topped trees of small size, omitting delimbing time altogether.) Furthermore, this machine permitted accumulation of a larger bunch size, which can increase production of supporting skidding equipment.

The full-tree machines differed in the accumulating function. Although the machine observed in the present study was equipped with an accumulator arm, it was used on only one plot. Hence, the production rates for the machine essentially represent that of a single-tree feller-buncher. On the other hand, the full-tree machine from the previous study accumulated trees continuously on the side of the machine (from 2 to 7 trees, depending on size) between dumps. A comparison of production rates shows the single-tree machine had lower productivity with trees less than 6 inches dbh, but higher productivity with trees over 7 inches. Thus, while the accumulator was important for maintaining production among smaller trees, its use with larger trees was counterproductive.

The results of this study show the influence of tree and stand characteristics on machine productivity, but other factors will also affect output and cost. Machine operators and machine designs have been mentioned, along with species. Terrain, underbrush, and machine maintenance are also considerations. Such factors may cause machine productivity to vary from the output levels shown herein for a given site, resulting, of course, in cost variation. In addition, other items must be evaluated for their effect upon total cost. For instance, tract size and moving costs are important considerations. The latter costs are especially needed for determining the economic feasibility of the minimum job for a particular machine or system. Ultimately, the planning and administration of the complete harvesting system will determine profit or loss.

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Additional key words: Mechanization, timber harvesting, logging costs.