Harvesting systems and costs for southern pine in the 1980s

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Abstract

Timber harvesting systems and their costs are a major concern for the forest products industries. In this paper, harvest costs per cord are estimated, using computer simulation, for current southern pine harvesting systems. The estimations represent a range of mechanization levels. The sensitivity of systems to factors affecting harvest costs — machine costs, fuel prices, wage rates, tract size, and planted stands — is examined to determine trends in harvest systems and costs.

Highly mechanized full-tree systems are the most cost-efficient and should increase in number in the 1980s. Tree-length systems and labor-intensive systems fall at the next average cost level with partially mechanized systems having the highest average costs. Although increasing real costs for machines and interest, high average costs on small tracts, and depressed markets will inhibit adoption of highly mechanized harvest operations, these types of systems will retain a substantial average harvest cost advantage. Decreasing labor availability and needs for plantation thinning also favor use of mechanized full-tree systems.

If sufficient progress is made toward the adoption of the most efficient systems, logging costs could rise less than the general inflation rate. Real cost increases may occur if depressed economic conditions and high machine costs prevent loggers from adopting highly mechanized systems as such systems must maintain stable, high volumes of output.

In this paper we examine current harvesting systems and factors that will influence costs and system selection for harvesting southern pine timber in the 1980s. First, costs for common harvesting systems operating in natural pine stands are determined by computer simulation. Next, factors likely to influence harvesting systems and costs in the 1980s are evaluated to determine the effect of factor changes on harvest costs for different systems. Results of these analyses form the basis for projecting harvesting trends through the current decade. Equipment, systems, and costs for situations such as thinning and residue logging are also discussed.

Modeled systems

Costs per cord were estimated for 10 current pulpwood harvesting systems representing a range of mechanization levels. This entailed developing model systems, gathering productivity data and 1980 factor costs, and performing a computer simulation of the harvest operation for all systems.

Harvesting operations

Shortwood, longwood, tree-length, full-tree, and whole-tree chip harvesting operations were modeled. Tables 1 and 2 summarize the equipment and manpower required for each system. Table 3 displays the total investment required for each system at 1980 purchase prices.

The Harvest System Simulator (HSS) computer program (11) was used to estimate total system productivity and average costs. Productivity rates for individual harvest functions such as felling, skidding, and loading were used as inputs in the simulations.

Productivity and cost inputs

Productivity rates were gathered from the available literature. They were based on a model southern pine

Forest products firms and forestry planners have a vital interest in timber harvesting systems and costs. Harvest cost estimates not only play a pivotal role in system selection and other evaluations in timber harvesting but are necessary to assess forest management and manufacturing opportunities as well.

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stand with an average diameter at breast height (DBH) of 9.4 inches and a volume of 17.67 cords (1,590 cubic feet) per acre. All harvests were assumed to be clearcut operations occurring on level to gently sloping terrain. A hauling distance of 30 miles to mill yards was assumed.

Machine and labor cost inputs were derived from fixed and operating costs calculated for each piece of equipment and wage rates determined by job classification. Straight-line depreciation and an interest rate of 12 percent were used in the machine rate calculations. Annual owner/operator profit for each system was assumed to include both return on investment and a salary for the entrepreneur. Profit levels were graduated by the size of the investment in the harvest system based
TABLE 4. — Harvest cost per cord, 1980 input prices.

<table>
<thead>
<tr>
<th>System</th>
<th>Cost per cord</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole-tree chip</td>
<td>($39.96)</td>
</tr>
<tr>
<td>Limited-area feller-buncher</td>
<td>37.54</td>
</tr>
<tr>
<td>Highly mechanized full-tree</td>
<td>37.66</td>
</tr>
<tr>
<td>Shortwood prehauled</td>
<td>41.30</td>
</tr>
<tr>
<td>Stump-to-stump bobtail</td>
<td>41.37</td>
</tr>
<tr>
<td>Manual tree-length</td>
<td>41.88</td>
</tr>
<tr>
<td>Highly mechanized shortwood</td>
<td>44.79</td>
</tr>
<tr>
<td>Skidder longwood</td>
<td>45.40</td>
</tr>
<tr>
<td>Semimechanized shortwood</td>
<td>46.92</td>
</tr>
<tr>
<td>Bobtail and farm tractor</td>
<td>49.11</td>
</tr>
</tbody>
</table>

TABLE 5. — Average age of southern pulpwood harvesting equipment.

<table>
<thead>
<tr>
<th>Harvest equipment</th>
<th>Average age (yr.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single axle bobtail trucks</td>
<td>6.1</td>
</tr>
<tr>
<td>Tandem axle bobtail trucks</td>
<td>5.3</td>
</tr>
<tr>
<td>Diesel tractor-trailer trucks</td>
<td>4.2</td>
</tr>
<tr>
<td>Forwarders</td>
<td>3.7</td>
</tr>
<tr>
<td>Cable skidders</td>
<td>4.5</td>
</tr>
<tr>
<td>Grapple skidders</td>
<td>2.7</td>
</tr>
<tr>
<td>Knuckleboom loaders</td>
<td>4.1</td>
</tr>
<tr>
<td>Bigstick loaders</td>
<td>4.7</td>
</tr>
</tbody>
</table>

Source: Weaver, et al. (15).

The sensitivity analyses revealed that the highly mechanized full-tree and whole-tree chip systems always retained their average cost advantage over tree-length and bobtail operations. Even with the combination of higher interest rates, fuel costs, and equipment costs, they still had significantly lower average costs. Higher wages increased the cost advantage of mechanized compared with manual systems as did increases harvest volumes per acre and high or low labor productivity rates. Harvests of low volumes per acre increased costs the most for tree-length operations and the least for bobtail systems but the relative costs among systems remained the same.

System implications

In 1980, mill prices in the South averaged about $38 per cord for pine roundwood and $31.68 per cord for whole-tree pine chips (12). Thus, the estimated average costs for most systems exceeded actual pulpwood prices (costs experienced by ongoing operations) during the year. This reflects that most wood is produced with equipment that has depreciation costs lower than would be the case if a system were made up of all new equipment. Stumpage costs for actual operations may also lag the 1980 average of $11.70 per cord used in the simulations. In addition, revenues for actual operations will be higher than the average pulpwood prices on a cord equivalent basis if sawlogs and veneer logs are sorted and sold.

Because the estimated costs reflect depreciation with current prices, they do indicate levels to which pulpwood prices will have to rise if equipment has to be replaced, assuming no change in other factors. In Table 5 are shown the findings of a recent survey (15) of the average ages for equipment used in southern pulpwood operations.

These data can be used to indicate which systems face imminent replacement decisions and may need price or other adjustments to survive in the next few years. Systems typified by the grapple skidder, which have the newest equipment and the lowest harvest cost, will apparently require only small increases in pulpwood prices to retain their profitability. Bobtail truck systems, on the other hand, are typically the oldest. In this case, however, the relatively old age may indicate that these systems are only competitive with used equipment since new bobtail truck systems are rare.

Harvest costs will vary for conditions different from those simulated. Other stand conditions may be more suitable for specific systems. Loggers working part-time with old equipment may still make profits with less efficient systems. Higher revenues are possible from multiproduct harvests. Also, specific operations may continue to be profitable where mill and stumpage prices differ from the average.

Factor changes

System selections will be influenced by changes in factor inputs — capital and related costs, labor availability and wages, and timber characteristics. Harvest equipment and system adoption in the United States has generally followed an evolutionary, rather
than revolutionary, path. This trend is likely to continue with systems producing wood for the lowest cost tending to dominate harvesting as producers shift to the most cost-efficient systems. Drastically new systems or equipment are unlikely in the short term since equipment development and adoption tends to be slow.

**Machine costs**

Machine costs comprise the largest portion of total costs for the most efficient systems. Although purchase prices for logging equipment have been found to be increasing less than the rate of inflation (13), purchase prices are not the only cost of owning machinery. Interest rates have nearly doubled since the mid-seventies and insurance has increased as well. The overall cost of owning and operating harvest machinery was found to have increased proportionately faster than other prices in a Minnesota study (7) and similar results would probably hold true for the South. High machine owners costs in particular may slow adoption of highly mechanized systems when timber markets are depressed because the large investments require continual production of high volumes of wood to pay for their costs.

Machine and labor cost distributions were computed for woods equipment for each harvest system simulated (Table 6). Using one-half of total costs as a criterion, five of the model systems may be characterized as capital-intensive and five as labor-intensive. The relative effects of capital and labor costs and availability can be judged with these cost breakdowns in mind. Increased capital costs or decreased availability would favor labor-intensive systems and vice versa.

**Energy costs**

Fuel prices have probably risen faster than any other factor cost in recent years. Although fuel and lubrication expenses are still not as large an operating cost for logging as are repair and maintenance, they are increasing in importance. Equipment designers consider energy efficiency a primary concern (1).

One of the sensitivity analyses found that doubling the real cost of fossil fuels would increase average harvest costs more for the primarily manual, chainsaw, tree-length system than for the highly mechanized feller-buncher, full-tree system. This indicates that highly productive mechanized systems can be favored by increases in fuel costs.

Large machines may consume less fuel on a per unit of output basis than smaller capacity machines. Also, manual systems rely heavily on chainsaws which have a high proportion of their operating costs attributable to fossil fuels — much higher than highly mechanized systems.

Systems which minimize fuel use per unit of output will be least affected by energy cost increases. As fuel costs increase, equipment developments such as turbochargers, hydrostatic drives, and larger payloads per turn will become more popular. In addition, the current trend toward larger horsepower equipment may stabilize or taper off somewhat (4).

**Labor trends**

Although labor costs appear to have increased less rapidly than total machine costs in recent years, a reversal of the trend toward more capital-intensive systems does not appear likely. Given the alternatives provided by current social programs and competing employment opportunities in rural labor markets, fewer persons seem willing to perform the manual tasks of felling, limbing, bucking, and piling of roundwood. Decreasing availability of manual laborers tends to favor mechanized systems despite relative cost advantages of labor-intensive systems.

However, if costs of capital and associated items continue to rise faster than labor, there will be increased efforts toward seeking productivity gains with existing equipment. Worker training and ergonomic research can enhance labor productivity and reduce injury rates. Investment in such labor-oriented programs has thus far been neglected and may offer a major opportunity to realize improved productivity and lower future costs with present mechanized harvesting systems.

**Tract size**

As the mechanization level and size of harvesting systems increase, costs of moving from tract to tract will become more important. Move costs based on 1980 prices were derived for the 10 harvest systems modeled using the time required to move (14) and the HSS program. Transportation costs were also calculated for moving equipment from one harvest to the next. The program calculated costs for nonproductive equipment fixed costs, system overhead, and wages. The program accounts not only for transportation and system rate costs but also for decreased average system productivity caused by idle time. Table 7 summarizes the calculated move costs based on a 20-mile move.

Small labor-oriented systems cost less to move. They have lower fixed costs for idle equipment and are also penalized less when operating on small tracts and with small volumes. As a result, the stump boattail and prehuler systems have the lowest harvest costs up to about 20 acres. Large mechanized systems, which have lower average harvest costs, do have the disadvantage of high move costs which raise their average harvest costs on small tracts. This will dampen the tendency to operate large mechanized systems based solely on their minimum average cost advantage unless small tracts can be coordinated to reduce move costs.
TABLE 7. — Estimated costs for a 20-mile move and tract sizes required to reach minimum cost.

<table>
<thead>
<tr>
<th>System</th>
<th>Cost</th>
<th>Tract size required for minimum cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>($)</td>
<td>(acres)</td>
</tr>
<tr>
<td>Stump boattail</td>
<td>49</td>
<td>10</td>
</tr>
<tr>
<td>Boattail and tractor</td>
<td>227</td>
<td>20</td>
</tr>
<tr>
<td>Shortwood preheader</td>
<td>373</td>
<td></td>
</tr>
<tr>
<td>Skidder longwood</td>
<td>548</td>
<td></td>
</tr>
<tr>
<td>Semimechanized shortwood</td>
<td>647</td>
<td></td>
</tr>
<tr>
<td>Manual tree-length</td>
<td>891</td>
<td></td>
</tr>
<tr>
<td>Highly mechanized shortwood</td>
<td>1,038</td>
<td></td>
</tr>
<tr>
<td>Highly mechanized full-tree</td>
<td>1,275</td>
<td></td>
</tr>
<tr>
<td>Limited-area fell-buncher</td>
<td>2,437</td>
<td></td>
</tr>
<tr>
<td>Whole-tree chip</td>
<td>2,414</td>
<td></td>
</tr>
</tbody>
</table>

1Harvest System Simulator (HSS) computer program (11). Stump boattail costs tended to increase slightly as tract size increased. Thus, other factors including access, terrain, and distance to mill can be more important than acres per se in determining an economical logging chance for this system.

Outlook

The harvest system costs and the review of input factor trends provide a foundation for assessing the net effect on system evolution and costs.

Systems

Shortwood.—The contribution of shortwood systems to future pine pulpwood production will be limited. The most economical shortwood systems—the stump-to-stump boattail truck and the shortwood preheader—rely heavily on persons willing to perform hard manual labor at minimum wages, a declining resource at best. Also, average harvest costs increased for more mechanized systems producing shortwood material.

Tree-length or full-tree skidding with manual or mechanized bucking at the landing are significantly more costly than less mechanized shortwood, tree-length, or full-tree systems. They are also more costly on smaller tracts than boattail or preheader operations. These hybrid longwood-shortwood systems may be characterized as short-term adaptations where shortwood is needed for transportation or mill yard purposes. In essence, the systems add a function—bucking or slashing—which generates no financial return.

Still, shortwood operations may survive for certain conditions or situations. The relatively low capital requirements permit easy entrance and exit according to fluctuating economic conditions. Manual shortwood systems also have low moving costs making them suitable for small tracts, particularly if adjustments are made in stumpage prices.

Preheader systems could also be maintained if bolt lengths were increased beyond the customary 5 feet. Part of the popularity of tree-length and full-tree systems is their compatibility with the development of integrated wood processing complexes. A minimum bolt length of 8-1/2 feet (similar to the 100-in. bolt length standard in the Lake States) would permit value maximizing by sorting out the logs suited for veneer or lumber. Also, it would improve the productivity of the preheader system.

Manual tree-length. —The manual tree-length system is comparable in cost with the labor-intensive stump boattail and shortwood preheader systems. However, it eliminates more than one-half the hand labor required in the low-cost shortwood systems, thereby increasing its chances for survival.

Compared with the highly mechanized full-tree systems, the manual tree-length operation has higher average costs, is affected the most by small diameter trees (8), and is a less efficient user of fossil fuels. Nevertheless, it is one of the most popular logging systems in the South and will probably continue to increase in numbers in the future as shortwood systems decline.

Despite the cost advantage of highly mechanized full-tree harvest systems, chainsaw and choker-skidder systems are a less costly step in mechanization and have lower fixed costs to be borne when economic conditions are depressed and mills limit wood purchases. Also, they have lower move costs, are more adaptable to rough or
Highly mechanized full-tree.—These systems have the lowest average harvest costs per cord for roundwood products. The rubber-tired, feller-buncher, grapple skidder system and the tracked, limited-area, feller-buncher system have similar low average harvest costs per cord and are cheaper than manual tree-length systems on average sites. Also, high productivity and proportionately lower fuel use per unit of output favor their adoption in the future.

However, the total investment required and high overhead costs will limit their use on small tracts unless several can be combined to provide a sufficient volume to be harvested for a given area. Forest industry policies will also affect their adoption. Before loggers invest in highly mechanized systems, assured markets are needed for the requisite large volumes produced. Long-term purchase agreements could provide assurances that would lessen uncertainties that develop from quotas imposed during poor markets or mill closures due to strikes. If quotas continue to be widely used, adoption of full-tree systems may occur more slowly than would be expected based on their cost advantage alone.

Whole-tree chip.—Whole-tree chipping was the lowest average cost operation simulated—about $3.50 per cord less than the highly mechanized full-tree systems. However, its cost advantage should not be equated with an advantage in profitability.

The whole-tree simulation assumed that the model stand would be purchased for the same price as a conventional harvest and would receive the 25 percent overrun of the chip system without any added stumpage cost. Sophisticated sellers realize that chipping systems harvest greater volumes and may demand greater purchase prices. Also, dirty whole-tree chips receive a $31.68 per cord price compared to $38 per cord for pine roundwood. These drawbacks indicate that while whole-tree chipping is a low-cost system, it is not as profitable as the highly mechanized roundwood systems due to its less desirable product output.

Whole-tree chipping would be advantageous with small tree sizes since the delimbing bottleneck would be eliminated (8). Labor would also be easier to recruit. However, the high machine-owning costs require continuous production and prevent economical operation on small tracts. The chipper is also a high consumer of energy.

In situations where dirty chips can be mixed with the other mill roundwood or used to make specialized products, whole-tree chipping may be the most efficient harvesting method. If an economical method is developed for cleaning the chips, it may rival the highly mechanized full-tree systems in profitability.

Other harvesting systems.—In addition to the general trends for pine pulpwood harvesting, there will be specialized systems or adaptations for other harvesting situations. Harvests in swampy terrain are likely to use some form of tree-length logging. Tracked feller-bunchers, high-speed tracked skidding machines, and high flotation tires are adaptations for boggy areas. Area with rough terrain and steep slopes are suitable for logging by cable-type skidders or small-scale cable yarer systems.

High-value hardwoods and sawtimber on favorable terrain will probably be harvested by more conventional systems. Large pine and hardwoods exceed feller-buncher capabilities and butt damage is a concern in machine felling. Pine limbs greater than 2 inches and hardwood limbs resist high-speed gate delimbing. Chainsaws provide higher quality felling and deliming. Large tree-length operations will still have a cost advantage compared with smaller operations but small crews will remain in business by logging small tracts and high-value species.

Multiproduct logging will become more prevalent with the trend toward tree-length and full-tree systems. Conventional systems that would be uneconomical for pulpwood alone can be profitable with higher value products. In effect, harvest costs can be allocated among all products, reducing the cost for pulpwood.

Residue logging offers the most opportunity for new system development in the eighties. Conventional high-volume whole-tree chipping operations might be used to economically harvest residue for fuel chips (10). Baling of forest residues for fuel use is also being examined as a new harvest method. Mobile chippers are being developed for residue harvesting or precommercial thinning with varying degrees of success (16). The costs of these systems are tentative but all have potential for development in the eighties.

Costs

System selection in the 1980s will evolve toward the most efficient systems but outlook for the relative level of harvesting costs is more uncertain. Prices for pulpwood have generally increased less than the costs of owning harvest machinery and hiring labor. This forces loggers to become more efficient or drop out of business. With increasing input costs for energy and machine ownership and fairly stable mill prices for roundwood, loggers must continue to become more efficient and adopt advanced technology. Instead of relying on low investment manual systems such as the bobtail truck or prehauler, or even the manual tree-length system, they will shift to the highly efficient feller-buncher, grapple skidder systems whenever possible.

If the forest industry provides an investment climate where such capital-intensive systems can maintain the requisite high output, harvesting costs for final cuts could continue to rise less than the rate of inflation. Highly mechanized full-tree systems offer enough potential for productivity increases over conventional systems to make up for increases in machine-owning costs and fuel costs. For thinnings and small diameter stand harvests, average harvest costs will be higher than those currently experienced for final harvests in the South.

If depressed economic conditions, quota systems, or periodic mill closings do not allow loggers to maintain stable high-volume operations, they will opt for labor-intensive systems and the potential cost savings promised by highly mechanized full-tree harvest systems will not be realized. The lower production and
efficiency of labor-intensive systems, coupled with the rising real prices of energy, are likely to result in rising relative harvest costs.

Optimistically, the forestry sector can look forward to stable or decreasing relative harvesting costs in the 1980s. Forest industries and forest planners must foster an environment which will lead to adoption of currently available efficient technology. Helpful actions may include long-term purchase agreements, support of training programs for loggers, aid in technology transfer, backing for equipment loans, and variable contract rates.

**Literature cited**