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.

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.

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

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TABLE 1. — *Units of equipment characterizing each harvest system.*

System	chainsaw	tree shear on dozer	rubber-tire feller-buncher	limited-area feller-buncher	farm tractor	90 hp choker skidder	110 hp choker skidder	120 hp choker skidder	110 hp grapple skidder	shortwood forwarder	bigstick loader	14,000 lb. knuckleboom	20,000 lb. knuckleboom	gate delimber	hydraulic slasher/loader	22 in. chipper	spare skidder/dozer	4 cord straight truck	5 cord straight truck	truck tractor	pole trailer	bundle-bucker trailer	shortwood trailer	chip van	6 by 6 van forwarder	lowboy	pickup	service/crew truck
	(No. of units)																											
Stump bobtail	2										1							1										
Bobtail and tractor	2				1						1								1								1	
Semimechanized shortwood	2	1					1					1								2			4			1	1	
Highly mechanized shortwood	1		1						1				1	1	1		1			2			4			1	1	1
Shortwood prehauler	3									1										1			2				1	
Skidder longwood	2					1						1								1		2					1	
Manual tree-length	5						1	1					1							2	2	2				1	1	1
Highly mechanized full-tree	1		2						2				1	1			1			3	3	3				1	1	1
Limited-area feller-buncher	1			1					2				1	1			1			3	3	3				1	1	1
Whole-tree chip	1		2						2							1	1			3				6	1	1	1	2

TABLE 2. — *Crew size and distribution characterizing each harvesting system.*

System	Supervisor	Saw hand	Equipment operator	Truck driver	Mechanic	Total
	(No. of workers)					
Stump bobtail	1/3	2	1/3	1/3		3
Bobtail and tractor	1/3	1-1/3	1	1/3		3
Semimechanized shortwood	1/3	2	2-1/3	2	1/3	7
Highly mechanized shortwood	1/2		3	2	1/2	6
Shortwood prehauler	1/3	3	1	2/3		5
Skidder longwood	1/2	1-1/2	1-1/2	1-1/2		5
Manual tree-length	1	3	2-1/2	2	1/2	9
Highly mechanized full-tree	1		4-1/2	3	1/2	9
Limited-area feller-buncher	1		3-1/2	3	1/2	8
Whole-tree chip	1		5	3	1	10

TABLE 3. — *Initial investment in each harvest system.*

System	Woods equipment	Hauling and support equipment	Total
	($)		
Stump bobtail	2,600	14,000	16,600
Bobtail and tractor	30,600	27,000	57,600
Semimechanized shortwood	146,500	146,000	192,500
Highly mechanized shortwood	197,700	170,000	367,700
Shortwood prehauler	41,500	61,000	102,500
Skidder longwood	80,000	76,600	156,600
Manual tree-length	156,500	170,600	327,100
Highly mechanized full-tree	321,700	231,400	553,100
Limited-area feller-buncher	301,700	231,400	533,100
Whole-tree chip	456,000	259,500	715,500

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.*

System	Cost per cord
	($)
Whole-tree chip	33.96
Limited-area feller-buncher	37.54
Highly mechanized full-tree	37.66
Shortwood prehauler	41.30
Stump-to-stump bobtail	41.37
Manual tree-length	41.88
Highly mechanized shortwood	44.79
Skidder longwood	45.40
Semimechanized shortwood	46.92
Bobtail and farm tractor	49.11

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

Harvest equipment	Average age (yr.)
Single axle bobtail trucks	6.1
Tandem axle bobtail trucks	5.3
Diesel tractor-trailer trucks	4.2
Forwarders	3.7
Cable skidders	4.5
Grapple skidders	2.7
Knuckleboom loaders	4.1
Bigstick loaders	4.7

Source: Weaver, et al. (15).

on estimates provided by industrial and academic harvesting specialists. Details on productivity rates and input costs are described by Cubbage (3).

Simulation results

The estimated harvest cost per cord for each system is shown in Table 4. Costs include stumpage, hauling, and overhead for owner/operator profit and system support equipment. Also, the costs are for the minimum optimal tract size where costs for moving and setting up no longer have a significant effect on the average harvest cost.

Highly mechanized full-tree systems have the lowest average cost per cord for harvesting roundwood. Costs averaged almost $4 per cord less than the manual tree-length system, shortwood prehauler system, and stump-to-stump bobtail system. Whole-tree chipping has the lowest cost per cord but falls between the highly mechanized full-tree systems and the low-cost tree-length and shortwood systems in profitability when both costs and lower chip revenues are considered. Partially mechanized shortwood, highly mechanized shortwood, and long log systems are generally not as competitive in average pine pulpwood harvesting conditions. The small scale mechanized shortwood operation—a bobtail truck and farm tractor—had the highest cost.

Sensitivity analyses were performed on selected harvest systems to determine the effect of changes in the assumptions. Different stand volumes and labor productivity rates; higher interest rates, wages rates, equipment purchase costs, and fuel costs; and the imposition of quotas were examined.

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 increased 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

TABLE 6. — *Machine and labor costs breakdown for woods equipment.*

System	Machine	Labor
	---------(% of total cost)---------	
Whole-tree chip	64.1	35.9
Limited-area feller-buncher	60.8	39.2
Highly mechanized full-tree	58.6	41.4
Highly mechanized shortwood	58.2	41.8
Semimechanized shortwood	51.3	48.7
Bobtail and tractor	46.4	53.6
Skidder longwood	46.0	54.0
Manual tree-length	39.1	60.9
Shortwood prehauler	25.9	74.1
Stump bobtail	22.1	77.9

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 midseventies 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 ownership 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 bobtail and prehauler 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.*

System	Cost[a]	Tract size required for minimum cost
	($)	(acres)
Stump bobtail	49	[b]
Bobtail and tractor	227	10
Shortwood prehauler	373	20
Skidder longwood	548	40
Semimechanized shortwood	647	40
Manual tree-length	801	60
Highly mechanized shortwood	1,038	60
Highly mechanized full-tree	1,275	100
Limited-area feller-buncher	2,437	120
Whole-tree chip	2,414	120

[a] Harvest System Simulator (HSS) computer program (11).
[b] Stump bobtail 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.

Plantations

During the 1980s, many of the southern pine plantations established by forest industry and other landowners will be reaching the age for a first commercial thinning. As of 1978, for example, almost 40 percent of the estimated 12 million acres of pine plantations in the five southeastern states were in the 10- to 19-year age class (9). Since harvesting productivity and costs are adversely affected by smaller tree sizes, the potential impact of plantation thinning is a major concern.

In general, the relative uniformity of tree size and spacing in plantations favors mechanical row thinning. For this reason and also unfavorable long-term trends in labor supply and wage rates, various tree harvesters have been developed and tested in southern pine plantations (2, 6). A comparison of thinning systems incorporating three types of harvesters using 1977 prices showed systems including full-tree machines or feller-bunchers had lower harvesting costs than those using shortwood or tree-length harvesters (5).

Using 1980 prices, harvest costs were calculated for the following pine plantation thinning systems:

1. Shortwood harvester/forwarding/shortwood hauling
2. Tree-length harvester/grapple skidding/tree-length hauling
3. Feller-buncher/grapple skidding/delimbing gate/tree-length hauling.

Harvester production rates used were for row thinning slash pine plantations at age 15 with a site index of 70 and a density of 500 surviving trees having an average DBH of 6.5 inches. System costs per cord by harvester type were: shortwood, $46.51; tree-length, $47.01; and full-tree or feller-buncher, $41.78.

As found with clearcutting in natural stands, the highly mechanized full-tree system is the most cost-efficient. For those who might find row thinning less acceptable than other thinning methods, more costly thinning systems would have to be justified by ultimate returns from the particular practice.

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 bobtail truck and the shortwood prehauler—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 bobtail or prehauler 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.

Prehauler 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 prehauler system.

Manual tree-length. —The manual tree-length system is comparable in cost with the labor-intensive stump bobtail and shortwood prehauler 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 wet land, and are useful in irregular stands with large timber.

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 chip 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 yarder 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 delimbing. 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.

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