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Bryce J. Stokes, William F. Watson, and I. Winston Savelle

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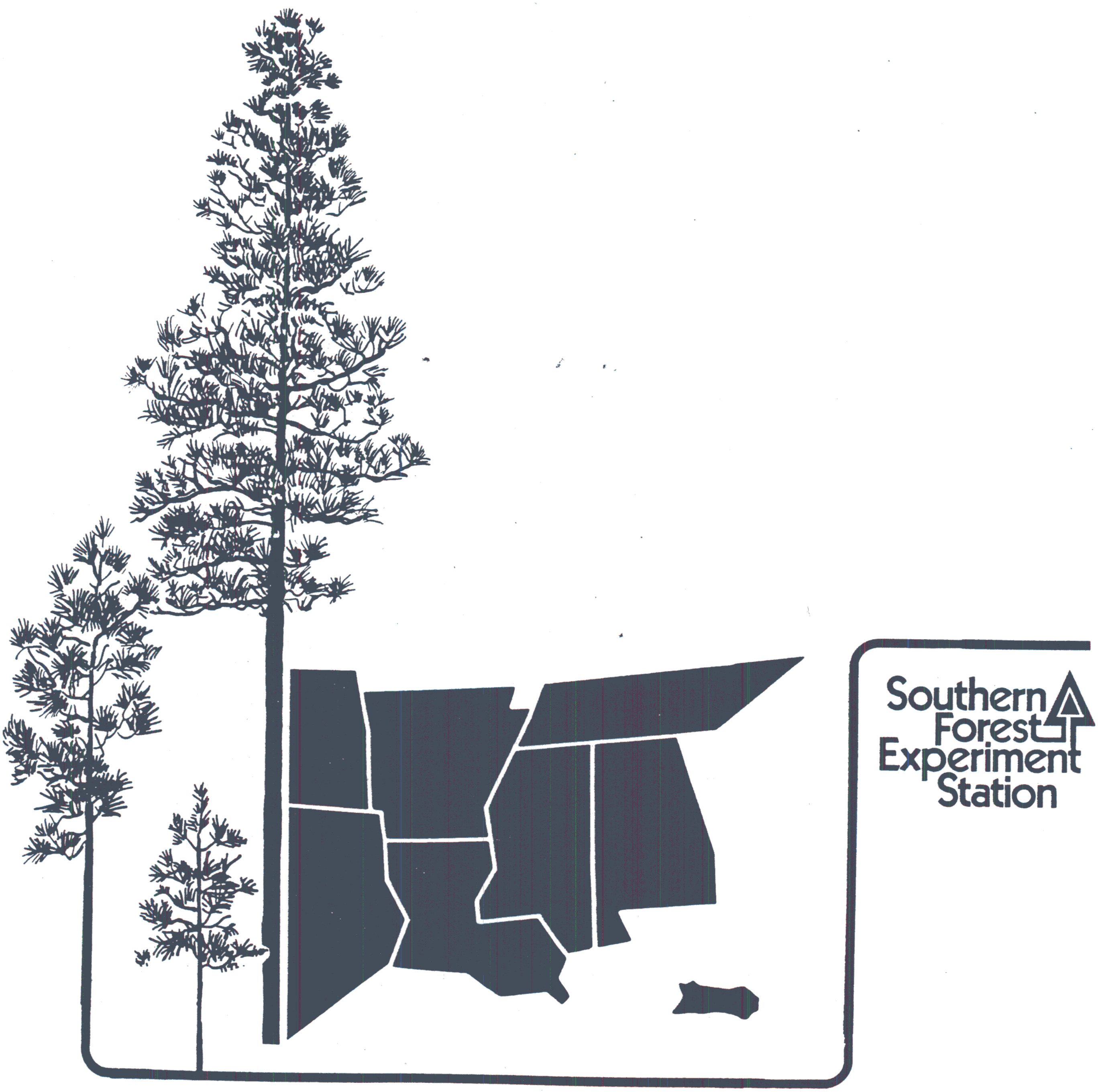

Alternate Biomass Harvesting Systems Using Conventional Equipment[1/]

Bryce J. Stokes, William F. Watson, and I. Winston Savelle[2/]

Abstract.--Three harvesting methods were field tested in two stand types. Costs and stand utilization rates were developed for a conventional harvesting system, without energy wood recovery; a two-pass roundwood and energy wood system; and a one-pass system that harvests roundwood and energy wood. The systems harvested 20-acre test blocks in two pine pulpwood plantations and in a natural pine sawtimber stand. The one-pass method resulted in the least cost and better utilization of biomass residue.

INTRODUCTION

Most of the conventional harvesting operations in use today leave usable biomass to be windrowed and burned. Typical management strategy in the South is to clearcut mature stands, do mechanical site preparation, and replant the site. Clear-cutting removes wood that can then be delivered to market at a profit. In most cases, the pine component of the the stand will be the most completely utilized. The tops and stems, some up to 6 inches dbh, are left to be disposed of during the subsequent site preparation operations. Sawlogs are usually the only hardwood component harvested from the stand--limby tops and hardwood stems less than 12 inches dbh are left on the clear-cut area.

It is not economical with conventional systems to obtain complete recovery of biomass, but they do have a great potential to improve utilization of this biomass. Feller bunchers have an accumulating ability that make it possible for them to efficiently harvest small stems.

Portable chippers have revolutionized the utilization of the entire tree. Young (1980) reported that with portable chipping more and more use has been made of tops for energy fiber. Chippers also increase utilization of defective and small trees.

This study was proposed to identify opportunities for reducing site preparation cost by more intensive utilization of residuals when harvesting with conventional operations. The study was accomplished in two phases. One phase was designed to quantify the harvesting costs associated with reducing residue during harvest. The second phase dealt with assessing costs for various site preparation methods and various levels of harvesting residue. In addition, site characteristics were determined before and after each phase to be sure that the particular strategies do not cause the site to deteriorate any more than other strategies studied. This paper reports results from the harvesting phase of the study.

Three harvesting methods were evaluated in two stand types; one was a pine pulpwood plantation and the other a pine sawtimber natural stand. The study was designed so that each harvesting method was studied on two 20-acre blocks for each stand type. Harvesting methods tested were (1) conventional--harvest all roundwood, (2) two-pass--a first phase to harvest energy wood and a second phase to conventionally harvest fiber and logs, and (3) one-pass--harvest all products simultaneously. Because of wet ground conditions, the harvesting tests were not repeated for the natural stand.

DATA COLLECTION

Three tracts were selected for the tests. Tracts I and II were 22-year-old slash pine plantations that were being clearcut for pulpwood. Both were in south Alabama but in different

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[2/] Research Engineer, USDA Forest Service, Southern Forest Experiment Station, Auburn, Al., Associate Professor, Department of Forestry, Mississippi State University, Mississippi State, Ms., and Assistant Forester, Mississippi Agricultural and Forestry Experiment Station, Leaksville, Ms.

locations. The third tract was a natural slash--loblolly pine stand in south Mississippi. In the natural stand the larger, mature pines were approximately 45 years old. The understory in the natural stand consisted of pine and hardwood. Each tract was divided into three harvesting blocks that were 660 ft wide and 1,320 ft deep. The 20-acre blocks were the same configuration to maintain average skidding distances among the harvesting methods.

A cruise was conducted to determine the standing inventory of each block. Fixed radius 1/10-acre plots were established to measure trees larger than the 3-inch dbh class. In the center of these plots, a 1/200-acre fixed radius subplot was taken to determine the standing woody biomass for all trees in the 1 to 3-inch dbh classes. Destructive sampling was used on the 1/200-acre plots and the total green weight was recorded for each tree. All heights were measured in the subplots and sampled in the plots.

After the block perimeters were established and the stand information obtained, each block was harvested. Harvesting took place from June to October. Servis recorders were mounted on each machine. Recorder disks were collected daily to obtain the number of productive hours each machine operated on each block. A monitor maintained a record of crew hours for each block. All haul trucks were weighed at the mill to obtain the amount of harvested material by product type.

HARVESTING METHODS

Conventional

All pine trees 6 inches or greater in dbh were harvested. Hardwood trees at least 12 inches in dbh were also harvested. The harvesting system in the plantations consisted of two feller bunchers and three grapple skidders. A skidder with a directional shear was used to fell and skid trees in the natural stand. Chainsaws were used to fell trees that were too large for the directional shear. Delimbing and topping were completed by chainsaws in the stand or at the deck after the trees had been processed through an iron gate. The tree-length material was skidded to the deck where a hydraulic loader was used to load the tree-length pulpwood and sawlogs. Since this was a conventional harvesting system, there was no energy wood recovered. No hardwood pulpwood was recovered either.

One-Pass

For all tracts, three feller bunchers and two grapple skidders were used in the harvesting system. The natural stand also had the skidder with a directional shear for felling and skidding. The feller bunchers separated the trees into piles of energy wood or roundwood. All pine less than 6 inches dbh and hardwood less than 12 inches dbh in the natural stand were put in energy wood piles.

The energy wood was skidded directly to the chipper. Roundwood was skidded full tree to the deck where two chainsaw operators bucked the tops off to nominal merchantable limits. The bucking point was at the lowest live limb in trees from plantations and at a 4 to 6-inch top near the base of the crown in trees from the natural stand. The chipper grapple was used to move the tops and feed them. All the roundwood was loaded tree length.

Two-Pass

Three feller bunchers and two grapple skidders composed the harvesting system in all three blocks for the first pass to remove the energy wood. The energy wood was cut first to utilize wood that would otherwise be destroyed if the merchantable wood was harvested first. This meant that the feller buncher operators had to carefully maneuver around the merchantable trees. The trees were skidded directly to the chipper producing a clean stand, ready for the second pass.

After the energy wood had been harvested, a second operation removed the roundwood. The second-pass system utilized two feller bunchers and three grapple skidders in the plantation blocks. In the natural stand, the skidder with directional shear did most of the felling and all of the skidding. Chainsaws were used to fell trees too large for the shear and to delimb and top the roundwood in the natural stand. The iron gate was used for delimbing in the plantations.

RESULTS

A summary of the total standing biomass is shown in Table 1. Total tree weight equations were developed during a hardwood study done by Franchi, et al (1984). These equations and equations for pines (Reams, et al, 1982) were used to determine the total wood biomass for each block.

In tract I, the pulpwood (trees greater than 5.5 inches dbh) accounted for 67 percent of the total standing woody biomass. Tract II, the second plantation stand, had 73 percent in pulpwood. The difference between the two plantation stands was that tract I had more energy wood. In the natural stand, about 58 percent of the total standing biomass was pulpwood and sawlogs.

A careful examination of the harvested tonnage (Table 2) gives some insight into the various harvesting methods. Not as much roundwood was recovered from the stand for the one-pass method as with the other harvesting methods. One reason for the reduction in the roundwood in this system is that the tops being sent to the chipper included more of the bole to facilitate feeding the chipper.

As expected, utilization was higher for the one-pass than the other harvesting methods. This was a result of chipping the limbs and tops of the merchantable roundwood in addition to the small diameter trees. Utilization was also generally better in the plantation stands than in the natural stand for the methods tested.

Machine and labor cost estimates were used instead of actual costs (Table 3). The machine rates were developed for each specific machine using new replacement costs. Labor rates, including fringe benefits, were assumed. These rates were used to develop cost estimates per green-ton-to-roadside for the different harvesting methods. However, harvesting costs (Table 4) do not include service equipment, crew transportation, and hauling costs.

The one-pass was the most economical alternative even though chipping costs associated with this method were higher than the two-pass. This is directly related to chipper utilization. During the process of removing the tops at the deck from the merchantable trees, the interaction of the skidders, buckers, loader, and chipper caused delays and affected chipper production. More refinement in the harvesting system components and methods might eliminate some delays and decrease chipping costs. The ratio of products going to the deck also affected balanced production of the system. This may restrict the one-pass effectiveness in several stand types because low utilization of the chipper results in high-cost energy wood.

In the natural stand, the conventional method was the lowest cost option because of tree size. Even though the harvesting costs were low, there was no energy wood harvested and the land manager had a large slash problem to handle.

CONCLUSIONS

In general, conventional equipment and systems can be used to economically harvest more of the total woody biomass. The one-pass method resulted in the best utilization of and lowest costs among the harvesting alternatives considered in these stand types. More information is needed on harvesting the energy wood components for different stands and different stand compositions. Studies are needed to identify the optimal equipment mix and to refine the operation of the one-pass system. Also, the system should be evaluated over a range of stand conditions.

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Table 1.--Cruise summary of plantation and natural stands

Tract	Block	Components (inches) All 1-3	Pine 4-5	Pine >6	Hardwood 4-11	Hardwood >12	Total
		green tons per acre					
I (plantation)	1	14.2	4.9	50.4	9.9	-	79.4
	2	5.4	7.9	68.8	3.0	-	85.1
	3	20.8	10.8	59.3	9.6	-	100.5
	Average	13.5	7.9	59.5	7.5	-	88.3
II (plantation)	1	6.9	12.7	63.9	9.3	-	92.1
	2	7.4	8.3	61.9	7.3	-	84.8
	3	7.0	9.9	57.9	7.5	-	82.0
	Average	7.1	10.3	61.2	8.0	-	86.3
III (natural)	1	25.0	7.0	62.7	11.9	0.0	106.6
	2	22.5	2.5	58.1	22.0	3.3	108.4
	3	23.4	1.2	40.4	16.2	19.8	101.0
	Average	23.6	3.6	53.7	16.7	7.7	105.3

Table 2.--Harvested green tons per acre

Tract	Block	Harvest Description	Energy Wood	Roundwood	Total	Percent[1]
			----green tons per acre------			
I (plantation)	1	Conventional	--	40.7	40.7	51.3
	2	One-Pass	34.4	43.3	77.7	91.3
	3	Two-Pass	30.3	48.0	78.3	77.9
II (plantation)	1	Conventional	--	60.6	60.6	65.8
	2	One-Pass	40.6	35.0	75.6	89.2
	3	Two-Pass	29.1	41.0	70.2	85.6
III (natural)	1	Conventional	--	42.5	42.5	39.9
	2	One-Pass	35.0	45.9	80.9	74.6
	3	Two-Pass	19.8	46.0	65.4	64.8

1/ Percent of cruised total-standing biomass.

Table 3.--Machine and labor rates

Function	Machine	Machine Rate per operating hour	Labor Rate[1] per scheduled hour
		----------------dollars----	--------------------
Felling	Feller buncher[2]	35.40 - 55.82	10.00
Trimming	Chainsaws	4.50	8.00
Skidding	Skidders[3]	33.12 - 38.11	10.00
Chipping	22-inch Chipper	83.03	10.00
Loading	Knuckle-boom	21.95	10.00

1/ Includes fringe benefits.
2/ Cost depends on feller buncher.
3/ Cost depends on which rubber-tired skidder used.

Table 4.--Harvesting costs by method[1]

Tract	Conventional	HARVEST METHOD One-Pass Energy wood	One-Pass Roundwood	One-Pass Combined	Two-Pass Energy wood	Two-Pass Roundwood	Two-Pass Combined
	----------------	--------	Dollars per green ton	--------	--------	--------	--------
I (plantation)	10.10	8.35	6.45	7.39	12.70	6.60	8.97
II (plantation)	9.88	8.30	7.11	7.75	12.11	6.61	8.89
Average	9.99	8.32	6.78	7.57	12.41	6.60	8.93
III (natural)	6.25	10.15	5.84	7.70	13.34	4.62	8.71

1/ Costs are per green ton to roadside and do not include service equipment, crew transportation, or supervision.