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INTEGRATION OF BIOMASS HARVESTING AND SITE PREPARATION

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INTEGRATION OF BIOMASS HARVESTING AND SITE PREPARATION[1/]

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Abstract. --This study was conducted to assess the costs of various site preparation methods with various levels of harvesting residue. Site impacts. soil compaction and disturbance. were examined. Three hawestfq methods were evaluated in pine pulpwood plantation and pine sawtimber stands. The harvesting methods tested were (I) conventional - hanesting all roundwood, (2) two-pass - first harvesting of energy wood followed by conventional harvesting of fiber and logs, and (3) one-pass - harvesting all products in one operation. The site preparation methods tested were (1) shear-rake-pile. (2) single disk. (3) double disk, and (4) herbicide treatments.

The results of the study indicate that conventional harvestfng system can be used to harvest energy wood components of some stand types. The intqratfon of biomass harvesting and site preparation can result In a credit to be applied to the harvesting or site preparation operations. One-pass hawertino_has the most potential for reducing harvest costs for some stand types. Single diskfq had the mst site preparation savings. In mrt cases, the soil characteristics were returned to c-arable conditions after site oreoaratfon.

INTRODUCTION

In the South, most current conventional hawestiq operations leave usable biomass to be windrowed and burned. On forest industry lands. only about &o-thirds of the total woody biomass is -removed during harvest (Hughes and McCollum 1982). The removal of biomass on nonindustrial lands is even much less. The pine component, sawlogs, and pulpwood of the stand are more completely utilized than the hardwood. Usually, sawlogs am the only hardwood component harvested from the stand. Hawestfng biomass is an alternative to extensive site preparation, since the incremental biomass harvested can reduce Site preparatfon costs. In such a case. a more practical management strategy would be to remove as much of the biomass as is feasible so that net harvesting and site preparation costs are minimired.

Conventional systems cannot completely recover biotnass economically but have much potential for improved utilfratlon. Feller bunchers can accumulate small stuns fnto bunches to be more efficiently handled in the system. Probably, the simplest method of removing biomass from the stand is to mve the trees with the biomass still attached (Ualbrfdge and Stuart 1984) and chip the stems at the deck. Portable chippers have revolutionized the utilization of the entire tree. Chipping productivity can be improved by reducing the interdependency between skidding and chipping.

This study was proposed to identify the opportunitfes for reducing sfte preparation costs through more intensive utilization of conventional harvesting systems during final harvest. The study was accomplished in two phases. One phase quantified the harvesting costs associated with reducing residues during harvest (Stokes et al., 1985). The second phase assessed costs of various site preparation methods with various levels of harvesting residue. Preliminary results were reported by Watson et al.. (1984). In addition, site characteristics were determined before and after each phase to evaluate the Site impacts among the alternative strategies. This paper reoorts results from the site-preparation phase of'the study.

Three harvesting uethods were evaluated in pine pulpwood plantatfons and a natural pine sawtimber stand. They were (1) conventional - harvesting of all roundwood, (2) two-oass - first harvesting of energy wood followed by conventional harvesting of fiber and logs, and (3) one-pass - harvesting of all pmducts in one operation. In the second phase of the study. the Site preparation methods tested were (1) shear-rake-pile, (2) single disk, (3) double disk, and (4) herbicide treatments.

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STUDY METHODS

Three tracts were selected for the tests. Two tracts were 22-year-old slash pine plantatlons in different locations in south Alabama. The third tract was a natural slash/loblolly pine stand with a mixed understory in south Mississippi. In the nrtuml stand. the larger mature pines were approximately 45 yews old.

Each tract was divided into three 8.1 hectare (20 acre) blocks having the same dimensions. A cruise was conducted to determine the total standfq inventory of each block.. The blocks were harvested from JUM to October, and machine and labor hours for each block were recorded daily. Each truckload was weighed at the mill to obtain the mount of harvested material by product type.

After the harvests, uch block was sampled to determine the amount of residual biomass. Site preparation treatments were selected to follow a particular harvesting method to ensure a suitable site for regeneration. Extensive slte preparation was mquf red on the conventionally harvested blocks because of the large mount of residual biomass. These sites required shearing, raking, piling, and disking; whereas sites on which the other two harvesting methods mm used required less extensive mechanical treatment (Figure 1).

TYPE OF HARVEST			
Conventional		Two-pass	One-pass
Shear, Rake, Pile, and Disk; 4 hectares (10 acres)	Herbicide 4 hectares (10 acres)	Single Disk. 2 hectares (5 acres)	Single Disk. 2 hectares (5 acres)
		Double Disk, 2 hectares (5 acres)	Double Disk, 2 hectares (5 acres)
		Herbicide 2 hectares (5 acres)	Herbicide 2 hectares (5 acres)
		Control 2 hectares (5 acres)	Control 2 hectares (5 acres)

Figure 1. Design for harvesting and site preparation tests.

As in harvesting, the machine and labor hours. were recorded for each treatment block. Company equipment and crews were used in the site preparation. There were no special considerations in the site preparation treatments, except for a prototype herbicide applicator.

An assessment of soil compaction and disturbance was made before harvesting and after site preparation operations. Soil samples were t&ken on a 61 x 61 m (200 x 200 ft) grid to 5 cm (2 in) and 10 cm (4 in) depths to obtain bulk densities follaiq the operations.

HARVESTINGMETHODS

Rubber-tfred feller bunchers and skidders were used in the plantation stands for all harvesting methods. In the natural stand. a directional shear mounted on a skidder was used for felling in the conventional and one-pass methods and In the second pass of the two-pass method. The feller bunchers were used for felling the energy wood material in the first pass of the two-pass test block in the natural stand. The skidders. includlq the one with the directional shear. were used for removing the wood in the natural stand.

In the conventional blocks, pine trees 15 centimeters (6 inches) or greater in diameter at breast height (DBH) and hardwood trees at least 30 centimeters (12 inches) in DBH were harvested. Delimbing and topping were completed in the stand or at the deck after the trees hrd been processed through an iron gate. The wood was loaded tree length with a hydmullc loader.

All pine less than 15 centimeters (6 inches) fn DBH and hardwood less than 30 centimeters (12 inches) in DBH were separated into piles of energy wood by the feller buncher operators in the one-pass method. The remaining products, pulpwood and sawlogs, were placed into separate piles. Energy wood was skidded directly to the chipper. Roundwood was skidded to the deck. where the tops were bucked by chainsaw operators. The loader on the chipper was used to pick up the cutoff tops and place them into the chipper. Roundwood was loaded tree length with another loader.

All energy wood was harvested in the ffrst pass of the two-pass method to utilize this system as much as possible. The feller buncher operators had to maneuver around the merchantable trees. The wood was skidded directly to the chipper. resulting in a clean stand for the second pass. In the second pass in the plantatlon stands, the merchantable trees were delimbed with an iron gate. Chainsaw were used in the natural stand for processing the stems into tree-length wood that was loaded with a hydraulic loader.

SITE PREPARATION METHODS

Only the plantatlon stands were totally site-prepared; the natural stand was too wet. Large crawler tractors were used in the mechanical functions of site preparation. The shearing and piling operations followed harvest in half of each of the conventionally harvested blocks. After the site had been raked and piled, a disk was used as a soil treatment.

The site preparation methods tested on the blocks harvested for energy wood were single and double' dfskfng without any other 'treatment. Double diskiq immediately followed the first dfskiq pass. Stumps caused problems such as broken disk blades because the sites were dfsked without shearing.

The herbicides were applied. to 2 or 4 hectare (5 or 10 acre) plots (Figure 1) as part of an additional test of a newly developed ground sprayer that was mounted on. a rubber-tired skidder. Conventionally harvested plots were sprayed with a mixture of 14.0 liters of Tordon-101[3] and 4.7 liters of Garlon-4 per hectare. A full treatment of plots within the blocks in which energy wood was harvested was completed with Roundup at the rate of 9.4 liters per hectare. All blocks were burned before planting.

RESULT3

A careful examination of the harvested tonnage (Table 1) gives some insight into the various harvesting methods. In all cases. the cruised roundwood was the largest component of the total standing biomass. A high percentage of this component was harvestad by each method. However, not as much of the total stand was recovered as roundwood for the one-pass method. In tract II, there was a significant reduction in the roundwood harvested. The trend continued for the other one-pass blocks. The tops being sent to the chipper included more of the bole to facilitate feeding the chipper. This partially accounts for the reduction in the roundwood fn the one-pass method.

As expected. utilization was higher for the one-pass method than for the other harvesting methods. This was a result of recovering the 1 imbs and tops of the merchantable roundwood f n addition to the small diameter trees. There was also generally better utllirатfon of harvesting methods in the plantation stands than in the natural stand.

[3] Discussion of herbicides in this paper does not constitute recommendation of their use or imply that uses discussed here am registered. If herbicides are handled. applied. or disposed of improperly, they can han humans, domestic animals. desirable plants. and pollinating insects, fish, or other wildlife. and may contaminate water supplies. Use herbicides only when needed and handle them with care. Follow the directions and heed all precautions on the container label.

Table 1. Harvested tonnage.

Block	Description	Energy Wood	Pulpwood	a l	% [1]
		--green tonnes per ha-- (green tons per acre)			
		PLANTATION I			
1	Conventional	- -	91.2	91.2	51.3
		(--)	(40.7)	(40.7)	
2	One-pass	77.1	97.1	174.2	91.3
		(34.4)	(43.3)	(77.7)	
3	Two-pass	67.9	107.6	175.6	77.9
		(30.3)	(48.0)	(78.3)	
		PLANTATION II			
1	Conventional	--	135.9	135.9	65.8
		(--)	(60.6)	(60.6)	
2	one-pass	91.0	78.5	169.5	89.2
		(40.6)	(35.0)	(75.6)	
3	Two-pass	65.2	91.9	157.4	85.6
		(29.1)	(41.0)	(70.2)	
		NATURAL III			
1	Conventional	--	95.3	95.3	39.9
		(--)	(42.5)	(42.5)	
2	one-pass	78.5	102.9	181.4	74.6
		(35.0)	(45.9)	(80.9)	
3	Two-pass	44.4	103.1	146.6	64.8
		(19.8)	(46.0)	(65.4)	

[1] Percentage of cruised total standing biomass.

Table 2. Harvesting costs.[1]

Harvest Method	Dollars per green tonne	Dollars per green ton
PLANTATION I		
Conventional	11.14	10.10
One-pass	8.15	7.39
Energy Wood	9.21	8.35
Pulpwood	7.11	6.45
Two-pass	9.89	8.97
Energy Wood	14.00	12.70
Pulpwood	7.28	6.60
PLANTATION II		
Conventional	10.89	9.88
One-pass	8.54	7.75
Energy Wood	9.15	8.30
Pulpwood	7.84	7.11
Two-pass	9.80	8.89
Energy Wood	13.35	12.11
Pulpwood	7.29	6.61
NATURAL III		
Conventional	6.89	6.25
One-pass	8.49	7.70
Energy Wood	11.19	10.15
Rounowood	6.U	5.34
Two-pass	9.60	8.71
Energy Wood	14.71	13.34
Roundwood	5.09	4.62

[1] Harvesting costs are for felling, skidding. delimbing (where needed). dnd chipping or loading.

Estimates of machine and labor costs were used instead of actual costs. The machine rates were developed for each specific machine using new replacement costs. Labor rates were assumed to include fringe benefftt. These rates were used to develop cost estimates to roadside. for the different harvesting methods. These hawesting costs (Table 2) de not Include service equipment, crew transportation. and hauling costs.

The one-pass method was the most econalcal alternative for all products fn the plantation stands because of better utilization. In the natural stand, the conventfonal method was the lowest cost option because of larger tree size. Even though the harvesting costs were low, there was a laqe slash problem to handle during site preparation because none of ♦♒♏ ● neqV wood was recovered.

The ● stluted site preparation costs are shown in Table 3. These costs am based on time study and uchfne rate calculations for the plantation stands. Herbicide treatment costs were estimated because the appl fcator was a prototype in development. Costs for the natural stand were estfuted to be 20 Percent hfgher than tha average costs for the same treatments in the plantations. Sfte preparation treatments in the natural stand were delayed because of wet ground conditions that probably would have invalidated the results. The increase-in-cost assumption is based on more residual material following all hawestfng operations.

Assuming #at all site preparatfon treatments were equally effective, a sfte preparation credit was calculated for the reduction is cost over the conventionally harvested and sfte prepared block. Of course, this assumption cannot be applied to the herbicide treatment following the conventfonal hawestfng; however, all the remaining treatments appear to have been surprisingly effective when combined with the energy hawestfng treatments. Followup examinatfon of seedling survival and growth and return of herbaceous growth will determine the validity of this assumption.

Savings ranged from approximately $31 per hectare ($12 per acre) for herbicide treatments to about $226 per hectare ($92 per acre) for single disking. Most savings were in the single disking applications, the least cost treatment. These costs did not include burning, which was also used. except in the control plots.

Credits on a green tonne (ton) basis were developed by taking the reduction in site preparation costs and dividing by the tonnes (tons) of chips generated from the energy wood harvest. Credits ranged from 50.34 to $5.10 a green tonne (50.31 to 54.63 a green ton). Even though the &e-Pass and two-pass nawestfng al ternatives were feasible for producing energy wood without these site preparation credits, these credits do allow some latitude in hauling distance and in reducing site preparation costs.

The average soil bulk densities are gfven in Table 4 for the treatments before harvest (undisturbed) and after site preparation In the plantation stands. In most cases, the soil characterfstics were returned to comparable condi tfons among the blocks after site preparatfon. Them was significant compaction on tract II at the 5-centimeter (2-inch) depth of the conventlonally harvested block and at the 10-centimeter (I-inch) depth of the two-pass block. No significant trend resulted from the tests in the plantations. Because of excessive delays in harvesting the natural stands. the evaluation of the sfte preparation was never completed.

CONCLUSIONS

This study shows that conventfonal hawesting systems can be used to harvest the energy wood components of some stand types. Integrating biomass hawestfng and site preparation can result In a credit to be applied to the harvestfng or site preparation operations. One-pass hawestfng has the most potantlal for reducing harvesting costs for some stand types. In this study, the most economical site preparation method was sfngle dfskfng.

LITERATURE CITED

Hughes, C. M. and If. P. McCollum. 1982. Needs and future directions for biomass research and application from an Industrial view point. In: Baldwin, V. C. and R. E. Lohrey, Eds. Proceedings of the 1982 Southern Forest Biomass Workshop. Fourth annual meeting of the Southern Forest Biomass Working Group: 1982 June 16-18; Baton Rouge. LA. New Orleans, LA. U. S. Department of Agriculture, Forest Service. Southern Forest Experiment Statfon, 1982:3-15.

Stokes, B. J., W. F. Watson, and I. W. Savelle. 1985. Al ternate biomass harvestf ng system using conventional equipment. In: Saucier, J. R.. Ed. Proceedings of the 1984 Southern Forest Bf omass Workshop. Sixth annual meeting of the Southern Forest Biomass Working Group, 1984 June 5-7, Athens, GA. Asheville, NC, U. S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station, 1985:111-113.

Straka, T. J. and W. F. Watson. 1985. Costs of forestry practices. Forest Farmer, 25th Manual Edition 44(5):16-22.

Table 3. Site preparation costs.

Harvest Method	Sfte Preparation Method	Dollars/hectare[1/] (acre)	Sfte Preparation Credit[2/] Dollars/hectare (Acre)	Dollars/Green tonne (ton)
		PLANTATION I		
Conventional	Shear-Rake-PIle-Disk	243.14 (98.47)	-- (--)	-- (--)
	Herbicide	1%. 97 (80.22)	45.06 (18.25)	-- (--)
One-pass	Single disk	45.90 (18.59)	197.23 (79.88)	2.56 (2.32)
	Double disk	91.83 (37.19)	151.31 (61.28)	1.96 (1.78)
	Herbicide	198.07 (80.22)	45.06 (18.25)	0.58 (0.53)
Two-pass	Siqle disk	47.70 (19.32)	195.43 (79.15)	2.88 (2.61)
	Double disk	95.78 (38.79)	147.36 (59.68)	2.17 (1.97)
	Herbicide	198.07 (80.22)	45.06 (18.25)	0.66 (0.60)
		PLANTATION II		
Conventional	Shear-Rake-Pile-Olsk	228.74 (92.64)	-- (--)	-- (--)
	Herbicide	198.07 (80.22)	30.67 (12.42)	-- (--)
One-pass	Single disk	46.99 (19.03)	196.15 (79.44)	2.16 (1.96)
	Double disk	93.63 (37.92)	149.51 (60.55)	1.64 (1.49)
	Herbicide	198.07 (80.22)	30.67 (12.42)	0.34 (0.31)
Two-pass	Single disk	46.99 (19.03)	196.15 [illegible]	3.01 (2.73)
	Oouble disk	93.63 (37.92)	149.51 (60.55)	2.29 (2.08)
	Herbicide	198.07 (80.22)	30.67 (12.42)	0.47 (0.43)
		NATURAL III[3/]		
Conventional	Shear-Rake-Pile-Disk	283.14 (114.67)	-- (--)	-- (--)
	Herbicide	237.69 (96.26)	45.46 (18.41)	-- (--)
One-pass	Sfngle dfsk	55.58 (22.51)	227.41 (92.10)	2.90 (2.63)
	Double disk	111.28 (45.07)	171.85 (69.60)	2.19 (1.99)
	Herbicide	237.68 (96.26)	45.46 (18.41)	0.58 (0.53)
Two-pass	Single disk	56.81 (23.01)	226.32 (91.66)	5.10 (4.63)
	Double disk	113.65 (46.03)	169.48 (68.64)	3.83 (3.47)
	Herbicide	237.68 (96.26)	45.46 (18.41)	1.03 (0.93)

1/ Herbicide costs are the average for ground Spraying (Straka and Watson 1985). Actual cost was slightly different because of experimental equipment.

2/ Credit per acre is the difference between other harvesting and site preparation treatments and the conventionally harvested and site prepared block as the base.

3/ Costs were estimated to be 20 percent higher than the average cost for the same treatment in the plantation stand.

Table 4. Average soil density in the undisturbed stand and after site preparation.

Tract	Harvest Method	soil Depth (in.)	Average Bulk Density				Significant Differences	
			Before Harvest	After Rake, Pile & Disk	After Singl Disk	After Doubl Disk	Before Harvest & After Site Preparation	Between Site Preparation Treatments
			g/cc					
I	Conventional	2	1.19	1.26	--	--	NS	--
		4	1.44	1.29	--		•	--
I	One-pass	2	1.29	--	1.04	1.16	Ns	NS
		4	1.51	--	1.30	1.22	•	NS
I	Two-pass	2	1.23	--	1.49	1.33	NS	NS
		4	1.44	--	1.56	1.46	NS	NS
II	Conventional	2	1.15	1.28	--	--	**	--
		4	1.38	1.43	--	--	NS	--
II	One-pass	2	1.21	--	1.23	1.28	NS	NS
		4	1.42	--	1.44	1.45	NS	NS
II	Tuo-pass	2	1.05	--	1.21	1.16	Ns	NS
		4	1.19	--	1.38	1.38	**	NS

NS=not significant; *=significant at 0.05 level; -significant at 0.01 level.

Walbridge, T. A. and If. B. Stuart. 1984. systems and procedures for integrated recovery of forest biomass. In: Daniels, R. F. and P. H. Dunham, Eds. Proceedings of the 1983 Southern Forest Biomass Workshop. Fifth annual meeting of the Southern Biomass Working Group, 1983 June 15-17, Charleston, SC. Asheville, NC. U. S. Department of Agriculture, Forest Service. Southeastern Forest Experiment Station. 1984:53-56.

Watson. W. F.. B. J. Stokes. and I. W. Savellc. 1984. Site preparation savings through better utilization standards. Forest resources management-the influence of policy and law. International Forest Congress Convention, 1984 August 5-7, Quebec City, Canada. Washington, DC, Society of American Foresters. 1984:389-391.