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LOW-COST HARVESTING SYSTEMS FOR INTENSIVE UTILIZATION IN SMALL-STEM LODGEPOLE PINE STANDS

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John Host
Joyce Schlieter

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John Host and Joyce Schlieter

INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
Forest Service
U.S. Department of Agriculture
Ogden, Utah 84401

THE AUTHORS

JOHN HOST received his B.S. in Forestry from the University of California, an M. F. in Logging Engineering from University of Washington, and an M. B. A. from University of Montana. He has more than 25 years of experience in logging, forest engineering, sawmilling, and research. Currently he is a research forester for the Forest Residues Utilization research work unit, at the Forestry Sciences Laboratory in Missoula.

JOYCE A. SCHLIETER received her bachelor's degree in Mathematics from Portland State University and her master's in Statistics from Michigan State University. Since 1975, she has been the Mathematician/Statistician for the Forest Residues Utilization research work unit, Missoula.

CONTENTS

RESEARCH SUMMARY

Three different skidding methods--small rubber-tired skidder, horse, small tracked tractor--were compared in an overmature lodgepole pine stand in Montana. Five comparable units were logged using two different utilization standards--loggers' choice and 2 1/2-inch top d.i.b. Skidding production, product volume removed per acre, and residue volume per acre are compared for each cutting unit. Skidding costs, in order of increasing costs were rubber-tired skidder, horse, and then farm tractor. On a capital investment basis, horse skidding is the most efficient.

INTRODUCTION

During the 1973 economic recession, Ravalli County, Montana, was an area of high unemployment. The Ravalli County Resource Conservation and Development Committee (RC&D)--part of the Rural Area Development Program--located in Hamilton, began seeking means for stimulating employment, particularly among farm and ranch workers chronically unemployed during the long winters.

One promising answer lay in expanding the logging of the large stands of lodgepole pine on the Bitterroot National Forest. The stands were underutilized at the time, and individual trees were of a size that could be skidded with equipment--also often idle in winter--found on many ranches and farms. Many ranchers who owned timber supplemented their incomes by logging during the winter. Creating similar work for others seemed a likely way to reduce unemployment.

The RC&D Committee enlisted the assistance of the staff of the Bitterroot National Forest and the Intermountain Forest and Range Experiment Station's Forestry Sciences Laboratory in Missoula. Two studies resulted from this cooperative effort. A study by Benson and Strong[1] evaluated the acreage, volume, and product potential of lodgepole stands on the Bitterroot National Forest. The second study is the subject of this report.

The study reported here had two objectives: (1) examine the feasibility of using inexpensive skidding equipment in a small-stem lodgepole pine stand in western Montana, and (2) determine forest residues volumes (unused wood) resulting from different ground skidding methods and utilization standards. Preharvest volumes, volumes removed, residues left on the ground, and unusable material hauled from the site were determined for various utilization standards. The efficiency of skidding with a horse, small tractor, and small rubber-tired skidder were compared.

Benson and Strong[1] reported the volume and product potential of mature lodgepole pine stands on the Bitterroot National Forest. Mature lodgepole pine stands cover 81,688 acres, of which only 44,147 acres are available for timber harvest. The cubic volume on these 44 thousand acres, 3 inches and larger in diameter, is segregated as follows:

	Million ft^3
Standing green	91.3
Standing dead	26.7
Down	63.8
Total	181.8
Suitable for solid wood products	122.5
Suitable for fiber	36.1
Not usable	23.2
Total	181.8

[1]Benson, R. E., and R. A. Strong. Wood product potential in mature lodgepole pine stands, Bitterroot National Forest. USDA For. Serv. Res. Pap. INT-194, 16 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

This is further segregated into product groups:

Product	*Million pieces*			
	Green	*Standing Dead*	*Down Dead*	*Total*
Houselogs	1.4	0.3	0.4	2.1
Corral rails	6.0	1.4	1.1	8.5
Fenceposts	12.7	1.1	1.2	15.0

Pure stands of lodgepole pine are a major component of forest lands in the Rocky Mountains. The stands consist of numerous stems per acre, which are small diameter, 5 to 9 inches d.b.h. Frequently about half the per-acre volume is dead standing and down trees. Table 1 points out the size classes, volumes, and sizes of these stands. Thirty-two billion board feet of sawtimber occur on 7.4 million acres. In general, a large portion of these stands are marginally operable because of high logging costs.

Because lodgepole pine comprises so much of the forests of western North America, there is growing interest in alternatives to the large, expensive tractors, skidders, and harvesters commonly used for harvesting timber. Close utilization of the stands, both as a means of extending wood supplies and as a means of disposing of the large volumes and deadwood associated with overmature timber, is also of wide concern. Therefore the results of this study should be useful beyond the original purpose and scope of the work.

Table 1.--*Lodgepole pine stand statistics for Rocky Mountain area*

Diam. class	North. Idaho		South. Idaho		West. Montana		East. Montana		Wyoming		Colorado	
	GROWING STOCK (MM FT^3)											
5.0-6.9	418.1		560.7		1,534.0		876.4		418.5		658.6	
7.0-8.9	479.4		561.5		1,620.0		1,076.0		435.4		454.3	
9.0-10.9	360.4		502.7		1,235.9		870.1		403.6		375.3	
Total	1,257.9		1,624.9		4,389.9		2,022.5		1,257.5		1,488.2	
	NET SAWTIMBER VOLUME (MM BD. FT.) INT. 1/4-INCH RULE											
9.0-10.9	1,795.8		2,812.2		5,738.4		4,251.5		2,178.2		2,301.2	
11.0-12.9	1,307.0		1,924.1		3,221.2		2,944.6		1,472.3		1,844.4	
Total	3,102.8		4,736.3		8,959.6		7,196.1		3,650.5		4,145.6	
	AREA IN M ACRES											
	NF	PVT	NF	PVT	NF	PVT	NF	PVT	NF	PVT	NF	PVT
Pole	438.4	64.7	213.3	18.5	1,145.6	328.2	645.4	148.5	460.9	31.7	237.2	267.3
Saw.	115.7	30.9	703.4	22.2	615.2	41.0	803.3	116.8	418.5	57.1	359.1	71.9
Total	554.1	95.6	916.7	40.7	1,760.8	369.2	1,448.7	265.3	879.4	88.8	596.3	339.2

SOURCE: Green, A. W., and T. S. Setzer. 1974. The Rocky Mountain timber situation, 1970. USDA For. Serv. Res. Bull. INT-10. Intermt. For. and Range Exp. Stn., Ogden, Utah.

STUDY AREA DESCRIPTION

The study area consists of five cutting units located on the Bitterroot National Forest about 20 miles from Hamilton, Montana (fig. 1). A well-traveled road formed the lower boundary of the cutting units. (This road is also the upper boundary of a designated roadless area.)

The study area was selected for uniformity of terrain and timber stand. Elevations ranged from 6,700 to 7,040 feet above sea level. The logged slopes ranged between 20 and 45 percent. All five units were situated in a stagnant, overmature 120-year-old lodgepole pine stand. (The cover photo of this report shows stand condition prior to cutting.) The silvicultural prescription was to clearcut and burn the slash, if necessary. Individual cutting units ranged from 1.13 to 1.65 acres.

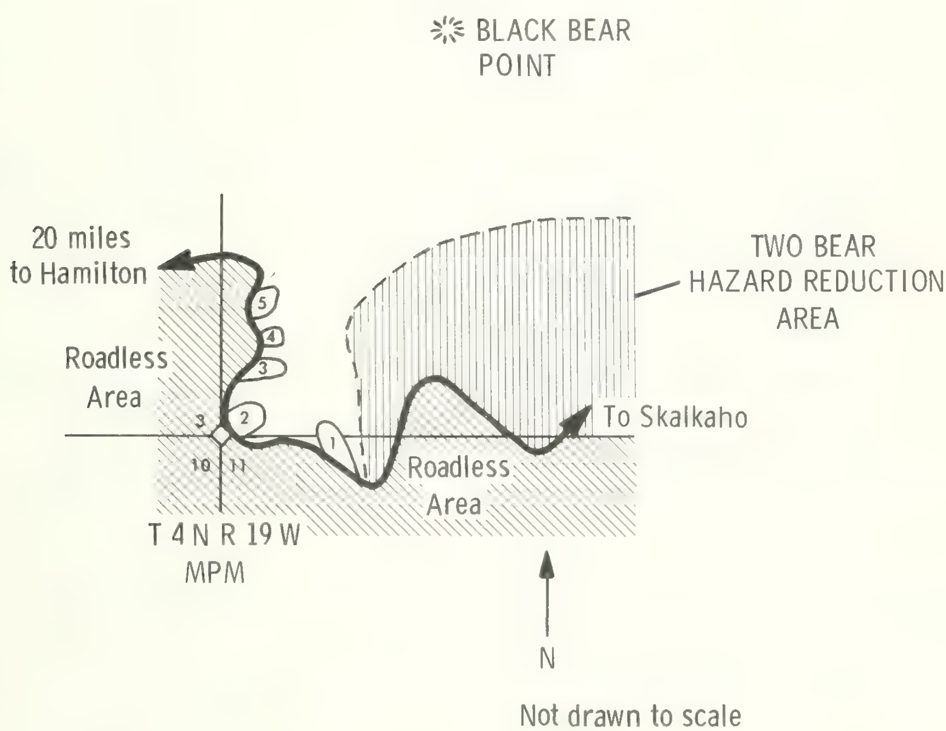

Figure 1.--Study area location.

PREHARVEST INVENTORY

Inventory data are presented for each unit in four stages: preharvest, harvest, postharvest and final product recovery. Average tree sizes and volumes for the different units were similar (table 2). D.b.h. ranged from 5.5 to 9.5 inches for all trees in the five units. The mean tree volume was 6.0 to 8.3 ft^3 for green trees and 2.7 to 5.2 ft^3 for dead trees. The cubic volume per acre for the various units varied between 4,104 and 5,588 ft^3. Preharvest inventory provided a baseline for measuring residue cleanup efficiency.

Procedures described by Brown (1974)[2] were used in preharvest and postharvest inventories of downed material. This procedure consists of measuring down material along a random line and converting measurements to cubic volumes.

Table 2.--*Preharvest inventory*

Unit No.	1	2	3	4	5	Total
Size (acre)	1.13	1.57	1.54	1.65	1.50	7.39
			STAND VOLUME (FT^3)1/			
Standing	1,596	2,599	3,004	4,877	3,598	15,674
Down	4,669	3,844	5,601	4,017	2,949	21,080
Total	6,265	6,443	8,605	8,894	6,547	36,754
Vol per acre	5,544	4,104	5,588	5,390	4,365	
			MEAN TREE VOLUME (FT^3)2/			
Green	8.3	7.1	7.3	6.0	6.5	
Dead	5.2	4.8	4.1	2.7	4.1	
			TREE D.B.H. (INCHES)			
Mean	7.1	6.8	7.0	6.4	6.4	
Range	5.5-9.5	5.6-7.7	5.6-8.8	5.7-7.2	5.9-7.4	

1/ Stand gross volume to 2 1/2 inch top d.i.b.

2/ Whole tree gross volume to 2 1/2 inch top d.i.b.

[2] Brown, J. K. 1974. Handbook for inventorying downed woody material. USDA For. Serv. Gen. Tech. Rep. INT-16, 24 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

HARVESTING ACTIVITY

Production was determined for three different ground skidding systems in five logging units skidded as follows:

Logging Unit	*Skidding System*
1	Rubber-tired skidder
2	Small, tracked tractor
3	Horse, Rubber-tired skidder
4	Horse
5	Rubber-tired skidder

Unit 3 was originally assigned to be horse skidded. Excessive steepness prevented horse skidding the entire unit; hence, the rubber-tired skidder was used on part of that unit.

The sale originally specified a 2 1/2-inch minimum top diameter and green material only. This was later changed to "logger's choice," which meant the purchaser had the option of taking or leaving any of the dead material. Green tree lengths were utilized up to the legal hauling length limit of 50 feet and some lengths exceeded this limit. There was no diameter limit. For dead material, the minimum top diameter was 2 1/2 inches and the trees had to be free of rot. Table 3 summarizes the operating conditions for each unit.

Table 3.--*Operating constraints and practices for each logged unit*

Unit	Utilization standard	Prelog activity	Skidding constraints
1	Full tree, green and sound dead	Stumps to ground level; direct fall uphill	None
2	Full tree, green and sound dead	Stumps to ground level; direct fall uphill	None
3	Full tree, green and sound dead	Stumps to ground level; direct fall uphill	Steep portion required diagonal slope skidding
4	2 1/2-inch top d.i.b.; green material	Stump height; less than 12 inches	Skidding followed prepared skid trails
5	2 1/2-inch top d.i.b.; green material. (Some dead removed for roadside decking.)	Stumps to ground level; direct fall uphill	None

The usual procedure for skidder and tractor methods was to skid at least a full truckload, then load the material and haul it out on the way home at the end of the shift. Hence, the workday consisted of driving the truck to work, skidding until 1 or 2 p.m., and loading and hauling the material to a sawmill or post and pole plant. Normal procedure was to start at a fixed time, 7:30 a.m., but skidding time ended when the operator assumed he had enough time and material to load his truck by 4:30 p.m. Consequently, skidding time ended from 1:05 to 3:30 p.m., with an average quitting time, 2:03 p.m. With a 60-minute lunch period, this represents a normal skidding day of 5 hours and 33 minutes, with 2 hours and 27 minutes for loading.

SKIDDING PRACTICES

Rubber-Tired Skidder

The rubber-tired skidder was a Garrett Tree Farmer Model 15, with a 60-horsepower engine. Total operating costs, itemized in the appendix, amounted to $10.18 per cunit (100 ft^3) skidded.

Felling was done to favor the skidding operation. All trees were felled uphill, with stumps being cut as close as possible to the groundline to allow the skidder to travel anyplace on the unit. This extra effort facilitated the skidding operation.

On unit 5, boles were bucked at 2 1/2-inch diameter when felled. Unit 1 was full-tree skidded except where the trees obviously exceeded legal hauling length. Hooking, skidding, and unhooking were all done by the skidder operator. Chokers consisted of high tensile chains with slider hooks. This permitted winding around the pieces so the pieces would be straightened out when bunching the turn together. Hence, it was possible to handle a large number of pieces per turn.

The lower boundary of all the units was a well-traveled road--especially so during hunting season. This road was used as a landing for all five units. The sale contract required the purchaser to keep the road open for through traffic. Unit 5 was skidded during hunting season. This unique situation necessitated that time spent on the landing be considered as a separate production element so total round-trip time would not be affected.

Horse Skidding

Only the lower third of unit 3 was horse skidded because the upper two-thirds of the unit was too steep. The logs tended to slide into the horses on a straight downhill pull and the units were too narrow to efficiently zigzag skid trails. Unit 3 was finished with the rubber-tired skidder after a trial with the farm tractor. Unit 4 was completely horse skidded.

On unit 3, trees were cut at the groundline and felled uphill to simplify the skidding operation. Felling on unit 4 was done with no consideration for horse skid trails. Consequently, as skidding proceeded into unit 4, skid trails had to be cleaned out and high stumps cut at groundline to prevent stump hangups.

Because of the small timber, a single horse sufficed for skidding. A log chain with a slip hook at one end for the log and a grab hook at the other end attached to the single tree was used to hook the logs. The landings for these units (3 and 4) were situated so as to minimize the necessity of clearing the road for traffic.

Although only one horse at a time was used for skidding, the operators had a relief horse, and horses were changed approximately every 2 hours. Generally, on a gross time basis, skidding was carried on for about 6 hours per day. One operator worked his horses from 7:00 a.m. until 3:00 p.m., with two half-hour rest periods and a one-hour lunch break. The other operator worked 8:30 a.m. until around 5:00 p.m., with variable rest and lunch breaks. On an 8-hour workday basis, horse skidding cost $77.52 per day or $12.48 per cunit.

Tractor Skidding

The tree felling operation for the tractor consisted of cutting the trees at ground level and pushing them uphill. Bucking that was necessary to meet legal load length was done on the truck rather than on the logging unit. (The hooking, bunching, skidding, unhooking, and landing operations were similar to the rubber-tired skidder operations.)

The tractor was a 25 hp John Deere Model 420, which is a fairly common size for light ranch work in the area. The operator was the same person who operated the rubber-tired skidder. Thus, it is reasonable to assume that the nonoperating functions would be closely comparable for both methods. Also, the differences in travel times should be free of operator performance differences. At a cost of $79.26 per day, the track skidding cost $15.70 per cunit.

STUDY RESULTS

Inventory of wood on the units prior to harvesting, measurement of material removed, and reinventory of the units after harvesting provide a basis for describing utilization, product recovery, and residue remaining.

Harvesting Statistics

Harvest volume is the total cubic volume skidded to the landing. Except for approximately 126 ft^3 of fuelwood left in a cold deck, all the material skidded to the landing was loaded out and hauled to a sawmill or post and pole plant. This material was classified as green or as dead. Table 4 shows the material removed from each unit, and material remaining as residue on the site. Figure 2 is a distant view of unit 4 (right) and unit 5. Figures 3 and 4 show closeups of residues on units 4 and 5, respectively.

Volumes of net usable material were determined from a computer program designed to calculate products and volumes from each piece loaded out. Three inspections at the log yard confirmed program reliability.

"Yard residue" refers to the amount of cull, or nonutilized material, hauled to the mill or post yard. Material removed from units 1 and 2 contained a large proportion of unutilizable material, according to the program. Much of this "yard residue" was disposed of as free firewood.

The residue removal ratio compares the volume of yard residue to total (logging plus yard) residues. A high ratio suggests a clean logging job. That is, logging residues have been carried to the yard. The difference is illustrated by the high product/residue ratio of 6.56 for unit 5.

Table 4.--*Volume removed and volume remaining after logging*

	1	2	3	4	5	Total
Area (acre)	1.13	1.57	1.54	1.65	1.50	7.39
HARVEST[1/] INVENTORY IN FT^3						
Live	4,678	2,381	4,851	858	2,390	
Dead	2,393	1,217	1,103	1,121	891	
Total	7,071	3,598	4,954	1,979	3,281	20,883
Product	3,006	1,588	3,073	1,694	2,847	12,208
Yard residue[2/]	4,065	2,010	1,881	285[3/]	434	8,675
Product/yard residue ratio	.74	.79	1.63	5.94	6.56	1.41
Average piece volume(ft^3)	4.73	4.51	4.53	5.76	4.89	
POSTHARVEST INVENTORY IN FT^3						
Logging residue	1,425	1,732	3,539	2,454	963[4/]	10,113
volume/acre-ft[3/]	1,261	1,103	1,102	1,487	642	1,315

[1/] Harvest volumes are based on total volume of individual pieces loaded onto the truck. Product volume is based on total volume of individual products derived from the material loaded onto the truck.

[2/] Yard residue = total harvest volume less product volume.

[3/] Material from unit 4 was to be delivered to a sawmill, while the material from the other four units went to a post and pole plant. Material from units 1, 2, and 3 were processed to highest value use.

[4/] Does not include a roadside deck of dead material containing approximately 126 ft^3. This material was left as fuelwood. The next summer practically all this material had been cut up and hauled away.

Figure 2.--Units 4 (right) and 5 after harvesting.

Figure 3.--Postharvest residues on unit 4.

Figure 4.--Postharvest residues on unit 5.

PRODUCT RECOVERY

Up to this point material utilized has been considered as a volume of usable wood. The following section considers the kinds of products that can be derived from this volume and type of wood.

Utilization Standards

This experimental sale originally specified utilization to a 2 1/2-inch minimum top diameter for green material. The specification was later changed to "logger's choice," which meant that the purchaser had the option of taking or leaving any of the dead material on the sale. For green material, whole-tree lengths were utilized up to the legal hauling length limit of 50 feet, with no minimum diameter. Dead trees had to be free of rot. Consequently, material that was on the ground prior to the falling operation was not removed.

The minimum piece length skidded was long enough to contain 2 or more products--2 houselogs, or 1 houselog and 1 studlog, etc. The primary length constraint was legal hauling length. Another consideration was the amount of rot in dead material.

Product specifications were as follows:

Product		*Min. small-end diameter*	*Min. length*
		(Inches)	*(Feet)*
Sawlog		12	8
Studlog		6	8
Houselog		8	12
Fencepost	1	6	7
	2	5	6
	3	4	6
	4	3	6
	5	2	5

Product recovery, in number of pieces and cubic volumes, is shown in table 5. Recovery is computerized, based on the length and diameters of the material loaded from each unit. Recovery is optimum because material is allocated to its most valuable end use. A sample estimate of the products at the plant site showed that the actual multiproduct recovery was as good as the programed recovery because of close tolerances in cutting out the products. For instance, some houselogs were actually a scant 8 inches in diameter and some 7-foot posts were 5 3/4 inches in diameter. It was not possible to get an accurate yard tally because products were mixed in the yard.

Recovery of larger, more valuable material was quite high--31 percent of total recovered volume--for the tree sizes involved. On the other hand, the large proportion of posts represents product recovery beyond what might be expected by a single product studlog operation. This table shows that the so-called unusable tops do have some use.

Table 5.--*Product recovery - number of pieces and volume in* ft^3

Unit	1	2	3	4	5	Total	
Product							
Saw log-number	1	3	2	3	2	11	
Houselog-number	66	36	81	30	64	277	
Studlog-number	350	154	356	196	257	1,313	
Number pieces, total	417	193	439	229	323	1,601	
Cubic volume, total	976	400	932	496	1,015	3,819	31%
Fencepost							
Class-1	34	26	14	5	7		
2	529	270	472	257	335		
3	680	395	643	370	404		
4	613	386	635	380	432		
5	632	359	558	240	375		
Number pieces	2,488	1,436	2,322	1,252	1,553	9,041	
Cubic volume	2,030	1,188	2,141	1,198	1,832	8,389	69%
Total pieces-product	2,905	1,629	2,661	1,481	1,876	10,642	
Total volume-product	3,006	1,588	3,073	1,694	2,847	12,208	
Pieces hauled	1,495	797	1,313	326	671	4,602	

Product specifications:

Saw log = 12-inch diameter × 8-foot length
Studlog = 6-inch diameter × 8-foot length
Houselog = 8-inch diameter × 12-foot length
Fencepost 1 = 6-inch diameter × 7-foot length
Fencepost 2 = 5-inch diameter × 6-foot length
Fencepost 3 = 4-inch diameter × 6-foot length
Fencepost 4 = 3-inch diameter × 6-foot length
Fencepost 5 = 2-inch diameter × 5-foot length

The number of pieces hauled from the woods was less than half (43 percent) the number of pieces finally derived from the material. This indicates how whole-tree logging can reduce handling costs. Whole-tree logging also permits efficient product choices, which improves product values. Conversely, multiproduct utilization permits full-tree logging, which reduces handling costs up to the product-bucking operation.

Residue Utilization Analysis

As defined earlier, residues are any unused wood materials. Harvest residues are slash. Yard residues are the residues left in the post yard. In the fall of 1973, post demand was high. The incremental cost of handling yard residues might be considered as the additional cost incurred to assure maximum material recovery.

The total product/yard residue ratio indicates the proportion of all the material hauled from the logging site that was usable. Conversely, the reciprocal of the ratio indicates the proportion of the hauled material that was yard residue. Total logging residue was only slightly higher than the total yard residue. This indicates that about 46 percent of all the residues generated on all five units was hauled away.

HARVESTING PRODUCTION ANALYSIS

Regression Analysis

Harvesting production was analyzed using regression analysis of important variables. Time was the dependent variable. The different independent variables were number of pieces per turn, skidding distance, and volume per turn. A prediction equation is of the form

$$Y = b_o + b_1X$$

Where b_o is the intercept and b_1 is the slope of the line. Table 6 shows the regression coefficients, b_o and b_1, R^2 and the F-statistic for all three skidding methods. R^2 indicates how important the specific independent variable is in explaining the variation of the equation. The F-statistic was used to test the significance of the regression.

Cases where the regression is not significant indicate that the data do not fit a straight line, or that there is no relationship between the variables compared in that instance. Scatterplots of the data were examined in these nonsignificant cases. The independent variable did not appear to affect the dependent variable, time.

Table 6 shows that distance has very little effect on travel time in and out. In this study the range of distances was too limited. However, it does appear that distance affects travel time more for the skidder and tractor than for the horse. Number of pieces per turn had more effect on hook time for the skidder and tractor than for the horse. (This is partially explained by the fact that the horse crew had a helper getting the next drag ready for hooking.) Roundtrip time is more dependent on volume per turn for the skidder and tractor than for horse skidding.

Table 6.--*Prediction equation regression coefficients, R^2, and F for skidding production*

Dep. var. Y	X	Skidder				Horse				Tractor			
		b_o	b_1	R^2	F	b_o	b_1	R^2	F	b_o	b_1	R^2	F
Time out	Dist.	1.38	0.006	0.22	43.1*	1.34	0.001	0.05	4.5*	1.63	0.006	0.21	18.5*
Time in	Dist.	1.06	.006	.22	44.8*	.78	.006	.17	16.8*	1.24	.008	.20	17.0*
Time in	NP	2.24	.02	.005	.81	1.55	.07	.02	2.0	2.42	.08	.04	3.1
Hook time	NP	1.05	.54	.35	83.9*	1.50	.14	.18	17.7*	.31	.62	.72	175.2*
Unhook time	NP	1.12	.06	.03	4.8*	.27	.04	.11	9.4*	.58	.15	.28	26.0*
RT time	NP	10.8	.60	.16	30.6*	7.46	.23	.08	7.4*	6.63	1.3	.58	95.0*
RT time	vol/turn	11.5	.12	.15	27.8*	7.63	.04	.07	6.2*	7.11	.28	.56	85.3*

$Y = b_o + b_1X$

* indicates significance at 0.05 probability level

RT = round trip

NP = number of pieces

Multiple regressions were also run on the data, with round trip time as the dependent variable and various combinations of distance, number of pieces, volume per piece and volume per turn as the independent variables. The equations are of the form:

$$Y = b_o + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4$$

The results are summarized in table 7. All regressions are significant at the 0.05 probability level.

Table 7.--*Multiple regression intercepts, coefficients,* R^2 *and F-statistic for skidding production*[1/]

b_o	b_1	b_2	b_3	b_4	R^2	F
Intercept	*Distance*	*No. Pcs*	*Pc Vol*	*Turn Vol*		
		SKIDDER				
4.08	0.02	0.61			0.32	54.0*
-13.85	.02	.45	4.33		.40	49.3*
3.82	.02			0.14	.37	66.2*
		HORSE				
4.19	.02	.16			.29	20.1*
2.57	.02	.14	.33		.31	14.4*
4.03	.02			.04	.30	21.6*
		TRACTOR				
.41	.03	1.2			.70	78.8*
31.97	.03	1.2	-6.84		.71	54.9*
.53	.03			.26	.68	72.8*

1/ Subscripts refer to following variables:
0 - intercept
1 - distance
2 = number of pieces per turn
3 = volume per piece
4 = volume per turn

* Indicates significance at 0.05 probability level

Using R^2 as a measure of reliability, table 7 suggests:

1. multiple regression does not improve the reliability of prediction equations;

2. although the reliability of the prediction equation for the rubber-tired skidder and horse is quite low, it is high for the tractor skidder.

Table 8.--*Average times for logging tasks and character of average turn (TOT = total operating time) (RTT = Round trip time)*

	Skidding Method								
	Skidder			Horse			Tractor		
Element (task)	Minutes	% of TOT	% of RTT	Minutes	% of TOT	% of RTT	Minutes	% of TOT	% of RTT
Time out	2.8	14.0	15.8	1.5	18.1	18.1	3.3	12.4	14.7
Time in	2.5	12.5	14.1	1.8	21.7	21.7	3.4	12.8	15.1
Hook time	7.2	36.1	40.7	2.0	24.1	24.1	7.8	29.3	34.7
Bunch time	3.3	16.5	18.6	2.6	31.3	31.3	5.6	21.1	24.9
Unhook time	1.9	9.5	10.7	.4	4.8	4.8	2.4	9.0	10.7
Round-trip time	17.7	--		8.3	--		22.5	--	
Landing time	2.0	10.0		.0	.0		3.7	13.9	
Total Operating time	20.0			8.3			26.6		
Turn character									
No pc/turn		11.5			3.7			12.1	
Dist. (ft)		254.0			164.0			260.0	
Slope (%)		19.0			22.0			21.0	
Production									
Pc/8 h		168.0			125.0			112.0	
$Vol/8h\text{-}ft^3$		795.0			621.0			505.0	

Table 8 presents the average times for separate logging tasks and character of the average turn for different skidding methods. The effect of labor can be estimated by comparing the labor-intensive tasks--hook time and unhook time. Because bunching time is part of the hooking process for horse skidding, it is necessary to include bunching for the skidder and tractor skidding for comparative purposes. The percent of round trip time, which excludes landing time, was:

	Skidder	*Horse*	*Tractor*
	(Percent)		
Hook time	40.7	24.1	34.7
Bunch time	18.6	31.3	24.9
Unhook time	10.7	4.8	10.7
Total	70.0	60.2	70.3

The total percentage of round trip time was as expected. That is, horse skidding ought to be lower than for the other skidding methods. The average number of pieces per turn explains this--3.7 for pieces horse skidding, 11.5 pieces for the skidder, and 12.1 pieces for the tractor.

Table 9 shows a production comparison on an 8-hour shift basis. Because the shift hours were not the same for all three skidding methods, the gross shift production is presented on an assumed 8-hour shift. Because horse skidding had no landing time, this will tend to distort horse skidding production time. This distortion is eliminated by including the column headed "% of # RTT", which is percent of round trip time, excluding landing time, for all three skidding methods.

Table 9.--*Production summary*

Item	Skidding Method: Skidder	Horse	Tractor
Residue vol./acre-ft^3	908	1,487	1,103
Product vol./acre-ft^3	1,125	726	757
Post material-% total product vol.	66	71	75
Man-days/acre	6.8	9.7	6.9
% of skidder	100	143	101
No. pcs/8 h day	168	125	112
% of skidder	100	74	67
Vol./8 h day-Cunit	7.95	6.21	5.05
% of skidder	100	78	64
Skidding Cost/cunit-$	10.18	12.48	15.70
% of skidder	100	123	154

CONCLUSIONS

Residue Reduction

Table 9 summarizes the study data. Although the top of table 9 is related to utilization standards rather than skidding methods, it shows the residue volumes that resulted. Assuming that the post material would probably be logging slash on a conventional harvest, at least 66 percent of the total products removed from the area would have been slash. Or, through increased utilization the logging residues were reduced to one-third or one-half times what might have been left. Logging residues have been reduced further because of the treetops hauled from the logging site, much of which became yard residues. Tables 2 and 4 show:

Initial Volume		36,754 (table 2)
Standing	15,674	
Down	21,080	
Volume removed		20,883 (table 4)
Products	12,208	
Yard residue	8,675	

The additional 8,675 ft^3 of material removed that was unsuited for solid wood products represents 24 percent of the total initial volume or 42 percent of the total material removed. The value of this material depends upon local markets. At the time of the study the post market was very good. Some of the material classed as unusable was used for small, electric-wire fenceposts and small, class 5 fenceposts. A large part of the material was disposed of as free firewood. During periods of tight chip supplies, the material could be chipped.

Effect of Skidding Variables

Based on the b_1 coefficient listed in table 6, the following observations can be stated:

1. The rubber-tired skidder was underutilized. That is, the b_1 coefficient is the same for both directions of travel, emptied out and loaded in. Also, the number of pieces per turn had less effect on travel time in for the skidder than for either of the other two skidding methods. The average number of pieces per turn for the skidder was 3 times more than for the horse and almost equal to the number for tractor skidding.

2. The horse was utilized well because of the difference in b_1 coefficient for time out (0.1 min) versus time in (0.6 min), per hundred feet of skidding distance.

There was no appreciable difference for steepness of skidding, except the upper portion of unit 3, to permit any comparison of grade effect on skid time.

Capital Investment and Production Efficiency

An important part of this study was to determine the capital investment levels to achieve different production levels. As it turned out, there were only two different levels of investment. Production levels, as measured by number of pieces skidded per day or cubic volume skidded per day, varied considerably. Table 10 is derived from table 8 and cost determinations in the appendix.

Table 10 shows:

For horse skidding,
60 percent of investment for skidder will produce
74 percent as many pieces per day or
78 percent of the daily volume for the skidder.

For the small farm tractor,
60 percent of investment for skidder will produce
67 percent as many pieces per day, or
64 percent of the daily volume for the skidder.

Table 10.--*Production and capital investment comparisons*

	Method		
	Skidder	Horse	Tractor
No. pieces/day	168	125	112
% of skidder	100	74	67
Cubic feet/day	795	621	505
% of skidder	100	78	64
Investment (dollars)	2,500	1,500	1,500
% of skidder	100	60	60

It is apparent that, based on this case study, the capital invested for skidding horses is more efficient than either of the other two skidding methods. Also, on a cost per cubic volume skidded, the horse is more efficient than the farm tractor. Although it is beyond the scope of this study, alternative uses for the tractor could very well make it the better choice.

Land Management Implications

1. Logging slash can be reduced considerably through logging procedures and utilization standards that require removal of small roundwood products. In fact, the slash disposal costs were minimal. Pile-and-burn along the road was the only slash abatement work done.

2. For processing plants where this material can be used for pulp chips and fuel, the yard residues can be utilized by machine-debarking the chips. Further studies on utilization economics of this material are needed to more fully evaluate the impact on land management possibilities.

3. An economical system for operating in this type of stand--stagnant growing stock size--would certainly help to get similar stands under management. The Rocky Mountain area has considerable acreage in this condition.

Product Recovered

The product recovered is greatly dependent upon the piece diameter and length. Bucking out rot reduced product options and values.

Slash volume studies in Engelmann spruce stands show a 50 percent product recovery in saw log operations. This is in higher value material with normal utilization standards. Hence, it is apparent that a recovery of 12,208 ft^3, or 33 percent of total initial volume, is a reasonably good recovery in these stands perceived to be marginally inoperable. When considering the yard residues, the total volume removed, 20,883 ft^3, amounts to 57 percent of the initial volume.

APPENDIX

Operating Costs

The appendix shows how operating costs were determined. The machine costs have been based on values of used machines, while the horses were considered as young horses.

The machines are smaller than might normally be available. Also, these machines, while doing the job efficiently, were well past their normally depreciable life span. Their replacement cost would certainly be much higher than the listed purchase price. Yet, it is unlikely that a new machine would we used on this type of logging chance. Hence, the listed purchase price relates to the market values of the machines when the study was undertaken.

The horses were priced at their current age value. It is assumed that this sort of work would be limited to mature, vigorous animals that bring high prices.

SKIDDER OPERATING COST

Model 15 Garrett Tree Farmer (1965)

Purchase Price $2,500

Useful Life 5 years

Depreciation	$500/yr with zero resale. $55.56/month @ 9 month/yr $2.65/day @ 21 days/month	$2.65
Interest, Insurance, and Tax = 10% AAI		
	$1,250 x 10% = $125.00 = 70¢/day	.70
Tires = $500/year = 265/day		2.65
Maintenance & Repair = $550/year = $2.91/day		2.91
Operator @ 8.00/hour = $72.00/day		72.00
	Total Daily Cost	$80.91

HORSE OPERATING COST

Purchase price $750/horse, $1,500.00

Useful Life 4 years

Depreciation = $375/yr = $1.98/day		$1.98
Upkeep 1 horse		
426/6 month working	$606/yr	
180/6 month nonwork	$3.21/day	6.42
Shoes = $96/yr - 51¢/day		1.02
Harness = $250/yr = $1.32/day		2.64
Vet Service = $150/yr or $200/2 horses		1.06
Tax, Interest, Insurance = AAI x 10%		
$740 x 10% = 40¢		.40
Teamster $8.00/hr		64.00
	Total Daily Cost	$77.52

TRACTOR OPERATING COST

John Deere 420-23.5 hp 1956
$1,500 resale value

Useful life 5 years.

Depreciation $300/yr = $1.59/day		$ 1.59
Interest, Insurance, and Tax AAI x 10%		
$750 x 10% = $75.00		.40
Maintenance & Repair		
$600/yr		3.17
fuel		2.10
Operator		72.00
	Total Daily Cost	$79.26

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Host, John, and Joyce Schlieter.
1978. Low-cost harvesting systems for intensive utilization in small-stem lodgepole pine stands. USDA For. Serv. Res. Pap. INT-201, 20 p. Intermountain Forest and Range Experiment Station, Ogden, Utah 84401.

Three different skidding methods--small rubber-tired skidder, horse, small tracked tractor--were compared in an overmature lodgepole pine stand in Montana.

KEYWORDS: timber harvesting, log skidding, lodgepole pine utilization.

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