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PRODUCTIVITY OF A LARGE-WHEELED SKIDDER AND ROLLER CHOPPER FOR PREPARING SITES

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The demand for wood for fiber and energy uses continues to increase. From 1976 to the year 2030, total wood consumption in the United States is expected to increase from 166 million cords (602 million m^3) to 358 million cords (1,298 million m^3) (Venuto 1980).

In 1979 Wisconsin was the leading paper-producing State in the Nation with an output of approximately 3.6 million tons or about 12 percent of the United States production (Skinner 1981). To meet its pulp and paper mill requirements, Wisconsin imports about 40 percent of the softwood pulpwood and 86 percent of the softwood residues from other States and Canada (table 1). The shortage of conifers and the escalation of conifer stumpage prices are providing increasing incentive to both public and private landowners in Wisconsin to convert poor quality hardwood stands to conifers.

An essential step in converting these hardwood stands is preparation of the site to reduce the amount and vigor of competing vegetation and to allow adequate survival and growth of the planted conifers (Burns and Hebb 1972, Knighton 1972, and Trevison 1977). Site preparation may include: (1) mechanical methods such as chopping, shredding, root raking, dozing, discing, tilling, etc.; (2) chemical methods using herbicides to kill competing trees and plants; or (3) prescribed burning. To develop economical and biologically feasible site preparation techniques or systems, cost and productivity information must be determined for the machines and the methods presently being used together with descriptions of the sites being treated. But documented data indicating the effectiveness of such machines and systems is generally lacking. In an effort to provide needed documentation, we studied the cost, productivity, and soil compaction of a large-wheeled skidder and roller chopper used to prepare a mixed hardwood site in Wisconsin.

Table 1.—*1979 Wisconsin pulpwood situation*

Raw material	Production	Exports	Imports	Mill receipts	Imports as percentage of mill receipts[1]
	Rough stand cords				*Percent*
Softwood	506,148	15,381	326,891	817,658	40
Hardwood	1,343,278	26,259	409,076	1,726,095	24
Softwood residue	48,523	2,588	285,920	331,855	86
Hardwood residue	210,723	40,644	21,485	191,564	11
TOTAL	2,108,672	84,872	1,043,372	3,067,172	34

Source: Wisconsin Wood Marketing Bulletin, Wisconsin Department of Natural Resources, Madison, Wisconsin 53711, February 1981.

[1]Calculated by Edwin S. Miyata and Helmuth M. Steinhilb.

TECHNICAL INFORMATION OF EQUIPMENT USED

Equipment used on this project was a Pettibone[1] master 1500 skidder pulling a Fleco Corporation Model SS812 single drum roller chopper (fig. 1).

The Pettibone Master 1500 skidder was equipped with a Carco F-50PS rear, frame-mounted winch with a maximum line pull of 50,000 pounds (22,680 kg) and line speeds from 100 to 400 fpm (30.5 to 121.9 m in). The skidder had a four-speed powershift transmission, four-wheel pivoted power steering, and a Detroit Diesel 6V92 N75 engine developing 255 hp at 2,100 rpm.

The roller chopper drum was 5 feet (1.52 m) in diameter, 8 feet (2.44 m) wide, and was equipped with 12 straight cutting blades—each 3/4 inch (1.9 cm) thick, 10 inches (25.4 cm) deep, and 8 feet (2.44 m) long—equally spaced around the circumference. Weight of the roller chopper and hitch was 14,090 pounds (6,391 kg) empty and 22,420 pounds (10,170 kg) when filled with 1,000 gallons (3,785 l) of water. Detailed specifications of the Pettibone Master 1500 skidder are given in Appendix A. The hitch connecting the roller chopper to the skidder allowed both vertical and horizontal movement of the roller chopper (fig. 2).

The list prices of the skidder and roller chopper were $136,620 and $20,990, respectively, including extra attachments.

FIELD TESTING

In May 1981, personnel from the USDA Forest Service's Forestry Sciences Laboratory, Houghton, Michigan, working in cooperation with Consolidated Papers, Inc., Rhinelander, Wisconsin, and Michigan Technological University, Houghton, Michigan, field tested the skidder and roller chopper. Detailed time studies were conducted to evaluate equipment cost, productivity, and effectiveness for site preparation. The treated area also was analyzed for soil compaction.

[1]*The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. It does not constitute an official endorsement or approval of any product or service by the United States Department of Agriculture to the exclusion of others which may be suitable.*

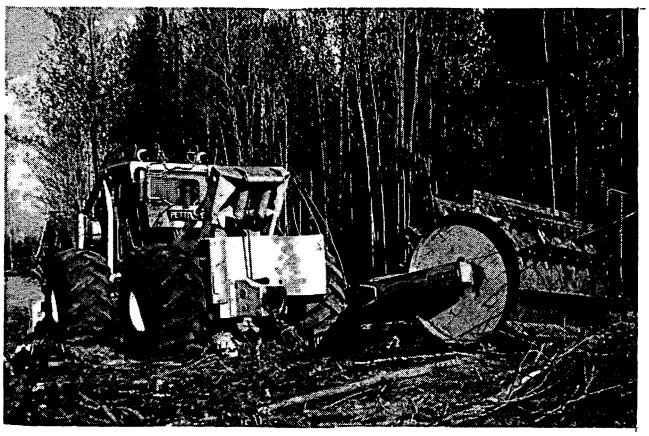

Figure 1.—*Pettibone Master 1500 skidder and Fleco Corporation Model SS812 single drum roller chopper.*

The study area was 5 miles northeast of Rhinelander, Wisconsin. The topography was flat to gently rolling with slopes averaging about 7 percent and maximum slopes not exceeding 25 percent. The soil was a well drained loamy sand. The area roller chopped was 23.4 acres (9.47 ha).

Just prior to site preparation, the light, scattered stand of aspen, red maple, red oak, and white and red pine was logged for pulpwood and a few pine saw logs. The stand remaining after logging contained about 700 trees per acre (1,730 trees per ha) with an average d.b.h. of 2 inches (5.08 cm) and a basal area of 15 square feet per acre (3.44 m^2/ha) (fig. 3).

RESULTS

The productive time of the skidder and roller chopper included the elements (1) "chopping"—the forward motion of the skidder and roller chopper; and (2) "back up"—the reverse movement of the machine

Figure 2.—*Hitch connecting skidder to roller chopper.*

Figure 3.—*Appearance of the study area before roller chopping.*

to maneuver on turns and slopes; and amounted to 12.19 productive hours to treat the 23.4 acres (9.47 ha) as shown below:

Time element	Hours	
Chopping	11.54	
Back up	0.65	
Productive time		12.19
Delays	7.28	
Total time		19.47

The delays in roller chopping were classified as either (1) mechanical—caused by malfunction, breakage, or maintenance of the machine; or (2) nonmechanical—those unrelated to mechanical problems or maintenance and are shown below:

	Hours	Percent
Mechanical delays		
Overheating	2.26	31
Repair or check	1.13	16
Loose winch	.23	3
Fueling	.25	3
Nonmechanical delays		
Personal (Wait for mechanic, get instructions)	2.23	31
Stuck	.28	4
Clear branches	.09	1
Other (Includes warmup and travel to site	.81	11
TOTAL	7.28	100

Fifty-three percent of the delay time was due to the mechanical category and 47 percent to nonmechanical. The skidder had overheating problems that made it necessary to periodically stop the machine and allow it to cool. Because of the limited time of the study, we did not make a detailed analysis of nonproductive time.

Production rate of site preparation was as follows:

Total area treated	23.4 acres (9.47 ha)
Average width of swath	8 feet (2.44 m)
Total productive time	12.19 hours (PH)
Total scheduled time	19.47 hours (SH)
Productivity (based on PH)	1.92 acres/PH (0.78 ha)
Productivity (based on SH)	1.20 acres/SH (0.49 ha)
Operator time, including travel, maintenance, etc.	25 hours

Estimated machine cost was $61.44 per productive hour for the skidder and $3.63 per productive hour for the roller chopper. Calculated machine rates, method of calculation, and assumptions used for each machine are shown in Appendix B.

Cost per acre for roller chopping is estimated as:

	Total cost	Cost per acre
Skidder cost ($61.44/hr x 12.19 PH)	$ 748.95	$32.01
Roller chopper cost ($3.63/hr x 12.19 PH)	44.25	1.89
Operator cost (25 hr x $9.00/hr)	225.00	9.62
TOTAL	$1,018.20	$43.52

Noise levels were measured with a General Radio Noisemeter, Model 1563. Inside the skidder cab with the windows open the noise level was from 90 to 97 decibels with the machine working and 82 decibels when idling. It is recommended the operator wear protective ear plugs.

Overall, the machine was effective in reducing the small trees and slash (fig. 4). The green stems of aspen, balsam, spruce, and red maple up to 4.5 inches (11.4 cm) in diameter were chopped into pieces if the long axis of the stems was oriented parallel to the travel path of the machine (fig. 5A). Any other orientation decreased the effectiveness of chopping (fig. 5B).

SOIL COMPACTION ANALYSIS

Five randomly located soil samples were taken before and after the roller chopping to evaluate onsite surface soil compaction (Blake 1965). Samples

Figure 4.—*Appearance of the study area after roller chopping.*

Figure 5A.—*Green stems of trees up to 4.5 inches in diameter were chopped into pieces by the roller chopper when their long axis was oriented parallel to the machine's travel path.*

Figure 5B.—*When pieces were not oriented parallel to the machine's travel path, they were not chopped.*

were obtained by digging a hole approximately 7.87 in. (20 cm) in diameter by 11.8 in. (30 cm) deep. Soil bulk density was measured by placing a flexible plastic liner in the hole and pouring water into it to determine the volume of each sample. Soil samples were dried at 221°F (105°C) to a constant weight in the laboratory to determine dry weight and moisture content. Two additional soil samples were taken to determine particle size distribution by the hydrometer method (Day 1965). Soil data were analyzed statistically by a one-way analysis of variance plus covariance using the F-test for significance (Sokal and Rohlf 1969).

The soil on the area was classified as a loamy sand averaging 80 percent sand, 16 percent silt, and 4 percent clay. The average soil moisture content averaged 22 percent. Bulk density values in the surface soil were not found to be significantly lower following roller chopping treatment—they averaged 1.17 g/cc after treatment versus 1.01 g/cc before treatment. However, use of analysis of covariance showed moisture content of the soil to be significant (0.01 level) in describing differences in treatment bulk densities with higher bulk densities being associated with higher moisture content.

This finding suggests that roller chopping on sites with higher soil moisture may cause increased compaction. Future study should be aimed at determining the critical soil moisture level for roller chopping on various textured soils to avoid excessive compaction.

Roller chopping was also observed to bring logging slash into contact with mineral soil. This contact could speed decay and result in accelerated nutrient release from slash, which could be beneficial to regeneration.

DISCUSSION

The average speed of the machine while traveling forward and actually roller chopping was 242 feet per minute (73.76 m in) with a standard deviation of 46 feet per minute (14.07 m in). The speed ranged from 166 feet per minute (50.60 m in) to 353 feet per minute (107.59 m in). Based on the average traveling speed on this site, we estimated the machine could have chopped an average of 2.67 acres per hour (1.08 ha/hour). However, the actual production was 1.92 acres per hour (0.78 ha/hour) or approximately 72 percent of the estimated production. This is because the machine was not constantly going forward but had to spend some time backing up to make turns or maneuver on slopes. Using the

same estimated 72 percent efficiency, the machine *theoretically* could have treated approximately 3 acres per hour (1.21 ha/hour), based on the fastest speed on this site. Higher productivity results in lower machine cost per acre and the costs per acre would be substantially lower at the faster machine speeds:

Productivity Acres per hour	Machine cost per acre excluding labor
1.92 (this study)	$33.90
2.50	$26.03
3.00	$21.69

CONCLUSIONS

1. The Pettibone Master 1500 skidder and Fleco SS812 roller chopper satisfactorily prepared the site for field planting at an acceptable cost per acre and without excessively compacting the soil.
2. The machine actually treated about 2 acres per productive hour. The speed capabilities of the machine suggest that productivity could increase to between 2.5 and 3.5 acres per hour (1.01 to 1.42 ha/hour) with a proportionate reduction in cost per acre or per hectare.
3. This work reports on only one case study. Further study should be done on different sites after roller chopping to determine the effect of the treatment on planting costs, the development of competing vegetation, the need for further plantation release, and plantation survival and growth.

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APPENDIX A
DETAILED SPECIFICATIONS FOR PETTIBONE MASTER 1500 SKIDDER

MANUFACTURER: Pettibone Corporation
FUNCTION: Skidder

FEATURES: 4 speed powershift transmission. 4 wheel drive. 4 metal pivoted power steering.

SPECIFICATIONS: *Power Unit & Train:* Detroil Diesel 6V92 N75 engine. 255 HP @ 2100 rpm. Displacement 522 in^3 (9046 cc). Power shift transmission. 4 speeds. Torque converter. Travel speeds (fwd & rev): 1st 1.6 mph (2.57 kph), 4th 12.2 mph (19.62 kph).

Operating Information: Brakes: service disc type, parking internal expanding. Steering: hydraulic power articulated frame 40° each way. Fuel capacity: 70 gal (265 l). Dimensions: length (less blade) 22′ 2″ (6.76 m), wheel base 10′ 8″ (3.25 m), height 10′ 3″ (3.12 m), width 10′ 3″ (3.12 m), clearance 21″ (53 cm). Oscillation: 11° each side of center.

Winch: Carco F-50PS mounted on rear frame. Cable capacity: 7/8 inch (2.2 cm) x 255 ft (77.7 m). Max line pull: 50,000 lb (22,680 kg). Line speeds: 100 to 400 fpm (30.5 to 121.9 m).

Hydraulics: 2 commercial shearing pumps. 46 gpm (174 lmp) @ 2,100 rpm & 1,500 psi (105.5 kg/cm^2)

Electrical: 12 V system.

Tires: 26.5–25 x 16 PR Loggers Special.

APPENDIX B CALCULATION OF THE HOURLY MACHINE RATES

Roller Chopper Machine Rate

Description

Manufacturer Fleco Model SS812 H.P —

Purchase Cost: $ 20,990.00

Less: Tire Cost - $ ---

Total Initial Investment (P) $20,990.00

Salvage Value (S) (20 % of P)

Estimated Life (n) 10 years

Working Days/Year 250 days

Scheduled Hours/Year (SH) 2,000 SH

Utilization (U) 70 %

Productive Hours/Year (PHG) 1,400 PH

Average Value of Investment (AVI) = $\frac{(P - S)(n + 1)}{2n} + S$ $13,433.60/yr

II. Fixed Cost

Depreciation (D) $\frac{P - S}{n}$ $ 1,679.20/yr

Interest 18 %
Insurance 3 %
Taxes 3 %

Total 24 % X (AVI = $ 13,433.60 /yr) $ 3,224.06/yr
Total fixed cost per year $ 4,903.26/yr
fixed cost per SH $ 2.45/SH
fixed cost per PH (A)* $ 3.50/PH

III. Operating Cost

Maintenance and Repair (10 % of $\frac{(P - S)}{n \times PH}$ $ 0.12/PH

Fuel Cost $ --- /PH
Oil and Lubricants $ 0.01/PH
Tires + $\frac{1.15 \times \text{tire price}}{\text{Total tire life in hours (miles)}}$ $ --- /PH

TOTAL OPERATING COST PER PH (B)* $ 0.13/PH

*Machine Rate per PH (A + B) $ 3.63/PH

Large-Wheeled Skidder Machine Rate

Description

Manufacturer Pettibone Model Master 1500 H.P 255

Purchase Cost: $ 136,620.00

Less: Tire Cost - $ 6,400 @ $1,600 ea.

Total Initial Investment (P) $130,220.00

Salvage Value (S) (20 % of P)

Estimated Life (n) 5 years

Working Days/Year 250 days

Scheduled Hours/Year (SH) 2,000 SH

Utilization (U) 67 %

Productive Hours/Year (PHG) 1,340 PH

Average Value of Investment (AVI) = $\frac{(P - S)(n + 1)}{2n} + S$ $88,549.60/yr

II. Fixed Cost

Depreciation (D) $\frac{P - S}{n}$ $20,835.20/yr

Interest 18 %
Insurance 3 %
Taxes 3 %

Total 24 % X (AVI = $ 88,549.60 /yr) $21,251.90/yr
Total fixed cost per year $42,087.10/yr
fixed cost per SH $ 21.04/SH
fixed cost per PH (A)* $ 31.41/PH

III. Operating Cost

Maintenance and Repair (50 % of $\frac{(P - S)}{n \times PH}$ $ 7.77/PH

Fuel Cost = 0.037 X HP X 1.50/gal $ 14.15/PH
Oil and Lubricants (40% of fuel cost) $ 5.66/PH
Tires + $\frac{1.15 \times \text{tire price}}{\text{Total tire life in hours (miles)(3,000)}}$ $ 2.45/PH

TOTAL OPERATING COST PER PH (B)* $ 30.03/PH

*Machine Rate per PH (A + B) $ 61.44/PH

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Productivity of a large-wheeled skidder and roller chopper for preparing sites. Res. Pap. 238. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1983. 8p.

Discusses the results of a field test of a Pettibone Master 1500 skidder and Fleco Corporation SS812 roller chopper for site preparation work in Wisconsin. Includes cost, productivity, and effectiveness of site preparation on 23.4 acres (9.47 ha).

KEY WORDS: Species conversion, hardwoods, conifers, costs, production, effectiveness.