Small Tractors for Harvesting Fuelwood in Low-Volume Small-Diameter Hardwood Stands[1]

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Abstract: Much of the nonindustrial, private forest land in the Northeast is characterized by small diameter trees with low volume. Conventional harvesting systems used in logging these stands generally result in submarginal economic returns. Often, small-scale harvesting systems have economic advantages in these areas. Time and motion studies were conducted for several small tractors over a range of silvicultural treatments to estimate preliminary cycle times and production rates. Further research is progressing to incorporate this and additional simulation results into a generalized stump-to-mill logging cost, estimating computer package.

Keywords: logging, time studies, production rates

As more and increasing demands are placed on forested lands for timber production, wildlife, esthetics, recreation, hunting, fishing, and other uses, owners of small woodlots are looking for creative ways to harvest or treat the stands to accomplish their objectives. Much nonindustrial, private forest (NIPF) land is characterized by small diameter trees with low volume. Harvests or treatments in these low diameter/volume stands generally result in submarginal economic returns. The increased demands on NIPF owners with small holdings, coupled with small tree diameters and low volumes per acre, present a serious challenge to the logging manager. Often, small-scale harvesting systems have economic applications in these areas.

A series of time and motion studies has been conducted on small-scale logging operations in the Northeast. Several small tractors were studied in a wide range of silvicultural treatments and operating conditions. Specifically, the small tractors included the Pasquali 933, a Holder A60 F, a Forest Ant Forwarder (Skogsmyran),[3a] Massey-Ferguson, and a Same Minitaurus.[3] This paper summarizes the machine attributes, terrain operating conditions, and preliminary cycle time and production results.

MACHINE ATTRIBUTES AND HARVESTING PROCEDURES

The Massey-Ferguson 184-4 farm tractor and the Same tractor were the primary skidding units used in two distinct firewood businesses in northwestern Vermont. The firewood was produced from nonindustrial private forests and was marketed in the local area.

The Holder A60 F, Pasquali 993, and Forest Ant (Skogsmyram) were skidding units selected for testing small tractors harvesting in low-quality small-diameter hardwoods stands in southeastern New York State. This was part of a fuelwood forestry project funded in part by the New York State Energy Research Development Authority (NYSERDA). Firewood and pulpwood were produced from State forest land and marketed in the local area.

The Massey-Ferguson 184-4, a four-wheel drive 60-horsepower diesel farm tractor, was equipped with a JL-456 Farmi winch (fig. 1). The Model 456 Farmi winch, designed for 50- to 120-horsepower, has a line-pull rating of 10,000 pounds with 165 feet of 1/2-inch cable. The tractor was equipped with chains on the rear wheels, extra weights for the front end, and calcium chloride added to both front and rear tires. No roll-over protection was placed on the tractor. To add additional weight and to pile logs at the landing, a bucket loader was attached later in the test.

The Same Minitaurus, a 60-horsepower, four-wheel drive farm tractor manufactured in Italy, was equipped with a JL-30 Farmi winch with a line pulling capacity of 6,600 pounds and a drum capacity of 165 feet of 3/8-inch cable. The tractor was equipped with chains on the rear wheels and calcium chloride loaded in the rear tires. Extra weights were added to the front, along with a bucket loader for added weight and for decking logs at the landing. The tractor had roll-over protection bars, but no safety cage (fig. 2).

The Holder, manufactured in West Germany, was an articulated, 48-horsepower diesel tractor. It was equipped with an Igland 3000 double-drum winch with a rated pulling capacity of 6,600 pounds. The accessory equipment included a dozer blade, a rear butt plate, front-wheel weights, and front tires weighted with calcium chloride. The tractor had a roll-over protection cage and underbody protection pan (fig. 3).

The Pasquali, manufactured in Italy, was an articulated frame, 30-horsepower diesel tractor. It was designed for small acreage farms, hobby farmers, landscapers, nurseries, and a second tractor for a "Big Tractor" farm. The tractor was equipped with a JL-25 single-drum Farmi winch with a pulling capacity of 5,500 pounds (fig. 4). The accessory skidding equipment included a protective roll bar, underbody protection pan, front bucket loader, and weighted front tires.

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[3] The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture or the Forest Service of any product or service to the exclusion of others that may be suitable.

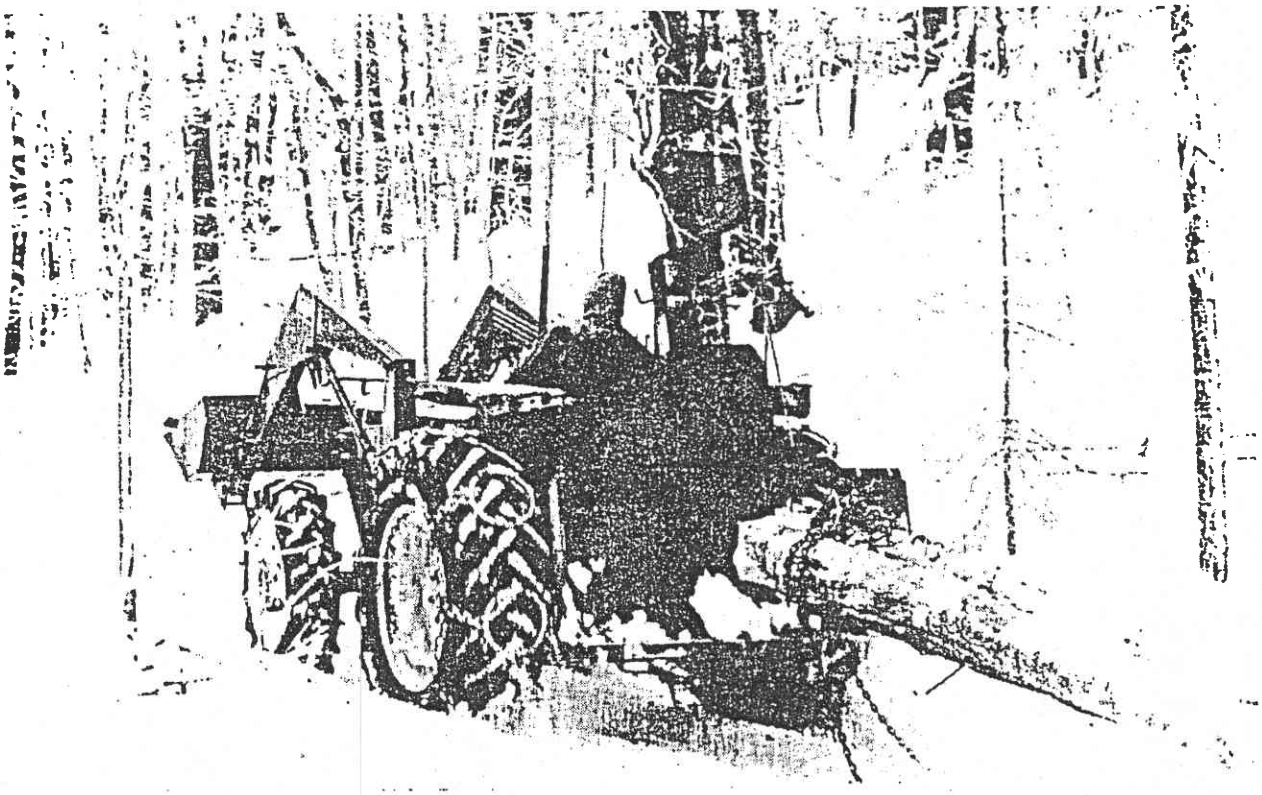

Figure 1--The Massey-Ferguson 184-4 equipped with JL-456 winch.

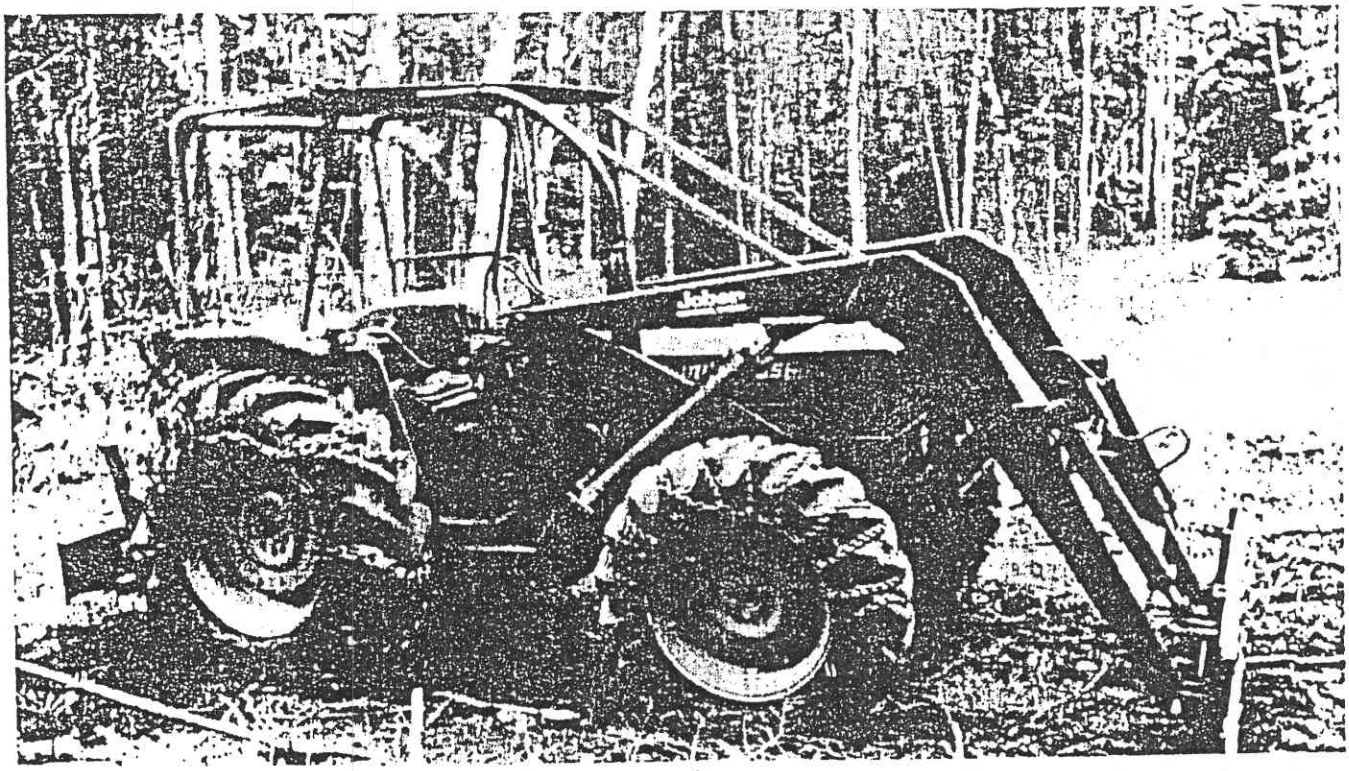

Figure 2--The Same Minitaurus with JL-30 winch, roll-over protection bars, and bucket loader.

Figure 3--The Holder A60 F equipped with an Igland Jones double-drum winch and roll-over protection.

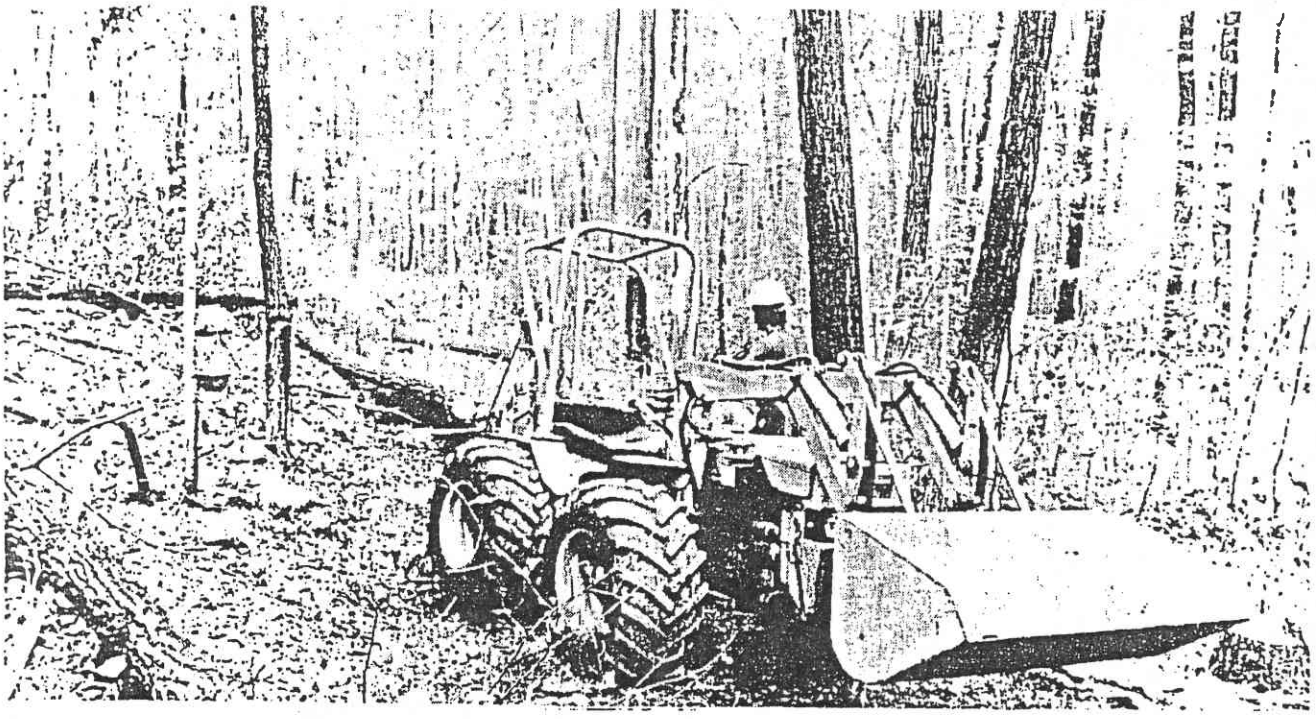

Figure 4--The Pasquali Model 993 with bucket, roll-over protection, and JL-25 single-drum winch.

The Forest Ant, manufactured in Sweden, was designed for gathering and forwarding small softwood loads to the main skid trails. The machine is an articulated tractor with a 12-horsepower, air-cooled engine. It was equipped with a clam bunk and knuckleboom loader with jaw-type grapple. The tractor steering and speed were controlled by a tiller bar in front. The machine had no cab and the operator walked at a comfortable speed with the machine following. There was a "dead man" control on the end of the tiller handle which stopped the machine when the tiller bar was released (fig. 5).

CHARACTERISTICS OF THE STUDY SITES

The study areas for the Massey-Ferguson and Same tractors were on low-quality hardwood stands marked for firewood production. The stand had shallow soils on moderately steep southeast aspect. Skidding ranged from 4 to 6 percent on primary skid trails and 2 to 22 percent on secondary short trails. The stands were predominantly mixed northern hardwoods with small pockets of red spruce. Table 1 shows the characteristics of each study site.

The study area for the Holder, Pasquali and Forest Ant was on the Harvard Black Rock Forest, in Cornwall, New York. The two test sites were similar and locally were called Aleck Meadows and Bugs Bunny. The topography was uneven on slopes of 0 to 14 percent, with scattered outcrops of rock ledges. Table 1 shows the general characteristics of the study sites.

SKIDDING CYCLE TIME AND PRODUCTION RESULTS

The average time per skidding cycle for each turn element is summarized in table 2. The sum of the outhaul, inhaul, hookup, and unhook time is the production time for each tractor. Hookup, unhook, and delay time is the fixed portion of the total time since the tractor is not moving during these elements. Inhaul, outhaul and deck time are the variable time elements, or the travel time. The sum of the productive time and delay time represents the total skid time and can be considered as the scheduled machine time.

The fixed time of hookup, unhook, and delay time for each of the tractors ranged from 63.5 percent to 83.8 percent of the total cycle time, and the variable time of inhaul, outhaul, and deck time accounts for the remaining 16 to 36 percent of total time. The hookup time included maneuvering and winching of stems into position to complete a load. Trees were directionally felled, either away from or toward the assumed tractor position, so that the choker could be set at either the butt or top end of the stem. Since winching angles were not to exceed 30 percent, the tractors were generally positioned in line with the direction of pull. Three to five chokers were used in most cases. The Forest Ant has a different hookup procedure from the other tractors and required more time. Its limited reach required that it be positioned very close to the log to be loaded. Also, the Forest Ant could not deck logs at the landing.

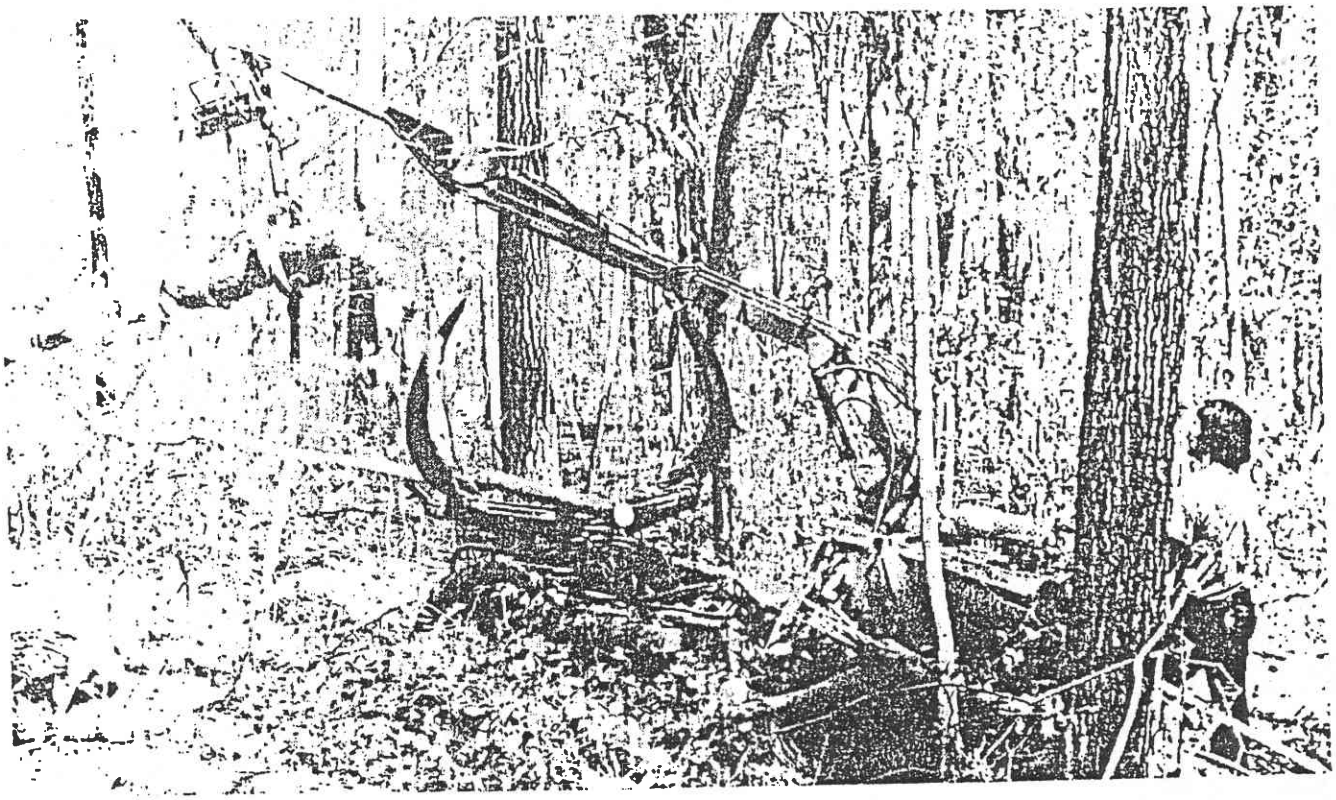

Figure 5--The Forest Ant equipped with clam bunk and knuckleboom loader.

Table 1--Characteristics of the study sites.

Tractor type	Study site No.	Average tree dbh	Basal area		Skidroad slope		Loaded skid direction	Type of cut
			Precut	Postcut	Primary	Secondary		
		Inches	ft^2 per acre		Percent			
Massey-Ferguson	1	9.4	109	80	4	22	Downhill	Selection
Massey-Ferguson	2	10.3	90	0	6	17	Uphill	Regeneration clearcut
Massey-Ferguson	3	10.3	90	0	6	2	Uphill	Regeneration clearcut
Same	4	11.0	110	85	5	15	Downhill	Selection
Pasquali	4	8.6	116	76	0	14	Uphill	Low thinning
Holder	4	8.6	116	76	0	14	Uphill	Low thinning
Forest Ant	5	8.4	96	71	0	12	Uphill	Low thinning

Table 2--Summary of cycle-time elements.

Tractor (Number of observations)	Statistics	Cycle time elements							
		Outhaul	Hookup	Inhaul	Unhook	Deck	Productive time	Delay time	Total time
Massey-Ferguson[a] (119)	Average time (min.)	5.30	11.15	4.68	5.74	--	26.88	7.26	34.14
	Std. dev.	2.02	11.58	2.15	2.81	--	12.86	9.09	15.54
	Percent of total time	13.40	41.60	11.88	14.57	--	78.73[b]	21.27	100.00
Same[a] (32)	Average time (min.)	11.58	13.69	10.73	7.39	--	43.40	17.74	61.14
	Std. dev.	5.63	9.28	4.73	3.33	--	14.58	31.25	31.12
	Percent of total time	18.94	22.39	17.55	12.09	--	70.98[b]	29.02	100.00
Holder[a] (45)	Average time (min.)	2.50	10.30	2.50	4.20	0.30	19.80	3.90	23.60
	Std. dev.	0.57	2.45	0.65	1.20	0.59	--	4.96	5.95
	Percent of total time	10.60	43.60	10.60	17.40	1.30	83.50[b]	16.50	100.00
Pasquali[a] (65)	Average time (min.)	2.70	9.60	2.70	1.70	.20	16.90	8.3	25.20
	Std. dev.	1.08	3.71	.98	.64	.66	--	20.42	21.22
	Percent of total time	10.70	38.20	10.70	6.70	.80	67.10[b]	32.90	100.00
Forest Ant[a] (30)	Average time (min.)	2.50	13.50	2.00	1.00	--	19.00	9.10	28.10
	Std. dev.	1.03	4.24	1.00	.58	--	--	12.27	13.91
	Percent of total time	8.90	48.20	7.10	3.50	--	67.70[b]	32.30	100.00

[a]Mean skid distance of 878, 2,183, 627, 402, and 237 feet, respectively.

[b]Machine utilization rate.

Table 3 shows the mean production data for each tractor studied. For the Massey-Ferguson, each turn produced 3.78 stems with a mean volume of 0.59 cord. Production averaged 1.32 cords per productive hour or 1.04 cords per scheduled hour (without delay time). The machine utilization rate was 78.7 percent.

The Same Minitaurus produced an average of 3.98 stems with a mean volume of 0.83 cord per turn. The daily production averaged 1.12 cords per productive hour or 0.80 cord per scheduled hour (without delay time). The machine utilization rate was 71.0 percent.

The Holder produced an average of 5.67 stems on each turn with a mean volume of 0.61 cord. The production averaged 1.85 cords per productive hour or 1.54 cords per scheduled hour (without delay time). The machine utilization rate was 83.5 percent.

The Pasquali produced an average of 3.94 stems per turn with a mean hitch volume of 0.29 cord. The production averaged 1.01 cords per productive hour or 0.68 cord per scheduled hour (without delay time). The machine utilization rate was 67.1 percent.

The Forest Ant produced an average of 7.10 stems per turn with a mean volume of 0.44 cord. The production rate averaged 1.39 cords per productive hour or 0.94 cord per scheduled hour (without delay time). The machine utilization rate for the Forest Ant was 67.7 percent.

CONSIDERATIONS FOR MANAGERS

The information and results should be valuable to forest managers and planners, and to loggers in evaluating the potential of small tractors operating in low-volume, small-diameter hardwood stands. Although this manuscript only summarizes cycle time and preliminary production results, research is under way to develop detailed comparable cycle time and production estimators for the data set described. Further, research is progressing to incorporate this and additional simulation results into a generalized stump-to-mill logging cost, estimating computer package.

The cycle time and production estimators will be developed so that similar variables such as slope yarding distance, volume per turn, logs per turn, and volume per log are included by machine in each cycle-time estimator. The similarity in production variables eases comparison of machine time and production. Having similar variables in each cycle-time estimator also simplifies the simulation efforts.

The cycle time and production estimators shown by machine, along with a range of stand and forest conditions, would be used as input to select various simulation models. The simulators would be run repeatedly over the range of conditions of interest. The resulting cost or production data points by machine and forest condition would be summarized in mathematical equation form suitable for incorporation into generalized stump-to-mill models. Computerized stump-to-mill methods could be used for estimating costs and production that would help managers, planners, and loggers to determine where specific machines are applicable.

Forest landowners and users are placing increased demands on the forest for a wide variety of uses. Often, the silvicultural treatment needed to bring the woodlot or forest to the desired state will require payment of the associated logging and harvesting costs incurred. Generally, the revenues to offset these costs derive from the value of the wood harvested. It is not intended that the results presented in this paper, or the additional research mentioned, will provide all the answers on the best management of the woodlot or forest. But these results summarized with the results of research in progress should provide managers, planners, loggers, and landowners with detailed and accurate logging cost estimators. The estimators could be used to evaluate and quantify the trade-offs posed by different forest uses and also allow for equipment comparison and selection.

Table 3--Mean production data for each tractor.

Tractor	Number of stems per turn	Volume per turn		Machine utilization rate	Cord volume per production hour[a]	Cord volume per scheduled hour[a]
		ft^3	Cords	Percent		
Massey-Ferguson	3.78	46.9	.59	78.7	1.32	1.04
Same	3.98	66.2	.83	71.0	1.12	.80
Holder	5.67	48.4	.61	83.5	1.85	1.54
Pasquali	3.94	22.8	.29	67.1	1.01	.68
Forest Ant	7.10	34.9	.44	67.7	1.39	.94

[a]Without delay time.

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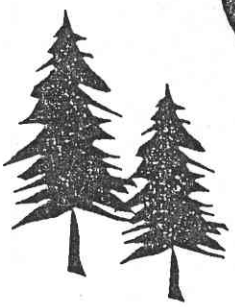

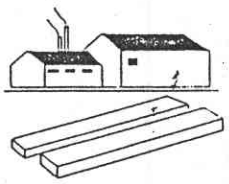

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