

A COMPARISON OF SMALL TRACTORS FOR THINNING CENTRAL HARDWOODS

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Abstract: Young-growth hardwood forests in the central hardwood region will require intensive management if they are to help meet the Nation's increasing demand for wood. Such management generally will require entries into the stands when the trees are small. Many small-scale machines are available for harvesting small wood. Time and motion studies were conducted on small-scale logging operations in the Northeast. The small tractors were studied in a wide range of forest and operating conditions. The machines include the Pasquali 933, a Holder A60F, a Forest Ant Forwarder (Skogsmýran), a Same Minitaurus, and a Massey-Ferguson. The use of small tractors in low-volume, small-diameter hardwood stands is feasible. The Forest Ant should be used only as a forwarding machine while the skidding tractors--Holder, Pasquali, Same and Massey-Ferguson--should be used in stands of medium to large stems and with short skid distances.

INTRODUCTION

As the Nation's demand for wood fiber increases for both wood products and as a source of renewable energy, more youth-growth hardwood forests in the central hardwood region will be required to meet this growing demand.

The intensive forest management required to maintain a sustained yield and attain the production potential of the forest land will require the harvesting of small-diameter, low-quality trees that are characteristic of the central hardwood region. Time of entries and suitable harvesting equipment must be evaluated to ensure a profitable operation.

Several small-scale harvesting machines with suitable economic and physical features are an attractive alternative to conventional ground-based machines that have raised profit ability and environmental concerns (Huyler et al. 1984, Turner et al. 1988).²

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²Huyler, Neil K. and Chris B. LeDoux. Cycle time equations for five small tractors operating in low volume small diameter hardwood stands. USDA For. Serv. Res. Pap. NE-__ (in preparation).

On the basis of time and motion studies, cost comparison and cycle-time equations were developed for five small tractors in select stand conditions. (See Table 1 for characteristics of the study sites.) The harvesting machines included a Pasquali 933, a Holder A60F, a Forest Ant Forwarder (Skogsmyran), a Same Minitaurus, and a Massey-Ferguson (Huyler and LeDoux 1989). This paper compares the productivity and cost of these five small tractors for select stand conditions.

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

MACHINE DESCRIPTION

The Pasquali Model 993 tractor is manufactured in Italy and was designed for use on small farms, landscaping projects, and light construction work in municipalities. It is powered by a 30-horsepower engine and has an articulated frame with four-wheel drive. The tractor is equipped with a 3-point hitch, live power takeoff (PTO), and a JL-25 Farmi logging winch. The winch has a 5,500-pound line pulling capacity, spooled with 100 feet of 3/8-inch cable. The Pasquali tractor is 4-1/2-feet wide and 8-feet long, excluding a 4-foot bucket. Safety options include liquid loaded front and rear tires, roll bar, skid pan, and wheel chains.

The Holder A60F tractor is manufactured in Germany and was designed for farm use and light forestry operations. It is powered by a 48-horsepower engine with an articulated frame. The tractor is equipped with a 3-point hitch, live power takeoff, and an Inland Jones 3000 double-drum winch. The winch has a 6,600-pound-line pulling capacity, spooled with 120 feet of 3/8-inch cable. Safety options included wheel weight, forestry cab, roll bar, and skid pan.

The Forest Ant is manufactured in Sweden and was designed to forward stems to the main skid trails in large forest operations. This small four-wheel-drive tractor has a 12-horsepower engine with an articulated frame. It is equipped with a knuckleboom loader and clam bunk. The tractor steering and speed is controlled by a tiller bar in front. The machine has no cab and the operator walks at a comfortable speed with the machine following.

The Massey-Ferguson 184-4, manufactured in the United States, is a medium-size, four-wheel-drive farm tractor. It has a 60-horsepower diesel engine and is equipped with a 3-point hitch and live power takeoff, and a JL-456 Farmi winch with a line-pulling capacity of 10,000 pounds. Tire chains were used on the rear tires and extra weight added to the front tires. All tires were loaded with calcium chloride for weight.

The Same Minitaurus 60 is manufactured in Italy and designed for small farm use. It is a medium-size four-wheel drive tractor with a 60-horsepower engine. It is equipped with a 3-point hitch, live power takeoff, and a JL30 Farmi logging winch. The winch has a 6,600-pound line pulling capacity, spooled with 165 feet of 3/8-inch cable. Optional and safety equipment included a bucket loader, front wheel weights, loaded rear tires, wheel chain and rollover protection. (See Figures 1 through 5 for illustrations of each of the five tractors.)



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.

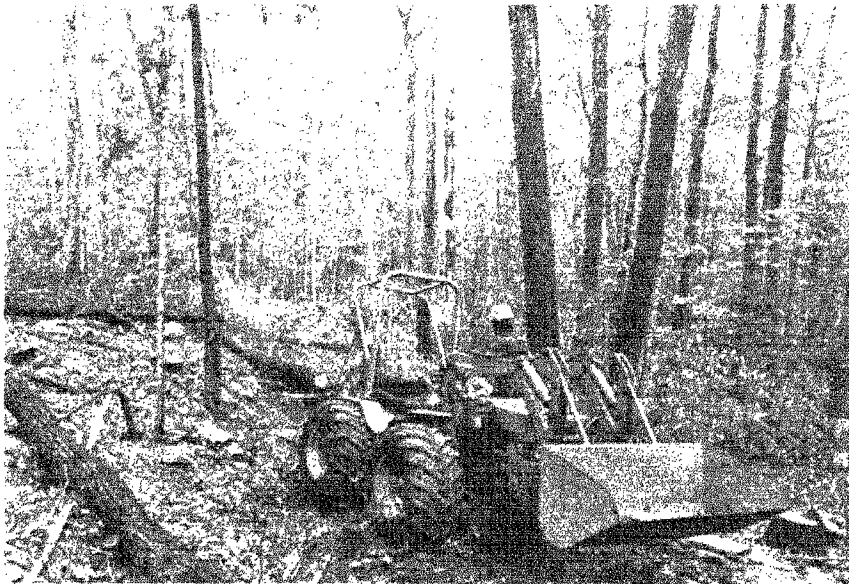


Figure 4. The Pasquali Model 993 with bucket, roll-over protection, and JL-25 single drum winch.



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

TRACTOR PRODUCTIVITY AND OPERATING COST

The harvesting areas for both the Massey-Ferguson and Same tractors were in low-quality hardwood stands. Two sites were marked for selection cuts and two sites were marked for regeneration clearcuts. The precut basal area ranged from 90 to 116 square feet per acre for all sites.

Time-study data were summarized and cycle-time equations developed for each tractor. The cycle-time and production estimators were developed using similar variables: slope yarding distance, volume per turn, number of logs per turn, and volume per log. Using similar variables in each cycle time estimator simplifies the comparison of machine cost of production and any simulation effort. Table 2 gives the mean production data for each tractor. The Massey-Ferguson and Holder produced volumes of 46.9 and 50.3 cubic feet per turn, respectively. The Same produced the largest hitch size at 64.8 cubic feet while the Pasquali had the smallest at 18.6 cubic feet per turn. The Forest Ant was slightly higher than the Pasquali at 34.9 cubic feet per turn.

Table 2.--Mean production data for each tractor

Tractor (Number of observations)	Number of stems per turn	Volume per stem	Volume per turn	Mean skid distance
		--ft ³ --	--ft ³ --	--ft--
Massey-Ferguson (119)	3.78	15.46	46.94	878
Holder (45)	5.62	9.26	50.26	1,147
Same (32)	4.07	19.11	64.77	2,174
Pasquali (65)	3.89	5.19	18.63	947
Forest Ant (30)	7.10	5.15	34.94	253

Table 3 shows owning and operating and labor hourly rate for the five tractors. The investment cost for each tractor was based on 1988 new equipment cost and any added safety and optional equipment.

COMPARISON OF COST

To compare the cost of the five tractors for similar operating conditions, we developed a PC computer program that held certain of the production variables constant while allowing others to change in value, e.g., volume per turn, number of logs per turn, and volume per turn held constant while the slope yarding distance was varied. The four variables significantly influenced productivity and cost for these tractors.² The PC program was run several times for each machine and combination of variables. Results were then graphed for comparison.

Table 3.--Owning and operating and labor hourly rates for the Pasquali, Forest Ant, Massey-Ferguson, Holder, and Same tractors.

Machine	Owning and operating ^a	Labor ^b	Total hourly rate
-----Dollars-----			
Pasquali	5.77	6.75	12.52
Forest Ant	4.27	6.75	11.02
Massey-Ferguson	5.40	6.75	12.15
Holder	14.42	6.75	21.17
Same	5.41	6.75	12.16

^aBased on 1988 new equipment cost, depreciation, insurance, taxes, interest, storage, operating cost (fuel, oil, lubricants, maintenance, and repair).

^bLabor rate at \$5.00/hour plus 35-percent fringe benefits.

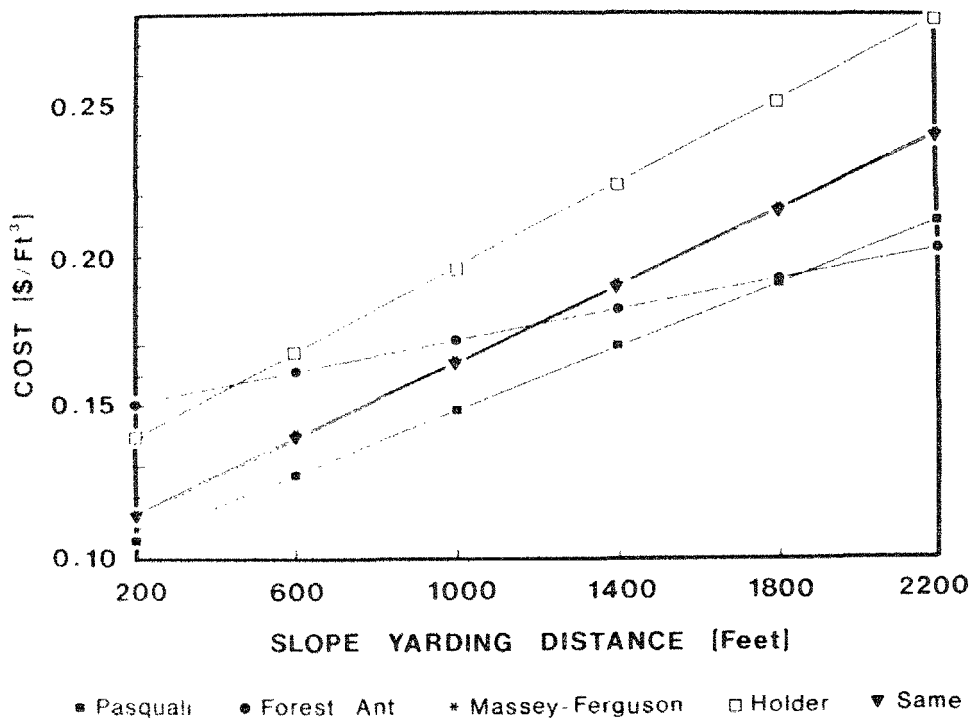


Figure 6. Cost per cubic foot by slope yarding distance for the Pasquali, Forest Ant, Massey-Ferguson, Holder, and Same tractors. Conditions: number of longs per turn=3, volume per turn=35.67 ft³, volume per log=11.89 ft³.

Figure 6 shows the impact of slope yarding distance on cost. Volume per turn was held constant at 35.67 cubic feet. Volume per log was held constant at 11.89 cubic feet with number of logs equal to 3. As slope yarding distance increases, the cost per cubic foot increases for all machines evaluated. The Pasquali tractor is the most competitive until a slope distance of about 1,800 feet is reached, at which time the Forest Ant is the most competitive. The Massey-Ferguson and Same tractors are equally competitive throughout the range of slope yarding distance. The Holder tractor is the least competitive throughout the variable range. At a slope yarding distance of about 1,200 feet, it is more economical to use the Forest Ant Forwarder than to skid the same turn with the Massey-Ferguson, Same, or Holder tractor. This illustrates the advantages of forwarding at longer skid distances.

Figure 7 shows the impact of slope yarding distance on cost with volume per turn, volume per log, and number of logs per turn held constant at 35.67 cubic feet, 4.46 cubic feet, and 8, respectively. For the combination of number of logs and volume per log, the Forest Ant forwarder is the most competitive throughout the range of slope yarding distance. The Same tractor is the next most competitive with the Pasquali close behind.

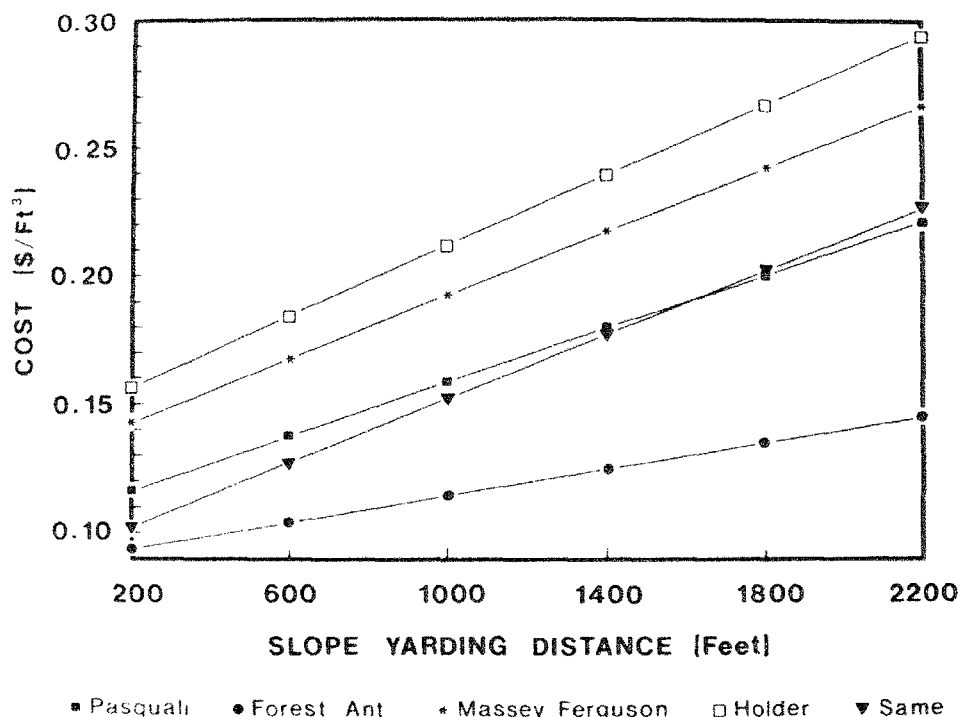


Figure 7. Cost per cubic foot by slope yarding distance for Pasquali, Forest ant, Massey-Ferguson, Holder, and Same tractors. Conditions: number of logs per turn=8, volume per turn=35.67 ft³, volume per log=4.46 ft³.

The Massey-Ferguson and the Holder tractors are the least competitive. This matches practical experience in that the tractors are not being used to capacity when this many small logs are being hooked. The Forest Ant is best when one is operating in stands where there are many and small logs.

The impact of number of logs per turn on skidding cost is shown in Figures 8 and 9. In Figure 8, number of logs per turn is allowed to change within the observed range of 1 to 7. The volume per log is held constant at 5 cubic feet with volume per turn ranging from 5 to 35 cubic feet. The slope yarding distance is held constant at 300 feet. The Forest Ant has a slight advantage over the Pasquali and Massey-Ferguson tractors. The Holder and Same are the least competitive, especially when there are 1 to 3 logs per turn and the volume per turn is 5 to 15 cubic feet. These results show that even when the slope yarding distances are short (300 feet), the Forest Ant is still at an advantage when small logs are skidded.

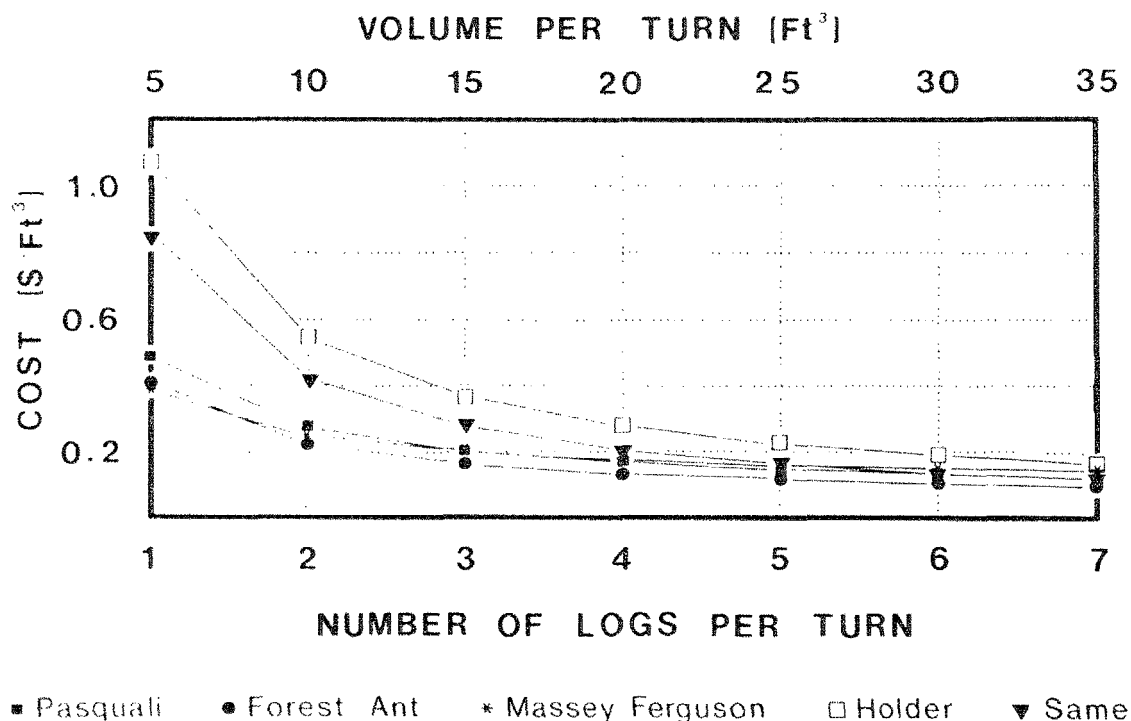


Figure 8. Cost per cubic foot by volume per turn (ft^3) and number of logs per turn for the Pasquali, Forest Ant, Massey-Ferguson, Holder, and Same tractors. Conditions: slope yarding distance=300 feet, volume per log=5 ft^3 .

Figure 9 shows the impact of larger volumes per log and number of logs on skidding cost for a slope yarding distance of 300 feet. When the volume per log is 15 cubic feet, the Massey-Ferguson and the Pasquali are most competitive when 1 to 3 logs are hooked. With 4 or more logs per turn, all of the machines are about equally competitive with the Same showing a slight advantage. The Forest Ant forwarder is not competitive when handling 1 to

3 medium-size logs. These results are consistent with previous results in that the forwarder is most efficient when the logs are small.

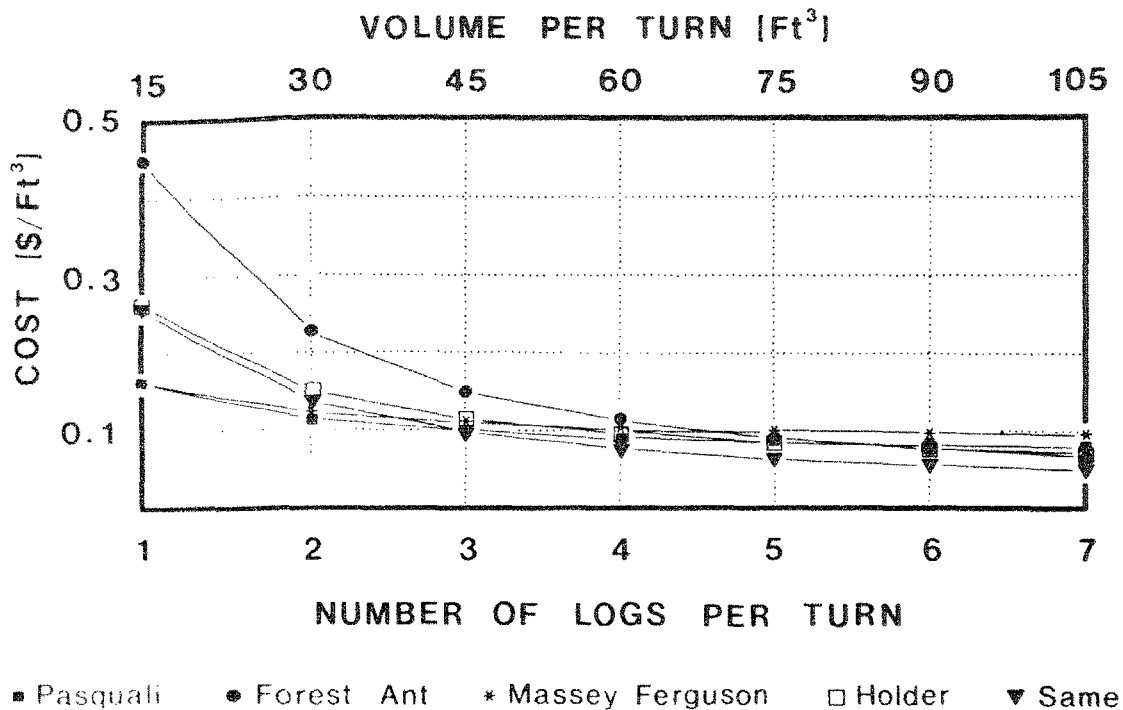


Figure 9. Cost per cubic foot by volume per turn (ft^3) and number of logs per turn for the Pasquali, Forest Ant, Massey-Ferguson, Holder, and Same tractors. Conditions: slope yarding distance=300 feet, volume per log= 15 ft^3 .

Figure 10 simply confirms previous results. Slope yarding distance and volume per turn were held at 300 feet and 30 cubic feet, respectively, while number of logs per turn and volume per log were allowed to change in value over the observed range. The Pasquali, Massey-Ferguson, and the Same are about equally competitive throughout the range. When the volume per log is 7.5 cubic feet and 4 or more logs are carried per skid, the Forest Ant is the most competitive. The skidding tractors are most efficient when skidding few large logs at short skid distances (Figures 1 and 5).

The impact of increasing volume per turn is shown in Figure 11. Slope distance is held constant at 300 feet with 3 logs per turn. It is interesting that when volume per turn is 25 cubic feet or higher, the cost curve for the Forest Ant is nearly constant. This is true of most forwarders at some payload level. The Massey-Ferguson, Pasquali, Same, and Holder, are about equally competitive when the volume per turn is about 40 cubic feet or larger, with the Same and Holder holding the advantage at volumes per turn of 55 cubic feet or larger. This also matches practical experience in that few large logs are best handled with the tractors and few small logs are best handled with the Forest Ant.

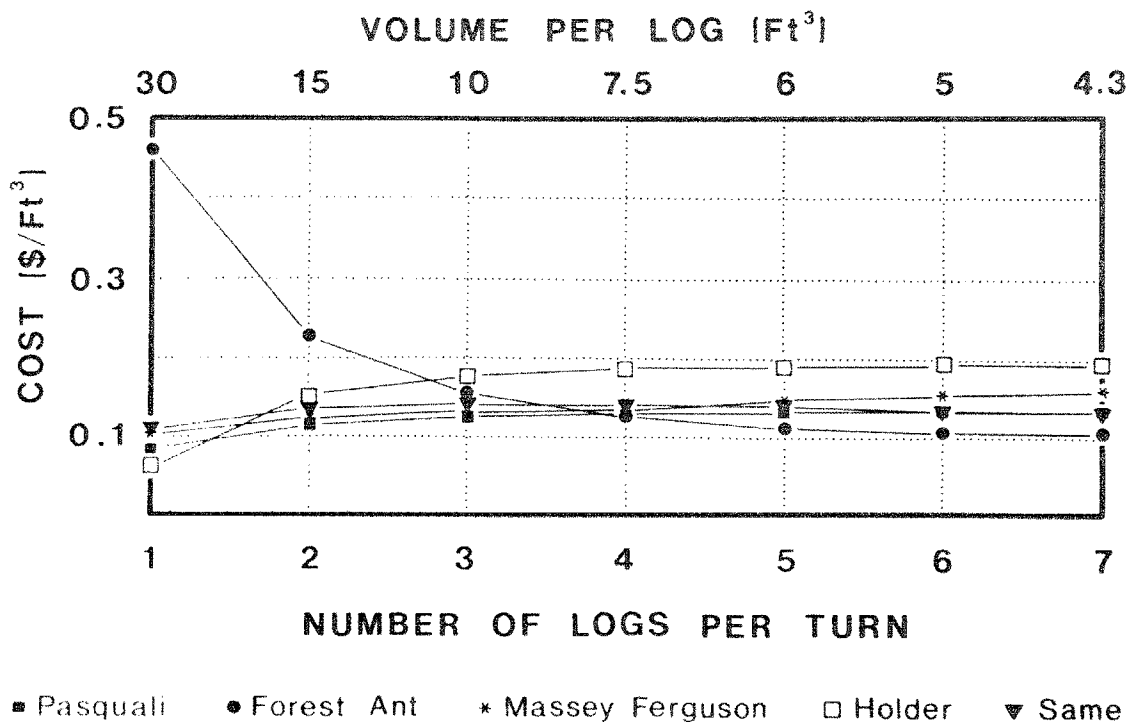


Figure 10. Cost per cubic foot by volume per log (ft^3) and number of logs per foot for the Pasquali, Forest Ant, Massey-Ferguson, Holder, and Same tractors. Conditions: slope yarding distance=300 feet, volume per turn=30 ft^3 .

MACHINE APPLICATIONS

The use of small tractors as a harvesting tool in low-volume, small-diameter hardwood stands is feasible. Timing of entry, type of machine, and careful site selection and layout are critical factors for ensuring a profitable operation.

The Forest Ant should be used only as a forwarder and performs best in stands that have many small stems over both short (300 feet or less) and long (1,200 to 1,800 feet) skid distances. Also the terrain should be relatively uniform (slopes up to 15 percent). The skidding tractors--Holder, Pasquali, Same and Massey-Ferguson--are most efficient when used in stands with medium to large stems and with short distances up to 300 feet.

All of the small tractors have good maneuverability over most terrain and in dense small-diameter stands. Other significant advantages observed when using small tractors as a harvesting tool are less soil compaction, ease of movement to and from the harvesting area, and little damage to the residual stand.

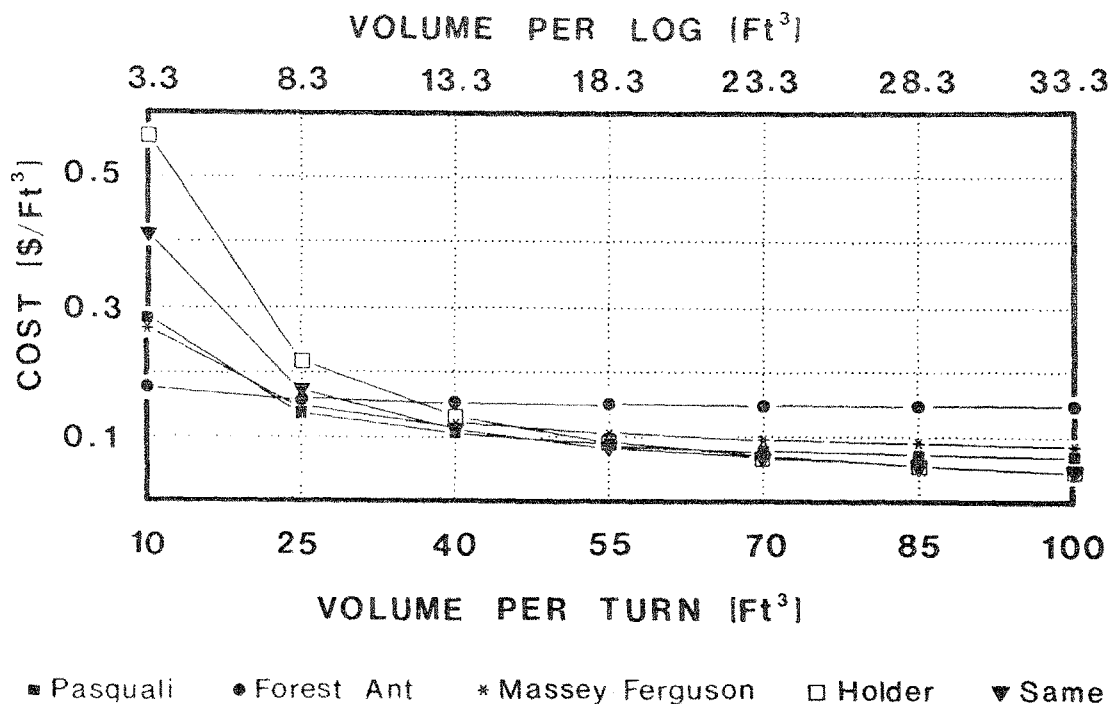


Figure 11. Cost per cubic foot by volume per log (ft³) and volume per turn (ft³) for the Pasquali, Forest Ant, Massey-Ferguson, Holder, and Same tractors. Conditions: slope yarding distance=300 feet, number of logs per turn=3.

CONSIDERATIONS FOR MANAGERS

These results should be valuable to forest managers and planners and to loggers in comparing the potential applications of small tractors operating in low-volume, small-diameter hardwood stands. Although this paper only summarizes the comparison of costs for four production variables, research is progressing to incorporate these and additional simulation results into a computer package for estimating stump-to-mill logging costs.

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. Including similar variables in each cycle-time estimator also simplifies 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 equations suitable for incorporation into generalized stump-to-mill models. Computerized stump-to-mill methods that could be used for estimating costs and production would help managers, planners, and loggers determine where specific machines are applicable.

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