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FELLING AND BUNCHING SMALL TIMBER ON STEEP SLOPES

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The logging industry has long needed a small-tree, steep-terrain feller/buncher. Commercial feller/bunchers today generally cannot operate on slopes of more than 30 percent. On steep slopes containing large timber, trees can be directionally felled and bucked with a chain saw. The large volumes justify the use of chain saw felling and forwarding by cable systems or perhaps even the more elaborate helicopter and balloon systems. The economics become questionable when felling small trees on steep slopes. Trees felled by chain saw are left scattered over the hillside and economic recovery to a landing is a problem. However, if small trees could be felled and bunched so that the potential yarding payload is increased, the aggregate bunch volumes may improve justification of using cable or other systems for recovering small trees from steep slopes.

A machine called the Menzi Muck[1] appears to offer promise for harvesting small trees on steep-terrain. The Ernst Menzi AG[1] of Widnau, Switzerland, developed this unusual machine, which is capable of operating on steep slopes, in swamps, and under other conditions where conventional equipment often cannot work. The Menzi Muck machine, developed in the late 1960's as an excavator, has also been used for construction and mining. Its versatility is principally due to the hydraulically adjustable rear legs with wheels and front stabilizing legs with pads.

Because of the unusual potential of this machine for logging and forestry applications, Canadian Climbing Backhoe, Ltd.[2] of Edmonton, Alberta, a Canadian distributor for the Menzi Muck; Ernst Menzi AG, the manufacturer; and the North Central Forest Experiment Station of the USDA Forest Service cooperated to evaluate this machine as a small-tree, steep-terrain feller/buncher. Canadian Climbing Backhoe, Ltd. provided a Menzi Muck excavator (model 3000 EHA) to the USDA Forest Service Engineering Project in Houghton, Michigan. We modified the machine by fabricating and mounting a small prototype 12-inch shear (without an accumulator) to the end of the boom.

This publication presents preliminary results on the operation and performance of the Menzi Muck as a small-tree, steep-terrain feller/buncher. The reader is cautioned that the data presented are obtained from a limited period of testing. The detailed results are presented for the sole purpose of establishing baseline data that can be compared by other investigators or industry to subsequent tests. Such information can help pinpoint where improvements are needed.

TECHNICAL INFORMATION AND WORKING PRINCIPLES

The Menzi Muck is a fully hydraulic machine mounted on two adjustable stabilizer legs with pads and two adjustable legs with wheels. These wheels are free-rolling, receive no driving power, and have a rachet-type locking mechanism that can be manually activated if desired on steep slopes to allow them to roll in only one direction. A HATZ two-cylinder, four-stroke diesel engine, developing 40 hp at 3,000 rpm, powers the machine.

The knuckle or telescoping boom has a maximum lifting capacity of 4,629 pounds (2,100 kg). It is used to move the machine and also contains the working

[1]*Mention of trade names does not consitiute endorsement of the products by the USDA Forest Service.*

[2]*Now Climbing Hoe of America, Ltd., Atlanta, Georgia.*

implement such as a shear or excavator bucket. An axial piston pump with horsepower regulator provides an operating hydraulic pressure of 2,850 p.s.i. (200 bar). The boom and cab can rotate 360° through the use of "Rothe Erde" ball races. The enclosed operator cab contains the controls for all operations such as tree felling and moving and leveling the machine. The machine is also equipped with a winch and cable to improve the stability of the machine on steep slopes and to aid in moving the machine.

The Menzi Muck has ground pressure of 4.84 p.s.i. (0.34 kg/cm^2 with standard equipment. Although this is higher than some conventional wheeled or tracked equipment, the wheels create little ground disturbance other than compaction. A special swamp package is available with a ground pressure of only 1.99 p.s.i. (0.14 kg/cm^2). The standard machine can operate on slopes up to 100 percent.

The machine is easily transported because it occupies a space of only 14 ft 9 in. by 6 ft 11 in. (4.5 m by 2.1 m) and weighs only 12,000 pounds (5,443 kg). It can load itself on a truck or trailer (fig. 1). The wheel base is hydraulically adjustable between 6 ft 6 in. (2.0 m) and 11 ft 6 in. (3.5 m). The maximum stabilizer leg base is 15 ft 1 in. (4.6 m). The machine can be pulled like a trailer for short distances. More complete manufacturer's specifications of the Menzi Muck are presented in Appendix I.

The Menzi Muck moves by means of the hydraulic boom (fig. 2). The shear head is lowered to the ground close to the machine (to push) or out ahead of the machine (to pull) and the stabilizers are raised so that the machine rests on only the shear head and the rear wheels. By applying hydraulic power to the boom, the machine advances or retreats "inch worm" fashion.

When in position to begin cutting, the stabilizer legs are lowered, and the legs and wheels are hydraulically adjusted to level the machine and attain maximum stability and operator comfort. To fell a tree the boom is extended and the shear is positioned at the base of the tree. The top clamps are closed on the tree, and it is sheared from the stump. The severed tree is lifted vertically and tilted back over the cab for stability, swung into position, and placed in bunches on the ground for skidding. (Skidding was not included in this study.) When all trees within reach are cut (it can harvest a 36-foot-wide swath), the machine is "inch wormed" to a new felling position. Because of the design and control of the two wheels and two stabilizing legs, the machine can accommodate a large variety of terrain conditions while operating up and down steep slopes or on side slopes. It can also climb over felled trees, stumps, large rocks, and other obstacles.

A part of the field test included use of the winch to improve the operability of the machine. Before moving straight up steep slopes, a cable from the power winch was run to the top of the hill and anchored. By maintaining cable tension, stability was improved and power could be applied to assist in moving the machine. This added assistance from the winch resulted in lower ground pressure under the heel of the shear so ground disturbance was reduced, which is especially important in sandy of soft soils. Ground disturbance can also be reduced by bottoming the shear on cut stumps.

Because the machine propels itself by pushing or pulling with the boom and the wheels receive no driving power, the tire life is expected to be substantially greater than conventional wheeled logging equipment.

FIELD TESTING

Two sites in the Six Mile Creek region of Baraga County, in the Upper Peninsula of Michigan were clearcut using the Menzi Muck. Both were too steep to harvest with conventional feller bunchers. One site was a pole-sized hardwood stand containing tree sizes and volumes similiar to those currently harvested on flat terrain in the Lake States area for whole-tree chips. The other site was a sapling-sized stand of hardwoods in which the trees were smaller, but much denser. Even though the volume per acre was low on the second site, it was selected to determine the shearing and bunching ability in a dense stand.

Both stands were inventoried before they were harvested to obtain the tree and stand factors necessary to describe the sites and to help evaluate the effect of stand on logging operations and productivity.

The areas were logged during the last half of November and the first half of December, 1979. Wet snow fell most of the time, and the ground was covered with 1 to 5 inches of snow over thick leaf litter.

Stop watch time study methods were used during the entire harvesting operation on both sites. The elements of the cycles were recorded as (1) travel, (2) reach and position, (3) shear, (4) lift and swing, (5) bunch, and (6) delay.

Following felling and bunching, data were collected on tree size, tree length, and bunch size. All felling and tree data were analyzed.

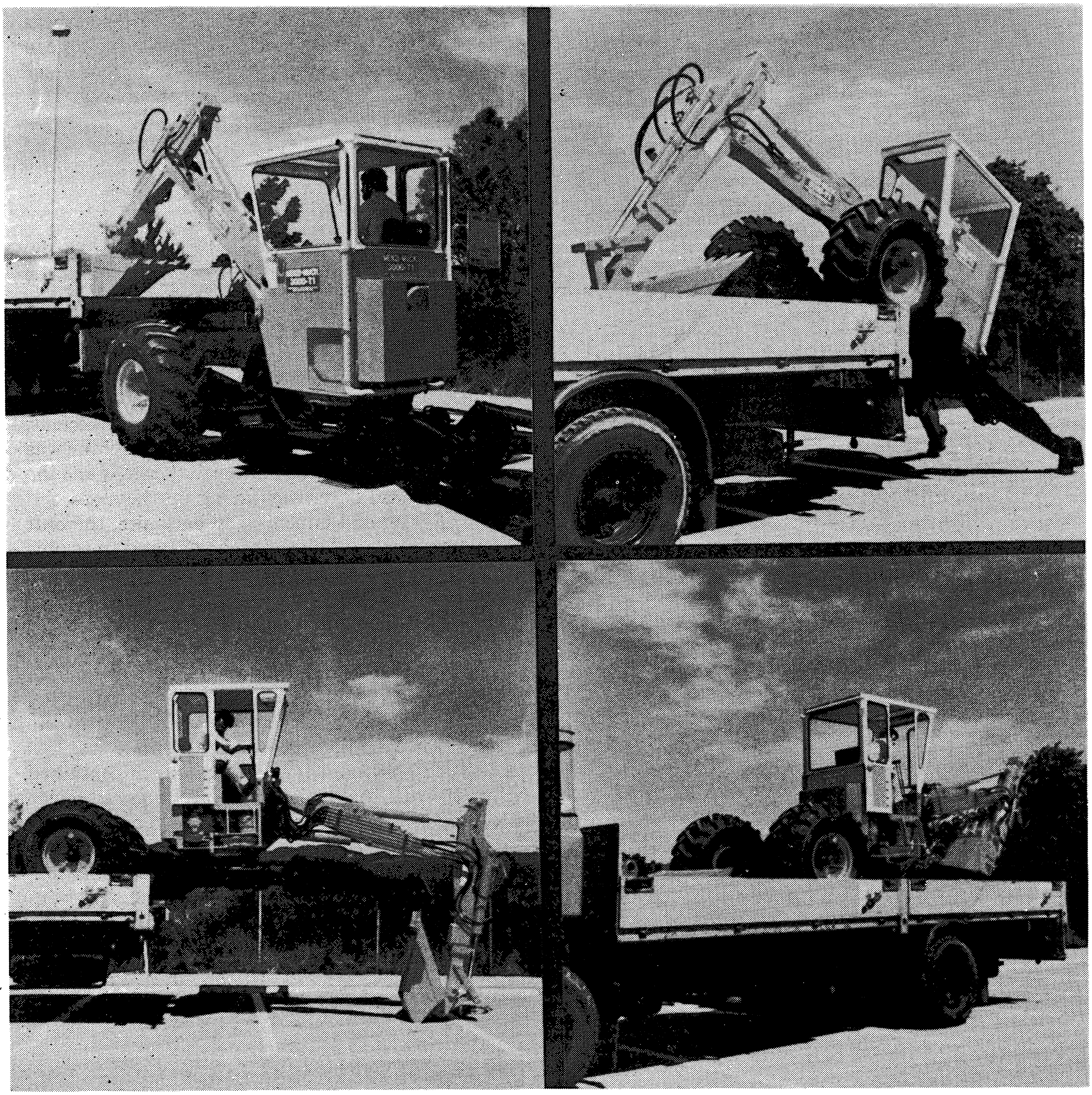

Figure 1.—*The Menzi Muck being loaded onto the bed of a transport vehicle (photos courtesy of Climbing Hoe of America, Ltd.).*

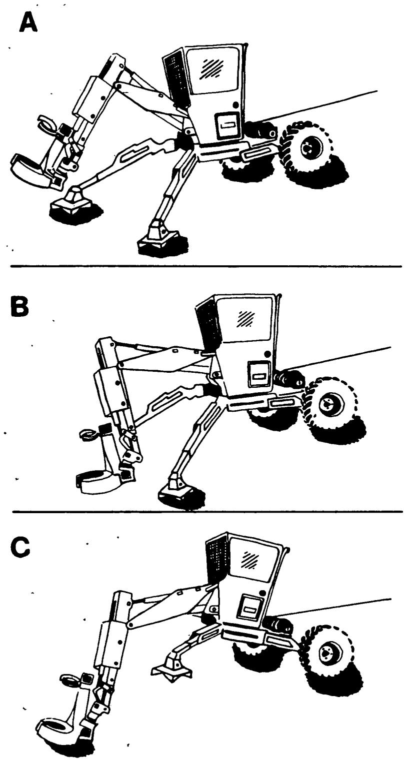

Figure 2.—*Simplified schematic illustrating movement of the machine up a slope. (A) Boom drawn towards machine. (B) Shear head bottomed on ground close to machine and downward pressure applied to lift the stabilizing pads from the ground. (C) Boom extended with shear head on the ground to push the machine up the slope. NOTE: The procedure can be reversed to pull the machine instead of push it.*

SITE DESCRIPTION

The pole stand contained white birch and red maple with small amounts of white pine, spruce, aspen, balsam, and red oak (table 1). Tree diameters ranged from 4 to 14 inches d.b.h. The basal area of trees ≥4 inches in diameter averaged 156 ft^2/acre. The number of trees ≥4 inches d.b.h. totaled 556/acre. The merchantable volume in trees ≥6 inches d.b.h. was 30 cords/acre. The soil was sandy and slopes ranged from 35 to 85 percent (fig. 3).

The preharvest cruise for the sapling stand indicated that white birch was the most prevalent species, followed by red maple and aspen (table 1). Individual tree diameters ranged from 1 to 9 inches d.b.h. Basal area of the trees ≥1 inch averaged 120 ft^2/acre and the trees ≥4 inches d.b.h. had a basal area of only 78 ft^2/acre. This stand contained more than 3,100 trees/acre ≥1 inch in d.b.h. The volume in trees ≥6 inches d.b.h. was only 3.5 cords/acre. The soil was sandy, and the slope was 80 percent (fig. 4).

RESULTS

The machine was initially used in the pole stand by working parallel to the slope. First, the crest of the slope was worked by felling and bunching all trees along a strip parallel to the contour line. Then, the machine was advanced to a lower elevation for each succeeding strip, still working parallel to the slope. On the second site, strips were cut at right angles to the contours, which proved to be more efficient, particularly on the steeper slopes. The machine was used working straight up and down the slope and the winch was used only when going up the slope.

After felling and bunching on each site, the butt diameters and tree lengths of the sheared trees plus the number of trees per bunch were recorded (table 2). Data on tree weights was estimated from work by Montieth 1979, and Steinhilb and Winsauer 1976. In the pole stand, the machine felled and bunched trees averaging about 7 inches in butt diameter and placed about seven trees in each bunch. The mean bunch was estimated to weigh about 2 green tons. In the sapling stand, average tree diameter at butt was less than 4½ inches, and the average bunch contained about 20 trees and weighed about 1.5 green tons.

The average cycle times in the pole and sapling stands were 1.27 minutes and 0.81 minutes, respectively (table 3). As shown in the following tabulation, the average number of trees sheared per cycle were 1.05 in the pole stand and 1.19 in the sapling stand.

Production data	Pole stand	Sapling stand
Trees cut (No.)	967	1,081
Scheduled hours (SH)	19.5	12.2
Productive hours (PH)	16.4	10.7
Machine utilization (U) (Percent)	84	87
Productivity per SH (No. trees)	49.7	88.3
(Tons)	13.9	6.2
Productivity per PH (No.trees)	58.9	100.9
(Tons)	16.5	7.1
Felling cycles (No.)	924	909
Trees/cycle (No.)	1.05	1.19
Average time/cycle (Min)	1.27	0.81
TOTAL YIELD (Tons)	271	76

Table 1.—*Number of trees and square feet of basal area per acre by species and diameter class*

POLE STAND

D.B.H. (inches)	White birch		Red maple		White pine		Aspen		Miscellaneous species		Total	
	Trees Trees	Basal area area	Trees Trees	Basal area area	Trees Trees	Basal area area		Basal		Basal		Basal
	No.	*ft²*	*No.*	*ft²*	*No.*	*ft²*	*No.*	*ft²*	*No.*	*ft²*	*No.*	*ft²*
4	68.76	6.00	68.76	6.00	—	—	—	—	—	—	137.52	12.00
6	111.98	22.00	40.72	8.00	30.54	6.00	—	—	10.18	2.00	193.42	38.00
8	74.36	25.96	28.60	9.98	17.16	6.00	—	—	11.44	4.00	131.56	45.94
10	54.90	29.94	—	—	—	—	3.66	2.00	—	—	58.56	31.94
12	23.32	18.31	—	—	2.54	1.99	5.08	3.99	2.54	1.99	33.48	26.28
14	—	—	—	—	—	—	1.88	2.01	—	—	1.88	2.01
Total	333.32	102.21	138.08	23.98	50.24	13.99	10.62	8.00	24.16	7.99	556.42	156.17
						SAPLING STAND						
2	1,833.48	40.00	458.37	2.50	—	—	—	—	—	—	2,291.85	42.50
4	611.20	53.34	76.40	6.67	—	—	38.20	3.33	—	—	725.80	63.34
6	16.97	3.33	—	—	—	—	50.90	4.44	—	—	67.87	7.77
8	9.53	3.33	—	—	—	—	9.53	3.33	—	—	19.06	6.66
Total	2,471.18	100.00	534.77	9.17	—	—	98.63	11.10	—	—	3,104.58	120.27

Figure 3.—*The Menzi Muck as a small-tree feller/buncher operating parallel to the slope on the pole-sized steep site.*

Figure 4.—*The Menzi Muck as a small-tree feller/buncher operating straight up the slope on the sapling-sized steep site.*

Table 2.— *Sizes and green weights of trees and bunches for pole and sapling stands*

POLE STAND

Element	Mean	Standard deviation	Range
Butt diameter (inches)	7.14	2.84	1 to 14
Trees/bunch (Number)	6.93	4.46	1 to 22
Weight/tree (green tons)[1]	0.28	0.24	0.014 to 1.160
Weight/bunch (green tons)[1]	1.94	1.15	0.036 to 6.025
SAPLING STAND			
Butt diameter (inches)	4.31	1.76	1 to 11
Trees/bunch (Number)	20.06	8.44	6 to 38
Weight/tree (green tons)[1]	0.07	0.08	0.01 to 0.61
Weight/bunch (green tons)[1]	1.50	0.71	0.34 to 3.85

[1]More than 70 percent of the basal area of trees in the study areas were white birch. However, white birch weight tables were not available for this area, so we calculated all weights from sugar maple weight tables developed for Northern Michigan (Steinhilb and Winsauer 1976) because Montieth (1979) suggests that sugar maple tables can be used to obtain weights for white birch.

Table 3.—*Element time per cycle*
(In minutes)

POLE STAND[1]

Element	Mean	Standard deviation	Range
Reach and position	0.25	0.10	0.05 to 0.74
Shear	0.16	0.13	0.07 to 1.55
Lift and swing	0.15	0.09	0.02 to 0.89
Bunch	0.11	0.06	0.04 to 0.72
Travel	0.40	—	—
Delay	0.20	—	—
TOTAL	1.27		
SAPLING STAND[2]			
Reach and position	0.23	0.11	0.03 to 1.04
Shear	0.11	0.05	0.07 to 0.65
Lift and swing	0.12	0.06	0.03 to 0.70
Bunch	0.10	0.14	0.05 to 0.37
Travel	0.15	—	—
Delay	0.10	—	—
TOTAL	0.81		

[1]556 trees per acre ≥ 4 inches d.b.h.
[2]3,105 trees per acre ≥ 2 inches d.b.h.

The definitions of the time study elements are as follows: "*Reach and Position*"—begins when travel of the machine stops, or the shear head begins to move after dropping a tree onto a bunch and ends when the shear is in position to cut the next tree. "*Shear*"—begins when the shear blade moves to cut and ends when the tree is severed from the stump. "*Lift and Swing*"—begins after the tree is sheared and ends when the shearing head is in position to tilt the tree over the bunch. "*Bunching*"—begins after the shear head is in position to tilt the severed tree above the bunch and ends when the shear head drops the tree onto the bunch. "*Travel*"—begins when the last tree within reach of the machine is bunched, and ends when the machine has moved into a position to harvest uncut trees.

Delays for the Menzi Muck were grouped according to (1) *mechanical*—caused by malfunction or breakage of the machine; (2) *operational*—needed to plan and expedite the harvesting operation; (3) *service*—needed to fuel, grease, or service the machine; (4) personal—machine operator breaks; and (5) *other* (table 4). Most of the delays were operational and comprised 74 percent of the total delay time in the pole stand and 79 percent in the sapling stand.

Table 4.—Analysis of delays for the Menzi Muck in the pole and sapling stands

Cause of delay	Pole stand		Sapling stand	
	Minutes	*Percent*	*Minutes*	*Percent*
Mechanical				
Replace broken fitting	33.16	18	—	—
Operational[1]				
Remove obstacles	41.99	23	22.02	24
Plan action	7.83	4	0.46	1
Set brakes, winch, or pad	54.22	30	40.13	44
Instruct operator	26.75	15	2.9	3
Tree too large for shear	0.37	<1	—	—
Move to tree	4.18	2	6.32	7
Service				
Clean window	1.30	1	—	—
Fuel and grease	—	—	5.82	6
Sharpen shear	9.27	5	2.43	3
Personal	3.11	2	5.82	6
Other	0.59	<1	5.34	6
TOTAL	182.77	100	91.24	100

[1]Operational delays are those necessary to plan or expedite the harvesting operation—they are not related to equipment deficiency or failure.

Some of the delays are avoidable. The operator was not familiar with felling and bunching techniques so it was necessary to stop periodically to instruct him. An experienced operator would possibly have eliminated some of this delay. By the time the operator moved to the second site, he had developed more skill in felling and bunching with the net result that he required fewer instructions.

As shown in the following tabulation, the traveling speed of the the Menzi Muck ranged from 6.4 to 14.7 feet/minute.

	Terrain		
	Level	Uphill	Downhill
	Speed (feet/minute)		
Pole stand	8.0	6.4	7.2
Sapling stand	11.1	7.0	14.7

In the soft, sandy soils of the study area, the machine sometimes had difficulty moving because the base of the shear would sink into the ground, thus creating holes. These "footprints" were more evident if the winch was not used when traveling uphill (fig. 5). The manufacturer rates the maximum speed of the machine at 4,000 feet/hour on flat, unobstructed terrain. When moving between shearing places, the machine traveled at rates ranging from 400 to 900 feet/hour. This lower speed is due to the steep terrain, soft ground with snow, obstacles, etc.

Figure 5.—*The Menzi Muck produces a line of "footprints" caused by pushing or pulling the machine with the boom and heel of the shear.*

The number of machine movements are affected by the number and spacing of the trees. In the pole stand, which contained more than 500 trees per acre, the machine moved 350 times to fell and bunch 967 trees. In the sapling stand, which contained more than 3,000 trees per acre, it moved only 200 times to harvest 1,081 trees.

Data from the pole stand revealed 967 trees, amounting to 271 green tons of wood, were harvested in 19.5 scheduled hours (including delays) or 16.4 productive hours (excluding delays). This yielded a production rate of 16.5 tons per productive hour or approximately 60 trees per productive hour. In the sapling stand, 1,081 trees or 76 tons of wood were harvested in 12.2 scheduled hours or 10.7 productive hours. The production rate was only 7.1 tons of wood per productive hour even though the tree felling and bunching rate in the sapling stand was close to 100 trees per productive hour.

Of major importance in this initial study was whether the machine could function as a small-tree feller/buncher on steep terrain. Of secondary importance was how well it functioned in terms of cost and productivity. Further testing of the machine for harvesting is needed to better define the range of operating conditions, strive for production performance, and isolate the improvements required before the machine can be developed as a commercial feller/buncher.

Costs for the Menzi Muck are difficult to determine because the machine has not previously been used for harvesting. However, based on the best information available, costs were calculated for the Menzi Muck when harvesting small trees on steep terrain on both sites using a single tree shear without an accumulator. The base machine and optional equipment cost information, together with a salvage value of 40 percent of purchase price, and a 10 year life for tires as provided by Climbing Hoe of America plus a machine life of 5 years (estimated by the authors) were used to calculate the hourly machine rate for the Menzi Muck on this test (Miyata 1980). Method of calculating this machine rate is shown in the following tabulation and results in a cost of $21.99 per productive hour excluding labor and $35.84 per productive hour including labor. Undoubtedly, future experience with the machine for logging will provide more accurate machine life, salvage, tire life, and maintenance and repair values, enabling a more realistic calculation of the machine rate.

MENZI-MUCK MACHINE RATE

Description

Purchase price		
(f.o.b. delivered)	$51,408	
Winch	6,000	
Shear head (estimated)	5,000	
Tire cost	-2,000	
Initial investment-P		= $60,408.00
Salvage value (40 percent of P)[3]-S		= $24,163.20
Estimated machine life-N	5 years	
Working days per year	250 days	
Scheduled hours-SH per year	2,000 hours	
Utilization-U	65 percent	
Productive time-PH per year	1,300 hours	

Average value of investment: $AVI = \frac{(P-S)(N+1)}{2N} + S$ = $45,910.08

Fixed cost

Depreciation cost: $D = \frac{(P-S)}{N} = \frac{\$60,408.00 - \$24,163.20}{5}$ = $ 7,248.96

Interest, insurance, taxes: = $11,018.42
IIT = (18 percent + 3 percent + 3 percent) x AVI
Yearly fixed cost: YFC = D + IIT = $18,267.38/yr.
Hourly fixed cost: HFC = YFC ÷ PH = $ 14.05/hr.

Operating cost

Maintenance and repair: MR = (100 percent of $\frac{D}{PH}$) = $ 5.58/hr.

Fuel cost: $F = \frac{1.65 \text{ gal}}{\text{hr.}}$ x $1.02/gal. = $ 1.68/hr.

Oil and lubricant-L = $ .50/hr.

Tire: $T = \frac{1.15 \times \$2,000}{13,000/\text{hr.}}$ = $ .18/hr.

Hourly operating cost: HOC = MR + F + L + T = $ 7.94/hr.
Hourly machine cost: HMC = HFC + HOC = $ 21.99/hr.

Labor cost: LC = $9.00/SH x 2,000 SH ÷ 1,300 PH = $ 13.85/hr.
Hourly machine cost with labor:
HMCL = HMC + LC = $ 35.84/hr.

[3] *Based on manufacturer's data when machine is used as an excavator.*

Based on the above hourly rate for productive hours, the cost of felling and bunching was estimated as $2.17 per green ton (or $0.60 per tree) in the pole stand and $5.05 per green ton (or $0.36 per tree) in the sapling stand.

These production figures are based on the nonaccumulating shear used in the study. Use of an accumulating shear would have reduced costs and increased productivity. For example, for trees averaging 7 to 7½ inches d.b.h., a shear with accumulator can produce about twice as many cords per hour as a shear without an accumulator (fig. 6) (Rome Industries 1974). The difference in production is even greater for smaller trees. Therefore, a recommendation is to equip the Menzi Muck with an accumulator shear in future small tree felling and bunching studies to determine if productivity could be increased and costs per ton and per tree reduced. Another recommendation is to use the Menzi Muck with the telescoping boom, which gives an added 3 feet 3 inches of reach over the knuckle boom. Thus, for a given setting, more trees would be within reach which should favorably influence productivity and cost per unit of production.

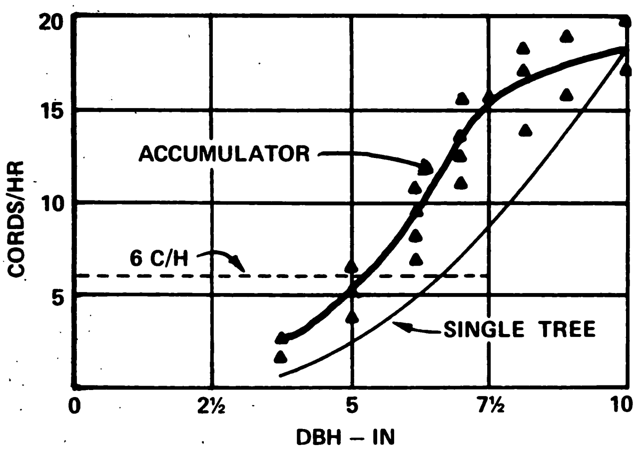

Figure 6.—*Productivity comparison of harvesting small diameter trees with a single tree shear versus a shear with a tree accumulating feature (Rome Industries 1974).*

CONCLUSIONS

This study demonstrated the potential of Menzi Muck to harvest small timber on steep slopes. Although the test covered only a short period of time and was limited in scope, these preliminary data can be used by other researchers or industry to compare with future tests of this machine. The productivity and cost results presented should be used with caution, because these figures are based on one machine operating for only 16.4 productive hours in a hardwood pole stand and 10.7 productive hours in a hardwood saping stand.

The Menzi Muck may have potential in felling and bunching small timber for cable yarding, strip thinning on steep slopes, and logging swampy areas. Included below is a partial list of other possible applications.

1. Bunching small trees or logs for a skyline system.
2. Placing tail hold anchors on steep slopes for skyline yarding systems.
3. Excavating ditches to drain swamps and roadways.
4. Recovering logging residue on steep slopes.
5. Chopping or shredding residue on steep slopes.
6. Harvesting stumps on swampy sites.
7. Constructing access roads or trails.

Further testing of this machine may solve other forestry and logging problems on adverse terrain.

LITERATURE CITED

Miyata, Edwin S. 1980. Determination of fixed and operating costs of logging equipment. U.S. Department of Agriculture Forest Service, General Technical Report NC-55, 16 p. U.S. Department of Agriculture Forest Service, North Central Forest Experiment Station, St. Paul, Minnesota.

Montieth, D. B. 1979. Whole tree weight tables for New York. Applied Forest Research Institute Research Report 40, 63 p. Applied Forest Research Institute, State University of New York, College of Environmental Science and Forestry, Syracuse, New York.

Rome Industries. 1974. Rome shear head application on 80 to 100 hp wheel loaders. 11 p. Rome Job Report, Rome Industries, Cedartown, Georgia.

Steinhilb, H. M., and Sharon A. Winsauer. 1976. Sugar maple: tree and bole weights, volumes, centers of gravity, and logging residue. U.S. Department of Agriculture Forest Service, Research Paper NC-132, 7p. U.S. Department of Agriculture Forest Service, North Central Forest Experiment Station, St. Paul, Minnesota.

APPENDIX
MANUFACTURER'S SPECIFICATIONS

Hydraulic System

The model 3000 MENZI MUCK is a fully hydraulic excavator.

- The axial piston pump with HP regulator is directly flanged to the engine and has a capacity of 85 liters/minute (22.5 gal/min). This pump feeds the hydraulic system for both the working movements and the undercarriage.
- Cylinders and swing motor are operated through two control blocks.
- The working movements are controlled by a "Bosch" segment-type control unit with special precision-control leading edges. The main pressure-relief valve is adjusted to a working pressure of 200 bar (2,850 p.s.i.). In addition, safety elements with secondary safety valves are built into every segment.
- The stabilizing movements of the undercarriage (feet and wheels) are controlled through a "Parker" monoblock.
- All hydraulic cyliners are made by MENZI.
- A self-braking hydraulic piston swing motor turns the superstructure.
- Hydraulic oil is returned through the oil cooler to ensure a constant oil temperature of 70°C (158°F).
- Hydraulic oil is filtered in the return line to protect all high-precision parts.

Undercarriage

The adjustment stabilizer and wheels give the MENZI MUCK maximum stability.

- The wheels may be brought into the desired vertical position hydraulically, the control being infinitely variable. The wheel track may be horizontally adjusted hydraulically from 2 to 3.5 m (6½ to 11½ feet).
- The wheels run freely in the working direction. If desired, the wheels may be locked to prevent rotation in the opposite direction.
- High, wide-ribbed tires resist skidding and punctures, provide low ground pressure, and absorb shocks.
- The telescoping swivel feet are hydraulically adjustable in vertical direction and may be extended to 4.60 m (15 feet 1 inch) wide.
- The stabilizer claws give the excavator excellent stability. MENZI MUCK may be equipped with self-emptying steel claws, rubber pads, or swamp plates (diameter up to 1.25 m = 4 feet 1 inch).
- All hydraulic cylinders of the undercarriage automatically lock in case of pressure loss.

Superstructure

The superstructure is the main compact unit of the MENZI MUCK excavator.

- The built-in diesel is easily accessible for daily maintenance and service work. It is supported by four rubber blocks that absorb shocks and ensure that a minimum of vibration is transferred to the excavator.
- An all-around view cab gives unrestricted visibility on all sides. Canadian and U.S. machines are equipped with a Tubelok rollover structure and seatbelts conforming with U.S. and Canadian Safety Standards. The control levers and instruments are conveniently located.
- The windsheild may be easily removed. The roof may be opened for better aeration. An efficient hot air heater is included.
- The "Rothe Erde" ball race joins the undercarriage and superstructure. It makes an operational range of 360° possible. A grease cut ensures good lubrication. The superstructure may be bolted in two positions for transportation.

Boom

The boom of the MENZI MUCK is the actual working device. The MENZI MUCK makes use of its boom not only for digging, but also for moving itself.

- The digging arm is available in three different types:

Model EH—digging arm mechanically adjustable by 100 cm (3¼ feet).

Model T1—digging arm hydraulically adjustable by 100 cm (3¼ feet).

Model T2—digging arm hydraulically adjustable by 200 cm (6½ feet).

A large range of excavation buckets fit all types of booms.

Engineering Data

Engine

Air-cooled HATZ two cylinder four-stroke diesel engine, direct injection, with optional heater plug, deep sump oil pan for off-the-road operation. Output 40 hp at 3,000 rpm. Displacement 2,014 cm^2 (123 $in.^3$), BOSCH injection pump. BOSCH injection valves. Electrical equipment 12 V with alternator.

Optional: with electric motor 30 kw (40 hp).

Hydraulic system

Pump: Axial piston pump with HP regulator. Operating pressure 200 bar.

Control unit: BOSCH for working movements. PARKER for the adjustment of stabilizer feet and axles.

Hydraulic cylinders: Manufactured by MENZI, hardened, impact-resistant chromium-plated piston rods, honed cylinders, supporting cylinders with protection against hose rupture.

Swing motor: Self-braking hydraulic piston swing motor.

Hydraulic Oil: 120 l multi-grade oil, working temperature 70°C (158°F), oil cooler connected to return line oil filter for return lines.

Output 3 to 4 working cycles per minute. Climbing ability 100 percent.

Tires 20-20, 10-ply (1,270 mm high, 520 mm wide).

MISCELLANEOUS

Weight with 60 cm bucket	5,500 kg (12,125 lb)
Lifting capacity	2,100 kg (4,629 lb)
Tearing power, long bucket	3,000 kg (6,613 lb)
Tearing power, short bucket	3,500 kg (7,716 lb)
Breakout force, long bucket	5,500 kg (12,125 lb)
Breakout force, short bucket	10,000 kg (22,046 lb)
Ground pressure:	
Standard equipment	0.34 kg/cm^2 (4.84) p.s.i.
With swamp equipment	0.14 kg/cm^2 (1.99) p.s.i.
Measurements:	
Smallest horizontal clearance required	2,000 mm (6 ft 6 in.)
Smallest wheel base	2,000 mm (6 ft 6 in.)
Largest wheel base	3,500 mm (11 ft 6 in.)
Largest stabilizer base	4,600 mm (15 ft 1 in.)
Smallest space needed for transportation	4,500 by 2,100 mm (14 ft 9 in. × 6 ft 11 in.)
Height with cab	2,550 mm (8 ft 5 in.)
Height without cab	1,710 mm (5 ft 7 in.)
Maximum reach	6,400 mm (21 ft)
Maximum digging depth	4,200 mm (13 ft 9 in.)
Maximum dumping height:	
Chassis on the ground	3,200 mm (10 ft 6 in.)
Chassis in raised position	5,200 mm (17 ft 1 in.)
Boom extension mechanically adjustable	1,000 mm (3 ft 3 in.)
Smallest operational range	3,200 mm (10 ft 6 in.)
Overall height with smallest operational range	4,050 mm (13 ft 4 in.)

Arola, Rodger A., Edwin S. Miyata, John A. Sturos, and Helmuth M. Steinhilb.

1981. Felling and bunching small timber on steep slopes. U.S. Department of Agriculture Forest Service, Research Paper NC-203, 12 p. U.S. Department of Agriculture Forest Service, North Central Forest Experiment Station, St. Paul, Minnesota.

Discusses the results of a field test of the unique Menzi Muck machine for felling and bunching small trees on steep slopes. Includes the analysis of a detailed time study to determine the productivity, costs, and economic feasibility of this unusual machine.

KEY WORDS: Logging, rough terrain, productivity, costs, mechanized harvesting.

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