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# The Economics of a Mechanized Multiproduct Harvesting System for Stand Conversion of Northern Hardwoods

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# THE ECONOMICS OF A MECHANIZED MULTIPRODUCT HARVESTING SYSTEM FOR STAND CONVERSION OF NORTHERN HARDWOODS

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To minimize the impact of raw material shortages and escalating softwood stumpage prices, many forest products companies are revising their forest management techniques and objectives as well as their wood harvesting practices. Two methods being considered to substantially increase raw material availability for the wood industry are:

- Conversion of understocked or poor-quality hardwood stands to more productive conifer species.
- Increased recovery and utilization of logging residue.

The need for stand conversion operations in northern hardwoods results from past timber harvesting practices that effectively replaced large acreages of productive conifer species or high-quality northern hardwoods with low-quality hardwoods (Cook 1955). This represents a very serious problem in terms of the earnings potential of such timberland regardless of the intended product.

Although the technology of converting northern hardwoods is very limited, much can be learned from past experiences in other regions. Current practices in the Southeast (Peevy and Brady 1972) and the Pacific Northwest (Yoho *et al.* 1969, Dimock *et al.* 1976) indicate that forest productivity can be increased significantly by using regionally proven and accepted stand conversion practices. Presently the capital outlays for conversion operations are extremely high because of the great expense of initial site preparation. These costs are a function of the removal method, the condition, and the disposal of the existing stand.

The existing stand can be removed from the intended conversion site by either destroying it or harvesting it. Destroying unwanted vegetation represents a large direct cost with no offsetting returns, but harvesting the same vegetation may lower the investment and enhance the profitability of stand conversion (Anderson 1974). Peevy and Brady (1972) report that removal of the old stand accounts for half or more of the costs incurred in stand conversion programs.

Stand conversion operations provide an opportunity to recover large quantities of woody material. Lowe (1973) reports that only 60 to 65 percent of the tree's total fiber leaves the forest under conventional sawtimber and pulpwood logging operations. Mattson and Carpenter (1976), in a case study of a northern hardwood timber sale, determined that 41 percent of the tree weight above the stump was left in the woods from sawtimber-size trees and 49 percent was left from poletimber trees.

Any stand conversion program for the Lake States region should be directed at minimizing the costs of removing the existing timber stand while maximizing the recovery of wood products and residues. Whole-tree harvesting with saw log sorting may provide an economical way to achieve these objectives. A mechanized multiproduct harvesting system would:

1. Minimize site preparation costs through the harvesting of existing timber.
2. Recover additional supplies of fiber and/or fuelwood through the removal of logging residues and small diameter standing timber.

3. Recover high-quality sawtimber from predominantly pole-size hardwood stands.
4. Create obstruction-free planting sites, thus facilitating machine planting.

This paper presents the results of a study that evaluated the economic feasibility of clear-felling several diameter northern hardwood stands in an effort to create debris-free planting sites while maximizing raw material recovery. Several methods were investigated in combining the saw log recovery with whole-tree and residue chipping.

The harvesting operations studied were part of a U.S. Department of Energy funded study, "Application of Sugar Maple and Black Locust to the Biomass/Energy Plantation Concept," being carried out by the Department of Forestry, Michigan Technological University, Houghton, Michigan.

# STAND DESCRIPTION

The study area comprised approximately 50 acres of predominantly pole-size northern hardwoods located in the Copper Country State Forest[1] in Michigan's Upper Peninsula. The topography was flat, with only about a 20-foot difference in elevation throughout the proposed study area. The soil was a sandy loam. The area contained usable logging roads and was bordered on the south by a blacktop highway (fig. 1).

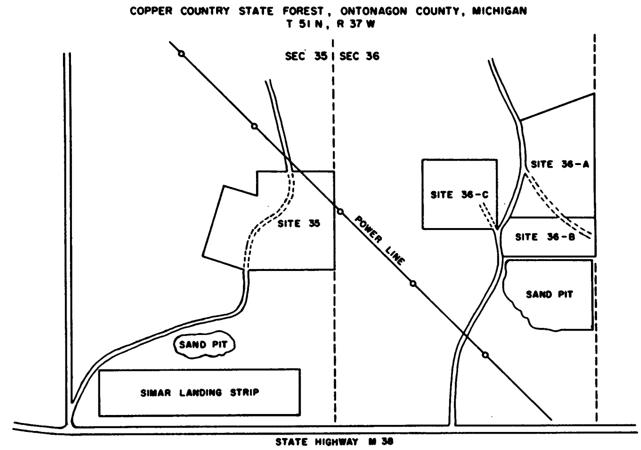

Figure 1.—*Map of the four logging sites.*

The area was divided into a 20-acre block in Section 35 (Site 35) and a 32-acre block in Section 36 (Site 36). Site 35 was of low quality consisting primarily of pole-size trees ranging from 1- to 12-inches d.b.h. and did not produce any saw logs. A preliminary survey indicated 807 stems per acre with a basal area of 116 square feet per acre (table 1). The estimated biomass on Site 35 was 102 green tons per acre.

Site 36 consisted of higher quality trees and was divided into three smaller blocks (Sites 36 A, B, and C) where several integrated harvesting methods were evaluated. Sites 36 A, B, and C were approximately 13, 8, and 11 acres, respectively, and contained, on a per acre basis, 531 to 626 stems, 124 to 139 square feet of basal area, and 118 to 137 green tons of biomass. Trees ranged from 1- to 20- inches d.b.h.

# METHODS

The 52-acre study area consisted of four separate study sites (Sites 35 and 36 A, B, and C). Each site was clearcut down to a 2-inch diameter by a different logging system. The major difference in logging methods was in the way whole-tree chipping was integrated with saw log removal.

Because Site 35 did not contain any saw log trees, a standard whole-tree chipping system was used to clearcut the site. The chips were sold to a pulp mill 22 miles from Site 35. The mill required that all trees be chain flailed to remove most of the twigs and small branches before chipping.

The feller/bunchers felled the trees and placed them on the ground in optimum size bunches with all the butts facing toward a central landing site (fig. 2). A grapple skidder transported the bunches from the felling area to the landing. After dropping the skid load at the landing for chain flail delimbing, the skidder operator picked up a grapple load of delimbed trees and shuttle-skidded them a short distance to the chipper where they were chipped. The chips were blown into chip vans and transported to the mill.

On Site 36 A, the same whole-tree harvesting and chipping equipment was used plus one saw log trailer with loader, one sawyer to fell the saw log trees, and one sawyer to cut saw logs from full trees skidded to the side of the saw log trailer. The loader was placed parallel to and about 20 feet to one side of the chipper (fig. 3). Its function was to lift and deck

[1]*Provided by the Michigan Department of Natural Resources on the east half of Section 35 and the west half of Section 36, T51N, R37W, Ontonagon County. The State of Michigan Department of Natural Resources and Michigan Technological University, Department of Forestry, cooperated in this study with the North Central Forest Experiment Station.*

Table 1. —*Stocking table for all species combined (per acre basis)*[1]

| Study area | Diameter distribution (d.b.h. inches) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | Totals |
| Site No. 35 | | | | | | | | | | | |
| Stems per acre | 169 | 306 | 232 | 83 | 15 | 2 | — | — | — | — | 807 |
| Basal area (sq. ft.) | 3.4 | 27.5 | 46.4 | 29.0 | 8.2 | 1.6 | — | — | — | — | 116.1 |
| Estimated biomass[2] (green tons) | 1.9 | 19.4 | 42.0 | 28.3 | 8.6 | 1.7 | — | — | — | — | 101.9 |
| Site No. 36A | | | | | | | | | | | |
| Stems per acre | 193 | 107 | 93 | 81 | 59 | 23 | 11 | 6 | 2 | 2 | 577 |
| Basal area (sq. ft.) | 3.9 | 9.6 | 18.8 | 28.4 | 32.4 | 18.2 | 11.8 | 8.4 | 3.5 | 4.4 | 139.4 |
| Estimated biomass[2] (green tons) | 2.2 | 6.8 | 16.9 | 27.6 | 33.9 | 19.2 | 12.8 | 9.1 | 3.8 | 4.7 | 137.0 |
| Site No. 36B | | | | | | | | | | | |
| Stems per acre | 195 | 139 | 128 | 94 | 45 | 15 | 7 | 1 | 2 | — | 626 |
| Basal area (sq. ft.) | 3.9 | 12.5 | 25.6 | 32.9 | 24.8 | 11.8 | 7.5 | 1.4 | 3.5 | — | 123.9 |
| Estimated biomass[2] (green tons) | 2.3 | 8.8 | 23.2 | 32.0 | 25.9 | 12.5 | 8.2 | 1.5 | 3.8 | — | 118.2 |
| Site No. 36C | | | | | | | | | | | |
| Stems per acre | 150 | 120 | 114 | 69 | 33 | 24 | 11 | 6 | 3 | 1 | 531 |
| Basal area (sq. ft.) | 3.0 | 10.8 | 22.8 | 24.2 | 17.8 | 18.8 | 11.8 | 8.4 | 5.3 | 2.2 | 125.1 |
| Estimated biomass[2] (green tons) | 1.7 | 7.7 | 20.6 | 23.5 | 19.0 | 20.0 | 12.8 | 9.1 | 5.7 | 2.4 | 122.5 |

[1]Stocking and yield estimates based on a 25-percent cruise of each stand.
[2]Includes saw log weights.

the bucked-out saw logs. The loader also sorted cut tops, branches, culls, and smaller diameter trees contained in that skid load, placing them next to the chipper for chipping. The logs were sold to a commercial sawmill that picked up the decked logs on site.

Figure 2.—*The Drott*[3] *feller/buncher was used to fell and bunch all pulpwood size trees.*

[3]*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.*

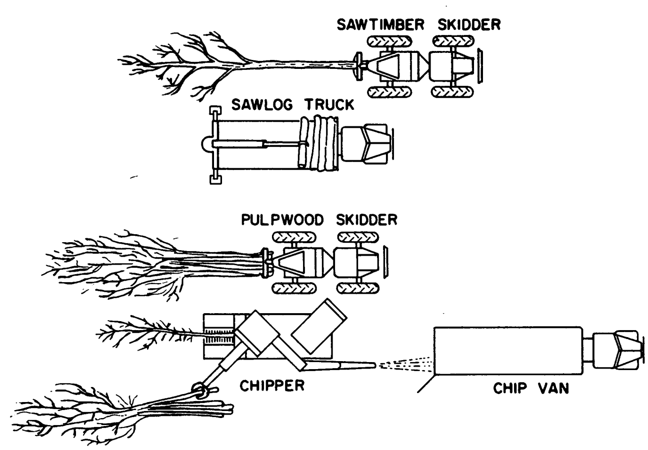


Figure 3.—*Plan view of the equipment layout at the landing for integrated harvesting of Site 36A.*

On Site 36B, all non-saw log trees were mechanically felled, bunched, chain flailed, skidded, and chipped first, leaving the saw log trees standing. The sawyer then felled and bucked the saw log trees at the stump. A forwarder prehauled the bucked logs to the roadside. The topwood was then skidded and chipped separately.

On Site 36C, the saw log trees were felled and bucked at the stump first. The remaining trees were felled mechanically and bunched with the tops from the saw log trees. The bunches were then chain flailed, skidded, and chipped. The forwarder then picked up the saw logs and prehauled them to the roadside.

All operations during the study were observed, sampled, and recorded to determine productivity and operating costs. The data included time, motion, and delay data of the feller/bunchers, skidders, chain flail, chipper, saw log trailer loader, and the sawyer felling saw log trees and bucking saw logs at the landing. Additional data included trucking time and distance; weight of chips produced; and the number, grade, and board feet of saw logs removed.

# YIELDS OF CHIPS AND SAWTIMBER

The chip yields from the near-complete harvest (2-inch d.b.h. and larger) of the 20-acre poletimber stand (Site 35) was 1,479 tons or 74 tons per acre (table 2). The three saw log sites produced 2,948 tons of chips plus 53,035 board feet of saw logs. Site 36A produced the most tonnage of biomass on a per acre basis including chips and saw logs (114 tons per acre) and Site 36B produced the least (80 tons per acre). But Site 36 B produced the highest volume of saw logs on a per acre basis (1,943 board feet per acre). The averages for the three saw log sites on a per acre basis were 91 tons of chips and 1,646 board feet of saw logs, or 101 tons of chips and saw logs.

The saw logs produced came from five species: sugar maple, red maple, black cherry, red oak, and yellow birch. They were graded as either veneer, No. 2, or No. 3 saw logs; the value ranged from $340 per thousand board feet for yellow birch veneer to $90 per thousand board feet for all No. 3 saw logs (table 3). The total value of saw logs produced was $7,690. The veneer was 20 percent of the total saw log volume, but it was worth 41 percent of total saw log value. Half of the remaining saw logs were No. 2 logs; the other half were No. 3 logs.

# CHIP PRODUCTION COSTS

The costs associated with the chipping and saw log operations were calculated on the basis of scheduled and productive hours of the equipment and sawyer (Miyata 1980, Miyata and Steinhilb 1981). Table 4 lists the equipment including the purchase price and other assumptions used in determining the fixed and operating costs for each machine (Miyata *et al.* 1981).

The costs of producing chips were greater with all three integrated chip-saw-log operations (Sites 36 A, B, and C) than with the conventional whole-tree chipping operation on the poletimber stand (Site 35) (table 5). The logging costs, excluding overhead and stumpage, ranged from $8.66 per green ton for the chips-only operation to $9.87 per green ton on Site 36C where the saw log trees were felled and bucked before whole-tree harvesting of all remaining trees 2 inches d.b.h. and larger. The most efficient integrated operation was on Site 36A ($9.20 per green ton) where the saw log trees were skidded along with the smaller trees to the landing to be sorted and bucked. If we add 15 percent for overhead costs and $1.20 per ton for stumpage, the chip production costs range from $11.16 per green ton to $12.55 per green ton.

Table 2.—*Chip and sawtimber yields from the four study areas*

| Study area | Acreage | Chips | Saw logs | | Total | Chips | Chips and saw logs | Board feet/acre |
|---|---|---|---|---|---|---|---|---|
| | *Acres* | *Tons* | *Bd ft* | -------- *Tons* -------- | | ---- *Tons/acre* ---- | | |
| Poletimber site 35 | 20.05 | 1,479.46 | — | — | 1,479.46 | 73.79 | 73.79 | |
| Saw log site 36A | 13.69 | 1,455.03 | 18,270 | 109.62[1] | 1,564.65 | 106.28 | 114.29 | 1,335 |
| Saw log site 36B | 7.76 | 534.21 | 15,075 | 90.45[1] | 624.66 | 68.84 | 80.50 | 1,943 |
| Saw log site 36C | 10.78 | 958.34 | 19,690 | 118.14[1] | 1,076.48 | 88.90 | 99.98 | 1,827 |
| Total for saw log sites | 32.23 | 2,947.58 | 53,035 | 318.21 | 3,265.79 | 91.45[2] | 101.33[2] | 1,646[2] |

[1]Assumed 6 tons/Mbf. Unpublished data by H. M. Steinhilb.
[2]Average of the three saw log sites.

Table 3.—*Amount, grade, and value of saw logs produced from the three sites*

| | | Logging sites | | | | | |
|---|---|---|---|---|---|---|---|
| | | 36A | | 36B | | 36C | |
| **Saw log grade** | **Range of saw log values[1]** | **Amount** | **Value** | **Amount** | **Value** | **Amount** | **Value** |
| | *Dollars[2]/Mbf* | *Bd ft* | *Dollars* | *Bd ft* | *Dollars* | *Bd ft* | *Dollars* |
| Veneer | 190–340 | 5,010 | 1,457.50 | 2,560 | 762.60 | 3,325 | 918.85 |
| Number 2 logs | 110–145 | 7,480 | 948.15 | 5,495 | 691.25 | 7,900 | 997.80 |
| Number 3 logs | 90 | 5,780 | 520.20 | 7,020 | 631.80 | 8,465 | 761.85 |
| TOTAL | | 18,270 | 2,925.85 | 15,075 | 2,085.65 | 19,690 | 2,678.50 |

[1]Due to variation with species.
[2]1980 U.S. dollars.

A breakdown of the costs for producing chips indicates that felling and transport account for 47 to 60 percent of the total cost for the four logging operations (table 5). Chain flail costs range from $0.83 to $1.15 per ton or 9 to 12 percent of the total cost. Refer to tables 8-11 in the Appendix for more detailed chip production cost analyses.

# SAW LOG PRODUCTION COSTS

The most efficient saw log operation was on Site 36B where all the non-saw log trees were harvested first; then a sawyer felled and bucked the saw log trees, and the saw logs were then prehauled by a forwarder to roadside (fig. 4). The range in saw log production costs (excluding overhead and stumpage)

Table 4.—*Equipment costs and cost assumptions*[1]

| **Equipment** | **Purchase cost** | **Economic life** | **Scheduled hours/year** | **Utilization** | **Productive hours/year** | **Repair cost multiplier[3]** | **Machine rate/hr without labor[5] Fixed** | **Operating** |
|---|---|---|---|---|---|---|---|---|
| | *Dollars[2]* | *Years* | *Hours* | *Percent* | *Hours* | | *Dollars* | *Dollars[6]* |
| 2 Drott feller-bunchers 40 LC ($139,000 ea.) | 278,000 | 5 | 2,250 | 65 | 1,463 | 100[4] | 32.38 | 24.18 |
| 1 John Deere grapple skidder 740 | 95,000 | 3 | 2,000 | 67 | 1,360 | 60[4] | 27.31 | 20.87 |
| 1 Morbark Chiparvester, 22" | 152,500 | 5 | 2,000 | 75 | 1,500 | 60[4] | 30.38 | 20.60 |
| 1 Pettibone Chain Flail PM 850 | 90,000 | 5 | 2,000 | 80 | 1,600 | 60 | 21.20 | 13.16 |
| 1 Caterpillar Dozer D7G | 150,000 | 5 | 1,000 | 80 | 800 | 100[4] | 37.85 | 28.07 |
| 1 fuel truck | 2,000 | 5 | 2,000 | 40 | 800 | 100 | .55 | 2.50 |
| 1 maintenance van | 2,000 | 5 | 2,000 | — | — | 5 | .28/SH[7] | .02/mi. |
| 4 truck tractors @ 45,000 ea. | 180,000 | 5 | 40,000 mi. | — | — | 50 | .37/mi. | .39/mi. |
| 13 chip vans @ 12,000 ea. | 156,000 | 8 | 20,000 mi. | — | — | 10 | .12/mi. | .06/mi. |
| Total cost | 1,105,500 | | | | | | | |

[1]Assumes 15 percent interest rate, 3 percent insurance rate, and 3 percent tax rate. (2 percent is insurance and tax rate on maintenance van and fuel truck).
[2]1980 U.S. dollars
[3]The percentage rate by which the hourly depreciation is multiplied to estimate hourly repair costs.
[4]Warren, B. Jack. 1977. Logging cost and production analysis. Timber Harvesting Report No. 4, p. 42. LSU/MSU Logging and Forestry Operation Center, Bay St. Louis, Mississippi.
[5]Based on productive hours.
[6]Fuel cost at $1.00 per gallon.
[7]SH = scheduled hour.

Table 5.—*Breakdown of costs for producing chips*[1]

| Operation | Logging site 35 | | 36A | | 36B | | 36C | |
|---|---|---|---|---|---|---|---|---|
| | *Dollars[2]/ton[3]* | *Percent* | *Dollars/ton[4]* | *Percent* | *Dollars/ton[5]* | *Percent* | *Dollars/ton[6]* | *Percent* |
| Feller/buncher | 2.86 | 33.0 | 1.63 | 17.7 | 3.26 | 33.3 | 2.55 | 25.9 |
| Skidder | 1.18 | 13.6 | 2.25 | 24.5 | 1.91 | 19.5 | 1.55 | 15.7 |
| Chipper | 1.19 | 13.8 | 1.28 | 13.9 | 1.16 | 11.8 | 1.52 | 15.4 |
| Chain flail | .84 | 9.7 | .85 | 9.2 | .83 | 8.5 | 1.15 | 11.7 |
| Transportation | 2.37 | 27.3 | 2.68 | 29.2 | 2.42 | 24.8 | 2.81 | 28.4 |
| Other | .22 | 2.6 | .51 | 5.5 | .21 | 2.1 | .29 | 2.9 |
| Subtotal | 8.66 | 100.0 | 9.20 | 100.0 | 9.79 | 100.0 | 9.87 | 100.0 |
| Overhead (15 percent) | 1.30 | | 1.38 | | 1.47 | | 1.48 | |
| Stumpage | 1.20 | | 1.20 | | 1.20 | | 1.20 | |
| TOTAL COST | 11.16 | | 11.78 | | 12.46 | | 12.55 | |

[1]Refer to tables 8-11 in Appendix for detailed chip production cost tables.
[2]1980 U.S. dollars.
[3]Based on 1479.46 tons of chips produced.
[4]Based on 1455.03 tons of chips produced.
[5]Based on 534.21 tons of chips produced.
[6]Based on 958.34 tons of chips produced.

for the three sites was $46.30 (Site 36B) to $84.22 per thousand board feet (Site 36C) (table 6). Refer to the Appendix for more detailed saw log production cost tables (tables 12-14). Adding an overhead cost of 15 percent and a stumpage of $60 per thousand board feet gives an estimated total saw log production cost range of $113.24 to $156.85 per thousand board feet.

A breakdown of the saw log costs indicates that the chain saw felling, limbing, and bucking costs, ranging from 46 to 52 percent of the total cost, were most efficient on Site 36B ($21.23/Mbf) where all the non-saw log trees were harvested first. These costs on Site 36B were less than half of the felling, limbing, and bucking costs for Site 36C ($44.19/Mbf). On the other hand, the most efficient method of transporting saw logs from the stump to the landing was by whole-tree skidding before bucking (Site 36A–$13.56/Mbf). Grapple skidding of saw logs on Site 36C was very inefficient ($45.75/Mbf). The saw log trailer with loader greatly increased the saw log production cost for Site 36A primarily because of the low utilization (41 percent).

Figure 4.—*Forwarder unloading saw logs from Site 36B along main haul road.*

## PROFIT POTENTIAL[2]

The conventional whole-tree chipping operation on the poletimber site (Site 35) produced 1,479 tons of whole-tree chips at an estimated cost of $11.16 per green ton. If we assume a realistic value of $13.50 per green ton for the chips, this logging method yielded an estimated profit of $2.34 per green ton or $173 per acre.

For the integrated harvesting operations on saw log sites 36 A, B, and C, we calculated the potential profits generated from chips and saw logs and from the alternative of chipping everything including saw logs (table 7).

[2]*All estimated profit values discussed are estimated value before income tax.*

Table 6.—*Breakdown of costs for producing saw logs*[1]

| Operation | 36A | | 36B | | 36C | |
|---|---|---|---|---|---|---|
| | *Dollars[2]/Mbf[3]* | *Percent* | *Dollars/Mbf[4]* | *Percent* | *Dollars/Mbf[5]* | *Percent* |
| Sawyer (felling, limbing, bucking) | 32.29 | 45.9 | 21.23 | 45.9 | 44.19 | 52.5 |
| Skidder | 13.56 | 19.3 | — | — | 45.75[6] | 36.3 |
| Forwarder | — | — | 25.07 | 54.1 | 28.53[7] | 11.2 |
| Saw log trailer With loader) | 24.53 | 34.8 | — | — | — | — |
| Subtotal | 70.38 | 100.0 | 46.30 | 100.0 | 84.22[5] | 100.0 |
| Overhead (15 percent) | 10.56 | | 6.94 | | 12.63 | |
| Stumpage | 60.00 | | 60.00 | | 60.00 | |
| TOTAL COST | 140.94 | | 113.24 | | 156.85 | |

Logging site: 36A, 36B, 36C.

[1]Refer to tables 12-14 in Appendix for detailed saw log production cost tables.
[2]1980 U.S. dollars.
[3]Based on 18.27 Mbf of saw logs produced.
[4]Based on 15.075 Mbf of saw logs produced.
[5]Based on 19.69 Mbf of saw logs produced.
[6]Based on 13.155 Mbf of saw logs skidded.
[7]Based on 6.535 Mbf of saw logs forwarded.

The potential profit generated by producing chips ranged from $1.72 per green ton on Site 36A to $0.95 per green ton on Site 36C. The profit per acre extended from $183 per acre on Site 36A to $72 per acre on Site 36B.

The estimated saw log production profits were $19, $25, and $-21 per thousand board feet ($26, $49, and $-38 per acre) on Sites 36 A, B, and C, respectively, based on the saw log revenue values listed in table 3.

Summing the profits generated by chips and saw logs and comparing the sum to the profits by chipping everything gives the following percentage of increase or decrease in profits with saw logs: 6-percent increase on Site 36A; 44-percent increase on Site 36B; and 51-percent decrease on Site 36C.

Table 7.—*Projected profit before income tax from producing chips and saw logs and from the alternative of chipping the total biomass including saw logs*

| Product | Total yield | | Cost/unit | | Total cost | Total revenue | Profit | Profit/acre | Profit/ton | Profit/Mbf |
|---|---|---|---|---|---|---|---|---|---|---|
| | *Tons* | *Mbf* | *Dollars/ton[1]* | *Dollars/Mbf* | *Dollars* | *Dollars* | *Dollars* | *Dollars/acre* | *Dollars/ton* | *Dollars/Mbf* |
| **SAW LOG SITE 36A (13.69 ACRES)** | | | | | | | | | | |
| Chips | 1,455.03 | | 11.78 | | 17,140 | 19,643 | 2,503 | 183 | 1.72 | |
| Saw logs | | 18.270 | | 140.94 | 2,575 | 2,926 | 351 | 26 | | 19 |
| Chips only | 1,564.65 | | 11.78 | | 18,432 | 21,123 | 2,691 | 197 | 1.72 | |
| **SAW LOG SITE 36B (7.76 ACRES)** | | | | | | | | | | |
| Chips | 534.21 | | 12.46 | | 6,656 | 7,212 | 556 | 72 | 1.04 | |
| Saw logs | | 15.075 | | 113.24 | 1,707 | 2,086 | 379 | 49 | | 25 |
| Chips only | 624.66 | | 12.46 | | 7,783 | 8,433 | 650 | 84 | 1.04 | |
| **SAW LOG SITE 36C (10.78 ACRES)** | | | | | | | | | | |
| Chips | 958.34 | | 12.55 | | 12,027 | 12,938 | 911 | 84 | 0.95 | |
| Saw logs | | 19.690 | | 156.85 | 3,088 | 2,678 | -410 | −38 | | -21 |
| Chips only | 1,076.48 | | 12.55 | | 13,510 | 14,532 | 1,022 | 95 | 0.95 | |

[1]1980 U.S. dollars.

# DISCUSSION

In an integrated saw log-chip logging operation, one of the most important objectives is to sort out saw logs without decreasing chipper productivity. In comparing the operations on Sites 36A (sorting at landing) and 36B (sorting at stump), chipper productivity on Site 36A decreased 14 percent based on scheduled hours (38.3 tons/hr on Site 36A versus 44.5 tons/hr on Site 36B), and it decreased 8 percent based on productive hours (50.2 tons/hr versus 54.5 tons/hr). This decreased chipper productivity increased chipping costs about 10 percent ($1.28 on for Site 36A versus $1.16 on for Site 36B).

Time study data collected on the saw log trailer with loader used on Site 36A indicated that 17 percent of the loader's time was used in moving the tops from the saw log trees to the chipper. Therefore, the saw log trailer's total cost was allocated 17 percent to the production of chips and 83 percent to the production of saw logs.

Some of the difference between the estimated standing biomass given in table 1 and the actual recovered tonnage given in table 2 can be partially accounted for by the reduction in biomass by chain flailing, loss of some stems during skidding, and the failure to harvest all of the small trees.

The results presented in this paper are for specific case studies and do not imply long-term averages. Factors that affect productivity were not constant from one logging method (or site) to another. These factors include, but are not limited to, stand characteristics, plot size, skidding or forwarding distances, operator ability, weather, and unavoidable delays. Therefore, the results should be regarded as exemplary.

# SUMMARY

This study has investigated the economics of clearcutting both a northern hardwood poletimber stand by a conventional whole-tree harvesting system and a sawtimber stand by several combinations of whole-tree chipping and saw log recovery. The conventional whole-tree harvesting of the poletimber stand yielded a projected profit of $2.34 per green ton before taxes or $173 per acre. The most profitable integrated harvesting method involved using the whole-tree chipper at the landing simultaneously with the saw log recovery system. Saw log trees and non-saw log trees were skidded to the landing together and then sorted. This method yielded a potential profit of $209 per acre, including profits of $1.72 per green ton generated by the production of 1,455 tons of chips and $19 per thousand board feet generated by the production of 18,270 board feet of saw logs.

Multiproduct recovery should be emphasized in future stand conversion operations to obtain the highest value end use of the standing timber and thereby minimize total conversion costs. Utilization of whole trees and forest residuals will increase in the future because of the changing combination of solid wood, fiber, and energy products demanded from the forest.

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# APPENDIX

Table 8.—*Harvesting and transportation costs for producing chips on site 35 based on productive hours*

| Operation | Time on job | | Machine rate F | Machine rate O | Total fixed cost | Total operating cost | Total labor cost[4] | Total cost | Cost per ton[5] | Total cost |
|---|---|---|---|---|---|---|---|---|---|---|
| | *SH*[1] | *PH*[2] | *Dollars*[3] | | | | | | | *Percent* |
| Feller/buncher | 73 | 62.0 | 32.38 | 24.18 | 2,007.56 | 1,499.16 | 730 | 4,236.72 | 2.86 | 33.0 |
| Skidder | 34 | 29.1 | 27.31 | 20.87 | 794.72 | 607.32 | 340 | 1,742.04 | 1.18 | 13.6 |
| Chipper | 34 | 27.8 | 30.38 | 20.60 | 844.56 | 572.68 | 340 | 1,757.24 | 1.19 | 13.8 |
| Chain flail | 34 | 27.6 | 21.20 | 13.16 | 585.12 | 363.22 | 303 | 1,251.34 | 0.84 | 9.7 |
| Trucks[6] | — | — | .37/mi | .39/mi | 846.56 | 892.32 | 1,360 | 3,098.88 | 2.09 | 24.1 |
| Chip vans[6] | — | — | .12/mi | .06/mi | 274.56 | 137.28 | — | 411.84 | 0.28 | 3.2 |
| Maintenance van[7] | 34 | — | .28/SH | .02/mi | 9.52 | 0.88 | — | 10.40 | 0.01 | 0.1 |
| Fuel truck[8] | 34 | 13.6 | 0.55 | 2.50 | 7.48 | 34.00 | — | 41.48 | 0.03 | 0.4 |
| Dozer[9] | 34 | 3.4 | 37.85 | 28.07 | 128.69 | 95.44 | 37 | 261.13 | 0.18 | 2.1 |
| TOTAL | | | | | 5,498.77 | 4,202.30 | 3,110 | 12,811.07 | 8.66 | 100.0 |

[1]SH = scheduled hours.
[2]PH = productive hours.
[3]1980 U.S. dollars.
[4]Labor cost = $10.00/hr for each operator including all fringe benefits.
[5]Cost per ton based on 1479.46 tons of chips produced.
[6]Hauling distance = 22 miles (one way) and 52 van loads.
[7]Fixed cost = $0.28/SH x 34 SH = $9.52. Operating cost = $0.02/mi x 44 mi = $0.88.
[8]Assumed 40-percent utilization.
[9]Assumed 10-percent utilization.

Table 9.—*Harvesting and transportation costs for producing chips on site 36A based on productive hours*

| Operation | Time on job | | Machine rate F | Machine rate O | Total fixed cost | Total operating cost | Total labor cost[4] | Total cost | Cost per ton[5] | Total cost |
|---|---|---|---|---|---|---|---|---|---|---|
| | *SH*[1] | *PH*[2] | | | *Dollars*[3] | | | | | *Percent* |
| Feller/buncher | 43 | 34.3 | 32.38 | 24.18 | 1,110.63 | 829.37 | 430.00 | 2,370.00 | 1.63 | 17.7 |
| Skidder[11] | 72.5 | 52.8 | 27.31 | 20.87 | 1,441.97 | 1,101.94 | 725.00 | 3,268.91 | 2.25 | 24.5 |
| Chipper | 38 | 29.0 | 30.38 | 20.60 | 881.02 | 597.40 | 380.00 | 1,858.42 | 1.28 | 13.9 |
| Chain flail | 38 | 27.3 | 21.20 | 13.16 | 578.76 | 359.27 | 304.00[12] | 1,242.03 | .85 | 9.2 |
| Trucks[6] | | | .37/mi | .39/mi | 941.28 | 992.16 | 1,520.00 | 3,453.44 | 2.37 | 25.8 |
| Chip vans[6] | | | .12/mi | .06/mi | 305.28 | 152.64 | | 457.92 | 0.31 | 3.4 |
| Maintenance van[7] | 38 | | .28/SH | .02/mi | 10.64 | 0.88 | | 11.52 | 0.01 | 0.1 |
| Fuel truck[8] | 38 | 15.2 | .55/SH | 2.50 | 20.90 | 38.00 | | 58.90 | 0.04 | 0.4 |
| Dozer[9] | 38 | 7.6 | 37.85 | 28.07 | 287.66 | 213.33 | 76.00[12] | 576.99 | 0.40 | 4.3 |
| Saw log trailer[10] with loader | 18 | | | | | | | 91.80 | 0.06 | 0.7 |
| TOTAL | | | | | 5,578.14 | 4,284.99 | 3,435.00 | 13,389.93 | 9.20 | 100.0 |

[1]SH = scheduled hours.
[2]PH = productive hours.
[3]1980 U.S. dollars.
[4]Labor cost = $10.00/hr. for each operator including all fringe benefits.
[5]Cost per ton based on 1,455.03 tons of chips produced.
[6]Hauling distance = 24 miles (one way) and 53 van loads.
[7]Fixed cost = $0.28/SH x 38 SH = $10.64. Operating cost = $0.02/mi x 44 mi = $0.88.
[8]Assumed 40-percent utilization.
[9]Assumed 20-percent utilization.
[10]17 percent of saw log trailer cost allocated to the production of chips. 18 SH X .17 X $30/SH (Contracted cost) = $91.80.
[11]7 percent of skidding time allocated to the production of saw logs. Saw log tonnage equaled 7 percent of total.
[12]Chain flail operator also operated dozer. Total labor cost of flail and dozer = 38 SH X $10/SH = $380.

Table 10.—*Harvesting and transportation costs for producing chips on site 36B based on productive hours*

| Operation | Time on job | | Machine rate F | Machine rate O | Total fixed cost | Total operating cost | Total labor cost[4] | Total cost | Cost per ton[5] | Total cost |
|---|---|---|---|---|---|---|---|---|---|---|
| | *SH*[1] | *PH*[2] | | | *Dollars*[3] | | | | | *Percent* |
| Feller/buncher | 33 | 25.0 | 32.38 | 24.18 | 809.50 | 604.50 | 330.00 | 1,744.00 | 3.26 | 33.3 |
| Skidder | 21 | 14.5 | 27.31 | 28.70 | 396.00 | 416.15 | 210.00 | 1,022.15 | 1.91 | 19.5 |
| Chipper | 12 | 9.8 | 30.38 | 20.60 | 297.72 | 201.88 | 120.00 | 619.60 | 1.16 | 11.8 |
| Chain flail | 12 | 9.8 | 21.20 | 13.16 | 207.76 | 128.97 | 108.00[10] | 444.73 | 0.83 | 8.5 |
| Trucks[6] | | — | .37/mi | .39/mi | 319.68 | 336.96 | 480.00 | 1,136.54 | 2.13 | 21.8 |
| Chip vans[6] | | — | .12/mi | .06/mi | 103.68 | 51.84 | — | 155.52 | 0.29 | 3.0 |
| Maintenance van[7] | 12 | — | .28/SH | .02/mi | 3.36 | 0.88 | — | 4.24 | 0.01 | 0.1 |
| Fuel truck[8] | 12 | 4.8 | 0.55 | 2.50 | 2.64 | 12.00 | — | 14.64 | 0.03 | 0.3 |
| Dozer[9] | 12 | 1.2 | 37.85 | 28.07 | 45.42 | 33.68 | 12.00[10] | 91.10 | 0.17 | 1.7 |
| TOTAL | | | | | 2,185.76 | 1,786.86 | 1,260.00 | 5,232.52 | 9.79 | 100.0 |

[1]SH = scheduled hours.
[2]PH = productive hours.
[3]1980 U.S. dollars.
[4]Labor cost = $10.00/hr for each operator including all fringe benefits.
[5]Cost per ton based on 534.21 tons of chips produced.
[6]Hauling distance = 24 miles (one way) and 18 van loads.
[7]Fixed cost = $0.28/SH x 12 SH = $3.36. Operating cost = $0.02/mi x 44 mi = $.88.
[8]Assumed 40-percent utilization.
[9]Assumed 10-percent utilization.
[10]Chain flail operator also operated dozer. Total labor cost of flail and dozer = 12 SH X $10/SH = $120.

Table 11.—*Harvesting and transportation costs for producing chips on site 36C based on productive hours*

| Operation | Time on job | | Machine rate F | Machine rate O | Total fixed cost | Total operating cost | Total labor cost[4] | Total cost | Cost per ton[5] | Total cost |
|---|---|---|---|---|---|---|---|---|---|---|
| | *SH*[1] | *PH*[2] | *Dollars*[3] | | | | | | | *Percent* |
| Feller/buncher | 44 | 35.5 | 32.38 | 24.18 | 1,149.49 | 858.39 | 440 | 2,447.88 | 2.55 | 25.9 |
| Skidder | 29 | 24.8 | 27.31 | 20.87 | 677.29 | 517.58 | 290 | 1,484.87 | 1.55 | 15.7 |
| Chipper | 30 | 22.8 | 30.38 | 20.60 | 692.66 | 469.68 | 300 | 1,462.34 | 1.52 | 15.4 |
| Chain flail | 30 | 24.3 | 21.20 | 13.16 | 515.16 | 319.79 | 270[10] | 1,104.95 | 1.15 | 11.7 |
| Trucks[6] | — | — | .37/mi | .39/mi | 586.08 | 617.76 | 1,200 | 2,403.84 | 2.51 | 25.4 |
| Chip vans[6] | — | — | .12/mi | .06/mi | 190.08 | 95.04 | — | 285.12 | 0.30 | 3.0 |
| Maintenance van[7] | 30 | — | .28/SH | .02/mi | 8.40 | 0.96 | — | 9.36 | 0.01 | 0.1 |
| Fuel truck[8] | 30 | 12 | .55 | 2.50 | 6.60 | 30.00 | - | 36.60 | 0.04 | 0.4 |
| Dozer[9] | 30 | 3 | 37.85 | 28.07 | 113.55 | 84.21 | 30[10] | 227.76 | 0.24 | 2.4 |
| TOTAL | | | | | 3,939.31 | 2,993.41 | 2,530 | 9,462.72 | 9.87 | 100.0 |

[1]SH = scheduled hours.
[2]PH = productive hours.
[3]1980 U.S. dollars.
[4]Labor cost = $10.00/hr. for each operator including all fringe benefits.
[5]Cost per ton based on 958.34 tons of chips produced.
[6]Hauling distance = 24 miles (one way) and 33 van loads.
[7]Fixed cost = $0.28/SH x 30 SH = $8.40. Operating cost = $0.02/mi x 48 mi = $.96.
[8]Assumed 40-percent utilization.
[9]Assumed 10-percent utilization.
[10]Chain flail operator also operated dozer. Total labor cost of flail and dozer = 30 SH X $10/SH = $300.

Table 12.—*Harvesting costs for producing saw logs on site 36A based on productive hours*

| Operation | Time on job | | Machine rate F | Machine rate O | Total fixed cost | Total operating cost | Total labor cost[4] | Total cost | Cost per ton[5] | Total cost |
|---|---|---|---|---|---|---|---|---|---|---|
| | *SH*[1] | *PH*[2] | *Dollars*[3] | | | | | | | *Percent* |
| Sawyer (felling, limbing, bucking) | 59 | 44.8 | — | — | — | — | 590 | 590.00 | 32.29 | 45.9 |
| Skidder[6] | 5.5 | 4.0 | 27.31 | 20.87 | 109.24 | 83.48 | 55 | 247.72 | 13.56 | 19.3 |
| Saw log trailer[7] (with loader) | 18 | 7.4 | 30/SH | — | — | — | — | 448.20 | 24.53 | 34.8 |
| TOTAL | | | | | | | | 1,285.92 | 70.38 | 100.0 |

[1]SH = scheduled hours.
[2]PH = productive hours.
[3]1980 U.S. dollars.
[4]Labor cost = $10.00/hr. for sawyer and skidder operators including all fringe benefits.
[5]Cost per Mbf based on 18.27 Mbf of saw logs produced.
[6]Seven percent of skidding time allocated to the production of saw logs. Saw log tonnage equaled 7 percent of total.
[7]Eighty-three percent of saw log trailer cost allocated to the production of saw logs. 18 SH x .83 x $30/SH (contracted cost) = $448.20.

Table 13.—*Harvesting costs for producing saw logs on site 36B based on productive hours*

| Operation | Time on job | | Machine rate F | Machine rate O | Total fixed cost | Total operating cost | Total labor cost[4] | Total cost | Cost per ton[5] | Total cost |
|---|---|---|---|---|---|---|---|---|---|---|
| | *SH*[1] | *PH*[2] | *Dollars*[3] | | | | | | | *Percent* |
| Sawyer (felling, limbing, bucking) | 32 | 24.3 | — | — | — | — | 320 | 320.00 | 21.23 | 45.9 |
| Forwarder | 14 | 11.4 | 10.86 | 10.01 | 123.80 | 114.11 | 140 | 377.91 | 25.07 | 54.1 |
| TOTAL | | | | | | | | 697.91 | 46.30 | 100.0 |

[1]SH = scheduled hours.
[2]PH = productive hours.
[3]1980 U.S. dollars.
[4]Labor cost = $10.00/hr for sawyer and forwarder operator including all fringe benefits.
[5]Cost per Mbf based on 15.075 Mbf of saw logs produced.

Table 14.—*Harvesting costs for producing saw logs on site 36C based on productive hours*

| Operation | Time on job | | Machine rate F | Machine rate O | Total fixed cost | Total operating cost | Total labor cost[4] | Total cost | Cost per ton[5] | Total cost |
|---|---|---|---|---|---|---|---|---|---|---|
| | *SH*[1] | *PH*[2] | *Dollars*[3] | | | | | | | *Percent* |
| Sawyer (felling, limbing, bucking) | 87 | 65.5 | — | — | — | — | 870 | 870.00 | 44.19[5] | 52.5 |
| Skidder | 12 | 10.0 | 27.31 | 20.87 | 273.10 | 208.70 | 120 | 601.80 | 45.75[6] | 36.3 |
| Forwarder | 8 | 5.1 | 10.86 | 10.01 | 55.39 | 51.05 | 80 | 186.44 | 28.53[7] | 11.2 |
| TOTAL | | | | | | | | 1,658.24 | 84.22 | 100.0 |

[1]SH = scheduled hours.
[2]PH = productive hours.
[3]1980 U.S. dollars.
[4]Labor cost = $10.00/hr. for sawyer and equipment operators including all fringe benefits.
[5]Cost per Mbf based on 19.69 Mbf of saw logs produced.
[6]Cost per Mbf based on 13.155 Mbf of saw logs skidded.
[7]Cost per Mbf based on 6.535 Mbf of saw logs forwarded.



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The economics of a mechanized multiproduct harvesting system for stand conversion of northern hardwoods. Res. Pap. NC-237. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1983. 12 p.

Describes chip and saw log yields, production, costs, and potential profits of clearcutting, down to a 2-inch diameter, a northern hardwood poletimber stand by a conventional whole-tree harvesting system and three sawtimber stands by several combinations of whole-tree chipping and saw log recovery.

KEY WORDS: Integrated harvesting, residue recovery, whole-tree harvesting, saw log sorting.