# PRODUCTION RATES AND COSTS OF GROUP SELECTION HARVESTS WITH A CHRISTY CABLE YARDER

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Group selection harvest studies in Eastern hardwoods have shown that economic success of such harvests rests heavily on product market values, tree quality, and logging costs (Boucher and Hall 1989; Bell 1989). Other studies have attempted to define group selection harvests and where they can be used (Roach 1974). Additional studies have documented the reproduction of hardwoods 10 years after cutting as affected by site and opening size (Minckler and Woerheide 1965). In this study, the group selection units are defined as small groups, .81 ha (2 acres) or less in area, on which most of the trees will be harvested.

The studies reported above, although valuable, either use different techniques to develop cost and production rates or fail to report such at all. This report summarizes results of more comprehensive, detailed time studies in calculating incremental stump-to-landing production rates and costs per volume for cable yarding hardwoods from group selection units. The results can assist in planning for efficient group selection harvests.

## LOGGING SITES AND STUDY METHODS

A commercial group selection cable sale, the Light Gap timber sale, consisted of four groups totaling 2.5 hectares (6.1 acres) located on the Toecane Ranger District of the Pisgah National Forest in North Carolina. The groups were selected from a 13 hectare (32-acre) stand. The sale consisted of approximately 98.1 $m^3$ (3467 $ft^3$) of small hardwood roundwood and about 125.5 $m^3$ (53.2 Mbf, Scribner Decimal C log rule) of hardwood sawtimber. The principal species were yellow poplar, ash, basswood, hemlock, and northern red oak.

All groups were clearcut and yarded separately to uphill landings. Approximately 488 meters (1600 feet) of spur road were constructed to log groups 3 and 4. Groups 1 and 2 were logged from an existing road and a landing that required a small amount of grading and widening. Logging took place during August and September 1989.

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An average of 50.9 $m^3$/ha (8,735 bf/acre) of sawtimber and 39.8 $m^3$/ha (568 $ft^3$/acre) of roundwood were removed. The average volume per log was 1.17 $m^3$ (41.3 $ft^3$).

Data were recorded by one person at the landing and one person at the hooking point. Total cycle time in minutes was recorded for each turn. The logs were scaled and numbered before yarding. The log numbers and other turn attributes were recorded both at the landing and the hooking point depending on the attribute and the visibility of the turn by the person recording the data. The time study monitored three of the four harvest units.

## LOGGING EQUIPMENT AND CREWS

The Light Gap timber sale was logged by Gilkey Lumber Company, Rutherfordton, North Carolina using a Christy[1] cable yarder and a Mini-Maki carriage (Fig. 1).

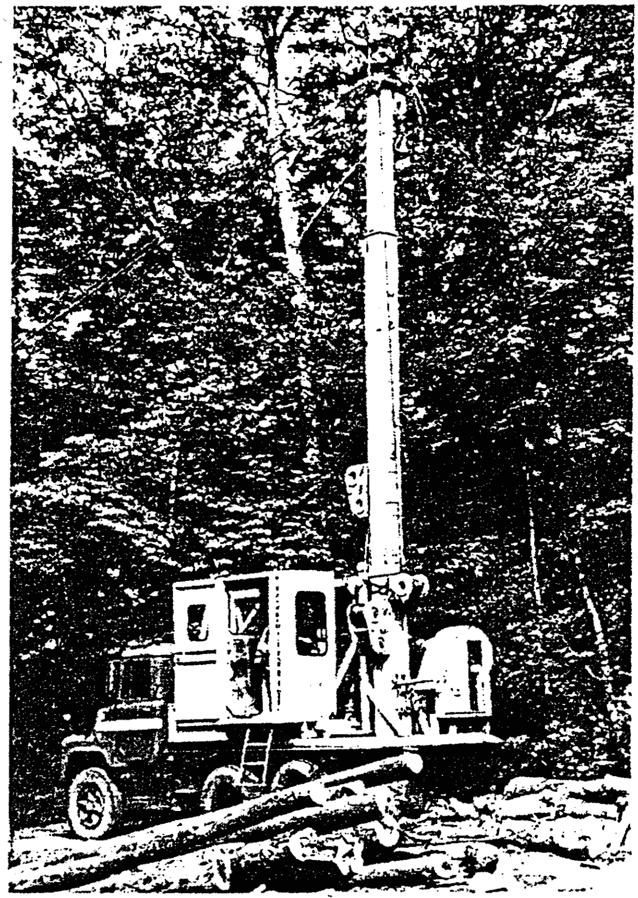

Figure 1. Christy cable yarder.

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[1]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.

A Barko 160 loader with slasher was used to sort, deck, buck logs to length, and load trucks. A John Deere 540-B rubber-tired skidder was used on group 2 to swing logs from the yarder chute area to the processing and loading area. Operations were performed by a crew of six: one loader operator, one yarder engineer, two choker-setters, one hooktender, and one chaser that doubled as the swing skidder operator. Sawlogs, pulpwood, and firewood products were sorted and loaded out almost daily.

## TIME STUDY RESULTS

Average cycle delay time was greatest on group 1 and lowest on group 3, 6.2 min and 0.5 min, respectively (Table 1). Most delay time was attributed to mechanical problems with the yarder, carriage hangups, and main line breaks (Fig. 2). For all groups, delay time averaged 26.2 percent of total scheduled time. Average delay-free cycle time was greatest on group 2 and lowest on group 1, 9.6 min and 6.7 min, respectively (Table 1).

Table 1. Summary Time Study Statistics for Yarding Cycles, Averages, and Ranges.

| Variable | Mean (Range) | | | |
|---|---|---|---|---|
| | Group 1 | Group 2 | Group 3 | All Groups |
| Number cycles | 73 | 142 | 26 | 241 |
| Total cycle time (min) | 13.0 (1.9-305.8) | 11.5 (2.8-48.1) | 8.5 (2.1-30.8) | 11.6 (1.9-305.8) |
| Cycle delay time (min) | 6.2 (0-293.8) | 1.9 (0-36.2) | 0.5 (0-12.0) | 3.0 (0-293.8) |
| Delay free time (min) | 6.7 (1.9-17.4) | 9.6 (2.8-17.8) | 8.1 (2.1-18.8) | 8.6 (1.9-18.8) |
| Slope yard dist. (m) | 96 (43-140) | 263 (23-341) | 147 (0-276) | 200 (0-341) |
| Lateral yard dist (m) | 14 (0-47) | 12 (0-43) | 5 (0-23) | 12 (0-47) |
| Volume/cycle ($m^3$) | 2.8 (0.2-7.5) | 2.3 (0.2-5.9) | 2.4 (0.5-5.2) | 2.5 (0.2-7.5) |
| Number logs/cycle | 2.1 (1-4) | 2.1 (1-4) | 2.3 (1-4) | 2.1 (1-4) |
| Volume/log ($m^3$) | 1.3 (0.1-7.5) | 1.1 (0.1-5.5) | 1.1 (0.03-3.9) | 1.2 (0.03-7.5) |
| Production | | | | |
| Total ($m^3$/hr) | 12.8 | 12.3 | 17.1 | 12.8 |
| Delay free ($m^3$/hr) | 19.4 | 14.7 | 18.0 | 17.4 |

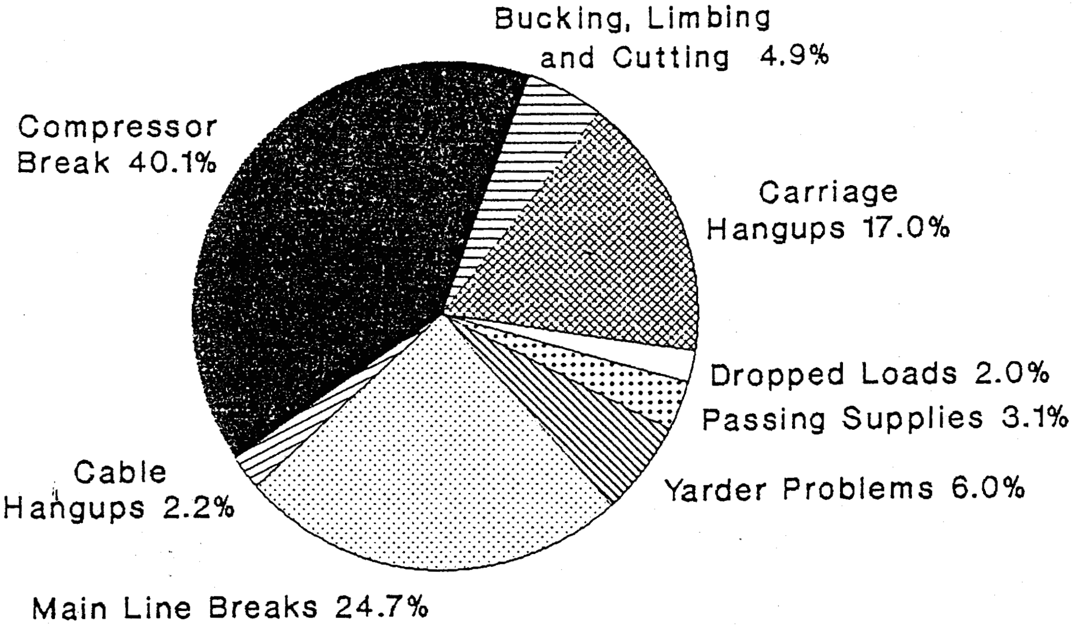


Figure 2. Breakdown of delays as a percentage of total delay time.

The difference in delay-free cycle time resulted primarily from the differences in average slope yarding distance between groups; 263 meters (862 feet) for group 2 and 96 meters (316 ft) for group 1 (Table 1). Average log and turn volumes were greatest on group 1. Logs per turn were relatively consistent for all groups. Although lateral yarding distances of 47 meters (155 feet) were recorded, average lateral yarding distance ranged from only 5 meters (16.5 feet) on group 3 to 14 meters (46.7 feet) on group 1. For all groups combined, production averaged 17.4 $m^3$ (613.6 $ft^3$) per delay-free hour and 12.8 $m^3$ (452.9 $ft^3$) per scheduled hour.

Ordinary least squares regression analysis was performed on the time-study data to develop a prediction equation for estimating delay-free cycle time. The data from all groups was pooled for this analysis. A forward stepwise regression procedure examined the effect of several variables on yarding cycle time. Variables selected were slope yarding distance, lateral distance, number of logs, cubic foot volume, and hooking crew size. The regression equations were chosen by comparing $R^2$ values and levels of significance of variables.

Analysis of covariance and heterogeniety of slopes tested the effects of choker-setting crew size on cycle time by treating crew size as a dummy variable. This analysis indicated that crew size had a statistically significant effect on both the equation intercept term and the lateral yarding distance coefficient. This is a logical result, showing that an additional person on the hooking crew would reduce the time required to pull cable laterally from the carriage and to hook chokers.

For the following equation, regression statistics are: N=241, $R^2$=0.565, standard error of the estimate = 2.341. All partial regression coefficents are significant at the 0.05 level.

$$Y=0.798+1.067X_1+.020768X_2+.284806X_3+0.5245X_4+0.001125X_5+.051509X_1X_5$$

Where:
- $Y$ = delay free cycle time - min;
- $X_1$ = choker-setting crew size dummy variable; with crew of 2, $X_1= 1$; with crew of 3, $X_1=0$;
- $X_2$ = slope yarding distance - meters;
- $X_3$ = turn volume - $m^3$;
- $X_4$ = number of logs per turn;
- $X_5$ = lateral yarding distance - meters.

## YARDING COST ANALYSIS

The production data from Table 1, the cycle time equation, and an hourly owning and operating cost of $52.73 for the yarder and crew were used to illustrate the incremental effect of each variable on yarding costs. The $52.73 hourly rate is based on all new equipment and does not allow for profit and risk. The output was used to develop Figures 3-6, which show the effect and sensitivity of each respective variable in the regression equation upon cost per unit of volume yarded. The variable of interest was allowed to change value while all other variables within the equation were held constant at their observed mean values.

Figure 3 demonstrates the effects of slope and lateral yarding distances on estimated yarding cost for a hooking crew of two and average turn volumes and logs per turn. These results indicate that as slope yarding distance increases, production decreases and unit cost increases. For example, a logging planner contemplating yarding units that average 122 meters (400 ft) and lateral distance averaging 12.2 meters (40 ft) could expect a cost of \$2.58/$m^3$ (\$0.073/$ft^3$) (Fig. 3). However, extending slope distance to 183 meters (600 ft) would increase cost by about 18 percent to \$3.04/$m^3$ (\$0.086/$ft^3$). Similarly, going from 122 meters (400 feet) to 244 meters (800 feet) at a cost of \$3.50/$m^3$ (\$0.099/$ft^3$), or to 1000 feet at a cost of \$3.92/$m^3$ (\$0.111/$ft^3$) would increase cost by approximately 35 and 52 percent respectively.

Figure 3 also shows the effect of varying the lateral yarding distance. If the planner is considering a skyline layout where the average slope yarding distance is 183 meters (600 ft) and average lateral yarding distance is 6.1 meters (20 ft), the unit stump-to-landing cost would be \$2.83/$m^3$ (\$0.080/$ft^3$). If the lateral distance increased to 24.4 meters (80 ft), the yarding cost would increase by approximately 21 percent to \$3.43/$m^3$ (\$0.097/$ft^3$). Increasing lateral yarding distance on group selection units can reduce the number of skyline corridors that would need to be rigged, possibly through uncut portions of the stand. Longer lateral yarding distances are often necessary to reach long corners due to terrain and unit boundaries. Results such as those in Fig. 3 can help to show the incremental costs of increasing lateral distances.

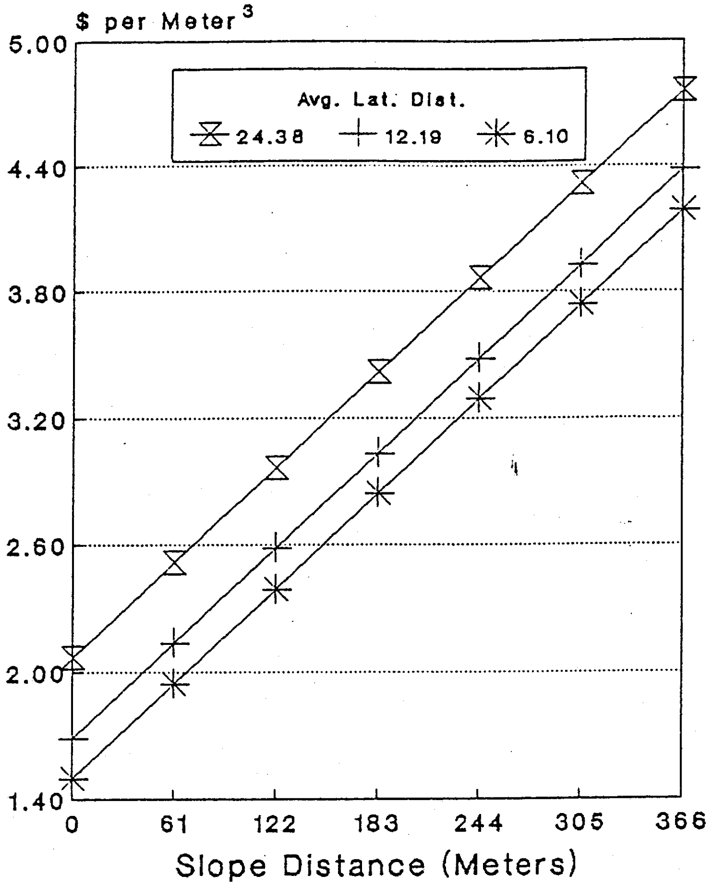


Figure 3. Effects of slope and lateral yarding distance on estimated yarding cost. Conditions: 2.12 logs per turn, 2.48 $m^3$ per turn, and hooking crew of 2 persons.

Figure 4 demonstrates the effects of turn volume and logs per turn on the estimated yarding cost using a hooking crew of two, and average slope and lateral yarding distances. For example, the cost to yard one log that forms a turn size of 2.8 $m^3$ (100 $ft^3$) is 2.62/$m^3$ (\$0.074/$ft^3$). Hooking four logs to form the same turn size increases the cost by about 19 percent to \$3.11/$m^3$ (\$0.088/$ft^3$). This increase is due to hooking additional pieces to form a given turn size. However, hooking additional logs of a given size to form larger turns decreases cost. For example, yarding one 0.71 $m^3$ (25 $ft^3$) log costs \$9.68/$m^3$ (\$0.274/$ft^3$). Yarding four logs of 0.71 $m^3$ (25 $ft^3$) each to form a turn of 2.83 $m^3$ (100 $ft^3$) decreases cost to \$3.11 $m^3$ (\$0.088/$ft^3$), approximately a 68 percent reduction. These results illustrate the importance of yarding large logs and turns to keep costs down. Yarding small roundwood will decrease the average log and turn size and will increase costs.

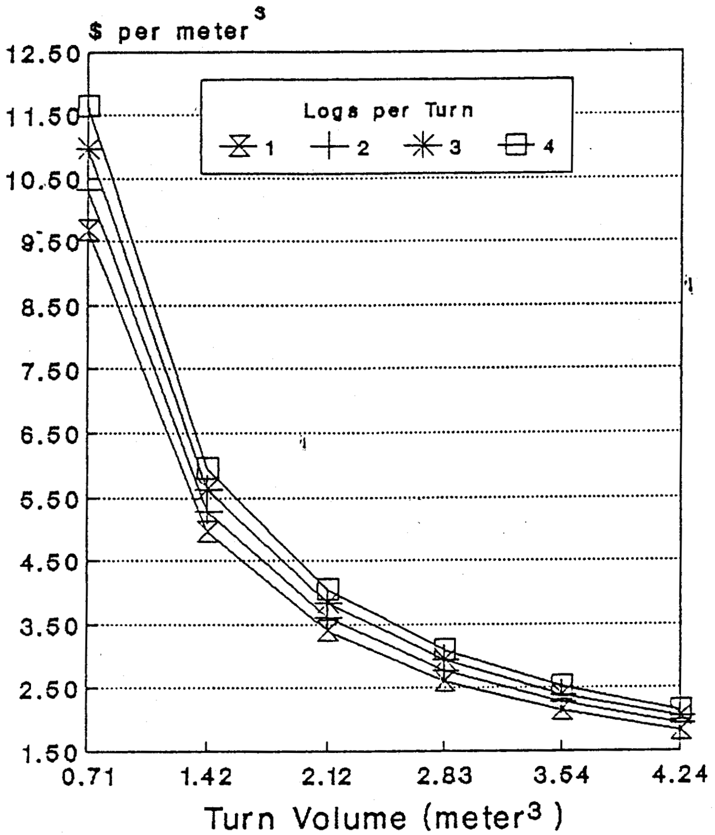


Figure 4. Effects of turn volume and logs per turn on estimated yarding costs. Conditions: Slope yarding distance = 200 meters, lateral yarding distance = 11.9 meters, and hooking crew of 2 persons.

Figure 4 also demonstrates the importance of turn volume, and the effects of logs per turn on costs which diminish with increasing turn volume. Hooking of two logs, along with the change in turn volume increasing from 0.71 $m^3$ (25 $ft^3$) to 1.42 $m^3$ (50 $ft^3$), reduces yarding costs by about 49 percent; from \$10.32 $m^3$ (\$0.292 $ft^3$) to \$5.38 $m^3$ (\$0.150 $ft^3$). Further increasing of turn volume to 2.83 $m^3$ (100 $ft^3$) decreases costs another 48 percent; from \$5.30 $m^3$ (\$0.150 $ft^3$) to \$2.76 $m^3$ (\$0.078 $ft^3$). The difference in estimated cost between one and four log turns decreases from \$1.94 $m^3$ (\$0.055 $ft^3$) at 0.71 $m^3$ (25 $ft^3$) per turn, to only \$0.32 $m^3$ (\$0.009 $ft^3$) at 4.25 $m^3$ (150 $ft^3$) per turn. These results indicate the importance of planned turn building, that is, hooking as much volume as allowed by log size distributions and payload constraints. During planning and layout, the planner should strive for as much payload capability as possible, ensuring adequate deflection for each skyline corridor.

The advantage of a 3-person versus 2-person hooking crew is shown as a function of average lateral yarding distance (Fig. 5). The differences in estimated yarding cost by crew size increases with lateral yarding distance. With the average yarding conditions sampled and an average lateral yarding distance of 6.1 meters (20 feet), the extra person reduced costs by only \$0.11/$m^3$ (\$0.003/$ft^3$) or about 4 percent. With an average lateral yarding distance of

24 meters (80 feet), however, costs are reduced by \$0.39 $m^3$ (\$0.011 $ft^3$), or about 11 percent. Although the reductions in yarding cost are rather small, the major advantage is in the hooking crew sharing the work load of pulling line laterally to hook a turn and having more energy reserve during the working day versus two people getting tired and slowing down as the work cycle progresses. A tired hooking crew not only contributes to lower production, but due to fatigue, also can create a safety problem. Line pulling involves pulling the mainline off to the side laterally to hook logs. Since, in this operation, there was no slackpulling capability at the carriage, all line pulling was done by the hooking crew. Although the mainline free spools at the yarder and feeds downhill using gravity, the weight of the cable forms a belly under the catenary, posing a significant line- pulling challenge. Generally, a hooking crew of three also will hook more logs to increase turn volume and reduce yarding costs.

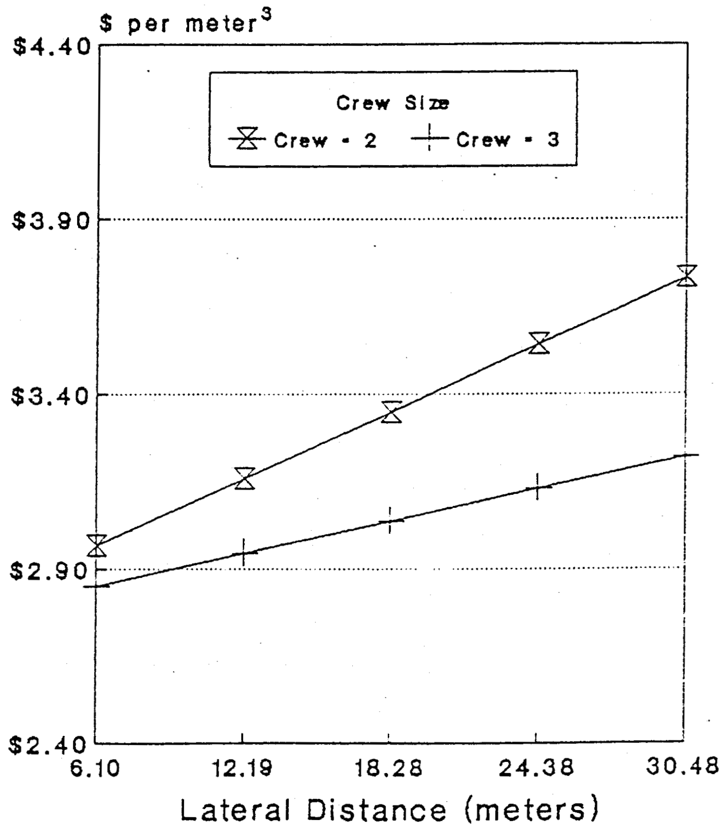


Figure 5. Effects of crew size and estimated yarding cost. Conditions: slope yarding distance = 200 meters, turn volume = 2.48 $m^3$, and logs per turn = 2.12.

To determine the cost of yarding different sized units, move in-and-out costs were calculated and added to yarding cost (Fig. 6). If group selection harvests result in very small and scattered harvest units that require frequent moves between units, then the cost to move in and out of each unit can become prohibitive.

Move-in-and-out costs include wages and system-fixed costs incurred when moving equipment and rigging the skyline. The costs in Fig. 6 were calculated by adding estimated yarding costs for the average conditions sampled ($3.14/m^3$ or $0.089/ft^3$) to the move-in-and-out costs (move cost/(area x volume/ha)). The assumed volume/ha equaled 161 $m^3$ for all units yarded. These results indicate that costs decline rapidly with increasing harvest unit area, and that minimizing of move costs and keeping the unit area .81 ha (2 acres) or larger can avoid excessive harvesting costs (Fig. 6). Obviously, for very small groups, the costs would be prohibitive. Most variables are held at their mean values so that results will change if other than mean values are used as constants. For example, increasing volume/ha would have an effect similar to increasing of harvest unit area.

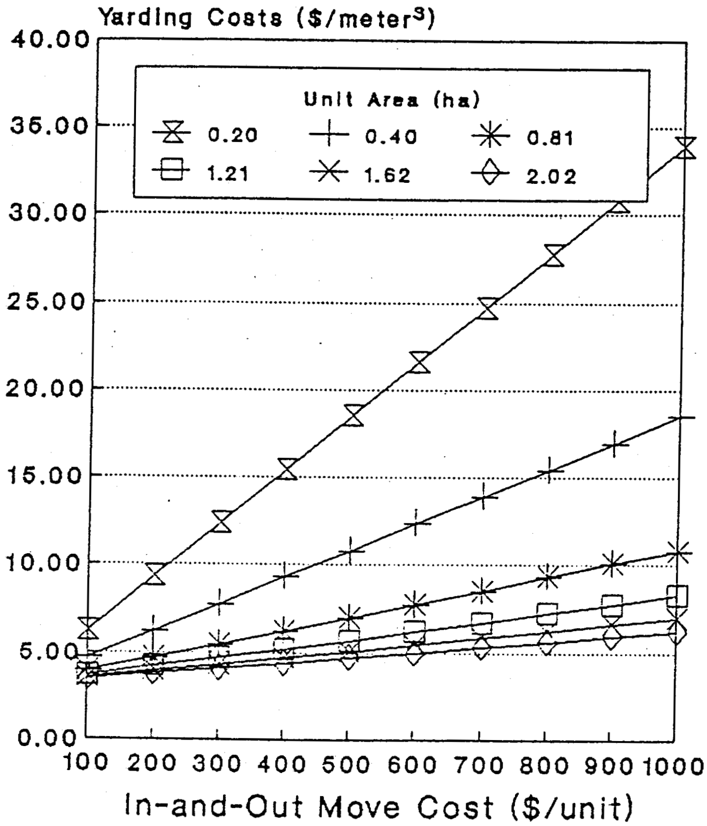


Figure 6. Effects of harvest unit area and move-in-and-out costs on estimated total yarding and move costs. Conditions: slope yarding distance = 200 meters, lateral yarding distance = 11.9 meters, turn volume = 2.48 $m^3$, number of logs per turn = 2.12, and hooking crew = 2 persons.

## CONSIDERATIONS FOR MANAGERS

Besides the prospect of removing over-mature trees, insect and disease damage, blow down, ice damage, and other small pockets of timber, there are other incentives: salvaging of valuable timber, maintaining aesthetic and visual management objectives, wildlife management, and water quality management. However, it is beyond the scope of this report to fully discuss all these management concerns. Supplemental research is under way to investigate and develop economic breakeven guidelines for group selection harvests in a systems theory approach.

This study includes data from three group selection harvest units that span most mixed hardwood sites. The yarding conditions and variables used to develop the production data cover the range of conditions normally encountered in cable logging of hardwoods. The prediction equation can be used to develop reliable estimates of stump-to-landing production rates that along with other associated costs, can be used to estimate group selection harvesting costs. The results can be used in simulation programs or other cable logging models. There is additional research in the developing of breakeven guidelines and there is a computer program (GROUP-PC) to evaluate the efficiency of harvesting group selection units. By having the ability to estimate the effect upon production and costs of yarding-group selection units, it is expected that economical designs can be made in future logging operations. Perhaps this harvesting approach will result in balanced management of forest stands for fiber, wildlife, and other objectives.

## REFERENCES

1. Bell, R.D. 1989. Influences of varying stand harvest methods on timber harvesting costs in Southeastern Virginia hardwoods. Masters thesis. Virginia Polytechnic Institute and State University, Blacksburg, Virginia. 68 p.

2. Boucher, B. A.; Hall, O. F. 1989. Implementing group selection in Appalachian hardwoods using economic guidelines. Paper presented at the 7th Central Hardwoods Forest Conference, March 5-8, 1989, Carbondale, Illinois.

3. Minckler, L. S.; Woerheide, J. D. 1965. Reproduction of hardwoods: 10 years after cutting as affected by site and opening size. Journal of Forestry; 63(2):103-107.

4. Roach, B. A. 1974. What is selection cutting and how do you make it work? What is group selection and where can it be used? Applied Forestry Research Institute, Miscellaneous Report No. 5. State University of New York.