Production Rates and Costs of Group-Selection Harvests with Ground-Based Logging System

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Abstract: As increased demands are placed on forest land for timber production, wildlife, esthetics, recreation, hunting, fishing, and other uses, owners of woodlots and forest land are looking for different ways to harvest or treat the stands to accomplish their objectives. The large clearcut harvest blocks that had been the standard for years with the forest industry are not always acceptable. The contemporary emphasis is on harvesting trees using partial and tree-selection cuts, thinnings, and group-selection methods. Group-selection involves taking small groups or clumps of trees in a somewhat random pattern to capture mortality, wood or weather damage, insect or disease infestations; to regenerate stands; and to harvest financially mature trees. As the size of group/clump (size of opening) decreases, so does the volume and value to be removed. How much the logging costs increase by decreasing the size of opening was the focus of this study. Cost and production information was developed to make decisions about harvesting units of different sizes with ground-based logging systems. The harvest units ranged from one-half to two acres in size.

INTRODUCTION

Changing times and attitudes toward forest land have changed the way timber is managed. As increased demands are placed on forest land for timber production, wildlife habitat, esthetics, recreation, hunting and fishing, as well as a multitude of other uses, owners of forest land are looking for different ways to manage timber stands to attain individual objectives. A growing number of small nonindustrial private landowners believe that clearcutting is an undesirable timber management method, especially when done on a large scale with cut blocks greater than 5 to 10 acres in size. These large clearcut harvests, which have been the standard for years in the forest industry, are not always acceptable, and are often viewed as degrading both visually and to the forest ecosystem. The contemporary emphasis is on harvesting timber using partial and tree-selection cuts, thinnings, and group-selection methods. These silvicultural harvesting methods recognize the long-term effects and benefits of good forest management above and beyond past methods that generally focused on only the short-term revenues realized from a timber harvest.

Group-selection involves harvesting small groups or clumps of trees in a somewhat random pattern across a stand to capture mortality, insect and disease infestations; to regenerate stands; and to harvest financially mature trees. The group-selection method has certain advantages over single-tree selection cuttings. Harvesting older mature trees can be carried out more economically and with less damage to the residual stand. There is greater latitude for creating the kind of environmental conditions necessary for reproduction. The reproduction develops in clearly defined even-aged aggregations, which is a substantial advantage in developing good tree form, especially in hardwoods (Smith 1986).

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Group-selection cuttings also create gaps in the forest canopy that can increase the area of favorable habitat for wildlife. Many species of wildlife benefit from the combination of environmental conditions existing within and along the boundaries between the young reproduction and older trees. Several kinds of protective cover are available in close proximity to various food plants that may be fostered by the broad spectrum of microclimatic conditions existing between the edges and the centers of the young groups.

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, LeDoux et. al. 1991, Brummel 1992, Erickson et. al. 1992). 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, 2 acres or less in area, on which most of the trees will be harvested.

The studies reported above, although valuable, do not provide detailed time and motion data for ground-based systems operating in group-selection units. This report summarizes results of comprehensive, detailed time studies for ground-based systems operating in Appalachian upland hardwood stands.

LOGGING SITES AND STUDY METHODS

Data for the study were collected from a commercial logging operation on the West Virginia University Experimental Forest, Monongalia County, West Virginia. The study area was approximately 54 acres in size. Stand composition across the study site was composed of Appalachian hardwoods dominated by yellow-poplar (*Liriodendron tulipifera*), northern red oak (*Quercus rubra*), chestnut oak (*Quercus prinus*), black cherry (*Prunus serotina*), red maple (*Acer rubrum*), as well as several other species of lesser importance. Within the 54-acre study area, treatment plots representing group-selection harvest blocks of 0.5, 1.0, 1.5, and 2.0 acres were located and replicated 4 times for a total of 16 cutting plots totaling 20.0 acres (Figure 1). Plots were located so individual treatments were separated by a buffer zone of approximately 150 to 200 feet.

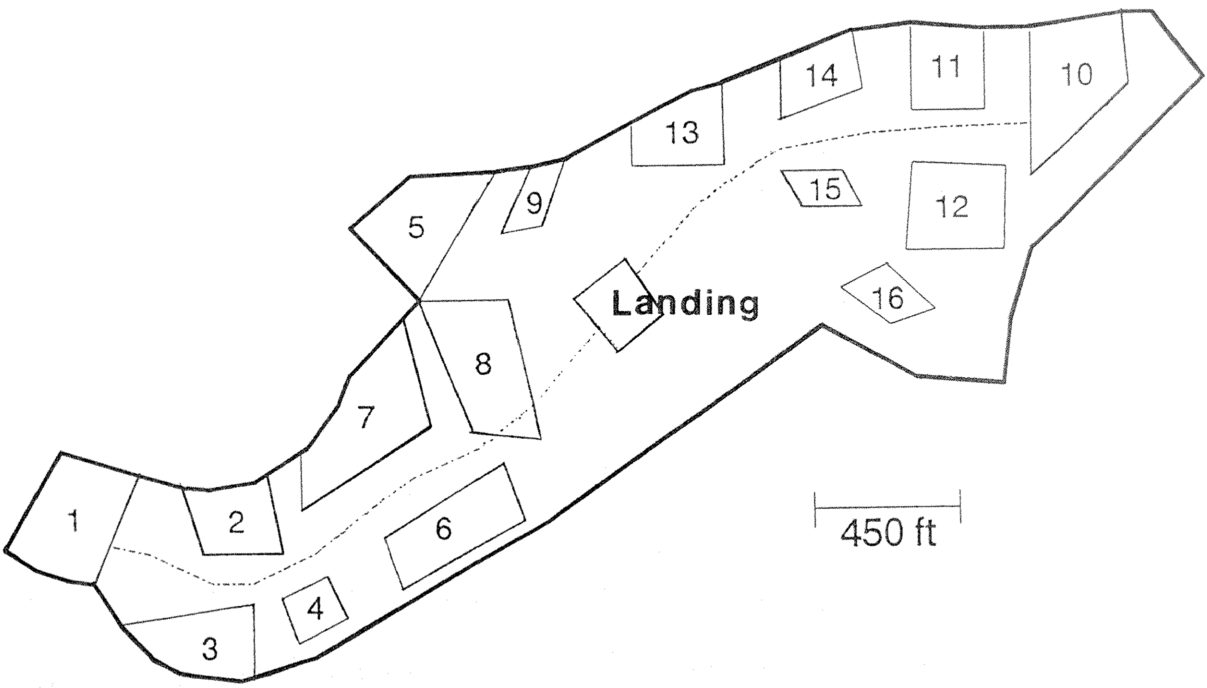

Figure 1.—Group-selection harvest units, plot boundaries, landing, and primary skid trail locations.

Before harvesting the group-selection units, a single centrally located landing and two primary designated skid trails from which the individual plots could be accessed were flagged in (Figure 1). The landing and skid trails, after being reviewed by the logging contractor and modified where deemed necessary, were developed before the cutting and skidding activities began. Within each of the harvest units, designated skid trails were not used and skidding was performed with a random approach, so long as the designated trails were used for entry and exit from the plots.

All trees within each group-selection unit, both sawtimber and pulpwood size, were chainsaw felled, limbed, and topped. All stems were processed into tree-length material with utilization levels in the form of minimum-top diameters left up to the cutters. Skidding of the processed tree-length materials on each of the study units was completed by one of three John Deere 640D cable skidders[3], each operated by one of four skidder operators. For the most part, skidding on an individual plot was performed by a single operator and sometimes two operators in an attempt to eliminate some of the system imbalances that may have occurred if all three machines were working in close proximity in the small cutting units. In addition to this, once an operator began skidding from a treatment block the operator was restricted to skidding the block to its completion so as not to complicate the collection of the time study data.

Continuous time and motion study data were collected for the skidding component for each of the treatment plots. All skidding element times, both productive and non-productive delay were recorded by data collectors stationed both at the study plot sites and at the landing. In addition to productive and delay element times, additional skidding parameters including skid distance, number of stems per turn, volume per turn, number of machine moves in a hooking cycle, as well as a number of other variables were recorded for each skidding cycle. Because of a shortage in available data collectors during two days of the harvest operation, detailed data were not collected for plots 4 and 5, so these plots were eliminated from the study. Continuous time data were collected on a total of 715 skid cycles involved in skidding the remaining 14 group-selection units in the study.

TIME STUDY RESULTS

Average total cycle time was greatest on groups of 0.5 and 1.0 acres and lowest on the groups of 1.5 and 2.0 acres, respectively (Table 1). The difference in total cycle time resulted primarily from the differences in mean one-way skid distance; about 1,100 feet for 0.5- and 1.0-acre groups and about 1,050 feet for groups of 1.5 and 2.0 acres. Average logs hooked per cycle were slightly larger on groups of 1.0 and 2.0 acres. The average number of winching cycles (pulls/cycle) to form a turn were relatively consistent for all groups. Average volume/cycle was about the same for all size groups with turn volumes of about 140 ft^3. For all groups combined, production averaged about 540.67 ft^3 per delay-free hour and 450 ft^3 per scheduled hour (Table 1).

Average cycle delay was about the same for all groups ranging from no delay to a maximum of 26 minutes for all groups (Table 1). Most delay time was attributed to nonproductive personal delays, feller/bucking, and system imbalance (Figure 2). For all groups, delay time averaged about 17 percent of total scheduled time.

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[3]The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endoresement 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.

Table 1.—Summary time study statistics for skidding cycles, averages and ranges

Variable	Group size				All groups
	0.5	1.0	1.5	2.0	
Number cycles	65	184	172	294	715
Total cycle Time (min)	17.41 (8.17-29.35)	17.29 (8.08-28.94)	15.68 (8.32-30.88)	14.96 (5.13-28.23)	15.95 (5.13-25.98)
Cycle delay (min)	2.75 (0-14.32)	3.27 (0-22.76)	3.51 (0-25.98)	3.10 (0-22.33)	3.21 (0-25.98)
Outdistance (ft)	1111 (572-2104)	1099 (500-1574)	1041 (422-1654)	1072 (200-2187)	1075 (200-2187)
Indistance (ft)	1106 (572-2104)	1098 (420-1574)	1034 (422-1654)	1068 (200-2187)	1071 (200-2187)
Number logs/ cycle	4 (1-8)	4.4 (1-9)	3.9 (1-7)	4.7 (1-9)	4.4 (1-9)
Moves/ cycle	.16 (0-1)	.23 (0-2)	.19 (0-2)	.28 (0-2)	.24 (0-2)
Pulls/ cycle	1.23 (1-2)	1.28 (1-3)	1.27 (1-3)	1.35 (1-3)	1.30 (1-3)
Volume/ cycle (ft^3)	153.86 (34-333)	128.61 (22-254)	149.66 (30-333)	147.57 (24-391)	143.76 (22-391)
Production Total (ft^3/hr)	457.78	375.42	468.04	490.22	450.08
Delay free (ft^3/hr)	530.37	446.35	572.86	591.87	540.67

[a]Mean value
[b]Range

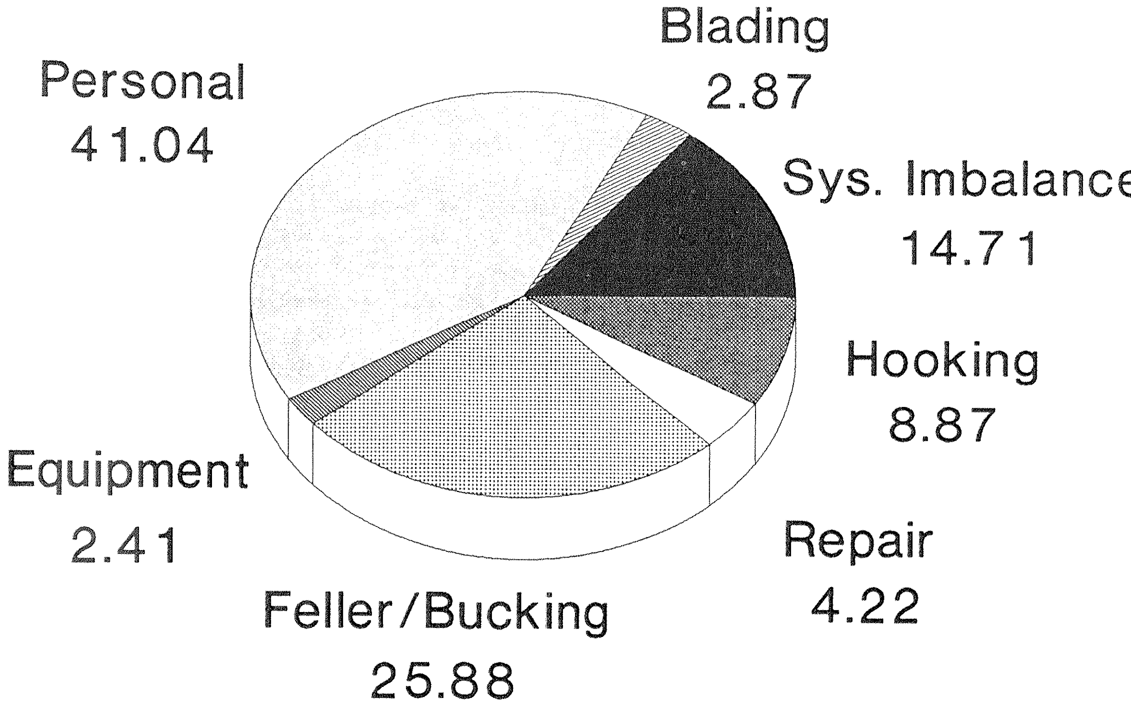

Figure 2.—Breakdown of delays as a percentage of total delay time.

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 and operators were pooled for this analysis. A stepwise regression procedure examined the effect of several variables on skidding cycle time. Variables selected were roundtrip distance/2, number of logs/turn, number of winching cycles to form a turn (pulls/cycle), cubic foot volume/turn, and dummy variables for group size of 0.5, 1.0, and 1.5 acres. Cycle time can be estimated for 2.0-acre groups by substituting zeros for all group size coefficients. The regression equation was chosen by comparing R^2 values and levels of significance of variables.

For the following equation, regression statistics are: N=715, R^2=0.487, standard error of the estimate = 3.023. All partial regression coefficients are significant at the 0.05 level.

$$
\begin{aligned}
Y = 5.41 &+ 2.71X_1 \\
&+ 2.54X_2 \\
&+ 1.40X_3 \\
&+ 0.00485X_4 \\
&+ 0.319X_5 \\
&+ 1.63X_6 \\
&- 1.59X_7 \\
&+ 0.00437X_8
\end{aligned}
$$

where:
Y = delay-free cycle time - min;
X_1 = group size dummy variable; with size of 0.5 acres, X_1=1, otherwise X_1=0;
X_2 = group size dummy variable; with size of 1.0 acres, X_2=1, otherwise X_2=0;

X_3 = group size dummy variable; with size of 1.5 acres, $X_3=1$, otherwise $X_3=0$;
X_4 = Roundtrip distance/2, feet;
X_5 = Number of logs/turn;
X_6 = Number of winching cycles to form a turn;
X_7 = Prebunched logs dummy variable, when logs are prebunched, $X_7=1$, otherwise $X_7=0$;
X_8 = turn volume, ft^3.

SKIDDING COST ANALYSIS

The production data from Table 1, the cycle-time equation, and an hourly machine rate cost of $36.94 for the skidder and operator were used to illustrate the incremental effect of each variable on skidding costs. The $36.94 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 skidded. The variable of interest was allowed to change value while all other variables within the equation were held constant at their observed mean values.

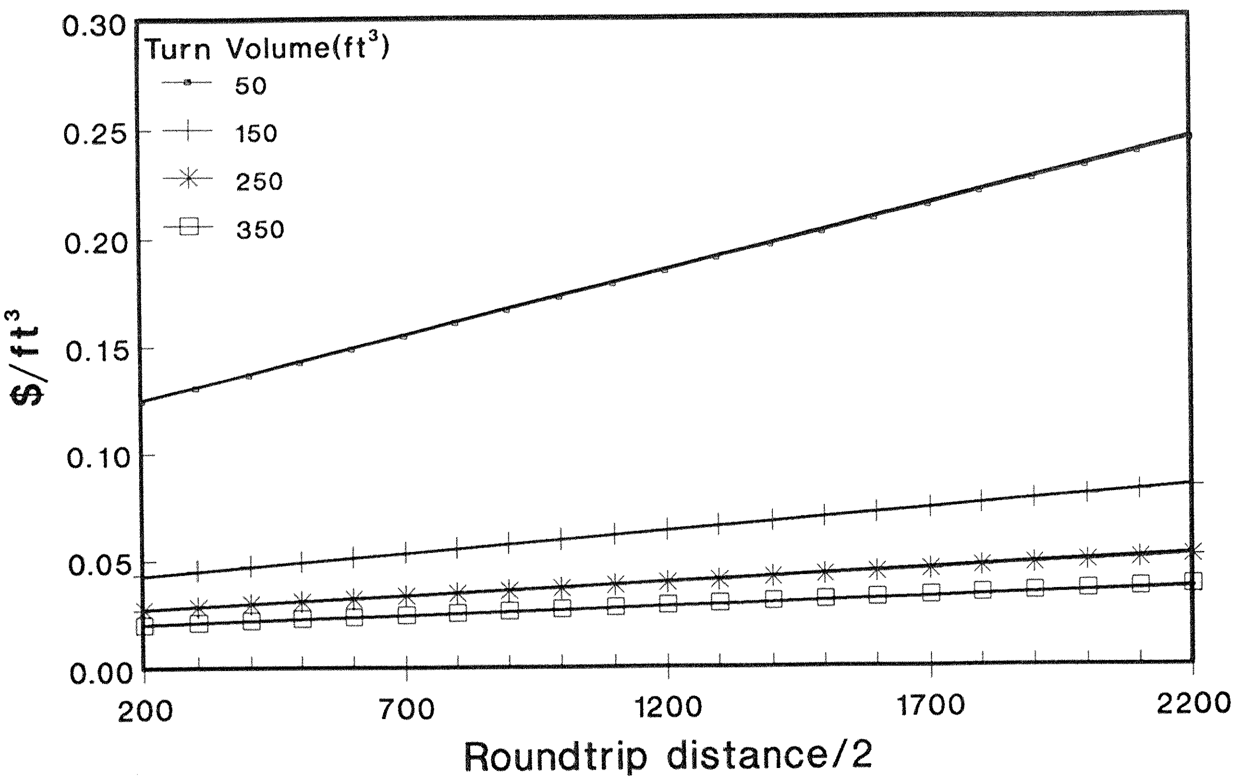

Figure 3.—Effects of slope distance and volume per turn on estimated skidding cost. Conditions: size of group = 2 acres, 4.4 logs/turn, 1.3 pulls/turn, and no prebunched logs.

Figure 3 demonstrates the effects of slope skid distance and volume/turn hooked on estimated skidding cost for average conditions. These results indicate that as slope skid distance increases, production decreases and unit cost increases. For example, a logger planning to log units where the average slope skid distances would be about 700 feet with 50 ft^3 turns could expect a cost of

$0.154/ft^3$ (Figure 3). However, extending slope distance to 2,000 feet would increase cost by about 50 percent to $0.232/ft^3$ for the same turn size. Similarly, going from hooking 50 ft^3 turns to 350 ft^3 turns at a distance of 700 feet would decrease cost by 84 percent from $0.154/ft^3$ to $0.024/ft^3$. Hooking 150 ft^3/turn versus 50 ft^3/turn at 700 foot distances would decrease costs by 65 percent, illustrating the importance of hooking larger turn volumes.

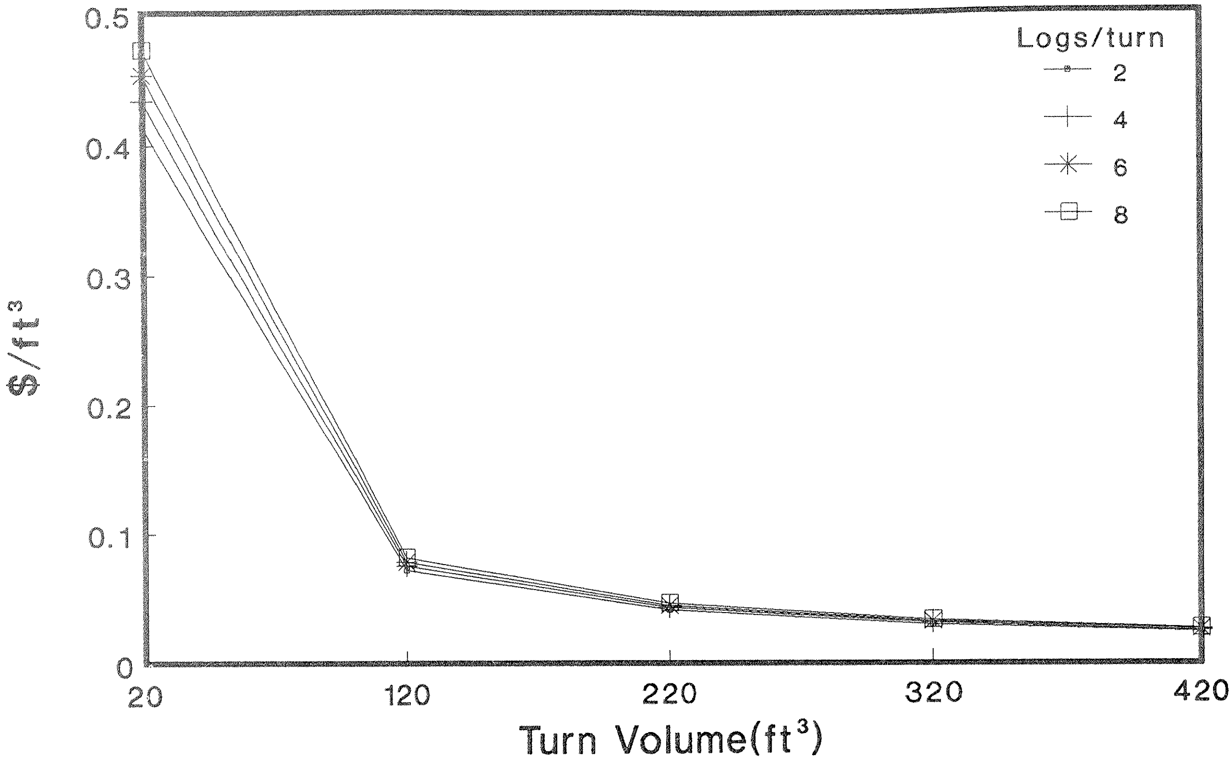

Figure 4.—Effects of volume per turn and logs/turn on estimated skidding costs. Conditions: slope distance is 1,073 feet, size of group = 2 acres, 1.3 pulls/turn, and no prebunched logs.

Figure 4 demonstrates the effects of turn volume and logs per turn on the estimated skidding cost for average conditions. For example, the cost to skid two logs that form a turn size of 20 ft^3 is $0.414/ft^3$. Hooking eight logs to form the same turn size increases the cost by about 14 percent to $0.473/ft^3$. This increase is due to the time involved in 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, hooking two logs to form a 20 ft^3 turn costs $0.414/ft^3$, whereas hooking the same two logs to form a 320 ft^3 turn decreases cost by about 93 percent to $0.028/ft^3$. These results illustrate the importance of skidding large logs and turns to keep cost down. These results indicate the importance of planned turn building, that is, hooking as much volume as allowed by log-size distributions and machine payload constraints. Skidding small roundwood will decrease the average log and turn size resulting in increased costs/unit volume.

Figure 5 demonstrates the effect of pulls/cycle and turn volume on cost/unit for average conditions. The number of pulls (winching cycles) needed to form a turn will affect production and costs. For example, hooking 50 ft^3/turn requiring one pull costs about $0.170/ft^3$. For the same conditions, requiring two pulls increases cost by 12 percent to $0.190/ft^3$. When three pulls are

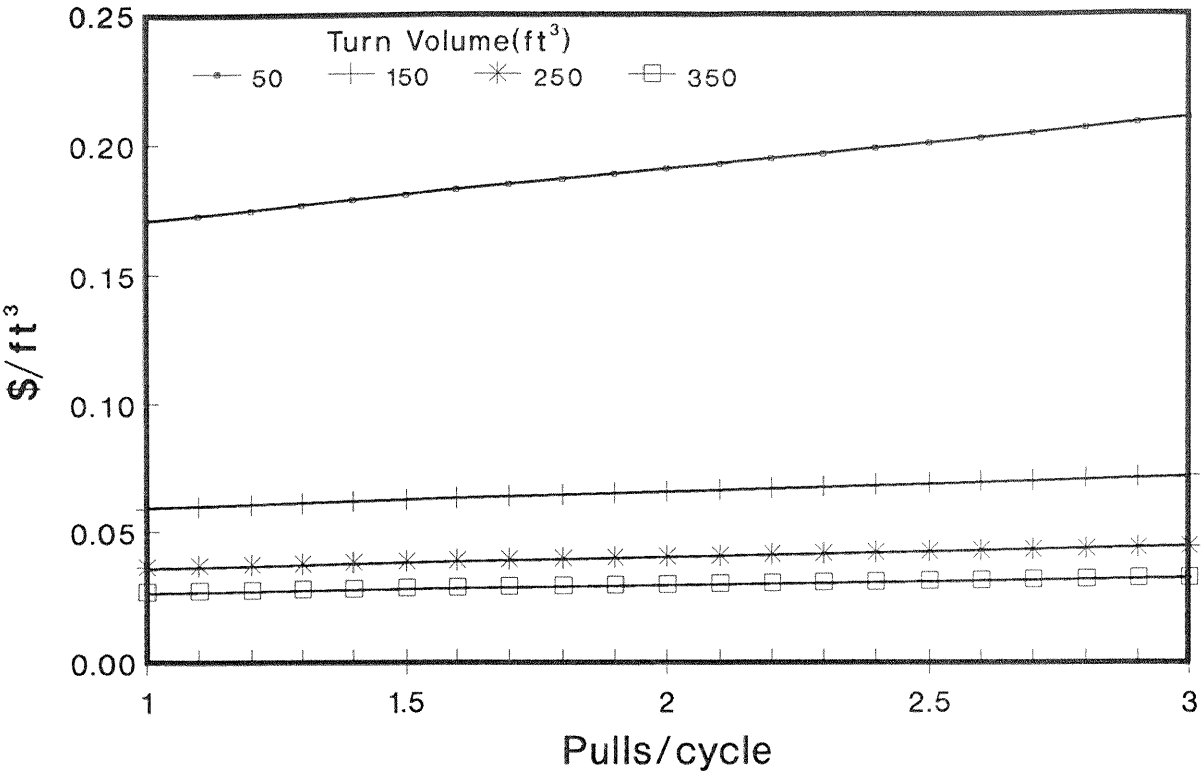

Figure 5.—Effects of pulls/cycle and turn volume on estimated skidding costs. Conditions: size of group = 2 acres, slope distance is 1,073 feet, 4.4 logs/turn, 1.3 pulls/turn, and no prebunched logs.

required to form the same turn, cost increases by 23 percent from \$0.170/ft^3 to about \$0.210/ft^3. However, one pull to hook a 50 ft^3 turn costs \$0.170/ft^3. For the same number of pulls but hooking a larger turn of 350 ft^3, cost decreases by about 85 percent to \$0.026/ft^3. This again illustrates the importance of turn size on production and cost.

Figure 6 shows the effect of logs/turn and log size on cost of skidding different log and turn sizes for average conditions. Hooking one 16 ft^3 log costs about \$0.504/ft^3. Hooking nine 16 ft^3 logs to form a 144 ft^3 turn reduces cost by about 86 percent from \$0.504/ft^3 to \$0.069/ft^3. By contrast, hooking one 64 ft^3 log versus a 16 ft^3 log decreases cost from \$0.504/ft^3 to \$0.128/ft^3 or about 75 percent.

To determine the cost of skidding different size units, move-in-and-out costs were calculated and added to skidding cost (Figure 7). When 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. The costs in Figure 7 were calculated by adding estimated skidding costs for each group size and the average conditions sampled to the move-in-and-out costs (move cost/(total area cut * volume/acre)). The assumed volume/acre equalled 3,000 ft^3 for all units skidded. These results indicate that costs decline rapidly with increasing harvest unit area, and that minimizing move costs and keeping the unit area 1. acres or larger can avoid excessive harvesting costs (Figure 7). Obviously, for very small scattered groups, the costs could be prohibitive. Most variables were held at their observed mean values so that results will change if other than mean values are used as constants. For example, increasing volume/acre would have an effect similar to that of increasing the harvesting unit area.

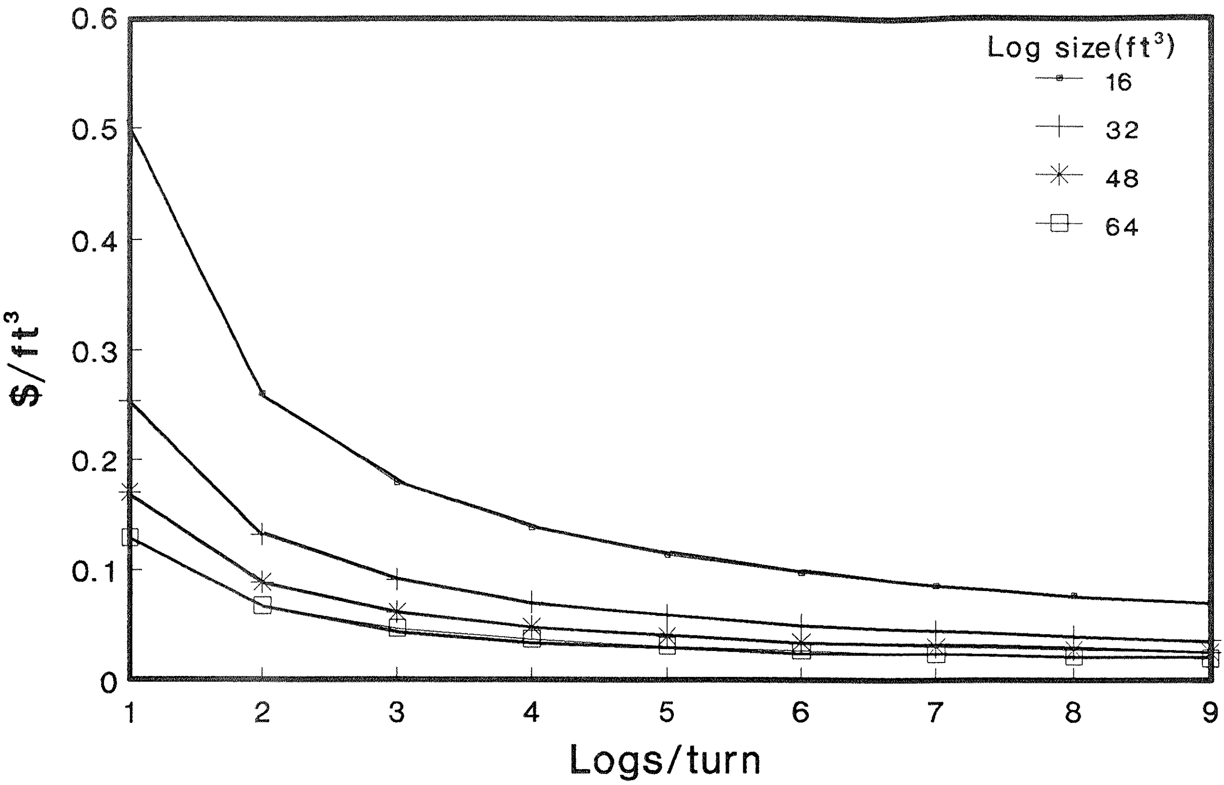

Figure 6.—Effects of logs/turn and log size on estimated skidding cost. Conditions: size of group = 2 acres, slope distances is 1,073 feet, 1.3 pulls/turn, and no prebunched logs.

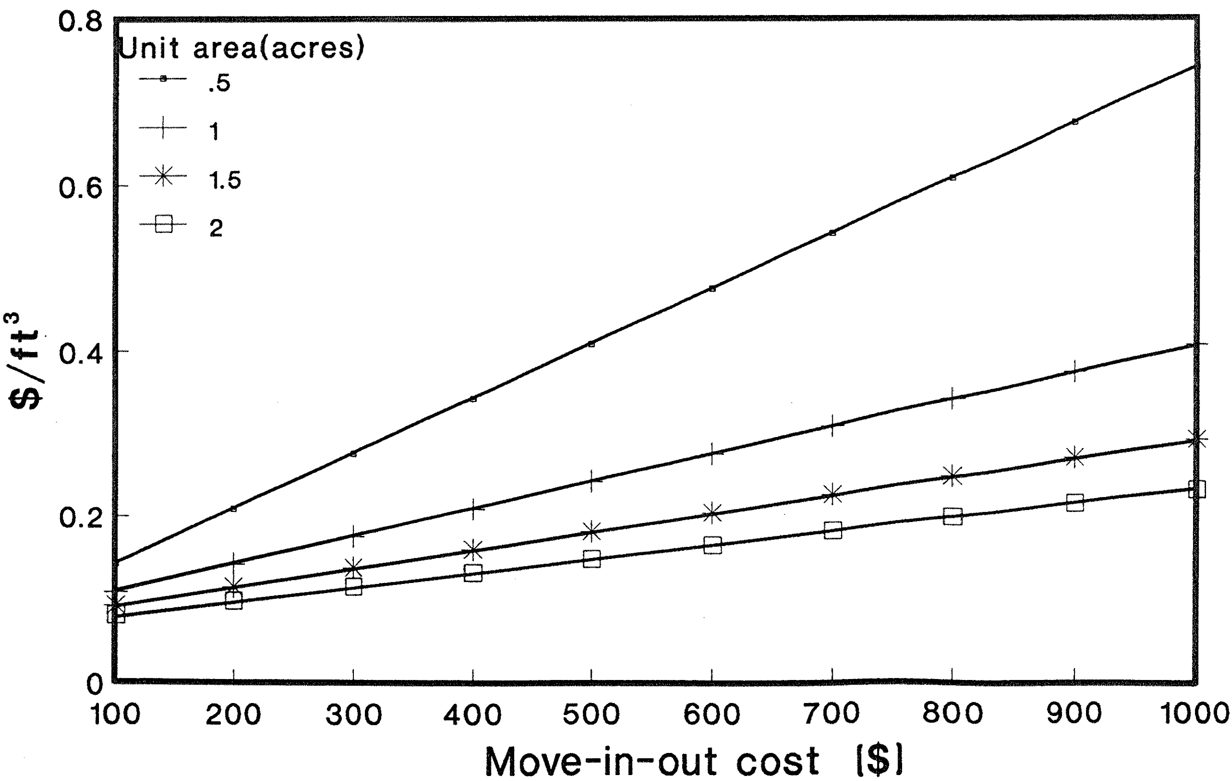

Figure 7.—Effects of harvest unit area and move-in-and-out costs on estimated total skidding and move costs. Conditions: slope distance = 1,073 feet, 4.4 logs/turn, 1.3 pulls/turn, and no prebunched logs.

CONSIDERATIONS FOR MANAGERS

Besides the prospect of removing overmature trees, insect and disease damage, blow down, ice damage, and other small pockets of timber, group-selection harvests offer other incentives: salvaging of valuable timber, maintaining esthetic 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 14 group-selection harvest units that span typical Appalachian mixed hardwood sites. The skidding conditions and variables used to develop the production data cover the range of conditions normally encountered in ground-based 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 ground-based 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. The ability to estimate the effect of several common skidding parameters on production and costs of skidding group-selection units, should make economical designs possible in future logging operations. This harvesting approach should result in balanced management of forest stands for fiber, wildlife, and other objectives.

LITERATURE CITED

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.

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

Brummel, K. R. 1992. The impact of group-selection silviculture on timber harvest cost in the southern Appalachians. Masters Thesis. Virginia Polytechnic Institute and State University, Blacksburg, Virginia. 145 p.

Erickson, M. D., Hassler, C. C., LeDoux, C. B. 1992. Group-selection harvests: Influence of group size on harvesting costs and productivity. In: Council on Forest Engineering 15th Annual Meeting; August 10-13, 1992; Hot Springs, Arizona.

LeDoux, C. B., Baumgras, J. E., Sherar, J., and Campbell, T. 1991. Production rates and costs of group-selection harvests with a Christy cable yarder. In: Proceedings of the Forestry and Environment - Engineering Solutions; June 5-6, 1991. Conference, ASAE: 75-84.

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.

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, Syracuse, New York.

Smith, D. M. 1986. The practice of silviculture. Eighth ed. John Wiley and Sons, New York. 527 pp.