THE IMPACT OF GROUP SELECTION SILVICULTURE ON
TIMBER HARVESTING COST IN THE SOUTHERN APPALACHIANS
by
Kenneth R. Brummel

Thesis submitted to the Faculty of the
Virginia Polytechnic Institute and State University
in partial fulfillment of the requirements for the degree of
Master of Science
in
School of Forestry and Wildlife Resources

APPROVED:

Robert M. Shaffer, Chairman

William B. Stuart

Thomas W. Reisinger

May 1992
Blacksburg, Virginia
THE IMPACT OF GROUP SELECTION SILVICULTURE ON TIMBER HARVESTING COSTS IN THE SOUTHERN APPALACHIANS

by

Kenneth R. Brummel

Robert M. Shaffer, Chairman

Department of Forestry

(ABSTRACT)

National Forest timber management in the Southern Appalachians is changing from traditional even-aged management and clearcutting to uneven-aged management and group selection silviculture. Group selection, with its small 1/2-to-2-acre patch cuts widely dispersed throughout a timber stand, has the potential to substantially increase timber harvesting costs over traditional clearcutting. This could exacerbate the below-cost timber sale issue. The objective of this study was to assess the impact of group-selection silviculture on timber harvest productivity and cost in hardwood stands of the southern Appalachians. This was accomplished by collecting and analyzing field production and cost data from typical Appalachian loggers operating on group-selection timber sales. Three logging systems were chosen for the study: (1) cable yarder (skyline) system; (2) feller-buncher/cable skidder system; and (3) motor-manual chainsaw felling/cable skidding system. At least one full week of time-study production data was
collected at each location. Cost information was obtained from the cooperating loggers' records, as well as historic production and cost data from previous clearcut sales for comparison purposes. Study results show that production was reduced and unit cost increased for all three logging systems when operating on group-selection timber sales as compared to clearcutting. Unit cost per ton for the cable yarder system was $40.18, a 29 percent increase over their previous average clearcutting cost. The feller-buncher/cable skidder system unit cost per ton was $14.79, a 19 percent increase over this system's average clearcutting cost. The chainsaw felling/cable skidder system cost of $16.15 per ton was 33 percent above their normal clearcutting cost. A large increase in delays and unproductive time as a result of specific group-selection timber sale characteristics appears to be the major cause of reduced logging productivity and increased costs.
Acknowledgments

I would like to express my thanks to the four Industrial Forestry Operations faculty. They include: Dr. Shaffer, who chaired my committee, guided and prodded me with patience and encouragement as I struggled with various aspects of this research; Dr. Stuart; Dr. Reisinger; and Dr. Aust. They were all helpful and greatly appreciated. Their assistance did not go unnoticed as they were always available to lend a listening ear, add constructive criticism, and offer advice through many friendly conversations. They made this project enjoyable and will be missed.

I also want to thank the other graduate students who became my friends, co-workers and companions through it all. Without their encouragement, the gripe sessions, and help in the field, none of this would have been completed.

But most of all, I want to express my deepest thanks and gratification to my Lord and Saviour, Jesus Christ. He was with me every step of the way. His guidance through the Holy Spirit provided all the means and fit all the pieces together to make it all worthwhile. Praise be to God.
Appendix D: Elemental Description for Rubber-Tired Skidder ............................................ 127

Appendix E: Elemental Description for Skyline, Cable Yarder ....................................... 128

Appendix F: Time Record Sheets Listing Elemental Segments Studied for Chainsaw Felling, Feller-Buncher Felling, Cable yarding and Rubber-Tired Skidding ............................................. 129

Appendix G: Cash Flow Analysis ......................... 134

VITA .................................................... 144
LIST of ILLUSTRATIONS

Figure 1. Hypothetical Group Selection Timber Sale ...... 7
Figure 2. Long Term Hypothetical Group Selection Timber Sale on a 5 Year Cutting Cycle ....................... 8
Figure 3. Material Flow Diagram for Cable Yarding System (Contractor #1) ............................................. 20
Figure 4. Material Flow Diagram for Feller - Buncher and Rubber-Tired, Cable Skidder System (Contractor #2) ................................................................. 23
Figure 5. Material Flow Diagram for Manual Felling and Rubber-Tired Cable Skidding System, (Contractor #3) ................................................................. 24
Figure 6. Southfork Group Selection Timber Sale Map .... 27
Figure 7. Wildcat Group Selection Timber Sale Map ...... 32
Figure 8. Cherokee Group Selection Timber Sale Map ..... 36
Figure 9. Box Plot Felling Times for Contractor #1 and #3 by Element Category Studied in Minutes .... 57
Figure 10. Skidding Time by Element Category for Contractor #2 and #3 in Minutes ....................... 70
Figure 11. Truck Weight Tickets of Deliveries During Group-Selection Harvest from August 1 to September 30, 1991 ................................................................. 89
Figure 12. A group-selection patch viewed from the yarder setting through a skyline corridor ............. 92
Figure 13. Skid trail from patch ................................. 93
Figure 14. Concentration of logging slash slowed felling production ............................................................. 97
Figure 15. Productivity decreased as logging slash increased during hook time as buried trees were common ................................................................. 98
Figure 16. Corridor alignment proved critical in set-up..100
Figure 17. The Feller-Buncher and Skidder Could not operate at the same time when a patch was small ........................................ 102
LIST OF TABLES

Table 1. Harvesting System Description for the Cable Yarding System (Logging Contractor #1) ........ 19

Table 2. Harvesting System Description for Feller-Buncher and Rubber-Tired Cable Skidder System (Logging Contractor #2) ......................... 21

Table 3. Harvesting System Description for Manual Felling and Rubber-Tired Cable Skidding System (Logging Contractor #3) ......................... 23

Table 4. Pre-Harvest Descriptive Data of the Southfork Timber Sale ................................... 39

4b. Individual Tree Volume (Cubic Feet); Mean, Median, Mode and Ranges ......................... 39

Table 5. Pre-Harvest Descriptive Data of the Wildcat Timber Sale ................................... 40

5b. Individual Tree Volume (cubic feet); Mean, Median, Mode and Ranges ......................... 40

Table 6. Pre-Harvest Descriptive Data of the Cherokee Timber Sale ................................... 41

6b. Individual Tree Volume (cubic feet); Mean, Median, Mode and Ranges ......................... 41

Table 7. Manual Chainsaw Felling Data for Contractor #1 and #3 ........................................ 55

Table 8. Average Productive Felling Times in Minutes for First 25 and Last 25 Percent of Recorded Times for Group Selection Harvesting .......... 59

Table 9. Productive Felling Time Data, Ranges, and Median Volume per Tree for Feller-Buncher (Contractor #2) ........................................ 61

Table 10. Mean Productive Elemental Felling Times (in Minutes) by Patch for Feller-Buncher (Contractor #2) ........................................ 63

Table 11. Productive and Delay Time for the Feller-Buncher ........................................... 64
Table 12. Mean Tree per Turn, Ranges and Average Volume per Turn for Contractor #2 and #3 ............. 67
Table 13. Mean Cycle Skidding Productive Time per Turn, the Range and Distance from the Landing for Contractor #2 and #3 .................. 68
Table 14. "First Three" and "Last Three" Mean Scheduled Skidder Turn Times by Patch .................. 71
Table 15. Productive and Scheduled Skidder Hours Recorded for Contractor #2 and #3 Plus Percent of Delay Associated to Cause .................. 72
Table 16. Mean Yarding Cycle Times and Volume per Turn for Contractor #1 and Ranges .................. 76
Table 17. Mean Yarding Cycle Productive Time, Total Time and Productivity (Contractor #1) ............ 78
Table 18. Contractor #1’s Mean Cycle Yarding Time and Ranges ............................................. 79
Table 19. Mean Cable Yarding Productive Time by Patch and Category in Minutes for Contractor #1 ..... 80
Table 20. Weekly Production and Cost per Ton of Group Selection Harvest by Contractor ............... 82
Table 21. Weekly Cost Component in Dollars for Three Study Contractors ............................... 83
Table 22. Weekly Cost Component in Percent for the Three Contractors .................................... 84
Table 23. Average Weekly Production by Contractor for Group Selection and Clear Cutting ............. 87
CHAPTER 1

Introduction

Today's forest managers are confronted with a wide array of public expectations for how forests, especially public forests, should be managed. As Tipple and Wellman (1989) stated,

"Today's ... forest resource managers must not only grasp the current scientific and technical issues of the field; they must also possess a thorough understanding of the role the public is demanding in resource management, together with the skills to facilitate public participation.... The increased public involvement in forest resource management is not a temporary aberration. Instead, it is a part of a societal trend toward more direct citizen participation in administrative decision processes."

Lately, this involvement has included questioning timber harvest practices.

Public concern over clear cutting, embodied within the environmental movement, has forced managers of publicly held forests to reevaluate silvicultural methods. Since the forest industry depends on wood from both public and private holdings for its raw material, these changing trends have caused concern over timber availability and cost. Fiber demands, whether for paper or solid wood products, are at an all-time high and are forecasted to increase. Forest managers have become caught in the dilemma of meeting increased demand while dealing with public opinion favoring
reduced harvesting. Thus, a range of silvicultural approaches is being considered in an attempt to meet the public's concerns. As one author opined, "Group selection has the ability to satisfy the multiple uses demanded by the diverse group of forest users ..." (Boucher, 1989). Whether or not this is universally true has yet to be determined.

Single-tree selection allows regeneration of shade-tolerant shrubs but not regeneration of shade-intolerant tree species. Therefore, in order to provide site conditions needed by shade-intolerant trees, openings are required to allow the proper amount of sunlight to reach seedlings. As Smith (1991) stated,

"When attempts were made to use the single-tree selection method for regeneration of hardwoods that are intolerant to shade, it became apparent that the reproduction and growth of those same species was not adequate. In other words, the forest floor conditions (primarily light) required for the reproduction of desirable species and subsequent growth of that reproduction, were not satisfactory. To overcome this problem, the single-tree selection method of regeneration was modified so that trees were removed in small groups to provide seedbed conditions more favorable for regeneration of the less shade-tolerant species."

Group selection silviculture, which is a system of small, scattered clear-felled patches, is particularly suited to hardwood management, because it can provide for regeneration of shade-intolerant species like northern red oak, which is
the major species found throughout Appalachia. For this reason, group selection has been considered appropriate for the Appalachian Mountain region, where few commercially important shade-tolerant tree species grow naturally.

Group selection has been studied from a silvicultural perspective for many years. Silvicultural research papers from as far back as the turn of the century describe in detail how these small, scattered, cut patches affect regeneration, tree form, and species composition. However, this approach has only recently been looked to as a means to respond to special interest groups who have been applying pressure on public forest managers to reduce reliance on even-aged harvesting methods (i.e., clear cutting -- which, for this paper, is defined as a harvesting method where all merchantable trees are removed from an area 4 to 20 acres in size) as the primary means for regeneration. Therefore, while forest managers understand the silvicultural implications of group selection, economic impacts, such as the effects on logging costs and production, are less well known.

These same vocal interest groups have been trying to legislate changes in harvesting practices. The laws of nature, however cannot always conform to every specific
human desire; certain species are intolerant of shade and need full sunlight to grow. Thus, discussion should actually focus on how large these open spaces must be. The seedlings’ perspective is the same from the middle of a two-acre "group" and a 40-acre clearcut.

Group selection, by definition, is an uneven-aged regeneration method that provides the specific forest floor conditions required for the regeneration of one or more species (Boucher, 1989). It is implemented when two or more trees are removed in one spot or group which provides three or more age classes (a requirement of uneven-aged management). In practice, group selection is the removal of timber from a cluster of small (up to 2.0 acres), dispersed openings throughout the forest stand. The size of the patch or group is a function of: 1) the biology of the regenerated species; 2) present stand characteristics; and 3) landowner objectives. The resultant opening usually has a radius no less than two times the trees' height (Boucher, 1989).

Economics must also be considered in determining which silvicultural system will be used. Single-tree selection methods favor regeneration of lower-value, shade-tolerant trees instead of higher-value, shade-intolerant trees. This
is especially true in the southern Appalachians, where high-value oaks are usually replaced by low-value red maple, hemlock, and dogwood under shady conditions. To keep the higher-valued, sun-loving species in the canopy, group selection or some form of clear cutting, which totally removes the canopy, is favored over single-tree selection.

Wildlife is also a source of enjoyment and pride in the Appalachian region and is a concern when considering which silvicultural system of regeneration to enact. While clear cutting and group selection keep valuable oaks as the dominant tree species, these same species are also more important for mast production (i.e., food sources) for wildlife. Thus, economic arguments aside, group selection benefits wildlife by suppressing the amount of shade-tolerant tree species that regenerate. By allowing site conditions that benefit the regeneration of the more important wildlife tree species, the needed food sources for wildlife creatures are insured through group selection.

The U.S.D.A. Forest Service within southern Appalachia also must consider group selection from a marketing perspective. Current practice is to locate group-selection cutting units within mature hardwood stands that contain large, high-quality, high-value timber. This allows the Forest Service
to market the sale in such a way as to generate the greatest amount of revenue and, hopefully, avoid a "below-cost" timber sale.

Once National Forest silviculturalists have identified an area where a group-selection harvest is feasible, a harvest plan is formulated. The plan includes a permanent skid trail and landing network intended to serve additional group-selection harvests within the same timber stand as they are scheduled over time (Figure 1). Thus, an area that previously would have been clear cut in a single harvesting operation will receive similar treatments over several cutting cycles under the group-selection method (Figure 2).

Harvesting a group-selection timber sale is believed by many logging experts to be more expensive than clear cutting. However, since group selection has never been widely used and accepted as a timber harvesting method, this perceived difference remains mostly an unknown. It is for this very reason many forest managers are hesitant to try such a system (Hall et al. 1991).

Boyd et al. (1988) state that "operators confronted with a ... new utilization standard [or silvicultural management
FIGURE 1. Hypothetical Group Selection Timber Sale
Figure 2. Long Term Hypothetical Group Selection Timber Sale on a 5-year Cutting Cycle.
system] will have a tough time predicting production." Reasons cited include unproductive time required for additional moving between landings, lost production, longer skidding distances, reduced travel speeds, increased problems with residual stand protection, decreased felling productivity due to the increased chance of hung trees, more intensive preharvest planning and increased accident exposure to both crew and equipment. These factors are expected to increase harvesting costs in comparison to conventional clearcutting systems. However, the impact of group-selection silviculture on harvesting costs for various logging systems is not known.

King (1981) stated, "Knowledge of these optimal limits ... can aid in negotiating a fair harvest contract." Sloan (1991) agreed, "When considering the application of non-traditional harvesting methods [group selection], logging costs must be a primary concern at the very outset of the planning process."

Using the Harvesting Analysis Technique (HAT), a computer simulation program, Bell (1989) modeled a group-selection harvest and a clearcut harvest on the same Appalachian hardwood timber stand. The skid trail network necessary to harvest 27 acres of patches in an actual group-selection
timber sale unit was used to define the area of a comparable 160-acre clear cut. Simulation results showed production from a conventional chainsaw/cable skidder operation was 21 percent less for the group-selection cut than for a comparable clearcut. Harvesting cost per cord for group selection was 26 percent higher than for the comparable clearcut operation.

Boyd et al. (1988) stated, "Logging costs are determined by a great number of factors, some measurable and some not; some related to the stand being harvested and some not; some controlled by the appraiser and some not; some applicable to all logging jobs and some not; and finally, some related to existing social and economic conditions and some not."

Thus, valid estimates of group-selection harvesting costs are necessary to accurately assess timber values for these small-acreage, low-volume, partial cuts. Hard data from actual group-selection harvesting operations is critical to validate or refute these earlier opinions and computer simulation findings.

Study Objectives

The objective of this study was to document the production and costs associated with harvesting group-selection timber
sales in hardwood forests of the southern Appalachian
Mountain region. This will be accomplished in the following
way:

1. By using time-study methods (elemental breakdown and
associated delays) to determine the productivity and cost
of a skyline cable system, a feller-buncher and rubber-tired
cable skidding system, and a conventional chainsaw felling
and rubber-tired cable skidding system, as they conduct
group-selection timber harvests.

2. By evaluating the costs and productivity of each
system in the group selection harvests and comparing these
with the loggers past production in clearcuts.

3. By identifying specific operational impacts of
group-selection silviculture on timber harvesting
productivity and costs in the southern Appalachians and
discussing them.

The results of this study should assist the National Forest
system and other users to more accurately appraise timber
sale values when group-selection harvests are specified, and
allow loggers to more accurately predict their harvesting
costs for group-selection timber sales.
CHAPTER 2

Literture Review

Literature that deals with the impacts of group-selection silviculture on harvesting cost is limited and becomes scarce when the focus narrows to just the Appalachian Mountain region. Part of the reason is that group selection has never been widely practiced in the United States; therefore, very little information, especially recent information applicable to this study, is available. The available literature typically deals with partial cuts in general and must be extrapolated somewhat to relate specifically to group selection. The following review is of literature that directly or indirectly relates specifically to group selection and to partial cuts in general.

Logging costs are part of the equation when determining whether a stand is profitable to be harvested. Anticipated profit, the primary issue in determining feasibility, utilizes logging costs, which are dependent on the type of silvicultural system and the logging system used. However, very little literature from North America addresses costs associated with group-selection timber stand management and the variety of logging systems used in this region.
A study by Filip (1967) was one of the first comparisons of costs and production for four cutting methods in beech, birch, and maple stands and include single-tree selection, patch cutting, diameter-limit, and clear cutting. He found that group selection (termed patch cutting) had the lowest total harvested volume (401.9 cunits versus 734 cunits per acre for clear cutting) of all four methods and generated the greatest amount of pulpwood from a sawlog stand. His study also showed that input, such as labor and skidding, were highest in group selection (4.67 man hours versus 4.42 man hours per cunit for a clear cut) and had the lowest production of all four methods. Translating this to costs, felling costs for patch cutting increased ($9.30 per cunit versus $8.82 per cunit in a clear cut [1967 dollars]), and skidding costs also increased ($3.80 per cunit versus $3.53 per cunit in the clear cut).

Kellogg et al. (1991) studied group-selection logging in Oregon and found that "an increased level of logging planning and field layout was required for successful implementation of ... group-selection silvicultural system compared to clear cutting." This study concluded that logging layout/planning cost for a group-selection skidding operation was 19 times higher than layout/planning costs for a clear cut performed with similar equipment ($2.66 per MBF
for group selection versus $0.14$ per MBF for the clear cut). These costs were also higher by a factor of six for a cable logging operation ($2.40$ per MBF for group selection versus $0.38$ per MBF for a clear cut). Additional planning was found to be necessary for proper implementation of group selection and was an unavoidable cost of using this silvicultural method.

Kellogg et al. (1991) also demonstrated that "the felling component was least affected by partial cut silviculture alternatives." Felling costs were lower in group-selection cable and ground-skidding units over clear cutting by 3.4 percent and 11.6 percent respectively. This was explained by the fact that group selection concentrates the Sawyer's activities in a small area and may have reflected the working environment of the Oregon logger.

Oregon State University (1991) studied the effects of various silvicultural management techniques, including group selection, on western cable-yarding operations. They found yarding costs increased significantly (24 percent) in group selection. Primary reasons for the increase included decreased volume of timber removed, greater moving time (nonproductive time), increased crew sizes, and additional preharvesting planning and layout. Ground-based operations
were affected to a lesser degree. Total costs for ground-skidding systems and cable yarding increased in a group-selection timber sale by 2.4 and 24.7 percent, respectively.

Hall et al. (1991) modeled group-selection harvests using the STVAL2 computer program. A 17-inch white oak tree was followed through different stand and harvesting criteria to determine the effects on its value. One analysis varying skidding distance showed that "for the white oak tree, an increase in skidding distance from 200 feet to 1500 feet" reduced the tree's value by a minimum of seven percent. This same white oak tree was modeled through different percentages of stand removal and showed "the value of the 17-inch white oak is reduced in value by about nine percent in a group selection cut taking only 13 percent of the stand, in comparison with being removed in a clear cut."

Miller et al. (1986) studied the costs associated with single-tree selection and clear cutting in a cherry-maple stand. They showed that as residual stocking increased (i.e., as they moved from clear cutting to a higher residual basal area when marking), production rates decreased for both felling and skidding. In the residual stocking treatment, leaving 75 percent basal area, felling and skidding production rates were 430 and 261 cubic feet,
respectively, while in the clear cut, felling and skidding rates were 538 and 292 cubic feet, respectively.

Dykstra (1976) evaluated partial cutting in Oregon and showed that "operating delays were longer for the partial-cut unit than for any of the cable-yarded clear-cut units." Delays included repairs, personnel, maintenance, and operating delays.

Using the Harvesting Analysis Technique (HAT) computer simulation, Bell (1989) analyzed various scenarios that compared clear cutting and group-selection harvesting in the same timber stand. He found that felling costs were 28.8 percent and skidding costs were 26.1 percent higher for group selection than for clear cutting. Productivity was consistently less in all phases, with 1.6 fewer cords per productive hour for felling (a decrease of 26 percent) and 0.5 fewer cords per productive hour for skidding (a 15 percent decrease). The longer skidding distances necessitated by the group selection were the major reason for these productivity decreases. Bell (1989) reported that for every 100 foot increase in skid distance, costs increased $0.68 per cord for group selection versus $0.33 for clear cutting.
Another important concept when considering harvesting in group selection sales, is the idea of load/steady state/and purge. In fact the foundation of time study research is the determination of these different stages.

The load stage begins when a logging contractor opens a sale and between machine inventories must be loaded before material begins to arrive at the landing. When coordination and scheduling between the sawyer and skidder operator reaches an efficient level, the steady state stage begins. In this stage, output from the system is relatively consistent and will remain that way until the purge stage begins. Output again decreases because of the time spent emptying between machine inventories and "cleaning up" before leaving the patch. This is also the period when logging debris is dispersed, skid trails are closed after use and equipment is readied for movement. Commonly, all three stages are present in a logging operation and are relatively consistent from site to site.

In summarizing partial cutting, Sloan (1991) concluded,

"If the fixed costs are high and the volume removed is low, the fixed cost portion of the total cost will be high. This will be the case with partial [group-selection] cutting for uneven-aged management. The fixed costs will be similar to those of clear cutting; however, the volume removed will be a lot less, resulting in proportionally higher total costs."
CHAPTER 3
Study Methods & Procedures

This study was initiated in cooperation with the U.S. Forest Service's Southern Experiment Station Forest Engineering Unit at Auburn, Alabama, because no representative cost data for group-selection harvesting were currently available. The primary objective of this study was to document the production and costs associated with harvesting group-selection timber sales in hardwood forests of the southern Appalachian Mountain region. This objective was accomplished by utilizing time-study techniques on three logging systems as they performed their harvesting functions in group-selection timber sales. The time-study data collected would be used to assist in the comparison and evaluation of costs and production of group selection versus clearcutting.

Harvesting System Descriptions

Three logging systems were studied:

1) a skyline cable yarder with manual chainsaw felling system (Table 1 and Figure 3);

2) a mechanized feller-buncher and rubber-tired, cable skidder system (Table 2 and Figure 4);

3) a conventional chainsaw felling with a rubber-tired, cable skidder system (Table 3 and Figure 5).
Table 1. Harvesting System Description for the Cable Yarding System (Logging Contractor #1).

**Equipment Spread:**

- 1 Edco Skyline Cable Yarder (1986)
- 1 Prentice 210 C Loader and hydraulic Sawbuck (1986)
- 1 Ford F250 Pick-up with tools (1985)
- 1 Clark 568 D Cable Skidder (1985)
- 1 Clark 688 C Cable Skidder (1987)
- 1 Caterpillar D-4HCS Dozer (1988)
- 1 Mack Tractor and Trailer Log Truck (1982)
- 6 Husqvarna Chainsaws

**Labor:**

- 1 Foreman
- 2 Chainsaw Operators
- 2 Choker Setters
- 1 Cable Yarder Operator
- 1 Skidder Operator
- 1 Deck Man
- 1 Loader Operator

**Total Crew: 9**

1 hired Sub-contractor for Trucking
2 Chainsaw Operators
Manual Felling, Limbing and Topping

2 Choker Setters

1 Cable Yarder Operator
Edco Skyline Cable Yarder

1 Skidder Operator
1 Clark 568 D
1 Clark 688 C
Cable Skidders

1 Deck Man Bucking Logs

1 Loader Operator
Prentice 210 C with Saw Buck

1 Truck Driver
1 Mack Tractor-Trailer Truck

Figure 3. Material Flow Diagram for Cable Yarding System (Contractor #101).
Table 2. Harvesting System Description for Feller - Buncher and Rubber-Tired Cable Skidder System (Logging Contractor #2).

**Equipment Spread:**
1 Prentice 210 C Loader with Saw Buck (1984)
1 Cat 518 Cable Skidder (1984)
1 Mack Straight Frame Log Truck (1982)
1 Mack Straight Frame Log Truck (1989)
1 Ford F 350 Pick-up complete with Tools (1987)
1 Bell Super T Feller Buncher (1990)
2 Stihl Chainsaws

**Labor:**
1 Owner/Operator
1 Rubber-Tired Skidder Operator
1 Feller-Buncher Operator
1 Limber and Topper

**Total Crew:** 4

One Truck Driver (part time)
Figure 4. Material Flow Diagram for Feller-Buncher and Rubber-Tired Cable Skidder System (Contractor #202).
Table 3. Harvesting System Description for Manual Felling and Rubber-Tired Cable Skidding System (Logging Contractor #3).

**Equipment Spread:**
- 1 John Deere Cable Skidder (1977)
- 1 International Straight Frame (Tandem Axle) Truck (1987)
- 1 Shop-Built Hydraulic Knuckleboom Loader (age unknown)
- 3 Stihl Chainsaws

**Labor:**
- 1 Owner/Operator
- 1 Chainsaw Operator
- 1 Skidder Operator

**Total Crew:** 3
1 Chainsaw Operator
Felling, Limbing and Topping

1 Skidder Operator
and Deck Man

1 Loader Operator
and Deck Man

1 Truck Driver

1 John Deere Cable Skidder

1 International Straight Frame (Tandem Axle)

Figure 5. Material Flow Diagram for Manual Felling and Rubber-Tired Cable Skidding System (Contractor #303).
The three logging contractors, though operating in three different Forest Service districts, had similar contract obligations. In all cases, the contract required that all non-merchantable material within the patch boundary be felled. (This was called "site preparation" by the Forest Service in the contract.) This requirement was handled differently by all three contractors. Contractor #1 had the sawyers fell the material as they performed their felling activities. Contractor #2 drove over and knocked down this material with the feller-buncher and skidder during the felling and bunching and skidding period. Any non-merchantable material remaining was cut by the sawyer while he was limbing and topping. Contractor #3 accomplished the site preparation after all merchantable material had been removed from several patches. His crew then returned and completed this task on all those patches.

In all study sites, all logging debris had to remain within the patch boundary. "Rub" trees along the skid trail (selected prior to the harvesting activity) could not be felled until all skidding from the patch was completed. The Forest Service selected and required use of landings and skid trails which were to become permanent fixtures for any future group-selection timber sales that would occur in the stand.
Logging Contractor #1 Harvesting the Southfork Group-Selection Timber Sale.

This skyline cable yarding operation was a company crew owned and operated by a local sawmill. The crew consisted of a foreman who actively took part in all aspects of the harvesting operation and eight crew members.

Figure 6 is a map of the timber sale. While the patch sizes of this sale meet the criteria of group selection, this sale varied from a traditional group-selection timber sale in that the residual stand between some patches was also thinned. Thinning with the cable yarder consisted of felling all trees in a straight corridor to allow the cable and carriage room to maneuver and felling the marked trees in the stand along the corridor in a herringbone pattern. This thinning created greater total timber sale volume. However, for the purposes of this "group selection" study, all costs, production and time data generated were kept separate and are not included in any discussion or calculations.

Many of the costs associated with this operation were shared with the other logging crews operated by the company and with the sawmill business. This created difficulties when determining costs directly associated with skyline yarding.
Figure 6. Southfork Group Selection Timber Sale Map.
This crew was observed to have high labor turnover which created problems. The hard, dangerous work of logging steep slopes paid no better than jobs in the service sector or in the mill. The business tried to replace the individuals who quit as quickly as possible. When this failed, they transferred mill employees to the woods. This high turnover required training of new crew members every week and caused a period of uncertainty as each person learned his role and became part of the crew.

A strict quota of one tractor-trailer load of pulpwood per week also constrained the business during the study period. This constraint was handled two ways. The first was to leave as much of the pulpwood in the group opening as possible. The logging crew preferred this method. Leaving the pulpwood in the felling area allowed them to avoid the costs of limbing, topping and yarding material they could not sell. The landowner, the U.S. Forest Service, insisted that pulpwood-sized trees be prepared and yarded to where they could be later marketed as firewood. This resulted in a net loss to the sawmill. The second strategy was to cut only sawlog material from the larger trees and to leave the pulpwood in the upper crown in the group opening.
The Southfork timber sale was the first group selection purchased and yarded by this crew. The yarding crew consisted of two choker setters, one yarder operator, one man on the swing skidder, one man on the loader, and one deck man. They followed the same harvesting strategy used in clearcuts. Two crew members felled all the trees prior to yarding, trying to fell one patch ahead of the yarder. The two functions operated independently until a patch was fully yarded. Then the entire crew assisted in the time-consuming break-down, movement and set-up of the yarder. However, if the sawyers had not completed felling on the patch where the yarder was being set-up, yarding had to wait until all the trees were felled.

In some cases, because of miscommunication between the sawmill and logging crew, yarding was delayed until a dozer was brought from the mill to complete landing construction. The swing skidder was often delayed because the truck landing was full of wood. The yarder operator then had to unhook his own chokers; this doubled the time for that operation.

Truck loading also caused delays. The landing was small, which forced skidding to stop until the truck was loaded and headed back to the mill. This usually took 30 to 45 minutes.
per load and happened at random, because little coordination and communication occurred between the logging crew and the main office.

Delays also occurred because the choker setters did not pre-plan the next group of trees to be yarded. When the carriage returned, time was needed to locate a suitable turn, hook the trees, and get out of the way.

The Forest Service designed and planned the sales down to designating yarder location and the routing of skyline corridors between the yarder and the group. Errors in layout required frequent realignment of the corridors or shifts of yarder position to get access to all trees in the group.

At times, when the patch shape necessitated it, the crew could reach the logs by locking the carriage further down the skyline and pulling additional slack to hook the stems. The turn was first moved away from the yarder to turn it and then yarded to the landing.

Some patches were laid out such that yarding overlap occurred; the patches were just large enough to make a second skyline location necessary but were small enough that
the second location overlapped the first. Fewer trees were yarded per set-up, but the same amount of time was needed to set up the second (or third) skyline setting.

The landing the Forest Service designed was not adequate when a truck was being loaded. The swing skidder was unable to drop its turn and return to the area under the yarder to keep it cleared, because the truck blocked the area where the trees were to be deposited next to the loader. The turn then had to be left in a dead area on the landing and moved under the loader after the truck left.

Logging Contractor #2 Harvesting the Wildcat Group-Selection Timber Sale.

Unlike Contractor #1, this contractor was an independent pulpwood producer who also produced a few loads of sawlogs per week. He leased a Bell Super T feller-buncher in an effort to improve his efficiency and production. This created a unique opportunity for this study, since feller-bunchers are not common in the southern Appalachians. Figure 7 is a map of the timber sale layout.

Contractor #2’s crew was experienced and had been with him for a number of years. In fact, two had worked with this
Legend For Sale Area Map

Existing System Road
Group Selection Area A
Skid Trail System
Landing •
Note: Individual Patches are labeled by letter

Sale Area Map: Logging Crew #202
Wildcat Group Selection Timber Sale

Figure 7. Wildcat Group Selection Timber Sale Map.
crew for 15 years. The crew was comprised of a feller-buncher operator, a skidder operator, and a sawyer (for limbing and topping bunched trees). The owner/operator alternated between driving the truck and operating the loader. This was the first time any of them had worked with a feller-buncher or with a group-selection timber sale.

All wood was removed from the groups, and normal equipment service was done at the end of each work day. Daily operation began with getting the feller-buncher in the field as quickly as possible after the crew arrived. The sawyer accompanied the machine. The skidder operator checked the skidder and loader for vandalism and oil leaks and was ready to start skidding as soon as a bunch was prepared.

A final truck was loaded at the end of each work day. This was delivered in the morning while the crew was getting the next load out. When this truck returned, the driver became the loader operator. Any remaining wood deliveries made that day were trucked by a part-time employee who knew approximately when the first load would be completed. He then arrived at the landing site and hauled the next load(s).
Due to the limited operating area in each patch, the feller-buncher was only able to bunch one skid-cycle load at a time. The chainsaw operator removed the limbs and tops from the trees while those trees were hooked by the skidder operator. In some cases, the feller-buncher operator assisted the sawyer in removing limbs and tops or helped the skidder operator in hooking trees.

Logging Contractor #3 Harvesting the Cherokee Group-Selection Timber Sale.

This independent logging contractor runs a small, family-owned business operating in the Appalachian region. The contractor had a one-load-per-day pulpwood quota and the market to deliver one or more loads per day of sawlogs to any one of several area sawmills. Because his production goal was only to cut and haul one or two loads a day, the pulpwood restriction had little effect on his overall output.

His overhead costs were the lowest of the three contractors because of the older, fully depreciated equipment operated. The Cherokee timber sale was the first group-selection harvested by the crew, which had been together for three years.
Figure 8 shows the layout of the timber sale. Again, as in the other sales, landings, skid trials, patch size and shape were selected and their location determined by the Forest Service.

The U.S. Forest Service, in order to increase the total timber sale volume and because of the mature status of this timber stand, marked trees in the residual stand between patches. This generated more interest in the sale but is not consistent with the definition nor typical of group-selection silviculture. This study focuses only on the harvest of the groups.

There was no apparent change in strategy or crew arrangement harvesting the group selection. Typically, the crew consisted of a sawyer and a skidder operator; the owner did the trucking and operated the loader.

The truck was loaded with logs at the end of each work day. This load was delivered first thing in the morning. While the truck was gone, the sawyer and skidder operator worked the morning to get a load of pulpwood skidded. When the truck returned, it was loaded with the pulpwood and sent to the mill. Meanwhile, the crew continued to skid the next day’s load of sawlogs. When they determined that a load was
Sale Area Map: Logging Crew #303
Cherokee Group Selection Timber Sale

Legend for Sale Area Map:
- Sale area boundary
- Payment unit boundary
- Existing road
- Temporary road
- Existing trail
- Hauling & skidding prohibited
- Protection limit
- Private ownership
- Reserve trees
- Groups

SCALE: 1 in = 100 ft

Figure 8. Cherokee Group Selection Timber Sale Map.
skidded, work stopped. They performed routine maintenance on the equipment and then went home. When the truck returned, the owner/operator loaded those skidded sawlogs which would be delivered the next morning.

Problems encountered by this crew and delays associated as a result of logging in a group selection were few. They were not a production-oriented crew and geared themselves toward a consistent goal of one or two loads per day.

Production Data Collection Techniques

A minimum of 40 scheduled hours (approximately one full week) of production and cost data were collected from each of the three systems. The study team, equipped with stopwatch and video camera, recorded all phases of felling and skidding elemental activities using time-study techniques (Olsen, 1983; Sobhany, 1984).

Data collected for each of the three contractors included volume per patch, volume per tree by patch, skidding/yarding distance for each patch, volume and time per turn by patch, felling time per tree by patch, group-selection patch size and location relative to the landing. The study team also observed and documented other relevant parameters, such as
the working conditions around the stump area (both felling and processing), skid trail conditions, and landing area and haul roads conditions (Appendix A). Slope, measured in percent, was also recorded.

Stand and stock information, slope, and harvest unit statistics are summarized by timber sale and contractor in Tables 4, 5, and 6. Daily and weekly production, haul distances, mill quotas, and trucking availability were also recorded.

Field Data Collection Techniques.

Data were collected during the period from April to August, 1991, from the three loggers on the group-selection timber sale units in the Jefferson National Forest in southwestern Virginia. Measurements on the timber stand and harvesting site were recorded prior to the actual harvest. Distance from the center of each patch to the designated landing (via the designated skid trail) was measured, and the acreage of each patch was determined. Diameter at breast height and merchantable height were recorded for each tree on the patch, and volumes were determined by patch using the U.S. Forest Service's local volume tables for Appalachian timber.
Table 4. Pre-Harvest Description of the Southfork Timber Sale.

a. Tract Information:

<table>
<thead>
<tr>
<th>PATCH</th>
<th>SIZE (acre)</th>
<th>TOTAL # TREES</th>
<th>VOLUME per PATCH (Cu. Ft.)</th>
<th>MEAN SLOPE (%)</th>
<th>YARDING DISTANCE from PLOT CENTER (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1.03</td>
<td>99</td>
<td>1,955</td>
<td>53</td>
<td>87</td>
</tr>
<tr>
<td>B</td>
<td>1.32</td>
<td>163</td>
<td>3,186</td>
<td>77</td>
<td>193</td>
</tr>
<tr>
<td>C</td>
<td>1.39</td>
<td>192</td>
<td>3,227</td>
<td>52</td>
<td>157</td>
</tr>
<tr>
<td>D</td>
<td>1.89</td>
<td>249</td>
<td>3,574</td>
<td>67</td>
<td>153</td>
</tr>
<tr>
<td>E</td>
<td>1.38</td>
<td>204</td>
<td>3,527</td>
<td>67</td>
<td>403</td>
</tr>
</tbody>
</table>

b. Individual Tree Volume Information:

<table>
<thead>
<tr>
<th>PATCH</th>
<th>MEAN (Cu. FT)</th>
<th>MEDIAN (Cu. FT)</th>
<th>MODE (Cu. FT)</th>
<th>RANGES (Cu. FT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>19.75</td>
<td>13.24</td>
<td>7.77</td>
<td>1.66 to 106.15</td>
</tr>
<tr>
<td>B</td>
<td>19.55</td>
<td>9.43</td>
<td>2.21</td>
<td>1.66 to 134.79</td>
</tr>
<tr>
<td>C</td>
<td>16.81</td>
<td>10.73</td>
<td>4.26</td>
<td>1.66 to 106.15</td>
</tr>
<tr>
<td>D</td>
<td>14.35</td>
<td>8.83</td>
<td>6.27</td>
<td>1.66 to 121.80</td>
</tr>
<tr>
<td>E</td>
<td>17.29</td>
<td>10.73</td>
<td>3.57*</td>
<td>1.66 to 218.55</td>
</tr>
</tbody>
</table>

*Bi-modal.
Table 5. Pre-Harvest Description of the Wildcat Timber Sale.

a. Tract Information:

<table>
<thead>
<tr>
<th>PATCH</th>
<th>SIZE (acres)</th>
<th>TOTAL # TREES</th>
<th>VOLUME per PATCH (Cu. FT)</th>
<th>MEAN SLOPE (%)</th>
<th>SKIDDING DISTANCE to LANDING (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2.87</td>
<td>174</td>
<td>2,578</td>
<td>12</td>
<td>1,062</td>
</tr>
<tr>
<td>B</td>
<td>1.40</td>
<td>108</td>
<td>1,228</td>
<td>9</td>
<td>966</td>
</tr>
<tr>
<td>C</td>
<td>4.46</td>
<td>130</td>
<td>1,438</td>
<td>3</td>
<td>591</td>
</tr>
<tr>
<td>D</td>
<td>1.95</td>
<td>119</td>
<td>773</td>
<td>17</td>
<td>438</td>
</tr>
<tr>
<td>E</td>
<td>1.11</td>
<td>110</td>
<td>1,002</td>
<td>9</td>
<td>75</td>
</tr>
</tbody>
</table>

b. Individual Tree Volume Information:

<table>
<thead>
<tr>
<th>PATCH</th>
<th>MEAN (Cu. FT)</th>
<th>MEDIAN (Cu. FT)</th>
<th>MODE (Cu. FT)</th>
<th>RANGES (Cu. FT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>14.82</td>
<td>9.44</td>
<td>2.21</td>
<td>1.66 to 74.98</td>
</tr>
<tr>
<td>B</td>
<td>11.37</td>
<td>7.11</td>
<td>2.74</td>
<td>2.21 to 53.12, 3.57*</td>
</tr>
<tr>
<td>C</td>
<td>11.06</td>
<td>10.90</td>
<td>2.74</td>
<td>1.66 to 58.77</td>
</tr>
<tr>
<td>D</td>
<td>6.50</td>
<td>6.50</td>
<td>3.57</td>
<td>1.66 to 29.05</td>
</tr>
<tr>
<td>E</td>
<td>9.13</td>
<td>8.51</td>
<td>1.66</td>
<td>1.66 to 31.44, 5.40*</td>
</tr>
</tbody>
</table>

*Bi-modal.
Table 6. Pre-Harvest Description Data of the Cherokee Timber Sale.

a. Tract Information:

<table>
<thead>
<tr>
<th>PATCH</th>
<th>SIZE (acre)</th>
<th>TOTAL # TREES</th>
<th>VOLUME per PATCH (Cu. FT)</th>
<th>MEAN SLOPE (%)</th>
<th>SKIDDING DISTANCE to LANDING (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.98</td>
<td>135</td>
<td>2,607</td>
<td>0</td>
<td>255</td>
</tr>
<tr>
<td>B</td>
<td>0.31</td>
<td>43</td>
<td>671</td>
<td>2</td>
<td>1,122</td>
</tr>
</tbody>
</table>

b. Individual Tree Volume Information:

<table>
<thead>
<tr>
<th>PATCH</th>
<th>MEAN (Cu. FT)</th>
<th>MEDIAN (Cu. FT)</th>
<th>MODE (Cu. FT)</th>
<th>RANGES (Cu. FT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>19.31</td>
<td>16.87</td>
<td>24.93</td>
<td>2.21 to 69.81</td>
</tr>
<tr>
<td>B</td>
<td>15.60</td>
<td>14.33</td>
<td>9.43</td>
<td>2.21 to 70.24*</td>
</tr>
</tbody>
</table>

*Bi-modal.
Loggers and suitable group-selection timber sale units were selected with the help of local Forest Service personnel. Each of the logging operations was visited to observe equipment and operating methods and to obtain cooperation for the study. This visit occurred while the logging crew was working in a clearcut prior to moving into the group-selection sale.

This visit allowed the sawyers and skidder operators to get used to the field team before the data collection began. The researchers, in turn, had an opportunity to become familiar with individual crew members, tasks, systems, and harvesting methods. These pre-study meetings also provided some timber felling and skidding/yarding production data for clear cutting.

Once consent was secured, pre-harvest field data were collected, and the contractors were interviewed. The loggers then notified the study team when the harvesting operation was scheduled to begin work on the group-selection study site, and production data collection commenced.

The time study was conducted in such a way that the basic work functions were broken down and the time data collected by elements (Appendix F). Examining the logging process on
an elemental basis assisted in comparing the same unit segments in an alternate harvesting method, such as clear cutting, and revealed which aspects were affected by a group-selection harvest. This also assisted in the comparison of production and cost differences between the silvicultural systems.

Harvesting cost data were obtained from the loggers' records and the literature, particularly Bell's (1989) study which included detailed cost data from eight Appalachian logger "interviews." Data from an unpublished report by Hancock (1991), which examined cost records in detail for nine typical Appalachian loggers, were also used. Time-study production data were combined with cost data to determine unit cost for the operations studied. This was compared with estimated unit harvesting cost by system for clearcut operations on similar timber stands to validate or refute Bell's (1989) computer simulation results.

Time and Production Study

An effort was made to be on the job the entire time the group-selection harvests were conducted. At least 50 percent of the cycles, for either the felling or skidding, were timed and recorded. In most cases, all elemental and
total-cycle times of all the phases were measured for each cycle.

**Manual Chainsaw Felling**

The cycle time for the chainsaw felling activities was divided into the following five elements: swamping, undercut, backcut, limbing and topping, and walking to the next tree. For a complete description of each productive element, see Appendix B.

**Feller - Buncher**

The cycle time study of the feller-buncher was simplified to the following three elements: felling, bunching, and moving to the next tree. Appendix C contains the description of each of the feller-buncher's productive elements.

Because patch size determined the extent to which both the feller-buncher and the skidder could work at the same time within a patch, time data were also collected on productive versus non-productive time for the feller-buncher.
Skidding

The cycle of the skidding activities was divided into the following five elements: travel empty, hook or choke, winch in, travel loaded, and unhook. A complete description of each productive element is provided in Appendix D. The number of stems skidded per cycle was recorded and an average determined. Also, because volume per tree and patch was known, an average volume per turn could be calculated.

Cable Yarding

The cycles for the skyline yarding system were recorded using the following five elements: outhaul, lateral outhaul, hooking chokers, lateral inhaul and travel loaded, and unhook. Appendix E lists each productive element and its description. In all cases, landing duties and truck-loading times were not recorded as part of the time study.

Delays

Measuring and categorizing delays were probably the most critical part of this study. Total clock time was recorded by patch. Within this scheduled time, productive time (i.e., the time used to complete an event or activity) was
measured and recorded. This allowed for the determination of productive versus non-productive categories.

Non-productive time was further divided into "unavailable times" and "delay periods." Each of the major cycle events (i.e., manual chainsaw felling, mechanized felling, skidding, and cable yarding) had its own unique set of unavailable time and delays within the non-productive period.

Delays were timed as they occurred in the production cycle; the clock time, the reason, the duration, and the element during which each delay occurred were recorded. If a delay was a result of the group-selection harvesting method, it was distinguished as such. These included interference or interruption of productive time as a result of patch size or patch shape plus pauses due to inventory. Contract requirements for the group selection (i.e., site preparation work) were also counted as delays.

Unavoidable delays such as personal time, equipment repairs, scheduled maintenance, and refueling were also recorded. For purposes of this study, however, it was assumed that delays of these types would occur on an equal proportion whether harvesting in group selection or a clear cut.
Delays caused by weather were also recorded and were also assumed to occur on an equal bases regardless of the silvicultural system employed.

Anticipated interruptions in productivity were not classified as delays associated with group-selection. These include waiting for: the skidder to move felled trees, the skidder to reach a safe distance so the sawyer could continue felling timber, the sawyer to get out of the way so that hooked trees could be winched in, enough trees to skid, and landing delays. For the purposes of this study, these were classified as productivity interruptions and were recorded in the field as such in the elemental category in which they occurred.

Data Analysis

Elemental times were summarized by element, by patch, and by contractor for each timber sale. Percentages of total time by element were calculated for felling and skidding or yarding. Productive working time was determined from the detailed field records, and delays (unproductive time) were also analyzed and trends noted. Weekly production volumes were calculated from mean cycle time, number of trees yarded/skidded per turn, mean volume per tree, and
productive work time per day. These were then compared with the average weekly production volumes that the logging contractors experienced when clear cutting. (These were determined through interviews and on-site evaluations of the loggers prior to their beginning the group-selection timber harvests.)

Data collected on productive versus non-productive time for the feller-buncher were used to determine productive time in percent per patch. Elapsed time for activities such as average set-up time per patch, mechanical delays, productive percentages, felling man hours, and total time spent per patch was also determined.

Statistical analysis was used to describe and/or test relationships or trends found in the data. Ranges and standard deviations for each category of time-study data were determined, along with means, medians and modes where appropriate. In some cases, box plots were used to facilitate concept visualization. T-tests or Duncan's Multiple Range Tests were performed when useful for refuting or supporting a hypothesis.
Cost Analysis

Total costs per week for each harvesting system were determined on a cash flow basis. Cost information obtained through contractor interviews included labor costs, benefits and insurance, equipment payments, repair and maintenance records, and expenses for fuel, tires, and oil. A survey was given to the contractor when questions could not be answered during the interview. By this method, the contractor could study his records and determined the specific cost items.

The logger used his own cost records, whenever possible, to provide information. When cost information from the contractor was lacking, and that varied from contractor to contractor, these gaps were filled from literature.

The economic analysis utilizes the cash flow approach. The discussion of costs assumes that the contractor’s weekly fixed costs will remain unchanged when moving between harvest types. It is also assumed that all equipment loans were financed at a 12-percent interest rate and have a finance period of no more than two-thirds the economic life of the machine. The duration of stumpage loans, where
relevant, are for no more than five years and at a 12-percent interest rate.
CHAPTER 4

Results

The objective of this study was to determine and document the productivity and costs of the three harvesting systems operating in group-selection timber sales in hardwood forests of the southern Appalachian Mountain region. The productivity and cost for group-selection harvest were then compared with those of the same three systems operating in clearcut harvests. Productivity for each system will be examined first and then harvesting costs will be compared.

The Timber Stands

Patch size and enforcement of contract requirements and specifications varied from one Forest Service district to another. The patches were consistently located in areas that contained scattered, large and over-mature timber. The group-selection timber harvest was designed to salvage these large-diameter trees before they died. The timber stand distribution had a profound effect on the harvest productivity and costs experienced by the logging operations.

Individual timber stand characteristics varied from sale to sale. Contractor #1 had the widest variability in tree
size, ranging from 1.66 to 218.66 cubic feet (Table 4b). The distribution was badly skewed, with a few very large trees suitable for the sawmill balanced by a large number of small trees which had to be yarded, decked, and left in the forest because of the pulpwood quota constraint.

Contractor #2’s groups were located in a low site index scarlet/black oak stand. Large trees were present, but most were so over-mature that they were hollow and suitable only for pulpwood. This suited the contractor, for he was mainly in the pulpwood business. The range of tree sizes was wide, from 1.66 to 74.98 cubic feet per tree (Table 5b), but not as extreme as in Contractor #1’s case.

Contractor #3 worked in a mature sawlog-sized hardwood stand similar to #2 with trees ranging from 2.21 to 70.24 cubic feet (Table 6b). The stand’s distribution was symmetrical, with mean, median and mode values clustered tightly. In fact, the modal size tree was larger than the mean in both patches studied.

The Operating Conditions

The topography and terrain varied across the three timber sales studied. Contractor #1’s sale was located in a steep,
mountainous region and had the steepest slopes on which to operate. Having operated regularly in this region, the crew was fairly comfortable with the steepness. Those crew members most affected were the sawyers and the choker setters. The entire cable yarding operation, however, is designed to operate on steep slopes.

Contractor #1 operated in an over-mature timber stand that had been breaking up for many years. The abundance of bushes and saplings made site preparation necessary just to walk around the patch. Contractor #2 operated on moderate slopes for this region and, thus, could use the feller-buncher without much difficulty. The slope itself did not disrupt the system's production. Contractor #3 operated on the flattest ground, where slope had no impact on productivity.

Contractor #2, utilizing the feller-buncher, was not hindered by underbrush that had grown under the canopy. Underbrush density varied from patch to patch as a function of the vigor of the mature trees the patches encompassed. Those that had little crown allowed sunlight to penetrate to the forest floor and offered conditions conducive to underbrush growth.
Contractor #3, operating in a mature sawlog stand, encountered minimal bushes and saplings. Little site preparation work was required. In most cases, those trees that were not pulpwood size just missed the minimum pulpwood criteria and could be easily felled after all merchantable material was removed from the patch.

Productivity by Function

Felling

Tables 7 summarizes the data for the two contractors (#1 and #3) who used chainsaw felling. The number of trees felled per productive hour versus scheduled hour reflects the sawyers' unproductive time and accounted for over 48 percent and 32 percent, respectively. The majority of this time was spent waiting for and coordinating activities with the skidder, fighting the concentrated logging slash, and taking safety precautions.

No trend was noted between the felling ranges and the diameter distribution of the individual patches. This indicates other factors had more effect on felling times than did tree size.
Table 7. Manual Chainsaw Felling Data for Contractors #1 and #3*.

<table>
<thead>
<tr>
<th>PATCH</th>
<th>SIZE (acre)</th>
<th>NUMBER OF TREES</th>
<th>MEAN FELLING TIME/TREE (minutes)</th>
<th>FELLING TIME per TREE RANGES (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1.0</td>
<td>99</td>
<td>5.99</td>
<td>3.09 to 9.50</td>
</tr>
<tr>
<td>B</td>
<td>1.5</td>
<td>163</td>
<td>3.80</td>
<td>0.77 to 12.77</td>
</tr>
<tr>
<td>C</td>
<td>1.4</td>
<td>192</td>
<td>4.23</td>
<td>1.62 to 12.82</td>
</tr>
<tr>
<td>D</td>
<td>1.9</td>
<td>249</td>
<td>4.62</td>
<td>1.25 to 8.15</td>
</tr>
<tr>
<td>E</td>
<td>1.4</td>
<td>204</td>
<td>4.55</td>
<td>2.25 to 8.00</td>
</tr>
<tr>
<td>A*</td>
<td>1.0</td>
<td>135</td>
<td>5.91</td>
<td>0.68 to 16.38</td>
</tr>
</tbody>
</table>
The timber sale contract requirement that all trees be felled within the individual patch boundary did have an impact on overall felling time per tree. More time was required to open up "holes" in the canopy to facilitate directional felling than comparable time per tree in clearcutting.

The sawyer usually began felling trees at the furthest point in the patch away from the exit skid trail or corridor (the down slope side for Contractor #1). This created "holes" in the canopy into which other trees could be felled. As more trees were felled, walking around the patch became increasingly difficult because of the concentration of logging debris and underbrush.

Figure 9 shows box plots for both contractors in each category in the felling process. Note the consistency between contractors. Contractor #3 did spend more time in the limbing and topping category, and Contractor #1 had patches located on steep slopes with a higher percentage of yellow poplar. When the yellow poplar hit the ground, the majority of the limbs broke off, and the tree rolled or slid to the bottom of the slope. Because of the restrictive pulpwood quota, many of the pulpwood-size trees were left unlimbed.
Figure 9. Box Plot Felling Times for Contractor #1 and #3 by Element Category Studied in Minutes.
When the tree was sawlog size, the sawyer did not bother to extract the pulpwood from the top.

Smaller patches that contained a greater number of large trees may have been part of the cause of Contractor #3's greater variability in the backcut time. He had to be more precise in directional felling to meet the contract requirement of keeping all logging debris within the patch boundary.

Productivity comparisons are based on contractors' performance within clearcut timber sales and group-selection timber sales. While no forest stand data (i.e., diameters, volumes or distributions) were recorded from the clearcut operations, each timber sale purchased by the contractor had, as one of the units, a clear cut from which elemental time data were recorded. Thus, both group-selection and clearcut timber stands were in the same sale and area and were the same timber type. Therefore, it is assumed that the timber stands had similar diameter distributions and volumes.

Table 8 shows the overall average felling time per tree and the average time to fell trees when first beginning and just
Table 8. Average Productive Felling Times in Minutes for First 25 and Last 25 Percent of Recorded Times for Group Selection Harvesting.

<table>
<thead>
<tr>
<th>CONTRACTOR</th>
<th>PATCH SIZE</th>
<th>MEAN FELLING TIME/TREE (acres)</th>
<th>FIRST 25 PERCENT (minutes)</th>
<th>LAST 25 PERCENT (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>B</td>
<td>1.03</td>
<td>3.80</td>
<td>4.09</td>
</tr>
<tr>
<td>1</td>
<td>C</td>
<td>1.39</td>
<td>4.23</td>
<td>5.12</td>
</tr>
<tr>
<td>1</td>
<td>D</td>
<td>1.89</td>
<td>4.62</td>
<td>4.83</td>
</tr>
<tr>
<td>1</td>
<td>E</td>
<td>1.38</td>
<td>4.55</td>
<td>4.85</td>
</tr>
<tr>
<td>3</td>
<td>A</td>
<td>0.98</td>
<td>5.91</td>
<td>6.67</td>
</tr>
</tbody>
</table>
completing a patch. (The table lists only those patches in which 50 percent or more of the trees felled were timed.) Note that opening times per tree are larger than the clean up times.

Creating "holes" in the canopy during the opening of a patch required more directional felling. In the beginning, the sawyer had to directional fell more trees and be more precise to avoid hanging up trees. As the canopy opened up, directional felling became easier, and time per tree decreased. While not all differences in the three times (initial, mean and last) are significant, the trend is clear.

Feller - Buncher

Table 9 summarizes feller-buncher data collected for Contractor #2. Note that patches A and C do not meet the strict definition of a group selection because they were larger than 2.0 acres.

Duncan's Multiple Range Test was used to check variability between the patches' mean felling times per tree. Only Patch A was different from the others at an alpha level of
Table 9. Productive Felling Time Data, Ranges, and Median Volume per Tree for the Feller-Buncher (Contractor #2).

<table>
<thead>
<tr>
<th>PATCH</th>
<th>SIZE (acres)</th>
<th>NUMBER OF TREES</th>
<th>MEAN FELLING TIME/TREE (minutes)</th>
<th>MEDIAN TREE SIZE (Cu. FT)</th>
<th>FELLING TIME per TREE RANGES (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2.87</td>
<td>174</td>
<td>0.83</td>
<td>9.44</td>
<td>0.10 to 2.96</td>
</tr>
<tr>
<td>B</td>
<td>1.40</td>
<td>108</td>
<td>0.56</td>
<td>7.11</td>
<td>0.27 to 1.04</td>
</tr>
<tr>
<td>C</td>
<td>4.46</td>
<td>130</td>
<td>0.78</td>
<td>10.90</td>
<td>0.40 to 1.44</td>
</tr>
<tr>
<td>D</td>
<td>1.95</td>
<td>119</td>
<td>0.65</td>
<td>6.50</td>
<td>0.29 to 1.31</td>
</tr>
</tbody>
</table>
0.05. Again, patch A had the largest mean tree volume and the widest range of volume per tree for all the patches on the Wildcat group-selection timber sale.

Table 10 demonstrates mean times per tree by patch and category for the feller-buncher as well as an overall mean for this particular timber sale. The differences were not statistically significant, indicating uniform operation of the feller-buncher. Patch size and stand characteristics had little effect on the production of bunches for the skidder operator.

Table 11 shows the percentage of productive and delay time for the feller-buncher on two patches that were examined specifically to determine the events that occurred during the non-productive time. Table 12 also lists the total scheduled hours on those same two patches for the feller-buncher.

The feller-buncher's utilization was roughly one-third of the scheduled time on any patch. The machine spent most of its time off the patch waiting for the skidder to clear the patch. When the skidder left the patch for the landing, the feller-buncher continued building new bunches until the
Table 10. Mean Productive Elemental Felling Times (in Minutes) by Patch for the Feller - Buncher (Contractor #202).

<table>
<thead>
<tr>
<th>PATCH</th>
<th>FELLING TIME</th>
<th>BUNCH TIME</th>
<th>TIME TO NEXT TREE</th>
<th>TOTAL TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.44</td>
<td>0.16</td>
<td>0.22</td>
<td>0.83</td>
</tr>
<tr>
<td>B</td>
<td>0.28</td>
<td>0.08</td>
<td>0.20</td>
<td>0.56</td>
</tr>
<tr>
<td>C</td>
<td>0.37</td>
<td>0.19</td>
<td>0.22</td>
<td>0.78</td>
</tr>
<tr>
<td>D</td>
<td>0.23</td>
<td>0.19</td>
<td>0.23</td>
<td>0.65</td>
</tr>
<tr>
<td>Means</td>
<td>0.37</td>
<td>0.16</td>
<td>0.22</td>
<td>0.75</td>
</tr>
</tbody>
</table>
Table 11. Productive and Delay Time for the Feller-Buncher.

<table>
<thead>
<tr>
<th>PATCH</th>
<th>SIZE (acre)</th>
<th>PRODUCTIVE TIME (%)</th>
<th>DELAY TIME (%)</th>
<th>TOTAL SCHEDULED TIME in PATCH (HOUR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>1.95</td>
<td>35</td>
<td>65</td>
<td>4</td>
</tr>
<tr>
<td>E</td>
<td>1.11</td>
<td>37</td>
<td>63</td>
<td>4</td>
</tr>
</tbody>
</table>
skidder reappeared or until the available space within that patch was filled.

The effects of the small, confined patches on the feller-buncher's operation did have an impact on productivity. The machine typically stopped operating when the skidder entered the patch. The patches were too small for both pieces of equipment to operate safely at the same time, and the feller-buncher operator was also concerned about burying trees previously cut and piled.

Notes recorded in the field from these two patches (Table 11) indicate that 95 percent of the delay time was a result of waiting for the sawyer to complete the limbing and topping and waiting for the skidder to achieve a safe distance so that felling could begin again. It was during this time that the machine was out of the patch and shut down. The remaining five percent of the non-productive time was spent on feller-buncher repairs and maintenance.

The feller-buncher data revealed a trend similar to that observed for chainsaw felling. Group-selection timber harvesting did affect productivity through delays. More than 60 percent of the machine's time was lost due to interference caused by the small patches.
Cable Skidding

Table 12 shows the trees-per-turn data for the two contractors that utilized rubber-tired cable skidders (Contractors #2 and #3). The mean trees per turn were significantly different for the two contractors. The trees per turn for contractor #2 were not influenced by patch size or skidding distance. Turn size was a function of the number of trees the feller-buncher chose to fell between skids.

Contractor #3, because of the longer distance to patch B, tried to compensate for the longer travel time by increasing load size. His skidder was not able to pull this increased volume, and the skidder operator repeatedly had to drop his load, drive ahead, and winch in. This decision to increase turn volume caused an increase in skidding time per cycle.

Table 13 lists the mean productive time per cycle for both contractors. Differences in cycle time between plots for each contractor were tested with Duncan's Multiple Range Test. No significant statistical difference was found for Contractor #2, indicating skid distance had no effect on skidding times or productivity. Contractor #3, on the other hand, did show differences between the average skidding
Table 12. Mean Tree per Turn, Ranges and Average Volume per Turn for Contractor #2 and #3.

<table>
<thead>
<tr>
<th>PATCH</th>
<th>ACRES</th>
<th>MEAN TREE per TURN</th>
<th>TREE per TURN RANGES</th>
<th>AVERAGE VOLUME per TURN (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2.87</td>
<td>6.26</td>
<td>1 to 12</td>
<td>2.21</td>
</tr>
<tr>
<td>B</td>
<td>1.40</td>
<td>6.31</td>
<td>3 to 11</td>
<td>1.69</td>
</tr>
<tr>
<td>C</td>
<td>4.46</td>
<td>7.39</td>
<td>1 to 15</td>
<td>3.04</td>
</tr>
<tr>
<td>D</td>
<td>1.95</td>
<td>8.86</td>
<td>4 to 15</td>
<td>2.18</td>
</tr>
<tr>
<td>E</td>
<td>1.11</td>
<td>7.50</td>
<td>6 to 9</td>
<td>2.55</td>
</tr>
<tr>
<td>A*</td>
<td>0.98</td>
<td>2.83</td>
<td>1 to 6</td>
<td>1.91</td>
</tr>
<tr>
<td>B*</td>
<td>0.31</td>
<td>4.89</td>
<td>4 to 7</td>
<td>2.74</td>
</tr>
</tbody>
</table>
Table 13. Mean Cycle Skidding Productive Time per Turn, the Range and Distance from the Landing for Contractor #2 and #3.

<table>
<thead>
<tr>
<th>PATCH</th>
<th>DISTANCE from LANDING (feet)</th>
<th>MEAN CYCLE SKIDDING TIME (minutes)</th>
<th>CYCLE SKIDDING TIME RANGES (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1,062</td>
<td>10.77</td>
<td>7.40 to 18.90</td>
</tr>
<tr>
<td>B</td>
<td>966</td>
<td>10.33</td>
<td>8.75 to 16.47</td>
</tr>
<tr>
<td>C</td>
<td>591</td>
<td>11.33</td>
<td>7.40 to 16.45</td>
</tr>
<tr>
<td>D</td>
<td>438</td>
<td>12.13</td>
<td>7.28 to 14.71</td>
</tr>
<tr>
<td>E</td>
<td>75</td>
<td>3.32</td>
<td>2.54 to 3.97</td>
</tr>
<tr>
<td>A*</td>
<td>255</td>
<td>11.95</td>
<td>6.30 to 35.78</td>
</tr>
<tr>
<td>B*</td>
<td>1,122</td>
<td>23.13</td>
<td>22.9 to 37.97</td>
</tr>
</tbody>
</table>
cycle times for the two patches. This is attributed more to the contractor's decision to increase volume per trip and not directly to the longer distance between the two patches.

Figure 10 contains box plots for Contractor #2 and #3 for skidding cycle times by element. Note the consistency between contractors in their travel-empty, hook and unhook elemental time categories. Differences in the winch-in and travel-loaded categories are explained mainly by the differences in the two skidders, not by group-selection harvesting itself.

Table 14 shows skidding distances and average turn times for rubber-tired skidders as well as the means of the first three and last three turn times from each patch. Skidder times were greater during the opening of a patch (first three turns) than when the patch was almost completed (last three turns). More time was needed to coordinate activities with the sawyer when the patch was first entered. Statistical analysis showed (at an alpha level of 0.05) that there was enough variability between the first three skids and the last three skids to be significant.

Table 15 shows the productive versus scheduled utilization time for the two contractors who used rubber-tired, cable
Figure 10. Skidding time by element category for Contractor #2 and #3 in Minutes.
Table 14. "First Three" and "Last Three" Mean Scheduled Skidder Turn Times by Patch

<table>
<thead>
<tr>
<th>CONTRACTOR</th>
<th>PATCH</th>
<th>MEAN TIME per TURN (minutes)</th>
<th>DISTANCE (feet)</th>
<th>FIRST 3 SKIDS (minutes)</th>
<th>LAST 3 SKIDS (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>A</td>
<td>10.77</td>
<td>1,062</td>
<td>14.66</td>
<td>9.16</td>
</tr>
<tr>
<td>2</td>
<td>C</td>
<td>11.33</td>
<td>591</td>
<td>15.60</td>
<td>8.96</td>
</tr>
<tr>
<td>2</td>
<td>D</td>
<td>12.13</td>
<td>438</td>
<td>13.26</td>
<td>8.87</td>
</tr>
<tr>
<td>2</td>
<td>E</td>
<td>3.32</td>
<td>75</td>
<td>30.00</td>
<td>15.00</td>
</tr>
<tr>
<td>3</td>
<td>A</td>
<td>11.32</td>
<td>255</td>
<td>13.26</td>
<td>8.84</td>
</tr>
<tr>
<td>3</td>
<td>B</td>
<td>23.13</td>
<td>1,122</td>
<td>36.62</td>
<td>25.33</td>
</tr>
</tbody>
</table>
Table 15. Productive and Scheduled Skidder Hours Recorded for Contractor #2 and #3* Plus Percent of Delay Associated to Cause.

<table>
<thead>
<tr>
<th>PATCH</th>
<th>PRODUCTIVE HOURS</th>
<th>SCHEDULED HOURS</th>
<th>UNPRODUCTIVE HOURS</th>
<th>MACHINE UTILIZATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>5</td>
<td>8</td>
<td>3</td>
<td>0.625</td>
</tr>
<tr>
<td>B</td>
<td>3</td>
<td>6</td>
<td>3</td>
<td>0.500</td>
</tr>
<tr>
<td>C</td>
<td>3.5</td>
<td>8</td>
<td>4.5</td>
<td>0.438</td>
</tr>
<tr>
<td>D</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>0.750</td>
</tr>
<tr>
<td>E</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>0.250</td>
</tr>
<tr>
<td>A*</td>
<td>10</td>
<td>32</td>
<td>22</td>
<td>0.313</td>
</tr>
<tr>
<td>B*</td>
<td>4.5</td>
<td>14</td>
<td>9.5</td>
<td>0.321</td>
</tr>
</tbody>
</table>

* No weather delays recorded.
skidders. Notes recorded in the field on reasons for the non-productive time showed several things. In the travel-empty stage, 71 percent of the non-productive time was spent waiting for the sawyer or feller-buncher to achieve a safe distance so the skidder could continue traveling. Twenty-three percent of the non-productive time was devoted to cleaning the skid trail, and 6 percent was accounted as personal time.

During the hook phase, 63 percent of the non-productive time was attributed to waiting for the hooked trees to be delimbed, 21 percent to waiting for the sawyer's chainsaw to be freed after being pinched in delimbing, 14 percent to waiting because of the lack of sufficient trees to hook (lack of inventory), and 2 percent to personal time.

There were very few delays during the winch-in phase, but those recorded were attributed directly to waiting for the sawyer to achieve a safe distance so the trees could be winched.

During the travel-loaded phase, 43 percent of the non-productive time was due to additional delimbing and topping that did not occur in the hook phase, 34 percent to waiting for the landing to clear so the load could be unhooked, 8
percent attributed to cleaning the skid trail, 8 percent to hooking an extra tree on the way to the landing, 4 percent to freeing the load that got hung up along the skid trail, and 3 percent to the cable/chokers breaking.

The unhook phase had few non-productive times, but those that did occur were directly attributed to landing delays.

Table 14 shows the inefficiencies of group selection as most evident in Contractor #2's patch E. This was the central landing for all the patches and was the focal point for machine and crew activity. Loading, skidding, delimming/topping, and the feller-buncher, along with the shortest skidding distance, caused many delays. In fact, the amount of scheduled time required for the skidder to complete a cycle on this patch was over 15 minutes despite the short 75-foot average skid distance.

Contractor #3, on the other hand, had skidding problems in the initial stages of a patch's opening when the skidder operator often had to wait for the sawyer to move out of the way (Table 14). Felled trees were scattered around the patch as the sawyer created openings to facilitate directional felling. The skidder had to spend more time during the initial stages to get a full turn or skid fewer
trees, as well as spend extra time moving around standing trees.

While individual elements in the skidding process -- especially hook and travel loaded -- were affected by group selection, the largest impact this silvicultural system had on skidder productivity was through the delays it created.

Cable - Yarding

Table 16 presents mean trees per turn, minimum/maximum ranges of trees per turn and volume, and mean volume per turn for Contractor #1. A Duncan's Multiple Range Test confirmed consistent mean-tree-per-turn statistics from patch to patch, indicating consistency in the number of trees hooked per turn.

A second Duncan's Multiple Range Test (at an alpha level of 0.05) found no significant differences in the mean yarding times across patches. The average volume yarded per turn also was not significantly different from patch to patch (Table 16).
### Table 16. Mean Trees per Turn and Volume per Turn for Contractor #1 and Ranges.

<table>
<thead>
<tr>
<th>PATCH</th>
<th>ACRES</th>
<th>MEAN TREES per TURN</th>
<th>RANGE of TREES per TURN</th>
<th>AVERAGE VOLUME per TURN (tons)</th>
<th>RANGE of TONS per TURN</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1.03</td>
<td>2.42</td>
<td>1 to 4</td>
<td>1.20</td>
<td>0.51 to 1.98</td>
</tr>
<tr>
<td>B</td>
<td>1.32</td>
<td>2.73</td>
<td>1 to 5</td>
<td>0.97</td>
<td>0.36 to 1.77</td>
</tr>
<tr>
<td>C</td>
<td>1.39</td>
<td>2.57</td>
<td>1 to 4</td>
<td>1.03</td>
<td>0.39 to 1.62</td>
</tr>
<tr>
<td>D</td>
<td>1.89</td>
<td>3.00</td>
<td>1 to 4</td>
<td>0.99</td>
<td>0.33 to 1.32</td>
</tr>
<tr>
<td>E</td>
<td>1.38</td>
<td>2.89</td>
<td>1 to 5</td>
<td>1.16</td>
<td>0.39 to 2.01</td>
</tr>
</tbody>
</table>
Table 17 shows the productive yarding time along with the mean turn time and volume per turn for Contractor #1. Note that the set-up time roughly equaled the total yarding time. Note, too, that yarding distance seemed to have had little effect on productivity. Table 18 lists Contractor #1’s mean cycle and minimum/maximum for the turn time.

Table 19 shows the mean elemental times by category for the cable yarder. No significant differences were found between patches for any of the elemental times, with one exception. Outhaul for patch E was significantly different from that for the other patches at the 0.05 alpha level.

Delays found in the yarding operation were often the result of the layout of the timber sale. Pre-cut corridors, mandatory for this sale, were a problem because they were not precisely aligned between the yarder and the patch. Additional time during the set up of the yarder was needed to fell extra trees and/or move the machine or block, strap and anchors to achieve a straight pull.

The impacts of group-selection on cable yarding were similar to those of the other operations cited above. More time was required to set up the yarder, to look for buried trees while fighting logging debris within the patch, and to take
Table 17. Mean Yarding Cycle Productive Time, Total Time and Productivity (Contractor #1).

<table>
<thead>
<tr>
<th>PATCH</th>
<th>SIZE (acres)</th>
<th>YARDING DISTANCE (feet)</th>
<th>MEAN TONS per TURN</th>
<th>TOTAL SET-UP TIME (hours)</th>
<th>TOTAL YARDING TIME (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1.03</td>
<td>87</td>
<td>1.20</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>B</td>
<td>1.45</td>
<td>193</td>
<td>0.96</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>C</td>
<td>1.40</td>
<td>157</td>
<td>1.02</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>D</td>
<td>1.90</td>
<td>153</td>
<td>0.99</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>E</td>
<td>1.40</td>
<td>403</td>
<td>1.17</td>
<td>5</td>
<td>14</td>
</tr>
</tbody>
</table>
Table 18. Contractor #1’s Mean Cycle Yarding Time and Ranges.

<table>
<thead>
<tr>
<th>PATCH</th>
<th>DISTANCE from YARDER (feet)</th>
<th>MEAN CYCLE YARDING TIME (minutes)</th>
<th>TURN TIME RANGES (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>87</td>
<td>5.07</td>
<td>4.3 to 6.3</td>
</tr>
<tr>
<td>B</td>
<td>193</td>
<td>5.66</td>
<td>4.5 to 8.4</td>
</tr>
<tr>
<td>C</td>
<td>157</td>
<td>6.72</td>
<td>3.9 to 8.7</td>
</tr>
<tr>
<td>D</td>
<td>153</td>
<td>5.99</td>
<td>3.5 to 10.9</td>
</tr>
<tr>
<td>E</td>
<td>403</td>
<td>7.46</td>
<td>3.6 to 14.6</td>
</tr>
</tbody>
</table>
Table 19. Mean Cable Yarding Productive Time by Patch and Category in Minutes for Contractor #1.

<table>
<thead>
<tr>
<th>PATCH</th>
<th>DISTANCE from YARDER (feet)</th>
<th>OUTHAUL</th>
<th>LATERAL OUTHAUL</th>
<th>HOOKING CHOKERS</th>
<th>TRAVEL LOADED</th>
<th>UNHOOK TOTAL TIME (average)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>87</td>
<td>0.37</td>
<td>0.81</td>
<td>1.74</td>
<td>2.17</td>
<td>0.82</td>
</tr>
<tr>
<td>B</td>
<td>193</td>
<td>0.37</td>
<td>0.99</td>
<td>1.81</td>
<td>1.64</td>
<td>0.85</td>
</tr>
<tr>
<td>C</td>
<td>157</td>
<td>0.48</td>
<td>1.41</td>
<td>2.41</td>
<td>1.43</td>
<td>0.98</td>
</tr>
<tr>
<td>D</td>
<td>153</td>
<td>0.38</td>
<td>0.94</td>
<td>2.12</td>
<td>1.61</td>
<td>0.89</td>
</tr>
<tr>
<td>E</td>
<td>403</td>
<td>0.65</td>
<td>1.49</td>
<td>2.62</td>
<td>1.66</td>
<td>1.05</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>0.48</td>
<td>1.18</td>
<td>2.21</td>
<td>1.51</td>
<td>0.94</td>
</tr>
</tbody>
</table>
down and move the yarder. Group selection created frequent delays and large segments of non-productive time. The yarder was only utilized 11 percent of the scheduled work time on the sale. The overall effect was decreased productivity and increased unit costs.

**Timber Harvesting Costs**

Cost data for this project was collected through contractor interviews, cost records and published data. Productivity is based on time studies of each system and delivery tickets obtained from the contractors.

Table 20 shows weekly production and cost ($/ton) on a cash-flow basis for the three systems studied. Appendix G presents the detailed the cost calculations.

Table 21 breaks down each logger's total weekly costs by component. Table 22 addresses those same components as percents of the total weekly cost. Note that Contractor #1, the skyline system, had the highest equipment percent at 39.1. The large difference in the "equipment" component between the two rubber-tired skidder systems #2 and #3 is due to #3's fully depreciated equipment and minimal equipment payments.
Table 20. Weekly Production and Cost per Ton of Group-Selection Harvest by Contractor.

<table>
<thead>
<tr>
<th>CONTRACTOR</th>
<th>SYSTEM</th>
<th>PRODUCTION (tons per week)</th>
<th>UNIT COST ($/ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Skyline</td>
<td>194.6</td>
<td>40.18</td>
</tr>
<tr>
<td>2</td>
<td>Feller-Buncher and Skidder</td>
<td>353.5</td>
<td>14.79</td>
</tr>
<tr>
<td>3</td>
<td>Chainsaw Fell and Skidder</td>
<td>147.2</td>
<td>16.15</td>
</tr>
</tbody>
</table>
Table 21. Weekly Cost Component in Dollars for Three Study Contractors.

<table>
<thead>
<tr>
<th>COST COMPONENT</th>
<th>Contractor 1</th>
<th>Contractor 2</th>
<th>Contractor 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Consumable Supplies</strong></td>
<td>$1,512</td>
<td>$1,463</td>
<td>$766</td>
</tr>
<tr>
<td>Deck/Landing Building</td>
<td>72</td>
<td>00</td>
<td>00</td>
</tr>
<tr>
<td>Taxes &amp; Licenses</td>
<td>56</td>
<td>53</td>
<td>30</td>
</tr>
<tr>
<td>Fuel, Oil &amp; Tires</td>
<td>460</td>
<td>914</td>
<td>389</td>
</tr>
<tr>
<td>Repair &amp; Maintenance</td>
<td>897</td>
<td>496</td>
<td>284</td>
</tr>
<tr>
<td><strong>Labor</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hourly Labor</td>
<td>3,107</td>
<td>2,062</td>
<td>1,300</td>
</tr>
<tr>
<td>Contract Truck Labor</td>
<td>2,587</td>
<td>2,062</td>
<td>1,300</td>
</tr>
<tr>
<td><strong>Equipment</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chainsaws</td>
<td>40</td>
<td>27</td>
<td>40</td>
</tr>
<tr>
<td>Yarder</td>
<td>801</td>
<td>00</td>
<td>00</td>
</tr>
<tr>
<td>Skidder(s)</td>
<td>855</td>
<td>00</td>
<td>00</td>
</tr>
<tr>
<td>Truck(s)</td>
<td>00*</td>
<td>500</td>
<td>144</td>
</tr>
<tr>
<td>Dozer</td>
<td>936</td>
<td>00</td>
<td>00</td>
</tr>
<tr>
<td>Loader</td>
<td>466</td>
<td>00</td>
<td>00</td>
</tr>
<tr>
<td>Feller-Buncher</td>
<td>00</td>
<td>750</td>
<td>00</td>
</tr>
<tr>
<td>Pick-up Truck</td>
<td>00</td>
<td>24</td>
<td>00</td>
</tr>
<tr>
<td><strong>Insurance</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>127</td>
<td>265</td>
<td>67</td>
</tr>
<tr>
<td><strong>Administrative Overhead</strong></td>
<td>15‡</td>
<td>163</td>
<td>60</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$7,819</td>
<td>$5,230</td>
<td>$2,377</td>
</tr>
</tbody>
</table>

* Contract Trucking

‡ Difficult to obtain due to shared cost record keeping of sawmill
Table 22. Weekly Cost Component in Percent for the Three Contractors.

<table>
<thead>
<tr>
<th>COST COMPONENT</th>
<th>Contractor 1</th>
<th>Contractor 2</th>
<th>Contractor 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumable Supplies</td>
<td>19%</td>
<td>28%</td>
<td>32%</td>
</tr>
<tr>
<td>Labor</td>
<td>40</td>
<td>39</td>
<td>55</td>
</tr>
<tr>
<td>Equipment</td>
<td>39</td>
<td>24</td>
<td>8</td>
</tr>
<tr>
<td>Insurance</td>
<td>2</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Administrative Overhead</td>
<td>*</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

* Less than One percent.
A general rule-of-thumb states that consumable supplies, labor, and equipment categories account for approximately 30 percent of the total costs. Each of the contractors studied, however, had more than 30 percent in the labor category, with #3 having the highest at 54.7 percent. This same logger was well below the 30 percent cost allotment for equipment because of the depreciated equipment.

A recent study of logging costs in the Appalachian Mountain area (Hancock 1991) examined nine pulpwood loggers to determine harvesting costs and components. While the study considered operations working primarily on clearcuts, his information is valuable for general comparisons with this study. For these nine contractors studied, average cost per ton ranged from $12.34 to $17.69. Table 20 shows that two of the contractors in the present study (#2 and #3) fell within that range ($14.79 for #2 and $16.15 for #3). Thus, while this project did not identify costs as thoroughly as Hancock (1991), having these costs within the range is reassuring.

**Weekly Production**

All three contractors' production rates decreased when they moved from clear cutting to group selection (Table 23).
Contractors #1, #2 and #3 experienced decreases of 56.8, 70.5 and 49.3 tons per week when they logged in group-selection silvicultural systems. This equates to percentage drops of 22.6, 16.7 and 25.2, respectively. Again, the reader is cautioned to keep in mind that historic productivity for Contractor #2 was based on his conventional harvesting method of manual felling and not with the feller-buncher. Thus, the 70.53 decrease in tons per week or a 16.7 percent decline compares productivity of the feller-buncher versus his conventional manual felling system employed in clearcut sales.

A common problem associated with harvesting small patches was that the load/steady state/purge pattern, common in all logging operations, was disrupted. In fact, the purge stage rarely occurred at all. Of the three logging systems studied, this load/steady state/purge was most profound for Contractor #1, the skyline system. This operation had to move for each patch, and each move was time consuming and costly. Because the operation was idle much of the time, #1 did not consume many supplies.
Table 23. Average Weekly Production by Contractor for Group Selection and Clear Cutting.

<table>
<thead>
<tr>
<th>CONTRACTOR</th>
<th>SYSTEM</th>
<th>MEAN WEEKLY PRODUCTION</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Clear Cut* (tons)</td>
<td>Group Selection (tons)</td>
<td>Decline (tons)</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Skyline</td>
<td>251</td>
<td>195</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Feller Buncher and Skidder</td>
<td>424#</td>
<td>354</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Chainsaw Fell and Skidder</td>
<td>196</td>
<td>147</td>
<td>49</td>
<td></td>
</tr>
</tbody>
</table>

* From logger’s past production records.

# Based on his conventional system which include manual chainsaw felling.
Group Selection Impacts on Deliveries

Weight tickets from Contractor #2 were collected for a two-month period (August 1 to September 30) bracketing the study to determine how weekly production was impacted by group selection. Figure 11 shows daily delivered tonnage plotted by date. The week of group-selection harvesting was in the middle of the two-month period (August 24 through September 4). The job averaged 60 tons per day delivered while clear cutting. During the week of the group selection, deliveries fell to less than 40 tons per day. Thus, Contractor #2, a production-oriented logger, lost an average of one truck load per day.

Contractor #3's daily pulpwood production was not affected. He shipped one load of pulpwood per day regardless of tract and method (while also trucking one or more loads of sawlogs on some days). Group-selection harvests caused him to lengthen the work day to get those loads. In fact, group selection reduced productivity for all the loggers evaluated. Not only did group selection reduce income over time, but it made them work longer and harder to achieve that decreased revenue.
Figure 11. Truck Weight Tickets of Deliveries During Group-Selection Harvest from August 1 to September 30, 1991.
Summary of Results

While all three logging contractors felt the impacts of group selection on their normal activities (felling, skidding or yarding), the single largest impact all three experienced came from delays. These delays, whether from a feller-buncher waiting for the skidder to move to a safe location or the skidder waiting for the landing to clear, all decreased productivity. As productivity decreased, costs generally increased.
Group-selection harvesting entails, by definition, cutting small patches that are widely dispersed throughout a timber stand at varying distances from each other and from the landing (Figure 12). Collectively, these patches could equal the total volume found in a typical clearcut sale, but realistically, total sale volume is generally reduced.

Because of these dispersed patches, skidding occurs through a greater portion of an unharvested stand and often at longer distances from the landing area (Figure 13). While not measured during this study, concern exists for the possibility that residual stand damage may increase on trees located along the skid trails and around the patch boundaries.

While residual stand damage was not quantified in this study, the U.S. Forest Service Districts which oversaw the group-selection timber sales implemented certain conditions to address possible damage. These varied from district to district but included requirements that marked trees along the skid trails must remain until all skidding from the patch was completed. These trees served as "rub" trees and
Figure 12. A group-selection patch viewed from the yarder setting through a skyline corridor.
Figure 13. Skid trails from patch.
could be felled and skidded after the patch had been cleared. Required directional felling within the patch, log-length skidding, and/or "rub" trees all had a negative impact on logging costs and productivity.

When harvesting the small patches associated with group-selection silviculture, the logging contractor reached optimum efficiency (i.e., coordination and scheduling between the felling and the skidding) just as the patch was completed. Thus, the load/steady state/purge pattern, common in all logging operations, was continuously disrupted.

In a group-selection sale, "start-up" in new patches occurred frequently. Thus, the load stage was common as skid trails were established to reach trees that were felled. As parity occurred between the felling and the skidding, the operation became more efficient (i.e., the steady state). But by the time the system reached this steady state, the patch was usually completed. At this point, a purge period would typically occur. However, the concentrated activities, limited area, and the necessity of constant housekeeping often eliminated the purge stage.
Of the three systems studied, this load/steady state/purge effect was most profound for Contractor #1, the skyline system. Only 19 percent of his total costs was in consumables, indicating that his equipment was idle much of the time.

Relating this study to the results determined by Bell (1989) and the use of the Harvesting Analysis Technique (HAT) computer simulation, similar conclusions can be drawn. He found that felling and skidding costs were, respectively, 28.8 percent and 26.1 percent higher for group selection than for clear cutting. Productivity was consistently less in all phases, with 1.6 fewer cords per productive hour for felling (a decrease of 26 percent) and 0.5 fewer cords per productive hour for skidding (a 15 percent decrease). Again, overall for all three contractors, this study documented a productivity decrease of approximately 20 to 28 percent.

Bell (1989) stated that the longer skidding distances in group selection were the major reason for these productivity decreases. He also reported that for every 100 foot increase in skid distance, costs increased $0.68 per cord for group selection versus $0.33 for clear cutting. While this study found skidding/yarding distance had minimal
effect on productivity, keeping skid distances as short as possible will definitely increase interference unless landing size is increased.

Impacts on the Cable Yarding System

The skyline yarding system had very high fixed costs and required a large crew. [Table 22 shows an almost equal split of costs between equipment (39 percent) and labor (40 percent).] Members of the crew often spent more time taking down and setting up the yarder than actually logging. Over the entire study, the yarder was found to be productive only 11 percent of the time. Overall productivity decreased (from 251.4 to 194.6 tons per week) by 22.6 percent from clear cutting (Table 23).

The sawyers voiced concern that felling all trees within the patch boundary concentrated tops and other logging slash. This increased felling times (Table 11) from 3.96 minutes per tree in a clear cut to 4.83 minutes per tree in group selection, created a safety risk to the sawyers (Figure 14), and created problems for the choker setters (Figure 15). The major interruption to the normal work flow was the large amount of time spent waiting due to delays caused by the
Figure 14. Concentration of logging slash slowed felling production.
Figure 15. Productivity decreased as logging slash increased during hook time as buried trees were common.
concentration of slash, equipment and people in the small operating area.

When the yarder was effectively working and the choker setters were finding trees readily in the small patches, volume could be quickly moved to the landing. The landing then became flooded, and yarding had to cease to give the loader operator time to clear it. This bottleneck also occurred when a truck arrived to haul logs to the mill. Because of the timber sale contract requirement for a minimum sized (permanent) landing, trucks entering the landing caused yarding delays.

Yarder placement and corridor alignment were critical. The Forest Service determined the yarder placement and then established corridors into the stand. However, when the planned yarder location did not coincide with actual yarder set-up, the corridors extending from that spot did not line up precisely with the patch. Additional trees had to be felled, or the machine had to be relocated to achieve a straight pull (Figure 16).
Figure 16. Corridor alignment proved critical in set-up.
Impacts on the Mechanized Felling and Cable Skidding System

Contractor #2's feller-buncher was an unexpected but welcomed addition to the study. Because the feller-buncher was leased just prior to the start of the group-selection timber sale, this contractor's previous clearcut production figures are based on his normal operation, which utilized chainsaw felling. Skidding was accomplished in both silvicultural systems with a rubber-tired cable skidder.

It is interesting that #2's patch E (the landing) had the shortest productive skidder cycle time (3.32 minutes) but had a scheduled cycle time that was actually the longest of all five patches (over 15 minutes). This demonstrates a major impact group selection had on this logger's production rate. In this case, all activities (loading, felling, and skidding) were concentrated in one small area and required the machines to operate in close proximity to one another.

Safety is always a major concern. Patch sizes were not large enough to allow all the equipment to work at the same time. This caused the feller-buncher and skidder operators to "take turns" operating to avoid interference and risk (Figure 17).
Figure 17. The Feller-Buncher and skidder could not operate together at the same time when a patch was small.
Of the three loggers studied, Contractor #2, a typical production-oriented logger, had the smallest percentage decrease (16.7 percent) in production from his normal clearcutting production rate. The feller-buncher working in the group-selection sale instead of his normal manual chainsaw felling may have offset some of the expected production decrease due to group selection. Logging slash, hung trees and directional felling within the patch boundary had less effect on the feller-buncher than they would have had on manual chainsaw felling. Even with the addition of the feller-buncher, this logger still had a decrease of 70.53 tons per week from his normal production when clearcutting.

The major problem for the feller-buncher system (Contractor #2) was unproductive time. In the patches, waiting occurred for the feller-buncher to drop enough trees, for tops and limbs to be removed, and for the loader to make room for the skidder to operate. Landings were not large enough to accommodate concentrated activities and the product sorting that occurred.
percent compared with 25 percent for Contractor #2. Labor costs, however, accounted for more than 50 percent of total costs and were the highest of all three loggers studied. His production goal was to produce one load of pulpwood and an occasional additional load of sawlogs each day, whether he was working on a group-selection sale or a clear cut. It took him longer to achieve his normal production when operating in group selection. In a clear cut, desired production was often achieved by noon; in group selection, it often took the crew until 3:00 p.m. The additional labor costs reduced what little profit he was generating.

Delays

Group selection harvesting resulted in frequent delays and unproductive time by decreasing productivity per scheduled hour and by increasing the effort needed to generate these lower volumes.

Delays occurred throughout the harvesting procedure. Common delays resulting from group selection included: 1) waiting for the sawyer to complete the limbing and topping in the travel-empty, hook, and travel-loaded phases and 2) waiting for the skidder, feller-buncher or sawyer to achieve a safe distance so that productive work could begin again.
for the sawyer to complete the limbing and topping in the travel-empty, hook, and travel-loaded phases and 2) waiting for the skidder, feller-buncher or sawyer to achieve a safe distance so that productive work could begin again. Delays also affected cable yarding, where set-up time per patch equaled productive yarding time. With minimum-sized landings, the yarder had to wait as trucks were loaded, the landing was cleared, or individuals performed their assigned duties.

While group selection caused individual elemental time categories to increase, the effect of those delays on harvesting productivity and cost was minor compared to the impact of the large blocks of non-productive time specifically created by the group-selection silviculture.

Group Selection and Costs

Hancock's (1991) study of nine typical loggers harvesting in Virginia and West Virginia reported that their 1988 and 1989 average cost per ton ranged from $12.34 to $17.69; the average for all nine loggers was $14.38 per ton. These loggers represented a "sample of the larger, more productive operations in the area," and their costs were shown to be extremely sensitive to weekly production levels. The unit
assuming the use of the feller-buncher and assuming that all costs were captured in this study.

Future Implications

The results can be summarized simply by stating that group selection decreased productivity while increasing costs. This is a direct result of the interference created by working in small patches that concentrate harvest activities. Group selection also has the possibility to increase road building and maintenance costs, increase administration costs, and increase residual stand damage.

Comparing the two contractors who used rubber-tired skidders (Contractors #2 and #3), one was very production oriented and had newer equipment, greater overhead/fixed costs, and a large wood quota. The second logger only cut one load of pulpwood per day and sometimes a load of sawlogs; his equipment was completely depreciated and paid for, so he had lower overhead/fixed costs; and he was more restricted by quota. If the Forest Service were to restrict logging to group-selection harvests, the effects on these two very different types of loggers may be as follows: The production-oriented logger may no longer be interested in bidding on group-selection sales because of the greater
costs and reductions in production. The "low fixed cost" logger may not be able to continue to bid on the sales, because the increased production cost may eliminate the small profit he normally makes and drive him out of business.

Thus, implications for continued debate on the "below-cost-timber-sale" issue seems assured. And from the timber harvesting contractors point of view, receiving less revenue due to reduced production while working harder and longer certainly is not an inviting proposition.
CHAPTER 6

Summary and Conclusions

Time-study techniques were used to evaluate three harvesting systems, and data were collected on the productivity of these systems while harvesting group-selection timber sales. System cost data were obtained through interviews, examination of financial records, and literature. This information was then used to compare productivity and costs from clear cutting, and to document the impact that group-selection harvests had on these three systems.

The cable yarding group-selection sale turned out to be least efficient and most expensive. The yarder was only productive approximately 11 percent of the time. The rest of the time was spent setting up, building corridors, and moving the machine.

Group-selection harvesting was more costly for all three contractors. The general complaint of the loggers was that as production in a patch began to increase, the patch was completed, and they had to move to the next one. A steady-state level of productivity was never reached.

Productivity for each of the three contractors studied decreased in the group-selection harvests. Delays and non-
productive periods were the single greatest reason for this decreased output. These delays included waiting for the skidder to remove trees or to reach a safe distance so felling could continue, waiting for trees to be hooked, and landing delays.

Logging in small patches increased costs dramatically. The smaller the patch size, the greater the operating difficulty and the higher the safety risk. Small patches exacerbate the delays caused by men and equipment forced to operate together in close confines.

Increased use of group selection by the U.S. Forest Service will likely add to the "below-cost" timber sale argument. As logging costs are increased, stumpage prices may be forced lower in order to attract loggers to bid on these sales.
Recommendations

A number of recommendations can be made as a result of this research. Without implying any order of importance, they include:

1. Eliminate the contract stipulation requiring all logging slash to be contained within the patch. This may enhance felling and skidding efficiency and safety. Alternatively, perhaps consider specifying a diameter limit for trees which may or may not be allowed to fall outside the boundary.

2. Increase the overall patch size. This may require changing the definition of "group selection." Efficiency is easier to maintain, safe working conditions are possible, and production can be increased on larger patches due to fewer delays.

3. Create a landing "patch" large enough for all parties to continue their assigned tasks without interruption (i.e., truck turn-around capability, loading and product sorting space).

4. Selectively thin areas between patches in stands where this is feasible. This will increase total sale volume and generate more volume per landing location.
5. Remove the contract stipulation that "site preparation" (the felling of all non-merchantable stems within the patch) must be completed by the logger.

6. Allow tree-length skidding through carefully aligned skid trails (i.e., straighter skid trails), and allow skidding of smaller trees with the tops on. This could improve efficiency by decreasing the number of cycles needed per patch.

7. Increase the communication and cooperation between logging contractors and the U.S. Forest Service when designing and planning the sale.

If cable yarding is utilized:

1. Allow the contractor to establish corridors and yarder sets. This reduces possibilities for poor alignment and delays created if they do not match.

2. Lay out patch boundaries with lateral outhaul capability and yarder constraints in mind.

Finally, carefully consider all the ramifications of increased harvesting costs due to group-selection.
silviculture on the overall National Forest timber sale program.


Appendices

Appendix A: Pre-Harvest Data Collection Sheets.
Appendix B: Elemental Descriptions for Manual Felling.
Appendix C: Elemental Descriptions for Feller-Buncher.
Appendix D: Elemental Descriptions for Rubber-Tired Skidding.
Appendix E: Elemental Descriptions for Skyline, Cable-Yarder.
Appendix F: Time Record Sheets.
Appendix G: Cash Flow Analysis.
Appendix A

Pre-Harvest Data Collection Sheet for Conditions Around the Stump Area.

Pre-harvest Data Collection Sheet for Conditions Around the Stump When Processing.

Pre-Harvest Data Collection Sheet for Conditions Around the Stump Area Transport.

Pre-Harvest Data Collection Sheet for Conditions On and Around the Skid Trail.

Pre-Harvest Data Collection Sheet for Conditions On and Around the Landing.
Pre-harvest data collection sheet for conditions around the stump area.

306.30 Working Conditions

306.31 Stump area, felling

306.311 Slope Class

1 2 3 4 5

306.312 Footing

a. firm-no sinkage or slipping
b. soft-walking man penetrates 5 cm
c. very soft-walking man penetrates 10 cm or more
d. slippery, humus, mud, stones, moss, ice, rain
e. obstructed, snow, mud, water

306.313 Brush

a. open, no obstruction to movement
b. light, circuitous travel unobstructed
c. moderate, movement impeded slightly
d. heavy, movement difficult, some clearing required
e. very heavy, clearing nearly always required

306.314 Residual stand interference

306.314.1 ___ % of trees over 10 cm left standing

306.314.2 Residual stems are

a. cull-can be damaged
b. to be removed in second pass-moderate damage acceptable
c. future crop trees-damage unacceptable

306.315 Snow

306.315.1 ___ depth cm.

306.315.2 Surface

a. loose, powdery
b. loose, wet
c. light crust
d. moderate crust
e. heavy crust

306.316 ___ walking quotient
Pre-harvest data collection sheet for conditions around the stump when processing.

<table>
<thead>
<tr>
<th>Study ID</th>
<th>Date</th>
</tr>
</thead>
</table>

**306.32 Stump area - processing - to be computed only if processing is conducted in woods independent of felling**

<table>
<thead>
<tr>
<th>Slope Class</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
</table>

**306.322 Footing**
- a. firm-no sinkage or slipping
- b. slippery, humus, mud, stones, moss, ice, rain
- c. obstructed snow, mud, ice

**306.323 Debris**
- a. light-no obstruction to movement-most travel on ground
- b. moderate - requires caution in movement but no clearing
- c. heavy - most movement on slash - some clearing
- d. very heavy - movement only on slash or holes or requires clearing

**306.324 Organization**
- a. random felling
- b. directional felling
- c. bunching
- e. piling
- f. other

**306.325 Snow**

<table>
<thead>
<tr>
<th>Depth cm.</th>
</tr>
</thead>
</table>

**306.325.1 Depth cm.**

<table>
<thead>
<tr>
<th>Surface</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
</table>

- a. loose, powdery
- b. loose, wet
- c. light crust
- d. moderate crust
- e. heavy crust

**306.328 Walking quotient**
Pre-harvest data collection sheet for conditions around the stump area transport.

306.33 Stump Area Transport Conditions

(to be completed only if skidder, forwarder, or other transport equipment travels directly to stump area)

306.331 Slope Class 1 2 3 4 5
306.332 Ground roughness
   1 very even 4 rough
   2 slightly uneven 5 very rough
   3 uneven

306.333 Soil Moisture
   a. frozen
e. saturated
   b. dry
d. standing water
   c. fresh

306.334 Brush, debris and residual stand
   a. open-no obstruction to movement
   b. light-circuituous travel unobstructed
   c. moderate - movement slightly impeded
   d. heavy - movement difficult, some clearing required
   e. very heavy - clearing nearly always required

306.335 Snow
306.335.1 ________ depth cm.
306.335.2 Surface
   a. loose, powdary
   b. loose, wet
   c. light crust
   d. moderate crust
   e. heavy crust

306.336 Material Organization
   a. random orientation
   b. directional orientation
   c. bunched
   d. tumbled
   e. piled
   f. Other ________

306.338 ________ walking and/or ________ machine movement quotient
Pre-harvest data collection sheet for conditions on and around the skid trail.

306.34 Strip road/skid trail conditions

<table>
<thead>
<tr>
<th>Study ID</th>
<th>____________________</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>____________________</td>
</tr>
<tr>
<td>New</td>
<td>Revised</td>
</tr>
</tbody>
</table>

306.340 No trail
306.341 Slope class 1 2 3 4 5
306.342 Slope relation to access (direction of loaded travel)

a. level
b. uphill
c. downhill
d. rolling or broken

306.343 Roughness

1. very even
2. slightly uneven
3. uneven
4. rough
5. very rough

306.344 Origin

a. no preparation
b. clearing only
c. clearing and humus removed
d. bladed
e. bladed and ditched
f. bladed, ditched and some surface applied
g. Other

306.345 Surface Composition

a. organic
b. clay
c. silt
d. fine sand/loam
e. coarse sand
f. gravel
g. stone
h. rock
i. snow
j. ice
k. slash

306.346 Surface moisture

a. frozen
d. wet
b. dry
e. saturated
c. fresh

306.347 Surface Condition

a. smooth
d. corrugations
b. rutted
e. other
c. holes and protrusions

306.348 Alignment

a. straight
d. crooked
b. slightly curved
e. very crooked
c. winding
Pre-harvest data collection sheet for conditions on and around the landing.

<table>
<thead>
<tr>
<th>Landing or roadside conditions</th>
<th>Study ID_________________________</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date _________________________</td>
<td>New Revised</td>
</tr>
</tbody>
</table>

306.350 No landings

306.351 Slope Class 1 2 3 4 5

306.352 Ground roughness
1. very even
2. slightly uneven
3. uneven
4. rough
5. very rough

306.353 Origin
a. no preparation
b. clearing only
c. clearing and humus layer removed
d. bladed

e. bladed and ditched
f. bladed, ditched and surfaced
g. other

306.354 Surface composition
a. organic
b. clay
c. silt
d. fine sand/loam
e. coarse sand
f. gravel
g. stone
h. rock
i. snow
j. ice
k. slash

306.355 Surface moisture
a. frozen
d. wet
b. dry
e. saturated
c. fresh

306.356 Management
a. excellent
b. very good
c. good
da. poor
e. very poor
Appendix B
Elemental Description for Manual Felling

1. **Swamping.** This phase included the amount of time needed to clear brush, vines, and small trees from the base of the tree so that it could be approached, directional felling planned, and an escape route planned. It began when the chainsaw operator started cutting obstructions away (either from the base of the tree or from the escape route) and ended when the saw touched the base of the tree to begin the notching phase.

2. **Under cut.** This phase included the time needed to create a notch to facilitate directional felling. This element began when the saw touched the tree (i.e., end of swamping phase) and concluded when the saw completed the notch, and the wedge was removed.

3. **Back cut.** This phase included the time from when the chainsaw operator began the final felling process (i.e., finished the undercut) until the tree hit the ground.

4. **Limbing and Topping.** This phase included the time required to remove limbs with the chainsaw and sever the top of the tree from the merchantable portion. This phase began after the tree hit the ground (i.e., end of back cut) and ended when, from the sawyer's point of view, the limbs and top were satisfactorily removed.
5. **Walking to next tree.** This phase included the time used to walk from the topped area of the previous tree to the next tree in the felling pattern. The phase began when the sawyer started to walk away from the topping area and ended when the next tree was reached (i.e., beginning of swamping phase).
Appendix C

Elemental Description of Feller-Buncher

1. **Felling.** This phase included the time required to sever the tree from the stump with a bar and chain felling head. It began when the sawhead touched the bole of the tree and ended when the tree was cut free from the stump.

2. **Bunch.** This phase included the time the operator required to move the tree around, after being severed, either positioning it on the bunch or beginning a new bunch. It ended when the sawhead released the tree.

3. **Move to next tree.** This phase began when the feller-buncher released the previous tree and ended when the machine began the felling process. This phase also included the time the operator used to determine the direction of fall.

The following is a working definition of stage four:

4. **Limbing and Topping.** This phase included the time required for the chainsaw operator to remove the limbs and to sever the top from the merchantable portion of the tree.
Appendix D
Elemental Description for Rubber-Tired Skidding

1. **Travel Empty.** This phase included the time required for the skidder to move from the landing or roadside to the hooking area. The period began when the skidder started moving off the landing (or roadside) and was completed when the winch was released in the hook area.

2. **Hook or choke.** This phase included the time required to hook the chokers to a turn of logs. It began when the cable was released (i.e., end of travel-empty phase) and ended when all logs were choked and the winch engaged.

3. **Winch In.** This phase included the time required to pull a turn of logs to the skidder. It began when the winch was engaged (i.e., end of hook phase) and concluded when the butts of the trees were drawn up against the butt plate of the skidder.

4. **Travel Loaded.** This phase included the time required to skid the logs from the hook area to the landing. It began when logs reached the butt plate of the skidder (i.e., end of winch-in phase) and ended when the winch was released at the landing.

5. **Unhook.** This phase included the time used to unhook the turn of logs on the landing. It began when the winch was released (i.e., end of travel-loaded phase) and ended when the cable was wound back onto the spool.
Appendix E

Elemental Description for Skyline, Cable Yarding

1. **Outhaul.** This phase included the time required to move the empty carriage from the landing (or roadside) to the hooking area. The period began when the carriage started moving (after unhooking activity ceased) and ended when the carriage stopped.

2. **Lateral Outhaul.** This phase included the time required to pull the cable from the carriage to the trees to be hooked. The period began when the carriage stopped (i.e., end of outhaul phase) and ended when the cable reached the first tree to be hooked.

3. **Hooking Chokers.** This phase included the time required to hook a turn of logs to the mainline cable. The phase began when the choker setter(s) reached the first log (i.e., end of lateral-outhaul phase) and ended when the log began to move.

4. **Lateral Inhaul and Travel Loaded.** This phase included the time used to winch logs, after being hooked (i.e., end of hooking-choker phase), to when the carriage stopped at the landing or roadside.

5. **Unhook.** This phase included the time required to release the logs on the landing. It began when the carriage stopped (i.e., end of travel-loaded phase) and ended when the carriage began to move again (start of travel-empty phase).
Appendix F

Time Record Sheets Listing Elemental Segments Studied for
Chainsaw Felling,
Feller Buncher Felling,
Cable Yarding,
and Rubber - Tired Skidding.
Appendix F

352.5 Elemental time studies

Manual Chainsaw Felling
(sample)

<table>
<thead>
<tr>
<th>Study ID</th>
<th>Date</th>
<th>Machine or work unit</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Reference</th>
<th>Elemental</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Swamping</td>
<td>Notch</td>
<td>Back cut</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reference</th>
<th>Elemental</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Swamping</td>
<td>Notch</td>
<td>Back cut</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reference</th>
<th>Elemental</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Swamping</td>
<td>Notch</td>
<td>Back cut</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reference</th>
<th>Elemental</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Swamping</td>
<td>Notch</td>
<td>Back cut</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reference</th>
<th>Elemental</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Swamping</td>
<td>Notch</td>
<td>Back cut</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reference</th>
<th>Elemental</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Swamping</td>
<td>Notch</td>
<td>Back cut</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reference</th>
<th>Elemental</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Swamping</td>
<td>Notch</td>
<td>Back cut</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reference</th>
<th>Elemental</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Swamping</td>
<td>Notch</td>
<td>Back cut</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reference</th>
<th>Elemental</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Swamping</td>
<td>Notch</td>
<td>Back cut</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reference</th>
<th>Elemental</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Swamping</td>
<td>Notch</td>
<td>Back cut</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reference</th>
<th>Elemental</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Swamping</td>
<td>Notch</td>
<td>Back cut</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reference</th>
<th>Elemental</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Swamping</td>
<td>Notch</td>
<td>Back cut</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reference</th>
<th>Elemental</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Swamping</td>
<td>Notch</td>
<td>Back cut</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reference</th>
<th>Elemental</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Swamping</td>
<td>Notch</td>
<td>Back cut</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reference</th>
<th>Elemental</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Swamping</td>
<td>Notch</td>
<td>Back cut</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reference</th>
<th>Elemental</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Swamping</td>
<td>Notch</td>
<td>Back cut</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reference</th>
<th>Elemental</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Swamping</td>
<td>Notch</td>
<td>Back cut</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reference</th>
<th>Elemental</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Swamping</td>
<td>Notch</td>
<td>Back cut</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reference</th>
<th>Elemental</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Swamping</td>
<td>Notch</td>
<td>Back cut</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reference</th>
<th>Elemental</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Swamping</td>
<td>Notch</td>
<td>Back cut</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reference</th>
<th>Elemental</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Swamping</td>
<td>Notch</td>
<td>Back cut</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reference</th>
<th>Elemental</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Swamping</td>
<td>Notch</td>
<td>Back cut</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reference</th>
<th>Elemental</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Swamping</td>
<td>Notch</td>
<td>Back cut</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reference</th>
<th>Elemental</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Swamping</td>
<td>Notch</td>
<td>Back cut</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reference</th>
<th>Elemental</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Swamping</td>
<td>Notch</td>
<td>Back cut</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reference</th>
<th>Elemental</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Swamping</td>
<td>Notch</td>
<td>Back cut</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reference</th>
<th>Elemental</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Swamping</td>
<td>Notch</td>
<td>Back cut</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reference</th>
<th>Elemental</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Swamping</td>
<td>Notch</td>
<td>Back cut</td>
</tr>
</tbody>
</table>
Appendix F

352.5 Elemental time studies

Feller - Buncher
(sample)

<table>
<thead>
<tr>
<th>Reference</th>
<th>Elemental</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Felling Tree</td>
<td>Move to Next Tree</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Study ID: ________
Date: ________
Machine or work unit: ________
Appendix F

352.5 Elemental time studies

Cable Yarding Time Sheet
(sample)

<table>
<thead>
<tr>
<th>Reference</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outhaul</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lateral</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hooking</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inhaul</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unload</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Study ID: 
Date: 
Machine or work unit: 

Comments: 

132
Appendix F

352.5 Elemental time studies

Rubber-Tired Skidding Time Sheet

(sample)

<table>
<thead>
<tr>
<th>Reference</th>
<th>Elemental</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Travel</td>
<td>Hook</td>
<td>Winch in</td>
</tr>
</tbody>
</table>

Study ID________
Date________
Machine or work unit_______
Appendix G

CASH FLOW ANALYSIS

Logging Cost Calculations By Contractor Studied

These analyses are based for the most part on the loggers own records. However, when information was not available data was found in literature by the following sources such as the American Pulpwood Association (1965, 1989), Brinker et al. (1989), Cubbage (1981), Howard (1987), Matthews (1942), Miyata et al. (1980a, 1980b, 1981), Rossie (1983), and Werblow et al. (1986).

Logging Contractor #1

Skyline, Cable Yarding System

Skyline System -- Edco Yarder
- Purchase Price (used) = $100,000.00
- Price included all related items needed to operate yarder.
- Purchased in 1986.
- 3 year financing at 12 % interest.
- Related costs such as insurance, depreciation, taxes, fuel, etc, are expensed in those categories.

Weekly Payment: formula used

\[ A = \frac{[I \times (1+I)^N] \times P}{[(1+I)^N] - 1} \]

where
- \( N \) = Years financed
- \( P \) = Principal or amount of loan
- \( I \) = Interest rate
- \( A \) = Annual Payment

\[ A = \$41,627.50 \text{ Annual Payment} \]

Divide by 52 weeks per year = $800.53 per week

Ford F250 Pick - Up 1985
- Complete with tools
- Completely Depreciated with a life of 5 years.
- Associated expenses will be determine within the fuel, oil, tires, repairs and etc. categories.
Prentice 210C Loader
- Purchased in 1986 for $58,147.00
- Economic life of 5 years
- Price includes buck saw and attachments
- Use formula utilized under Yarder
- 12% interest financed for 3 years

Weekly Payments:

A = $24,209.44 Annual Payment
Divided by 52 weeks per year = $465.57

Chainsaws
- 6 Husqvarna chainsaws 3 of which were new for 1991
- One year economic life
- $635.00 delivered purchase price
- Zero salvage value
- 1,200 hours of work per year
- Chainsaw expenses are expensed
- remaining expenses in Fuel & Oil plus Repair and Maintenance.

Clark Skidders
- Two skidders: One 1987 Clark 688 C
  One 1985 Clark 568 D fully depreciated
- Associated expenses such as Fuel, Oil, Depreciation, Repair and Maintenance, and Tires are expensed below.
- Purchase price of $106,760.00
- 5 year economic life.
- 12 percent interest financed for 3 years

A = $44,449.42 Annual Payment
Divided by 52 weeks/year = $854.80/ week payments

Caterpillar D-4HCS Dozer
- Complete with Low-Boy
- Purchased in 1988
- Total purchase price of $116,955.00
- Five year economic life
- 12 percent interest financed for 3 years.

A = $48,694.10 Annual Payment
Divided by 52 weeks per year = $936.42 weekly payments

Labor
- Figure approximately $0.23 per $1.00 for workman compensation, $0.03 per $1.00 for Unemployment Insurance, and $0.06 per $1.00 for Social Security.
- Workers were paid by the hour with no other benefits.
- Totaled workers (8) hourly rate = $49.00 per hour

\[ 49.00 \times 1.32 = 64.68 \text{ per hour labor costs} \]

Weekly Costs:

\[ 64.68 \times 40 \text{ hours per week (average)} = 2,587.20 \text{ per week} \]

Trucking
- Costs shown include hired driver at $40.00 per load for both pulpwood and sawlogs.
- Costs do not include repair and maintenance or fuel and tires.
- Travel distances include 61 miles one way for sawlogs and 67 miles one way for pulpwood.
- Twelve trips per week average delivering sawlogs and only one allowed per week delivering pulpwood.

\[ 40.00 \times 13 \text{ trips average per week} = 520.00 \text{ per week total costs for trucking} \]

Road Building
- Dozer and Lowboy costs already itemized
- Costs include hired temporary operator ($7.50 per hour), time (1 day every 4 that the logging crew worked), etc.

\[ 72.00 \text{ per week in costs} \]

Interest
- Includes interest on money borrowed ($17,000.00 at 12 percent for 3 years) for stumpage acquisition.

\[ A = 7,077.88 \text{ Annual Payment} \]

Interest is $4,233.64 total for three years or $27.14 per week.

Insurance
- Other than those associated with labor.
- Types: General Liability, Trucking insurance, etc.

\[ 127.20 \text{ per week in costs} \]

Taxes & Licences

\[ 55.60 \text{ per week in costs} \]
Fuel, Oil & Tires
$460.00 per week in costs

Repair & Maintenance
$896.80 per week in costs

Miscellaneous & Administration Costs
- Chaps, Hard hats, wedges, etc.
$15.20 per week in costs

TOTAL COSTS FOR THIS LOGGING CREW: $7,818.46 per week

Productivity:

With delays; 3.45 cords per hour*1
18.8 productive hours per 40 hour work week (47%).
Total: 64.86 cords per week

*1 determined by using average cycle time associated with the yarding process. This include 2.75 trees per turn, 6.34 minutes per turn, and 10.59 cubic feet volume per tree.

THUS, $7,818.46 in costs per week divided by the production of 64.86 cords per week, gives an average cost per cord of:

$120.54

or $40.18 per ton
- based on 3 tons of hardwood per cord
Logging Contractor #2

Rubber-Tired Skidder and Feller-Buncher System

Chainsaws
- Two new Stihl saws purchased for $695.00 each.
- One year economic life with no salvage value.
- 1,200 hours of work per year per saw.
- Related expenses such as Fuel, Oil, Repair & Maintenance are listed within those appropriate categories.

\[
\begin{align*}
$695.00 \times 2 &= $1,390.00 \\
$1,390.00 / 52 \text{ weeks per year} &= $26.73 \text{ per week in costs}
\end{align*}
\]

Prentice 210 C Loader
- Fully Depreciated (1984)
- Mounted
- Associated costs are found in the appropriate categories.

Skidder
- Cat 518 purchased in 1984
- Fully Depreciated
- Related expenses are found within Fuel, Oil and Tires as well as Repair and Maintenance.

Trucks
- Two Mack short bed trucks. One is fully depreciated and paid for. The other is leased for $2,000.00 per month.
- Costs for hired driver and loading time are within Labor expenses.
- Repair and maintenance, tires and fuel etc costs are expensed under those appropriate titles.
- Eleven loads per week of pulpwood averaged and two loads of sawlog delivered on average per week.
- Distances include 51 miles one way for delivering pulpwood and 56 miles one way when delivering sawlogs.

\[
\begin{align*}
$500.00 \text{ per week total trucking costs}
\end{align*}
\]
Pick - up
- 1987 Ford F350 complete with tools
  
  $24.40 per week in costs

Feller Buncher
- Bell Super T
- $3,000.00 per month payment

  $3,000.00 / 4 weeks per month =
  $750 per work week

Labor*
- Costs include 23 percent for workman’s compensation,
  3 percent for Unemployment Insurance and 6 percent
  for Social Security.
- Costs include 6 percent for fringe benefits
- Total dollars per hour for four men equals $37.25

  $37.35 * 1.38 = 51.54 per hour
  $2,061.72 per week in costs

  * Includes Owners’ Salary

Insurance
  - Other than Workman’s Comp.

  $265.20 per week in costs

Taxes & Licences

  $53.20 per week in costs

Fuel, Oil and Tires

  $913.60 per week in costs

Repair & Maintenance

  $496.00 per week in costs

Miscellaneous & Administrative Costs

  $163.20 per week in costs

TOTAL LOGGING COSTS FOR THIS LOGGER: $5,227.32 per week
Productivity:

With delays:  3.76 cords per hour\(^2\)
31.34 hours per 40 hour work week (78\%) an average.

Total: 117.83 cords per week

\(^2\) determined by using average cycle time associated with the skidding process. This includes 6.99 trees per turn, 11.84 minutes per turn, and 8.49 cubic feet of volume per tree.

THUS, $5,227.32 in costs per week divided by the production of 117.83 cords per week, gives an average costs per cord of:

$44.36

or $14.79 per ton

- based on 3 tons per cord (hardwood)
Logging Contractor #3

Rubber-Tired Cable Skidder and Chainsaw Felling System

Chainsaws
- Three new Stihl chainsaws at $695.00 each.
- One year economic life with no salvage value
- 1,200 hours of work per year.
- Remaining expenses such as Fuel, Oil, Repair and Maintenance are added within those appropriate categories.

\[
\begin{align*}
\text{\$695.00} \times 3 &= \text{\$2,085.00} \\
\text{\$2,085.00} / 52 \text{ weeks per year} &= \text{\$40.10 per week in costs}
\end{align*}
\]

Skidder
- 1977 John Deer Cable Skidder
- Fully Depreciated
- Related expenses located within Repair and Maintenance as well as Fuel, oil and tires.

Loader
- Fully depreciated
- Related costs calculated in Repair and Maintenance as well as fuel, oil and tires.

Truck
- 1987 International Truck
- Purchased used for $18,000.00
- Financed at 12 percent for 3 years
- Costs such as driver and loading times are within Labor category.
- Costs do not include repair and maintenance, fuel, tires or oil costs which are expensed with those appropriate headings.
- Six loads delivered of sawlogs per week on average and two loads of pulpwood delivered on average per week.
- Travel distances include 64 miles on way for pulpwood and 31 miles one way for sawlogs.

\[
A = \text{\$7,494.28 Annual Payment}
\]

Divided by 52 weeks per year = $144.12 per week
Labor*
- Calculated with 23 percent workman's compensation, 3 percent Unemployment Insurance, and 6 percent Social Security but no other benefits.
- Workers (one Sawyer and the skidder operator) paid on $35.00 per load while other Sawyer paid $30.00 per load regardless of pulpwood or sawlog.
- Owner/Operator allows himself a $500.00 per week salary

\[
(8 \text{ loads per week}) \times 100.00 \text{ (tallied workers wage)} = 800.00
\]

\[
800.00 + 500.00 \text{ (Owners salary)} = 1,300.00 \text{ per week total labor costs.}
\]

* Includes owner's salary

Fuel, Oil and Tires
$389.20 per week in costs

Repair & Maintenance
$284.40 per week in costs

Interest
- On money borrowed ($42,000.00 at 12 percent interest for 5 years) to purchase stumpage.

\[
A = \frac{P \times r \times (1 + r)^n}{(1 + r)^n - 1} = 11,651.23 \text{ Annual Payment}
\]

Total interest is $16,256.15 or $62.52 per week

Insurance
- Other than Workman's Comp.
$67.30 per week in costs

Taxes and licences
$30.00 per week in costs

Miscellaneous & Administrative Costs
$60.00 per week in costs

TOTAL WEEKLY LOGGING COSTS FOR THIS CREW: $2,376.54 per week
Productivity:

With Delays: 2.00 cords per hour*3
24.8 hours per 40 hour work week (62%)
an average.

Total: 49.05 cords per week

*3 determined by using average cycle time
associated with the skidding process. This
includes 3.86 trees per turn, 22.95 minutes per
turn, and 15.61 cubic feet of volume per trees.

THUS, $2,337.54 in costs per week divided by the production
of 49.05 cords per week, gives an average cost per cord of:

$47.66

or $15.89 per ton
- based on 3 tons per cord (hardwood)
VITA

The author was born in Grand Rapids, Michigan in 1964. This large city offered few chances to walk in the woods or climb a tree. It wasn't until trees began to grow in the vacant lots behind his home that he began to consider a career in forestry. It is on these abandoned lots, however, that forestry was first practiced by the author in the form of thinnings, pruning techniques, and various other related activities.

Upon completing high school, where hunting and fishing were more important than school work, he left this large metropolitan area for the rural and wild area found in Michigan's Upper Peninsula. In 1982 he began studying at Michigan Technological University (MTU) in their forest technology program. This program was completed in 1984 with an earned Associates of Applied Science degree. He then began a logging career with Mayes & Stenvig Timber Harvesting, leaving that company in the fall of 1985 to complete a Bachelor of Science degree in Forest Management at MTU, emphasizing in forest business. While completing this undergraduate degree, he had two summer jobs that included a period over seas with Metsahalotuis (The Finnish Forestry Service) in the development sector and also a research position with the U.S.D.A. Forest Service in the
Panhandle of Northern Idaho, researching root rot diseases and their relation to tree stress.

Upon completion of the requirement for the B.S. degree in November 1987, the author accepted a job as a District Forester with the Michigan Soil Conservation Districts serving Oceana & Newaygo Counties in the north-central lower Peninsula of Michigan.

In the fall of 1990, the author left that position to begin graduate work in Industrial Forestry Operations in the Department of Forestry at Virginia Tech. Upon graduating with a Master of Science Degree in the Spring of 1992, he accepted a job with Glatfelter Pulp Wood Company as logging supervisor based out of the corporate office in Spring Grove, Pennsylvania.

Kenneth R. Brummel