ADAPTING CONVENTIONAL HARVESTING EQUIPMENT TO SMALL DIAMETER STANDS - THE FRITZ EXPERIMENTS -

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ABSTRACT

Two units, one on steep slopes and one on gentle slopes, were harvested using variations to conventional harvesting systems in northeastern Washington. On the steep slope unit, cut-to-length processing and forwarding were observed on the steep slopes in small diameter timber. Adjacent stands were harvested using the cut-to-length processor and a feller-buncher, but were transported to the landing with a cable yarder. On the gentle slope units, cut-to-length harvesting at 40-foot trail spacing was compared to whole tree harvesting, a unit felled mechanically but processed at the forwarder trail, and a unit felled by hand but processed at the trail when trail spacing was set at 130 feet. Comparisons are made between production and cost for these system variations. Harvesting costs on the gentle slope units were significantly less than on the steep slopes. Whole tree harvesting was the least costly system. On steep slopes, the lowest costs were observed with the cut-to-length processor and forwarder, followed by the costs of cable yarding and bunched logs uphill. The processing and bunching provided by the cut-to-length processor appeared to improve production of the cable yarder when handling small timber.

Keywords: cable yarding, cut-to-length, whole tree harvesting, small timber harvesting

INTRODUCTION

Harvesting small timber economically has always been a significant challenge, but when the timber is located on steeper slopes or when mechanized systems are limited, the challenge is intensified. In steep slopes, not only does the harvesting operation generally require use of higher cost cable logging systems, but it is also more difficult to take advantage of the bunching capabilities of mechanized equipment. On gentle slopes, restrictions on the number and spacing of skid trails can limit the use and effectiveness of mechanized systems. Bunching operations, usually combined with the felling step, can gather the smaller trees and logs into reasonably sized units for transportation to the landing. Normally, the pieces bunched in felling or through cut-to-length processing operations are transported to the landing with ground-based vehicles capable of quickly grasping or loading the gathered pieces. In the past these operations were restricted to terrain with slopes less than 30–35%. Newer felling and processing equipment capable of negotiating slopes up to 50% have created opportunities to use aspects of a mechanized operation on steeper slopes, often in conjunction with a cable system.

Two study sites, one on steep slopes and one on more gentle terrain, were established in northeastern Washington. On the steep slopes, felling and processing systems were used in combination with cable yarding systems. On the gentle slopes, conventional mechanized equipment was used in conjunction with hand felling and other harvesting variations on wider skid trails. Costs and production for all options were considered. One objective of utilizing mechanized harvesting and processing operations with cable systems was to increase the efficiency of the yarding function when working in small timber. Bunched trees or logs should provide an opportunity to increase the number of pieces yarded on each yarding cycle and reduce hooking time. Another objective, analyzed in complementary studies, was to reduce site disturbance by reducing the amount of vehicle traffic on the site. The study sites were included in a commercial timber sale from U.S. Forest Service lands in northeastern Washington, and were harvested by professional timber harvesting contractors.

The Colville National Forest in northeastern Washington has many acres of smaller diameter timber located in stands that are generally overstocked. Thinning operations generally focus on removal of the smaller material and retention of larger trees. Maximum diameter of harvested trees in this study was about 12 inches. A critical factor in thinning these stands through a commercial timber sale is a mill capable of effectively handling small diameter material. One of the sawmills in the area utilizes a sawing system that will manufacture and trim boards from small diameter logs on one pass through the saw. The mill is set up to process small diameter logs to a 4-inch top. Recovery and removal of material smaller than about 6-inch base diameter depends on the market for pulpwood.

This commercial timber sale included eight units designated for specific harvesting, silviculture, and ecology studies. The harvesting analysis reported here is part of a larger study looking at long term factors related to silviculture, ecology, and soil impacts. These studies involve long term plots as well as soil and vegetation data collected before and after harvesting operations. Harvesting operations on the steep slope units occurred during late summer, 1998. Operations on the gentle slope units occurred in late summer, 1999.

HARVESTING OPTIONS

Steep Slope Units. Four steep-slope variations of cut-to-length and whole tree harvesting were studied.

<u>Unit 17: Cut-to-length fell and process with downhill yarding</u>. A cut-to-length processor felled and processed trees for the skyline system. Slopes ranged from 35–50%, with external yarding distances ranging from 500–900 feet. The processor bunched the processed logs next to the skyline corridor and the skyline yarded the processed logs downhill to the landing. Corridors were 14 feet in width, spaced at 40-foot intervals.

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Unit 16: Feller-buncher and downhill yarding. A steep slope feller-buncher felled and bunched trees next to pre-designated skyline corridors. Bunched trees were yarded downhill to the landing with a skyline system and were later processed into logs at the landing. Slopes ranged from 35–55% with external yarding distances ranging from 600–850 feet. Corridors were 14 feet in width, spaced at 40-foot intervals.

Unit 8: Cut-to-Length fell and process and uphill yarding. A cut-to-length processor cut and processed trees and bunched the processed logs next to the skyline corridor. The bunched logs were yarded uphill to the landing. Slopes ranged from 35–50%. External yarding distances ranged from 600–800 feet. Corridors were 14 feet in width, spaced at 40-foot intervals.

Unit 9: Cut-to-length and forward downhill. A cut-to-length processor and forwarder system operated with slopes ranging from 35–55%. The cut-to-length processor was capable of negotiating slopes to 55%. The forwarder had the capability of moving processed logs down slopes in this range, but needed a "go-back" trail for slopes above 45%. The cut-to-length processor operated in a conventional manner, cutting and processing trees as it worked up slope. External yarding distances ranged from 200–500 feet. Corridors were 14 feet in width, spaced at 40-foot intervals.

Gentle Slope Units. Four units involving variations in trail spacing and recovery method.

Unit 2: Hand felling with trees bunched to forwarder trails. People with chainsaws felled trees both on and off the skid trails. Skid trails were felled first and were then processed using a dangle-head processor. Trees off trail were then directionally felled to the trails. The processor returned to both bunch and process these trees. Processed logs were forwarded to the landing. Trails were spaced at 130 feet.

Unit 3: Conventional cut-to-length and forwarding. Trees were felled and processed at the forwarder trail with a cut-to-length processor at 40-foot trail spacing

Unit 4: Whole-tree unit with mechanized felling. Trees were felled with a feller buncher and were carried to skid trails spaced at 130 feet apart. Whole trees were delivered to the landing with wheeled skidders. Processing into long logs took place at the landing.

Unit 19: Trees felled and bunched to forwarder trails. Trees were felled with a feller buncher and were carried to forwarder trails spaced 130 feet apart. The bunched trees were processed into short logs by a dangle-head processor. Processed logs were forwarded to the landing.

Elemental time and production studies were used to determine cycle times and production for each of the equipment options. This data and estimated hourly costs of the equipment were used to determine cost per log and per cubic foot. Production and costs for the four variations are compared.

HARVESTING EQUIPMENT

Harvesting was conducted by professional loggers with several years of experience on their respective equipment. Cut-to-length felling and processing was done with a Valmet Model 500T, with tilting cab. Forwarding utilized a 1993, Valmet Model 892 forwarder with a 14-ton load capacity. Whole tree felling utilized a Timbco Model 445 B feller buncher with a Quadco felling head with a 20-inch capacity. Mechanized processing at the landing and along forwarder trails utilized a Kobelco Mark IV SK200LC, tracked carrier with a Keto 500 dangle head. Whole tree skidding was done with Caterpillar Model 518 wheeled skidders with swing grapples.

A Skagit Model 333 yarder was used in cable yarding operations. Originally designed as a two-drum yarder, the Skagit had been adapted with a third drum, normally used as a line for pulling out heavier cables (strawline). In downhill yarding, the strawline was utilized as the mainline and the line normally used as the mainline was used as the haulback line. The system included a Christy haulback carriage with a radio controlled skyline clamp. A hydraulic accumulator in the carriage provided power to the skyline stop. A loader was used at the landing to move logs away from the yarder. During the downhill yarding operations a mobile tailhold was located on an upper road to provide lift to the skyline. The tailhold was mounted on a crawler tractor and, in a more traditional setting, would have been capable of traveling off haul roads to provide lift.

Hourly costs for all equipment except the yarder were developed from the cost of new equipment and through established procedures for estimating owning and operating costs. The hourly costs include an allowance for profit and risk. Hourly costs used in this study are shown in Table 1.

Table 1.—Hourly Cost of Equipment.

Machine Type	Total Hourly Cost
Feller-Buncher	$110.00
Chain Saw and Faller	$27.00
CTL Processor	$131.00
Excavator / Processor	$104.00
Forwarder	$113.00
Grapple Skidder	$69.00
Yarder / Loader	$240.00

Measured time consisted of both productive and delay times. Costs and production are shown here on the basis of scheduled machine hours (including delays). While some of the working delays for each operation were directly correlated to the unit and site, a general allowance for personnel and maintenance/mechanical delays had more relationship to the equipment than to the harvest unit. Assumptions for these delay percentages are shown in Table 2.

Table 2.—Personal and maintenance delay: percent of Total Scheduled Time.

Personnel Delay Time	2%
Maintenance/Mechanical	
Cut-to-Length Processor	13%
Steep Slope Feller Buncher	13%
Processing on Landing	8%
Processing on Trails	13%
Hand Falling	23%
Forwarder	10%
Wheeled Skidder	8%
Cable Yarder Uphill	8%
Cable Yarder Downhill	10%

Although the units were similar in stand and terrain conditions, there were slight differences in observed piece size and recovery distances across the units. To provide a fair comparison in production rates and costs, travel times for all units were adjusted for a 600-foot average distance and average piece sizes as shown in Table 3.

Table 3.—Average volume per piece.

Average Vol. per Tree between Trails	9.236 CuFt
Average Vol. per Tree in Mechanized Trails	8.460 CuFt
Average Vol. per Tree in Hand Fall Trails	5.711 CuFt
Average Vol. per Sawlog	4.013 CuFt
Average Vol. per Pulpwood Piece	1.390 CuFt

FELLING AND PROCESSING

Cycle times, production rates, and costs for felling and processing on steep slopes is shown in Table 4. The primary working delay in the operation was returning to the bottom of the slope to start a new corridor. Even though it was midsummer during the harvesting operations, loose bark slowed the cut-to-length processing operation. Bark slippage resulted in the processor making two or more passes over a felled tree to allow the measuring device to accurately measure log lengths. This was observed on 33% of the trees harvested. The effect on processor cycle time was significant in some units. On a sub-sample of processor operations, productive cycle times when there was bark slippage averaged, 0.90 minutes per cycle; when there was no slippage, the productive time averaged 0.67 minutes per cycle, a 34% increase in cycle time.

Production rates and felling times in the gentle slope units are illustrated in Figures 1 and 2. The units required bunching of trees to skid or forwarder trails spaced 130 feet apart. At this spacing, the feller-buncher had to travel off the trail to cut the trees and back to the trail for bunching. The bunches developed in the whole tree units were generally in the trail or at a slight angle to the trail. Bunches in the unit requiring subsequent processing were located at a 90° angle to the trail. This change in orientation of the bunches affected the production of the felling operation as noted in Figure 1.

Production of the hand-fallers on and off the trail is shown in Figure 2. Felling off the trail was more difficult because of the difficulty of getting the small trees to the ground. Processing costs for the trees harvested in the steep slope units are shown in Figure 3. The lowest processing costs occurred when the processor operated at the landing, followed by the processing of trees bunched at trailside by the feller-buncher. Processing costs for the material felled by had were significantly higher than for the other units because the material was located on and off trail and had to be first bunched before it could be processed.

Table 4.—Felling and processing times on steep slope units.

	Cut-to-Length Processor			Feller-Buncher	
	Minutes per Cycle	**Percent of Time**		**Minutes per Cycle**	**Percent of Time**
Productive Time	0.70	77.5%		0.40	73.3%
Working Delay Time	0.09	10.5%		0.08	14.7%
Personal / Maintenance	0.11	12.0%		0.07	12.0%
Total Cycle Time	0.90	100.0%		0.55	100.0%
Production Rates	**Trees**	**Pieces**	**Cu Ft**	**Trees**	**Cu Ft**
per Productive Hour	86	171	552	211	1360
per Scheduled Hour	66	132	428	155	997

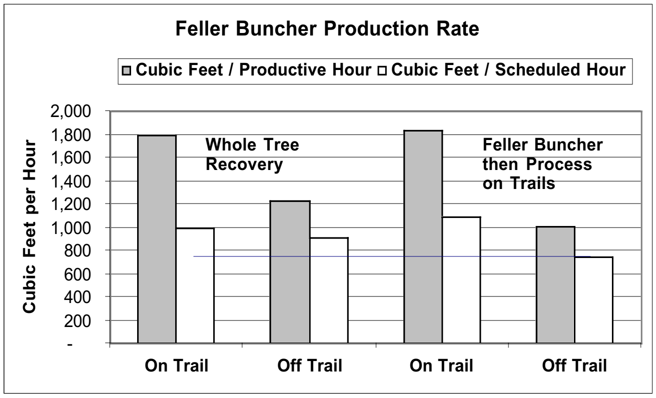

Figure 1.—Production rates for feller-buncher on gentle slope units.

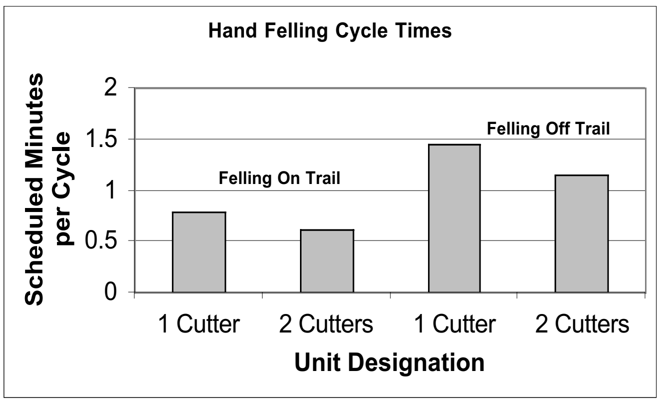

Figure 2.—Cycle times for hand felling on steep slope units.

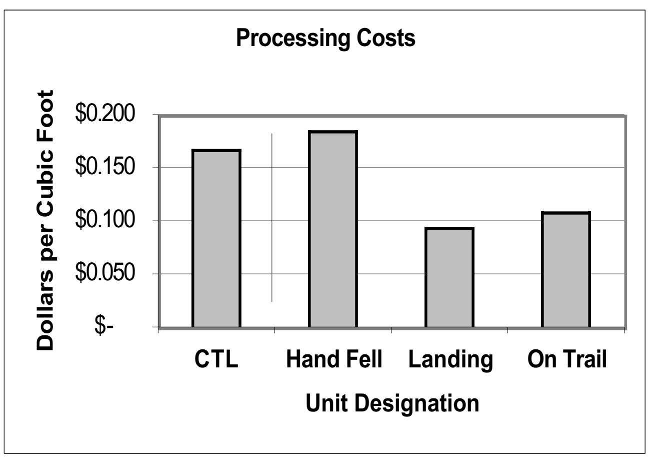

Figure 3.—Processing costs for the gentle slope units.

YARDING, FORWARDING, AND SKIDDING

Steep Slope Yarding

Production rates for yarding in the steep slope units are shown in Figure 4. Details of the steep slope production and conditions are presented in Johnson (1999).

Settings for downhill yarding were configured with the haulback line routed over several corridors, up the hill, and back to the yarding corridor. This allowed yarding of 4–5 corridors before re-rigging the haulback line. The yarding crew was able to yard logs from the cut-to-length corridor on either side of the skyline corridor. Moving logs from an adjacent corridor involved lateral yarding distances of 40–60 feet, with an average lateral distance of 18 feet.

The yarder was capable of operating as a live or a standing skyline. After initial attempts to swing the short logs into decks with the yarder in a live skyline configuration, the operation switched to a standing skyline setup. Logs were moved from under the yarding corridor by a separate loader that was already on site for landing maintenance.

The number of logs yarded per cycle averaged 5.3 pieces per cycle in the downhill yarding setting. This number might have been higher, but load sizes were limited because of the limited anchoring capacity of the small stumps available at the tailhold. Multiple stump anchors were generally used on each setting. The lack of identifiable bunches that could be easily hooked also limited turn size. Yarding production during downhill yarding was slowed by relatively slow line speeds in both the inhaul and outhaul directions. The mainline, used as a haulback in this setting, had adequate power, but not great speed. Chokers were preset by the choker setter. The crew operated with both one and two choker setters.

Downhill yarding of whole trees was more efficient on a volume per cycle basis and on the basis of cubic feet per hour without allowance for setup time. However, rigging was required on every corridor of the whole tree unit, compared to every second or third corridor of the cut-to-length unit. As a result, setup time is estimated at 34% of total cycle time.

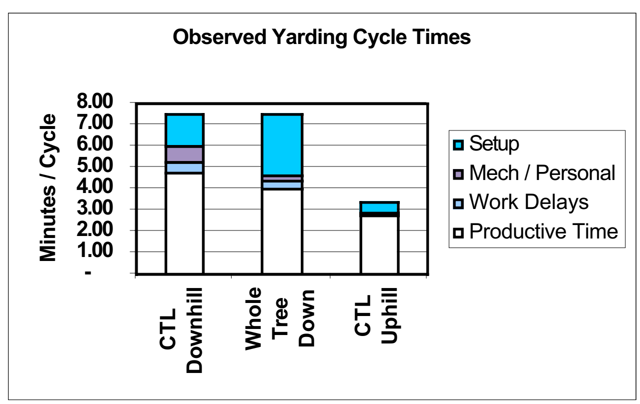

Figure 4.—Cycle time for yarder in downhill and uphill settings.

The yarder operated much more efficiently when yarding cut-to-length logs in the uphill direction. The productive cycle times shown in Figure 4 are lower than for either of the downhill yarding units, due in part to a shorter average yarding distance, but also due to increased line speeds and a reduction in mechanical and hang-up delays. As with the downhill yarding operation in the cut-to-length unit, the yarder was able to set up every second or third corridor, so setup time required about 20% of total time. The benefits of bunching were more evident in this unit as the number of logs per cycle increased to an average of 6.8.

Steep Slope Forwarding

The lowest cost option in the steep slope settings for moving logs to the landing involved a cut-to-length processor and a six-wheeled drive forwarder. Logs were forwarded with the Valmet 892 forwarder. The forwarder worked on the same range of slopes as the cable units. On slopes up to 45%, the forwarder was able to work up and down the processor corridors without deviating from the processor trail. In steeper areas, a “go-back” trail was required to allow the machine to travel back up the slope. The harvest unit was located directly above a mid-slope road and the cut banks on the road presented a challenge for both the processor and forwarder. The forwarder required some earthwork to create a trafficable ramp up the cut slopes. A crawler was used to break down the cut slopes and to create the “go-back” trail for the forwarder. These activities resulted in more site impact than initially anticipated with this system.

The steep slopes resulted in a reduction of forwarder production times and capacity. The machine worked at 50–75% of its load capacity on the steepest slopes. Travel was also slowed in both the forwarding and return portions of the cycle.

Production of the forwarder is shown in Table 5.

Table 5.—Production of forwarder on steep slope units.

Average Forwarding Distance	129 Feet	
	Minutes per Cycle	**Percent of Time**
Productive Time	20.51	79.8%
Working Delay Time	2.10	8.2%
Personal/Maintenance	3.07	12.0%
Total Cycle Time	25.68	100.0%
Logs/Cycle	66.0	
Production Rates	**Logs / Hr**	**Cu Ft / Hr**
per Productive Hour	192	619
per Scheduled Hour	153	494

Gentle Slope Skidding and Forwarding

The costs per cubic foot to deliver the trees or logs to the landing are shown in Figure 5. Costs on gentle slopes are predictably less than those on steep slopes. Costs involved with the whole tree skidders (Unit 4) are the lowest of all those observed. The forwarder had consistent costs across the gentle slope units, but these costs were about one third of those encountered by the forwarder on steep slopes. In the steep slope unit, the forwarder had to utilize longer return trails to get back to the woods and also had to carry a smaller load.

Yarding costs are lowest in the uphill setting (unit 8) and nearly equal in the two downhill settings (units 16 and 17). Downhill yarding costs are 50–70% higher than those in uphill yarding.

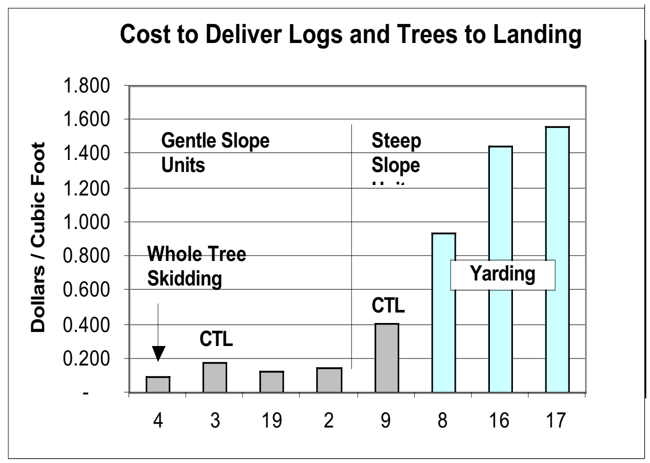

Figure 5.—Comparison of skidding, forwarding and yarding costs with equal recovery distance.

TOTAL SYSTEM COSTS

Total system costs for the gentle slope units are summarized in Figure 6. The system costs on steep slopes are shown in Figure 7. Figures 6 and 7 show a breakdown of felling, processing, and delivery costs. Figures 8 and 9 compare costs for all units. Total costs on the gentle slope units were one-third to one-half the costs for the steep slope units. Harvesting of the whole tree unit (4) resulted in slightly lower costs than the cut-to-length unit (3). Cut-to-length harvesting on the steeper slopes (9) was twice that on the gentle slopes. This was the result of both bark slippage in processing on the steep-slope unit and the lower forwarder production. The costs of felling-bunching on the gentle slope units was higher than would usually be experienced with a feller-buncher because of the 130-foot trail spacing and the requirement to carry trees back to the trail.

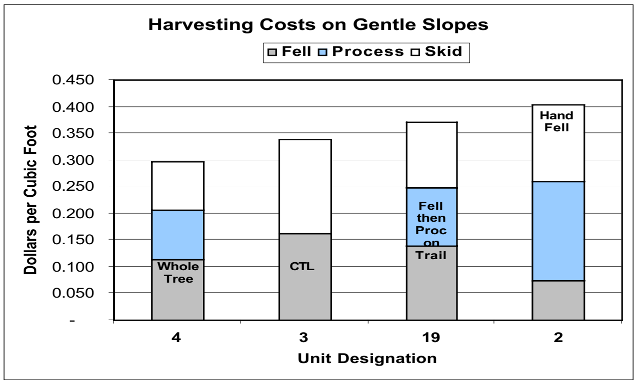

Figure 6.—Total harvesting costs on gentle slope units.

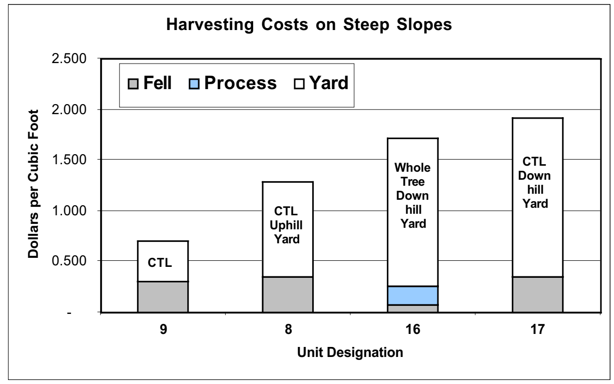

Figure 7.—Total costs for steep slope units.

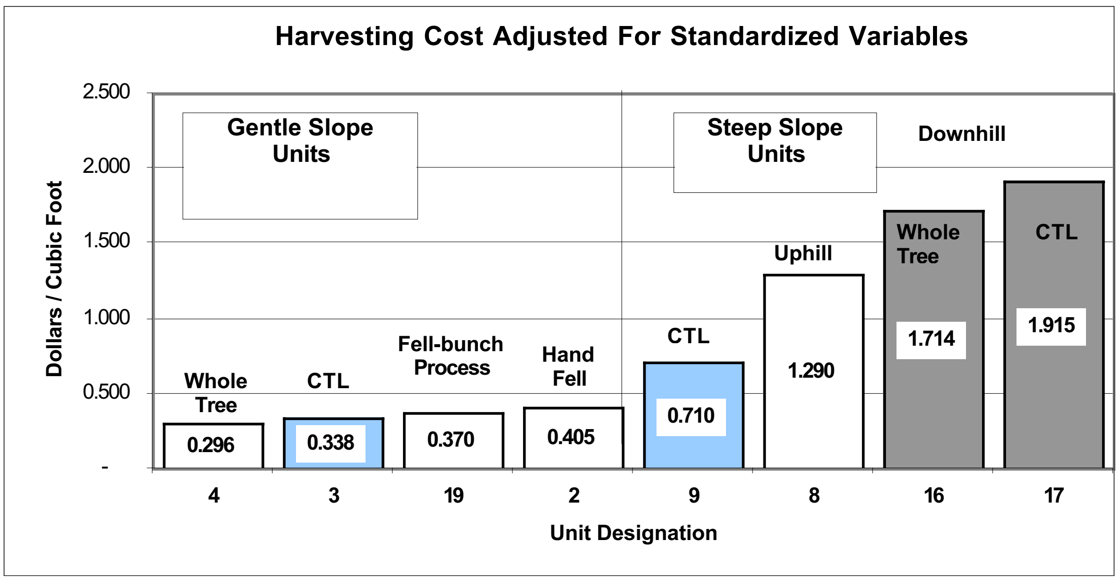

Figure 8.—Total cost comparison for all units.

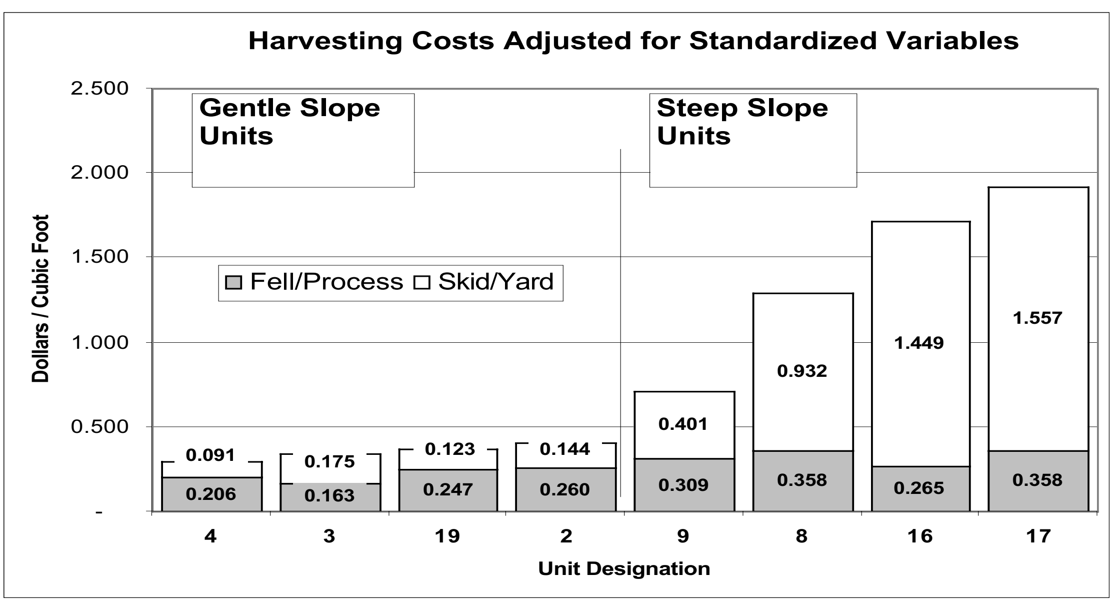

Figure 9.—Total costs for all units with breakdown of felling/process and delivery.

SUMMARY

The two sets of experiments conducted on the Colville National Forest have produced a baseline of comparative costs for several harvesting options. They also provided indications about potential improvements to production and cost through system improvements. Other studies are investigating the impacts on residual trees, soils, and the reduction of fuels.

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