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Cost and Production Analysis of the Bitterroot Miniyarder on an Appalachian Hardwood Site

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Abstract

An 18-horsepower skyline yarder was studied on a steep slope clearcut, yarding small hardwood trees uphill for fuelwood. Yarding cycle characteristics sampled include: total cycle time including delays, 5.20 minutes; yarding distance, 208 feet (350 feet maximum); turn volume, 11.6 cubic feet (24 cubic feet maximum); pieces per turn, 2.3. Cost analysis shows yarding costs will range from $18.00 to $36.00 per cunit, depending upon crew efficiency and yarding conditions.

Introduction

The harvest and utilization of small trees are essential to the intensive management of Appalachian hardwood forests. Thinnings on the better sites and harvest cuts on poorer sites require the removal of many trees 5 to 10 inches diameter breast height (d.b.h.). Much of the fuelwood now harvested from standing timber or salvaged from logging residue is also obtained from small-diameter trees or logs. Cable logging is often the preferred harvesting method for the steep slopes common to Appalachia because of reduced environmental damage. However, logging small trees with cable yarders is generally too costly considering the low value of the products removed. The high initial investment and extensive setup and rigging times associated with most cable yarders limit their application to high-volume or high-value removals (Matics 1982).

The Bitterroot Miniyarder was developed by the USDA Forest Service, Missoula Equipment Development Center, for cable yarding small trees and logging slash on steep slopes. This small and very mobile cable yarder is relatively inexpensive to own and operate, quick to setup, and easy to operate (USDA Forest Service 1983). These characteristics identify the Bitterroot Miniyarder as a machine with the potential for reducing the cost of cable yarding small hardwood trees on steep slopes.

This small skyline yarder was tested in the South and the West (American Pulpwood Association 1983, Brown and Bergvall 1983, Cubbage and Gorse 1984). To obtain detailed cost and production information for eastern hardwood applications, the small yarder was studied logging a steep slope Appalachian site. The objectives of this study were to determine production rates and costs for the Bitterroot Miniyarder and to identify those factors that affect yarding cost.

Yarding Operations

The Bitterroot Miniyarder was studied yarding fuelwood from a 2-acre clearcut block on the Jefferson National Forest in Virginia. On this unit, 200 trees per acre larger than 4 inches d.b.h. were harvested, yielding 1,350 cubic feet per acre of wood and bark. The cutting unit was located in a poletimber stand that contained a few scattered low-quality sawtimber trees. The d.b.h. of cut trees averaged 7.7 inches, and the diameter distribution shows that more than 90 percent of the trees harvested were 10 inches d.b.h. or smaller (Fig. 1). Total height of the dominant and codominant trees ranged from 50 to 60 feet. The species composition was predominantly chestnut oak and scarlet oak with minor components of hickory, red maple, and pitch pine.

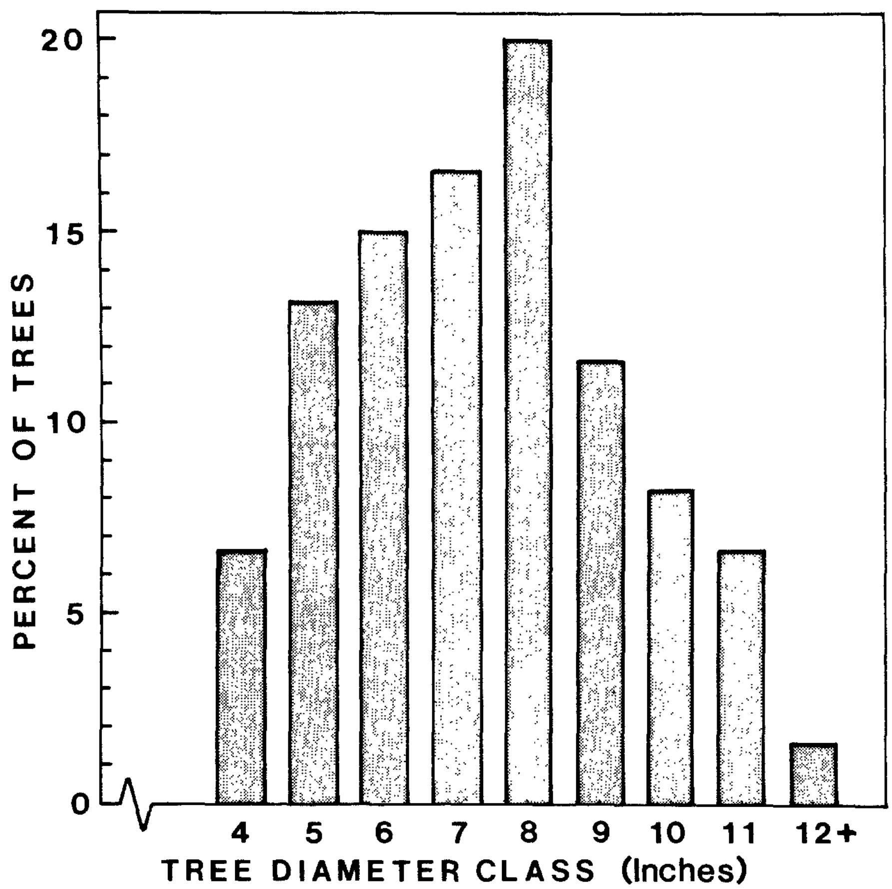

Figure 1.—The diameter distribution of merchantable trees on the logging site.

All trees larger than 1.0 inch d.b.h. were felled before yarding, but few trees smaller than 4.0 inches d.b.h. were actually yarded. Trees 4.0 inches d.b.h. and larger were limbed and topped to a variable top diameter as small as 2.0 inches diameter outside bark. Sawtimber-size trees were bucked into log lengths. The resulting piece-volume distribution shows that the volume of most pieces yarded was less than 10 cubic feet (Fig. 2). Piece volume averaged 5 cubic feet.

The small yarder was mounted on a two-wheeled trailer that could be towed by a pickup truck (Fig. 3). With the exception of the original ¼-inch diameter skyline that had been replaced with approximately 640 feet of ⅜-inch cable, the following specifications provided by Missoula Equipment Development Center describe the yarder tested.

Weight: 1,600 pounds rigged

Engine: 18-hp Briggs and Stratton,[1] twin cylinder, air cooled, electric start

Transmission: Sundstrand series 15 hydrostat

Axle: Dana Spicer GT-20 with 72-tooth spur gear

Skyline and Mainline Drums: 800 feet of ¼-inch cable, 0 to 2,000 pound line pull, 0 to 400 ft/min line speed

Mainline Clutch: Dog type

Brakes: Band type, mechanically operated, 12¾ inch diameter

Boom: 2¾-inch pipe A-frame, 17½ feet long, 180 degrees fairlead swivel, manually raised and lowered

Controls: 15-foot mechanical push/pull cable

[1]The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture or the Forest Service of any product or service to the exclusion of others that may be suitable.

During each yarding cycle, the live skyline was lowered for unhooking the chokers at the landing. The skyline was also periodically lowered to permit the chokersetters to move the carriage stop, which was clamped on the skyline. The small Christy carriage was locked on the skyline at the carriage stop, releasing the mainline to be pulled laterally by the chokersetters. As many as five wire-rope chokers were used when yarding very small pieces. When a turn of choked pieces was laterally yarded to the carriage, a ball attached to the mainline released the skyline lock and simultaneously locked the carriage to the mainline for the trip to the landing. The lift provided by the skyline generally kept the leading end of the pieces off the ground and free from stumps and slash.

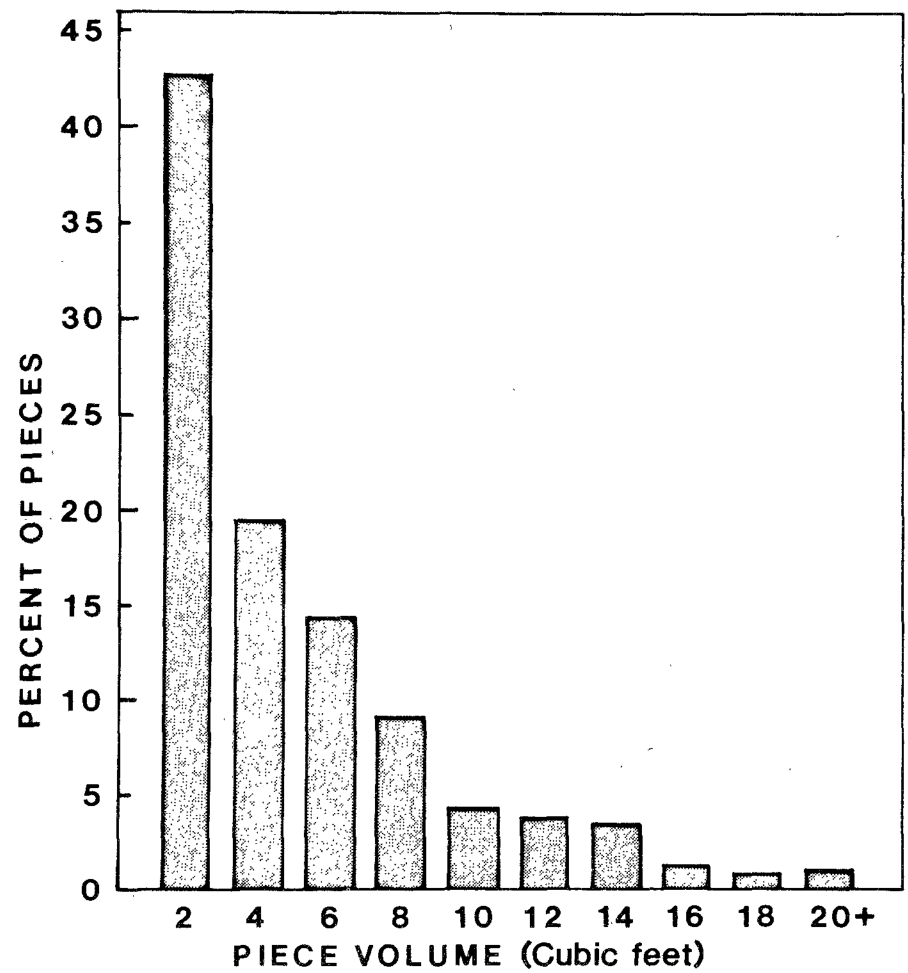

Figure 2.—The distribution of piece volume in cubic feet by percent of pieces yarded.

Figure 3.—The Bitterroot Miniyarder mounted on a two-wheeled trailer.

The fan-shaped clearcut block was yarded uphill to a single landing located below the yarder (Fig. 4). The slope distance from the yarder to each of the four tailholds used to anchor the skyline ranged from 390 to 490 feet. Tailholds were rigged at a height of 2 to 3 feet by attaching the skyline to large standing trees located outside of the unit boundary. The slope of the skyline corridors ranged from 15 to 40 percent.

The Forest Service logging crew consisted of a yarder operator, two chokersetters, and one chaser unhooking at the landing. A tractor operator also used a small crawler to clear the landing and deck the yarded wood along the access road for sale at roadside as fuelwood. The tractor and operator were not included in the time study or the cost analysis.

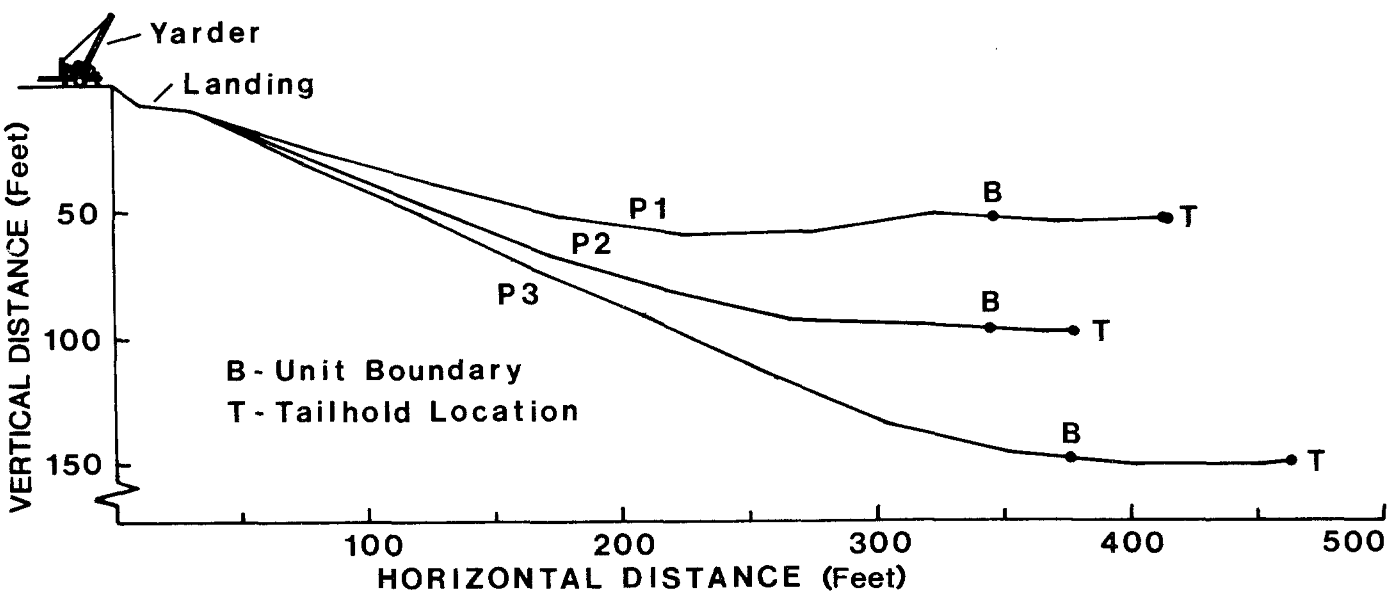

Figure 4.—Ground profile of three skyline roads.

Study Methods

A time study of the yarding operation was conducted using continuous timing over the span of each yarding cycle. Start and stop times were recorded for the productive and delay portion of each of the five major yarding cycle elements:

- Outhaul starts when the carriage leaves the landing and ends when the carriage hits the skyline stop releasing the mainline.
- Hooking starts when the mainline is released and ends when the chokers are hooked and the yarder operator is signaled to begin lateral yarding.
- Lateral yarding starts with the signal to begin lateral yarding and ends when the turn is laterally yarded, releasing the carriage lock.
- Inhaul starts when the carriage lock releases and ends when the turn reaches the landing.
- Unhooking starts when the turn reaches the landing and ends when pieces are unhooked, the skyline is raised, and the carriage begins to leave the landing.

In addition to yarding time data, yarder cycle characteristics were recorded, including: slope yarding distance, the distance from the landing to the carriage stop measured along the slope; slack-pulling distance, the distance from the skyline stop to the farthest piece hooked; number of pieces hooked; and the dimensions of each piece including both end diameters outside bark and length. From piece dimensions, piece volumes and total turn volumes were estimated. Piece and turn weights were estimated from the volumes using conversion factors developed by Timson (1975). For the species mix sampled, the conversion factor used was 59 pounds per cubic foot of wood and bark.

Linear regression methods were used to determine the functional relationships between site factors and yarding cycle time, and yarding element times. The objectives of this analysis were to identify those factors that affect yarder productivity and to develop equations for predicting cycle time so that yarding conditions could be used to predict yarder production.

The static mainline pull at a 250-foot-slope yarding distance was measured using a dynamometer anchored to a stump. For the three skyline road profiles shown in figure 4, the payload capability of the system was estimated using the handheld calculator programs developed by Falk (1981). These programs include the effects of partial load suspension, which was appropriate for this application since logs were dragged rather than yarded fully suspended.

The yarding cost model developed by Peters (1984) was used to estimate yarding cost and to predict the response of yarding cost to changes in operating efficiency and changes in piece size and volume per acre. This model uses the inputs listed below to estimate the time required to yard a given unit, the production rate, and the cost per unit of production.

Site specific variables

- Volume harvested per acre
- Average piece volume
- Harvest unit area
- Percent slope
- Geometric parameters required to compute average slope yarding distance and lateral yarding distance

Yarder specific variables

- Hourly cost of yarder and crew
- Cycle time regression coefficients
- Yarder payload capacity
- Load curve statistics to estimate average volume per turn and number of pieces per turn from average piece volume

Operation specific variables

- Time to move and set up yarder
- Time change to a new skyline corridor
- Downtime for mechanical or system delay
- Operational delay time during yarding cycle

Time Study Results

The yarding operation was observed a total of 22.4 scheduled work hours. Two changes of skyline corridor required a total of 2.1 hours. Of the remaining 20.3 hours, the yarder operated 19.7 hours. Detailed cycle time and production data were collected from 16.1 hours of yarder operating time that included 13.2 hours of delay-free yarding time. Within this time span, 186 turns were yarded producing 427 pieces and 2,162 cubic feet of wood and bark. The estimated weight of the pieces yarded was 64 green tons. The average productivity of the yarder was 134 cubic feet or 4 tons per productive hour, and 164 cubic feet or 4.8 tons per delay-free hour.

The following summary of cycle characteristics defines the yarding conditions sampled:

	Average	*Minimum*	*Maximum*
Slope yarding distance—feet	208	25	350
Slack-pulling distance—feet	26	1	80
Volume per turn—cubic feet	11.6	3	24
Weight per turn—pounds	680	180	1,400
Number of pieces per turn	2.3	1	5

The dimensions of the clearcut unit and the spacing of the skyline roads limited slope yarding distance to 350 feet and slack-pulling distance to 80 feet. With respect to payload, the yarder was thoroughly tested as several of the turns yarded represented the maximum capacity of this yarder. Because of the small diameter of the pieces yarded, the average volume yarded was only half of the maximum volume and as many as five pieces were yarded per turn. Volume yarded per turn seldom exceeded 16 cubic feet (Fig. 5).

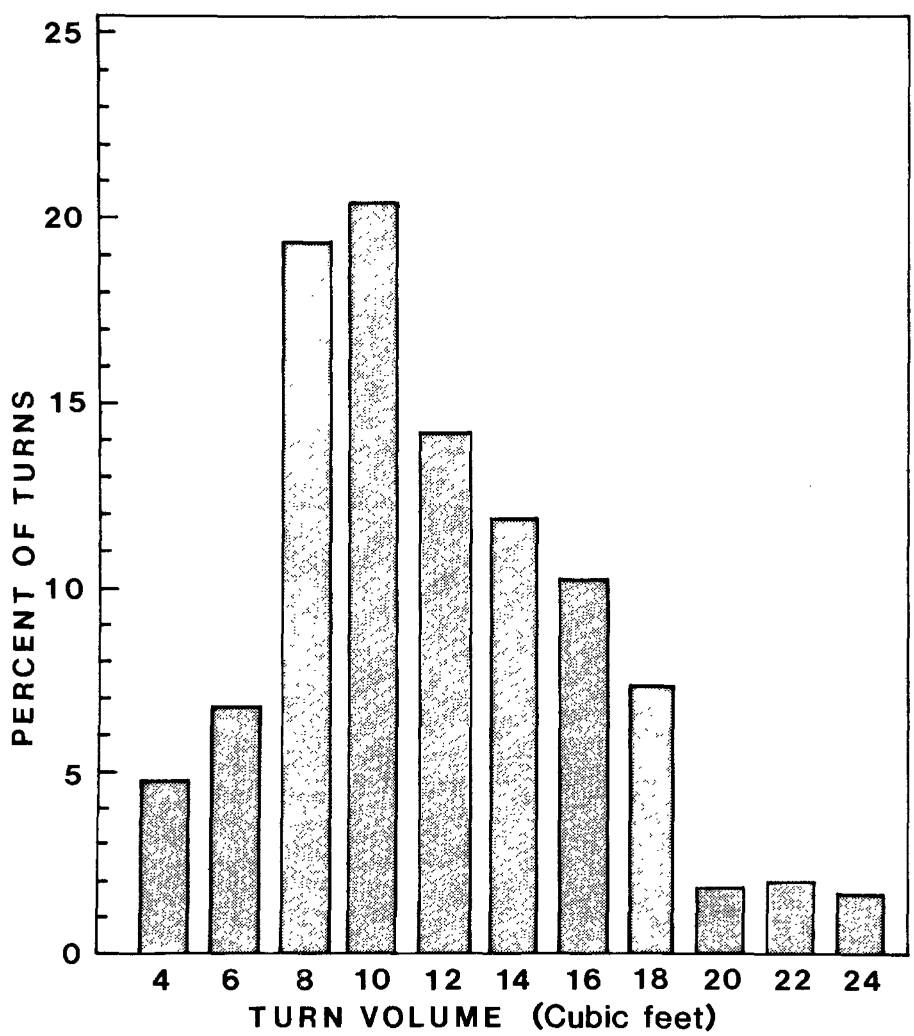

Figure 5.—The distribution of turn volume in cubic feet by percent of turns yarded.

Delay-free cycle time averaged 4.25 minutes per turn, including 0.48 minutes outhaul time, 1.46 minutes hooking time, 0.33 minutes lateral yarding time, 0.89 minutes inhaul time, and 1.09 minutes unhooking time (Table 1). Together, hooking and unhooking accounted for 60 percent of delay-free yarding time. The time required to move the turn of logs from the stump to the landing includes lateral yarding and inhaul, and accounts for less than 30 percent of delay-free cycle time.

Yarding delays averaged 0.95 minutes per turn, increasing the average total cycle time to 5.2 minutes. Half of all turns samples encountered delays that averaged 1.9 minutes. Delays in outhaul, hooking, and inhaul showed low frequencies of occurrence that ranged from 0.02 to 0.08 per turn. The average duration of these delays ranged from 1.0 to 2.9 minutes per delay (Table 2). Because of the low frequencies, the average delay time per turn was only 0.05 minutes for outhaul, 0.08 minutes for hooking, and 0.12 minutes for inhaul (Table 2). Collectively, these delays accounted for 26 percent of all yarding delay.

Collectively, lateral yarding delays and unhooking delays accounted for 74 percent of all yarding delay time. Both types of delay occurred with a frequency of 0.20 delays per turn. Average delay time per cycle was 0.38 minutes for lateral yarding and 0.32 minutes for unhooking (Table 2). Nearly all lateral yarding delays occurred when excessive loads were hooked or heavy logging slash covered the pieces and the turn had to be rehooked or bucked before the small yarder could move the turn to the carriage. Half of the unhooking delay time was incurred when the incoming turn hung on previously yarded pieces that extended over the downhill edge of the small landing. Other unhooking delays occurred while the tractor cleared the landing or when the carriage stop was moved.

Table 1.—Statistical summary of delay-free yarding element time.

Yarding element	Mean	Standard deviation	Minimum	Maximum
	Minutes			
Outhaul	0.48	0.17	0.09	0.79
Hooking	1.46	.54	.38	3.14
Lateral yarding	.33	.31	.04	2.36
Inhaul	.89	.42	.18	3.38
Unhooking	1.09	.40	.39	2.80
Complete cycle	4.25	.96	1.65	7.65

Table 2.—The frequency and average duration of yarding delays, average delay time per cycle, and percent of delay time by yarding element.

Yarding element	Frequency	Average duration	Average[a] delay time	Proportion of delay time
	Delays/cycle	*Minutes/delay*	*Minutes/cycle*	*Percent*
Outhaul	0.02	2.33	0.05	5.3
Hooking	.08	1.03	.08	8.4
Lateral Yarding	.20	1.86	.38	40.0
Inhaul	.04	2.87	.12	12.6
Unhooking	.20	1.54	.32	33.7
Complete Cycle	.54	1.72	.95	100.0

[a]Not equal to product of frequency and duration due to rounding.

Mainline Test and Payload Analysis

The maximum static mainline pull at a 250-foot-slope yarding distance was 1,150 pounds by measurement. The measured mainline pull corresponds to a drum radius of 6.4 inches; the bare-drum radius is 3.4 inches. The pull at bare drum is calculated as the product of the measured line pull and the ratio of drum radii, or 1,150 (6.4/3.4) = 2,165 pounds, which agrees with published values of 2,000 pounds (American Pulpwood Association 1983). Measured line pull also correlates closely with the estimated weight of the maximum turn volumes yarded. The largest turn weighed an estimated 1,400 pounds, and only eight turns exceeded 1,100 pounds. When turn volumes approached 20 cubic feet, lateral yarding became increasingly difficult and delays more frequent. Delays related to the mainline pull were also encountered when heavy logging slash covered the pieces to be yarded. Comparison of mainline pull capacity to the Appalachian hardwood tree weights published by Wiant (1977) shows that only trees 10 to 11 inches d.b.h. or smaller can be yarded stem length to a 4-inch outside bark top diameter.

The estimated payload capability in the skyline corridor, limited by the mainline and skyline respectively, are: profile 1, 2,000 pounds and 2,360 pounds; profile 2, 1,780 pounds and 2,230 pounds; profile 3, 1,720 pounds and 1,770 pounds. Therefore, the skyline profile did not determine the payload capacity, but in all instances, the payload capacity was determined by the mainline pull required to breakout and laterally yard the turn to the carriage. If payloads were limited only by skyline payload capability, they could have been increased by 35 to 50 percent.

Regression Analysis Results

The independent variables tested in the regression analyses of delay-free cycle time and cycle element time include slope yarding distance, slack-pulling distance, number of pieces yarded per turn, and cubic volume per turn. Only variables that were significant at the 0.05 level are included in the final equation shown in table 3. With the exception of slack-pulling distance, all variables that appear in the element time equations also appear in the cycle time equation.

The results shown in table 3 indicate that the independent variables in the equations for outhaul time, inhaul time, and cycle time explained 32 to 84 percent of the variation sampled. The equations for hooking, lateral yarding, and unhooking time explained only 3 to 12 percent of the sampled variation. Increases in slope yarding distance, turn volume, and number of pieces hooked all result in increased cycle time.

Table 3.—Regression equations, where Y = delay-free yarding element time in minutes, X_1 = slope yarding distance in feet, X_2 = slackpulling distance in feet, X_3 = number of pieces per turn, and X_4 = volume per turn in cubic feet of wood and bark.

Yarding element	Equation	Regression	
		R^2	S.E.
Outhaul	$Y = 0.099 + 0.0018 X_1$	0.84	0.07
Hooking	$Y = 1.182 + 0.1189 X_3$	.06	.52
Lateral yarding	$Y = 0.228 + 0.004 X_2$	.03	.30
Inhaul	$Y = -0.137 + 0.0035 X_1 + 0.0254 X_4$	.58	.27
Unhooking	$Y = 0.820 + 0.1189 X_3$	.12	.38
Complete cycle	$Y = 2.148 + 0.0061 X_1 + 0.1941 X_3 + 0.0328 X_4$	.32	.80

The relationships between predicted delay-free yarder production and slope yarding distance, turn volume, and number of pieces per turn are shown in figure 6. The equation P = (60/CT)V was used; where P is production, CT is delay-free cycle time, and V is turn volume. To simplify the illustration, the effects of pieces per turn are shown only for the 15-cubic-foot turn volume.

Because of the effect of yarding distance on cycle time, increasing yarding distance from 100 feet to 600 feet, reduces delay-free production from 163 to 89 cubic feet per hour when yarding a 10-cubic-foot turn (Fig. 6). Although cycle time also increases with turn volume, the effect of fewer turns per hour is offset by the additional volume. Yarding 300 feet, the increase in turn volume from 10 to 20 cubic feet boosts the production estimate from 122 cubic feet to 230 cubic feet per delay-free hour (Fig. 6).

The five production curves shown for the 15-cubic-foot turn volume in figure 6 indicate that production will decline when piece size dictates that more pieces must be hooked to maintain a specific turn volume. However, production will generally increase when hooking more pieces results in additional volume. Yarding 300 feet with a 2-piece, 15-cubic-foot turn, the estimated production rate is 185 cubic feet per hour. Adding a 5-cubic-foot piece and yarding a 3-piece, 20-cubic-foot turn, increases the estimated production rate to 230 cubic feet per delay-free hour (Fig. 6).

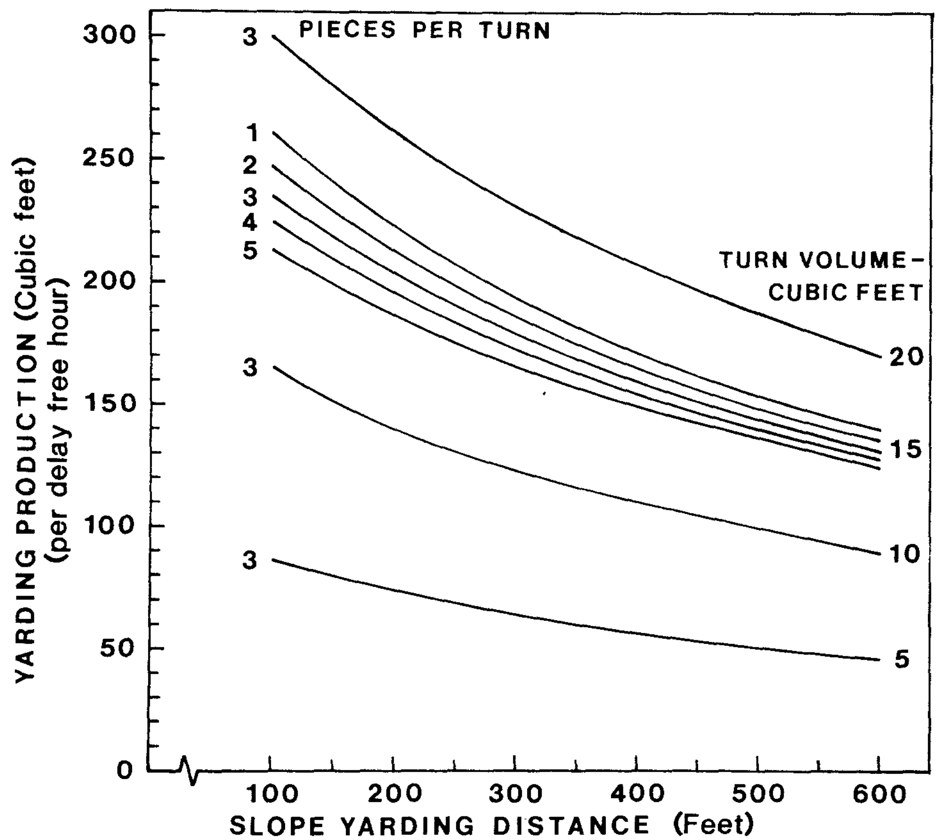

Figure 6.—The effects of slope yarding distance, pieces per turn, and volume per turn on estimated delay-free yarder production.

Yarding Cost Analysis

The total labor and equipment cost for the yarding operation; excluding felling, decking, and hauling, was estimated to be $270.00 per 8-hour day based upon 220 operating days per year. Fixed and operating costs for the yarder, chainsaws, and communications equipment totaled $62.00 per day (Appendix). Although the crew used handheld two-way radios for communications between the chokersetters and the yarder operator, the cost estimate includes the talkie-tooter type radio and transmitters normally used with cable yarders. Payroll cost for the crew of four with wages averaging $5.00 per hour and associated costs of 30 percent were $208.00 per day. Since labor cost represents 77 percent of the total cost, the daily yarding cost will be much more sensitive to changes in labor cost than to changes in the equipment costing assumptions.

The stump to landing yarding cost at the study site was estimated using the yarding cost model with two sets of inputs to show the effects of nonproductive time. Case 1 and Case 2 differ only with respect to the following nonproductive time elements. Case 1 represents the operation studied with the site, yarder, and operational variables required by the costing model being obtained from the study data. Because the short duration of the time study did not provide an adequate sample of downtime, the percent of scheduled operating time lost to mechanical or systems delays was assumed to be 10 percent in Case 1 and 5 percent in Case 2.

The increased efficiency shown in Case 2 might be expected as the crew became more experienced in cable logging and learned the limitations of the small yarder. The net result of these prospective improvements would be a 20 percent increase in production and a 17 percent reduction in yarding cost.

The yarding cost estimates in Cases 1 and 2 are specific to the conditions at the study site. These include an average piece volume of 5 cubic feet and a volume per acre of 1,350 cubic feet. To determine the sensitivity of yarding cost to changes in these two variables, the yarding cost model was applied to the conditions specified in Case 2, changing only volume per piece and volume per acre. Piece volume was incremented in 1-cubic-foot intervals from 3 to 12 cubic feet for each of three volume-per-acre levels—1,000, 2,000, and 3,000 cubic feet.

	Case 1	Case 2
Corridor change, minutes per move	60	30
Yarding delay, minutes per turn	0.95	0.50
Downtime, percent of scheduled operating time	10	5
Production rate, cunits per 8-hour day	7.6	9.1
Yarding cost, dollar per cunit	35.70	29.50

The results of this sensitivity analysis indicate that yarding costs will decline significantly with increases in either average piece size or volume per acre. Yarding 1,000 cubic feet per acre when piece size averages 4 cubic feet costs $34.00 per cunit. This compares to $18.00 per cunit when 3,000 cubic feet are yarded per acre and piece volume averages 12 cubic feet (Fig. 7).

These variations in yarding cost reflect a change in the expected production rate from 7.8 cunits to 15.0 cunits per 8-hour day. As volume per acre increases, proportionately more time is spent yarding and less time is spent moving the yarder or changing tailholds. Increasing average piece volume results in greater turn volumes and fewer pieces per turn.

Based upon the results of this study and the assumption incorporated into the cost analysis, $18.00 to $20.00 per cunit might well be the minimum expected yarding cost for the Bitterroot Miniyarder and a crew of four. The cost curves shown in figure 7 represent an efficient operation with an average yarding distance of 200 feet, and nonproductive time elements at the levels shown in Case 2. Furthermore, on sites with piece sizes consistent with the capacity of this yarder, volume per acre and average piece volume will seldom exceed those values that correspond with the cost curves at $20.00 per cunit. Under less favorable conditions, such as those at the study site, the costs would exceed $30.00 per cunit.

Aside from the increases in yarding production that are linked to crew efficiency and site conditions, yarding costs can also be controlled through crew size. The yarding operation studied used a crew of four. However, this and other small yarders can operate efficiently with crews of three or even two (Kellogg 1983, Brown and Bergvall 1983). At the wage rate used in the previous cost analyses, a crew of three cuts the daily cost of the yarding operation from $270.00 to $218.00 per day. This cost is $166.00 per day with a crew of two. To yard for $20.00 per cunit, the crew of four must produce 13.5 cunits per day, whereas the crew of three needs 10.9 cunits, and the crew of two only 8.3 cunits. Assuming that mechanical downtime, outhaul, lateral yarding, and inhaul are unaffected by crew size; there must be significant increases in the remaining time elements to offset the economic advantages of smaller crews.

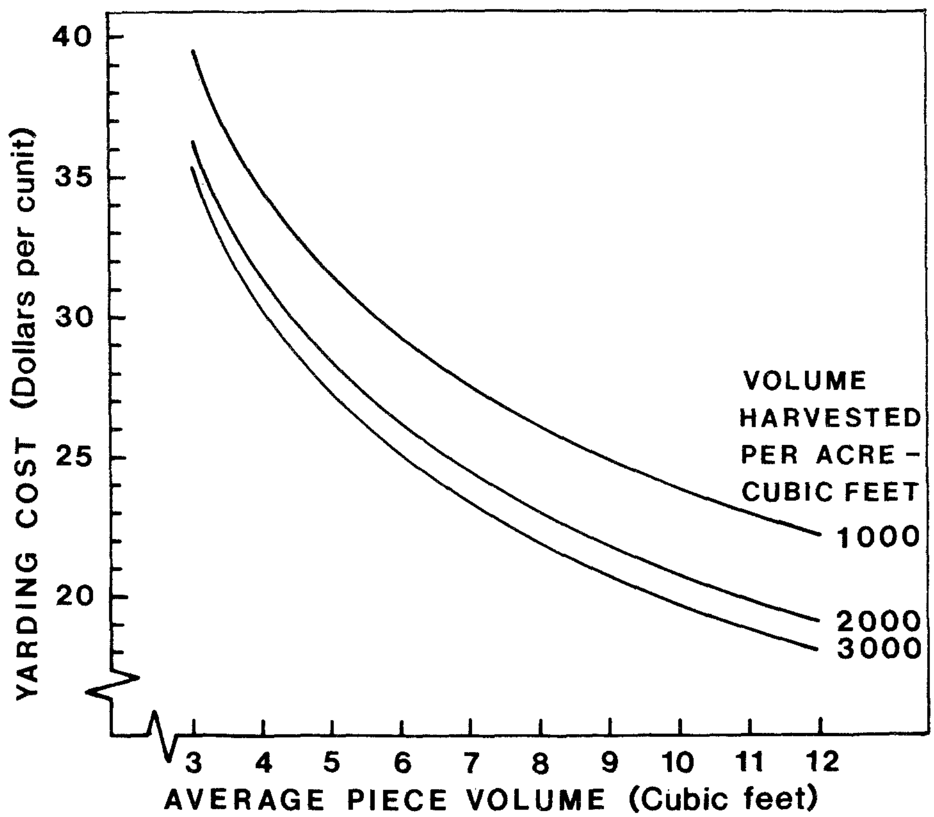

Figure 7.—The effects of volume harvested per acre and average piece volume on estimated yarding cost.

Conclusions

For successful application of cable yarding technology, the cost of yarding must be kept within the allowable limits. These limits will depend upon the forest management objectives of the landowner; the value attached to the environmental benefits of cable logging; and the difference between product value and the sum of additional costs such as felling, decking, loading, and hauling. With respect to yarding cost and potential applications, the two most important attributes of the Bitterroot Miniyarder are its low cost and low payload capacity.

To effectively manage the tradeoff between cost and capacity, it is essential to balance the cost of the yarding operation against the expected production rate. Although yarder production depends on crew efficiency and yarding conditions, it is constrained by yarder capacity. Due to the low cost of owning and operating this yarder, this balance would best be achieved through labor cost. Since the operation studied used a crew of four and the minimum crew size is two, the relationships between crew size, productivity, and yarding cost definitely warrant further investigation.

The material to be yarded must be compatible with the design capacity of the yarder. With the available line pull only poletimber and small sawtimber-size hardwood trees can be yarded in bole length or merchantable sawlog length pieces. Therefore, this yarder should be used to harvest small diameter sawlogs or sawbolts, pulpwood, or fuelwood. The material removed from thinnings will generally meet these criteria as will residue from regeneration cutting. Although the widespread need for thinning and the abundance of harvesting residue create numerous opportunities to use this yarder in the eastern hardwood region, its application will depend on local markets for these products.

Yarder capacity is an important consideration in planning the location of roads, landings, and corridors for all cable logging operations. Because of the capacity of this and other small yarders; felling, bucking, and other operational procedures must also be well planned. In the yarding corridors, even small trees should be felled and large tree tops lopped to avoid time consuming hangups. Directional felling will also reduce yarding delays, particularly in thinnings; and stems should be bucked to the capacity of the yarder. In thinnings, the chokersetter must position the carriage stop to keep turns within the lateral yarding corridor to reduce both delays and damage to the residual stand. The implementation of these essential practices will undoubtedly require an experienced and well-trained crew.

Landing and decking procedures must also be included in the planning process. When wood decked at the yarder interferes with yarding, either wood or the yarder must be moved. Often a tracked or wheeled skidder is used to swing the wood from the yarder to a loading deck. Although a small tractor could be used with this yarder, the cost of this machine will contribute significantly to the cost of the operation. When road and landing layout permits self-loading trucks to work directly from the yarder deck, the need for a swing tractor can be eliminated. Yarding closely spaced parallel corridors, the highly mobile yarder can also be moved frequently to build a series of decks along the access road.

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Appendix—Yarding Equipment Costs

FIXED-COST ESTIMATE

Equipment description	Life	Initial cost	Salvage value	Average annual investment	Annual fixed cost[a]
	Years	*Dollars*			
Cable yarder[b]	5	15,750	3,150	10,710	4,662
Chainsaws, 2	1	1,100	0	1,100	1,320
Radio and transmitters	4	4,500	0	2,812	1,688
Total annual fixed cost					7,670[c]

OPERATING-COST ESTIMATE

Equipment description	Operating cost items	Annual operating cost
		Dollars
Cable yarder	Maintenance and repair at 50% of depreciation	1,260
	Fuel at 4 gal/day, 220 days/year	1,100
	Filters, lube, and oil at 15% of fuel	165
	Cable, $1,250 with 2-year life	625
	Chokers, tools, and miscellaneous equipment	350
Chainsaws	Maintenance and repair at 100% depreciation	1,100
	Fuel and oil—220 days/year	725
	Miscellaneous equipment (bar, sawchain)	200
Radio	Maintenance and repair	350
Total annual operating cost		5,875[c]

[a]Depreciation plus sum of taxes, insurance, and interest estimated at 20 percent of average annual investment.
[b]Yarder without cable.
[c]Total annual fixed and operating cost = $13,545 and daily cost at 220 days/year = $61.56.

Baumgras, John E.; Peters, Penn A. **Cost and production analysis of the Bitterroot Miniyarder on an Appalachian hardwood site.** Res. Pap. NE-557. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1985. 13 p.

An 18-horsepower skyline yarder was studied on a steep slope clearcut, yarding small hardwood trees uphill for fuelwood. Yarding cycle characteristics sampled include: total cycle time including delays, 5.20 minutes; yarding distance, 208 feet (350 feet maximum); turn volume, 11.6 cubic feet (24 cubic feet maximum); pieces per turn, 2.3. Cost analysis shows yarding costs will range from $18.00 to $36.00 per cunit, depending upon crew efficiency and yarding conditions.

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Keywords: Timber harvesting, cable yarding, logging, cost

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