Bucking Logs to Cable Yarder Capacity Can Decrease Yarding Costs and Minimize Wood Wastage

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Abstract. Data from selected time and motion studies and a forest model plot, used in a simulation model, show that logging managers planning felling, bucking, and limbing for a cable yarding operation must consider the effect of alternate bucking rules on wood wastage, yarding production rates and cost, the number of chokers to fly, and total logging costs. Results emphasize the need to consider initial logging activities in terms of effects on cable yarding system efficiencies and wood wastage. Results also emphasize the need to match payload (piece size) to cable yarder capacity. Results suggest that cable yarding costs can be decreased by 20 to 32% by simply bucking logs to yarder capacity.

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The first step in timber harvesting on steep terrain is the conversion of trees to logs, which includes felling, bucking, and limbing, usually with chainsaws. Felling, bucking, and limbing critically affect the amount of wood retrieved from a site and the efficiencies of cable yarding. If trees are bucked without regard to end use, value may be lost. Bucking big, long logs may result in logs too heavy for the yarding equipment to handle; conversely, bucking small, short logs may result in wood wastage and cable yarding inefficiency due to increased handling time and costs resulting from small loads per turn.

Regression equations have been developed for predicting felling, bucking, and limbing time (Jiles and Lehman 1960, Koger 1980, 1983, Martin 1975, Matthes et al. 1977, Wren 1965). Also, felling, bucking, and limbing have been analyzed as component costs within the harvesting system (King 1970, Schnell 1964). Others have studied felling, bucking, and limbing of integrated sawlog-pulpwood operations (Gabriel 1971) and cull trees (Gabriel and Nissen 1971). The studies successfully quantified felling, bucking, and limbing times per tree, and in some cases, regression equations to predict time were developed. Detailed felling, bucking, and limbing techniques used by professional timber cutters in the Pacific Northwest and other regions are discussed by Bromley (1976), Conway (1973), FAO (1980), and Pearce and Stenzel (1972).

Generally, these past studies do not consider the impact of alternate bucking strategies on cable yarding efficiencies and wood wastage. This article illustrates the application of a methodology for evaluating the effect of alternate bucking rules on hourly production rates, log distributions per acre, wood wastage, and total logging costs. A simulation model called THIN (LeDoux and Butler 1981) and a log bucking algorithm[1] are used. The results can be used by logging managers to determine felling, bucking, and limbing policies for cable logging operations.

[1] LeDoux, C. B. 1984. Hardwood Log Bucking Simulator. Program on file, Northeast. For. Exp. Stn., Morgantown, WV.

LOG BUCKING METHODOLOGY

Forest model plot number 8[2] was selected to be bucked, and the results were used to illustrate the effect of alternate bucking rules on cable yarding efficiency and wood wastage. Forest model plot number 8 is typical of most hardwood stands: average dbh, 9.10 in.; average merchantable height to 4-in. top, 35.9 ft; number of trees, 229; gross volume, 4,703 ft^3/ac; species mix, soft maple, red oak, white oak, black birch, yellow birch, hickory, beech, black cherry, walnut, ash, and yellow-poplar. A log bucking simulation model (see footnote 1) was used to simulate bucking of the trees within the plot. The model will buck trees into logs explicitly considering log grade, volume, and yarding system payload capacity For any one tree, the simulation will attempt to buck logs to maximize log grade and volume while simultaneously meeting a yarder payload constraint. The end product of the bucking simulator is as many grade logs as possible, given a specified maximum allowable log weight.

The results from 3 simulated bucking rules are shown in Table 1. Bucking logs for a maximum weight of 1,500 lb results in 974 logs/ac averaging 11.4 ft^3 per log Bucking logs to weights of 3,000 and 6,000 lb increases average log size by 20.2% and 37.7%, respectively. The number of logs per acre for a 1,500 lb limit bucking rule is 974, or 13.4% more logs per acre than a 3,000 lb rule, and 20.2% more logs per acre than a 6,000 lb rule. The percentage of products for a 1,500 lb rule is shown in Figure 1.

Although forest model plot number 8 has a total biomass volume of 4,703 ft^3, only 3,231 ft^3 of merchantable wood (4-in. top) is realized when using a bucking rule of 1,500 lb. Only trees with

[2] United States Department of Agriculture One-acre forest model plot data on file Northeast. For. Exp. Stn., Morgantown, WV.

Table 1. Simulated log distributions by bucking rule for forest model plot number 8.[a]

Bucking rule[b] (lb)	Log size Ave.	Max.	Min.	Stand. dev.	Ave. log length	Number of logs[c]	Merchantable volume removed ac
	(ft³)				(ft)		(ft³)
1,500	11.4	24.8	0.50	8.4	28.5	974	3,231
3,000	13.7	48.2	0.70	12.9	33.1	843	3,360
6,000	15.7	86.5	0.90	18.9	35.8	778	3,556

[a] Assumed weight per ft³ is 60 lb (all species pooled).
[b] Maximum weight allowed per log.
[c] Number of logs for a 1,000- × 150-ft skyline corridor.

dbh of 5.0 in. and greater are considered merchantable. Log sections less than 4 ft are left on the site and not included in the total merchantable volume. When bucking rules of 3,000 and 6,000 lb are used, the merchantable wood retrievable is increased from 3,231 to 3,360 and 3,556, increases of 4.0% and 10.1%, respectively. The increases in merchantable wood with the heavier bucking rules are due to cutting bigger and longer logs from respective trees, minimizing wood wastage. Bucking to light bucking rules (1,500 pounds) results in many short logs and top portions of stems that do not meet the 4-ft merchantability constraint. The gain in wood volume is in the firewood/pulpwood component (Figure 2). The number of logs per acre as well as average size will significantly affect cable yarding production rates.

CABLE YARDING PRODUCTION RATES

Hourly production rates for cable yarding are influenced significantly by the bucking rule. To illustrate these effects, the log distributions shown in Table 1 were input into the THIN simulation model. The model was then used to simulate the hourly productivity rates and costs associated with yarding each log distribution with a yarder capable of a 6,000 payload. The results are shown in Table 2. The simulations were run with a fixed number of chokers and also an unlimited number of chokers using bucking rules of 1,500, 3,000, and 6,000 lb. For example, a yarder with capacity of 6,000-lb yarding logs bucked to 1,500 lb flying 4 chokers produces 273.58 ft³/hr. Under similar conditions, yarding logs bucked to 3,000- and 6,000-lb rules results in hourly production rates of 330.33 and 360.40 ft³, increases of 20.7% and 31.7%, respectively. Conversely, if an operator used a 1,500-lb rule instead of the 6,000-lb capacity, the above percentages would represent losses. However, when similar runs were made with unlimited number of chokers, the hourly production rate for the 1,500-lb rule increased by 29.7%, from 273.58 to 354.89 ft³, an increase attributable to flying more chokers (6 compared to 4). Similarly, the hourly production rate increased for the 3,000 bucking rule, an increase of 11.2%, from 330.33 to 367.22 ft³, again attributable to flying more chokers. Figure 3 illustrates the increases in production rate by the number of chokers flown.

Flying more chokers is not always desirable. For example, when simulating the yarding of a 6,000-lb bucking rule using unlimited chokers, only 2.8 logs were hooked per turn suggesting that 3 chokers would be enough. Repeated simulations were used to show the optimal number of chokers to fly by bucking rule and number of logs per corridor:

Bucking rule (lb)	No. logs/ corridor	No. optimal chokers
1,500	980	6
	485	4
	323	3
3,000	843	5
	420	4
	278	3
6,000	778	3
	389	3
	258	3

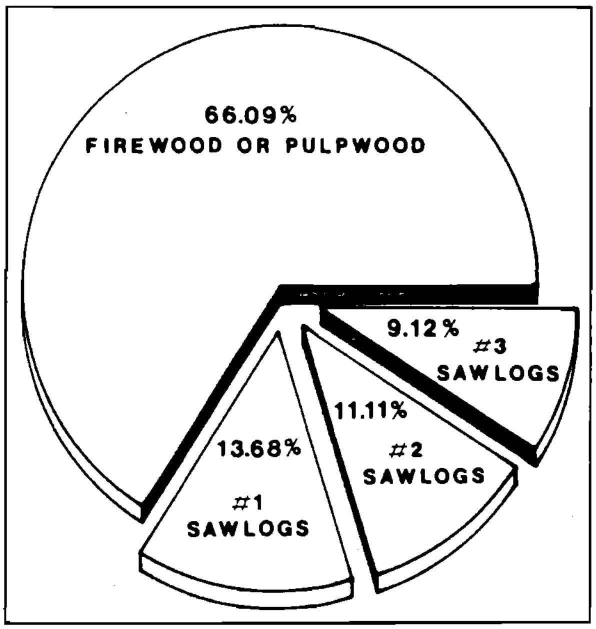

Figure 1. Percentage of products for bucking rule of 1,500 lb, for forest model plot number 8.

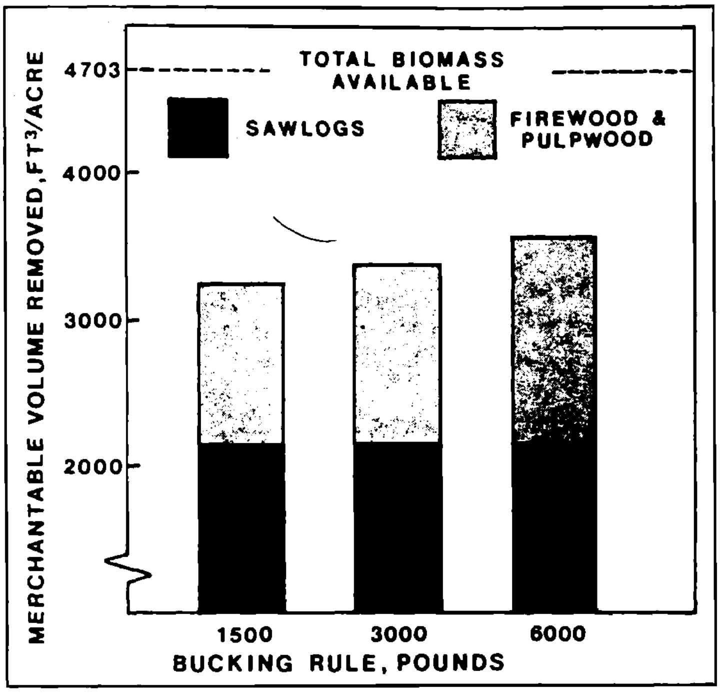

Figure 2. Simulated sawlog and firewood/pulpwood component of merchantable volume removed by bucking rule for forest model plot number 8.

Clearly, the results summarized are specific to forest model plot number 8 and will change for other stands; however, additional simulations could be conducted for other conditions. Alternate bucking rules will also affect felling, bucking, limbing, yarding, and total harvesting costs.

TOTAL HARVESTING COSTS

The impact of alternate bucking rules on total logging costs for a specific set of conditions is subtle, but important (Table 3). The specific components by bucking rule are detailed, note the change in felling, bucking, and limbing cost to each component. For example, the yarding cost per acre for a 1,500-lb bucking rule is $603.89, while the felling, bucking, and limbing cost is only $165.38 per acre or 27.4% of yarding cost per acre. The percentage of felling, bucking, and limbing cost for a 1,500-lb bucking rule to total cost is only 11.8%, while yarding cost is $603.89 per acre or 43.1% of total logging cost. One may wonder about the relative importance of felling, bucking, and limbing costs since as a percentage of total cost they are quite low. However, although the impact of bucking rules on felling, bucking, and limbing cost is small (decreases of 5.5% and 9.1% when going from 1,500 to 3,000 and 6,000 lb) the major contribution is in the reduction of yarding costs. For example, yarding costs per acre are $603.89 for a 1,500-lb rule, $478.64 and $412.27 for 3,000- and 6,000-lb rules; or decreases of 20.7% and 31.7% respectively. Clearly, the advantage of bucking logs to yarder capacity reduces yarding costs.

Table 2. Simulated hourly production rates by bucking rule for flying four chokers and flying unlimited chokers for logs per 1,000- × 150-ft skyline corridor.

		Flying 4 chokers		Flying unlimited chokers	
Bucking rule (lb)	Logs corridor	Hourly prod. rate	Logs hooked per turn	Hourly prod. rate	Logs hooked per turn
		(ft³/hr)	(no.)	(ft³/hr)	(no.)
1,500	974	273.58	3.5	354.89	5.2
3,000	843	330.33	3.3	367.22	3.8
6,000	778	360.40	2.8	361.33	2.8

CONSIDERATIONS FOR MANAGERS

Matching log size through bucking to payload capacity of specific cable yarders is an important cost savings and should be considered. To apply the results to your situation, initially cruise the proposed stand and determine the payload capacity of your chosen yarder. Then fellers should be instructed to buck logs to yarder capacity as much as possible. Such a practice will generally result in yarding tree-length trees. Yarding tree-length wood to the landing results in an additional bonus; that is, bucking and sorting can be done on the landing for the high-value products most efficiently Tree-length logging may result in damage to the residual stand if stems are improperly felled. The bucking rule, however, is not the only important item; for example, properly oriented logs to the skyline corridor has shown significant gains in yarding productivity (LeDoux and Butler 1982). Good management and advanced planning of the felling operation are crucial to cable yarding success The skyline corridors should be identified and felled, and fellers should be instructed to fell trees so that good extraction angles and paths are formed.

Although the effect of high stumps, extraction paths, and limbing practices on cable yarding cost was not quantitatively explored in this study, felling and bucking instructions should consider these practices. The primary reason for not considering them quantitatively was the lack of data.

During the limbing process, many buckers will leave the underlying limbs on a stem intact as this facilitates limbing. However, for yarders with low mainline pull, it would be highly desirable to buck off these limbs to facilitate lateral yarding. Even the smallest underlying limbs can penetrate the soil a few inches and cause

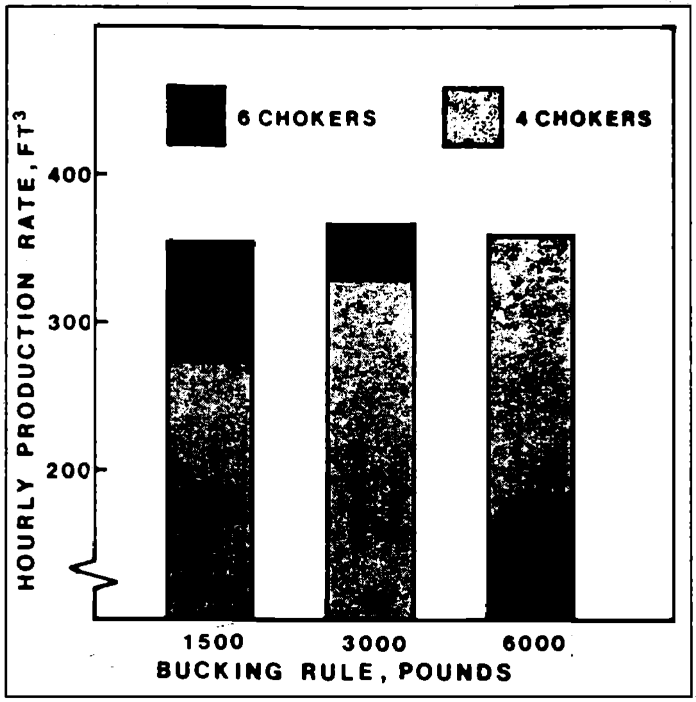

Figure 3. Increases in simulated hourly production rates by bucking rule for four and six chokers for forest model plot number 8.

substantial lateral yarding delays. Buckers should be instructed to remove as many limbs as possible when processing trees into logs for cable yarders.

Stump height should also be considered. For example, approximately 15% of total breakage occurs during the felling process, the result of felling trees across stumps (Conway 1973). Lower stumps will result in less breakage, minimize wood wastage, and most important, minimize timely and costly delays due to turns of logs hanging up on high stumps during the yarding process.

Although this work was based on data from one forest model plot and one tree distribution, similar analysis could be conducted for other conditions by simply making additional simulation runs. It is beyond the scope of this article to deal with all aspects of felling, bucking, and limbing trees into logs, and it is not envisioned that results from field studies as used in simulation models such as those summarized here will provide all the answers. Such methods should illustrate the effect of alternate bucking strategies on cable yarding cost and wood wastage; thereby, logging managers can make better decisions. □

Table 3. Impact of bucking rules on total harvesting cost.

Harvesting component	Bucking rule (lb)		
	1,500	3,000	6,000
	($/ac)		
Felling, bucking, limbing	165.38	156.27	150.27
Yarding	603.89	478.64	412.27
Loading	76.17	78.13	80.16
Hauling	362.45	376.92	381.91
Move in and out plus delays	193.86	193.86	193.86
Total cost	1,401.75	1,283.82	1,218.47

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