Individual Stem Value Recovery of Modified and Conventional Tree-length Systems in the Southeastern United States

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Abstract

We compared value recovery of a modified tree-length (MTL) logging system that measures product diameter and length using a Waratah 626 harvester head to that of a tree-length (TL) system that estimates dimensions. A field test compared the actual value cut to the maximum potential value suggested by the log bucking optimization program Assessment of Value by Individual Stems (AVIS) for 25 felled trees on each of three sites for two loggers. One half of each site was harvested with a TL crew and the other half with a MTL crew. ANOVA on individual stems using site as a blocking factor showed significant differences between TL and MTL, with TL recovering 80.3% and MTL recovering 73.7% of total value after downgrades.

Keywords: Value recovery, logging, forest products.

Introduction

Numerous studies have found that cut-to-length (CTL) harvesting systems recover more value at a lower additional sorting cost than tree-length systems (Gingras 1996; Gingras and Soucy 1999). Other studies have shown that CTL systems in the Southeast can recover up to 90-94% of the optimum value of a harvested stand (Boston and Murphy 2003; Conradie et al. 2004). Most markets in the southeastern United States demand tree-length products, however. Some tree-length harvesting operations in the southeastern United States are starting to use mobile carriers equipped with processing heads to aid in product sorting and bucking at roadside. These modified tree-length systems (MTL) produce bucked logs similar to a CTL operation.

Solid wood products markets in the southeastern United States still purchase predominantly tree-length material, and often set their delivered prices to encourage delivery of this type of material. Real-time information exchange between harvesting operations and sawmills, allowing bucking-to-order or bucking-to-demand optimization, is typically not done. The predominant approach of most harvesting contractors in the southeastern United States is still bucking-to-value, and this is often done based on visual estimation of individual log measurements.

Advantages of using a harvester to measure and buck logs may be higher value recovery for the landowner, measurements and information about products from the harvesting site, and increased loader production by allocating the product sorting function to the harvester. These advantages may be offset by higher logging costs from adding a high-cost piece of equipment to a system and lack of markets in the Southeast for cut log products. No studies have examined the cost or value recovery of modified tree-length systems in comparison to tree-length systems (TL) in the Southeast. This study evaluates these harvest systems by comparing the two systems' value recovery of individual stems on three paired harvest blocks.

Methods

The TL crew's equipment consisted of two grapple skidders, a feller-buncher, a knuckleboom loader, two chainsaw operators, and a delimbing gate. The loader operator sorted the stems on the landing, separating stems that included potential sawtimber precut products, one of the higher valued products. The chainsaw operators cut the sawtimber logs

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from these stems at measured lengths.

The MTL crew's equipment consisted of a track-mounted loader with a model 622 Waratah harvester head operated as a processor on the landing, a grapple skidder, a knuckleboom loader, and a feller-buncher. The processor operator utilized diameter and length measuring technology in the harvester head to aid his decision-making but did not use a log optimization program to make bucking decisions. The processor operator had four years experience operating a processor.

We identified three tracts that our industry cooperator had scheduled for clearcut in 2007. All study sites were previously thinned loblolly pine (*Pinus taeda* L.) plantations between 24 and 33 years of age located in central Georgia. Each tract was divided roughly in half to form two blocks of approximately equal acreage. We randomly assigned the TL or MTL crew to harvest each block. Additional site information is provided by Hamsley *et al.* (2009).

Twenty-five stems were marked on each contractor's harvest block, for a total of 150 trees. DBH was recorded on the standing trees. Each selected tree was felled at the time the block was harvested. A 30 m (100 ft.) tape was attached to the butt of each stem and the following measurements were taken after felling:

1) Large-end diameter (LED) over bark;
2) Diameter over bark in 3 m (10 ft.) increments of length up the stem to a 5 cm (2 in.) top;
3) Quality factors including sweep, knot size and number, and cankers/defects with their corresponding beginning and ending lengths from the large end;
4) Total tree height, excluding stump.

After the felled trees were measured, they were processed and sorted into product categories. The loader operator on the TL crew sorted products and set aside stems to be bucked into shorter logs by the chainsaw operators on TL blocks. The processor operator on the MTL crew processed and sorted selected trees on MTL blocks. After processing,

Table 1. Mill specifications, delivered prices, and residual timber value for products harvested by the tree-length (TL) and modified tree-length (MTL) harvesting systems; prices adjusted using Timber Mart South 2007 Georgia averages.

Product	Mill	Mill Specifications	Delivered	Residual Timber Value	
				TL	MTL
			$/tonne	($/tonne)	($/tonne)
Pole	A	7-8" top, 11" DBH	$84.50	$64.15	$63.13
ST1**	B	Min 8" top in lengths of 25', 29', or 33' and greater	$62.70	$44.00	$42.98
ST Precut1	B	Min 8" top in lengths of 12'6" and 16'6" only	$62.70	$44.00	$42.98
ST2	C	Min 8" top, min 12" butt, min 25' length	$59.40	$40.70	$39.68
ST Precut2	C	Min 10" top, min 12" butt; length 12'6",14'6", or 16'6"	$62.70	$44.00	$42.98
CNS A	D	5.0" top, minimum length 29'	$38.50	$20.48	$19.46
CNS B	D	5.0" top, minimum length 21'	$36.30	$18.28	$17.26
CNS Precut1	D	6" top, 16'6" in length	$38.50	$20.48	$19.46
CNS	E	9" butt, 5" top, minimum length 29'	$41.80	$23.78	$22.76
CNS Precut2	E	16.5" length	$41.80	$23.78	$22.76
PSP	F	7-9" butt; 5" top; minimum length 25'	$33.30	$14.16	$13.13
PPW	G	3.0 " top, min length 20' TL, min length 12' DB, max diam. 26"	$26.42	$7.28	$6.26
HPW	H	6.0-22.0" butt; 3" top; minimum length 21'	$25.98	$8.22	$7.19
Post	I	6-10" butt; 2.5-3" top; min 24' length	$0.00	N/A	$4.58*

*Product market only available to MTL
**Abbreviations: ST=Sawtimber, CNS=Chip-n-saw, PSP=Pine Super Pulpwood, PPW=Pine Pulpwood, HPW=Hardwood Pulpwood, DB=Double bunk or cut length, TL=Tree-length, MTL=Modified Tree-length

the product type and destination for all products was recorded as well as their corresponding actual small-end diameters (SED), LED, and lengths. On MTL blocks, the researcher sat in the cab of the processor with the operator and recorded product types and processor estimates of diameters and lengths as well as measured actual product dimensions after processing.

Because we used the same MTL and TL crews throughout the study and did not replicate the systems, it is impossible to separate the impacts of operator decisions from those of the equipment configuration. Replicating crews was not feasible at the time of study, but the operators performing product sorting were both experienced operators and considered to have similar experience and expertise with sorting. The main purpose was to determine if the measurement ability of the processor improved value recovery compared to bucking with a chainsaw.

To determine the value recovery of each system we used AVIS (Assessment of Value by Individual Stems) optimization software (New Zealand Forest Research Institute 1995). Value recovery is the percentage of optimum value that the logger actually produces based on how he bucks the stem. AVIS was developed to determine actual value loss in the woods (Geerts and Twaddle 1984). Developed in the late 1970s-1980s, AVIS uses dynamic programming to optimally buck individual stems given specifications and stem characteristics (New Zealand Forest Research Institute 1995). AVIS has been used for research and industry purposes for many years (Geerts and Twaddle 1984; Boston and Murphy 2003; Conradie et al. 2004).

Our industry cooperator provided mill dimension and quality product specifications (Table 1). Prices were determined by applying observed price differentials between products in the marketplace during the study to the reported 2007 average timber prices for Georgia from Timber Mart-South (Harris et al. 2008). These inputs, along with site considerations and stem data, were entered into AVIS to obtain the optimal solution for each stem by site. We also entered each contractor's bucking solution to compare the contractor's actual solution to the optimal solution. Measurements were taken in English units but were converted to metric units prior to entry into AVIS.

In some cases, the actual value for a stem bucked by the logger had greater value than the optimal solution because the contractor deviated from mill specifications. In these instances, we downgraded out-of-spec logs to reflect their value as if they had been bucked correctly. We allowed a tolerance of 25 mm (one inch) for diameter and 75 mm (three inches) for length. These tolerances were based on discussions with field personnel regarding allowable mill tolerances.

We compared the individual stem value recovery of each system with analysis of variance (ANOVA) (SAS Institute Inc. 2002-2004).

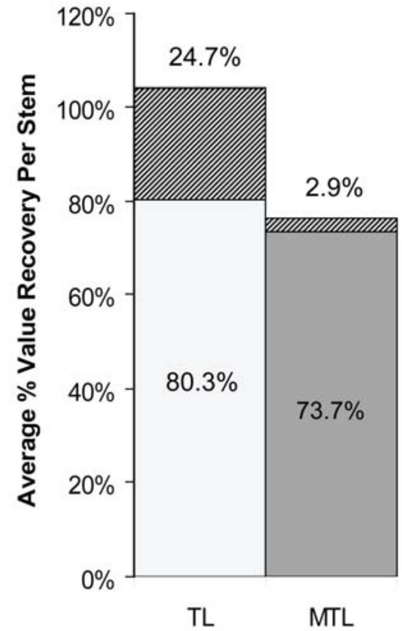

Figure 1. Average value recovery (%) for individual stems using tree-length (TL) and modified tree-length (MTL) harvesting systems. The shaded portions of each bar represent value corrections for out-of-specification stems cut by each system.

Results

ANOVA on individual stems using site as a blocking factor showed significant differences between TL and MTL, with TL recovering 80.3% and MTL recovering 73.7% of

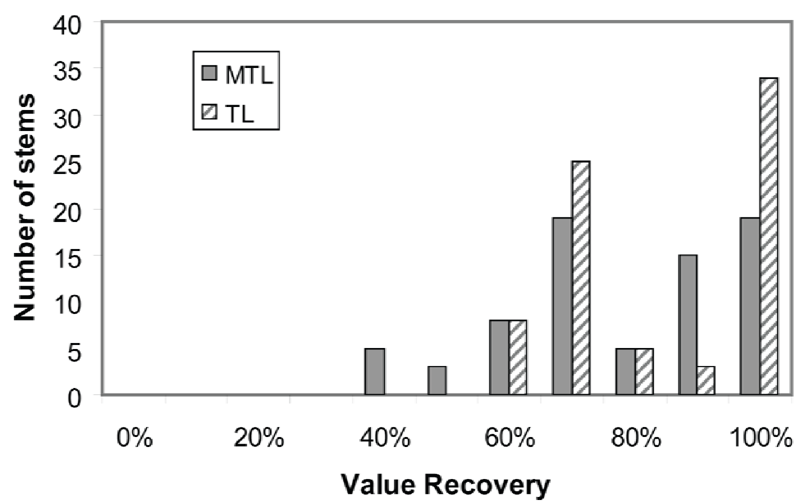

Figure 2. Frequency distribution of value recovery (%) per stem for each system across all harvesting sites.

total value after downgrades (Figure 1). Total dollar value loss was not significantly different, with both operations losing approximately $6.50 per stem on average. Downgrades for stems that did not meet mill specifications reduced value recoveries for both systems by 24.7% for TL and 2.9% for MTL.

Value losses were largely bimodal for TL crews, with one mode in the 100% recovery range (between 95% and 100% recovery) and the other at 70% recovery (65 to 74.9%) (Figure 2). The largest value losses occurred from misallocating stems into the appropriate product classes, for example sorting a tree-length pole as sawtimber. Smaller value losses of 5-10% resulted from differences in bucking decisions and allocation of products to different minor classes, much of which may have been driven by market availability. For example, sending a chip-n-saw (CNS) stem as a B grade rather than an A grade would drop the value almost 6%.

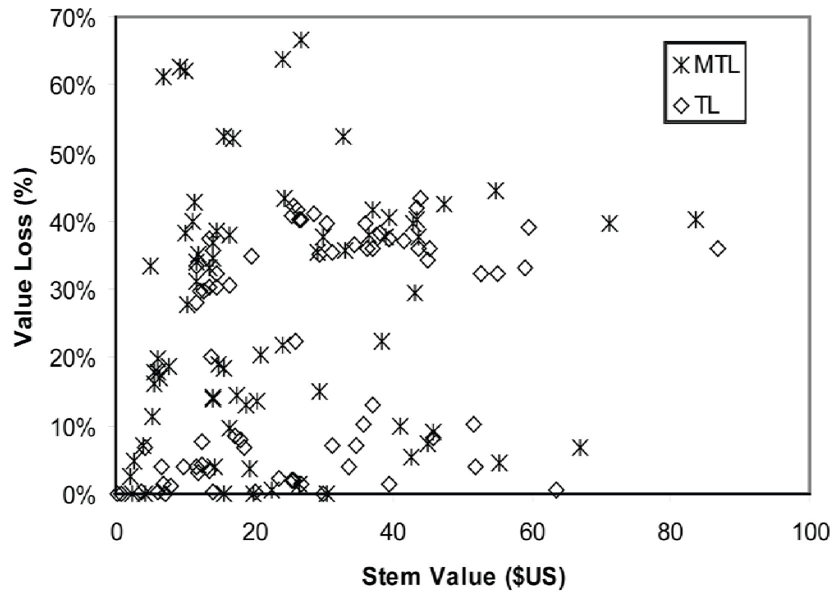

Figure 3. Value loss (%) from bucking decisions and maximum potential stem value for each harvesting system.

Value losses for MTL were considerably more variable. Two pronounced modes were seen, but significant numbers of stems had value losses between the modes (Figure 2). This was a result of the increased opportunities for the processing head to make bucking decisions along the stem without the guidance of a bucking optimization program. Deviations from the optimal bucking solution within different product classes were more frequent. Rather than simply sending a stem as tree-length CNS or tree-length sawtimber, it was more common to see pre-cut CNS and sawtimber pieces made from stems that would have recovered more value tree-length.

Value losses for both systems resulted from recovery of lower volumes of the highest value product (pole or sawtimber) compared to the optimal solution. No pattern is apparent with regard to value loss as a function of stem size or total stem value (Figure 3 and Figure 4). Because of a failure to identify poles, some of the most valuable stems incurred large value losses (>40%). The extremely low value recoveries were primarily from merchandizing CNS when the optimal solution made sawtimber or poles.

The adjustment for out-of-specification stems lowered the value recoveries of each system on each tract. The modified system had lower, more consistent adjustments (2% to 10%) than the tree-length system (7% to 25%). This suggests the processor operator was less likely to overestimate the quality of stems. If mills are willing to accept out-of-specification materials, this improved accuracy may be financially detrimental.

An examination of the accuracy of the processor head showed diameter overestimation by 1.90 cm for the large end diameter and 1.84 cm for the small end diameter (Table 2). The harvester underestimated length by an average of 4.10 cm. Diameter measurement errors occurred uniformly across all pieces, while length measurement errors typically occurred in pieces less than 8 m in length with 5 cm top diameter (i.e. cut length pulpwood), where the measuring wheel may have had trouble fully contacting the stem. These overestimates are within the allowed tolerances for the purchasing mills, but consistent errors of this magnitude would be expected to result in more bucking errors and value loss.

A number of possible explanations exist for the difference in average value recovery per stem. One is the variability of performance of each system. TL had value recoveries of 60% or higher per stem while MTL had value recoveries that ranged from 30% to 100% (Figure 3). Although no effect of operating speed in the range of 430 to 610 cubic meters per

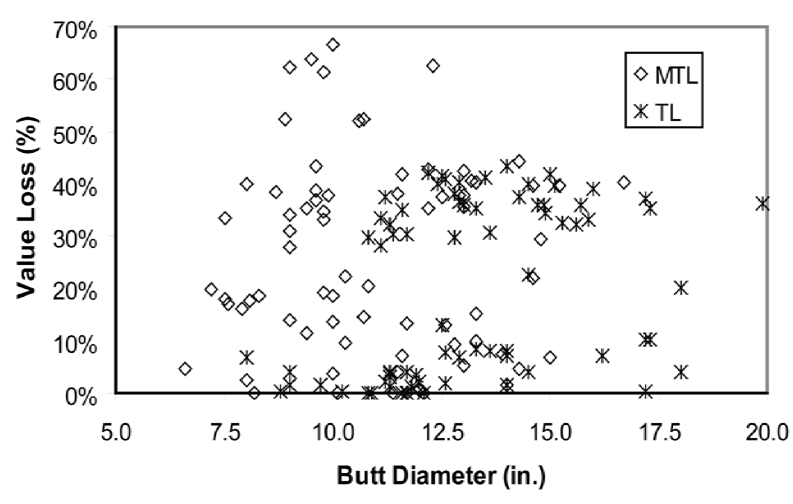

Figure 4. Value loss (%) from bucking decisions and butt diameter (in.) of felled stems for each harvesting system.

Table 2. Accuracy of measurement for processing head used by the modified tree-length system.

Measurement Type	Mean error (Actual – Reported) (cm)	Std. deviation (cm)	*t* statistic	Pr = 0
Length	4.10	27.1	2.00	0.047
SED*	-1.84	2.39	-10.10	< 0.001
LED	-1.90	2.77	-9.04	< 0.001

* SED = small end diameter, LED = large end diameter

day was detected on value recovery in New Zealand, operators in a Swedish study indicated that they had difficulties seeing defects in logs at the current feeding speed of 4 m/s (Gellerstedt 2002; Murphy et al. 2005). Perhaps the operator in this study sacrificed value for production speed. The lowest value recovery of MTL on Site C of 68% was largely attributed to a failure to merchandize poles. MTL had recently acquired pole quota when they moved to Site C and the operator was somewhat hesitant to merchandize poles. While this shift in market demand may have had some effect on the operator's ability to merchandize poles on that site, it is also likely that field measurements of the felled trees may have missed defects that precluded these trees from meeting stringent pole specifications allowing AVIS to assign them a higher value than they deserved.

Average value recovery was 80% for 39 operations worldwide; MTL and TL systems averaged slightly below this worldwide average (Murphy 2003). Value recoveries of CTL systems in the southeastern United States ranged from 90%-94%, although one CTL system recovered only 58% of optimum value from poor measurement (Boston and Murphy 2003; Conradie et al. 2004). While TL and MTL systems in this study had similar value recoveries to each other, they are well below the 90-94% reported for CTL systems on similar sites. A shovel operation in Washington that used a harvester with a bucking computer as a stationary processor recovered 83% of optimal value while a CTL operation in Oregon recovered 92% (Marshall and Murphy 2004). Value recovery for a contractor in New Zealand *Pinus radiata* plantations with a Waratah HTH 626 processor on a Caterpillar 330 CL excavator base that processed stems extracted in tree-length form to a landing was 89.8% for one site and 90.4% for another site (Murphy et al. 2005). The highest value recovery of the MTL system studied here was 78% of optimum and is below reported value recoveries in Washington (83%) and New Zealand (90%).

Conclusions

The individual stem analysis with AVIS showed MTL averaged lower value recovery (73.7%) than observed for TL (80.3%). The MTL harvester operator did not use a bucking optimization program to aid his decision-making. Future work could examine a MTL system that did utilize a bucking program to determine if the bucking program could improve value recovery. It appears there is room for value recovery improvement for these systems as they were below the 90%-94% value recoveries reported for CTL systems in the southeastern United States (Boston and Murphy 2003; Conradie et al. 2004).

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