Comparison of Two Cut-to-Length Harvesting Systems Operating in Eastern Hardwoods

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ABSTRACT

We compared production rates, operating costs, and break-even points (BEP) for small and large cut-to-length (CTL) harvesting systems operating at several machine utilization rates (MUR) in mixed hardwood and softwood stands in Vermont. The small CTL harvester produced 11.08 m^3 [391.4 ft^3] per productive machine hour (PMH) compared to 14.83 m^3 [523.80 ft^3] per PMH for the large harvester. The impact of average tree size (volume) on cost was substantial but similar for both CTL systems. At a fixed stump-to-landing logging cost of about $14.12/$m^3$ or [$0.40/$ft^3$], the BEP tree size was 0.14 m^3 [5.0 ft^3] for the small harvester and 0.26 m^3 [9.33 ft^3] for the large system at the 85 percent MUR. At an MUR of 70 and 85 percent, the processing cost for trees that averaged 0.08 m^3 [3.0ft^3] was $22.19 and $18.28/$m^3$ [$0.6285 and $0.5176/$ft^3$], respectively, for the small CTL harvester. Results were similar for the large harvester. Either CTL system would be effective in helping managers meet forest management goals in eastern hardwood stands.

Keywords: *Cut-to-length harvesting, production rate, cost, break-even point, hardwoods, single-grip harvester, processor, slashber, partial cutting, thinning.*

INTRODUCTION

Cut-to-length (CTL) harvesting, a completely mechanized system, is a popular alternative to conventional harvesting, that is, the use of a rubber-tired skidder along with manual felling, bucking, and limbing [1, 2, 6]. Conventional harvesting causes a considerable amount of residual stand damage and soil disturbance [7, 12]. There is much less damage to the residual stand with a CTL harvester because logs and trees are not pulled through the stand and the latter can be felled directionally [9, 16]. Because delimbing occurs in front of the harvester, limbs and slash are used as a mat upon which the machine travels. As a result, soil disturbance and compaction are minimized [10, 13, 15]. Also, working conditions are safer with CTL versus conventional harvesting [3], and the CTL harvester holds an important advantage over the rubber-tired system in areas where there is a shortage of woods workers.

The CTL harvester's greatest disadvantage are the high investment cost for the harvester and head, costs to repair and maintain the machine's complex, computerized electrical system, and the inability of the machine to handle hardwood stems larger than 55.88 cm [22.0 inches] in stump diameter. Also, the additional fuel loading (limbs and other woody debris) can pose a fire hazard under certain stand conditions.

In this study we compare production rates, operating costs, and break-even points (BEP) for small and large CTL harvesters operating at several machine utilization rates (MUR) in mixed hardwood and softwood stands in Vermont.

STUDY AREA

A 14.17-ha [35.0-acre] woodlot located on Colchester (Vermont) School District property was selected as the study site for the small CTL harvester. This small woodlot typifies those within the suburban forested area along Lake Champlain. The stand is primarily white pine (*Pinus strobus*) and northern red oak (*Quercus rubra*); timber quality was classed as good. The site is nearly flat except for a small section with a side slope of about 3 percent. The soil is dry and sandy and is an Adams-Windsor soil classification. The average length of the main skid trails is 366 m [1,200 feet]. The trails were located and marked by a district forester with the Vermont State Department of Forests, Parks, and Recreation. The long-range forest management objectives for this site are to grow high-quality, large-diameter white pine and red oak, provide a wildlife area in a suburban environment, and create a forested area for a high school environmental studies program.

The stand prescription was primarily a thinning to reduce the basal area to the B level as prescribed by [8] for white pine, and [14] for red oak in New England. The stand was marked for a heavy thinning to reduce the preharvest basal area from 27.55 m^2/ha [120 ft^2/acre] to about 22.95 m^2/ha [100 ft^2/acre]. This was accomplished primarily by removing the white pine, red oak, and hemlock sawlogs

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generally across all dbh classes. Because the stand had several cubic feet of white pine, hemlock, and hardwood sawlogs with stump diameters that were beyond the capabilities of the harvester, most of the sawlog volume was removed with a chain saw and rubber-tired skidder.

A 17-ha [42-acre] test and sale area on the Groton State Forest in central Vermont was selected as the study site for the large CTL harvester. The stand is predominately spruce fir (*Picea* and *Abies* species) and mixed northern hardwoods. Most of the hardwood component was poor-quality, small-diameter chipwood and pulpwood material (white birch (*Betula papyrifera*)and red maple (*Acer rubrum*). Yellow birch (*Betula alleghaniensis*) was scattered throughout the stand. The site had little or no slope and the soil was extremely wet in certain areas and poorly drained in much of the remaining areas. The forest management objective for this stand was to encourage multiple-age classes to improve habitat for moose, snowshoe hare, and white-tailed deer. The preharvest mean stand diameter was 20.32 cm [8 inches]. Sawlog quality was poor to fair, and most of the hardwood competition was removed in the cut. The estimated postharvest basal area ranged from 19.51 to 20.66 m^2/ha [85 to 90 ft^2/acre].

EQUIPMENT

CTL harvesters, sometimes called feller processors, perform three basic functions in the stand: (1) fell the stem, (2) delimb, and (3) buck the stem to a predetermined length. Most of the CTL harvesters used in the Northeast are the single-grip type rather than the heavier, more expensive double-grip type. The single-grip harvester usually is faster and more versatile than the double-grip machine and thus better adapted to the smaller woodlots that are prevalent in the Northeast.

The small CTL system was a Peninsula design, roller processing sawhead Model RP1600. The maximum cutting diameter is 35.56 cm [14.0 inches] and the limbing diameter ranges from 1.27 to 22.86 cm [0.5 to 9.0 inches]. The harvester was mounted on a modified 988 John Deere, 70-tracked excavator platform. The hydraulic system on the 4125 meter-kilograms per second excavator was modified to include a 181.68-liters/min [48 gal/min] hydraulic pump system. The higher capacity was required because the hydraulic system on most excavators is not designed for harvester heads.

The large CTL harvester was a Timbco Model T425 tracked excavator-type machine fitted with an Ultimate 5600 single-grip processor head. This harvester has a cab-leveling capability and can operate on moderate slopes, in wet areas, and in tight selective cuts. The maximum cutting diameter is 55.88 cm [22 inches] and limbing diameter of 5.08 to 25.40 cm [2 to 10 inches]. The hourly machine rates used in this study were $115.00 for the small harvester and $146.72 for the large machine and were calculated according to [11].

METHODS

The complete harvesting system for the small harvester included a feller processor and forwarder; the large harvester also included a slasher at the landing. We did not obtain data for the forwarder and slasher.

The operating sequence for the CTL harvester was as follows: The operator scanned the area for marked trees and positioned the processor head on the tree to be cut. The accumulator arms gripped the tree while cutting it with the circular saw-type cutting head. The tree was then turned horizontal to the ground and spiked feed rolls pulled it through the delimbing knives to remove limbs. The operator then cut the stem to length, usually 2.44 m [8 feet] for pulpwood and 3.66 to 4.88 m [12 to 16 feet] plus 10.16 cm [4 inches] for trim allowance for sawlogs. The cut stems were placed in bunches or piles of pulpwood and/or sawlogs. White pine and spruce fir that were 20.32 cm [8 inches] and larger were marked for sawlogs, as were hardwoods that were 30.48 cm [12 inches] and larger. Because only one operator per harvester was studied and different operators worked with both harvesters, the impact of an operator on productivity was not controlled. Therefore, productivity, costs and break-even points represents only the operators in question.

Time and motion data were recorded over a 5-day period for both systems to determine the delay-free total cycle time for a range of tree volumes. Total cycle time includes felling the tree, delimbing, cutting the tree to length, piling, and travel time to the next tree. We recorded total number of trees per bunch, volume of each tree, and time required to create the bunch. Timing began when a tree was cut to create a bunch, and ended when a new bunch was started. The number of trees was recorded for each bunch along with the length and small- and large-end diameter of each piece in the bunch.

The production, cost, and stand data used in the comparison are from two field studies [4, 5]. Average tree sizes and hourly machine rates were used to develop stump-to-landing cost curves for the small and large CTL systems. Numerous cost data points were computed by average tree and machine size combinations and graphed to determine the impact of tree size, machine use, and utilization rate on stump-to-landing costs and BEP. The latter were determined using the prevailing price of $14.12/$m^3$ or [$0.40/

ft^3] for small-diameter wood products in the New England area.

RESULTS

At an observed MUR of 80 percent, the average rate for the large CTL system, the small CTL harvester produced 11.08 m^3 [391.44 ft^3] per productive machine hour (PMH) compared to 14.83 m^3 [523.80 ft^3] per PMH for the large CTL harvester. The average number of trees processed for the small harvester was 68.79/PMH, or 16.47 bunches/PMH. The large harvester processed 47.48 trees/PMH, or 15.99 bunches/PMH.

The bunches created during the study contained an average of 0.51 m^3 [17.83 ft^3] for the small harvester and 1.87 m^3 [66.19 ft^3] for the large harvester. Large CTL bunches contained more sawlogs (and greater cubic-foot volume) than small CTL bunches.

The average piece size for the small harvester was 13.97 cm [5.50 inches] at the small end and 16.5 cm [6.50 inches] at the large end versus 16.5 cm [6.50 inches] at the small end and 21.84 cm [8.60 inches] at the large end for the large harvester. The average piece length was 4.53 m [14.86 feet] for the small system and 4.02 m [13.20 feet] for the large machine. The average tree volume for the small harvester was 0.16 m^3 [5.69 ft^3] and ranged from 0.08 to 0.34 m^3 [2.80 to 11.89 ft^3]. For the large harvester, the average tree volume was 0.31 m^3 [11.03 ft^3] and ranged from 0.08 to 0.53 m^3 [2.98 to 18.63 ft^3].

Figures 1 and 2 show stump-to-landing logging cost curves by average tree size for the small and large size CTL systems operating at an MUR of 85 and 70 percent, respectively. The impact of average tree size on cost is substantial and similar for both systems. For example, processing trees that average .06 m^3 [2.00 ft^3] with the small system cost \$19.53/m^3 [\$0.5529/ft^3], while trees that averaged .2823 m^3 [10.00 ft^3] cost \$8.93/m^3 [\$0.2529/ft^3], or a reduction in cost of about 54.25 percent. Processing trees that average .06 m^3 [2.00 ft^3] with the large system cost \$20.38/m^3 [\$0.5771/ft^3], while trees that average .48 m^3 [17.00 ft^3] cost \$11.08/m^3 [\$0.3137/ft^3], or a reduction in cost of about 45.64 percent.

Figure 1 also shows BEP average tree size for the small and large CTL systems. At a fixed stump-to-landing logging cost of about \$14.12/m^3 [\$0.40/ft^3], the BEP tree sizes are .14 m^3 [5.00 ft^3] (BEP1) and .26 m^3 [9.33 ft^3] (BEP3), respectively. At a reduced fixed stump-to-landing logging cost of about \$12.36/m^3 [\$0.35/ft^3], the BEP tree sizes are .17 m^3 [6.17 ft^3] (BEP2) and .38 m^3 [13.33 ft^3] (BEP4), respectively. Loggers could operate in stands of these tree sizes and break even. Loggers operating in stands with tree sizes that are above the BEP would see a profit. In contrast, in stands where the average piece size is less than the BEP, they would operate at a loss. Reduced logging costs allow the logger to operate at break-even in younger, smaller-diameter stands. Piece size is a critical factor in stands where average tree size is less than .14 m^3 [5.00 ft^3]. Focusing on the cost curves in Figure 1 by size of CTL system, we see that costs decrease at decreasing rates (flatter slopes) for piece size of .20 m^3 [7.00 ft^3] to .31 m^3 [11.00 ft^3] and .20 m^3 [7.00 ft^3] to .51 m^3 [18.00 ft^3] for the small and large size systems, respectively. This suggests that loggers generally will see a profit in stands where the average tree size exceeds the BEP.

IMPACT OF MACHINE UTILIZATION RATES

At an MUR of 85 percent for the small size CTL system, the cost to process trees that average .08 m^3 [3.00 ft^3] is \$18.28/m^3 [\$0.5176/ft^3] (Figure 1). For the same size of machine and average tree size, at the 70 percent utilization level, the cost is \$22.20/m^3 [\$0.6285/ft^3], an increase of 21.4 percent (Figure 2). Similar comparisons by size of CTL system, average tree size, and utilization level can be made from Figures 1 and 2. A more dramatic result is the break-even average tree size that a given system can operate in at alternative utilization levels. For example, the large CTL system at 85 percent utilization can break even in stands that average about .26 m^3 [9.33 ft^3] (BEP3) (at \$14.12/m^3 [\$0.40/ft^3] fixed logging cost, Figure 1). For the same size CTL system and fixed logging cost at the 70 percent utilization level, would require that the average tree size be .43 m^3 [15.25 ft^3] (BEP3, Figure 2). For the same conditions, at the \$12.36/m^3 [\$0.35/ft^3] fixed logging cost, the large size CTL would not break even in the range of average tree sizes shown.

Another way to look at this is from a profit standpoint. For example, for the small CTL system operating in stands where the average tree size is .31 m^3 [11.00 ft^3], the cost is \$10.21/m^3 [\$0.2891/ft^3] (Figure 2) at the 70 percent utilization level. For the same conditions, and using \$14.12/m^3 [\$0.40/ft^3] at the break-even level, the operator could realize a profit of \$3.92/m^3 [\$0.1109/ft^3]. However, for the same machine and piece size, the cost is \$8.41/m^3 [\$0.2381/ft^3] (Figure 1) at the 85 percent utilization level, with a profit of \$5.72/m^3 [\$0.1619/ft^3]. The operator could realize a gain in profit of \$1.80/m^3 [\$0.0510/ft^3], or a gain in profit of 31.5 percent compared to the 70 percent utilization level. This gain in profit could be realized by developing strategies to increase the utilization.

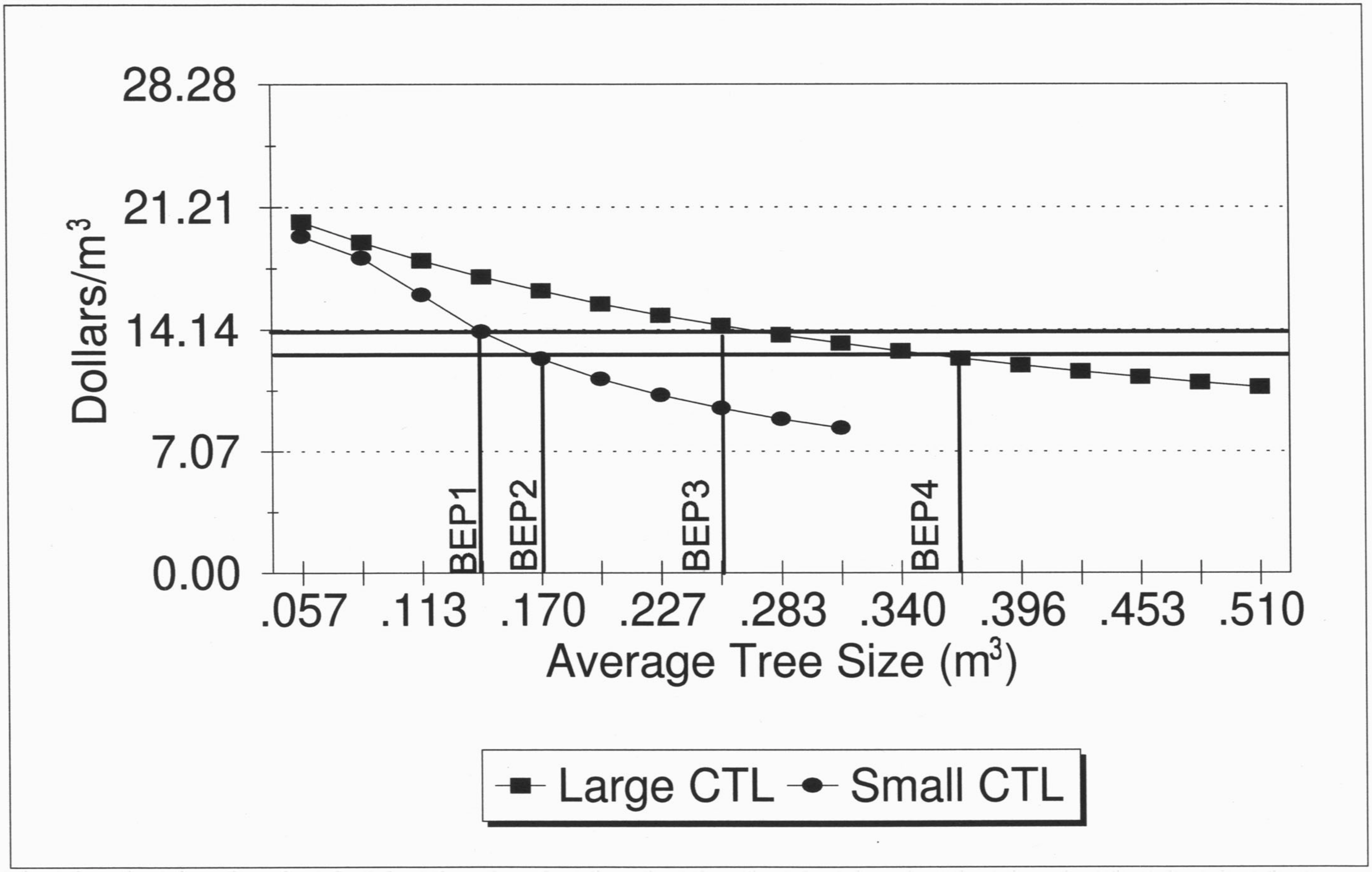

Figure 1. Stump-to landing logging cost curves and breakeven points for small and large CTL harvesters by average tree size at 85% utilization (hourly machine rates are $115.00 and $146.72, respectively.

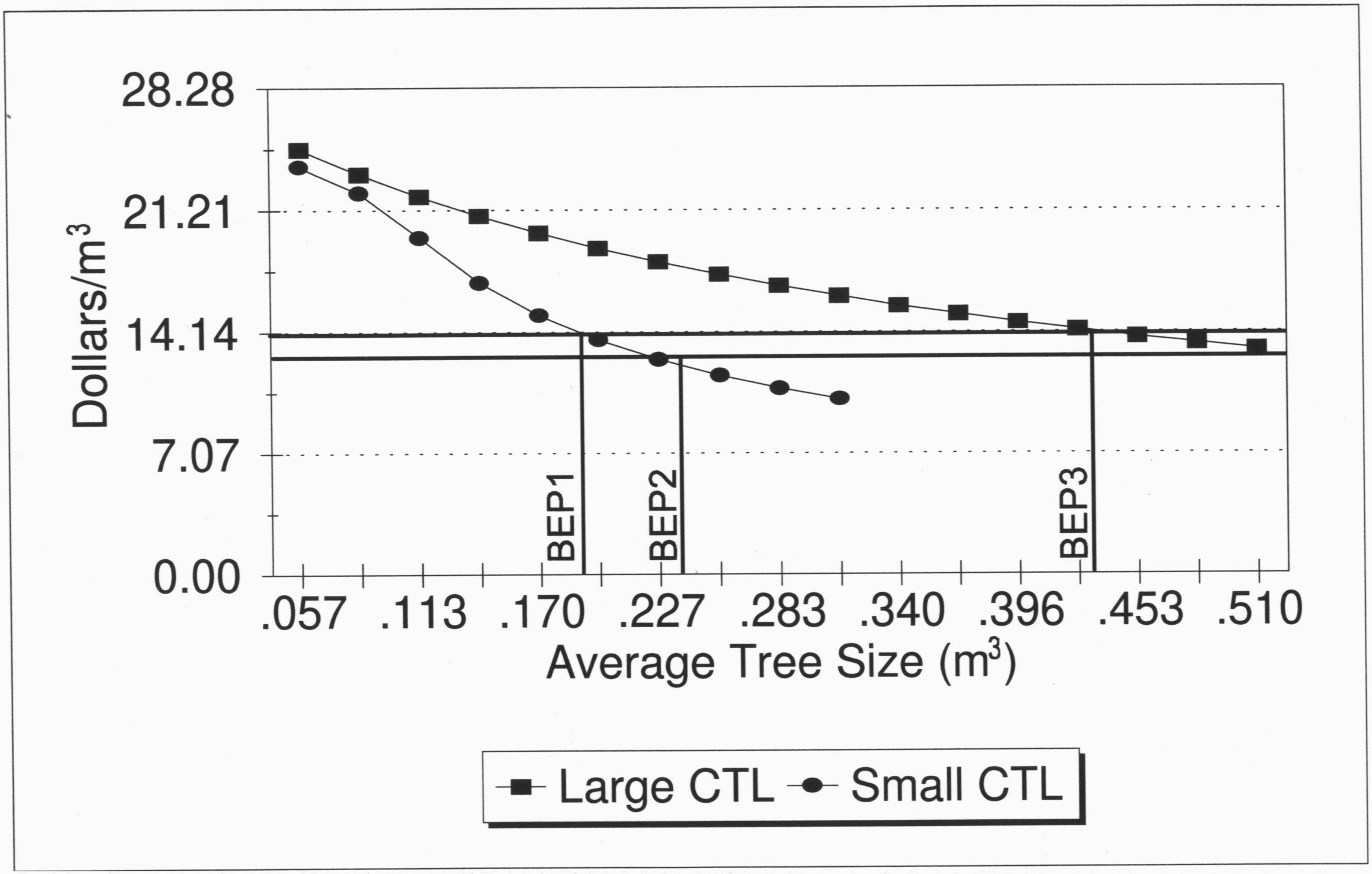

Figure 2. Stump-to landing logging cost curves and breakeven points for small and large CTL harvesters by average tree size at 70% utilization (hourly machine rates are $115.00 and $146.72, respectively.

CONSIDERATIONS FOR FOREST MANAGERS

Matching the size of CTL systems to the size of trees harvested can increase profits and allow the logger to enter stands when the trees are younger (smaller). The small machine can break even at smaller average tree sizes than the larger CTL system at any utilization level. At an MUR of 85 percent, processing trees that average .28 m^3 [10.0 ft^3] would result in a profit of \$.30/m^3 [\$0.0084/ft^3] and \$5.20/m^3 [\$0.1471/ft^3], respectively, for the large and small CTL systems. In this example, the small CTL system would realize an increase in profit of 1651.19 percent.

Figures 1 and 2 can be used to match machines to the size of tree harvested and allow loggers, landowners, and planners to meet more nontimber-related goals. There are many small municipal parks and public wood lands in the Northeast that need some form of silvicultural treatment to improve growth and aesthetics. These sites must be harvested in a manner that will minimize environmental impacts while maintaining a high degree of aesthetic value. Both of these CTL harvesting systems would be effective in meeting these objectives.

NOTE: The use of trade, firm, or corporation names in this paper 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.

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REFERENCES

[1] Araki, D., R. P. F. 1994. At-the-stand and roadside log processing in Alberta: a comparison. FERIC Special Report No. SR-96. Vancouver, BC: Forest Engineering Research Institute of Canada, Western Division. 29 p.

[2] Brinker, R.W. and R.A. Tufts. 1990. Economics of cut-to-length harvesting systems in second thinning. In: Proceedings of the Council on Forest Engineering, 13th annual meeting; 1990 August 12-16; Outer Banks, NC. 35-39.

[3] Green, D.W., B.L. Lanford, and B.J. Stokes. 1984. Productivity of the Valmet 940 Gp grapple processor in southern pine plantation thinning. In: Proceedings of the Council on Forest Engineering/IUFRO; 1984 August 11-18; Orono, ME: University of Maine. 105-108.

[4] Huyler, N.K. and C. LeDoux. 1996. Cut-to-length harvesting on a small woodlot in New England: a case study. In: Proceedings, planning and implementing forest operations to achieve sustainable forests. General Technical Report NC-186. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experimental Station: 102-108.

[5] Huyler, N.K. and C. LeDoux. 1999. Performance of a cut-to-length harvester in a single tree and group selection cut. Research Paper. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station. [In press].

[6] Kellog, L.D. and C.G. Brown. 1995. Using a single-grip harvester and skyline yarding system in a forest health improvement application. In: Proceedings of the Council of Forest Engineering, 18th annual meeting; 1995 June 5-8; Cashiers, NC. 130-142.

[7] Kelly, R.S. 1983. Stand damage from whole-tree harvesting in Vermont hardwoods. Journal of Forestry. 81(2):95-96.

[8] Lancaster, K.F. and W.B. Leak. 1978. A silvicultural guide for white pine in the Northeast. General Technical Report NE-41. Broomall, PA: U. S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 20 p.

[9] Leech, P.E. 1989. Rottne log-length logging system. In: Proceedings of the Southern Regional Council on Forest Engineering, 1st annual meeting; 1989 May 3-4; Auburn, AL. 125-132.

[10] Meek, P. 1995. Concentrating on a slash distribution solution. Canadian Forest Industries; July-August: 46-49.

[11] Miyata, E.A. 1980. Determining fixed and operating costs of logging equipment. General Technical Report NC-55. St. Paul, MN: U. S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 16 p.

[12] Ostrofsky, W. D., R. S. Seymour, and R.C. Lemon, Jr. 1986. Damage to northern hardwoods from thinning using whole-tree harvesting technology. Canadian Journal of Forest Research. 16:1238-124.

[13] Pawlett, S. 1985. Swedish harvesting system debuts in New Brunswick. Canadian Forest Industries. 105(10):13-14.

[14] Sampson, T. L., J.P Barrett, and W. B. Leak. 1980. A stocking chart for northern red oak in New England. Durham, NH: University of New Hampshire, Institute of Natural and Environmental Resources. 12 p.

[15] Sexias, F., T.P. McDonald, and R.L. Raper. 1995. Effect of slash on forwarder on soil compaction. In: Proceedings of the Council of Forest Engineering, 18th annual meeting; 1995 June 5-8; Cashiers, NC. 77-86.

[16] Tufts, R.A. 1991. Productivity and cost of the Norcar 600 harvester. In:Proceedings of the ASAE Forestry and Environmental Conference; 1991 June 5-6; New Orleans, LA. American Society of Agricultural Engineers: 85-92.

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