FEASIBILITY OF UTILIZING SMALL DIAMETER SOUTHERN PINE FOR BIOMASS IN THE VIRGINIA COASTAL PLAIN

Nathan C. Hanzelka, M. Chad Bolding, Scott M. Barrett, Jay Sullivan[1]

Abstract—New or retrofitted wood-fired energy plants have increased demand for woody biomass in the state of Virginia. Loblolly pine (*Pinus taeda*) commonly serves as a feedstock for these energy plants. Pulpwood conventionally requires a minimum diameter of 4 inches diameter at breast height (DBH) for merchantability, whereas a minimum merchantable diameter for biomass is currently undefined. A harvesting case study was completed during the first thinning of a 15 year-old loblolly pine stand in the Virginia Coastal Plain to determine production rates and costs while harvesting densely stocked small diameter loblolly pine stems (< 4 inches DBH). Pre-harvest stand attributes included a quadratic mean diameter (QMD) of 4.2 inch DBH, an average density of 1,377 stems/acre, and an average volume of 73.7 green tons/acre. Post-harvest 34.0 green tons/acre remained. Harvesting equipment included three Tigercat 718 feller-bunchers, two Caterpillar 535C skidders, and one Peterson 4300 chipper. Elemental time studies conducted on the feller-bunchers, skidders, and chipper determined individual machine productivity rates of 30.8, 23.4, and 83.7 green tons/productive machine hour (PMH), respectively. Use of the Auburn Harvesting Analyzer determined an on-board truck cost of $16.52/green ton and a total cut-and-haul cost of $23.46/green ton. Regional average prices for in-woods chips indicate the harvest was not economically feasible.

INTRODUCTION

Woody biomass energy use has seen a large increase in the southeast US throughout the last decade. It is estimated that wood-consuming bioenergy projects may increase total wood use to 45 million green tons per year in the US south by the year 2023 (Forisk 2015). In Virginia, several wood-fired energy plants have been established and the state ranks 5th in US biomass energy plant total nameplate capacity (Biomass Magazine 2015). Small-diameter stems (i.e., < 4 inches DBH) from pre-commercial thinning (PCT) may be a potential source of feedstock for energy facilities. PCT is a practice used in the southeastern US to mitigate southern pine beetle risk and increase residual tree diameter growth (Burkhart and others 1986, Nowak and others 2008). PCT residues are normally left on-site and do not produce forest products (Perlack and others 2011).

Since PCT treatments normally incur an added management cost to landowners, some states in the southeast provide cost-share programs available to private landowners to help combat the expense of PCT. In Virginia, the Virginia Department of Forestry offers the Pine Bark Beetle Prevention Program, which provides private landowners a 60 percent cost-share for PCT treatment (Watson and others 2013). Previous studies have suggested the potential use of small-diameter PCT residues for woody biomass energy production (Perlack and others 2011, Staudhammer and others 2011), which, if utilized, could potentially reduce the added management cost of PCT.

A variety of harvesting case studies analyzing harvesting productivity and costs of utilizing small-diameter stems have been completed (Bolding and Lanford 2005, Mitchell and Gallagher 2007, Pan and others 2008). However, many of these studies have focused on stands older than 20-years, which would not typically be considered for a "normal" PCT (less than 15 years old). Additionally, some of these studies have also focused on integrated harvest scenarios in which a variety of forest products are produced, whereas a PCT biomass harvest would likely be a biomass-only harvest.

PURPOSE

The purpose of our study was to perform a biomass harvesting case study on a site with "near-PCT" conditions to determine machine productivity and operating costs while harvesting small-diameter stems in a young pine stand. The main goals of our study were to: 1) determine stand density and volume attributes, 2) collect machine productivity information, and 3) calculate harvesting costs and compare to regional delivered prices for biomass.

[1]Graduate Research Assistant, Associate Professor, Assistant Professor, Professor, respectively; Department of Forest Resources and Environmental Conservation, Virginia Tech, 310 West Campus Drive, Blacksburg, VA 24061.

Citation for proceedings: Schweitzer, Callie J.; Clatterbuck, Wayne K.; Oswalt, Christopher M., eds. 2016. Proceedings of the 18th biennial southern silvicultural research conference. e–Gen. Tech. Rep. SRS–212. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 614 p.

METHODS

The site selected for this case study was located in Greensville County, VA, within the southern coastal plain region and near the city of Emporia. The stand comprised 87 acres of 15 year-old planted, non-bedded loblolly pine. The nearest biomass energy plant to which the majority of the chips were taken was roughly 30 miles away from the site.

Pre-harvest and post-harvest inventories of the stand were completed using: 1/10th fixed-acre plots for stems ≥ 2 inches DBH and 1/100th fixed-acre for stems < 2 inches DBH. Inventory data was used to determine initial, residual, and removed stand volumes and densities.

Harvesting equipment used for the operation included three Tigercat 718 feller-bunchers, two Caterpillar 535C skidders, and one Peterson 4300 mobile chipper. Each machine had separate operators. To evaluate productivity, activity and work sampling time studies were used to determine the amount of green tons (gt) produced per productive machine hour (PMH) for each type of the three harvesting components. Cycles times for the feller-bunchers, skidders, and chipper were observed. Stem counts were also observed in each of the feller-buncher and skidder cycles. Based on the inventory data, the average volume of the removed stems (gt/stem) was calculated and used in productivity calculations.

Each cycle time interval was defined by the time from when the previously observed cycle time ended and to the time when the current observed cycle ended. For example, feller-buncher cycle times would start when the previously observed bunch of trees was dropped, and end when the currently observed bunch of trees was dropped. The same principle applied to each skidder cycle, using the time from skid turn to skid turn, and the chipping cycle, using the time between the filling of each chip van. After productivity rates were calculated, the machine rate method (Miyata 1980) was used with the Auburn Harvest Analyzer (AHA) (Tufts and others 1985) to estimate harvesting costs. To assess the effect of machine configuration changes on total harvesting costs, sensitivity analyses were conducted in the AHA by adjusting the number of machines in each harvesting component.

RESULTS

Inventory results show an initial, pre-harvest stand density of 1,377 stems/acre with a residual, post-harvest density of 390 stems/acre (table 1). Initial stem diameter averaged 3.8 inches DBH and the QMD was 4.3 inches DBH. Following harvest, stem diameters averaged 5.1 inches DBH and QMD was 5.3 inches DBH. The initial standing volume was 73.7 gt/acre with a residual 34.0 gt/acre, indicating a removed volume of 39.7 gt/acre.

Feller-buncher cycles (*n* = 398) averaged 1.5 minutes and 19 stems per cycle (table 2). Overall individual feller-buncher productivity was 30.8 gt/PMH. Cycle times varied among the feller-buncher operators; on average, Operator 1 had the longest cycle time followed by Operator 2 and Operator 3. These longer cycle times translated to a higher productive rate for Operator 3 (35.7 gt/PMH) followed by Operator 2 (32.2 gt/PMH) and Operator 1 (29.9 gt/PMH), which was expected considering Operator 3 had more experience followed by Operators 2 and 1.

Skidder cycles (*n* = 145) averaged 10.04 minutes and 97 stems per cycle (table 3). Overall productivity averaged 23.4 gt/PMH. Operator 1 had a lower average cycle time than Operator 2, equating to a higher productive rate for Operator 1 (25.6 gt/PMH) than Operator 2 (21.0 gt/PMH). However, Operator 2 had an average skid distance nearly 600 feet greater than Operator 1, contributing to their lower productive rate. Chipper cycles (*n* = 48) averaged 19.1 minutes per cycle. After chipping, loaded chip vans averaged 26.7 gt/load, equating to a productive rate of 83.7 gt/PMH.

Individual harvesting component costs as a percentage of the total cut-and-haul cost were 33 percent for hauling ($6.94/gt), 24 percent for felling ($5.12/gt), 22 percent for chipping ($4.67/gt), and 21 percent for skidding ($4.34/gt). Hauling represented the largest proportion of total harvesting costs, which was consistent with hauling costs observed in previous

Table 1—Pre- and post-harvest inventory results (stems ≥ 2 inches DBH)

	Pre	Post
Loblolly pine density *stems/acre*	**723**	**267**
All stem density *stems/acre*	**1,377**	**390**
Mean loblolly pine DBH *inches*	**5.2**	**5.8**
Mean all stem DBH *inches*	**3.8**	**5.1**
All stem QMD *inches*	**4.3**	**5.3**
Loblolly pine volume *green tons/acre*	**57.9**	**26.2**
All stem volume *green tons/acre*	**73.9**	**34.0**

Table 2—Feller-buncher time study summary statistics

	n	Time per bunch *minutes* Mean	SE	Stems per bunch Mean	SE	Productivity *gt/PMH*
Overall	398	1.5	0.03	19	0.4	30.8
Operator 1	170	1.8	0.04	22	0.6	29.9
Operator 2	129	1.4	0.06	19	0.6	32.2
Operator 3	99	1.1	0.04	16	0.8	35.7

Table 3—Skidder time study summary statistics

	n	Time per skid turn *minutes* Mean	SE	Stems per skid turn Mean	SE	Skid distance *feet* Mean	SE	Productivity *gt/PMH*
Overall	145	10.0	0.5	97	2.8	1,427	41.7	23.5
Operator 1	83	9.0	0.5	95	4.2	1,186	33.4	25.7
Operator 2	62	11.4	0.9	99	3.2	1,751	67.7	21.1

studies (Bolding and Lanford 2005, Mitchell and Gallagher 2007, Pan and others 2008). However, felling costs comprised a larger proportion of total costs than similar studies (Pan and others 2008, Bolding and others 2009), which was likely due to the high harvesting costs of using additional feller-bunchers in this study compared to other studies that used fewer feller-bunchers.

The calculated on-board truck cost, which includes felling, skidding, and chipping, was $16.52/gt (table 4). Including hauling, the total cut-and-haul cost was $23.46/gt. The regional average price for whole tree in-woods pine chips at the time of the case study was $17.35/gt (Timber Mart South 2014), lower than the calculated cut-and-haul cost. Sensitivity analysis conducted in the AHA found that the overall system was "balanced" by reducing the number of feller-bunchers from three to two, reducing the total cut-and-haul cost to $22.28/gt.

DISCUSSION

Individual machine productive rates from this study were compared to similar studies (table 5). The average productive rates of the feller-bunchers and skidders in this study were in-between the rates observed in similar studies (Pan and others 2008, Bolding and others 2009). However, the productive rate of the chipper was much higher than rates observed in other studies (Bolding and Lanford 2005, Mitchell and Gallagher 2007, Bolding and others 2009). This higher productive rate can likely be attributed to the relatively large size of the chipper used in our study in comparison to these other studies. Additionally, considering some of these other studies merchandised stems while our study chipped all stems without merchandising, higher productive rates of the chipper could further be expected as a result of increased chipper use.

Some insight regarding the utilization of PCT stands for woody biomass energy is gained by this study. Although the total-cut-and haul costs of this study are higher than the delivered price for biomass, landowners may still have an opportunity to reduce the cost of conventional PCT treatment by harvesting PCT biomass instead. If the payment to a logger for harvesting PCT biomass is less than the cost of conventional treatment, biomass harvesting would be financially preferable to the landowner.

CONCLUSION

This study analyzed the productivity and costs of a biomass-only operation harvesting small-diameter stems in a 15 year-old loblolly pine stand in the coastal

Table 4—Harvesting costs and biomass prices

	Per green ton
On-board truck (felling, skidding, and chipping)	$16.52
Total cut-and-haul (felling, skidding, chipping, and hauling)	$23.46
Delivered chip price (Timber Mart South 2014 3rd Quarter)	$17.35

Table 5—Machine productivity (gt/PMH) comparison

	Our study	Bolding and others 2009	Pan and others 2008	Mitchell and Gallagher 2007	Bolding and Lanford 2005
			gt/PMH		
Feller-buncher	32.6	38.1	23.8	N/A	N/A
Skidder	23.5	16.2	34.8	N/A	N/A
Chipper	83.7	24.7	N/A	66.7	20.2

plain of Virginia. Individual productive rates for the feller-bunchers, skidders, and chipper were 30.8, 23.4, and 83.7 gt/PMH, respectively. A total cut-and-haul cost of $23.46/gt was determined, and is higher than the regional average delivered price for in-woods chips.

Going forth, production studies are needed in more traditional PCT stands to gain better insight on the harvesting productivities and costs associated with utilizing PCT biomass since the stand used for this case study was at the upper age limit for typical PCT stands. Furthermore, alternative harvesting equipment configurations should be analyzed to investigate potential harvesting cost reductions. Lastly, since this study does not consider effects of stem removal on nutrient availability, soil disturbance, and other site characteristics, further work is needed to help analyze these effects.

ACKNOWLEDGMENTS

Virginia Department of Forestry

Virginia Tech Department of Forest Resources and Environmental Conservation

LITERATURE CITED

Biomass Magazine. 2015. 2015 U.S. Biomass Plants. Available at: http://biomassmagazine.com/plants/listplants/biomass/US/ [Last accessed: September 17, 2015].

Bolding, M.C.; Lanford, B.L. 2005. Wildfire fuel harvesting and resultant biomass utilization using a cut-to-length/small chipper system. Forest Products Journal. 55(12): 181-189.

Bolding, M.C.; Kellogg, L.D.; Davis, C.T. 2009. Productivity and costs of an integrated mechanical forest fuel reduction operation in southwest Oregon. Forest Products Journal. 59(3): 35-46.

Burkhart, H.E.; Haney, H.L.; Newberry, J.D. [and others]. 1986. Evaluation of thinning for reduction of losses from southern pine beetle attack in loblolly pine stands. Southern Journal of Applied Forestry. 10(2): 105-108.

Forisk. 2015. Available at: http://forisk.com/resources/resources-from-forisk-wood-bioenergy-us-free-summary/ [Last accessed: February 2, 2015].

Mitchell, D.; Gallagher, T. 2007. Chipping whole trees for fuel chips: a production study. Southern Journal of Applied Forestry. 31(4): 176-180.

Miyata, E.S. 1980. Determining fixed and variable costs of logging equipment. Gen. Tech. Rep. NC-55. St. Paul, MN: U.S. Department of Agriculture Forest Service, North Central Forest Experimental Station. 20 p.

Nowak, J.; Asaro, C.; Klepzig, K.; Billings, R. 2008. The southern pine beetle prevention initiative: working for healthier forests. Journal of Forestry. 106(5): 261-267.

Pan, F.; Han, H.S.; Johnson, L.R.; Elliot, W.J. 2008. Production and cost of harvesting, processing, and transporting small-diameter (≤ 5 in) trees for energy. Forest Products Journal. 58(5): 47-53.

Perlack, R.D.; Stokes, B.J., lead authors. 2011. US billion-ton update: biomass supply for a bioenergy and bioproducts industry. Oak Ridge, TN: United States Department of Energy, Oak Ridge National Laboratory. 235 p.

Staudhammer, C.; Hermansen, L. A.; Carter, D.; Macie, E.A. 2011. Wood to energy: using southern interface fuels for bioenergy. Gen. Tech. Rep. SRS-132. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 100 p.

Timber Mart South. 2014. Norris Foundation, University of Georgia, Athens, GA. 4th quarter. 44 p.

Tufts, R.A.; Lanford, B.L.; Greene, W.D. Burrows, J.A. 1985. Auburn harvesting analyzer. Compiler. 3(2): 14-15.

Watson, A.C.; Sullivan, J.; Amacher, G.S.; Asaro, C. 2013. Cost sharing for pre-commercial thinning in southern pine plantations: willingness to participate in Virginia's pine bark beetle prevention program. Forest Policy and Economics. 34: 65-72.