HARVESTING BIOMASS TO IMPROVE LOW-VALUE BEECH DOMINATED HARDWOOD STANDS IN MAINE

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ABSTRACT

Feller-buncher productivity and residual stand damage were evaluated for a mechanical whole-tree harvest removing pulpwood and non-traditional biomass (energywood) from natural hardwood stands dominated by small diameter, diseased, beech (*Fagus grandifolia* Ehrn.) in central Maine. Two trail spacings (18.3 m and 12.2 m) were tested to determine if modified harvesting practices could improve the productivity of a tracked, swing to tree, feller-buncher. Residual stand damage was evaluated following the harvest to assess the relative impact of harvesting and skidding operations at both spacings. Time studies were conducted on the feller-buncher to assess the influence of small-diameter stems and narrower trail spacings on the harvesting operation. Feller-buncher productivity did not differ significantly ($p = 0.48$) between the two trail spacings. Mean productivity (green tonnes per hour) was 74.2 using an 18.3 m spacing and 57.4 using a spacing of 12.2 m. Time study elements did not differ significantly between the two trail spacings (p-values > 0.05). The proportion of residual trees receiving one or more injuries ($\bar{x}$ = 34% at 18.3 m, $\bar{x}$ = 43% at 12.2 m) also did not differ significantly (p = 0.12) between the two trail spacing treatments. Based on the results of this study there seem to be no advantages to selecting one of the two trail spacing over the other.

INTRODUCTION

Recently, interest in using woody forest biomass as a renewable alternative fuel source in the United States has resurfaced. Currently low-value, small, defective trees, as well as previously unmerchantable species are becoming economically viable forest products as a result of whole-tree harvest technology and improved markets for whole-tree chips. Growing markets for non-traditional forest biomass (energywood) have the potential to assist landowners in improving the composition and quality of their stands by improving the economics of costly rehabilitation work. In Maine, a stand condition where a significant opportunity exists in this regard can be found on mid-site sugar maple (*Acer saccharum* Marsh.), yellow birch (*Betula alleghaniensis* Britt.) stands that were shelterwood harvested over the past 20 or more years and have become dominated by diseased beech (*Fagus grandifolia* Ehrn.). There is currently no financially feasible silvicultural approach to rehabilitating these sites by shifting the regeneration to maple and yellow birch; however, an integrated system of biomass harvesting and vegetation management may provide an economic means for landowners to rehabilitate these stands.

This article reports on the energywood harvesting phase of rehabilitating young beech-dominated hardwood stands in Maine. The purpose of this research was to investigate the influence of 18.3 m and 12.2 m trail spacings on a whole-tree energywood harvest operation.

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18.3 m was selected as a spacing used in whole-tree thinning operations in Maine. A narrower spacing of 12.2 m was selected to evaluate if feller-buncher productivity could be improved by limiting its movement to the harvest corridor, relying mainly on the boom reach to harvest the residual strips in between. An assessment of residual stand damage was used to determine the relative impact of the two harvest layouts.

METHODS

Three study blocks, each 1.2 ha (73.2 m x 165.0 m) in size, were established in natural hardwood stands dominated by small diameter, diseased beech trees in Township 32, in Hancock County, Maine. Blocks were located within 1,500 m of one another. Each of the three study blocks were divided in half (0.6 ha – 36.6 m x 165.0 m) and assigned one of two treatments; (*i*) mechanized whole-tree harvest using a trail spacing of 18.3 m (measured from trail centerlines), and (*ii*) mechanized whole-tree harvest using a trail spacing of 18.3 m. Trail spacings were established by using one trail in the center of harvest blocks assigned a spacing of 18.3 m, and three trails in harvest blocks assigned a spacing of 12.2 m. The harvest prescription for each block was to remove the existing beech-striped maple (*Acer pensylvanicum* L.) understory, including all stems >2.54 cm DBH, while leaving overstory sugar maple and yellow birch unless they were standing in the trail.

A preharvest cruise was used to assess stand composition (Figure 1) and biomass quantity. Twenty four, 0.002 ha fixed radius sample plot centers were established in each harvest block. All stems, including both live and standing dead, >2.54 cm at DBH within the plot were sampled. Species and DBH were recorded for each sampled tree. Total green tree weight estimates were calculated using species specific DBH-weight relationship equations developed by Young *et al*. (1980).

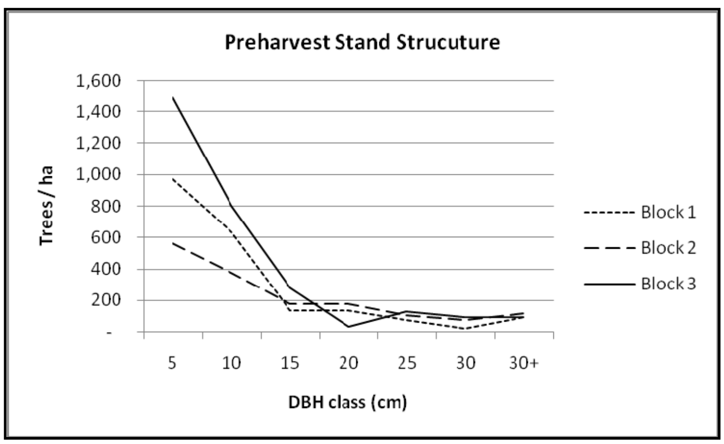

Figure 1. Preharvest stand structure of the three study blocks.

Harvest operations were conducted by a contractor hired by Huber Resources Corporation using a John Deere 853G tracked feller-buncher with an FS22 continuous type disk saw felling head. Harvest activities were recorded using two handheld digital video cameras so feller-buncher movements could be analyzed later. One camera was held inside the machine cab behind the operator to record machine movements associated with the felling head. The second camera was operated at a safe distance away from the machine to record machine movements associated with the carriage, cab, and boom. A post-harvest time study was conducted on each harvest block using the harvest videos and UMTPlus® time and motion study software (Laubrass Inc. 2006). The harvesting work cycle was divided into the following elements:

Productive movement: Begins when the feller-buncher starts to move (track movement), and ends when the harvester stops moving.

Selecting tree: Begins when the feller-buncher begins swinging and/or moving the boom towards the tree and ends just before the tree is cut.

Felling: Begins when the head begins cutting through the tree and ends when the stem has been accumulated (i.e. the accumulator grab arms on the head have secured the tree).

Bunching: Begins after the feller-buncher has cut the last tree and starts moving towards the twitch location and ends when the bunch is dropped from the felling head.

Time study analysis began when the feller-buncher started cutting within the harvest block and ended when it exited the harvest block. The same researcher conducted the time studies for all blocks. All analysis is based on productive machine hours.

Energywood was the primary product from this harvest; however, the contractor also sorted out pulp quality logs. Each truckload of pulp was weighed at the mill to determine the total tonnage removed from each block. Energywood produced on each block was estimated by subtracting pulpwood weights and estimates of residual biomass based on post-harvest cruise data from preharvest biomass estimates.

Following harvesting and skidding operations, residual trees were examined for damage. A complete tally of all standing residual trees 2.54 cm or greater at DBH was conducted within each harvest block.

Analysis of variance was used to determine whether the harvesting treatments were statistically different. All statistical analyses were performed using a significance level of $\alpha = 0.05$. The Shapiro-Wilk's W-statistic was used to test the null hypothesis that samples came from normally distributed populations. A Brown-Forsythe test was used to verify the assumption of equal variance of the two samples.

RESULTS

Production studies

Overall, total harvesting times varied from 1.9 hours (blocks 2a and 2b) to 2.6 hours (block 3a), but there were no significant ($F = 0.80$, $p = 0.4204$) differences in total harvesting time between treatments. On average, blocks harvested using the wider trail spacing harvested 16.8 more tonnes

Table 1. Summary of total productive harvest time (in decimal hours), and productivity in tonnes/hr and stems/hr by harvest block and treatment.

Harvest Treatment	Total harvest time, (h.hh)	Productivity, tonnes/hr	Productivity, Stems/hr
18.3 m trail spacing			
1a	2.08	58.1	355
2a	1.85	106.9	292
3b	2.31	57.7	358
Avg.	2.08	74.2	335
12.2m trail spacing			
1b	2.39	36.4	381
2b	1.91	83.5	325
3a	2.59	52.3	361
Avg.	2.29	57.4	356

of total biomass (pulpwood and energywood) per productive hour than blocks harvested using the narrower trail spacing; however, the difference was not significant ($F = 0.53$, $p = 0.5059$). The highest feller-buncher productivity (106.9 tonnes/productive hr) was achieved on block 2a using the wider trail spacing, and the lowest productivity (52.3 tonnes/productive hr) occurred on block 1b using the narrower trail spacing. The number of trees felled per productive hour varied by harvest block from 292 – 381, but also was not significantly different between treatments ($F = 0.59$, $p = 0.4862$).

Similar proportions of time were allocated to each of the four work tasks tracked in the time study (Figure 2). There were no significant differences in total bunching times ($F = 0.94$, $p = 0.3876$), moving times ($F = 0.28$, $p = 0.4082$), or selecting times ($F = 0.54$, $p = 0.5042$) between treatments. Total felling time composed an insignificant proportion (less than 2%) of the total harvest times and was not analyzed.

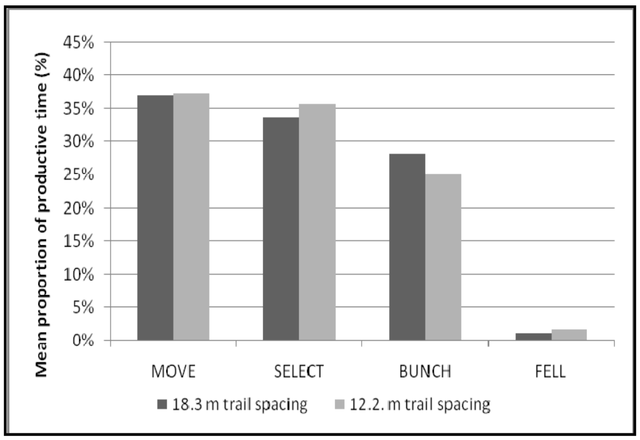

Figure 2. The average proportion of total productive time allocated to the feller-buncher work tasks move, select, bunch and fell by treatment treatment.

Stand damage studies

At least 30% of the trees in each block were damaged to some degree. Out of a total of 595 residual trees assessed for damage across the three harvest blocks treated using the 18.3 m trail spacing, 200 (34%) were found to be injured. Mean diameter of trees wounded was 4.1 cm (± 4.4 cm). The blocks treated with the 12.2 m trail spacing had a higher proportion of residual trees injured (163 out of 376, 43%); however, the difference was not significant ($F = 3.84$, $p = 0.1217$). Half of the residual stems on blocks 2b and 3a were injured. Mean diameter of trees wounded at this spacing was 6.6 cm (± 5.5 cm). 37% and 35% of all injured trees had observed root and/or crown damage for the wider and narrower trail spacing, respectively.

Only a small proportion of the stems wounded in either treatment received multiple wounds and the average number of injuries found on trees wounded multiple times was relatively low. At the wider trail spacing the mean number of wounds per injured tree was 1.2 with over 80% of injured trees receiving only one wound. On blocks treated with the narrower trail spacing, the mean number of wounds per injured tree was 1.3, with an average of 74% of injured trees receiving only one wound. Less than 12% of wounded trees on any of the six harvest block received three or more wounds.

DISCUSSION AND CONCLUSIONS

Reducing skid trail spacing to a 12.2 m interval for the most part limited feller-buncher activity to the trail corridor while the 18.3 m spacing required the feller-buncher to track short distances off of the trail in order to harvest the block. Theoretically, the narrower spacing allowed trees to be harvested from the residual strips between trails much faster, but required that the operator spend more time harvesting corridors to the back of the block. Twice as much time should have been dedicated to harvesting trail corridors at the narrower trail spacing in this study. On the other hand, while the wider trail spacing theoretically should have reduced the amount of time dedicated to harvesting trail corridors, more time should have been required to move from bunching sites on the trail out to the block boundaries and back. Based on the results of this study these trade-offs proved to be relatively equal, resulting in insignificant differences in productivity between the two treatments.

The insignificant differences in feller-buncher productivity between the two trail spacings cannot be explained by the time studies that were conducted as individual elements of the harvest work cycle also did not differ significantly between the two treatments. Further investigation of the actual layout of harvest trails within each block and a more detailed time and motion study may help in forming an explanation.

Although no significant differences were found between mean productivity using the 18.3 m and 12.2 m trail spacings, it is important to note that productivity was considerably greater in the blocks harvested at the wider trail spacing than the narrower trail spacing. In each of the three harvest block pairs (a & b) the block harvested using the wider trail spacings had productivity levels 10 to 60 percent greater in all cases than the block treated with the narrower trail spacing. The ANOVA test may not have been sensitive enough to conclude that the difference in productivity was statistically significant due to small sample size and the amount of variation in productivity levels between harvest blocks in each treatment.

Proportions of residual stand damage were comparable with those reported in other mechanized whole-tree partial harvests in northern hardwood stands (Kelley 1983, Nichols *et al*. 1993). Although not significantly different by treatment, the highest overall proportion of injured trees occurred in block 2b treated with the narrower trail spacing, while the lowest overall proportion occurred in block 2a treated with the wider trail spacing.

While Ostrofsky *et al*. (1986) found that residual stand damage levels were significantly different between trail spacings of 20 m and 40 m, it may be that the substantially narrower trail spacings used in this study were too similar to result in different damage proportions. It is also possible that at these narrow trail spacings the relationship between distance from trail and probability of being wounded becomes less distinct. Similarities in proportions and character (i.e. height above ground, area, severity) of residual damage among treatments in this study should be somewhat expected since blocks were harvested and yarded using the same machines, operators, and harvesting method. Based on the results of this study we cannot conclude that there are any advantages to selecting one of the two trail spacing over the other.

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