PRODUCTIVITY OF A SMALL CUT-TO-LENGTH HARVESTER IN NORTHERN IDAHO, USA

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Abstract
The application of small harvesters in harvest operations in forest stands composed of small-diameter trees is of increasing interest to natural resource managers; this interest is due to the efficiency and cost effectiveness in harvesting of small diameter trees. This paper presents research regarding the productivity of a Neuson 11002 HV harvester in a clearcut/restoration treatment of a Douglas-fir tussock moth damaged stand, and the investigation of the influence of tree branch characteristics upon harvester productivity. Tree heights, diameter at breast height (DBH), species, branch size and branch interval data were collected, to investigate the effect of these characteristics on productivity. A detailed time study was conducted on video footage of the harvest operations, to determine machine productivity. Production for the clearcut is estimated at $5.43/m^3. Analysis suggests that branch characteristics are influential upon tree harvest time, with branch size of high statistical significance.

Keywords: small harvester, branch size, branch interval, branch characteristics, Neuson 11002 HV, Logmax 3000, clearcut, restoration cut.

Introduction

While small harvesters have been in use in the forests of Europe and the North east of North America for some time, their use in the Western US is relatively new. The interest in the application of such machines has been initiated by the need to thin second growth forests (Kellogg and Bettinger 1994), and by the identification of 12 million hectares of high density/ high stem count forest stands as high priority for fuel abatement treatment in the western states of the US (Vissage 2003).

Small harvesters, designed to harvest smaller diameter trees, offer the natural resource manager a machine of lower capital cost. The work of Ewing (2001) on a series of small, tracked harvesters confirmed that these machines offered reasonable efficiency, lower capital cost, and cost effective operation. Ewing observed a production rate of 67 trees per productive machine hour (PMH), with a volume production of 14.1m^3/PMH, with direct operating cost of C$96/PMH, and unit production cost of C$7.00/m^3 in a 34% volume removal thinning of a mixed-wood forest stand with 1340 stems/ha, 161m^3/ha and 16cm mean diameter at breast height (DBH). Rummer (2002) investigated the use of the Neuson 11002 HV in a lodgepole pine thinning trial. The results were a productivity of 4.2m^3/ SMH, with a cost per unit production of $16.60/m^3, in a stand of 10cm mean DBH (Rummer 2002).

The researchers noted that tree branch characteristics are highly influential upon tree processing times. The influence of branch size and interval were identified by Drolet *et al.* (1971) in their investigation of the effect of branch characteristics of jack pine (*Pinus banksiana*), black spruce (*Picea mariana*) and balsam fir (*Abies balsamea*) on mechanised delimbing. Drolet *et al.* (1971) found that delimbing of 95% of all trees studied would be possible with a machine capable of removing branches with a branch stub area of 51.6cm^2

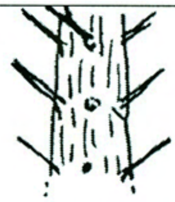
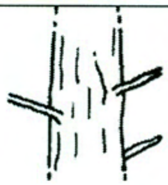
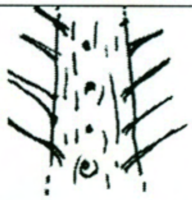
(8.1cm diameter branch) at a 7.6cm interval, and a 77.4cm^2 branch stub area (9.9cm diameter branch) at 30.5cm interval. In contrast to the substantial machine suggested by the results of the above study, the small harvester design imposes design limitations on dimensions, machine weight and horsepower, resulting in reduced power at the harvester head, diminished delimbing capabilities and ability to handle large trees. Thus, it might be hypothesised that the contributing effect of branch size and interval upon the processing time of the harvester will increase with decrease in harvester size (in terms of available horsepower, hydraulic systems etc.).

The objective of this research was to investigate the productivity and cost effectiveness of the Neuson 11002 HV harvester, and the influence of branch size and branch interval upon the time taken to process harvested trees.

Study Methods

The Neuson 11002 HV harvester is a purpose built, tracked-based harvester, manufactured in Austria. The harvester undercarriage is derived from a D4 caterpillar carriage, on which is mounted the leveling harvester body and 76 kW (102hp) engine. The harvester is equipped with a Patu parallel action crane (9.1m reach), and mounts a Logmax 3000 harvesting head, and is capable of harvesting trees up to 50 cm diameter at the base. Machine slope capabilities are specified by the manufacturer to 50% (Rocan 2003).

Figure 1: Harvester branch assessment key.

Branch size code	Description	Appearance	Branch interval code	Description	Appearance
0	Fine Branches < 1.2cm (½ inch) diameter (Includes brittle dry branches and fine live branches.		1	0.9m (3 feet) or greater branch interval	
1	Light Branches 1.2 to 2.5 cm (½ to 1 inch) diameter		2	0.45 to 0.9 m (1 ½ to 3 feet) branch interval	
2	Sturdy Branches 2.5 to 5 cm (1 to 2 inch) diameter		3	< 0.45m (1 ½ feet) branch interval.	
3	Heavy Branches > 5cm (2 inch) diameter		**How to use branch assessment key:** Branch size code and branch interval code are added to give total branch score; e.g. branch size code 2 and a branch interval code 1, total branch score of 3. (Exception: branch size code 0, default total branch score of 0.)		

To examine the effect of tree branches upon harvester productivity a branch classification key was developed that would allow rapid assessment of branch characteristics (Fig. 1).

Prior to the start of harvesting operation 500 trees within the trial were assessed for tree species, DBH, tree height, proportion of clean bole, proportion of dead crown, proportion of live crown, branch size, branch interval (Fig 1.), and tree form (sweep, crook, fork etc.). All trees were marked with a unique number, for reference by the observer. Tree details were entered into a spreadsheet, and analysed in that format. Tree volumes were calculated using formulae prescribed by Wykoff *et al.* (1982).

The Neuson Harvester was studied in operation in the University of Idaho Experimental Forest, in a 3.25 ha clearcut unit. The stand was composed of 66% Douglas-fir (*Pseudotsuga meziesii* var. *glauca*), 16% grand fir (*Abies grandis*), 16% ponderosa pine (*Pinus ponderosa*), and 2% western larch (*Larix occidentalis*). Harvest was scheduled to salvage trees severely defoliated by Douglas-fir tussock moth (*Orgyia peudotsugata*). Stand volume was estimated as 253 m^3/ ha, 23cm estimated mean DBH, and a harvest DBH range of 12.5 to 45cm. Stand density was approximately 710 stems/ha of 12.5cm DBH and greater. Slopes on the clearcut site varied from 5 to 36%, with a mean of 18%. The silvicultural prescription for the clearcut was the harvest of the unit, retaining stems of ponderosa pine and western larch for aesthetic/stand structural reasons.

Logging operations were video taped using a video camera equipped with a telescopic lens, mounted on a light tripod. Tree numbers were reported to the observer by the harvester operator via a two way radio equipped with a voice activated microphone, the number then being repeated into the video camera microphone. A time study was then conducted on the recorded operations using a Husky *feX*21 field computer, equipped with a time study program (Wang *et al.* 2003). During the time study, density of brush treated by the harvester at each tree was assessed, being described as nil, light, moderate or heavy, and a nominal brush code allocated (0 for nil, 1 for light brush, 2 for moderate brush, up to a score of 3 for heavy brush).

Machine owning and operating costs were calculated using standard machine rate analysis (Miyata, 1980); assumptions being U$290,000 delivered cost, 2000 Scheduled Machine Hours (SMH), estimated salvage price of 20% after five years, fuel consumption of 13.25 litres/hour, maintenance and repair at 70% of depreciation, interest rate of 11%, insurance cost of 4%, taxes estimated at 1%, fuel cost estimate $0.27/litre, labour cost of $25/hour with benefits of 40%.

A non-parametric statistical analysis, using the Mann-Whitney test, was conducted on the effect of branch size code, branch interval code, and total branch score on tree process time, to assess the significance of these factors on process time. Stepwise analysis of the dependent (travel time and head placement, brushing, felling, and processing) and independent variables (travel distance, brush density, clean bole, DBH, tree height, tree volume, branch size code, branch interval code, total branch score) was conducted, to assess the significance of the independent variables in the operation, and to construct a predictive equation for tree harvest time.

Results and Discussion

Mean productivity of the Neuson was 68.5 trees /PMH or 19.17m^3/ PMH. Mean tree size harvested was 0.28 m^3. Cost of machine operation was $94.82/ SMH. Estimated production of 17.45m^3/ SMH resulted in a calculated production cost of $5.43/$m^3$. Utilisation was noted as 91% over the duration of the study. Delay free cycle time components were summarised as:

11% brushing, 37% machine movement and locating the harvester head on the tree, 11% cut and fall, and 47% processing (delimbing and bucking).

Machine operation per unit production is relatively competitive. Data for a large harvester (Valmet 500T) in a commercial thinning estimated production as 21.1m^3/SMH, \$104.54/SMH owning and operating cost, and cost per unit production of \$5.47/m^3, for a thinning with trees of 0.63m^3 mean volume (Turner and Han 2002). When compared to the data generated by the study, the costs for the operation of the Neuson are quite favourable, given the smaller trees which the Neuson was harvesting.

The unit production cost for this study was notably low when compared to the results of the study conducted by Rummer (2002). It might be argued that the very high proportion of small diameter trees in Rummer's study, and the desire to recover the greatest proportion of material from these smaller diameter classes, had an adverse impact upon the productivity of the harvest operation.

$$\text{Delay free cycle time (seconds)} = -3.4968 + 2.5398 \cdot \text{Travel distance (m)} + 1.7892 \cdot \text{DBH (cm)} + 19.0512 \cdot \text{Brush code} + 4.2932 \cdot \text{Branch size code}$$

Adjusted $R^2 = 0.529, \quad n = 397$

Average delay free cycle time to harvest a tree was 52.6 seconds, with mean values of 2.28m travel distance, 21.6cm DBH, 0.3 brush code, and 1.3 branch size code. The effect of travel distance, brush code, DBH and branch size code were all found to be highly significant ($\alpha = 0.05$, $p < 0.05$). The results of the Mann-Whitney test revealed that the branch size code had high statistical significance, branch interval code showed no significant effect on process time. Total branch score, which accounts for both branch size and branch interval, demonstrated marginal significance, due to insignificance of branch size code upon process time.

The potential cause of low statistical significance of the total branch score is the relatively low proportion of trees with short branch interval (high branch interval code) and large branch sizes (high branch size code) were observed to account for much of the variance noted in the analysis. Thus the trees that were observed to take the longest time to process impacted the correlation between total branch score and tree process time, and also impacted the tree harvest time.

A large amount of variation in processing method was noted by the researchers during the time study, and this too might be suggested as a cause of variance in tree harvest cycle time. This variation was caused by the operator making use of the full rotation of the harvester, and reach of the parallel action crane, in the handling of unprocessed and processed trees. This amount of movement was greatest with smaller, lighter, trees, and diminished with increase in tree size. In addition, the desire of the operator to optimise the product from the trees harvested was observed to cause increased handling during processing.

It must be noted that the harvester operator in this study was not employed full time in logging activities, though he was experienced in the operation of the machine. As such, the observed productivity of the harvester in the operation might be considered an underestimate of the full productive potential of the machine, an observation supported by the findings of Ewing (2002) in his study of small harvesters

Conclusion

Analysis of the data generated in this study suggests that the productivity of the Neuson harvester is significantly affected by the harvester travel distance (as a function of harvest stem density), tree DBH, and brush density (as an effect on time spent in brush clearance). Where these factors combine to adversely affect harvester productivity, such as the study conducted by Rummer (2002), productivity of the harvester is diminished, and financial viability of the operation is impacted. However, the rate of production observed with the Neuson 11002 HV harvester in this study suggests that this machine can be a competitive and financially viable harvester when used in stands composed of smaller trees. This would allow the conclusion that similar forest stands in North America might be successfully harvested using this machine.

The investigation into the effect of branch characteristics upon tree processing and total harvest time strongly suggests that branch size is of significant influence upon tree process and harvest time, and branch interval has no statistically significant effect. This result indicates that further investigation of the effect of branch characteristics is merited.

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