Using a harvester simulator to evaluate work methods in thinning

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SUMMARY

Biomass harvesting using multi tree handling heads has increased harvester productivity using the traditional selective work methods. New work methods adapted to the new technology can further improve productivity. One new method is “thinning in sections”, where the work is concentrated to sections perpendicular to the strip roads. It reduces the amount of boom and machine movements and allows the operator to concentrate on one small section at the time which reduces operator work load. Operators using the method states that their stress levels are lower and that productivity increased since they started to use the method. To study differences between “thinning in sections” and operators previous work method a study was set up in a simulator environment. Three experienced machine operators were studied in a harvester simulator where they thinned the same stands using both work methods. First their performance and mental loads were measured with their ordinary work method; thereafter they were trained in “thinning in sections” and used it in their daily work for two months before a final evaluation was done in the simulator. To measure perceived workload NASA Task Load Index test was used. The new method increased productivity (+31 % and +51 %) for the two operator with the initially lowest productivity, while the productivity of the high performing operator not was affected by the change in work method. The operators perceived work load did not significantly change when applying “thinning in sections”.

INTRODUCTION

The work load when operating a harvester is generally high. There are many decisions to make in a short time. Thinning is seen as a more demanding work due to the fact that you have to decide which trees to harvest and at the same time avoid damaging remaining stand during operations. Among thinnings the general principle is that denser stands result in higher work load (Gellerstedt 1993). As a result the operator has a considerable influence on both productivity and harvesting quality and there is a strong positive correlation between these two parameters (Sirén 2001).

Biomass harvesting using multi tree handling heads has increased harvester productivity using the traditional selective work methods. When new technology is introduced it is often followed by a development of new techniques adopted to the technology. When working with multi tree handling heads it is possible to use the same techniques applied with traditional felling heads. However, the introduction of multi tree handling heads and an increasing interest in small tree harvest of energy assortments have raised questions about how to best apply them (Belbo 2011). Work methods adapted to the new technology has potential to further improve productivity.

One improved method is “thinning in sections”, where the work is concentrated to sections perpendicular to the strip roads (Anon. 2014). This method is mainly adapted for early thinning where the number of stems to be harvested is high at the same time as the incomes from each tree is low. This calls for a work method where many decisions need to be made in a short time, risking operator fatigue and a risk of sub-optimal choice of harvested trees.

Therefore the method is intended to reduce the amount of boom and machine movements at the same time as it allows the operator to concentrate on one small section at the time which should reduce operator work load. Since the work mainly is done in sections perpendicular to the strip road this concentrates the boom movements in space as well as reduce the amount of boom movement needed and thus it should reduce fuel consumption and risk of damaging remaining stand.

The method has been put into use by several Swedish forest companies but a scientific evaluation have not been done until now. Evaluating the effect of a new work method is difficult since two demands has to be met. 1) the evaluations has to be done under as identical stand conditions as possible, and 2) the operators has to become skilled with the new method so that the comparison is not affected by learning effects. The first demand can be met by doing the studies in a simulated environment where the same stands can be harvested multiple times (Fridley et al 1982). This results in almost the same absolute performance and even more consistent relative performance in comparison to in field studies of forest operations (Ovaskainen 2005). The second demand has to be handled by giving the operator enough time to get experienced with the new method.

A learning curve describes the increasing performance over time. The performance initially increase and an operator can be regarded as “experienced” when more training has almost no effect on performance. The shape and slope of the curve differ between operators but the normal harvester operator reach top performance in 6-12 months (Purfürst 2010). Fully trained operators also have a learning effect when entering new machines or applying new techniques. Von Bodelschwingh and Pausch (2003) concludes that operators entering a new machine need 20 days to attain full performance. Höllerl (2005) examined the effects of altered controls and found that operators need about four weeks to reach their previous level.

Since “thinning in sections” is developed to increase performance and reduce work load there was two aims for the study:

- Does applying “thinning in sections” affect harvesting performance?
- What effect does the work method have on operator work load?

METHODS & MATERIALS

To determine effects on productivity and work load caused by the work method, three experienced harvester operators were studied first when using their normal work method. Thereafter they were trained in “thinning in sections” and studied when they had two months experience using the new method. The studies were done using t the harvester simulator in Troëdsson Forest Technology Laboratory.

The operators had been working in harvesting between six and eighteen years and all of them worked in teams where all operators take turns operating both harvester and forwarder.

All operators were studied when thinning two simulated stands, stand A and B (table 1). Both were 30 by 30 meters and resembles different stages of normal Swedish early thinnings in pine stands. The machine simulated was a Komatsu 911 equipped with LogMax 4000b multi-tree harvesting head.

Table 1. Stand data for simulator stands

	Stand A	Stand B
Stems ha^{-1}	1 978	2 144
Average DBH (cm)	7,0	8,0
Average height (m)	9,9	10,2
Average stem volume (dm^3)	24,4	33,5

The operators spent three days in the simulator with different aims. The first day was spent on practicing the controls and adapting to the simulator environment. The second day, they made three thinnings of each stand using their work method of choice. After this the operators were instructed on “thinning in sections” and encouraged to apply it to their daily work. The third day, which took place two months after the instructions, the operators made three thinnings of each stand applying “thinning in sections”.

Continuous time studies were done of the harvesting work. DBH was registered for each harvested tree to calculate harvested volume. Since the stands were identical from one repetition to the next and there was uncertainties in the simulator measurement of stem diameter, the number of stems harvested per efficient work hour was used as measurement of harvesting performance.

To assess subjective work load NASA Task Load Index was used (Anon. n.d.). Each operator was given the forms after the second run of each stand on both of the evaluation days in the simulator.

The statistical analysis was done using SAS Enterprise Guide 6.1.

None of the operators experienced a significant learning effect regarding the simulator environment during the two days of work method studies. A statistical analysis concluded that the order of the runs had no correlation with the performance.

RESULTS

The average thinning took 17 minutes and the performance varied from 132 to 264 harvested stems per hour (fig. 1). Average performance using the initial work method was 182 harvested stems per hour while when applying thinning in sections the average performance was 228 harvested stems per hour.

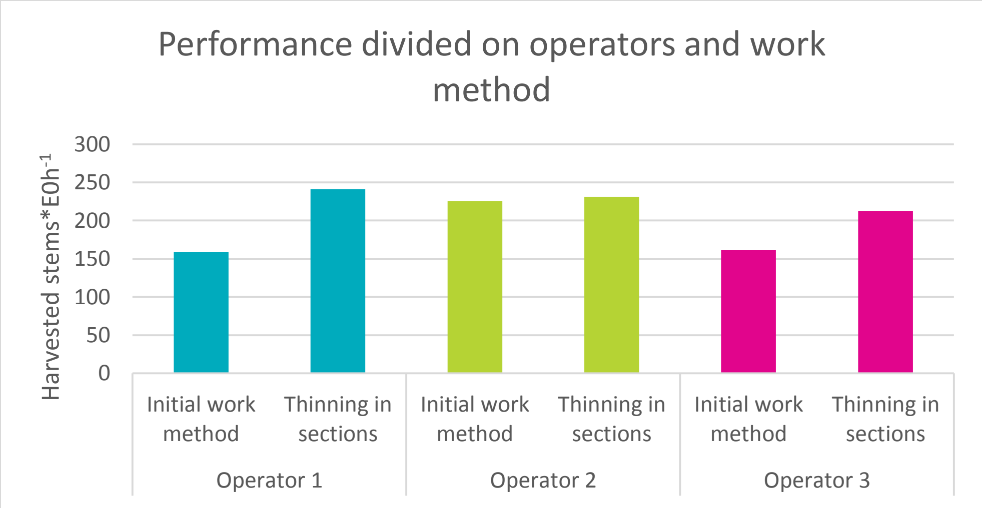

Figure 1. Performance (harvested stems*E0h^{-1}) in thinnings separated on operator and work method.

The statistical analysis (table 2) concludes that the only significant effect on harvester performance was operator, work method and their interaction. Worth noticing is that stand had no significant effect on performance.

Table 2. GLM (General Linear Model)-analysis of parameter effects on harvesting performance (harvested stems*E0h^{-1})

	Type III SS	Mean square	F-value	Pr > F
Operator	11 203,3	5601,6	14,86	<,0001
Work method	19 535,5	19 535,5	51,82	<,0001
Stand	0,1	0,1	0	0,9899
Operator*work method	9470,9	4735,4	12,56	0,0001
Operator*Stand	867,1	433,5	1,15	0,3311

R-square	Coeff var	Root MSE	Mean stems*E0h^{-1}
0.79	9.43	19.42	206

This combination of variables explains a large part of the variation (table 2) and only leaves the question of closer examination of the effects on performance when applying “thinning in sections”.

The choice of work method has had a significant effect on performance for two of the operators, operator 1 and 3 (table 3). Operator 2, however, had an initially high performance and did not increase this performance when using “thinning in sections”. When analysing the least squares means for the effect of operator and work method (fig. 3) some differences are revealed. There was a difference in operator performance when they were using their initial work method, but when applying “thinning in sections” there is no statistically significant difference between the three operators.

Table 3. Least square means of operator performance (harvested stems*E_0h^{-1}) separated on operator and work method. Values within columns followed by the different letters are significantly separated on the 5% level, as are values within rows followed by different greek letters.

Operator	Initial work method	Tinning in sections
1	159aα	241aβ
2	226bα	231abα
3	162aα	213bβ

While using the initial work method the operators used multi tree handling in 28 % of the crane cycles and when applying thinning in sections multi tree handling was used in 24 % of the crane cycles. The relative time spent in the harvest was divides roughly the same between the different work elements when using the two work methods (table 4) The only exception was that Operator 3 spent less time accumulating and more time felling and processing when he used “thinning in sections”.

Table 4. Relatvie time consumption of different work elements divided on operator and work method

	Operator 1		Operator 2		Operator 3	
	Initial work method	Thinning in sections	Initial work method	Thinning in sections	Initial work method	Thinning in sections
Boom-out	34 %	31 %	28 %	24 %	26 %	26 %
Accumulation	23 %	25 %	27 %	30 %	33 %	25 %
Felling/processing, boom-in	38 %	41 %	41 %	43 %	23 %	41 %
Movement	5 %	3 %	4 %	3 %	4 %	7 %

The self-assessment done using NASA-TLX showed no significant effect on the operators perceived work load when changing work method.

DISCUSSION

Applying “thinning in sections” resulted in a significantly higher performance for two operators (+31 % and +51 % compared to the initial work method). The third operator had an initially high performance and the change of work method had no significant effect on his performance. When applying “thinning in sections” there was no significant difference between the operators’ performance. These effects were observed after two months of applying “thinning in sections”. If these operators are to be considered have worked long enough with the new work method to become experienced or not can be argued. The time it takes to reach previous performance when entering a new machine is about 20 days (Von Bodelschwingh & Pausch 2003) and new controls require about four weeks of training before original performance is attained (Höllerl 2005). As the studied operators had worked as harvester operators for years it is likely that they will become experienced to a new work method in about the same time or at least less than the two months practice they had before the study of their performance when applying “thinning in sections”. Especially considering that a new harvester operator reach a steady performance after 6-12 months (Purfürst 2010).

The work method “Tinning in sections” is designed for use in dense thinnings. An essential part of this work is an effective application of multi tree handling. The operators in this study used multi tree handling to a relatively small extent. This could be explained by the fact that the operators expressed that the simulator environment proved difficult for multi tree handling due to a different “feel”. Given that “thinning in sections” derives from a high degree of multi tree handling, the potential of the work method could be greater than implied by the study.

The two main goals of the work method “thinning in sections” are to increase performance and reduce work load. There is a potential to increase operator performance when applying “thinning in sections”, especially for operators with a low initial operator performance. An operator with a low performance has probably not developed a suitable work method for these dense thinning stands and instead use a method that works well in ordinary thinning of less dense stands. “Thinning in sections” provide the operators with a standardised and rational method for selection of trees and a work pattern adapted to the selection. If the operator already have an efficient method for working in dense stands, the effects of the new work method can be expected to be small. Applying “thinning in sections” do not affect the perceived work load of the studied operators.

To further validate the effects of “thinning in sections” on performance and work load further studies are recommended. They should include stands with both higher and lover stand densities. Furthermore, future studies could gain from adding more methods for measuring work load.

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