Advantage
Restricted to FERIC Members and Partners Vol. 5 No. 37 September 2004

Contents

Comparison of two- and three-machine cut-to-length systems in harvesting small-dimension softwoods

Author
Deric Hillman
Eastern Division

Abstract

In stands with small stems (<0.10 m³/stem), the two-machine cut-to-length harvesting system (a single-grip harvester paired with a forwarder) generally has low productivity. In this situation, a multi-stem head should be used to improve the system's productivity. However, at high densities (>1800 stem/ha), even multi-stem heads may not be enough to make the two-machine system viable. This report identifies the conditions under which a three-machine system (a feller-buncher teamed with an at-the-stump processor and a forwarder) would be viable based on the results of four recent studies as well as on data from past FERIC studies. The report also discusses the productivity of processor operators as a function of their number of years of experience.

Keywords:

Shortwood harvesting, Three-machine system, Two-machine system, Comparison, Productivity, Costs.

Introduction

Shortwood (cut-to-length) harvesting is attractive from the viewpoint of product quality and the environment. However, the cost of harvesting with a single-grip harvester is high in marginal stands. The use of a multi-stem head can improve the single-grip harvester's productivity in stands with low-volume stems (Gingras, 2002). However, when the density of stems becomes too high (>1800 stem/ha), the operator has difficulty selecting merchantable trees from amidst the many unmerchantable stems. Under such conditions, an increasingly popular solution consists of using a feller-buncher to fell the wood, which is then processed using an at-the-stump processor before extraction to roadside; this is known as the "three-machine system".

Based on four recent studies and on data from past FERIC studies (included in FERIC's *Interface* harvesting-simulation software, which utilizes the data from all of FERIC's previous field studies), this report describes the conditions under which it is appropriate to use the two- and three-machine systems. A costing model for the two systems was established using the data from the four studies and from *Interface*, thereby permitting a comparison of wood costs at roadside in both systems. The data from the recent studies were also used to update the *Interface* database and validate the portions of the curves for stands with low-volume stems (<0.10 m³/stem), and also to evaluate the impact of operator experience on the choice of a processor-based harvesting system.

Figure 1. Feller-buncher working in a high-density stand (>1800 stems/ha) with small stems (<0.10 m³/stem).

Operations studied

Table 1 summarizes the sites and operations that we observed, as well as the models of processing heads used in each operation. In each case, the site conditions were favorable (CPPA terrain class 1.1.1).

Results

Three-machine system

Feller-buncher productivity under the study conditions averaged approximately 24 m³/PMH. Because of its ability to quickly brush unmerchantable stems, the feller-buncher allows the three-machine system to remain productive despite the low mean stem volume and the high stand density (Figure 1). The observed feller-buncher productivities all followed the productivity curve generated by *Interface*. Thus, this curve was used to determine the cost of the felling phase in the three-machine system.

The data obtained for the at-the-stump *processor* validated the *Interface* curve for stems of 0.10 m³/stem and up, as shown in Figure 2., The data also strengthened the *Interface* curve for small stems (0.05 to 0.10 m³/stem), for which data had been lacking.

Figure 2. Productivity data for at-the-stump processors, and the *Interface* curves before and after the addition of the new data to the FERIC database.

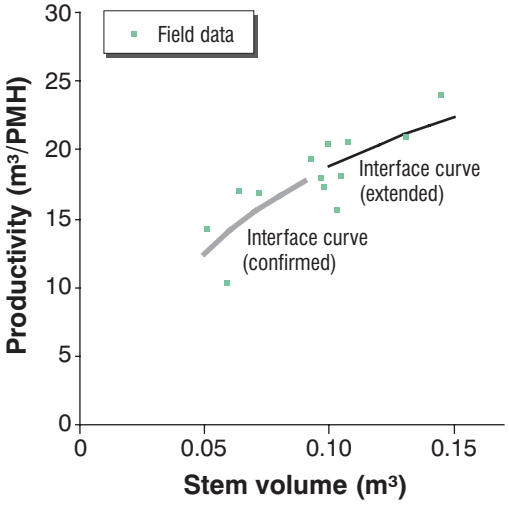

Table 1. Description of the four operations that FERIC observed

	Type of stand			Processing head
	Species	Density (stem/ha)	Volume/stem (m³/stem)	Processing head used
Ontario (northeast)	Pine, spruce, aspen	800	0.15 to 0.25	Waratah 616 (both processing and felling plus processing)
Québec (northwest)	Pine, spruce	800 to 1000	0.10 to 0.15	Métal Marquis and modified Logset (only in processing)
Québec (northeast)	Spruce, Fir	1300	0.09 to 0.13	Métal Marquis (only in processing)
Nova Scotia (east)	Fir	≥1800	0.06 to 0.12	Logmax 750 (both processing and felling plus processing)

Forest Engineering Research Institute of Canada (FERIC)

Find us online! www.feric.ca

Eastern Division and Head Office
580 boul. St-Jean
Pointe-Claire, QC, H9R 3J9
☎ (514) 694–1140
(514) 694–4351
admin@mtl.feric.ca

Western Division
2601 East Mall
Vancouver, BC, V6T 1Z4
☎ (604) 228–1555
(604) 228–0999
admin@vcr.feric.ca

Publications mail #40008395 ISSN 1493-3381

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For the *shortwood forwarders*, the productivity data we obtained were comparable whether the machines were working in the two- or three-machine system. For an average extraction distance of 150 m in a typical stand with a density of 1000 to 1300 stems/ha and a mean volume of 0.10 m³/stem, the forwarder's productivity was around 25 m³/PMH in both systems. This productivity was thus used to establish the forwarding cost in both systems.

Two-machine system

Our observations of the *single-grip harvester* took place in the same operations as in the three-machine system. To accomplish this, we asked the processor operators to work in a harvester mode (both felling and processing), when the head configuration permitted this. Most of the data obtained in typical stands, with a density of around 1000 to 1300 stems/ha and stem volumes of around 0.10 m³/stem, followed the *Interface* curve. However, the productivities observed in very dense stands (>1800 stems/ha, with volumes less than 0.10 m³/stem) were lower than those predicted by *Interface*. For example, at 0.05 m³/stem, previous versions of *Interface* indicated a productivity of 8 m³/PMH, versus the value of 2.3 m³/PMH observed in the present study. This suggests that in high-density stands of low volume trees, the use of single-grip harvesters is not viable.

Comparison of the production costs in the two systems

Using the updated *Interface* curves, we were able to compare the production costs at roadside between the two- and three-machine shortwood system (Figure 3).

Figure 3 shows that at a mean volume of 0.15 m³/stem and above, the *direct* costs of the two systems are nearly identical (at around $14/m³ at roadside, *excluding* general costs such as travel, accommodation, a risk allowance, and profits). In contrast, at mean stem volumes less than 0.15 m³/stem, it would be better to use the three-machine system.

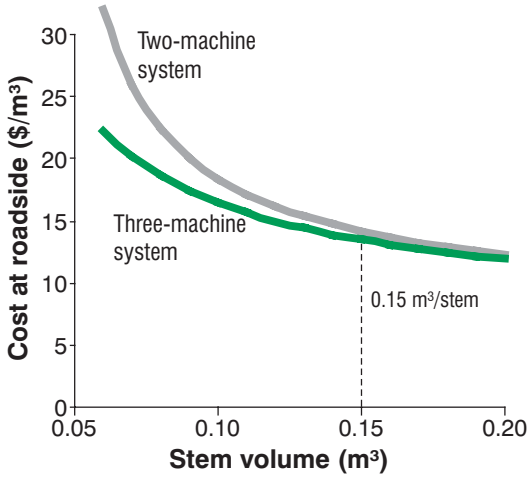

Figure 3. Comparison of the direct harvesting cost at roadside in the two- and three-machine systems.

Effect of operator experience on processor productivity

The productivity of operators with less than 1 year of experience was generally lower than that of operators with more than 2 years of experience. At a mean volume of 0.10 m³/stem, the average productivity of operators with less than 1 year of experience was around 15 m³/PMH, versus 18 m³/PMH for more experienced operators. The data also indicated that there appears to be no significant productivity difference between operators with more than 2 years of experience. It's worth noting that the operators with less than 1 year of experience using a processor, but who had formerly worked for many years on other forestry machines, were more productive than the average for this class of operator.

Implementation

Selecting a new harvesting system represents a substantial investment. Before requesting that your contractors purchase a specific type of equipment, it's important to consider the consequences and to consider the implications of changing the harvesting system based on the anticipated operating conditions for a relatively long period into the future. The need to train workers to use the new equipment means that it can take a few years before they reach their full potential productivity.

The two-machine system is best-suited to more complex treatments (e.g., selection cuts, commercial thinning), for work on sensitive sites, or in small, dispersed cut blocks, where its use permits faster travel between blocks. However, the three-machine system may offer more flexibility. Some processing heads offer the ability to process large-diameter hardwood stems in mixedwood stands as well as stems with irregular shapes (Hillman 2002) that would pose problems for a single-grip harvester. In addition, in very dense stands (>1800 stems/ha), the feller-buncher lets the three-machine system remain productive by brushing unmerchantable stems and by bunching merchantable stems for the processor. When the stems are small, but stand density is within the normal range, the two-machine system with a multi-stem head is indicated.

For managers, there are two management options for blocks with low-volume stems:

1. Spread the harvest of low-volume stems throughout the year, and equally between all crews.
2. Create a special team with the appropriate equipment to treat marginal areas (e.g., those with stems smaller than 0.10 m^3/stem, densities greater than 1800 stems/ha).

Some heads designed for processing can also operate as single-grip harvester heads. However, owners of this type of processor report that the heads break more frequently if they are used primarily in harvesting mode by workers that have not been properly trained in this task. Thus, such heads should be used only occasionally for harvesting, primarily to help out in the short term.

If you plan to use a three-machine system for more elaborate silvicultural treatments such as partial cuts, you should use a small processor rather than a large machine or a machine with a butt plate. Large heads can be used in clearcutting or to process large stems such as hardwoods.

In stands with small stems but densities within the normal range, it may be beneficial to use the two-machine system with a multi-stem single-grip head (Gingras 2002). Stand density should be less than 1800 stems/ha, since at this density level, the operator will find it difficult to work productively with a single-grip head and will waste considerable time felling unmerchantable stems. In this case, the three-machine system will be more productive.

Upon analyzing the processor data, we noted that the learning curve for this type of machine is significant. At a mean volume of 0.10 m^3/stem, an operator with 2 or more years of experience will produce between 15 and 20% more wood than a less-experienced operator. Beyond 2 years of experience, the additional productivity increases will be minimal and appear to depend more on personal characteristics (e.g., level of organization).

For managers who want to implement a shortwood harvesting operation, we recommend consulting FERIC's shortwood operations guide, which is available on our Web site (http://www.feric.ca/en/ed/html/ctl-operations.htm).

Acknowledgments

The author wishes to thank the companies and contractors who participated in this study, and particularly Domtar's Val d'Or division, Tembec's LaSarre division, Gogama Forest Products and Stora-Enso Port Hawkesbury.

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