Long-Term Benchmark Study of Fuel Consumption by Feller-Bunchers

Technical report no. 49 - April 2017

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ABSTRACT

In the fall/winter of 2016/17, FPInnovations conducted a long-term study to quantify the fuel consumption and calculate the energy intensity of two feller-bunchers, and to compare the results with a typical short-term benchmark study. Fuel data from an electronic computer module were recorded by an FPDat for 4 months. The fuel-consumption data were tested against operational conditions, such as stem size and slope, to see whether trends could be identified. The heterogeneity of the forest and terrain conditions contributed to the difficulty of identifying a significant trend.

ACKNOWLEDGEMENTS

This project received financial support from Natural Resources Canada as part of the agreement on the Forest Research Institute Initiative.

The authors also thank Tolko Industries Ltd. and its contractor.

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1. CONTEXT

Monitoring and tracking fuel consumption of harvesting equipment can be challenging, especially in remote locations. Most of the fuel use comes from various portable tanks, and usually the tanks are not fitted with a properly calibrated fuel meter or monitoring system, therefore the quantities dispensed into each machine are not tracked. Prior to this study, FPInnovations has performed multiple benchmark studies in which a fuel meter was installed for 1 or 2 weeks to allow for fuel monitoring of each individual machine. These types of studies would be logistically onerous if a longer-term benchmark is desired. In other FPInnovations research work, when examining data downloaded from the electronic computer module (ECM) of harvesting equipment, it was observed that fuel consumption data can be used but needs to be calibrated. The use of data obtained from the electronic computer module (ECM), when access was possible, showed that fuel-consumption information could be easier to get compared to benchmark studies with fuel meter. Usage of ECM data could also provide insight into fuel consumption over a longer period of time. In October 2016 FPInnovations conducted tests and calibrated the ECM on two feller-bunchers. Both machines were equipped with an FPDat, which recorded working hours and fuel-consumption data from the ECM.

2. OBJECTIVES

In addition to determining the on-site productivity of two feller-bunchers, the aim of this long-term benchmark study was to identify possible trends and factors that could have significant impacts on the fuel consumption or energy intensity of the machines. The main objectives were to:

- Collect fuel-consumption and productivity data for two feller-bunchers over a 4-month period in order to document energy intensity and to conduct a longer-term trend analysis with ECM data.
- Collect stand-attribute data for all timber cut during the October 2016 to January 2017 operating season.
- Collect data about harvested volume per cutblock in order to better understand how variations in stand and timber characteristics can impact energy intensity and, hence, the cost of harvesting operations.

3. SITE CONDITIONS

The study took place in southern British Columbia, at a Tolko Industries harvesting operation located about 25 km west of Princeton and 30 km south of Merritt. The two machines were operating in different cut blocks located in Tolko's operations. Table 1 presents the characteristics of the two Tigercat 870 feller-bunchers (Figure 1) used in this study.

Table 1. Equipment description: Tigercat feller-bunchers

Model year	**2011**	**2014**
Make	Tigercat	Tigercat
Model	870	870C
Year manufactured	2011	2014
Hours	10 163	4 287
Engine power (kW)	224	224

Figure 1. Tigercat feller-buncher 870C being serviced at the harvesting site.

4. METHODOLOGY

FPInnovations conducted a visit during the first week of October 2016 to calibrate the ECM with tank fill according to the known standard (Surcel & Michaelsen, 2009) and to determine the initial energy intensity baseline before conducting a concurrent hydraulic tune-up study (Rittich, 2017). ECM fuel data from two Tigercat 870 feller-bunchers operating on different cutblocks were collected for 4 months, from October 1, 2016 to January 30, 2017. FPDat dataloggers were installed on each feller-buncher, which recorded working and idling hours using a motion sensor.

Machine productivity

The productivity of a feller-buncher is often described in terms of volume of wood produced over a period of time. In this study, the volume harvested by each feller-buncher over the 4-month period was estimated per cutblock based on cruise data. The average net volume in cubic metres per hectare was then used to calculate a total harvested net volume per block, according to the treated area. The treated area per feller-buncher was estimated using GPS data.

The GPS information, which was provided by the FPDat dataloggers, allowed the calculation of the total net volume harvested per feller-buncher and per cutblock, assuming the volume in m^3/ha was uniform over the cutblock area. The working and idling hours recorded by the datalogger were summarized per cutblock to calculate an average productivity for each individual block.

Fuel consumption

Fuel consumption was calculated using data recorded from the ECM. The data were published through the J1939 communication protocol of the CAN bus and recorded by the FPDat. The total fuel consumption per machine was adjusted with the calibration factors that were calculated during the first field visit (Rittich, 2017), where the two feller-bunchers were studied to evaluate the effect of a hydraulic tune-up on energy intensity. The calibration factors were +23% for the 870 feller-buncher and +14% for the 870C feller-buncher. The adjusted fuel consumption was summarized per block and was divided by the total working hours in the block to get the consumption in litres per hour.

Energy intensity

Energy intensity represents the amount of energy used in the production of a unit. For harvesting equipment, the energy intensity is expressed in litres of fuel burned per cubic metre of wood produced. To calculate and compare the energy intensity of the two feller-bunchers in this study, the total fuel consumed by each feller-buncher was divided by the total volume harvested.

5. RESULTS

Tables 2 and 3 summarize the feller-bunchers' productivity, energy-intensity, and fuel-consumption data by month of operation and cutblock.

For the Tigercat 870, which was manufactured in 2011, the energy intensity varied from 0.35 to 1.28 L/m^3 and fuel consumption varied from 40.4 to 51.4 L/h (Table 2). These values are within the range observed by FPInnovations in previous field studies and are within the range that could be expected in terms of fuel consumption and energy intensity of a large feller-buncher. Some of the energy-intensity values calculated for three blocks (417-7, NA1146, NK1203) were greater than 1.0 L/m^3, which can be considered high. Unfortunately, no operational factors, other than low productivity, could explain the high energy intensity in these cases.

For the newer feller-buncher, the 870C, which was manufactured in 2014, energy intensity varied from 0.51 to 0.73 L/m^3 and fuel consumption varied from 31.3 to 36 L/h (Table 3). These values are within the range observed by FPInnovations in a previous field study and are in the middle of the range that could be expected in terms of fuel consumption and energy intensity of a large feller-buncher.

Table 2. Productivity, energy intensity, fuel consumption of the Tigercat 870 feller-buncher, by month of operation and cutblock

Month of operation & cutblock ID	Fuel, adjusted (L)	Working time (h)	Idling time (h)	Total time (h)	Productivity (m^3/h)	Energy intensity (L/m^3)	Fuel consumption (L/h)
October 2016							
416-3	2155	38.5	6.1	44.6	122.4	0.46	48.3
417-8	3775	69.6	12.4	82.0	92.4	0.59	46.0
417-9	1973	37.8	3.2	41.0	83.3	0.63	48.1
November 2016							
417-7	2043	37.0	2.7	39.7	49.0	1.13	51.4
A124	1351	24.4	2.6	27.0	159.9	0.35	50.0
A92	1902	34.6	2.7	37.3	152.6	0.36	51.0
NA1131	486	9.5	0.8	10.2	60.3	0.85	47.5
NA1145	632	12.1	0.7	12.8	55.5	0.94	49.4
NA1146	248	4.8	0.8	5.5	40.5	1.28	44.7
December 2016							
NT1106	1555	32.1	6.4	38.5	120.8	0.40	40.4
NT1139	2307	45.1	7.6	52.7	66.4	0.77	43.8
January 2017							
NK1152	1558	29.3	1.4	30.6	64.5	0.82	50.9
NK1153	1775	35.4	6.9	42.4	67.9	0.74	41.9
NK1203	1458	28.5	0.9	29.4	50.4	1.02	49.6

Table 3. Productivity, energy intensity, fuel consumption of the Tigercat 870C feller-buncher, by month of operation and cutblock

Month of operation & cutblock ID	Fuel, adjusted (L)	Working time (h)	Idling time (h)	Total time (h)	Productivity (m^3/h)	Energy intensity (L/m^3)	Fuel consumption (L/h)
October 2016							
416-3	1638	42.2	5.4	47.6	52.9	0.73	34.4
417-8	3725	93.3	11.0	104.3	75.5	0.53	35.7
417-9	922	23.7	3.7	27.4	75.8	0.51	33.7
November 2016[a]							
417-7	6539	160.9	20.6	181.6	55.1	0.74	36.0
-	6082	159.7	29.0	188.7	N/A	N/A	32.2
December 2016							
-	4859	128.5	27.0	155.5	N/A	N/A	31.3
January 2017							
-	5973	136.6	43.9	180.6	N/A	N/A	33.1

[a] Machine worked in various blocks after this time period; volume data not available.

Fuel consumption

The average fuel consumption of a large feller-buncher is around 42 L/h, and the range is from 30 to 58 L/h, as based on the benchmark compendium, which is a compilation of all the previous fuel studies done by FPInnovations.

Table 4 compares each feller-buncher's fuel consumption for the four blocks harvested simultaneously by the two machines. Fuel consumption varied by up to 5 L/h for the Tigercat 870 and by up to 2.4 L/h for the Tigercat 870C. Fuel consumption difference per block was between 22.4% to 30.1% better for the 870C. This shows that the newer 870C feller-buncher (built in 2014) is more economic than the older 870 (built in 2011). This is probably because of machine maintenance, with the newer feller-buncher having 6000 fewer machine hours than the older one, and because of operator practices. Because the operator of the older feller-buncher was more experienced, he was therefore assigned the more challenging ground, when the two units shared a cutblock. This no doubt resulted in a higher fuel consumption. .

Many operational and human factors can influence fuel consumption. In the current study, fuel-consumption data were tested against cutblock variables such as average piece size, slope, and stand density, but no significant patterns emerged. Most of the variation observed in this study could, then, be related to operator practices, machine specifications, and the general condition of each machine.

Table 4. Comparison of the feller-bunchers' fuel consumption

Cutblock ID	Tigercat 870 feller-buncher (L/h)	Tigercat 870C feller-buncher (L/h)	Variation (%)
416-3	48.30	34.38	28.8
417-7	51.42	36.02	30.0
417-8	46.04	35.72	22.4
417-9	48.13	33.65	30.1

Energy intensity and productivity

Based on FPInnovations' previous field studies and observations, the energy intensity of a large feller-buncher is typically around 0.50 L/m³ and can range from 0.25 to 0.90 L/m³. Energy intensity takes into account machine productivity (m³/h) and fuel consumption (L/h). Over a longer period of time, fuel consumption tends to be more constant than productivity. FPInnovations developed a productivity model, used in FPInterface that shows the effects of different operational factors on machine productivity. The model has revealed that the two factors which have a more significant impact are average piece size harvested and operator technique. Table 5 compares the energy intensity and productivity of both feller-bunchers for the four blocks that were cut simultaneously. The older Tigercat 870 was more productive in three of the four blocks, with productivity ranging from 49 to 122.4 m³/h, while the productivity of the newer 870C ranged from 52.9 to 75.8 m³/h. Even if the 870 was more productive, the energy intensity value was better for the 870C, except in Block 416-3, where the 870 was twice as productive as the 870C.

The 870C was more energy efficient even if it was less productive than the 870 and showed less variation in energy intensity. No trends could be established between operational factors, such as stem size or slope, and energy intensity.

Table 5. Comparison of the feller-bunchers' energy intensity and productivity

Cutblock ID	Energy intensity			Productivity (m³/h)		
	Tigercat 870 feller-buncher (L/m^3)	Tigercat 870C feller-buncher (L/m^3)	Difference (%)	Tigercat 870 feller-buncher (m^3/h)	Tigercat 870C feller-buncher (m^3/h)	Difference (%)
416-3	0.46	0.73	–58.7	122.4	52.9	56.8
417-7	1.13	0.74	34.5	49.0	55.1	–12.4
417-8	0.59	0.53	10.2	92.4	75.5	18.3
417-9	0.63	0.51	19.0	83.3	75.8	9.0

6. CONCLUSION

The present study showed that doing a long-term benchmark study helps build knowledge about fuel consumption by type of machine and for various forest and operational conditions. However, heterogeneity of the forest and terrain conditions makes it hard to identify particular factors. Being able to determine more defined and accurate information about terrain and stand conditions would help FPInnovations validate trends about the factors that can have a significant impact on fuel consumption and energy intensity. As well, operating practices as well as machine conditions and specification can have a significant effect on both hourly fuel consumption and productivity and thus energy intensity. In this case, the older, and seemingly, less energy efficient machine was operated by a more experienced operator. It is therefore difficult to separate one factor from the other. Ideally, to properly benchmark both the machines and the operators, operators would be switched from machine to machine to isolate each parameter. As well, the ore experienced operator the less challenging sectors in an attempt to gauge that operational parameter's influence. Being able to spate each influence would allow to gauge a less experienced operator's performance and help in training and development.

The results of this study also show that a short-term study can be useful for highlighting possible opportunities to reduce energy intensity, but without accurate and fairly detailed information about terrain and forest conditions it could be challenging to validate trends in a long-term analysis. Using an FPDat device to record and transfer ECM fuel data is easier than recording fuel data from a mechanical meter or than obtaining it from a single ECM download in the field. To benchmark, monitor, and manage machine fuel consumption, the recording of ECM data could be a valuable practice for any contractor, especially from the perspective of continuous improvement.

FPInnovations could look at the possibility of using long-term benchmark data to validate its existing fuel-consumption equation models and to build a new energy intensity equation. More data from different pieces of equipment should be gathered and analyzed to improve knowledge of fuel-consumption modelling.

7. REFERENCES

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