HARVESTING TECHNICAL NOTE

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Productivity Impacts of Bunching for Hauler Extraction

Summary

This report describes a project undertaken to better understand the extent to which bunching of trees for hauler extraction is used currently in New Zealand. There were three objectives of the study: i) to gather information on steep country bunching operations in terms of terrain and duration, using a daily data collection form; ii) to identify hauler crews for subsequent study; and iii) to investigate the impacts of tree bunching on cable yarding productivity through detailed productivity studies. From the shift level data collection, the conclusion was drawn that bunching of trees for hauler extraction can be used extensively (up to 80% of time in one operation) and on various terrain slopes (exceeding 22 degrees) when conditions permit. Two cable yarding operations were later studied in detail: a Thunderbird TSY355 swing yarder operation with manual felling and bunching of 2.26 m^3 trees; and a Madill 071 tower operation with manual felling and bunching of 1.02 m^3 trees. Both operations bunched trees using 30-tonne excavator loaders. Results for both studies showed that more trees were hooked on per cycle for bunched versus unbunched trees. Shovelling and bunching for yarder extraction improved yarder utilisation (fewer line shifts) and harvesting system productivity. A standardised comparison of performance showed that extraction of bunched trees resulted in a 24% increase in harvesting system productivity, and a 5% reduction in unit cost.

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Introduction

Bunching of trees to improve payload in harvesting is not a new phenomenon, and has been reported extensively in both ground-based and cable hauler operations worldwide to increase extraction machine productivity. Previous Future Forests Research (FFR) reports have surveyed the international literature from the last twenty years on the topic of felling and bunching on steep terrain (Amishev *et al*., 2009) and described an operation in New Zealand bunching trees for grapple yarder extraction (Evanson and Amishev, 2009). The extent to which bunching of trees for hauler extraction is used in New Zealand (Figure 1) however, was not well understood.

This study is part of the FFR programme investigating methods for improving productivity and safety in steep country harvesting operations. The objectives of the study were to :

i) gather information on steep country bunching operations in terms of terrain and duration;

ii) identify crews for subsequent detailed productivity studies of bunching for hauler extraction; and

iii) better understand the impacts of bunching on crew productivity.

Figure 1: Trees bunched for yarder extraction

Study Methods

1. Shift Level Data Collection

Two productivity data collection forms were designed for members of selected logging crews to complete in order to collect information on bunching at the daily shift level: one for the operator of the bunching machine and one for the hauler operator. The buncher operator was asked to complete the number of hours spent bunching, any major delay time (with comments if longer than 15 minutes) and number of hours

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doing work other than bunching. The area bunched was to be marked on a topographic map of the setting, and any reasons given for areas not bunched (Figure 2).

The hauler operator was requested to provide information on total hours worked during the day, major delays (greater than 15 minutes), and daily production such as number of hauls, and number of pieces extracted. In order to relate the two forms afterwards, both crew members were to fill in the crew name, setting and skid number, location, and date for each page.

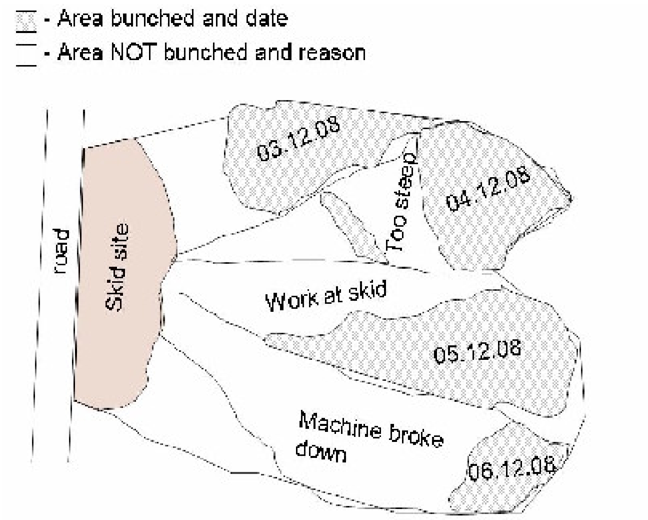

Figure 2: Example map for buncher operator to complete.

These forms were distributed for data collection to a sample of harvesting contractors provided by members of the FFR harvesting theme. It was intended that the daily shift level studies be followed up with detailed studies of the effects of tree bunching on cable yarding productivity of two selected crews.

2. Bunching Productivity Studies

Two harvesting crews, one in the Rotorua district and one in Gisborne district, were chosen for detailed study. Both yarder contractors, FPNZ Limited and Mana Logging Limited, were using bunching systems on terrain planned for yarder extraction. The extraction phase of both systems comprised the use of an excavator to shovel, then bunch stems for hook-on by chokers for yarder extraction.

Harvest Area Description

Study One:

Study One was in Manawahe Forest, Central North Island, managed by PF Olsen Ltd. The harvest area (Figure 3) comprised approximately 55% flat to rolling-steep slopes, with the remainder short steep slopes on pumice soils.

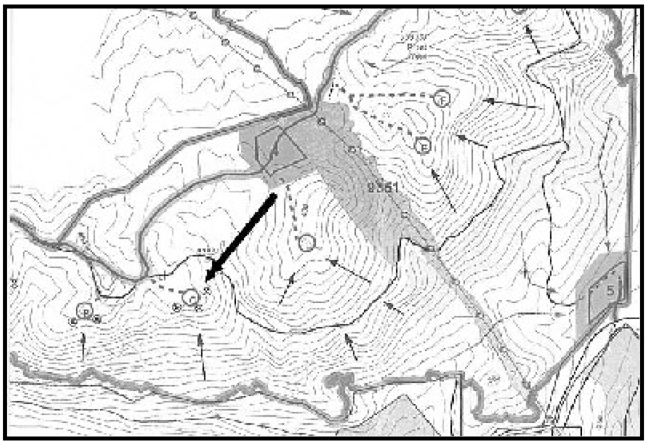

Figure 3: Study One location with haul direction marked.

Study Two

The second study area was in Wairangi Forest, on the east coast of the North Island. The forest was owned and managed by Hikurangi Forest Farms Ltd. Figure 4 shows the setting studied with haul direction marked.

Stand conditions of the two harvest areas studied are summarised in Table 1.

Table 1: Stand characteristics

	Study 1	Study 2
Age	26 years	31 years
Stocking	242 spha	437spha
Stand Volume	547 m^3/ha	446 m^3/ha
Piece size	2.26 m^3	1.02m^3

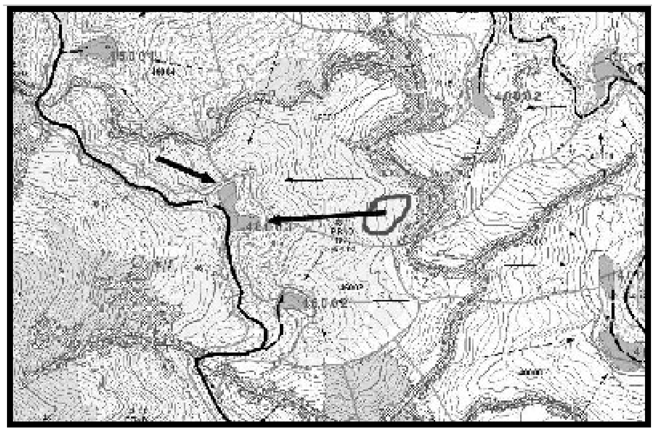

Figure 4: Study Two location with haul direction marked (bunched area is outlined).

Harvesting Equipment and Crews

The Manawahe Forest block was logged by FPNZ Limited. Manually-felled trees were laid downhill-diagonally and a 30-tonne Sumitomo SH300 excavator with a live heel was used to shovel and bunch the trees into large bunches, enabling multiple hauls from the same bunch. The swing yarder was a Thunderbird TSY355, using a running skyline rigging system with two chokers and one breaker-out. A 46-tonne Volvo excavator was used as a mobile tail hold.

The processor, located on the landing with the yarder, was a Sumitomo SH400 equipped with a Woodsman Pro 800 harvester head. The processor cleared the chute (Figure 5) and processed thirteen log grades. The processor also stockpiled extracted trees for later processing.

Processed logs were self-loaded onto a Terex forwarder and forwarded 70 m up a steep adverse grade to a landing to be sorted and stacked by a 30-tonne Cat excavator loader.

The Wairangi Forest block was logged by Mana Logging Ltd. Trees were manually-felled and a 30-tonne Komatsu PC300 excavator, with built-up grousers and quick hitch, was used to shovel and bunch the trees into large bunches, enabling multiple hauls from the same bunch. This method was used in selected areas in the setting.

Figure 5: Processor clearing the chute

The yarder was a Madill 071 tower, and during the study both shotgun and North Bend skyline systems were used with two or three radio-controlled chokers, and two breaker-outs. A Caterpillar D7F mobile tail hold was used. Sometimes, when yarding with the North Bend system, a tail rope block was attached to the stick of the Komatsu loader to enable bridling.

Figure 6: Processor under the Madill tower clearing the chute

The processor, located on the landing with the yarder, was a 24-tonne Volvo excavator with a Waratah 624 Super harvester head (Figure 6). The processor cleared the chute, and either delimbed and placed the trees in a surge pile or processed the piled trees and sorted ten grades. Processed logs from the stacks were then re-

sorted and stacked by a Volvo EL240 excavator loader

Study Method

Time study methods were used to evaluate the productivity of the extraction and processing phases of each operation. It was expected that the effects of bunching would be reflected in hauler cycle times, and the immediate effect of changes in yarder productivity would affect the processing phase.

The haul cycles of the two yarders were observed over a total of five days (two days at Study One and three days at Study Two). Video recordings were made for later division of cycle times into elements. The measured time elements are given in Table 2.

Table 2: Yarder time study elements

	Time Element
Productive Cycle	Raise rigging
	Outhaul
	Walk in
	Hook on
	Walk out
	Raise rigging (tower only)
	Inhaul
	Unhook
Delays	Operational
	Mechanical
	Personal

Non-time parameters measured were haul distance, slope, number of trees per haul and number of logs processed. Haul distances were measured by laser rangefinder. The relationships between the time elements and other parameters were then analysed.

Results: Shift Level Data Collection

Only two crews were identified bunching trees for hauler extraction on an operational basis, and the forms were distributed to them and collected back after two months. This indicated the limited extent to which this technique is employed in New Zealand. Unfortunately no clear conclusions can be drawn in terms of the reasons for such limited use of mechanisation in cable yarding.

Of the forms distributed to the selected crews, one completed by the buncher operator in one crew revealed that, over the 38 days of data collection, the excavator loader was bunching trees for an average of 7.35 hours per day, ranging from 2 to 11.5 hours. Other activities included cleaning the skid, pushing edge trees, clearing new skids and truck loading. The records showed that bunching trees formed the major activity for the excavator loader, and that bunching was done more than 80% of the crew operational time.

For the other crew, summarised data and topographic maps with marked areas where bunching, shovel logging, or yarding only had been undertaken in several settings was provided by the supervisor of the crew (Table 3).

Table 3: Summary of shift level data by area and corresponding ground slopes.

Harvesting Method	**Area Ha**	**Slope deg**	**Proportion %**
Bunched	4.1	0 - 9	3.3%
	3.7	9 -18	3.0%
	4.7	18 - 22	3.8%
	17.9	>22	14.4%
Shovelled	3.7	0 - 9	3.0%
	5.3	9 -18	4.3%
	5.9	18 - 22	4.8%
	22.5	>22	18.2%
Yarded only	4.5	0 - 9	3.6%
	2.5	9 -18	2.0%
	5.2	18 - 22	4.2%
	43.9	>22	35.4%
Total	**123.9**		**100.0%**

In these results, bunching and shovelling was done on slopes ranging from $0-9^0$ to more than 22^0. Of the total area of 123.9 ha, 67.8 ha or 55% was bunched or shovel logged. Of the area in the slope class of more than 22^0 (84.3 ha) 48% of the area was either bunched or shovelled.

This result demonstrated that, when adopted by a cable logging crew, bunching of trees for hauler extraction can be used extensively and safely on various terrain classes (exceeding 22^0), when conditions permit.

Results: Bunching Productivity Studies

Yarder Productivity

Table 4 summarises cycle time and production data for the two yarders operated during the 5-day time study. Most of the observed yarder cycles were from bunched trees.

Table 4: Summary of yarder productivity.

Yarder	Sample Size	Cycle Time	Hourly Productivity
Thunderbird TSY355			
-Bunched	n=57	3.28min	91.3m^3/PMH
-Unbunched	n=6	4.60min	44.2m^3/PMH
Madill 071			
-Bunched	n=38	5.31min	25.3m^3/PMH
-Unbunched	n=27	4.61min	39.8m^3/PMH

In Study One, over the two days, 63 cycles were timed, comprising 57 bunched cycles and 6 unbunched cycles. The low sample of unbunched cycles was because the mobile tail hold could not be moved to bring unbunched trees within reach of the rigging. No line shifts (tail hold moves) or yarder moves were observed during Study One.

Average haul volume per cycle was 5.0 m^3 (2.21 butt trees per cycle * 2.26 m^3 average tree size) extracted over 128 m average haul distance (AHD). Delay-free cycle time was 197 seconds or 3.28 minutes (Table 5). Delay-free productivity was calculated at 91.3 m^3/PMH (18.3 cycles/PMH * 5.0 m^3 / cycle.

Only six unbunched cycles were observed. Comparison with bunched cycles is therefore indicative only. Hook-on time was increased and haul size for the unbunched cycles was 32% lower (1.5 butt pieces per haul or 3.4 m^3/haul) compared to bunched hauls. Total cycle time averaged 4.6 minutes, giving indicative productivity from this small sample of 13.0 cycles/PMH, or 44.2 m^3/PMH over a haul distance of 127 m.

Table 5: Study One - yarder cycle time: bunched

Element	**Cycle Time (sec)**	**St. Dev.**
Raise rigging	16.9	7.1
Outhaul	26.9	10.0
Walk in (n=7)	1.5	
Hook on	79.2	29.7
Inhaul (128m)	51.9	11.0
Unhook	20.6	9.0
Delay-free total	197.0	

In Study Two, over the three days 38 bunched and 27 unbunched cycles were timed. There were two long delays in the 3-day period, involving a major setting shift /yarder re-position from the shotgun setting to the North Bend setting (taking several hours); and a tail hold breakdown. During the unbunched cycles, three tail hold moves of approximately 5 minutes each were observed. No tail hold moves for bunched cycles were observed during Study Two.

Figure 7: Trees shovelled and bunched for yarder extraction

A shotgun skyline yarding system was used, but poor deflection due to a convex haul profile meant that the skyline needed to be raised at least four times during each inhaul cycle. The shotgun carriage had two radio-controlled chokers, worked by two breaker-outs.

For bunched cycles, average volume per cycle was 2.24 m^3 (2.2 butt trees per cycle * 1.02 m^3 average tree size) extracted over an average haul distance of 253 m (range 233 to 278 m). Average delay-free cycle time for the bunched cycles was 319 seconds or 5.31 minutes (Table 6). Delay-free productivity was calculated to be 25.3 m^3/PMH (11.3 cycles/hr * 2.24 m^3/cycle).

Table 6: Study Two - yarder cycle time: bunched

Element	Cycle Time (sec)	St. Dev.
Raise rigging (n=2)	1.9	
Outhaul	46.1	
Lower rigging	15.2	3.7
Walk in	8.2	4.9
Hook on	80.9	33.4
Move out	11.5	3.2
Raise rigging (n=32)	16.7	
Inhaul (253m)	138.4	
Delay-free total	318.9	

In Study Two, a total of 27 unbunched extraction cycles were timed over an average haul distance of 74 m (range 30 to 135 m). A North Bend system was used hauling uphill and two breaker-outs used three radio-controlled chokers.

Table 7: Study Two - yarder cycle time: unbunched

Element	Time per cycle (sec)	St. Dev.
Raise rigging (n=2)	3.3	
Outhaul	33.9	
Lower rigging (n=10)	3.6	
Walk in	16.3	9.6
Hook on	133.7	51.0
Move out (n=26)	23.6	14.6
Raise rigging (n=4)	5.1	
Inhaul (74m)	50.9	
In slow (n=6)	6.1	
Delay-free total	276.4	

Average haul volume per cycle, unbunched, was 3.06 m^3 (3.0 butt trees per cycle * 1.02 m^3 average tree size). Average delay-free cycle time for unbunched cycles was 276 seconds or 4.61 minutes (Table 7). Delay-free productivity was calculated at 39.8 m^3/PMH (13.0 cycles/PMH * 3.06 m^3).

Comparison of bunched/unbunched cycles

The effect of bunching was determined by comparing the haul cycle variables shown in Table 8.

Mean walk in and walk out times were significantly different (p>0.05) and may be due to the clearer access to bunched wood and terrain differences observed, as the bunched trees were located on easier slopes.

The trees per choker variable was significant at the p>0.1 level. On average 10% more trees were hooked on in the bunched cycles. Occasionally, two trees were hooked with one choker.

Table 8: Comparison of selected variables. Values marked with "1" are significantly different at p>0.05.

Element	Bunched Mean	Unbunched Mean	s.d.
Walk in	8.20	16.3	1
Walk out	11.5	23.6	1
Hook on/choker	41.0	44.6	
Hook on/stem	37.3	44.6	
Trees/choker	1.10	1.0	

To compare productivity of bunched and unbunched cycles it was assumed that both used a North Bend rigging system, and a bunching excavator was employed for 8 PMH/day in bunching activity. All cycle elements, except Walk in, Hook on, and Walk out, were held at unbunched cycle mean values (Table 7). Differences in Walk in, Hook on, and Walk out times, and trees/choker values followed the observed patterns in Table 8.

Results in Table 9 showed that the key drivers for productivity were the number of chokers used, and the increase in the number of trees hooked per choker. The improved walk in/out and hook on times in bunched cycles also improved the total cycle time.

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It is estimated that under the above standard conditions (3 chokers), bunching provided a 10% increase in haul size, a 24% increase in productivity, and a 5% reduction in unit cost (Table 9).

Table 9: Comparison of estimated system costs: Yarder 5.9 PMH/day, AHD 74 m, North Bend system, 2 Breaker-outs

	Unbunched	**Bunched**	**% Change**
Cycles/PMH	13.0	14.6	+12
No. Chokers	3	3	0
Trees/choker	1.0	1.1	+10
Trees/cycle	3.0	3.3	+10
Trees/PMH	39.0	48.2	+24
m^3/PMH	39.8	49.2	+24
$/m^3	20.65	19.61	-5

Processor: Study One

The processing of 26 butts (at 4.3 logs per tree) and 10 pieces (at 1.5 logs per piece) were timed. Average delay-free cycle time was 133.7 seconds, or 2.23 minutes (Table 10).

Table 10: Study One: processor cycle time

Element	**Cycle Time (sec)**	**St. Dev.**
Move	10.4	6.6
Move with tree	5.3	7.7
Clear chute	15.8	12.7
Stockpile trees	6.1	8.8
Process butt	81.1	19.5
Process piece (0.4 per cycle)	13.1	
Clear slash	1.9	4.9
Delay-free total	133.7	
Delays:		
Operational	3.1	
Mechanical	0	
Personal	0	
Total cycle time	136.8	

Delay-free hourly productivity was calculated to be 60.8 m^3/PMH (26.9 cycles/PMH * 2.26 m^3). This value excludes logs processed from tops or broken pieces.

Results showed that during the period of Study One, yarder productivity exceeded the chute clearing/processing productivity of the processor (by approx 13 trees per PMH) which resulted in stockpiling of trees for later processing.

Processor: Study Two

Fifty processing cycles were timed. Average delay-free processing cycle time was calculated to be 87 seconds, or 1.45 minutes (Table 11). Delay-free hourly productivity was calculated at 42.2 m^3/PMH (41.4 cycles/hr * 1.02 m^3).

Table 11: Study Two: processor cycle time

Element	**Cycle Time (sec)**	**St. Dev.**
Move (n=10)	3.9	
Clear chute, process 1.2 logs (n=11)	10.2	
Process 2.5 logs	54.5	21.9
Clear chute, delimb, stockpile (n=27)	15.6	
Move logs (n=2)	1.2	
Clear slash (n=6)	1.8	
Delay-free total	87.2	

Under these conditions, clear chute and process productivity exceeded yarder productivity (even at short haul distances) which suggested potential for system production improvement. However, because of the limited crew size, the processor operator also helped with tail hold shifts and relieved the loader operator. Surplus capacity enabled this flexibility.

Operation Costings

Productivity was estimated using calculated production values and representative costs (Forme, 2009).

In Study One, for bunched cycles, daily productivity was calculated at 539 m^3/day (91.3 m^3/PMH * 5.9 PMH per day). Estimated unit cost for this productivity was calculated at $20.02/m^3. This unit cost is derived from delay-free data.

In Study Two, estimated daily productivity was 149 m^3/day (25.3 m^3/PMH * 5.9 PMH per day) for bunched cycles, and system cost was calculated at \$38.09/m^3. This unit cost is derived from delay-free data.

Conclusions: Shift Level Data Collection

Despite the low returns from the survey data collection, some conclusions could nevertheless be drawn. Results from one crew suggested that when bunching is part of the crew's operation, it is used to a large extent (more than 80%) of operational time.

The summary data provided for the other crew showed that bunching and shovelling was done safely on slopes of more than 22 degrees. In fact, 32% of the total setting areas were bunched or shovelled with an excavator on slopes greater than 22 degrees. This suggests that when adopted by a crew, bunching of trees for hauler extraction is used extensively and on various terrains when conditions permit.

Conclusions: Bunching Productivity Studies

These two studies describe harvesting operations where haul size, cycle time and system productivity were enhanced through bunching for yarder extraction.

In Study One, the use of excavator bunching enabled a single breaker out with two chokers to hook on enough trees to supply a processor for a single shift (estimated 8.8 PMH). Yarder productivity while yarding bunched wood was high (91 m^3/PMH *v.* indicative productivity in unbunched wood of 44 m^3/PMH). Yarder productivity in bunched wood exceeded processor productivity resulting in the processor working longer hours.

In Study Two, the effect of bunching was determined. Key values in determining productivity were the number of chokers used, and the number of trees hooked per choker. Bunching enabled more trees to be hooked on per choker, probably because butts were better aligned. Walk-in, hook-on and walk-out times, all key elements in the manual breaking out cycle, were significantly shorter for bunched cycles. Bunching enabled ready and clear access for the breaker-outs, and butts were easily accessed for hooking on.

It was calculated that under standardised conditions bunching provided a 10% increase in haul size and a 24% increase in productivity. This increase in productivity was within the average hourly capacity of the processor to handle, suggesting potential for further productivity improvement. It is assumed that the increase in daily production would also be within the capacity of the sorting and loading phases of the operation.

Possible improvements to the bunching system, in selected setting locations, include:

- The use of a single, long choker in conjunction with haul-sized bunches. Larger average haul sizes would have to be closely monitored to prevent overloading of working ropes.
- Haul-for-haul buncher presentation of trees for hook on, either by choker or by grapple (Evanson and Amishev, 2009).

Another advantage of bunching is the reduction in time spent in rope shifts, mainly tail hold shifts, on a setting basis. This results in an increase in yarder utilisation. In one study, yarder productivity in bunched/shovelled trees was assessed without any observed tail hold moves over a two-day period. The shovelling of trees from hard-to-reach areas (for example where there is a blind lead), may reduce the number of setting shifts required and may reduce average haul distances per setting, thus resulting in higher productivity and reducing the total costs of logging.

Further research will be focused on the techniques and methods used to operate free-moving bunching machines safely on steep terrain, and the effect on productivity of different grapple/hook-on systems.

Acknowledgements

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Forme (2009): INFORME Harvesting and Forestry Equipment Price Survey, March 2009. Forme Consulting Group Limited, Wellington. http://www.forme.co.nz/

The costs stated in this report have been derived using estimates obtained from INFORME Harvesting 2009, supplemented with cost data from other sources where appropriate. They are an indicative estimate and do not necessarily represent the actual costs for this operation.