Forest Growers Research Ltd
P.O. Box 1127
Rotorua 3040
Phone: 07 921 1883
Email:
forestgrowersresearch@fgr.nz
Web: www.fgr.nz

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Productivity of a winch-assisted forwarder and processor: A case study in the Hawkes Bay region

Authors:
Rien Visser
and
Cameron Leslie

Research Provider:
School of Forestry
University of Canterbury
Te Whare Wānanga o Waitaha
Christchurch, New Zealand

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EXECUTIVE SUMMARY

Winch-assist technology to support harvesting operations on steep slopes is now well-established in New Zealand. The most common configuration is the winch, or dual winch, mounted on an excavator (or bulldozer) to support an excavator based steep slope harvesting machine felling, pre-bunching or shovelling. More recently such winch assist systems have been used to extend the operating range of grapple skidders.

For this study, a winch assist unit was used to support both the feller-processor working in cut-to-length operations, as well as forwarder-based extraction. As it is the first winch-assisted harvester-forwarder cut-to-length system to be studied in New Zealand, the main goal of the study was to assess forwarder productivity and understand what type of delays the system experienced.

The study was carried out in Hampton Forest near Napier with a John Deere 1910E Forwarder being supported by a T-Winch 10.2, operating on slopes ranging from 14 to 29 degrees (average 25 degrees, or 46%). During the two-day forwarder study 16.4 hours of data was collected which included 32 forwarder cycles. The average forwarder cycle time was 23.9 minutes with an average payload of 16.6 tonnes. Average forwarder productivity during work time only was 41.6 m^3 per productive machine hour (PMH). The utilisation rate, the ratio of productive to total time, was 77.6%, hence productivity per scheduled hour was 32.3 tonnes. Of the average cycle time, only 1.9 minutes was used to connect and disconnect the winch.

The time study differentiated between productive and delay time. For the forwarder productive time was split into the following elements: ‘travel empty’, ‘loading’, ‘travel loaded, ‘unloading’, ‘connecting winch rope’, and ‘disconnecting winch rope’. Two additional elements were included to record the time required to connect and disconnect the winch assist from the machine in each cycle.

Factors found to have an impact on the forwarder system productivity were extraction distance, slope and the assistance of the loading machine with unloading the forwarder packet. Operational delays observed throughout the study were: relocating the winch-assist machine, manoeuvring around out of sight stumps, blading the extraction track, radio communication and stabilising dislodged logs on the forwarder packet mid cycle.

INTRODUCTION

Winch-assisted harvesting is now a well-established system to support harvesting machines on steep slopes (Visser & Stampfer, 2015). Terms such as cable assist', 'traction assist' and 'tethering' all refer to 'winch assist' technology that supports a machine to operate on steep slopes safely (Cavalli & Amishev, 2019).

The benefits of winch-assist include improved safety performance through the mechanisation of manual tasks such as chainsaw felling, as well as overall productivity increases through system efficiency gains such as bunching felled trees for extraction (Visser, Raymond and Harrill, 2014). However, these systems are expensive to operate, and hence it is important to understand the productivity and utilisation of various options for their cost-effective implementation (Leslie 2019). Expanding machine access on steep terrain using winch-assist allows stands which were previously required to be harvested using cable logging to now be harvested by ground-based machinery (Cavalli & Amishev, 2019).

Manufacturers of winch assisted technology emphasise that the operator's safety should not be reliant on the winch (Koszman, 2018,). The draft new ISO standard (ISO 19472-2:2022 Machinery for forestry — Winches — Part 2: Traction aid winches) distinguishes between traction aid winches and climbing support winches. Traction Aid winch systems require the machine to be able to move on the slope, and the winch increases machine stability and reduces environmental impact (Cavalli & Amishev, 2019). In New Zealand, the concept of Climbing Support winches is mainly used, where the winch is allowing machinery to access terrain it could not move on without winch support.

Cost-effectiveness is an important factor used in deciding which harvesting system is most appropriate (Enache *et al.* 2015). Winch assist can be successful in a range of different configurations (Figure 1). In a comprehensive study of six harvesting operations in New Zealand and Canada, Leslie (2019) showed winch assist can be successful in a range of different configurations and across a range of different operating conditions.

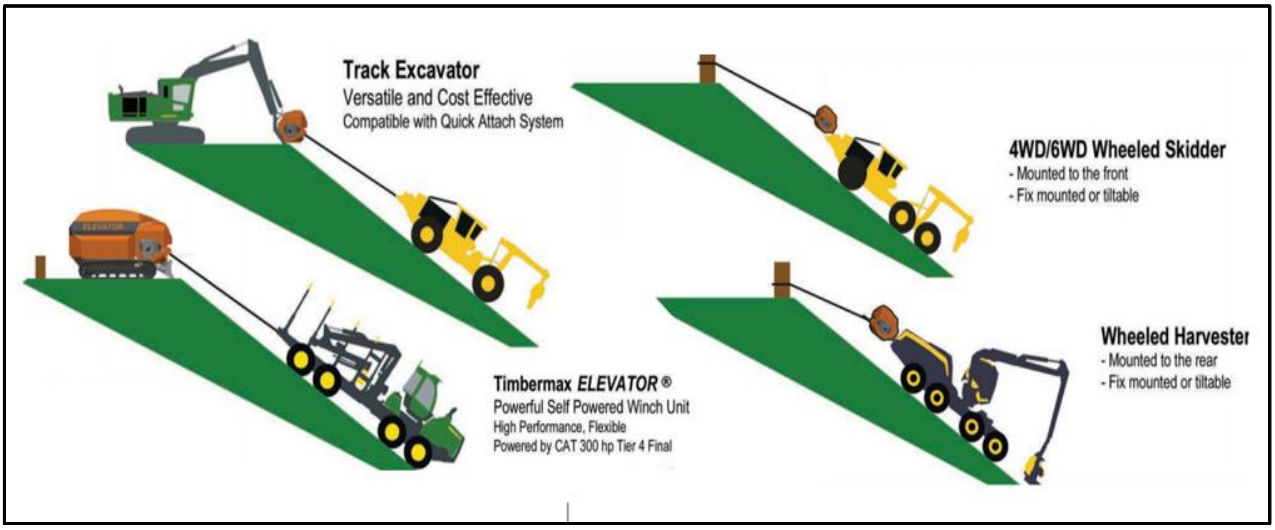

Figure 1: Harvest machine applications on steep slope (from TimberMax)

Apart from simply accessing steeper terrain, such systems offer an opportunity for reducing road construction and enabling cost-effective longer extraction distances (Thompson & Hunt, 2016). This was confirmed in one study of a Tigercat 635E skidder attached to a T-Winch 10.1, where 1.1km of road construction was saved at the test site in Alberta (Strimbu & Boswell, 2018).

In Europe, traction assist has been developed to support wheeled harvester forwarder operations (Visser and Stampfer 2015). Many of the winch units provide safe pulling forces in the 5 to 12 tonne range (using the Factor of Safety of 2 as allowed in the ISO Standard). These relatively low forces provide the opportunity to integrate the winch onto the harvester, forwarder, or skidder (on the right of Figure 1). This concept is valuable when operating on sensitive soils or environmental constraints (Thompson & Hunt, 2016). By operating a forwarder system in the Traction Aid set-up, it may in time allow for the introduction of European style winch assist systems into the New Zealand market.

In New Zealand, most of the winch assist equipment is larger scale than that used in Europe to support larger tracked excavator-based felling, bunching and or shovelling machines. A separate machine provides the chassis that supports the winch unit and provides power for the system (on the left-hand side of Figure 1). More than 250 such systems now operate in New Zealand. While initially used to support felling and or bunching for cable yarding operations, over time their use has expanded to include shovelling. More recently, winch assist technology in New Zealand has expanded to successfully support skidder operations (Pedofsky and Visser, 2019; Visser and Spinelli, 2021). The use of winch-assisted forwarders is already common in the Pacific Northwest, and this presents a logical extension to harvesting systems options in New Zealand conditions.

The objective of this study was to improve understanding of winch-assist cut-to-length harvesting (processor / forwarder) operations by completing a short study where factors affecting productivity were quantified.

METHODS

Logging Crew and Location

The study took place over the period of two days in Hampton Forest, near Napier, New Zealand. The logging crew was Cox Forestry Services Ltd, operating a John Deere 909MH with a harvester head, supported by an EMS Tractionline winch assist machine (Figure 2).

Figure 2: EMS Tractionline supporting the felling-processing machine (cut-to-length). The felled trees are cut-to-length and laid across the slope.

A John Deere 1910E forwarder was supported by a T-Winch 10.2 model winch assist machine (Figure 3).

Figure 3: The Ecoforst T-winch (left) and the John Deere forwarder (right) at the study site.

The forwarder and processor machines were operated by experienced machine operators Richard Scott (forwarder) and Jason Lang (processor). The cut-to-length logs were bunched on the slope.

Because of the steep slopes, where required some tree stumps were cut higher than normal to support the bunches prior to extraction by the forwarder (Figure 4).

Figure 4: Cut-to-length logs being supported by a higher stump on the slope for stability prior to extraction by forwarder.

Tree stumps were cut higher than normal in specific locations along the ridge to redirect the winch assist rope around, giving greater access across the terrain for the processor and forwarder (Figure 5).

Figure 5: High stump being used to redirect the EMS Traction Line winch assist rope.

All cut-to-length timber was extracted back to a landing where it was sorted and stacked for subsequent loading and transportation to customer (Figure 6).

Figure 6: Landing where logs were stacked prior to loading out.

Time Study

A time study was completed on the forwarder, and at the same time to record time study elements for the processor. For the forwarder, a cycle was simply the time taken to pick up a load. The harvester 'cycle' was felling and processing at a single location, before moving to the next location. As such the number of trees being processed at each location varied depending on the difficulty of the slope. For the forwarder each cycle was divided into work elements and classified as productive time or delay time as presented in Table 1.

Table 1. Time study elements for the Forwarder, and factors measured.

Element	***Description***
Travel empty*:*	*Begins when the forwarder leaves the landing area.* Factor: Record travel empty distance to first pick up point (m)
Loading	*Begins once the forwarder starts to load the first logs. Includes the time spent after the forwarder finishes loading the logs from one pile and moves to the next pile, until the forwarder is fully loaded.* Factor: Record number of logs on forwarder bunk (can tally during loading, or if out of sight tally during unloading) Factor: Record loading distance (from first to last pick up point)
Travel loaded	*Begins once the bunk of the forwarder is full; it begins to move with the load to the landing. Stops once the forwarder has moved on to the landing.* Factor: Record travel loaded distance
Unloading	*Includes any time on the landing moving into position to unload and unloading itself. It excludes delays.* Factor: If the bunk is not fully loaded (to top of stanchions), an estimate of how full the bunk is made.
Delay	*Includes any interruption to the productive time elements.* Factor: Cause of delay (e.g., operational, mechanical, or personal) is recorded.

The payload volume for each forwarder cycle was estimated from the number of logs on the bunk and the type of logs, multiplied by the average weight for each log type. Using cycle time and volume extracted for the forwarder, productive machine hour (m3/PMH) was calculated.

For the felling machine each cycle was divided into work elements and classified as productive time or delay time as presented in Table 2.

Table 2. Time study elements for Felling / Processing

Element	***Description***
Felling:	Felling head (attached to tree) cuts and fells tree to the ground: *Starts when felling head touches tree.* *Finishes when tree fells and hits the ground.* Factor: Record Number of trees: (1,2,3,4,5)
Processing & 'Bunching':	Felled stems are slewed and processed, then 'stacked' in the terrain: *Starts when tree fells and hits the ground.* *Finishes when machine moves towards next tree or starts to undertake a new task (i.e., shovel).*
Brushing:	*Includes any interruption to remove unmerchantable trees and vegetation or clear processing debris.*
Moving (travel/shift)	Machine tracks move changing position and attaching to next standing tree: *Starts when felling head stops touching tree on the ground.* *Finishes when tracks have moved and felling head touches next tree.*
Shovel	Stems and or logs are shovelled away from the felled location as part of the extraction process. Does not include moving stems / logs as part of processing and bunching (see above).
Delay	*Includes any interruption to the productive time elements.* Factor: Cause of delay (e.g., operational, mechanical, or personal) is recorded.

The volume processed in each processor cycle was estimated from the number and length of logs (long or short) multiplied by their respective weight; longs were estimated at 0.9 tonnes per piece and shorts were estimated at 0.45 tonnes.

Productivity in cubic metres per productive machine hour (m^3/PMH) was calculated using the cycle time and logs processed by the processor.

Machine utilisation and productivity per scheduled machine hour (m^3/SMH) was calculated using the ratio of delays to productive time. Given the short nature of the time study, information on utilisation and or productivity per scheduled machine hour is relevant to this case study only. For more definitive information, longer studies must be completed to accurately represent the frequency and duration of delays (Leslie, 2019).

RESULTS

Forwarder Productivity

During the two-day study, 32 forwarder cycles were recorded during 16.4 hours of data collection. Productive time was defined as; 'travel empty', 'loading', 'travel loaded', 'unloading'. Two additional elements were included to record the time required to connect ('hook-up') and disconnect ('unhook') the winch assist rope from the machine in each cycle.

The average total cycle time was 23 minutes and 53 seconds (23.9 min). This average cycle time is consistent with that reported previously of 24.2 and 22.8min in a study by Proto *et al.* (2017) for two other forwarder operations (one at the West Coast and one at a Balmoral location in New Zealand).

Travelling loaded for about 8 minutes and loading at just over 6 minutes were the two longest time elements for each cycle (Figure 7).

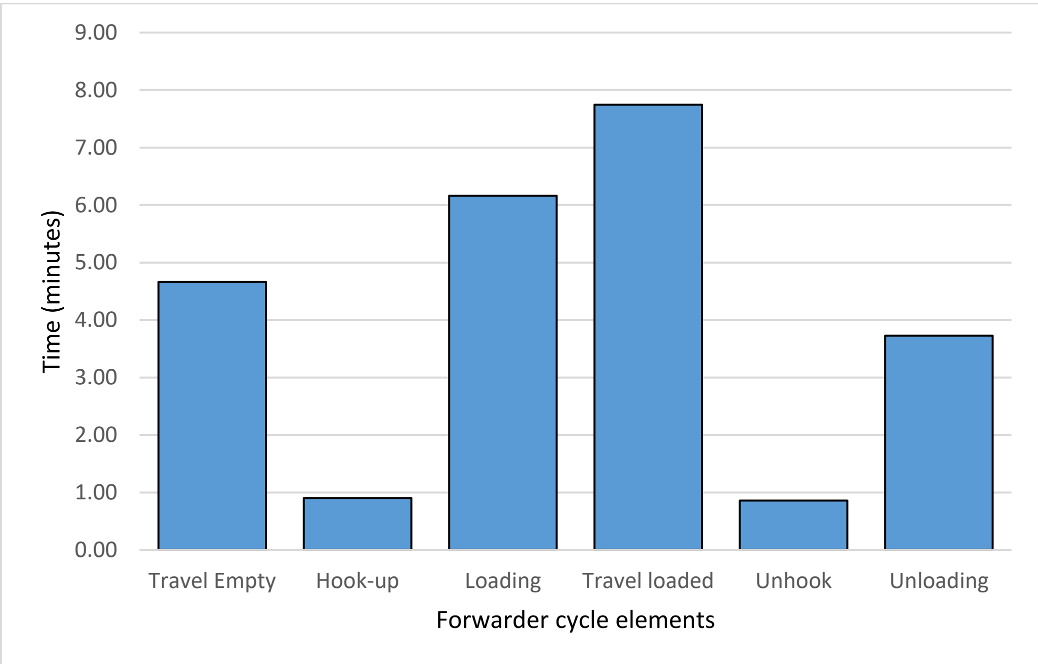

Figure 7: Average time recorded for each element under analysis during a forwarder cycle.

The average payload was 16.6 tonnes, giving an average productivity of 41.6 m^3/PMH (cubic metres per Productive Machine Hour – i.e., without delays). This productivity level is similar to that reported of a John Deere 1910 forwarder operation in Balmoral Forest (42.7m^3/PMH) which was operated without winch-assist but over longer extraction distances (Proto *et al.* 2017). In that same report, a smaller John Deere 1110E operating on the West Coast produced 37.1 m^3/PMH at similar extraction distances.

Being winch assisted, the forwarder was not able to unload on the landing while still tethered, hence the forwarder needed to both connect and disconnect from the winch each cycle (Figure 8).

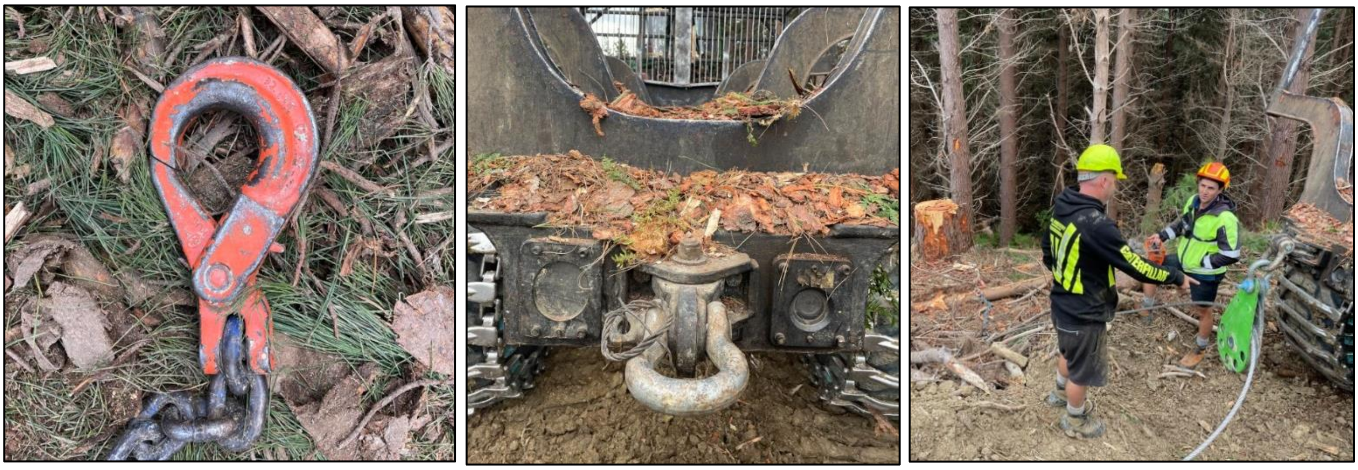

Figure 8: Connection points between the T-winch and forwarder (Left and middle); and the block used to create double purchase (Right).

Factors that were found to have an impact of the system productivity included forwarder extraction distance (forwarding distance), terrain slope, and the assistance of the loading machine with unloading the forwarder packet. Figure 9 shows the productivity per cycle against total forwarding distance, and slope for each cycle. As expected, productivity decreases with increasing extraction distance, due to the longer total cycle times. There were a few slower cycle times at shorter distances (that is examples of low productivity), otherwise there was a strong negative correlation between extraction distance and productivity. Average productivity at 250m was 55m^3/PMH, and this reduced to 35m^3/PMH at 1100 metres.

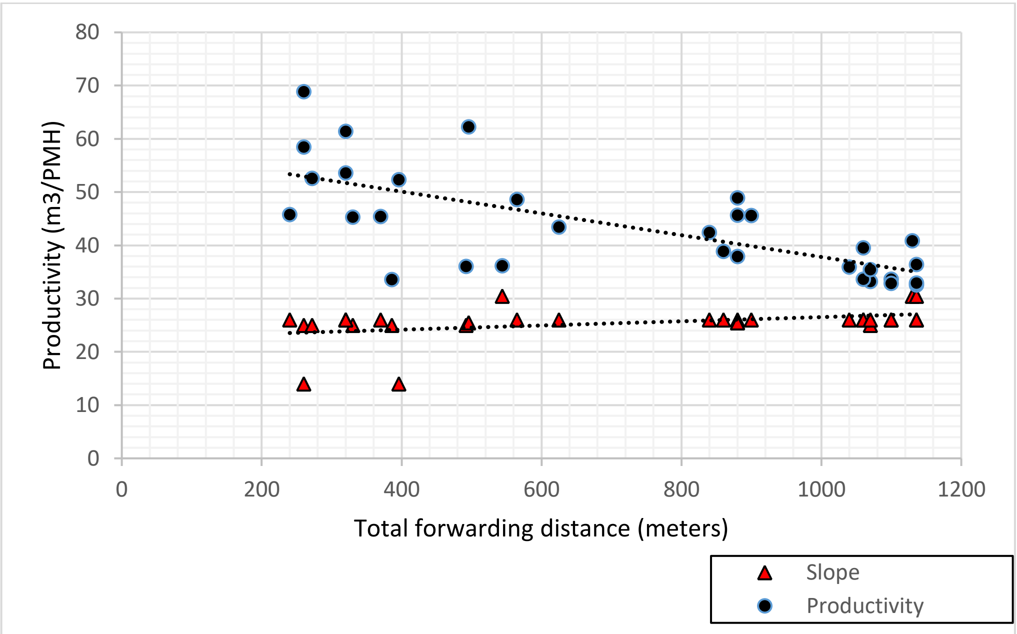

Figure 9. Relationship between distance and productivity (m3/PMH) for each cycle at different slope classes.

The average slope throughout the study was 25.4 degrees (47%). The maximum slope being 30.5 degrees and the minimum 14 degrees. As shown in Figure 10, the average slope increased with distance from about 24 degrees up to 29 degrees (45 to 55% slope). An increase in slope in part explains why there is lower productivity at longer distances. The forwarder track became more defined on the landscape, and Figure 10 below left shows the logs laid out after the harvester had passed through and prior to extraction, whereas on the right is the same track after 15 passes of the forwarder. While some soil disturbance is visible, there was no deep rutting of the track.

Figure 10. Common working slope during the study; slope 25 degrees, extraction distance 550m. Left: prior to extraction. Right: after 15 cycles

Figure 11. Forwarder loading on a 25-degree slope.

Utilisation is defined as the ratio of the time the machine was working on its primary tasks as a percentage of the total scheduled time. The time not included in productive time were delays which were defined as either operational, mechanical, or personal delays. Operational delays observed throughout the study were: relocating the winch-assist machine, manoeuvring around out of sight stumps, blading the extraction track, radio communication and stabilising dislodged logs on the forwarder packet mid cycle. The forwarder utilisation rate over the two-day period was 77.6%. Productivity per scheduled machine hour (in m^3/SMH) was 32.3 tonnes.

Operational Considerations

Hooking up

The average time required to hook-up and unhook from the winch-assist machine was plotted (Figure 12).

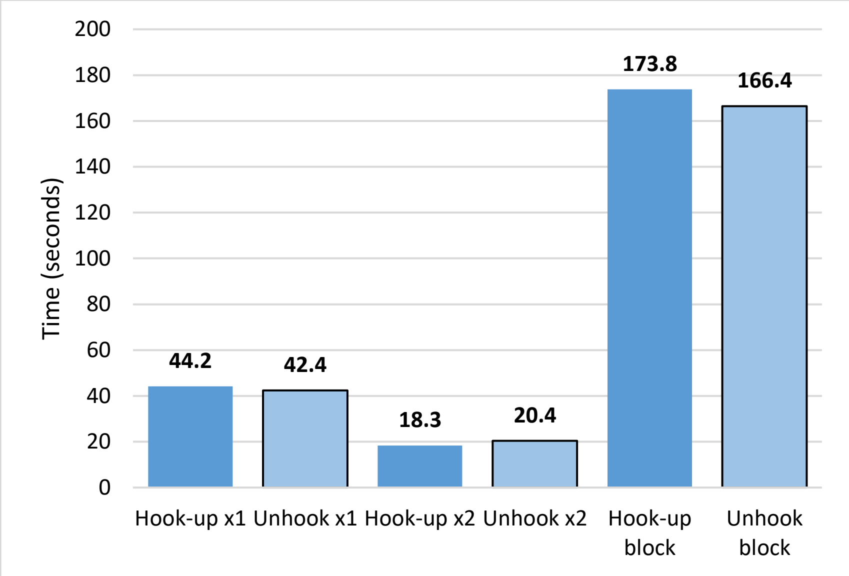

Figure 12. Average time and number of workers required to hook-up and unhook from winch-assist machine.

Of the 32 cycles for the forwarder, 22 were carried out by 1 person, 4 with the assistance of a second person, 3 required double purchase and for 3 cycles the forwarder was not attached to the T-winch. Double purchase is where the wire rope is passed around a pair of pulley blocks in sequence to increase the purchase or force applied to the rope.

The average total time required to hook-up and unhook the forwarder from the winch-assist machine was 86.6 seconds per cycle. The conventional method using one person required 44 seconds to hook-up and 42 seconds to unhook (a total of 1.44 minutes). The assistance of a second person reduced the hook-up and unhook time by 26 and 22 seconds respectively (equating to a combined hook-up and unhook time of 0.65 min), a reduction of 0.8 min per cycle. Arranging double purchase on the block connection took a combined time of 5.67 minutes on average, an increase in hook-up time of 130 sec and in unhook time of 122 seconds.

Unloading by Loader

Unloading the forwarder on average took 3.7 min. However, when available, the loader on the landing supported the unloading (Figure 13).

Figure 13. Loader operator assisting with unloading the forwarder packet.

The forwarder unloading by itself, took on average 4.46 min. Unloading the forwarder with the loader on average decreased this element by 2 minutes, taking 2.45 min.

Processor Productivity

For the short processor study, 2.8 hours of data was collected, recording 47 felling and processing cycles. Working time was defined as; 'falling', 'processing', 'brushing' and 'moving' (Figure 15). Operational delays were common (10.5% of cycle time) listed (in order); 'preparing' 'log wall', 'setting up' and 'planning', 'handling ropes', 'slashing tracks' for the forwarder and slewing issues.

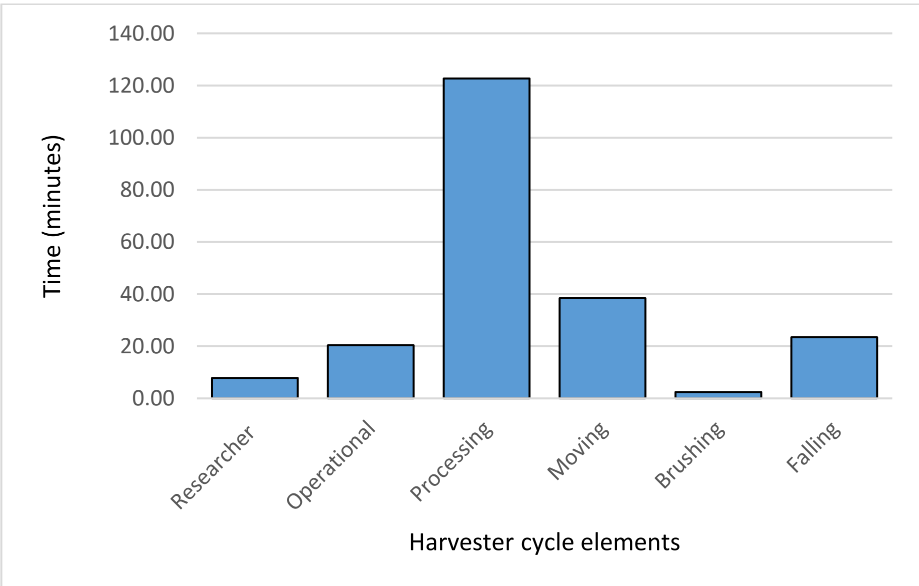

Figure 14. Average time recorded for each element under analysis during a processor cycle.

The average felling-processor cycle time was 3.6 min with an average volume felled and processed of 3.9 tonnes. This equates to an estimated productivity of 66.3 m^3/PMH. The utilisation rate of the processor during the study was 86.7%.

Delays with the harvester include, placing log walls and setting up and planning. These contributed 58% of the operational delay time (Figure 15). The processor was also used to “slash the tracks” for the forwarder (placing slash on the tracks then walking across the tracks to form and compact the tracks prior to forwarder extraction to improve traction).

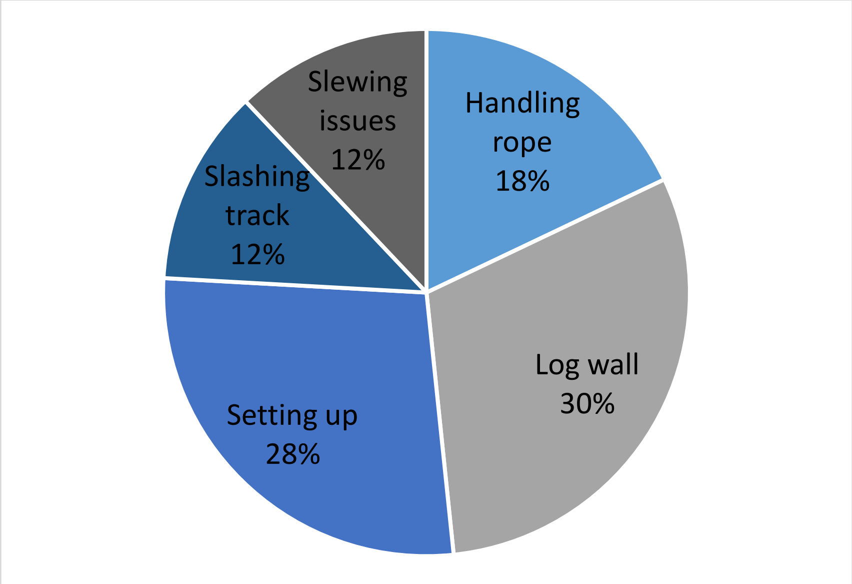

Figure 15. Breakdown of processor Operational Delays.

When the processor stacked logs up against stumps or root balls, attention was required to ensure that the logs did not dislodge and roll down the slope. This was important at the beginning of a new processing location during the setup for the log stack. Root balls were used to hold logs on the slope where stumps were not an option. It was observed that the processor had difficulties manoeuvring large trees on steep slopes, as the processor cab levelling was at maximum (completely “levelled out”.) The processor being completely levelled out noticeably reduced hydraulic power. The processor operator stated that processing on slopes over 25 degrees required 50% more time than processing on even slopes. This is due to the increased time required to place logs on the slope and placing slash in the correct location for the forwarder extraction track. During the processor study, minimal shovelling was observed as processing areas had been planned to allow the winch-assisted forwarder to access most of the setting.

Redirecting using Stumps

Stumps were successfully used to redirect the wire rope on the slope. This is common practice for winch assist operations in New Zealand. To facilitate this, the processor operator cut stumps much higher than normal practice in those locations where they would be required along the ridge line. Having high stumps that were “notched” to eliminate the risk of the rope ‘jumping’ off the stump was common practice in this operation. Due to the length of wire rope moving forward and back around each stump as the forwarder moved up and down the slope, significant wear was observed on the stumps (Figure 16).

Figure 16: Wear on a stump used to redirect the wire rope.

CONCLUSION

A cut-to-length system, comprising a harvester-processor, combined with a forwarder, supported by winch-assist, was studied for the first time in New Zealand to establish baseline productivity in cubic metres per productive machine hour (m^3/PMH) and to understanding the type of delays the system experienced.

Overall, the system worked well for the brief period that the study was carried out (two days), while operating on slopes up to 30 degrees. Average productivity of the forwarder was measured at 41.6 m3/PMH, which was the limiting production rate for the system. Brief time study of the harvester-processor indicated over 60 m^3/PMH, indicating fewer productive hours to work the harvester-processor to balance the productivity of the harvesting system. The study clearly showed the impact of extraction distance on forwarder productivity. Forwarding productivity reduced from 45-70 m3/PMH at 250 metres extraction distance to 30-40m3/PMH at distances over 1000 metres.

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