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

Programme: Harvesting & Logistics

Project Number: 1.6 **Report No.: FGR-H051**

Koller K602H Automated Cable Yarder Productivity Study: Coronet Forest, Arrowtown, New Zealand

Authors:
Dougal Shepherd
and
Prof. Rien Visser
School of Forestry, University of Canterbury

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

Date: 18 March 2021

TABLE OF CONTENTS

Disclaimer

This report has been prepared by University of Canterbury, School of Forestry for Forest Growers Research Ltd (FGR) subject to the terms and conditions of a Services Agreement dated 24 September 2019.

The opinions and information provided in this report have been provided in good faith and on the basis that every endeavour has been made to be accurate and not misleading and to exercise reasonable care, skill and judgement in providing such opinions and information.

Under the terms of the Services Agreement the University of Canterbury, School of Forestry's liability to FGR in relation to the services provided to produce this report is limited to the value of those services. Neither University of Canterbury, School of Forestry nor any of its employees, contractors, agents or other persons acting on its behalf or under its control accept any responsibility to any person or organisation in respect of any information or opinion provided in this report in excess of that amount.

supported by forestgrowers commodity levy

EXECUTIVE SUMMARY

Due to the number and smaller size of many New Zealand woodlots, and the steep slopes typical of these forests, smaller modern cable yarders might be a niche solution for cost effective harvesting. The Austrian Koller K602H trailer mounted cable yarder is a light and highly manoeuvrable machine; currently the only one of its kind in New Zealand.

A study was undertaken to determine the productivity of the Koller K602H at Coronet Forest, west of Arrowtown. The stand was young Douglas fir planted between 1984 and 1996, with an average piece size of only 1.1 cubic metres (m^3), that was being harvested early as part of the wilding tree mitigation effort to control spread in the alpine landscape.

The Koller K602H cable yarder was using a Koller MSK-3 motorised slack-pulling carriage. The volume per cycle was estimated based on large-end diameters of the stems and the average piece size from inventory; scaling the stems under the skyline during the operation was not acceptable due to the safety risk. The extraction cycle was measured using four elements: Unhook, Outhaul, Hook up, and Inhaul. All delays were recorded and categorised as either personal, operational, or mechanical, and the reason for each delay was recorded.

Over the four days of the study the Koller extracted an average volume of 67.1 m^3 per day. The main reason for the low daily production was that the machine was pulling over a long extraction distance, 202 metres average, and most of the timber was being extracted beyond the intermediate support. The average cycle time was 10.7 minutes. The inhaul element alone averaged 4.2 minutes due to the time taken breaking out stems, and frequent problems getting over the intermediate support. Delay-free productivity averaged 13.4 m^3 per productive machine hour (PMH). The average utilisation rate was 56%, with one very long operational delay for a line shift that included setting up a new intermediate support (7.6 hours). Other delays included repairs to the carriage, as well as frequent hang-ups.

Productivity was lower than previous Koller studies in New Zealand. Not only was the extraction distance longer, but it was also extracting downhill using an intermediate support. Productivity was high compared with typical European studies however, because those operations are invariably selective harvesting (thinning) or patch-cut harvests. Hourly productivity was low when compared against the overall New Zealand cable yarding average, as derived from the FGR Benchmarking database. The Koller system operates with only three workers, and the lower capital cost and low operating costs, especially labour costs, still may make it an attractive alternative for woodlot operations.

INTRODUCTION

Cable yarders are an effective extraction system for harvesting plantations on steep terrain where ground-based systems cannot be used. The use of cable yarders has increased significantly from around 15% of the total volume harvested in New Zealand in 1976 (Fraser *et al.* 1976) to over 40% by 2014 (Visser 2015). Cable yarding provides environmental benefits due to the partial suspension of logs and avoiding ground-based machinery disturbing the soil (Liley 1983; McMahon 1995).

Small woodlots (<200 ha in area) make up about 30% of the total national plantation forest (MPI 2017), with forecasts indicating the volumes from these woodlots to increase from 8 to 15 million m3/year from 2020 to 2035 (MPI 2016). Cable harvesting costs have increased almost $1.00 per tonne on average per annum from 2009 to 2018 and are on average around $13/tonne more expensive than ground-based options (Visser and Obi 2020). As such it is becoming more difficult for the harvesting of small woodlots to remain viable economically, especially if they are on steep terrain.

Due of the size and terrain slope of these small woodlots, it has been proposed that an alternative modern, smaller, and more portable yarder might provide a more cost-effective harvesting option. Such systems are well established in Europe (Heinimann *et al*. 1998; Visser and Stampfer 1998; Enache *et al.* 2016). These smaller yarder systems, with towers typically smaller than 30ft, have been extensively studied under European conditions, including summary publications reporting on productivity (Ghaffariyan *et al.* 2009; Spinelli *et al.* 2015; Lindroos and Cavalli 2016), utilization and cost (Spinelli *et al*. 2010; Holzleitner *et al.* 2012; Schweier *et al.* 2020), the effect of stand and terrain parameters (Erber *et al.* 2017), and installation times (Stampfer *et al.* 2006). However, truly comparable data to New Zealand is not available as most European harvests are either in thinning or very small patch-cut harvests. The average tree size is typically also smaller, and access more difficult (Enache *et al.* 2016).

Some comparable studies have been completed in North America, including a K-300 study in North-eastern USA (Huyler and LeDoux 1997), and comparing four harvesting systems in Douglas-fir in commercial thinning (Han and Kellogg, 2000). Another study looked at the positive effect of training on yarder performance (Haynes and Visser 2001). Such studies were completed to evaluate the opportunity of lower impact, lower operating cost, cable yarding systems in comparison to the more common larger scale American yarders, such as Madill or Thunderbird, that are most common in New Zealand (Harrill, Visser and Raymond, 2019). A yarder survey in 2018 showed there was only one Koller machine operating in New Zealand out of a yarder population of 314 (Harrill and Visser 2018). The Austrian-designed trailer-mounted Koller K602H cable yarder is significantly lighter than the North American yarders, weighing only 18 tonnes (Koller 2021). Due to the size and weight, it is highly manoeuvrable, so may be suited to working in New Zealand woodlots, where access is often restricted.

The Koller K602H yarder working in New Zealand was previously trialled in Mangatu Forest near Gisborne in February 2015 (Evanson and Hill 2015). The forest block comprised Pinus nigra (Corsican pine) at high stocking with trees of small piece size on moderately steep slopes. It was proposed that the yarder could be competitive in forest stands with average piece size of less than 1.6 tonnes, and in small landing and roadside operations. The Koller K602H was also trialled over five consecutive days in March 2016 in a radiata pine plantation of 2.3m^3 piece size at Waikura Station, East Cape. The study showed delay-free hourly productivity of 31.9m^3 per productive machine hour, or PMH (Campbell 2016, Evanson *et al.* 2017). The Koller K602H yarder is now working for Hurring Logging Ltd (Figure 1). A study was undertaken to determine the productivity of the Koller K602H and provide some comparison to past studies as well as traditional North American yarders.

Figure 1. The Koller K602H yarder and the crew of Mike Hurring Logging Ltd (from left: Travis Pukehika, Sylvester Reeves and Drew McBride).

STUDY DETAILS

Forest Site

The study took place at Coronet Forest, west of Arrowtown, New Zealand over four consecutive days from 30th November - 3rd December 2020. The Koller K602H yarder was operating in a unique situation, where a larger Douglas fir forest was being harvested to prevent the spread of wildings, and the yarder was being used as a low-impact machine to extract trees downhill.

Figure 2. Coronet Forest planted in Douglas fir. Evidence of the wilding spread can be seen around the stand boundaries.

The Douglas fir forest, with an area totalling 172.5 hectares, was planted between 1984 and 1996. The trees were being harvested significantly earlier than the optimal rotation age due to wilding tree spread problems (Figure 2). The area was planned to be replanted in native tree species. The weather was mixed with rain/overcast about half the time and the rest of the time sunny, as well as variable winds.

System Description

The Koller K602H yarder is capable of supporting 660m of 22mm diameter swaged skyline and has 10.5 tonnes of pulling power. The mainline and haul back are both 12mm diameter with 6.0 tonnes and 4.5 tonnes of pulling power respectively. The yarder was operated in a standing skyline configuration, pulling downhill over a long face with stems lying mainly horizontally across the slope and butts facing the skyline. The skyline corridor consisted of a steep front slope up to an intermediate support at 154 m distance from the yarder, followed by a moderate slope to an excavator tail hold at approx. 270m from the yarder.

The stems were being pulled onto a landing for two-staging away using a skidder to extract the stems to the processing landing (Figure 3). A grapple processor mounted on an excavator base delimbed the stems and pre-bunched them into piles. The skidder serviced both the yarder as well as a shovel extraction system further up the track.

Figure 3. Koller K602H yarder landing in Coronet Forest, Arrowtown

The Koller K602H cable yarder was using a Koller MSK-3 motorised slack-pulling carriage (Figure 4), weighing 690 kg, and powered by a 5.6 kW engine.

Figure 4. Koller MSK-3 Carriage

STUDY METHODOLOGY

Time and Motion Study

The main goal of the study was to measure productivity, which is the volume in cubic metres extracted per productive machine hour (m^3/PMH). To compare the Koller against previous studies, the productive extraction cycle was broken into four elements: Outhaul, Hook up, Inhaul and Unhook, times. In addition, delays were recorded.

Outhaul: The carriage leaves the landing to gather stems from hillside. Element starts the moment the rigging is raised after the previous load has been dropped and ends when the carriage stops on the skyline.
Hook Up: When the carriage picks up its load. Element starts the moment the carriage stops travelling along the skyline and ends when the carriage begins its return journey to the landing with a full payload.
Inhaul: Carriage returns to the landing with payload. Element starts the moment the carriage starts to move back along the skyline to begin its return to the landing and ends when the carriage stops at the tower to drop its load.
Unhook: Carriage unloads stems onto the drop zone to be two-staged away. Element starts the moment the carriage stops at the tower and drops its load on to the landing and ends when the empty strops are raised back to the carriage.
Delay: Delays were recorded to identify reasons the operation stopped.

Scheduled machine hours (SMH) were recorded from the crew arriving at the yarder landing to leaving the site – whereby crew members arrived earlier onsite to attend a common tail-gate meeting. A stopwatch and timesheet were used to record these times and documented as either operational, mechanical, or personal delays. Using cycle and delay times, the utilisation rate was found using the equation:

Utilisation (%) = PMH/SMH * 100

where PMH is productive machine hours and SMH is the scheduled machine hours.

Stem volume was estimated using callipers to measure stems across the large end diameter (LED) where possible, or the LED was estimated if it was unsafe to access the landing. A basic tree form function was used to relate the LED to stem volume.

The reported productivity used an average tree size of 1.0 m^3 which is based on the diameter measures and volume scaling, but also corroborated from Queenstown Lakes District Council's inventory data. Approximately 90% of all pieces extracted were stems. That is, only 10% of the pieces pulled where broken heads. Using volume and cycle time information, productivity for both productive and scheduled machine hours was calculated (m^3/PMH and m^3/SMH respectively).

The extraction distance was measured using the range finder where possible, but also the Koller inbuilt control unit displayed carriage distance and this measure was taken when the carriage was not in sight.

RESULTS

Productivity, Extraction distance and Cycle times

The productive time, number of cycles, average extraction distance, average cycle time, average productivity and total extracted volume are shown below in Table 1. The data is presented for each day of the study to provide an indication of the variation from day-to-day in a complex yarding operation. Day 1 was characterised by poor weather (heavy rain at times), many mechanical delays, but also problematic extraction including head-pulls and the carriage struggling to go over the intermediate support. Day 2 had only 1.3 productive hours with most of the time setting up the new yarding corridor, including setting up a new intermediate support. Once the system was set up with an improved angle over the support and the operators had gained confidence, Day 4 reflected a very productive day with 8.2 hours of extraction resulting in a total of 118 m^3 extracted in 43 cycles. This was partially attributed to the change in intermediate support location, showing that the slope angle in and out of the support is critical.

Table 1. Productive time, extraction distance, cycle time, productivity, and total volume

Study Day	**Productive Time (PMH)**	**Number of Cycles**	**Average Extraction Distance (m)**	**Average Cycle Time (min)**	**Average Productivity (m^3/PMH)**	**Total extracted volume (m^3)**
Day 1	5.9	25	218	14.2	9.1	54.3
Day 2	1.3	7	143	9.5	15.6	19.2
Day 3	4.6	34	155	7.9	17.7	77.1
Day 4	8.2	43	242	11.1	15.2	118.0
Total	**20.0**	**109**				**268.6**
Average	***5.0***	***27***	***202***	***10.7***	***13.4***	***67.1***

The average scheduled machine hours per day was 8.9 hours, with 5.0 hours productive time. This is a machine utilisation rate of 56%, which is similar to the 55% calculated at the Waikura study

(Campbell, 2016). This machine utilisation is however significantly lower in comparison to the New Zealand industry standard for cable logging of 65-70% (Visser 2018).

The average extraction distance was 202 metres, which shows that most of the extraction took place beyond the intermediate support (154m), which provides some justification to the average inhaul element of 4.2 minutes (Table 2). However, this is still significantly longer time than other studies (Evanson *et al.* 2017).

Table 2. Cycle time broken up into elements with reference to extraction distance

Study Day	Extraction Distance (m)	Outhaul (min)	Hook Up (min)	Inhaul (min)	Unhook (min)	Cycle Time (min)
Day 1	218	2.3	5.7	4.6	1.6	14.2
Day 2	142	0.9	3.3	3.5	1.8	9.5
Day 3	154	1.3	2.5	2.9	1.2	7.9
Day 4	242	1.8	2.9	5.1	1.3	11.1
Total	***202***	***1.70***	***3.44***	***4.20***	***1.37***	***10.71***

The reason for the long inhaul element times was due to the cycles on the first day had difficulty getting over the intermediate support with a combination of the large load, and not being able to engage the automated mode where a computer guides the carriage. On the last day, the stems at the back were piled together and required extra time to breakout, thus, increasing the time to in-haul. It is known that higher break-out forces are required if other stems were on top of the target load (Harrill 2017).

As expected, when the extraction distance increases, so does the cycle time (Figure 5). A linear trend was plotted to estimate the cycle time at different extraction distances, which is useful when comparing studies done at different distances.

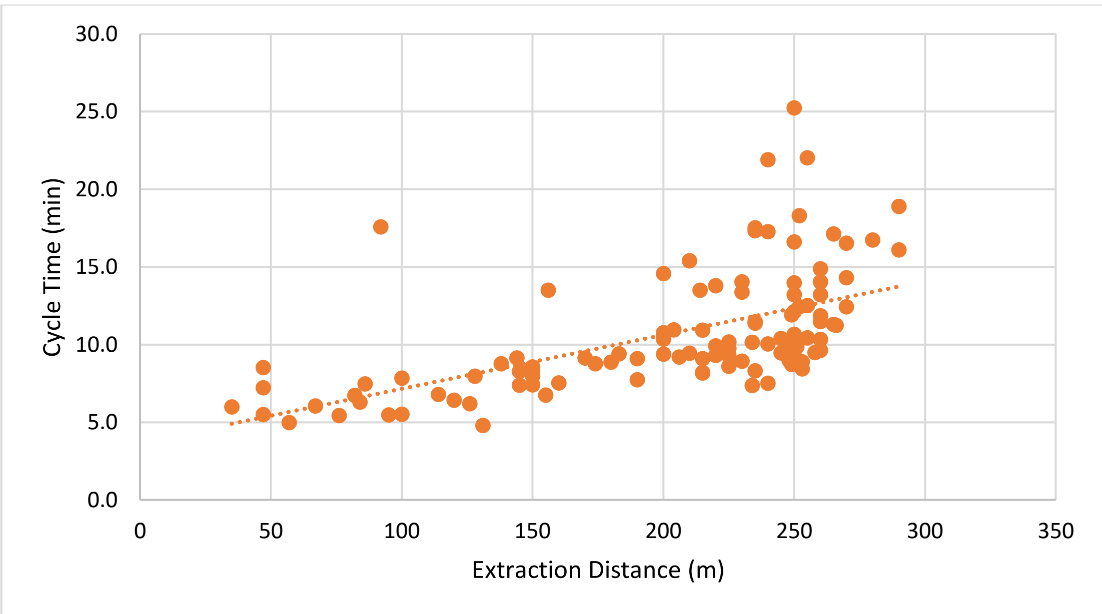

Figure 5. Cycle time with extraction distance

The average cycle time was 10.7 min and average productivity was 13.4 m^3/PMH. The long in-haul times had the largest impact on the total cycle time. This cycle time is significantly longer, and productivity lower than the Waikura study (Campbell, 2016) where under favorable conditions (uphill, larger stems size, no intermediate support) they achieved 32 m^3/PMH. The average turn volume per cycle was 2.4 m^3, which was similar to Waikura and Mangatu (Table 3).

Table 3. Comparing Coronet Forest study to other Koller studies (from Evanson et al. 2017).

Average Values	**Chile**	**Mangatu**	**Waikura**	***Coronet***
Productive hr/day	7.4	7.4 (Est)	4.6	*5.0*
Haul distance (m)	240 max.	50	117	*202*
Tree volume (m^3)	1.0	0.74	2.33	*1.1*
No. trees/cycle	2.46	1.5	1.13	*2.3*
Haul volume (m^3)	2.46	1.11	2.63	*2.4*
Total cycle time (min)	8.3	4.8	5.75	*10.7*
Volume/day (m^3)	133	103	126	*67.1*

When comparing the Coronet Forest operation to previous studies on the Koller K602H yarder, there are some large differences. The productive time is similar, however, this is subject to the time the study takes place, for example, if a line needs to be set up or the weather is poor. The average haul distance at Coronet was much longer than the other New Zealand studies, which explains the longer average cycle time. However, using Figure 5 to estimate the cycle time over an extraction distance of 120 metres this would result in an estimated cycle time of approximately 7.5 minutes, which is significantly longer than the other two New Zealand studies' times at this extraction distance.

The average volume extracted per day of 67 m^3 is also a lower than that of the other studies. However, on Day 4, 118.0 m^3 was extracted at 242 m haul distance, which demonstrates that high daily production could be achieved if longer productive time was available.

Delays

Delays were broken into three categories: Mechanical, Operational and Personal (Table 4).

Table 4. Delay types each day

Study Day	**Operational (min)**	**Mechanical (min)**	**Personal (min**	**Total (min)**
Day 1	163	72	62	296
Day 2	558	4.6	0.0	563
Day 3	226	27	57	198
Day 4	58	8	60	126
Total (hrs)	***16.7***	***1.9***	***3.0***	***21.6***

On the first day, the most significant delay was 62 minutes spent trying to fit chains and cutting the mainline that had jammed in the carriage. Tail hold repositioning also took 17 min and experimenting with automatic mode and new chokers took 30 min. On the second day, 7.6 hours were spent shifting the skyline and fixing the intermediate support tieback due to it slipping and ripping the bark off. Delays on Day 3 included shifting the tail rope taking 1.9 hours. On Day 4 no significant delays over 10 minutes were incurred, other than the set up and close-down and personal breaks, resulting in a 91% utilisation rate. This low level of delays on Day 4 resulted in longer productive time, as shown in Table 4. Overall, 77% of the delays were operational.

The average utilisation rate over the four days was 56%. Using the productive machine hours (PMH) and scheduled machine hours (SMH), the average productivity can be found for while the machine is working and when it is scheduled to work (Table 5).

Table 5. Productivity using scheduled and productive machine hours

	SMH	PMH	Utilisation Rate (%)	Total Extracted (m3)	Productivity (m3/PMH)	Productivity (m3/SMH)
Day 1	8.8	5.9	67.4	54.3	9.2	6.2
Day 2	9.0	1.3	14.4	19.2	14.8	2.1
Day 3	9.0	4.6	51.1	77.1	16.8	8.6
Day 4	9.0	8.2	91.1	118.0	14.4	13.1
Average	***8.9***	***5.0***	***56.0***	***66.9***	***13.4***	***7.5***

DISCUSSION

A more direct comparison of productivity can be made with the Chilean study, where the average tree volume was 1.0m^3 (vs. 1.0m^3 in this study) and 2.4 pieces per cycle were extracted (vs. 2.3), and a cycle time of 8.3 minutes (vs. 10.7min). Productive time in the Chile study averaged 7.4 hours per day, resulting in daily production of 133 m^3/day, compared to 5.0 PMH/day and 67 m^3/day. The Chile study is considered to be close to optimal productivity, with similar productivity values coming from European studies on an hourly basis (Erber *et al.* 2017), although European studies often have lower average utilisation rates because of their smaller total harvest volumes (Holzleitner *et al.* 2012).

This Koller K602H yarder study showed relatively low productivity. However, there are numerous factors that influenced this result. The extraction distance was significantly longer at Coronet Forest causing longer cycle times. When comparing the Koller K602H yarder to North American yarders in New Zealand consideration must be taken that the costs to operate this smaller yarder are significantly lower. Although detailed costings were not undertaken in this study, factors such as lower fuel consumption (approx. 8-10 l/PMH), lower capital cost, and fewer workers required are expected to result in competitive harvesting costs, despite lower daily production. The overall average productivity of 13.4 m^3/SMH is approximately half that of the average New Zealand productivity rate of 26.2m^3/SMH as reported from the FGR Benchmarking database (Visser, 2019). However, this average includes all types of yarders, including the highly productive mechanised swing yarders, operating in different conditions.

Similar to the earlier Waikura study (Campbell 2016), it was found that inexperience and lack of knowledge of the technical aspects of the machine makes it very difficult to operate efficiently. The crew expressed that the manual is not much help and potentially not translated effectively. Therefore, to gain knowledge of the machine, the best option may be to bring an experienced Koller machine operator to New Zealand to help train the crew.

CONCLUSION

The four-day study of the Koller K602H yarder at Coronet Forest was successful in terms of measuring the productivity and utilisation of the yarder operation. The study measured the productivity of a unique yarder for New Zealand, which may have application in harvesting steep terrain woodlots due to its small size, automation aspects requiring a smaller crew in New Zealand.

The earlier Koller K602H yarder study in Waikura concluded that the yarder is unlikely to be a viable direct replacement for typical North American yarders, but that it has several advantages which may make it a highly efficient system if applied correctly (Campbell, 2016). This study validates that finding, showing that the productivity is not likely to reach average New Zealand daily production levels.

ACKNOWLEDGEMENTS

The authors would like to thank Mike and Josh Hurring and the yarder crew from Mike Hurring Logging Ltd: Adrian Gillion, Travis Pukehika, Drew McBride, and Sylvester Reeves, for their support in conducting this study on site, as well as providing insight into production issues with the yarder. We would also like to thank the EU Koller / TechnoSteep project and Forest Growers Research Ltd for funding this study.

REFERENCES

Campbell, T. 2016. Assessment of the Opportunity of Modern Cable Yarders for Application in New Zealand. A thesis submitted in partial fulfilment of the Master of Forestry Science, June 2016. New Zealand School of Forestry, University of Canterbury, New Zealand.

Enache, A., M. Kühmaier, R. Visser, K. Stampfer. 2016. Forestry operations in the European mountains: A study of current practices and efficiency gaps. Scandinavian Journal of Forest Research, Volume 31(4):412–427. doi:10.1080/02827581.2015.1130849.

Erber, G., A. Haberl, T. Pentek, K. Stampfer. 2017. Impact of operational parameters on the productivity of whole tree cable yarding – a statistical analysis based on operation data. Austrian J. For. Sci. 134(1):1–18.

Evanson, T., and Hill, S. (2015). The Koller K602H Yarding System. Harvesting Technical Note HTN08-01. Future Forests Research, Rotorua, New Zealand 2015.

Evanson, T., Hill, S., Campbell T. and Visser, R. (2017). Productivity of the Koller K602H Yarder in Radiata Pine. Harvesting Technical Note HTN09-04. Forest Growers Research, Rotorua, New Zealand 2017.

Fraser, T., Murphy, G., & Terlesk, C. J. 1976. A survey of the logging industry for the year end 31 March 1974. Economics of Silviculture Vol. 84. Production Forestry Division, Forest Research Institute, Rotorua, New Zealand.

Ghaffariyan, M., Stampfer K., Sessions J. 2009. Production Equations for Tower Yarders in Austria, Int. J. For. Eng. 20:1, 17-21, DOI: 10.1080/14942119.2009.10702571.

Han, H.S., Kellogg, L. 2000. Damage characteristics in young Douglas-fir stands from commercial thinning with four timber harvesting systems. West. J. Appl. For. 15(1):27–33. doi:10.1093/wjaf/15.1.27.

Harrill, H., R. Visser, K. Raymond. 2019. New Zealand Cable Logging 2008–2018: a Period of Change. Current Forestry Reports https://doi.org/10.1007/s40725-019-00092-5

Harrill, H. 2017. A Study of Breakout Forces in Cable Logging. Harvesting Technical Note HTN09-06. Forest Growers Research Ltd, Rotorua, New Zealand.

Harrill, H., R. Visser. 2018. Survey of Yarders and Rigging Configurations: 2018. Harvesting Technical Note HTN10-04. Forest Growers Research Ltd, Rotorua, New Zealand.

Haynes, H., and R. Visser 2001. Productivity improvements through professional training in Appalachian cable logging operations. Proc. Int. Mtn. Logging 11th Pacific Northwest Skyline Symp. 11:10–12.

Heinimann, H.R., R. Visser, and K. Stampfer. 1998. Harvester-cable yarder system evaluation on slopes: A Central European study in thinning operations. In: Proc. Harvesting Logistics: From Woods to Markets, July 20-23, Portland, OR. Council on Forest Engineering. pp. 39-45.

Holzleitner, F., Stampfer, K., Visser, R. 2012. Utilization Rates and Cost Factors in Timber Harvesting Based on Long-term Machine Data. Croat. J. For. Eng. 32 (2011): 501-508.

Huyler, N.K. and C.B. LeDoux. 1997. Cycle-time equation for the KollerK300 cable yarder operatingon steep slopes in theNortheast. Res. Paper NE-705. USDA Forest Service.

Koller (2021). Specifications for Koller K602H – Trailer Mounted Yarder. Retrieved from: https://www.kollergmbh.com/media/attachments/2019/10/01/komplettprogramm_en_2019_v07_web.pdf

Liley, W.B. (1983): Cable Logging Handbook: N.Z. Logging Industry Research Association Inc, Rotorua, New Zealand

Lindroos, O., R. Cavalli 2016. Cable yarding productivity models: a systematic review over the period 2000–2011. Int J For Eng. 27(2):79–94.

McMahon, S. (1995) Survey method for assessing site disturbance: A procedure for estimating site disturbance caused by production thinning, harvesting, or mechanical site preparation. Project Report, No. No. 54. New Zealand Logging Industry Research Organisation: Rotorua, N.Z.

MPI. 2016. Wood Availability Forecasts – New Zealand 2014–2050. Prepared for the Ministry for Primary Industries by InduforAsia Pacific Limited. September 2016. Ministry for Primary Industries, Wellington, New Zealand

MPI. 2017. National Exotic Forest Description as at 1 April 2017, Edition 34. Ministry for Primary Industries. Wellington, New Zealand

Schweier, J., M-L. Klein, H. Kristen, D. Jaeger, F. Brieger, U. Sauter. 2020. Productivity and cost analysis of tower yarder systems using the Koller 507 and the Valentini 400 in southwest Germany. Int. J. For. Eng. 31:3, 172-183, DOI: 10.1080/14942119.2020.1761746

Spinelli, R., N. Magagnotti, C. Lombardini. 2010. Performance, capability, and costs of small-scale cable yarding technology. Small-Scale For. 9(1):123–135. doi:10.1007/s11842-009-9106-2.

Spinelli R, N. Magagnotti, R. Visser 2015. Productivity models for cable yarding in Alpine forests. Eur. J. For. Eng. 1(1):9–14.

Stampfer K, R. Visser, C. Kanzian. 2006. Cable corridor installation times for European yarders. Int J For Eng. 17(2):77. doi:10.1080/14942119.2006.10702536.

Visser, R. and K. Stampfer. 1998. Cable extraction of harvester-felled thinning: An Austrian case study. International J. of Forest Engineering. 9(1): 39-46.

Visser, R. 2015. Harvest Cost and Productivity Benchmarking: 2014 Update. Harvest Technical Note Vol. HTN07-05. Future Forests Research Limited, Rotorua, New Zealand.

Visser, R. 2018. Benchmarking Harvesting Cost and Productivity–2017 Update. Harvesting Technical Note HTN10-02. Forest Growers Research Ltd, Rotorua, New Zealand.

Visser, R. 2019. A Decade of Benchmarking Harvesting Cost and Productivity. Harvesting Technical Note HTN12-01. Forest Growers Research Ltd, Rotorua, New Zealand.

Visser, R. and Obi, F. 2020. Benchmarking 2019 data and longer-term productivity and cost analyses. Harvesting Report H045. Forest Growers Research Ltd, Rotorua, New Zealand.