Efficiency and ergonomic benefits of using radio controlled chokers in cable yarding.

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Abstract

Using radio controlled chokers in cable yarding can improve both productivity and safety during the unhooking phase part of the extraction cycle. However, the additional weight of the radio controlled chokers may also increase the work load of the choker-setters on the slope. A study has been completed in Austria on the Wanderfalke yarder. The factorial study design alternated extraction corridors with and without the use of radio controlled chokers. A standard choker for this system weighs 0.34 kg and cost 11 Euro each, whereas the radio controlled chokers weighs 1.6 kg and cost 9,000 Euros for the set of four chokers. Work-load was measured by continuously monitoring the heart-rate of the workers. Results showed that was a slight productivity gain, but also an increased work-load for the choker-setter. This is reflected in the comments from the yarder crew; the yarder operator thinks it great not having to get down to unhook the turn, the choker-setter is not impressed with the extra weight and work load.

Introduction

Efficient forest management in steep terrain is mostly linked to cable-based harvesting systems. Technical developments and system optimization during the last decades targeted on more efficient, social acceptable and ecological sustainable ways to use cable yarding systems. Radio-controlled applications fostered automation of processes and enables both the yarder operator as well as the choker-setter to control the yarder (Heinimann et al., 2006). Unhooking chokers at the landing is time consuming, accounting for almost 10 to 20% of the productive cycle time, depending on the system (Baker et al., 2001). Therefore automation of choker releasing is a significant opportunity for further improvement of both productivity as well as safety.

During the 1970's the first trials of mechanical self-releasing chokers were done in Austria and Norway (Samset, 1985). Use was limited due to their unreliability. It was not until the first radio-controlled chokers were developed that the potential for efficiency improvements was recognized. However, their reliability was also limited, with one major problem being a weight of more than 4 kg (Hemphill, 1985; MacDonald, 1990). Technical developments and new materials over the last two decades have allowed the weight of a choker to be significantly reduced – as low as 1.6 kg for smaller diameter chokers.

Radio-controlled chokers have the potential to improve efficiency and work safety during cable logging operations. For operations where the yarder operator leaves his cab to unhook, the time taken to get in and out of the cab can be saved. For systems where the logs are landing either next to or in front of the yarder, the job of the 'poleman' (person who unhooks at the landing) is not required, which also reduces the yarders operational delay time (Huyler and LeDoux 1997; Biller and Fisher 1984).

The classic goal of modern ergonomics is to optimize both the systems efficiency and the working conditions. The heavier weight of the radio-controlled chokers could lead to an increase of the choker-setters physical strain. It is therefore important that an increase in productivity is not at the expense of an increase of physical strain on the choker-setter.

Acquisition costs of radio-controlled chokers are high (product information Giritzer und Fortronics), and hence the question of payback time of the investment should also be considered. Currently, there is no literature available on productivity, physical strain of choker setter, work safety, and cost effectiveness. This study examines efficiency and ergonomic impacts of radio-controlled chokers and evaluates their cost-effectiveness.

Methodology

Study layout

There are many productivity studies on cable yarding operations, whereby yarding productivity is commonly used as the dependant variable. The main source of variation is, mean volume per piece, yarding distance, as well as lateral yarding distance.

In this study the following productivity hypothesis is used:

Yarding productivity = f (tree volume, yarding distance, lateral yarding, CHOKER TYP)

A factorial layout is utilized to investigate the productivity hypothesis. Six extraction corridors with and without the use of radio-controlled chokers are alternated within one operation area.

Harvesting system

The study location is characterized by patches of wind thrown trees. The root balls of the wind-thrown trees are cut using a chain saw. The trailer mounted "Wanderfalke" yarder (company Mayr-Melnhof) extracted the whole trees to the forest road. The Sherpa U 1.5 carriage, with a maximum pay load of 1.5 tons, was used. Further processing of trees was done using a harvester head Kesla 20RH that is mounted on wheeled excavator base. A closed work chain was used, whereby through the use of radio-controlled units both the operator of the processor as well as the choker setter can control the tower yarder.

In addition to the standard manual chokers, radio-controlled chokers (Company Giritzer) were used. The radio-controlled system "Ludwig" (Figure 1) has an automatic 'push-button' release. The weight of each choker is 1.6 kg, with a maximum choker cable diameter of 13 mm.

Figure 1: Radio controlled choker system "Ludwig"

Study sites

The study area is located in the eastern part of the Austrian Alps. The forest consists almost exclusively of Norway Spruce (see Table 1), with an average extracted tree volume during the study ranging from 0.42 to 0.86 m^3. The age varies between 55 and 85 years. As per the study design, six cable corridors were used, with the length of the corridors ranging from 89 to 201 meters. Slope gradient ranged from 50 to 60 percent. Due to small-area windbreaks, timber volume extracted per corridor varied from 50 to 220 m^3.

Table 1: Stand descriptions

	Standard choker			**Radio-controlled choker**		
Age (J)	85	53	55	55	65	65
Tree species share (1/10)	Spruce 10	Spruce 9 BL 1	Spruce 10	Spruce 10	Spruce 9 Larch 1	Spruce 10
Av. Tree volume (m^3)	0.86	0.59	0.60	0.42	0.66	0.60
Corridor length (m)	137	102	140	148	201	89
Slope (%)	52	58	50	60	55	50
Total harvesting volume (m^3)	50.2	220.0	76.3	56.7	103.0	76.3
Harvesting volume (m^3/m)	0.37	2.16	0.55	0.38	0.51	0.86

Data collection

Time study

A time and motion study of the yarder system and choker-setter were recorded using "Latschbacher" portable-time study computers. Work was divided into work elemental tasks for system (Table 2) and the choker-setter (Table 3).

Table 2: Work task definitions for yarder system

Work task	Description
Carriage out	Carriage movement from the landing out to the choker setter
Hook-up	Rope is fed out from the carriage until load touches the carriage
Carriage in	Carriage movement from the choker setter back to landing
Landing	Lowering load and feeding in and out of the mainline
Release Choker	Operator unhooks load, includes getting in and out of the cab
Manipulation	Moving or processing trees by loader arm
Waiting	Operational delay time
Delays < 15 minutes	Delays shorter than 15 minutes
Delays > 15 minutes	Delays longer than 15 minutes
Miscellaneous	Non assignable times

Table 3: Work task definitions for the choker-setter

Work task	Description
Pull rope out	Rope is fed out from the carriage until first timber is reached
Hook-up	Load is hooked up
Lateral in	Load pulled back to carriage, until carriage is unclamped from skyline
Load preparation	Preparing work for the next yarding cycle
Chain saw work	Operating chain saw
Waiting	Operational delay time (choker setter is waiting for carriage)
Delays < 15 minutes	Delays shorter than 15 minutes
Delays > 15 minutes	Delays longer than 15 minutes
Miscellaneous	Non assignable times

For each of the six study replicates, the following response variables, factors and covariates have to be gathered or calculated at the yarding-cycle level (Table 4).

Table 4: Variable Definition for Data Sampling

Dependant variables	cycle	total time for one yarding cycle	min
	load volume	total load volume for each yarding cycle	m^3
	productivity	(load volume/cycle)*60	m^3 per PSH_0
Factor	CHOKER	(0) standard choker, (1) radio-controlled choker	2 levels
Covariates	tree volume	mean tree volume per load	m^3
	pieces	number of pieces per load (trees, tops, butts)	n
	lateral yarding	Lateral distance from skyline and felled trees	m
	distance	distance between tower yarder and stopping position of carriage	m

Heart rate

Heart rate is measured during the entire working day, including rest and lunch breaks. A Polar RS 800 G3 portable heart rate monitor is used. It consists of a pericardial heartbeat capturing-transmitting unit on a strap with electrode areas and a receiver-storage unit similar to a digital wristwatch.

The heart rate reserve (%HRR) was determined by applying the following formula:

$$\%HRR = (HRw - HRr)*100/(HRmax - HRr)$$

Where:

HRw = Working heart rate: Average number of heart beats per minute (bpm) during different working processes.

HRmax = Maximum heart rate: 220 - age

HRr = Resting heart rate: Two approaches are used to determine the resting heart rate. The average heart rate value in a sitting position for a 10 minute period in the morning or the minimum heart rate per minute for the whole working day.

Statistical analysis

Variance analysis attempts to quantify the influence of nominal or ordinal-scaled variables. The statistical analysis is carried out using SPSS 15.0 for Windows, with the statistical fundamentals as described in Stampfer (2002). The following analysis strategy was chosen:

- Estimation of significant effects of covariables and factors and analyzing of their statistical significance (variance analysis)
- Evaluation of non-linearity of covariables
- Analysis of interactions between factors and covariables
- Parameter estimation of significant factors and covariables
- Regressions analysis
- Check model assumptions (residual analysis)
- Adjustment of model

The co-variable tree volume is a major component of all production functions, but the relationship between productivity and tree volume is rarely linear. A power factor is used to transform tree volume, whereby Häberle (1984) recommends the estimation of this power value using an iterative procedure with regard on optimizing the coefficient of determination and the distribution of the residues.

Results

Table 5: Variability of the response variables and covariates

	Mean	**0.05 quantile**	**0.95 quantile**
Cycle (min)	4.64	2.61	7.97
Load volume (m^3)	0.87	0.27	1.64
Productivity (m^3/PSH_0)	12.4	3.31	26.5
Extraction Distance (m)	65.5	23.0	115.5
Pieces / turn (n)	1.3	1.0	2.0
Tree volume (m^3)	0.75	0.20	1.51

Overall, the radio-controlled chokers reduced the average cycle from 4.70 to 4.42 minutes. Much of that time saving can be contributed to the landing phase, which reduced from 0.33 to 0.12 minutes. There was no difference in the hook-up phase, and only a slight, but not significant difference in the carriage in. Interestingly, there was an increase in the carriage out phase, where the average carriage speed decreased from 2.3 to 1.6 m/sec. This was attributed to the varied choker lengths used with radio controlled chokers, and that at greater speed they would hit, and sometimes tangle in the trees lining the extraction corridor.

Overall, the statistical analysis of in total 936 cycles resulted in the following efficiency model:

$$\text{Efficiency (min/m}^3\text{)} = 0{,}960 + 3{,}495\text{*tree volume} - 0{,}528\text{*CHOKER} \quad (R^2=0{,}77).$$

This equation suggests that 77% of the efficiency (min/m^3) variance can be explained through the variables tree volume and CHOKER. We would normally also expect extraction distance to figure into this resulting equation. This study mainly worked with short extraction distances (average 65.5 m), and therefore this variable had no significant influence on the time consumption. Similarly, the extraction corridors typically used in Austria for full tree extraction are only 20 meters apart (Stampfer, 2002), so there is little lateral extraction and this was also not significant in the final analyses.

Figure 2 shows the productivity for cable yarding extraction dependent on tree volume and choker system. At an average tree volume of 0.6 m^3 the productivity increased from 7.10 to 7.72 m^3/PSH_{15} when using the radio-controlled choker system. This corresponds to an increased productivity of 9%.

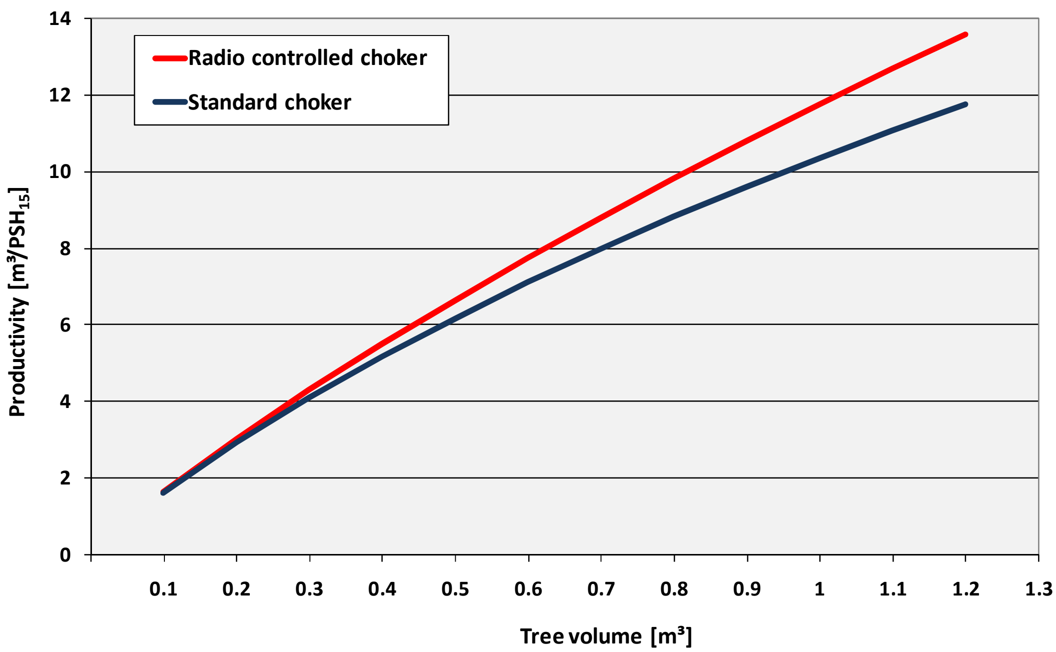

Figure 2: Productivity of the cable yarder system depending on tree volume and choker system

For comparison, in recent trials conducted at two different sites in New Zealand there was a slight decrease in productivity when using the radio-controlled chokers. This decrease was contributed to the lower average turn volume when using radio-controlled chokers. Both of these studies did show a significant time saving in the unhook phase. However, the very long extraction distances resulted in long extraction cycles, and this meant the landing phase short compared to the total cycle time.

It is possible to provide an indicative estimation of the pay-back time based on this study. The difference in productivity is 0.62 m^3/PSH_{15} with an average tree volume of 0.6 m^3. For this particular operation the felling and extraction rate 32 Euro/m^3. This suggests that using the radio-controlled chokers would increase revenue by 0.62*32=19.84 Euro per hour. If we simply divide the investment cost of 9,000 Euros by 19.84 Euros per hour, then the payback period would be approximately 450 hours (not including depreciation or repair and maintenance costs). By a harvest rate of 25 Euros/m^3 the payback period would be 580 hours.

In total 95 hours of heart-rate data was collected from the choker-setter using manual and radio-controlled chokers. A sustainable work load for a day is defined as the heart rate reserve being not greater than 40%. When using the manual chokers the work load was 40% HRR, and this increased significantly to 44% HRR when using radio-controlled chokers (Figure 3). For comparison, these values are considerably higher than those measured by Kirk und Sullman (2001). In their study of choker-setter in New Zealand the heart rate reserve ranged from 31.9 to 38.5 %HRR.

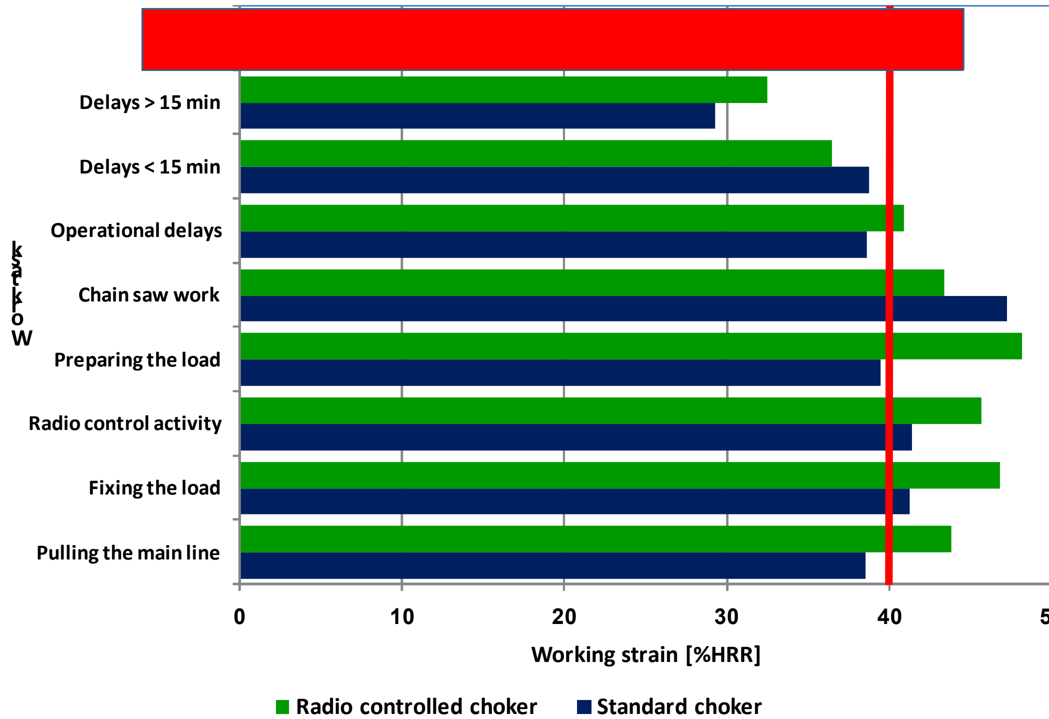

Figure 3: Working strain for the choker-setter depending on choker system

Figure 3 shows that the tasks of preparing the load, the radio-controlled activity, fixing the load as well as pulling the mainline the heart rate reserve was considerably higher for the radio-controlled chokers. Only in the ‘other’ activities of chainsaw work and short delays was the heart-rate higher for the manual chokers.

Discussion

While this study showed that the radio-controlled chokers can increase productivity, it also highlighted that it may have come at a cost of a higher workload for the choker-setter. It was noted that during the study the choker-setter rarely took a rest-break, and this may be attributed to the exceptionally short extraction distances, as dictated by the study area. This is also evident in the overall productivity model which showed no correlation with extraction distance. This result should therefore be considered preliminary until some additional data can be captured for longer extraction distances.

The yarder operator was particularly pleased with this new technology, and noted not only the simplification of his routine but also the additional safety around the landing. However the choker-setter did note the added difficulty associate with the varied choker lengths. The lengths were varied to avoid the chokers impacting on each other. This however caused quite wild swinging motions in the carriage out phase, resulting in the operator having to reduce carriage out time. He also noted additional maintenance of the chokers associated with the difficulty of wind-throw, as well as the reduced choking effect on smaller tree diameters. He suggested that an additional safety hook may prevent the cap from releasing early.

Overall there were only small problems associated with either the radio-control of the yarder and of the chokers: once the battery had to be replaced because it was not turned off. Otherwise there were no major problems during the study.

Conclusion

Radio-controlled chokers were studied during cable yarder extraction of wind-thrown trees in the Austrian Alps. The primary benefit associated with these chokers is in the reduced time associated with the landing of the trees (un-hooking), and the corresponding improvement in safety by eliminating this potentially hazardous task. This proved to be correct with the time study showing an overall improvement in productivity. The study also indicated that despite the relatively high investment cost associated with purchasing a set of radio-controlled chokers, that with a productivity improvement of 0.62 m^3/PSH_{15} in the pay-back time is just 480 hours. However this calculation does not include repair and maintenance costs.

To be truly considered a system improvement then the work load on the choker-setter should not increase, or at least not exceed the sustainable work rate for the day. The study however showed that the radio-controlled chokers did significantly increase the heart rate, and it did exceed the sustainable work load.

References

Baker, S., Sloan, H., Visser, R. 2001. Cable logging in Appalachia and opportunities for automated yarder equipment. In: Proceedings of the 24^{th} Annual Meeting of the Council on Forest Engineering, Appalachian Hardwoods: Managing Change. CD ROM. Wang, J., Wolford, M., McNeel, J. (editors). July 15-19, 2001, Snowshoe, West Virginia, USA: 1-5.

Biller, Cleveland J. and Edward L. Fisher. 1984. Whole-tree harvesting with a medium capacity cable yarder. Transactions of the ASAE 27 (1):2-4.

Häberle, S. 1984. Standardisierung zweidimensionaler Ausgleichsfunktionen über Richt-grad und Richtkonstante. Forstarchiv 55 (6): 220-225.

Heinimann, H.R.; Stampfer, K.; Loschek, J.; Caminada, L. (2006): Stand und Entwicklungsmöglichkeiten der Mitteleuropäischen Seilgerätetechnik. Centralblatt für das gesamte Forstwesen (Austrian Journal of Forest Sciences) 123 (3): 121-139.

Hemphill, C. 1985. Automatic releasing chokers. Logging Industry Research Association (LIRA), Technical Release 7 (1): 4 p.

Huyler, N.K.; LeDoux, Ch.B. 1997. Cycle-time equations for the Koller K300 cable yarder operating on steep slopes in the Northeast. Research Paper NE-705, United States Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 4 p.

Kirk P.M., Sullman M.J.M. 2001. Heart rate strain in cable hauler choker setters in New Zealand logging operations. Applied Ergonomics 32 (4): 389-398.

MacDonald, A.J. 1990. Bunch yarding with radio-controlled chokers in coastal British Columbia in second growth timber. FRDA report 108. Vancouver. 20 p.

Samset, I. 1985. Winch and Cable Systems, Construction Work and Forest Operation. Dordrecht/Bosten/Lancaster: Martinus Nijhoff / Dr. W. Junk Publishers. 539 p.

Stampfer, K. 1998. Stress and strain effects of forest work in steep terrain. In: Proceedings of the IUFRO/FAO Seminar on Forest Operations in Himalayan Forests with Special Consideration of Ergonomic and Socio-Economic Problems in Thimphu/Bhutan. (Heinimann, H.R. and Sessions, J. editors). http://www.upress.de/abstracts/3-933146-12-7.html. Kassel University Press, Kassel: 113-119.

Stampfer, K. 2002. Optimierung von Holzerntesystemen im Gebirge. Habilitationsschrift, Universität für Bodenkultur Wien. 96 S.