HARVESTING TECHNICAL NOTE

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Productivity of the Active 70 Tower Yarder

Summary

This study assessed the performance of a medium sized yarder called the Active 70 manufactured by Active Equipment Ltd, a New Zealand company specialising in the manufacture, rebuilding, refurbishment and repair of cable yarders. The machine studied is a rebuild of an older yarder base and 70ft tower, with modern mechnical, electrical and system control features. This assessment was performed over two study sites that had different forest harvest characteristics. The studies assessed productivity measures through time study, breaker-out work levels and noise level evaluations. Results from both sites showed production levels were lower than the New Zealand yarder average (as derived from FFR Benchmarking data). Productivity averaged 22.3m^3/PMH and the utilisation rate was 65% when working with a motorised drop line carriage. When operating in the North Bend configuration, the system achieved 23.7m^3/PMH and 71% machine utilisation. This productivity reflected the difficulty factor of harvesting at the two sites. Heart rate data indicated the breaker-outs were operating at the lower end of the scale for 'prolonged continuous work'. Noise monitoring showed the yarder to be relatively quiet, with hearing protection required only when workers were within 10 metres of the machine.

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INTRODUCTION

In the FFR Steep Land Harvesting Programme there has been a lot of research into cable yarding with the focus generally concerning productivity and worker safety issues (Harrill and Visser 2014). The majority of yarders working in the New Zealand forest industry are of North American design or build (Visser, 2013), generally based on pre-1990 designs. This machinery is considerably larger and more powerful than its European counterparts (Visser *et al.*, 2011; Heinimann *et al.*, 2001; Liley, 1983). This study was aimed at investigating a modern machinery option for contractors in New Zealand that may offer both ergonomic and cost-efficiency benefits.

In New Zealand the average cable logging rate is currently around $36.00 per tonne, which is high compared to ground-based harvesting costs of around $24.00 per tonne (Visser, 2015). This cost difference has become of increasing importance as the proportion of cable logging has increased from 15% of all operations in 1976 (Fraser *et al.*, 1976) to over 40 percent in 2014 (Visser, 2015). Areas that are cost prohibitive to harvest are often small, steep and remote. The value of being able to harvest these areas economically is high, with smaller scale forest owners with forests of less than 1000 hectares making up 30% of the national forest estate in 2014 (NZFOA 2015). The implications of this were highlighted in a recent study in the Whanganui region, where under the pricing conditions at the time an estimated 5-10% of the area of forest blocks under 1000 hectares in size would not be viable to harvest (Park, *et al.*, 2012).

Personnel safety is also a key consideration concerning cable logging. Studies show that fatigue is felt by all workers on site, including machine operators (Inoue, 1996; Kirk & Sullman, 2001) and is recognised as being one of the largest safety issues within the forest industry. Workers who reported high levels of fatigue also reported higher rates of near miss incidents over the previous 12-month period (Lilley *et al.*, 2002). One of the proposed solutions to these issues is the utilisation of more modern machinery and equipment, with improved ergonomic conditions likely to result in comparatively lower fatigue rates.

The Active 70 yarder has been developed by Active Equipment Ltd, based in Rotorua, New Zealand, a company specialising in the manufacture, rebuilding, refurbishment and repair of cable yarders. The initial prototype, which is the one studied here, is a rebuild of an older machine with major mechanical, electrical and control system redesign. The specifications are a 70-foot tower (21.3 metres), a 384 kW engine and is equipped with 28mm skyline, 22mm mainline and 22mm tail rope. New features that are uncommon to most yarders in New Zealand include: an improved cab with simplified controls and better vision; an integrated computer system with GPS tracking of breaker-outs, and tension monitoring of both skyline and mainline; a modern turbo diesel engine; and use of a motorised carriage with radio controlled drop line.

Developing on from the Active 70 model yarder, an updated range of Active yarders is currently being constructed and are new from the ground up. This includes models such as the Active 150, 160 and 175. For example, the 175 model has 32 mm skyline capability Active Equipment, 2016). The aim of this study was to investigate the productivity and performance of a medium sized yarder with modern features to assess its potential for working in NZ plantation forests.

STUDY METHOD

To reduce site-induced bias, the system was studied at two different locations.

Study Site One

Site One was located in Tahorakuri Forest managed by PF Olsen Ltd, 10 kilometres north of Taupo, New Zealand (Figure 1).

Figure 1: Active 70 yarder operating from the landing at the study site in Tahorakuri Forest.

The forest was planted in 1987/88 and the area to be harvested had a stocking of 307 stems per hectare and a mean tree size of 2.2 m^3 equating to 647 m^3/ha. The study area was part of a larger harvest area of 20.2 hectares. The trial took place over five consecutive days from 15–19 June, 2015. The yarder was located on the same landing over this period, with one yarder shift and five line shifts recorded (Figure 1).

Over the study period the yarder employed a standing skyline system using a Boman Z7850 motorised drop line carriage (Figure 2) operated in the shotgun (gravity return) rigging configuration. The carriage was equipped with three electronic chokers. Two breaker-outs were used to hook on stems. A 30-tonne excavator was used as a mobile tail hold and this facilitated fast line shifts. Weather conditions were mainly clear, with intermittent light showers and wind on two days of the study, but this was not considered significant enough to influence productivity results.

Figure 2: Boman Z7850 motorised carriage with radio controlled drop line.

Study Site Two

Site Two was located in Ryan's Forest, managed by PF Olsen Ltd, 10 kilometres north-east of Te Aroha, in the Waikato region. The forest was planted in 1978 and had a stocking of 219 stems per hectare and a mean tree size of 2.5 m^3 equating to 547 m^3/ha. The trial took place over

three consecutive days from 30 November–2 December, 2015. The yarder was located on the same landing over this period, with four line shifts recorded; the yarder was not moved over this period.

During this study the yarder employed a standing skyline operated in the North Bend configuration. The butt-rigging was fitted with three remote control chokers. The same two breaker-outs from Site One were working at this site. In this study all line shifts were performed manually to stumps. Weather conditions were windy every day, with light showers on the second and third day. This may have had a slight effect on productivity due to poor conditions for the breaker-outs.

The operation was based on two-staging with a Caterpillar D6 tractor pulling to a larger landing 50 metres behind the yarder. There was a dead zone from 0–200 metres from the yarder due to a previous logging operation. This resulted in no hauls extracted within 200 metres of the yarder.

The systems operated at both sites were typical of those the crew normally used and with which they were experienced.

Productivity and Heart-Rate Measurement

The productivity was assessed by a time and motion study. Cycle time was collected by recording the start and end of each cycle by stopwatch. Volume per cycle was estimated by the number, length and large end diameter of the logs in each cycle. At Site One, outhaul distance was captured by a GPS unit mounted on the carriage, and checked by manually measuring the distance to the carriage using a Nikon Forest Pro range finder. At Site Two, the distance was measured using the on-board computer which recorded at 20 second intervals the mainline length via drum counters.

Heart rates were measured every 5 seconds using a strap mounted pericardial heartbeat transmitter. This connected wirelessly to a wrist watch mounted storage unit. This method is considered accurate and has minimal interference on the ability of workers to do their job effectively (Kirk & Parker 1996, Kirk & Sullman 2001, Stampfer *et al.* 2010).

Indices such as "relative heart rate at work" are used to remove human bias in heart rate data. These indices have previously been found to be an effective method for assessing the physiological strain of forest workers. Common terms used in these indices are:

- Working heart rate (HRw) = Average heart beats per minute over the day (bpm)
- Maximum heart rate (HRmax) = 220 – age
- Resting heart rate (HRr) = Average heart rate value in a sitting position for a 10-minute period.
- Relative heart rate at work (%HRR) =

  ((HRw – HRr) / (HRmax – HRr))*100

Under this assessment, prolonged continuous physical work scores between 30 and 40%HRR (Astrand & Rodahl, 1986). In one New Zealand study breaking out scored Relative Heart Rate at Work of 36.3% ± 3.1% (Kirk & Sullman, 2001).

Typically a resting heart rate will be between 40 and 80 beats per minute, or bpm (Astrand & Rodahl, 1986) with heart rate patterns varying depending on the individual. Differences in heart rates can be attributed to: age, genetics, fitness, health issues, smoking and body type.

Multiple factors can contribute to work levels and productivity, other than just the machinery (Kirk & Parker, 1994; Sullman & Byers, 2000). Examples of other factors include; slope, roughness of terrain, obstacles and climatic conditions (Kirk & Parker, 1996; Kirk & Sullman, 2001).

Noise Level Measurement

The noise level of a machine is measured in decibels. Cable yarders are traditionally loud, and prolonged exposure can lead to a number of health related issues, the most common being industrial hearing loss. Data were collected using a decibel sound monitor resting on a pick-up truck that was parked close to the yarder. The data were collected by recording the maximum sound level of the machine at two-second intervals over the period of the working day. The decibels were averaged across the collection days and then decibel levels at varying distances were calculated.

The noise monitor was also exposed to operational noise that occurred on the landing including chainsaws and large excavators (Figure 3). The additional sources of noise may have had an influence on the results, but due to averaging over eight hours per day this was expected to be of minimal influence.

Figure 3: Operation close to where the noise measurement was carried out (decibel meter is located behind camera).

RESULTS

Site One

Results of the production study at Site One are given in Table 1. The average cycle time was 9.4 minutes, and the average cycle volume was 3.5 m^3, ranging from 2.7 m^3 to 4.6 m^3. On average, 35 cycles were completed per day resulting in daily production volume of 122 m^3. The average extraction distance was 140m with a range of 66m to 219m. Little variation existed in the average piece size (1.1m^3). This was significantly lower than the average tree size of 2.2m^3, indicating significant breakage.

Table 1: Time Study Results: Site 1

Factor Measured	Mean
Average delay-free cycle time (min)	9.4
Average cycle volume (m^3)	3.5
Cycles per corridor	35
Total corridor volume (m^3)	141
Average extraction distance (m)	140
Deflection	5%
Piece size (m^3)	1.1
Pieces per cycle	3.3

The deflection was measured at each skyline corridor and varied significantly across the study from 2% to 8%, with an average of 5% (very low). This was found to be a significant factor affecting daily production rates. The average cycle load in pieces was positively correlated with the measured deflection and averaged 3.3 pieces per cycle.

Intermediate ridges reduced available deflection and had a significant effect on the maximum payloads that could be extracted per cycle. This was particularly an issue for the third corridor and the yarder was moved to the fourth corridor to mitigate this issue. This movement of the yarder coupled with a new tail hold location for corridor 5 improved deflection and allowed the largest payloads of the study period to be extracted. Extraction distances were significant predictors for productivity when matched to individual cycles.

Table 2: Machine utilisation rate: Site 1

Productive machine hours	27.2
Delay time (hours)	14.5
Scheduled machine hours	41.7
Machine Utilisation rate	65.2%

Common utilisation rates for cable yarding systems in New Zealand have been recorded at around 65-70% (Harper, 1992). The overall machine utilisation rate for the yarder over the week was 65% (Table 2). This low utilisation rate was caused by operational delay factors such as: one yarder shift, five line shifts and a large surge pile on the landing that needed to be processed.

Mechanical delays included a carriage breakdown. Personal delays included operational briefings and crew 'smoko'. Without the delayed starts for corridor 1 and 4 and the significant mechanical delay for corridor 1, a similar average would have been achieved.

The site average productivity was 22.3 m^3/PMH at the utilisation rate of 65.2%. This equated to a productivity rate in scheduled machine hours of 14.6 m^3/SMH.

Site Two

Results of the production study at Site Two are given in Table 3. Over the three days of the study, a total of 428 m^3 was extracted over four skyline corridors, resulting in daily production volume of 142 m^3/day. The average cycle time was 11.15 minutes, and the average cycle volume was 4.4m^3, ranging from 3.5–4.8 m^3/cycle. Average extraction distance was 351m, with the furthest being 399m (on day one) and the shortest at 249m.

Table 3: Time Study Results: Site 2

Factor Measured	Mean
Delay-free cycle time (min)	11.15
Cycle volume (m^3)	4.4
Cycles per corridor	24
Average corridor volume (m^3)	107
Extraction distance (m)	351
Deflection	11%
Piece size (m^3)	1.51
Pieces per cycle	3.0

To better understand variation in production levels and site conditions, the data were separated by the four corridors. On average, 24 cycles were completed per corridor with an average volume of 107 m^3 per corridor. The deflection varied by only 2% across the study area and with no overloading delays noted, it is unlikely to have had an effect on production.

The average piece size was of 1.51m^3. This was significantly lower than the average tree size of 2.5m^3, indicating significant tree breakage during felling. Piece size was significantly smaller in the first corridor, almost 0.5m^3 smaller than the three following corridors. The number of pieces per cycle was very consistent across the study (average 3.0 pieces per cycle).

The machine utilisation rate for the yarder was 71.8% (Table 4). Factors that contributed to this utilisation were shorter personal delays and line shifts, with only one short mechanical delay (<15 minutes) recorded. This indicated that this study captured the machine operating at the higher end of the common machine utilisation range.

Productivity at Site Two averaged 23.7 m^3/PMH with machine utilisation of 71.8% which equated to productivity in scheduled machine hours of 17.0 m^3/SMH.

Table 4: Machine utilisation rate: Site 2

Corridor/Time	Sum
Productive machine hours	18.1
Delay time (hours)	7.1
Scheduled machine hours	25.2
Machine Utilisation rate	71.8%

For both sites the productivity rates were below the New Zealand average of 23.4 m^3/SMH for cable logging operations (Visser, 2015). Productivity at Site One was negatively impacted by poor deflection resulting in a lower payload per cycle. At Site Two there was a "dead zone" that existed from the yarder out to 200 metres where there was no wood to extract, eliminating any short haul distance cycles.

Heart rate data analysis

There were significant differences in resting and maximum heart rates for all the breaker-outs assessed. This evidence supports the use of indices to standardise data, as differences clearly existed due to non-workload related factors.

The motorised carriage has slack pulling capabilities and should be easier for the breaker-outs to use compared to fall-block systems such as North Bend, because of the ability of the breaker-outs to control the drop line release. This should result in lower work rates as the slack for the chokers can be paid out as needed.

Using modern equipment, with improved ergonomic conditions, such as a motorised drop line carriage was seen as having potential to reduce work load related fatigue.

At Site One the two breaker-outs wore heart rate monitors for the full five days of the study. The purpose of collecting these data was to assess the workload of breaker-outs using the Boman motorised drop line carriage. There were no issues with watches being lost or data corruption over the time of the trial, resulting in over 70 hours of usable data.

At Site Two the head breaker-out wore the heart rate monitor over each of the three days of the study and this resulted in 22 hours of usable data.

Figure 4: Example of steep and brushy terrain in which breaker-outs were working.

At Site One the Relative Heart Rate at Work (%HRR) score was 31.5%, while Site Two had a score of 29.6%. Scores in the 30% to 40% range indicate prolonged continuous work. This result indicated that breaking out, regardless of machine configuration, scored at the lower end of the “prolonged continuous work” scale.

There was however no discernible difference in work rate when using the motorised carriage or North Bend rigging configurations. Although site conditions can affect work rates, both sites were similar (Figure 4) and scored very similarly on the terrain and site assessment calculation and differences were deemed to be negligible.

Noise level analysis

Table 5: Decibel ratings at various distances from the yarder

Distance from yarder (m)	Volume (dB, A)	Risk of hearing damage
1	100	significant
5	86	significant
10	80	moderate
20	74	minimal
50	66	minimal
100	60	minimal

The decibel ratings of the operating yarder at varying distances are shown in Table 5. It was found that within a five-metre exposure of the machine there was sufficient noise to cause hearing damage to 95% of workers if the worker was exposed to this level for 8 hours per day for an extended period without hearing protection. Based on these findings anyone working within 10 metres of the yarder should wear hearing protection.

CONCLUSION

The success of skyline harvesting operations is strongly influenced by how well the skyline is positioned on the terrain. At Study Site One, poor positioning of the yarder resulted in low deflection, which was a significant factor affecting daily production.

When operated with a motorised drop line carriage the system reached an average production of around 15 m^3/SMH (122 m^3/day) and a utilisation rate of 65%. This was influenced by extraction distance and available deflection.

At Study Site Two, harvesting of a previous setting had created a “dead zone” within 200 metres of the hauler. This resulted in haul

distances ranging from 249-399 metres and long cycle times (11.15 min average).

When rigged in the North Bend configuration, the system produced an average of 17 m^3/SMH (142m^3/day) and a utilisation rate of 71%. Production was negatively impacted by the 200m dead zone in front of the yarder. It is felt that both sites were above average difficulty factor.

Regarding work load, the use of the motorised carriage with its slack pulling capability showed no reduction in workload for breaker-outs compared to using butt rigging in North Bend configuration. Heart-rate data collected during both studies showed that the work was labour intensive and was at the lower end of the “prolonged continuous work” scale.

The Active 70 yarder is a new model yarder, developed by a company specialising in the manufacture, rebuilding, refurbishment and repair of cable yarders yarders produced in New Zealand. It features an ergonomic operator cab with improved controls and better vision, and a modern turbo diesel engine which is quieter compared to other yarders; with persons working within 10 metres only requiring hearing protection to prevent noise-induced hearing loss.

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