FUTURE FORESTS RESEARCH

HARVESTING TECHNICAL NOTE

HTN05-07
2013

ClimbMAX2 Steep Slope Harvester

Summary

Since 2010, Future Forests Research Ltd's harvesting programme has supported the development of the ClimbMAX steep slope feller buncher. As part of this development, the productivity and performance of this machine has been assessed in a range of regionally specific situations. In this evaluation the latest version of the steep slope feller buncher (ClimbMAX2) was studied working in a Marlborough forest. The study area was a hauler setting, with a large area comprising convex slopes of greater than 26 degrees. The ClimbMAX2 felled and bunched 29-year-old radiata pine with an average live stocking of 219 stems per hectare and average merchantable piece size of 1.9 m^3 per tree. The trial area was characterised by significant areas of windthrow, much of it covered in blackberry and undergrowth. The feller buncher felled and bunched trees at a rate of 60 m^3/productive machine hour (PMH). Fifteen percent of the observed time was spent cutting and bunching windthrown trees. It is estimated that a cable harvesting system matched to the productivity of the ClimbMAX2 working 8 PMH per day was capable of daily production rates of up to 480 tonnes/day. A site/soil disturbance assessment showed that only 9% of the surveyed area had deep soil disturbance. This finding was consistent with a previously reported assessment of soil disturbance in another cable logging operation.

Tony Evanson and Dzhamal Amishev, Scion.

Introduction

In March 2009, the first prototype steep slope harvester designed by Kelly Logging Ltd and Trinder Engineers Ltd became operational in the Nelson Marlborough area. This first prototype was based on a Hitachi ZX 280 high and wide chassis with lengthened track frames (Figure 1).

Figure 1: Prototype Steep Slope Harvester (Trinder Engineering).

An evaluation of this machine was published in 2010[1]. The first prototype steep slope harvester felled and bunched 65 m^3/PMH in 1.92 m^3 tree size, on slopes averaging 21 degrees.

In 2010, with financial assistance from FFR under the Primary Growth Partnership, work started on the development of a second or beta prototype (ClimbMAX1). ClimbMAX1 was based on a Hitachi ZX400 of 44.0 tonnes operating weight and was equipped with a front-mounted winch, 380m of 7/8-inch swaged rope, a blade at the rear of the machine, and a Trinder-designed boom and felling head (Figure 2).

Figure 2: ClimbMAX1 Steep Slope Harvester.

Construction was completed in 2012 and this machine started its testing programme. The machine is owned and operated by Kelly Logging Ltd. Construction of the next machine (ClimbMAX2) commenced in mid-2012, and in January 2013 this was ready for pre-commercial trials in the Marlborough region. Although it has similar features as ClimbMAX1, this machine was based on a smaller Hyundai carrier (41.9t full operating weight). The results of a productivity study of ClimbMAX2 are detailed in this report.

Future Forests Research Ltd, PO Box 1127, Rotorua. Ph: 07 921 1883 Email: info@ffr.co.nz Web: www.ffr.co.nz

Figure 3: ClimbMAX2 Steep Slope Harvester (Hyundai carrier).

System and Study Area

The block where the machine was studied had an average tree size of 1.98 m^3 and a stocking of 219 stems per hectare (sph). The forest was in its first rotation on converted farmland. Almost half the trees in the trial area had been wind damaged and were lying on the ground covered by blackberry. Slopes were convex in shape, averaged 23 degrees (10 to 33 degrees) and were up to 250 m in length. The soil type on the site was well-drained (Class 5), Stony and Sandy Loam (Orthic Brown Soil) with a low to very low total carbon content.

Trees were mechanically felled by the Trinder Steep Slope Harvester (ClimbMAX2), mostly downhill in the steeper sections, and across slope in other areas. Felled trees were bunched tip-first, across slope at an angle of up to 45 degrees. Windthrown trees had rootballs cut off before being bunched in a similar manner to felled trees. After felling several trees, the machine would move downhill a few metres to enable slewing/bunching using gravity. Windthrown trees would be lifted and dropped to remove soil prior to removal of the rootball. This made the rootballs more stable when placed on the slope or in holes left by toppled trees. Trees were extracted by swing yarder, mostly by using chokers. A grapple was used for part of the setting. Trees were two-staged to a skid for mechanised processing.

The ClimbMAX2 was operated by Nigel Kelly of Kelly Logging Ltd. Nigel noted that his experience in felling trees did not match that of his main operator who was away at the time of the study.

Study Method

The ClimbMAX2's productive activities were videoed, then recordings were analysed in the form of a continuous time study. Cycle time elements are given in Table 1.

Table 1: Cycle Element description

Fell	Slew to position head, back-cut or scarf and back cut, tree falls to the ground. All slew movements start from boom in centre-front of tracks.
Slew to Move	The boom moves from its last action to its static position (centre tracks) for machine movement
Move down	Movement downhill
Move up	Movement uphill
Bunch	Slew, pick up one or more felled trees and/or pieces, slew and place tree or piece into a bunch. Repeated for a single long piece or butt stem.
Bunch Windthrow	Slew to a windthrown tree, grapple, cut off the rootball, sew to grapple the tree, repeat slewing movements with tree until bunched.
Clear/Access	Slew, pick up tree or piece briefly, move aside but not bunch.
Shift Rootball	Slew, pick up a rootball and move aside or place with other rootballs.
Re-position	A manoeuvre within a machine movement, a change of direction.
Other	Operational delays (e.g. pauses, reposition the cable, cut stumps, failure to lift trees, clear slash before felling).

Windthrow related elements were later removed to enable an estimate of windthrow-free productivity. A comparison was made with a previous study of the first prototype steep slope harvester.

ClimbMAX2 was tracked by a GPS attached to the cab. An accelerometer/slope recorder was also attached to the machine. A CBR (California Bearing Ratio) value which provides an indication of soil load bearing capacity, was measured using a Scala Penetrometer. This was done to enable a performance comparison between this study and future evaluations in different conditions.

Results

Three hours of video footage were analysed using continuous time study methods. ClimbMAX2 was tracked by GPS showing where it had travelled on the cutover (Figure 4). The track map indicates the slope length of track was approximately 210 m.

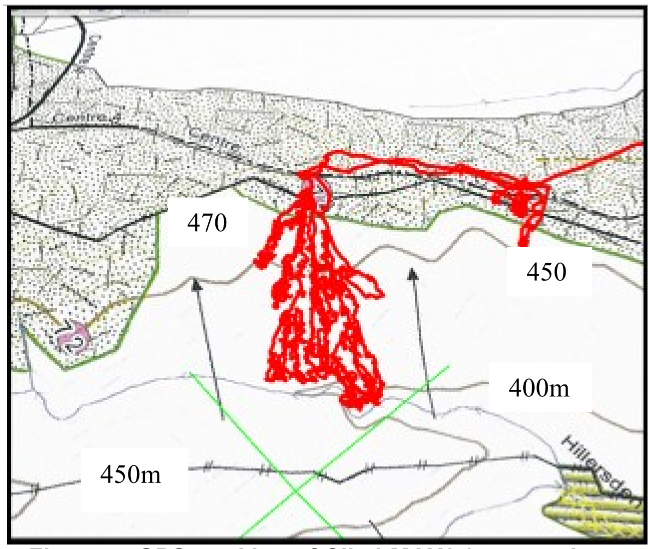

Figure 4: GPS tracking of ClimbMAX2 (arrows show haul direction, scale is 1:6000).

Accelerometer (slope meter) results are shown for one day's recording (Figure 5). The relative percentage frequency of recordings indicates the length of time positioned on varying slopes (as shown by the cab-mounted recorder).

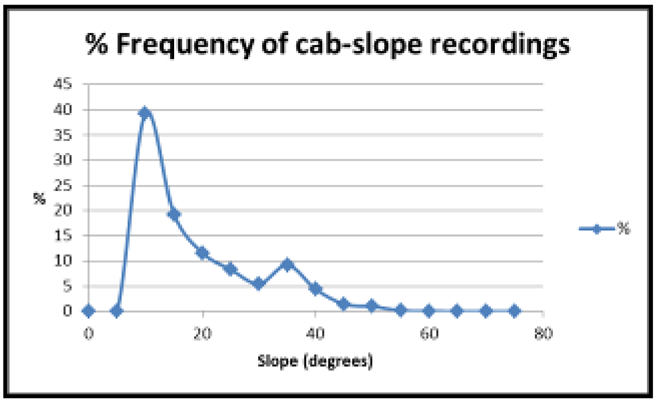

Figure 5: Slope measurement by accelerometer (Dr. R. Visser, University of Canterbury)

Twenty-two percent of the recorded time was spent on slopes of thirty degrees or greater. Slope values reported by the operator from instruments averaged 35 degrees, ranging from 32 to 40 degrees. Slopes measured during a site/soil disturbance assessment of a 7-ha area traversed by ClimbMAX2 averaged 23 degrees, ranging from 10 to 33 degrees.

A number of trees to be felled were marked with coloured bands to indicate tree DBH so that felling times could be compared to tree size.

In total, 97 trees were observed being felled, or in the case of windthrown trees, their rootball removed and then bunched. Of the 97 trees observed, 47 were felled from standing and the remaining 50 had been windthrown. Figure 6 describes the distribution of activities observed. Felling and bunching comprised 40% of observed time.

Felling Time

Felling time accounted for 14% of total observed time (Figure 6).

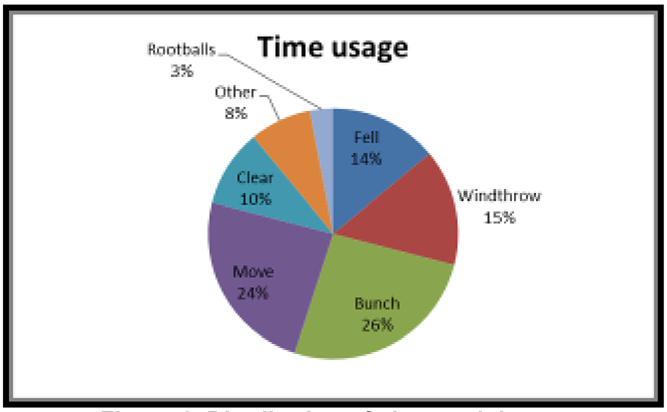

Figure 6. Distribution of observed time

Results of the time study analysis are given in Table 2. Average fell time was 31.7 seconds. Felling time was more related to the requirement to double cut some trees. The average fell time was the average of felling smaller trees with a single cut (60% of trees at an average 25 seconds per tree) and felling larger trees with double cuts (40% frequency at an average of 37.5 seconds per tree). The average tree size cut with a single cut was 44 cm. The average tree size requiring a double cut was 52 cm butt diameter.

Felling Technique and Direction

Trees were mostly felled downhill. Two uphill-leaning trees were felled by pushing them over instead of felling them with the saw (fell, cut rootball, and bunch times of 43 and 30 sec). One tree was pushed over after making a single cut. Some trees were manually felled in the block (but not during the study) because short, steep drop-offs made machine movement dangerous.

Future Forests Research Ltd, PO Box 1127, Rotorua. Ph: 07 921 1883 Email: info@ffr.co.nz Web: www.ffr.co.nz

Table 2: Results of time study analysis

Cycle Element	Average per cycle (incl. windthrow)	Average per cycle (fell only - no windthrow) estimate	Previous results of alpha prototype (2010)
Number of trees	97	47	
Fell tree (s)	15.6	31.7	23.1
Slew to Move (s)	3.0	3.0	
Move uphill (s)	12.8	12.8	30.1
Move downhill (s)	10.6	10.6	
Bunch (s)	29.6	44.1	38.0
Bunch Windthrow 50 trees (s)	17.2		5.7
Clear/Access (s)	11.5		6.5
Shift rootball (s)	2.8		
Re-position (s)	1.7	3.4	
Other (s)	8.9	7.0	2.4
Total (min)	**1.895**	**1.876**	**1.763**
Trees/PMH	31.7	32.0	33.7
Tree size (m^3)	1.9	1.9	1.92
Productivity (m3/PMH)	60.2	60.8	64.7

Machine Movement

Moving time (including re-position time) accounted for 24% of total observed time. Travel speeds were approximately 1.5 km/hr (25 m/min) uphill and 3 km/hr (50 m/min) downhill. Observed movement during felling and bunching activity were found to be at slower average rates, 15 m/min (range 14 to 18) uphill and 37 m/min (range 21 to 47) downhill. Faster times might be expected where travel distances are longer, such as returning uphill to the anchor point.

Bunching

Bunching of felled trees and broken pieces accounted for 26% of total observed time. Of the 138 bunching events recorded, 41 (or 30%) involved bunching of pieces only. Bunching broken pieces averaged 18 seconds per event and accounted for 27% of total bunching time.

The bunching method involved several slewing movements, each using gravity to assist. Trees were slewed tip-first and bunched at about 45 degrees to the contour. Felled trees were generally bunched immediately after felling, but on occasion the machine was repositioned prior to bunching to ensure it was in a more stable position. Some trees slid downhill when placed in a bunch.

Windthrow

Cutting and bunching of windthrown trees accounted for 15% of observed time. Over half of the trees handled were windthrown. Slew, grapple, cut and bunch times ranged from 10 seconds for a small tree, up to 69 seconds per tree. Some windthrown trees were entangled and did not move easily when grappled. When this occurred, the time taken was allocated to ‘Other’ time.

Clear/Access

Grappling and moving trees aside a short distance to enable access accounted for 10% of the total observed time. This activity may also have aided bunching because the trees or pieces could then be grappled together.

Rootballs

Once cut from a windthrown tree, rootballs presented a hazard to activity downslope, and to machine movement because they could be unstable on the slope. They were sometimes bunched together, or allowed to roll downslope and away from the area being worked. Dealing with rootballs accounted for 3% of observed time.

Re-position

During a machine movement event, the ClimbMAX2 would sometimes change direction. This was coded as Re-position because no distance was travelled, as a result. This activity was included in Move time as a proportion of total observed time, but excluded from Move up or Move down time.

Other

Activity that did not fall easily into other categories was coded as “other time”. Other time accounted for 8% of total observed time. Nearly all this time would be classed as operational delay. It included pauses in the productive cycle, failures to lift or slew, cutting stumps, clearing slash and shifting the winch cable. Nearly half the events were coded as pauses. Pause time accounted for 26% of other time. This was often when the operator was using the radio to talk to the others in the crew, or report a slope reading to the observer with the video camera.

Productivity and cost of adding a ClimbMAX2

The productivity of the ClimbMAX2 was 60 m^3 per productive machine hour when felling and bunching

trees. When comparing the productivity of the ClimbMAX2 working in partially windblown trees, the productivity was similar. This potentially gives a daily production of 480 m^3 at a rate of around $24.00 per cubic metre (Table 3), when matched to grapple hauler productivity extracting from bunched trees. While grapple hauling achieves these production rates where operator vision is good, the addition of a SSH (ClimbMAX2) extends grapple hauling beyond current practice.

Table 3: System cost model (most costs derived from InForme 2012[2]).

Machine	Daily Rate	Productive hrs
ClimbMax 2 (Estimated cost)	$1,750	8.0
Swing yarder	$1,550	6.5
(1.6 butts/haul, 150m AHD, 2.47min/cycle)		
Clearance	$1,000	7.9
Process	$1,400	7.6
Sort/Load	$750	7.9
Load	$800	7.9
Other costs	$2,726	
Operators	$1,500	
Total Cost	$11,476	
Production (m3)/day (8 hr*60m3 /PMH)	480	
Cost/m3	$23.91	

Comparison with the study of alpha prototype (2010)

To enable a comparison with the previous study, time which could be associated with windthrown trees was excluded from the cycle time summary.

Trees felled and bunched per PMH: In this study productivity was estimated at 32.0 trees/PMH vs. an estimate of 33.7 trees/PMH reported in 2010.

Apart from the variability inherent in short-term time studies, there are obvious differences in variables such as different operator, machine, terrain and stand. Differences are also apparent in the Fell time per tree, as well as, bunching and other time. Some other possible reasons for differences are outlined below.

Fell time: Average fell time for single cut trees was 25.0 sec. For scarf and backcut trees, the average fell time was 37.5 sec. In 2010, the average reported fell time for all trees was 23.1 sec. Many of the trees felled in 2010 could have been single-cut trees. Forty percent of the trees in this operation were felled with two cuts.

Bunch time: The 2010 study reported 38 sec/cycle for felled trees vs. 44.1 sec/cycle for this study. Bunch time differences could be related to the number of pieces handled, as well as a different bunching method (e.g., the number of swings per tree).

Move time: Move time in the 2010 study was 30.1sec/cycle vs 26.8sec in this study.

Other time: In 2010 a lower value of 2.4 sec/cycle was reported. Excluding time coded as pauses, this study reported other time of 6.3 sec/cycle, when pauses were excluded. A large proportion of observed other time was used dealing with windthrown trees. For example, the 2010 study reported 5.7 sec/cycle; this study found 20 sec/cycle required to deal with windthrown trees.

Soil/Site Disturbance

A site disturbance assessment was made using an established method several months after the logging operation[3]. The setting included a small area of downhill-uphill extraction, with the majority being uphill extraction only, over a convex slope (Figure 7).

Figure 7: Part of the 7 ha assessed for site/soil disturbance.

The swing yarder used a grapple for a small part of the setting, but mostly chokers were used. Differences in soil types, harvesting systems and terrain meant that a comparison with assessments carried out in other areas was indicative only.

The deep disturbance value, including rutting and subsoil exposure, (Table 4) was similar to that found

in a historical tower hauler operation assessment[4], when windthrow effects (soil disturbance from rootballs and rootball holes) were excluded (9%+/- 1.2 vs 12% +/- 1). Another report[5] detailed disturbance in a cable logged compartment in the Coromandel area (Whangapoua Forest), as part of a sediment transport study. The authors recorded a deep disturbance level of 11%, again similar to the recent finding.

Table 4: Soil/Site disturbance comparisons

Soil disturbance value	M266-2 (rootballs excluded) % occurrence	Absolute error (+/- %)	Mangatu (1995) tower	Absolute error (+/- %)
Undisturbed	7	1.0	6	1
Shallow disturbance	53	2.0	62	2
Deep disturbance	9	1.2	12	1
Slash cover	26	1.8	13	1
Non-soil	5	0.9	7	1
	100%		100%	

Most deep disturbance in this study was caused by rutting, two-thirds of it caused by tracked machine (tailhold tracks could not be separated from ClimbMAX2 tracks). Only one-third of deep disturbance resulted in exposed mineral soil. Larger proportions of slash were identified in this survey, possibly as a result of bunching activity, although McMahon[4] quoted a stocking of 300 sph (vs. 219 sph live trees in this study). However, slash from windthrow was also included in the recent assessment.

A Scala Penetrometer was used to record a range of soil CBR values at the time of the study. The mean recorded CBR value was 2.4, with 0.5 and 0.95 quantiles of 1 and 5 (average slope 35 degrees recorded by the operator).This compares with a study of the Valmet Snake (tracked) harvester[6], probably one of the most steep-slope-capable machines available, which was studied on Austrian soils, with CBR values averaging 2.5 (with 0.5 and 0.95 quantiles of 1.4 and 4) and slopes ranging from 11 to 34 degrees.

Conclusion

The ClimbMAX2 Steep Slope Harvester studied showed felling and bunching productivity of 60 m^3/PMH in 1.9 m^3 tree size on steep Wairau valley terrain. It was estimated that a cable yarding harvesting system matched to the ClimbMAX2's capabilities was capable of daily production rates of up to 480 tonnes/day.

A site/soil disturbance assessment showed that 9% of the surveyed area was characterised by deep soil disturbance. This was consistent with other reported assessments of soil disturbance in cable logging operations.

Acknowledgements

The assistance and cooperation of Trinder Engineers and Kelly Logging Ltd with this study is acknowledged. Other assistance with the reporting process was rendered by Nelson Forests Ltd, and Dr. R. Visser, University of Canterbury.

References

1. Evanson, T., and Amishev, D., *A steep slope excavator feller buncher.* Harvesting Technical Note, No. 3 (2). Future Forests Research Ltd: Rotorua, New Zealand. (2010).

2. Forme, *Informe harvesting 2012.* No. 1. Forme Consulting Group Limited: (2012).

3. McMahon, S., *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. (1995).

4. McMahon, S., *Cable logging disturbance on an unstable slope: A case study.* LIRO Report, No. No. 12. New Zealand Logging Industry Research Organisation: Rotorua, N.Z. (1995).

5. Marden, M., Rowan, D., and Phillips, C., *Sediment sources and delivery following plantation harvesting in a weathered volcanic terrain, Coromandel Peninsula, North Island, New Zealand.* Australian Journal of Soil Research, *44* (3), pp. 219-232. (2006).

6. Stampfer, K., Steinmuller, T., *A new approach to derive a productivity model for the harvester "Valmet 911 Snake".* In Proceedings: The International Mountain Logging and 11th Pacific Northwest Skyline Symposium 2001, Seattle, Washington. Oregon State University. (2001).