FUTURE FORESTS RESEARCH

HARVESTING TECHNICAL NOTE

Vol: 1 Number: 7
2009

Felling and Bunching on Steep Terrain – A Review of the Literature

Summary

In New Zealand in recent years there has been a substantial research investment into establishing better forests on steep and marginal land. There has however, been very little investment into research in reducing the cost of harvesting in difficult terrain. The introduction of mechanised systems into the felling and bunching phase of harvesting operations is one way to increase harvesting productivity and reduce costs.

As part of the Future Forests Research harvesting theme programme "Future Felling", a review of the international research into felling and bunching on steep terrain over the last 20 years is presented. This review of the literature has shown that globally, there has been very little research into felling and bunching on steep terrain in recent years, and almost nothing has been done on the topic in New Zealand for the past 10 years. The main barriers to the widespread mechanisation of felling and bunching in New Zealand are the large tree size and the steep terrain. This literature review has identified some promising opportunities.

Dzhamal Amishev and Tony Evanson, Scion
Keith Raymond, Future Forests Research

Introduction

In New Zealand, approximately 44 percent of the 1.8 million hectares of plantation forest is on steep terrain which requires specialised harvesting techniques, such as cable logging.

For example, an estimated 85 percent of the plantation forest in the Gisborne District is classed as cable-hauler harvesting country on steep, erodible soils where cable hauling costs are very high. In addition, roading and landing construction costs are comparatively high, depending on accessibility, availability of aggregate, existing roading infrastructure within the forest, and total volumes to be harvested (MAF, 2008a).

Much of the resource available for harvest over the next few years in New Zealand is in quite small, remote blocks (many of which are not supported by good infrastructure) and widely spread geographically, with volumes and log qualities that are less well understood than the resource currently being harvested. Average harvesting costs are likely to increase if a higher percentage of the volume is taken from this steeper, more remote country, where satisfying environmental standards will require extra attention (MAF 2008b).

In this steep country, the cost of harvesting alone can contribute over 40% of the delivered cost of wood. In some locations throughout New Zealand, using current harvesting technology, the total cost of harvest engineering, harvesting and transport may exceed the value of the log products. In these situations there is no incentive for land owners to support an increase in plantation forest area, as desired by schemes such as the Afforestation Grants Scheme (encouraging more tree planting in small forests and on farms), and the East Coast Forestry Project (addressing the wide-scale erosion problem in the Gisborne district).

Many regions of New Zealand are going to encounter increasing challenges to reducing their harvesting costs. One way that harvesting productivity can be increased, and costs reduced, is the introduction of mechanised systems in the felling and bunching phase of harvesting.

In 2008, Future Forests Research commenced a programme of research in steep country harvesting, with the goal of achieving year-on-year reductions in harvesting costs. An early step in the project has been a review of the international literature on research undertaken

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

over the last 20 years in felling and bunching on steep terrain.

Bibliography

Brown, J., McMahon, S., and Evanson, T. (1996): Excavator bunching in clearfell for skidder extraction. LIRO Report Vol. 21 No. 19. Logging Industry Research Organisation, Rotorua, New Zealand.
This study examined excavator bunching of manually felled stems on short steep slopes for cable skidder extraction. Three operations were studied. In the first operation, a Cat EL240C excavator loader pulled stems downhill off slopes up to 26^{0}. In Operation 2, a Cat EL300 excavator shovel logged stems up to 70m on 25^{0} slopes. In the third operation, a Thunderbird 738 tracked log loader pulled stems downhill. Bunching production rates ranged from 58 m^3/PMH in 1.57m^3 tree size to 112 m^3/PMH in 3.95m^3 tree size.

Carson, B., Mann, C. N., Schiess, P. (1985): An Evaluation of Cable Yarding Bunched Trees on Steep Slopes. Paper presented at the 8th Annual Council on Forest Engineering Meeting, Tahoe City, California, August 18-22, 1985.
Tree-length bunches (approx. 35-40 stems) were laid along the contour by a Kaiser X5M Spyder walking feller-buncher on slopes of up to 70% (36^{0}) working both uphill and downhill. Trees were small (>3000 spha), with over 50% being 10cm or less in diameter.

Average haul size for the Washington TL6 yarder (highlead rigged for two 5.5m chokers) was 3.36 tonnes. Extraction productivity of 30.5 tonnes/PMH was achieved. Hook times ranged from 2.0-3.2 min/haul.
Conclusions included:

- Slope (0-70%) did not have any effect on yarding production
- Bunches on steeper slopes were smaller
- Bunch size exceeded what could be hooked by one choker.

Recommendations for improved productivity included: matching of bunch size with choker length; pre-setting chokers in the felling cycle; increasing bunch size.

Dempster, P., Gallo, N., Hartsough, B., Jenkins B., and Tittmann, P. (2008): California Department of Forestry Equipment Review, Agreement Number 8CA05704. Final Report to State of California Department of Forestry and Fire Protection. Department of Biological and Agricultural Engineering University of California, Davis, CA. 26 December 2008.
This report is a review of equipment, currently in commercial use, under development, or previously tested or used, that can be, or has potential to be, used for harvesting forest biomass in site and stand conditions common to the Central Sierra Nevada, California. A range of harvesting systems suitable for small tree size in California is reviewed covering all harvesting systems from ground-based skidding to cable yarding. Costs and productivity figures are presented from a synthesis of other research results.

In the review of cable yarding, the potential for using machinery to fell and bunch or fell and process trees prior to cable yarding is discussed. The authors propose the scenario where trees are located adjacent to the yarding corridors, eliminating the need for lateral yarding and providing the opportunity to use a grapple instead of chokers, eliminating much of the labour requirement and the time to set and release chokers. Cable-operated grapples are commonly used in Canada on clearfell operations, and the authors highlighted a combination cable/hydraulic grapple recently developed by Eagle Carriage and Machine Inc. http://www.eaglecarriage.com/pullingcarriages.htm (Figure 1). Called the Mega Claw grapple, it is remote controlled by Talkie Tooter® and features a camera mounted on the carriage and a 23cm monitor in the yarder so the operator can see exactly what is being picked up.

The authors examined estimated stump-to-landing costs for the base-case cable yarding system (chainsaws and cable yarder with chokers) and four alternatives: 1) feller-buncher

Vol: 1 Number: 7
2009

and cable yarder with a drop line carriage and chokers; 2) feller-buncher and cable yarder with grapple; 3) a harvester producing cut-to-length (CTL) logs and a cable yarder with chokers; and 4) a combination feller-buncher-yarder.

Figure 1: Eagle Grapple carriage

The net benefits of alternatives 1 and 2 were estimated to be about 20% and 30% respectively, for the average yarding distance of 152m assumed for the base case.

The authors estimated the cost-per-tonne disadvantage of the CTL harvester-plus-yarder combination to be about 25-100% compared to the base-case system, primarily because large parts of the smaller trees were not recovered when using a CTL harvester, substantially increasing the cost per recovered tonne.

Option 4 involved using a feller-buncher as the tail hold and having the yarder extract trees as soon as the feller-buncher cut them. This increased the utilisation of the feller-buncher, and the yarder could operate with a smaller crew (no fallers and fewer breaker outs). Their preliminary analysis of this concept indicated it might reduce costs by over half compared to the base-case system.

Fischbacher, M. and Mairhofer, M. (2007): New skyline logging technology for yarding and tree processing with a two-person crew. The International Mountain Logging and 13th Pacific Northwest Skyline Symposium 2007, April 1-6, Corvallis, Oregon.

An economic way of harvesting small wood on steep terrain is offered by technology developed by Koller Forsttechnik GmbH in Austria. http://www.kollergmbh.com/english/frameset.htm

New techniques provide a safer environment for a two-person logging crew using the K507 tower yarder with integral harvester (Figure 2) :

- Weight 33.5 tonnes) :
- Tower height: 11.5m
- Skyline 1000m of 20mm diameter cable
- 2 main winches: each with 1400m cable
- 11mm-diameter swaged rope with 4.3 tonne line pull at average drum diameter.

Safety features of the system included:

- Radio control
- Adjustable overload shut-down
- Maximum force in the mainline adjustable
- Use of radio-controlled chokers
- Electronic monitoring system to protect against machine breakdown
- Cable break protection at the carriage with emergency clamping
- Emergency skyline drop down by radio control.

Economic Factors:

- Low personnel costs, only two persons are necessary to operate
- High production at minimum personnel cost
- Short rigging times
- Less time to transport and set up as the tower yarder and harvester is mounted on one truck unit.

Results:

- Average wood rate per line was between 300 and 400 cubic metres
- Average tree size of the fir and larch harvested ranged between 1.5 and 4.0 cubic metres per tree
- Average skyline length 450m
- Daily production rate ranged between 100 and 200 cubic metres.

Vol: 1 Number: 7
2009

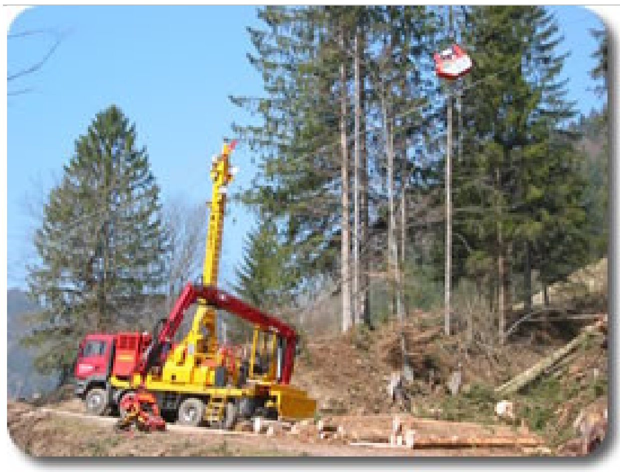

Figure 2: Koller K507 Processor tower yarder

Hartsough, B. R. (1990): Pre-bunching with a Log Loader for Grapple Skidding. Applied Engineering in Agriculture. 6(5): 657-660, 1990. ASAE Paper No. 89-7596. American Society of Agricultural and Biological Engineers, St. Joseph, Michigan. This study examined the use of a small excavator loader to pre-bunch redwood logs for grapple skidder extraction in California.

Bunching had the advantages of reported lower tyre damage and a reduction in wheeled travel area. A second skidder could be added to the system, but would only be utilised at haul distances over 200m. A production buffer would be necessary to reduce delays, especially at short haul distances.

Pre-bunching increased productivity over un-bunched logs (and reduced "on-truck" costs) for small logs in thinning, but not for clearfell operations. The approach appeared to reduce log breakage and damage to residual trees.

Heinimann, H.R., Stampfer, K., Loschek, J. and Caminada, L. (2001): Perspectives on Central European Cable Yarding Systems. The International Mountain Logging and 11th Pacific Northwest Skyline Symposium 2001, Dec 10-12, Seattle, WA.
This paper presented the state-of-the-art of both yarder technology and technical production systems in central European conditions, and identified future challenges. Processor Tower Yarders (PTY) represent the state of current technology in Central Europe, with integrated working drums, steel spar, power supply, boom and processor head, all on one carrier. An automatic control device for carriage movement and stop, together with radio control, makes it possible to operate the yarding system with a two-person crew. In thinning operations, mechanisation of tree processing resulted in cost savings of about 40% for both the cut-to-length (CTL) system with a steep slope harvester, and the full-tree (FT) system with a processor tower yarder. Future improvements will focus on the reliability of system components, the optimisation of harvesting system design, and work force development by using simulators for training.

Manufacturer	***Yarder Type***	***Processor Type***
Herzog	Grizzly-1000	Keto 150
Koller	K-500	Konrad Woody 50
Konrad	Mounty-4000	Konrad Woody 60
Mayr-Melnhof	Syncro Falke	Silvatec 445 MD50
Tröstl	TST 700	Silvatec 555 MD60
Valentini	V 600	Wolf 50 B
Wolf	PKM 12	

Table 1: Processor Tower Yarders (PTY) of Central European manufacturers.

Hittenbeck, J. (2007): Limits of Wheel Based Timber Harvesting in Inclined Areas. Austro2007 / FORMEC´07: Meeting the Needs of Tomorrows´ Forests – New Developments in Forest Engineering, October 7 – 11, 2007, Vienna, Austria.
The slope and ecological limits of wheel-based highly mechanised harvesting has a lot of influence on the economics of harvesting. The discussion about the limits is very controversial while real scientific investigations are lacking. This project focussed on safe and ecological timber harvesting in steep areas. A model about the limits of wheel-based forest machinery on slopes was developed, based on drawbar pull measurements under even conditions done with

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

a forwarder. The relationship between slip and tractive force was compared with the downhill slope force. An ecological limit resulted from an accepted slip level, while the maximum tractive forces determined the absolute limitation of wheel based machinery.

Kellogg et al, (1992): Mechanized Harvesting: A compendium of harvesting research. Forest Research Laboratory, College of Forestry, Oregon State University, Corvallis, Oregon, March 1992.
This comprised a collection of summaries taken from harvesting research studies:

Citation: Fisher, J.G.(1986): Logging with a hydraulic excavator: a case study. M.F. paper. Department of Forest Engineering, College of Forestry, Oregon State University.
This study involved bunching for a grapple yarder using a Cat 245 excavator equipped with a 17m boom and 152cm grapple. Trees (mean $2.5m^3$) were manually felled, limbed and topped on the slope, and then bunched or swung above or below an intended road. Mean slope was 35% (20^0). Production rate was defined as $129.4m^3$/PMH for conventional swinging (shovel logging).

LeDoux, C.B., Kling, B.W., and Harou, P.A., (1987): Predicting bunching costs for the Radio Horse 9 Winch. NE-RP-595. Northeastern Forest Experiment Station. USDA Forest Service, Broomall, PA.
As an alternative to feller-bunchers, trees or logs could be pre-bunched with a small winch. Small radio-controlled pre-bunching winches allow full payloads of small, scattered trees to be accumulated prior to moving in a large cable yarder. They would essentially replace the lateral yarding elements of the cycle of a large yarder, thus speeding the yarder's productivity.

LeDoux *et al*. (1987) reported productivities for pre-bunching with a radio-controlled winch. Several other attempts have been made to utilise winches to pre-bunch for yarders, but none has been economically successful in the long run. The reduced costs of yarding bunches has not adequately compensated for the added cost and effort of pre-bunching with a small winch. Pre-bunching with a small winch is an example of relatively poor utilisation of the human resource, because the human is paired with a low-power mechanical device that is used to transport the wood.

Some pre-bunching winches were commercially available in the past (e.g., Moore, 1987), but we know of none being manufactured at present.

Lileng, J. (2007): Harvester and Forwarder in Steep Terrain. Paper presented to the 3rd Forest Engineering Conference 2007, October 1 - 4, Mont Tremblant, Canada.
A recent development in western Norway is that of harvesters and forwarders operating in very steep terrain. The machines studied were a Valmet 911.3 Harvester and a Valmet 840.3 forwarder operating on skid roads prepared with a Caterpillar 317B excavator. The studies were carried out in a 50-year-old Norway spruce forest with a mean size of $0.4m^3$. The mean slope of the terrain was 59% (31^0). About 10% of the trees were harvested manually. The mean transport distance for the forwarder (six loads studied) was 650m. The results showed that harvesters and forwarders can maintain a high productivity when they operate in very steep terrain on skid roads. The environmental impact of the skid roads on steep terrain was not quantified.

McDonald, A. J. (1990): Bunch yarding with radio-controlled chokers in coastal British Columbia second-growth timber. FERIC Special Report No. SR-63 January 1990. Vancouver, B.C.: Forest Engineering Research Institute of Canada.
On intermediate terrain where a feller-buncher can be used but where tractive transport equipment cannot, mechanised felling creates bunches at the skyline corridor and thereby eliminates lateral yarding. A single choker can be placed around a whole bunch, if the bunch is properly sized and if the feller-buncher places the trees so a choker hole is available under the bunch.

MacDonald (1990) studied yarding of whole trees, most of which had been mechanically felled and bunched (using a Chapman FB 122, 56cm Rotosaw). Tree size was 1.12m^3 at a stocking of 375spha. Two yarding systems (using the Madill 044 yarder) were compared: a drop line carriage with hand-set chokers; and grapple yarding.

Conclusions of the study were that the highest productivity was achieved with the grapple system at haul distances less than 150m (108m3/PMH). Grapple yarding was cheaper at short distances because of the very short terminal times, especially the short grappling time relative to the time to set chokers.

At distances greater than 150m, use of chokers was more productive because the breaker-outs could hook more trees than the grapple could pick up (7.3m^3 per haul vs 2.1m^3/haul). Since inhaul times dominated the cycle time at these longer distances, the benefits of the larger choker payloads more than offset the extra cost of manual chokers. The productivity of the drop line carriage system was 75m3/PMH.

If systems were combined, grapple for short distances, choker for longer, costs were only $0.12 less than using the grapple system for all hauls. Choker systems should be considered for operations over longer haul distances (than studied), or in poor deflection or visibility.

Moore, T. (1987). A Portable Winch for Bunching Wood. LIRA Report Vol. 12 No. 3 (1987). Logging Industry Research Association, Rotorua New Zealand.
In 1987, LIRA conducted a trial hauling and bunching small wood (0.14m^3 piece size) on slopes ranging from 28^0 to 34^0, using a KBF brand chainsaw-powered winch. Tests were conducted on line speeds, line pull of rope, and bunching productivity. The study showed the winch was capable of bunching two pieces per haul, at 11 cycles per hour, giving productivity of 3.0m^3 per productive machine hour. The average drag size was only 0.3 tonne, even though the line pull capacity of the winch exceeded 1.0 tonne. The conclusions were that the winch was a low-cost option for bunching and hauling small wood, and that there was potential for increasing the payload of the winch. The winch had sufficient power to handle larger piece size, and would be suitable for small wood recovery in limited scale operations.

Moshenko, D. W. (1991): Grapple yarding in the interior of British Columbia. FERIC Technical Note TN 176. Forest Engineering Research Institute of Canada.
This study evaluated a felling and extraction system comprising a Washington 108 swing yarder and a Timberjack 2520 feller-buncher. Tree size was 0.45m^3, mean slope 20%, 700 spha. The feller-buncher felled strips perpendicular to the yarding road and bunched parallel to the yarding road. The utilisation of the feller-buncher was 91% and the breakdown of the feller-buncher work cycle was as follows:

Activity	**% time**
Swing empty	19.6
Cut	19.8
Swing loaded	23.1
Move	18.4
Clean (unmerch)	8.7
Prep. Bunch	1.9
Travel	2.3
Delay	6.2

Nitteberg, M. (2007): From off-road to on-road harvesting in steep terrain in Norway. Paper presented to the International Mountain Logging and 13th Pacific Northwest Skyline Symposium 2007, April 1-6, Corvallis, Oregon.
Traditional cable logging systems in Norway are operated off-road. The most common system is a cable crane with running skyline, built on a second-hand forwarder. In 2004, a contractor operating on the west coast of Norway purchased a truck-mounted cable crane system, the Mounty 4000, from Konrad Forsttechnik in Austria. This system was built on a 6WD MAN truck and powered by a 400 hp diesel engine. The cable crane is a standing skyline system primarily built for uphill yarding, and used a Liftliner motorised carriage. For downhill yarding a Woodliner 3000 self-propelled radio controlled

carriage was used. Only three workers were needed to operate the cable crane system: one machine operator to unhook the load and operate the harvester, one manual faller, and one breakerout. The Mounty system had only one machine with one engine, fewer hydraulic components and hoses, which reduced the costs of maintenance and repairs.

Figure 3: Konrad Mounty 4000 yarder

The transport cost was another important advantage for the on-road system. When the equipment was rigged down, and loaded on the base machine, the truck could drive on to the next logging site, thus the system was not dependent on transport with a low-bed trailer. It was therefore very flexible and could move over large areas in a short time, at low cost.

When compared to off-road cable logging systems the following advantages were obtained with the new system:

- Increased profitability of cable logging operations
- Reduced operating cost
- Reduced need for workers
- Higher flexibility.

Olund, D. (2001): The Future of Cable Logging. Paper presented to the International Mountain Logging and 11th Pacific Northwest Skyline symposium 2001, Dec 10-12, Seattle, WA.

This paper from the then President of Madill Equipment in Canada explores some recent developments in cable logging systems.

Figure 4: Madill 124 Swing Yarder with grapple

The shift from old growth logging to second-growth and plantation timber harvesting has favoured mechanised operations. Tower yarding on mountain terrain has come under increasing cost pressure from timber owners as they try to compete in the global market place. The development of steep-slope felling machines has resulted in improved productivities of grapple swing yarders.

Mechanised harvesting using a feller-buncher in conjunction with a grapple swing yarder can raise yarder productivity into the 100-tonne-per-hour range at haul distances up to 365m. The Madill 124 swing yarder pictured (Figure 4) produced 160,000 tonnes per year (700 tonnes per day average).

Peters, Penn A. (1991): Mechanized Felling on 40 to 100% slopes. ASAE Meeting, Chicago, Illinois, Dec. 17-20, 1991.

This overview examines the development of some steep slope, tracked feller-bunchers. Steep slope, swing-to-tree feller-bunchers were found to be most productive when working

FUTURE FORESTS RESEARCH

HARVESTING TECHNICAL NOTE

Vol: 1 Number: 7
2009

uphill. Types of steep slope feller-bunchers included the quad-track Allied Tree Harvester ATH 28, Menzi Muck 300 EH and Kaiser X5M Spyder (machines with both wheels and "legs"). Operating slopes ranged up to 85% (Spyder). Self-levelling machines with skilled operators such as the Timbco 420 could work on slopes up to 60%. A prototype steep country feller-buncher (Adaptive Suspension Vehicle, ASV) was developed at Virginia Tech in 1992. The desirable characteristics of a steep slope feller-buncher were seen to include: design for optimal operation on a 70% slope; capable of working on a 100% slope, having a walking speed of 3-6 km/hr; having six legs for stability.

Figure 5: Menzi Muck A91 harvester

Peterson, J. T. (1986): Bunched Turn Grapple Yarding. Paper presented to the 67th Annual Meeting, Woodlands Section, CPPA, Montreal, Que, Jan. 27-29, 1986. Canadian Pulp and Paper Association.
Trees of average piece volume of 0.59m^3 were felled mechanically and yarded by a Madill 084 grapple yarder.
Average haul size was 2.18 pieces for bunched timber vs 1.41 pieces for un-bunched timber. Average haul distance for both piece sizes was approximately 70m.
The study concluded that:

- Hook time was 17% longer in un-bunched timber.
- Decking time was 150% longer in un-bunched timber.
- Move time/PMH was decreased in bunched wood.
- Larger grapples resulted in more pieces/PMH (approx. 20% increase).
- Grapple yarding bunched timber reduced yarding costs (felling and bunching costs excluded).

Peterson, J. T. (1987): Effect of felling techniques on grapple yarding second-growth timber. FERIC Technical note TN 107.
Trees of mean 1.5m^3 tree size, 460 spha on slopes up to 13% were felled by a 91cm Weyerhaeuser feller-director in two felling patterns: (1) bunched at 45^0 to the haul road; and (2) felled and not bunched at 45^0 to the haul road. A Washington 108 swing yarder extracted both the bunched and un-bunched wood. The bunched wood led to 10% increase in trees/PMH and 36% more trees/cycle extracted. Terrain and operator visibility were factors in the productivity differences.

Stampfer, K. 1999. Influence of terrain conditions and thinning regimes on productivity of a track-based steep slope harvester. In Proceedings of the International Mountain Logging and 10th Pacific Northwest Skyline Symposium, March 28-April 1, 1999, Corvallis, Oregon, pp. 78-87.
Developments in the late 1990s have seen the production of steep terrain harvesters that are capable of operating safely on slopes between 35 and 55%. Specially designed tracked platforms such as the Valmet 911 Snake (Figure 6) have provided a solution for mechanised harvesting of forests on steep terrain. The steep terrain harvesters (Table 2) are more productive, cost-effective and safer means of felling timber on steep terrain, when compared to harvesting with chainsaws, and are popular in countries where there is a shortage of forest workers.

Current experiences in Austria indicate that the economics of steep terrain harvesters with cable extraction only become viable for tree sizes with a DBH over 20cm. A productivity model developed for a Königstiger steep terrain harvester by Stampfer (1999) indicated the effect of tree size and slope on the productivity of the harvester. Increases in tree size increase the harvester productivity, whereas increases in

Vol: 1 Number: 7
2009

slope have a reducing effect on overall harvester productivity.

Harvester	Tractive Method	Mass kg	Boom reach m	Slope Limit Degree [%]
Robin 2.29 SN	Tracks	8,700	9.2	-
MHT Robin	Tracks	9,000	9.0	-
Neuson 9002 HV	Tracks	11,000	9.0	30 [58]
Menzi Muck A111	Wheels / legs	11,500	8.6	35 [70]
Neuson 1100 HV	Tracks	11,600	9.1	30 [58]
Kaiser S2	Wheels / legs	12,700	11.5	45 [100]
Valmet 911	Tracks	16,900	9.5	39 [80]
Timberjack 608L/762	Tracks	25,720	9.5	27 [51]
Timbco 445c	Tracks	27,500	15	27 [51]

Table 2: Examples of steep terrain harvesters.

Figure 6: Valmet 911 Snake on steep terrain
http://depts.washington.edu/sky2001/presentations/ValmetSnake-Steinmuller_files/frame.htm

Stampfer, K. and Steinmuller, T. (2001): A new approach to derive a productivity model for the harvester "Valmet 911 Snake". Paper presented to the International Mountain Logging and 11th Pacific Northwest Skyline Symposium 2001, Dec 10-12, Seattle, WA.

This paper described a method for deriving a productivity model where there was limited information (e.g., on delays). The harvester was a Valmet 911 X3M Snake – the four wheels of a Valmet 911 had been replaced with four independent trapezoidal tracks (Figure 6). The productivity and climbing capability of the harvester up to 70% slope was verified.
The average cycle time for felling and processing a 0.6m^3 tree (range 0.18 to 1.16m^3) with an average DBH of 31cm (range 19 to 42cm) and tree height of 21m (range 15 to 26m) was approximately one minute, ranging from 0.35 to 1.86 min. Average terrain slope on which the machine operated was 36% (20^0), and ranged between 19% and 68% (11^0 to 35^0).

Tiernan, D., Owende, P.M.O., Kanali, C.L., Spinelli, R., Lyons, J., and Ward, S.M. (2002). Selection and operation of Cable Systems on Sensitive Forest Sites. Development of a Protocol for Ecoefficient Wood harvesting on Sensitive Sites (ECOWOOD). Contract No. QLK5-1999-00991 (1999-2002). Forest Engineering Unit, Agricultural and Food Engineering Department, University College Dublin, IRELAND, February 2002.
Generally, there has been a decline in the use of cable systems in Europe due mainly to the cheaper cost (less that 50% of the production costs for cable extraction) and increased capability of harvester and forwarder combinations to operate on steep terrain. Currently, less than 3% of the annual timber harvested in the European Union (EU) countries is by cable systems. The notable exception is Austria, where 17% of the annual cut uses cable systems for extraction, and is estimated to have doubled over the last ten years.

While the harvester and forwarder combination is a well-developed concept for flat terrain, logging costs and lack of workers have forced development of a mechanised solution for steep terrain. Recent trends in Central Europe have seen the replacement of chainsaw operators, especially in thinning operations, with steep terrain harvesters. It is mainly the excavator-based harvesters with tracks or wheels/legs that have been developed for steep terrain. The

Vol: 1 Number: 7
2009

innovation of tiltable operator cabins on tracked chassis has also enhanced the operational capability of harvesters on steep terrain.

Cable systems with steep terrain harvester are used in CTL harvesting systems with the bunching done along the skyline corridor. The combination of steep terrain harvesters with cable crane extraction has resulted in large increases in productivity. The productivity of the steep terrain harvester is 12 to 15 times higher than the productivity of chainsaws, and this difference increases with increasing tree size dimensions.

Research has shown that the steep terrain harvester with cable extraction of 4m assortments is more productive than chainsaw felling with cable extraction of whole trees.

Conclusion

In New Zealand in recent years, there has been a substantial research investment, through both public and private sector sources, into establishing better forests on steep and marginal land. There has however, been very little investment in New Zealand into research in reducing the cost of harvesting in difficult terrain.

While chainsaw felling has much lower productivity than feller-bunchers, chainsaws are cost-competitive in New Zealand because of their negligible capital costs and therefore low hourly costs (mostly labour). From a system standpoint however, chainsaws provide none of the downstream system benefits produced by mechanised felling and bunching, and are some of the most hazardous equipment in harvesting.

The introduction of mechanised systems into the felling and bunching phase of harvesting operations is one way to increase harvesting productivity, and reduce costs.

The main barriers to the widespread mechanisation of felling and bunching in New Zealand are the large tree size and the steep terrain.

The evidence is clear from this review of the literature that globally, there has been very little research into felling and bunching on steep terrain in recent years, and almost nothing has been done on the topic in New Zealand for the past 10 years.

The use of ground-based harvesters was traditionally not possible on steep terrain with slopes over 35%. Up till recently these areas were seen as the sole preserve of chainsaw harvesting because other harvesting machinery could not operate safely on these steep slopes. However, developments in the late 1990s have seen the production of steep terrain harvesters that are capable of operating safely on slopes up to 70%. This new development is a more productive and safer means of felling timber on steep terrain than motor manual harvesting, and with further enhancement of mobility of harvesters and ability to handle larger diameter trees, will become more cost effective.

Future scenarios where equipment is available to mechanically and economically harvest trees on steep topography are already being discussed in New Zealand. Research and development will be critical to New Zealand's international competitiveness, as it can identify ways to lower production costs. This cannot happen, however, unless innovation and productivity are valued, and substantial industry support and funding are provided for a strong research capability. (MAF 2008b).

References

MAF (2008a). *East Coast Forest Industry and Wood Availability Forecasts 2008*. Ministry of Agriculture and Forestry, Wellington, New Zealand.

MAF (2008b). *Future Drivers for New Zealand Forestry October 2008*. Ministry of Agriculture and Forestry, Wellington, New Zealand.

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