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Mechanised Steep Slope Felling for New Zealand – Current Developments

Summary

The availability of mechanisation for steep slope felling in New Zealand forests is reviewed, including the costs and benefits of implementation and recommendations made for future development. The quad-track Valmet 911 X3M Harvester is commercially available and may have potential in New Zealand. The Kaiser Spyder or Menzi Muck "walking" excavators could be used where tree size is small and for small woodlots where access is limited for large machines. The ClimbMax steep slope harvester developed by Trinder Engineers Ltd in Richmond, Nelson is the machine with the most promise for New Zealand. It has the potential to reduce overall cable logging system costs by as much as $3.00 per cubic metre. Further opportunities for development of forestry machinery are discussed.

Dzhamal Amishev, Scion

Introduction

A key focus of the FFR Harvesting research programme is improving the health and safety of workers and the economics of cable harvesting systems on steep hill country.

The forest is a hazardous working environment and it is doubtful whether these hazards can ever be eliminated. While there has been considerable focus and effort in recent years placed on minimising hazards to make the harvesting work environment safer, removal of people from the hazards of the working environment is the best long-term solution.

To a large extent this has been accomplished on flat country harvesting sites with the widespread introduction of mechanised felling, grapple skidders and log processing machines. However, extending ground-based felling machines safely onto steeper slopes has been a slow process and this means that the hazardous tasks of tree felling and breaking out are still mainly carried out manually. Until recently, opportunities to mechanise felling on slopes greater than about 50% (27^0) have not been available.

The economics of steep country harvesting are also of concern to the New Zealand industry. The cost of harvesting by cable hauler exceeds that of the more cost-effective mechanised ground-based harvesting systems by typically $10.00 per tonne or more.[1] Labour costs are a major component of the mainly manual cable hauler crews with up to 35% more workers per crew and nearly 40% lower productivity (in tonnes per productive hour) than ground-based crews.[2] Innovation is needed to reduce production costs of hauler operations in New Zealand. The use of mechanised felling on steep slopes has the potential to alter existing processes within the harvesting system, providing productivity and value recovery gains.

The focus of the FFR programme Mechanisation on Steep Terrain over the last three years has been on existing technologies in forestry in other countries, new technology in other industries, determining the potential of new concepts being developed in New Zealand and in supporting the development of a steep slope feller buncher for New Zealand conditions.

Mechanised systems reported in the forest industries of other countries include;

- Self-levelling feller bunchers on steep slopes
- Quad-track crawler harvesters
- European developed "walking excavators"
- Harvester / forwarder cut-to-length logging systems specifically targeting steeper slopes
- Unmanned remote controlled harvesters

In New Zealand recent developments in felling and bunching have involved:

- excavator based loaders under haulers on short steep slopes for bunching
- excavator based loaders for feeding the hauler grapple
- cable-assisted excavator based feller bunchers for felling, bunching and feeding the hauler grapple

This report summarises the most applicable of these systems and describes progress in the development of a steep slope felling machine for the New Zealand industry. These systems have been described and referenced in more detail in a separate FFR report. [3]

Self-levelling Feller Bunchers

Feller bunchers with self-levelling cabs have been operating on steeper slopes in both New Zealand and Australia for many years. One recent study was carried out to evaluate a self-levelling feller buncher on steep terrain and its potential to improve the overall productivity of the cable logging system. [4]

The Valmet 445EXL feller buncher was operating in good conditions in relatively small tree size (0.8 m^3) clear felling (Fig. 1). Total fell and bunch cycle time per tree averaged about 0.33 min resulting in hourly productivity of 180 trees/PMH or 144 m^3/PMH. The average bunch size was 4.3 trees ranging from two to six trees per bunch.

Terrain conditions were favourable with maximum slopes of 25 degrees (47%) and firm dry sedimentary-based soil conditions which enabled maximum traction. Extraction haul sizes were increased from 1.5 pieces per cycle to 2.3 pieces per cycle in bunched wood which on average resulted in a 25% increase in productivity for the swing yarder. [5]

Due to its high capital cost the purpose-built self-levelling feller buncher has a high daily cost structure. With its high productivity and high daily cost it is essential that the feller buncher is operated to its maximum capacity, which would require it to service more than one cable logging crew. Felling and bunching cost for a single feller buncher servicing two cable yarders was calculated to be about \$2.40/m^3. [4]

Results of this study demonstrated that in good conditions a high production rate can be achieved by a tracked self-levelling feller buncher. Mechanical felling and bunching is particularly advantageous in smaller tree sizes because extraction efficiency is improved through bunching. Research into the performance of self-levelling feller bunchers working in larger tree sizes (1.8 – 2.6 m^3) and in different soil and slope conditions, more typical of New Zealand would be particularly useful for New Zealand logging contractors.

Figure 1: A Valmet 445 EXL feller buncher in a cable hauler setting in Victoria, Australia.

Quad-Track Harvesters

The development of tracked harvesters enabled mechanised felling and processing of trees on steeper slopes than the self-levelling feller buncher for the first time. Tracked harvesters can cope, depending on the soil conditions, with slopes up to 60% or 31^o [6]. To address the disadvantages of a one-piece track, the Valmet 911 X3M Harvester (Fig. 2) was designed with four independent trapezoidal tracks which provides substantial climbing ability and increased stability of the machine.

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

In one study the number of trees processed each move, stand density and the terrain slope was found to influence the locomotion of the harvester. Under favourable soil conditions the Valmet 911 X3M Harvester could work effectively on steep slopes up to 70% (35°). [6]

Figure 2: Valmet 911 X3M Harvester

With a 140 kW engine, standard harvesting head (Valmet 960 S-2) and telescoping boom it can cope with trees of up to 65 cm diameter. This machine may be suitable for New Zealand clearfell conditions and is commercially available from Komatsu Forest Machinery.

Walking Excavators

A Kaiser Spyder S2 “walking excavator” (Fig. 3) was studied working on slopes in the Waikato region, clearing slash and bunching trees for extraction on a farm woodlot.[7] The machine was observed lifting and slewing trees of estimated 1.5 tonne piece size, and it was able to move a tree of estimated size of 2 – 2.5 tonnes.

The machine used its standard method of pushing itself uphill supported by two wheels and the extending boom. Travel speed up a 25-30 degree slope on an uneven surface was approximately 0.7 km/h. Speed on steeper slopes could limit its ability to compete with a manual faller, particularly in bigger piece size.

Such machines could have two applications as a felling machine in clearfelling small piece size stands (under 1.5 m^3 piece size) or thinning operations. They could also be used for clearing small piece size woodlots when combined with other civil engineering type work (e.g. road building).

Figure 3: Side view of Kaiser Spyder showing degree of cab levelling possible

The owner-operator of the machine stated that the newer models of Kaiser Spyder are potentially 40% more powerful than the S2. The estimated cost of a Menzi Muck machine (very similar to Kaiser Spyder S2) landed in New Zealand, was approximately $NZ500,000.

Opportunities to upsize the machine were explored but it was felt that these could be limited due to the extra pressure required to be applied through the stabilising legs to prevent the machine sliding downhill. It was concluded that mechanised felling on steep terrain with this machine may be more expensive ($2 to $3 per tonne) than manual tree felling ($1 to $2 per tonne). In this case felling on slopes improves overall system productivity through bunching but does not necessarily reduce felling costs.

Cut-to-Length System Improvements

One successful steep terrain harvesting system was observed in southwest Germany in 2010. [8]

The operation comprised an excavator-based harvester, the Impex Königstiger and a Herzog Forcar FC200 forwarder.

The latest innovation from Herzog Forsttechnik AG of Switzerland is the bogie lift. Its function is to lift the front axle (Fig. 4) which makes it easier to enter sites where steep embankments are found. It achieves a smaller turning radius and levels the machine on steep or uneven terrain. The bogie lift is activated by the machine operator from the cab through one lifting control.

Figure 4: Herzog's front axle bogie lift.

Herzog has also produced a retro-fitted crane tilt and a traction winch. The crane of the OEM manufacturer is removed and the Herzog crane is fitted that tilts to 26.5 degrees (46%), allowing better crane performance on steeper slopes and in thinning operations.

The traction winch (Herzog Alpine Synchrowinch) can be fitted to harvesters and forwarders. One end of the cable is attached to a suitable point such as a stump at the top of the slope, and the winch then assists the machine by providing more control over forward and reverse movement.

The forwarder winch is permanently attached to the rear frame of machine, while the harvester winch is attached with a quick-release adaptor, which enables it to be used on more than one machine. The winch, fitted with 280m of 15mm cable, requires a hydraulic supply of 170 litres / minute from the base machine. The crane's hydraulic pump is usually used as the power source for the winch. In order for the machine operator to remain comfortable while working, a seat tilt plate is fitted between the seat spring and the floor of the cab. This enables the seat to level up to 23 degrees (40%) along the horizontal axis of the machine. A camera is optional to monitor operation of the winch unit.

After seeing this forwarder operate it was concluded that a cable-assisted forwarder in combination with a quad-track feller processor has potential in steeper New Zealand terrain.

Remote Controlled Harvesters

Another development in cut-to-length harvester-processors is the Swedish built Gremo Besten (Fig. 5).

Figure 5: Gremo Besten 106 RH teleoperated harvester in clearfelling in Sweden.

This 6-wheel drive remote controlled harvester has a 181 kW engine and a 10 metre boom reach. The processor is operated remotely by the forwarder operator and loads processed logs direct to the forwarder bunk. To date it has not operated on steeper slopes but six-wheel bogie drives with band tracks have been used on steep slopes in the past (on forwarders).

Another future development may be combining the traction assist winch system with the remote-controlled harvester, which may have some potential in steeper New Zealand conditions.

Cable-assisted Excavator Feller Bunchers

There are two New Zealand examples of excavators using a cable traction-assist system where the machine is tethered to an anchor to assist mobility on steep slopes. Both machines have been studied as part of the FFR programme and detailed reports have been published. [3] [9] [11]

The two operations used different methods to anchor and operate the cable: one was a bulldozer with combined winch and anchor; the second had the winch integrated into the felling machine and used stumps as anchors.

The first operation (Ross Wood's bulldozer winch) used a felling head and the stems were bunched for grapple yarder extraction (Fig. 6).

Figure 6: Bunched wood ready for grapple yarder extraction.

In the study tree felling was observed to be significantly slower when the machine was tethered then when felling on flatter slopes without the cable. The study showed an average 60% increase in the number of trees hauled per cycle with mechanically felled and bunched wood versus manually felled and unbunched wood. [9]

The second machine (Nigel Kelly's winch-assisted excavator feller buncher) used a stump as an anchor). This machine was working with a grapple yarder and was operated both in bunching the wood for the hauler and to feed the grapple allowing for a faster cycle time for the hauler. A significant increase in hauler system productivity (over 25%) was observed in this operation.[11] The concept of presenting to the grapple is also a good example of the potential for process change where it is possible to have a machine operating under hauler ropes safely.

Due to the risks associated with any piece of equipment working on steep terrain, the ultimate goal is to entirely remove workers from hazards especially on steep slopes. Modifications to the machines and/or the working methods will improve both productivity and safety. A possible future enhancement to the system is to install remote control to existing machines to allow them to be operated from a distance (teleoperation).

Feller Buncher Developments in NZ

Previous studies in New Zealand have clearly shown there are productivity advantages in felling and bunching for the hauler at the same time providing a safer environment for workers on the slope by putting them into machine cabs. [3] [4] [5] [10] [12]

In one of the New Zealand cable-assisted excavators, the tethering method was retro-fitted to a standard excavator. In the other case the winch was integrated into the track frame of the excavator. Further developments have improved the location and positioning of the winch.

As of mid-2011, the Alpha prototype of the Kelly steep slope feller buncher built by Trinder Engineers of Richmond, Nelson had almost 5000 operating hours felling and bunching trees on steep slopes in Nelson forests.[3] In November 2011, the Beta prototype 42-tonne machine called the ClimbMax Steep Slope Harvester rolled out of Trinder Engineers' workshop (Fig. 7).

Figure 7: The Beta prototype of Trinder's steep-slope feller buncher featuring Trinder-designed felling grapple (Photo courtesy of FICA)

The Beta prototype of this feller buncher is purpose-built and according to Trinder will have more power and improved operating systems compared to the Alpha Prototype. Some of the features of the ClimbMax Steep Slope Harvester include:

- A redesigned winch relocated to the front of the machine (Fig. 8) which is controlled by a separate computer freeing up the operator to focus on harvesting.
- A new fast acting blade at the rear of the machine to act as a secondary safety device should any critical machine functions stop working.
- A dry sump engine which provides the machine with an increase in power.
- A new custom-designed boom and arm to enhance machine performance without a weight penalty. Boom weight is critical to slewing performance, especially on slopes.
- Fully integrated design of winch, track gear, cab, boom, arm and head purpose-built for steep slope harvesting applications.

Trinder Engineers have spent around 3000 worker-hours designing and building the ClimbMax Steep Slope Harvester. They have also developed a new purpose-built felling grapple designed to fell trees on slopes greater than 26° (50%). The grapple has a high clamping force for trees on steep slopes and also features a retractable saw box that allows shovel logging when in grapple rather than saw mode.

Figure 8: The redesigned winch of the ClimbMax steep slope harvester (Photo courtesy of FICA).

Estimated costs of the ClimbMax Steep Slope Harvester based on current machinery/supplies prices at current exchange rates (early 2012) are:

- Hitachi Zaxis 400 LCH excavator (or other chosen base machine) - $350,000
- Modifications and improvements - estimated at $580,000
- Trinder purpose built felling grapple - $100,000
- Total price of Beta prototype ClimbMax steep slope harvester - $1,030,000.

Trinder Engineers expect the increased efficiency, horsepower and ergonomic design of the Beta prototype to result in greater productivity in steep slope felling and bunching operations than the alpha prototype. On the basis of an earlier productivity study of the Alpha prototype a 26% system productivity improvement was reported. [11]

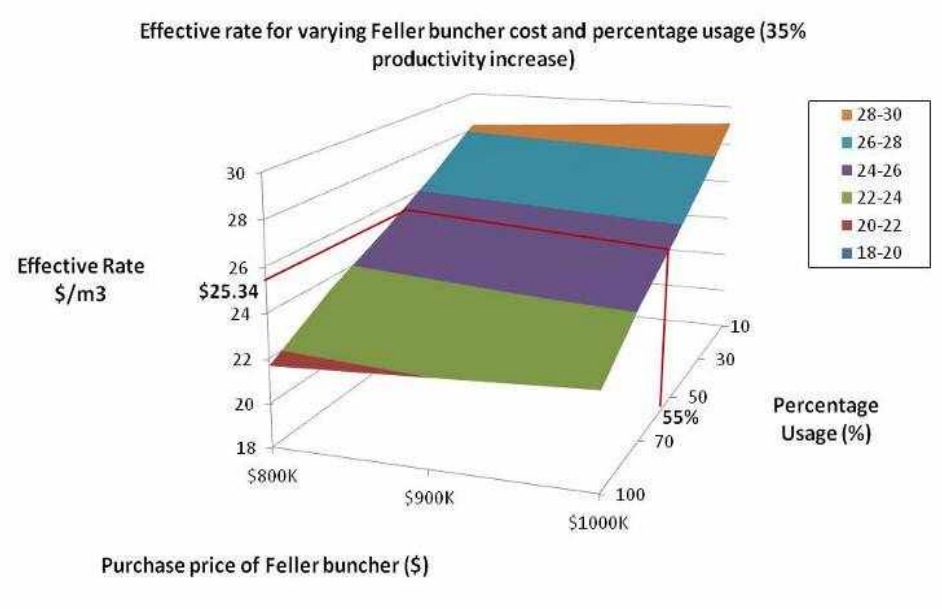

Figure 9: Effective cable logging rate surface for a range of capital costs and utilisation levels (assuming 35% gain in cable system productivity).

It is expected that the improvements in felling and bunching features of the beta prototype will result in a 30-40% performance improvement from previous productivity results. This would equate to a 35% productivity increase (in tonnes per day) for the whole extraction system compared to a similar cable extraction system using manual fallers.

At the estimated total cost of NZ$1.0 million, the steep slope harvester system has a break-even usage of 55% of operating time to justify its purchase. At expected productivity rates this gives an effective logging cost of $25.34/m^3 per tonne (Fig. 9). Substantial gains would be achieved with increasing usage of the machine beyond 55%. It has been calculated that if used 100% of the time the effective logging cost would be $22.33/m^3). This results in potential benefits of about $3.00/m^3 versus a similar cable system using manual fallers.

Future Research & Development Opportunities

The performance of the new ClimbMax Steep Slope Harvester will be the subject of detailed production studies in mid-2012 and will be reported in a separate FFR report.

Increasing productivity of cable extraction through innovation is a key goal of the FFR Harvesting Theme. Opportunities for future forestry machinery development include:

1. Machine design.
   - Integrating other functions to be multi-purpose
   - Improved fuel efficiency and quality of the entire work process
2. Machine-terrain interaction
   - Adaptation to the ground conditions (vibration damping, obstacle negotiation, anti-slip traction control)
   - Minimised soil-machine disturbance (track slippage, & fatigue to machine structures and operator)
3. Machine-tree interaction
   - Accurate and reliable measurements (length, diameter, quality)
   - Internal quality measurement (e.g. sonics)
   - Scanning whole trees for full optimisation
   - Reducing damage to wood material or remaining trees during the felling process
4. Man-machine interface

- Improved operator vision
- Safety, usability, & operator comfort (semi-automation of functions)
- Machine performance and condition monitoring & diagnostics
- Operator performance and skill observation
- Self learning and expert systems
- Teleoperation of machine

5. Real time data exchange.
   - Positioning & navigation
   - Route optimisation through forest
   - Real-time updating of forest inventory data
   - Scanning of standing trees/forest
   - Information network (help desk & other services)

In further new forestry machine development these opportunities should be considered if a substantial breakthrough is to be achieved. The implementation of some of these functions will be more challenging than others and their impacts on total system productivity will vary. The challenge will then be to ensure that the rest of the logging system (processing, sorting / stacking and truck loading) is structured in a way that enables the full production potential of the improved system to be achieved.

Implementation of highly mechanised cable harvesting operations will require coordination, balancing and possibly further improvements to the whole-of-supply-chain logistics to ensure the large increases in felling and extraction productivity do not create bottlenecks further down the operational wood supply chain. Such changes are seen as a necessary evolution within the harvesting industry, providing technology and new methods to enable the New Zealand industry to compete economically in the world wood market.

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