Developing Fully Mechanised Steep Terrain Harvesting Operations

Rien Visser, Keith Raymond[1] and Hunter Harrill
Associate Professor, [1]Harvesting Programme Leader and PhD Student
School of Forestry, University of Canterbury, Christchurch, New Zealand
[1]Future Forests Research Limited, Rotorua, New Zealand
Email: rien.visser@canterbury.ac.nz

Summary

Harvesting the extensive areas of maturing New Zealand plantation forestry on steep terrain has highlighted significant productivity and safety issues associated with using traditional systems. Chainsaw felling, followed by cable yarding extraction using choker-setters, with subsequent processing on a landing involving skid workers has been the mainstay of steep terrain harvesting for decades. A high level of risks to forest workers operating these systems provides both the need, but also the potential benefits, of mechanising the manual aspects of this system. A number of initiatives and innovations are starting to eliminate the need for forest workers to be exposed to these hazards. This paper details developments that include cable assisted felling machines, motorised grapple carriages and advanced planning systems.

Keywords
Safety; Mechanisation; Steep slope harvesting; System productivity; New Zealand

Introduction

The forest industry in New Zealand is based around large scale pine plantations, grown on 25 year rotations. It is NZ's third largest export earner. Over the last 5 years the total annual harvest volume has increased by 30%, driven both by the availability of the maturing resource and the market demand from China for logs. The majority of the forests currently being harvested are on terrain that can be characterised as steep and difficult (Amischev 2012). Cost-effectively harvesting this resource requires not only the need for improved operational efficiency to remain competitive in an international market, but also challenges of safety and environmental performance (Raymond 2012). There is now a very strong industry focus on improving the level of mechanisation and integrating new technology to achieve these goals.

Improved steep terrain harvesting has been fuelled by extensive research programmes in New Zealand that help develop new ideas, improve our understanding, and therefore speeds up implementation. The largest forest operations research consortium is the Harvesting theme of Future Forest Research (FFR), which is co-funded between industry and competitive government grants. It has a comprehensive longer term programme under the theme of "no worker on the slope, no hand on the chainsaw". Industry is actively testing and implementing these new developments as they look to gain the productivity and safety benefits of these new systems (Raymond 2010).

This paper and accompanying presentation will overview a number of the advances that have been studied and implemented. It includes; (a) Extending the operating range of ground-based systems on steep slopes, (b) mechanisation of cable yarder extraction through improved grapple carriage systems, and (c) advanced planning and performance monitoring systems.

Extending the operating range of ground-based systems on steep slopes

Ground-based harvesting systems are typically more productive and cost-effective than cable or aerial systems. Steep slopes create an operating limit for ground-based machines, although that limit is often not well defined. Forestry machines working on steep slopes typically lose traction before they are close to their static roll-over limit (Visser 2013a), so both terrain slope and soil strength must be taken into account. A cable can be used to assist the traction capability of a machine, and thereby extend the operating range. Figure 1 shows how a cable with 10 tonne of tension can extended the operating limit of a 37 tonne machine on slopes, dependant on the soil strength. The soil strength is represented by the soils co-efficient of traction (cof).

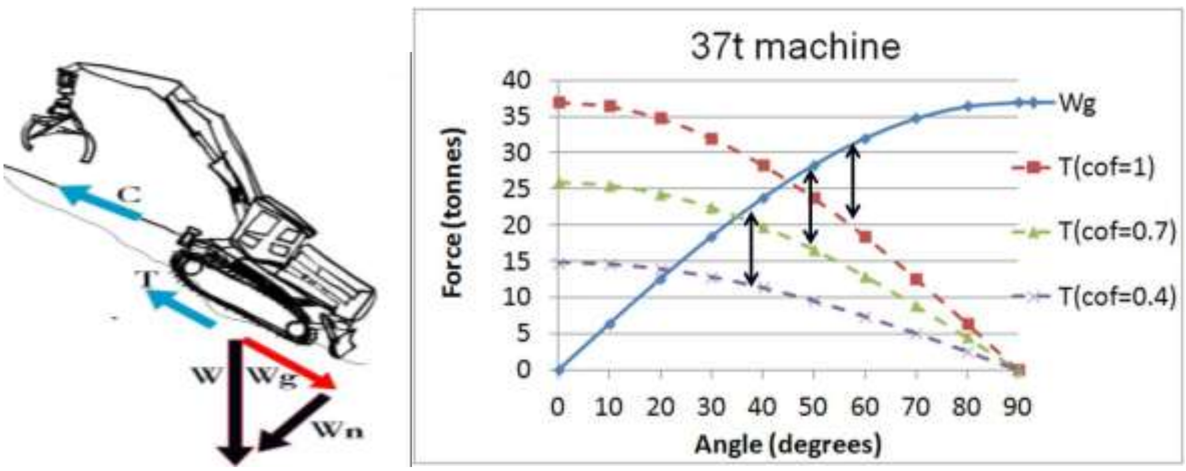

Figure 1: Basic force diagrams (left) can be used to illustrate the potential improved operating range on steep slopes dependent on soil strength (right). (From Visser 2013)

Cable assisted harvesting machines are not new; in Europe they have been most commonly used for forwarders but now also available for harvesting machines (Amischev et al 2009). However, New Zealand conditions include very steep (50+% common) and unstable terrain (geologically young, often highly erodible), in combination with relatively large tree size ($3m^3$+ common), which has required larger felling machines than were commercially available. The ClimbMAX Steep Slope Harvester (Figure 2), developed by Nigel Kelly and Trinder Engineering, is an example of a machine that meets these requirements. This is a 43 tonne purpose built machine which integrates the winch system into the chassis. With development work that included research and testing, it is now fully commercialised with units sold in both NZ and Canada.

Figure 2: ClimbMAX felling machine with integrated winch mounted on chassis

It complements other cable assist systems that are being developed based around purpose built self-levelling steep terrain harvesters that are tethered to an uphill anchor machine (typically a bulldozer) that both houses and powers the cable winch (Figure 3). With the largest risk of forest worker fatality associated with motor-manual felling on steep terrain, a number of NZ forestry companies are actively encouraging their logging contractors to adopt these mechanised felling / bunching / shovelling systems that can work on very steep slopes.

Figure 3: Purpose built self-levelling harvester (right) being cable assisted by the winch mounted on the dozer (left)

A comprehensive research project looking at a range of forestry machines working on 'typical' terrain established that many exceeded the safety guidelines of 30% slope for rubber tyred, and 40% for tracked machines (Berkett and Visser 2012). Machine operators typically do not measure actual machine slope, or predict the slopes they might be exposed to when they harvest a block. Interpine Forestry has developed on-board navigation application that provides the operator of any steep slope harvesting machine with information on harvest area terrain (www.interpine.co.nz). This 'App' can be used by the machine operator to plan harvest routes, or by forestry companies to establish areas where slopes are likely to exceed safe limits and upload that directly into the machine (Figure 4).

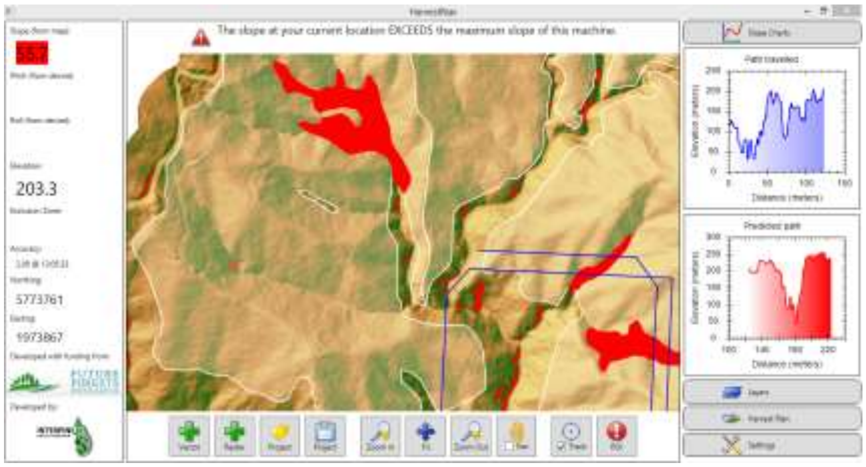

Figure 4: Screenshot of HarvestNav app that provides not only machine slope information, but allows the machine operator to plan the route through the stand to avoid exceeding slope limits.

Mechanisation of cable yarder extraction by grapple carriage systems

Most cable yarding rigging configurations in New Zealand still require the use of choker-setters to attach chokers to the felled trees for extraction. Next to tree fallers, chokers-setters have the second highest risk of serious harm injury. The use of grapples on cable yarding systems eliminates the need for choker-setters to work on the steep slopes. The use of a mechanical grapple, typically coupled with a swing yarder, has been around for a long time. The design of a 'grapple restraint' to help control the movement of the grapple and improve its productivity shows that existing systems can always be improved upon (Evanson and Brown 2012). However, the mechanical grapple system is typically limited to terrain with good deflection, short extraction distances and good piece size.

While swing yarders are versatile, powerful and fast, they are also expensive to purchase and operate. Two-thirds of NZ yarders are tower yarders (Visser 2013b) which are not well configured for running skyline / mechanical grapple carriages (Harrill and Visser 2012). With improved control features, a powered grapple carriage can operate successfully on the existing tower yarders. Two powered grapple carriages are now working in NZ.

The Falcon Forestry Claw is a 1.8 tonne carriage housing an internal 57 hp engine that powers the grapple. It has been subject to an extensive study including scenarios of extracting motor-manually felled stems, machine felled stems (pre-bunched), as well as working with an excavator/shovel in the cut-over that 'feeds' the stems directly into the grapple (McFadzean and Visser, 2013). The second carriage is the Alpine which was developed in South Africa, but modified for NZ conditions. It is hydraulically-powered so relies on accumulated hydraulic pressure to operate the grapple. The advantage of a hydraulically grapple is reduced carriage weight, with the disadvantage in terms of needing to accumulate hydraulic pressure before the grapple can be actuated.

Figure 5: 'Motorised' grapple carriages; Falcon Forestry Claw with internal motor (left), and hydraulically powered Alpine (right).

One disadvantage of the grapple carriage extraction system is that due to visibility limitations the operator can have difficulty in picking up stems. Traditionally this limitation is overcome by using a 'spotter'. A spotter is a worker that places themselves along the harvest corridor where they are able to see the grapple and the stems to be extracted, and provides feedback to the yarder operator in terms of carriage control commands through a walkie-talkie. Although using a spotter is effective, it does not meet the objective of fully mechanising the system. An idea has been developed to use camera technology to provide the yarder operator with good visual information to assist in the grappling phase.

Two types of camera systems have been developed. The first is a camera system that is either directly integrated into the carriage such as used on the Falcon Forestry Claw, or trailed on a block behind the carriage and or rider block which can then be used on a mechanical grapple carriage as well (Figure 6). The second system places the camera in the cutover (Evanson 2013). While this camera also sends the video image back into the yarder cab, the operator can remotely control both the direction and zoom of the lens so as to focus on the immediate area below the carriage. Commercialisation of the CutoverCam camera system has been completed and the first commercial unit has been sold (http://cutoversystems.com).

Figure 6: Left, camera mounted on a block that is towed by a carriage or rider block along the skyline. Right, camera mounted in the cutover. Both cameras transmit a video signal back to the yarder cab to assist the operator with the grappling task.

Advanced cable planning and performance monitoring.

Most forestry companies actively use GIS, not just as mapping software but extensively as an information management system. It therefore makes sense to create harvest plans in this environment, especially for cable logging operations where terrain information is critical to successful layout of landing locations, setting boundaries and cable corridors.

Cable Harvest Planning System (CHPS) has been developed to work in the ArcGIS environment (www.cableharvesting.com) and integrates the fundamental calculations that determine payload with the capability of various machines and rigging configurations. It allows the harvest planner to select their preferred system, and then by identifying landing locations automates the calculation on physical feasibility with regard to both corridor distance and payload limits (Figure 7).

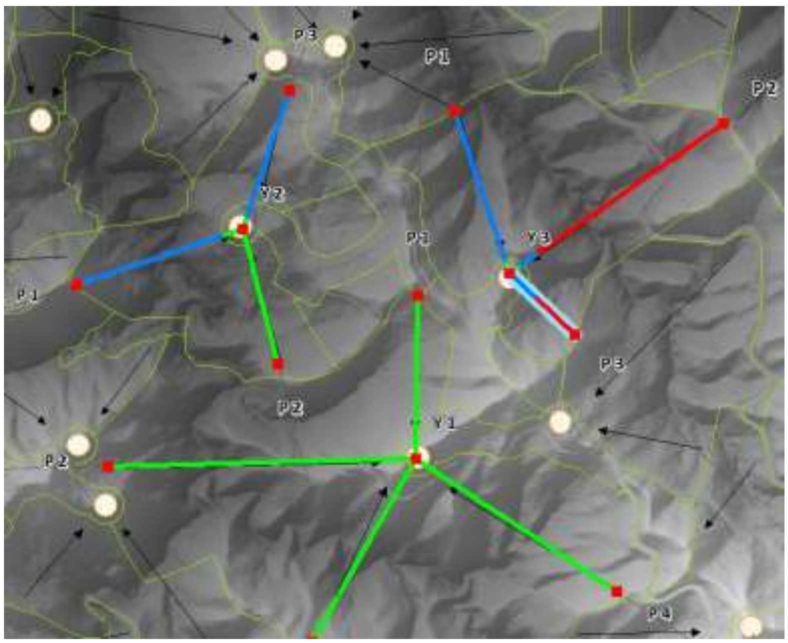

Figure 7: Example of the CHPS map interface which allows the harvest planner to identify landing locations and corridors. Corridor colours are used to denote payload limit ranges.

Considerable work has been completed to improve our understanding of skyline tension / deflection / payload relationships. While these mathematical relationships are often accurate for standing skyline with fully suspended loads, they are invariably quite inaccurate for the live-skyline partial suspension scenarios that are most common for large scale cable yarder operations. Rigging configurations such as North Bend is not included in most analyses packages, and little is known about the new generation of motorised carriages and their effect on skyline tension.

Extensive tension monitoring of various rigging configurations have highlighted the importance of not relying on just mid-span deflection/tension/payload, which is typically the design calculation for most software programmes. Figure 8 shows a typical curve for a skyline tension cycle, including shock loading, which was measured for a motorised carriage operation (Harrill 2014). Comprehensive tests on nine different operations has shown little relationship between payload and maximum tension, indicating that as payload increases more of the weight is being carried by the ground or transferred to the other working ropes. In Figure 8, high skyline tension occurred during the out-haul phase (purple) as the skyline was tightened to speed up carriage return, then again when the skyline was raised to lift up the payload (start of green in-haul phase), then then again as the carriage moved through mid-span.

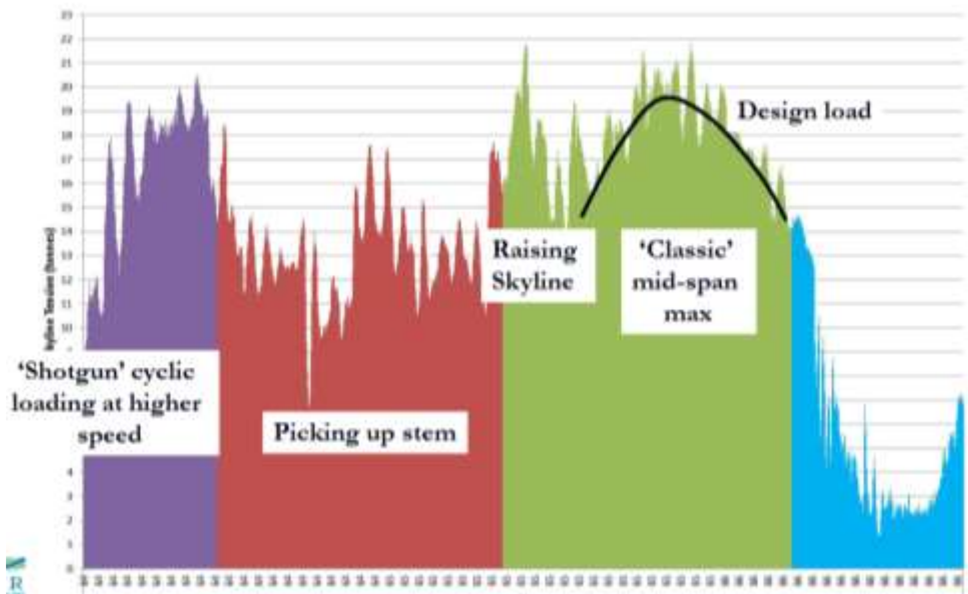

Figure 7: Skyline tension data showing the four phases of the extraction cycle of a motorised carriage system; purple = out-haul; red = picking up stems; green = in-haul and blue is dropping load at landing.

So while operational tension monitoring can be used for both immediate operator feedback with regard to safety and payload optimising, as well as improving our understanding of the effect of different configurations on actual skyline tension, the one aspect not fully explored is to feed this information back into our cable planning software algorithms to more accurately predict cable tensions and thereby allow for more advanced payload planning.

While automated control systems have long been a feature of the new yarders produced in Europe, this new technology is now also being developed and retro-fitted into the existing larger yarders. Active Equipment of Rotorua has released the ACDAT system that integrates tension monitoring, GPS tracking of the carriage, production monitoring and remote control camera all onto a touch-screen that is designed to be retro-fitted into the yarder cab (www.activeequipment.co.nz). Another example is the Brightwater PLC Air Control system, which in addition to tension monitoring provides the opportunity to optimise the yarder / winch system performance by selecting the type of rigging system that is used (grapple, carriage or scab) (www.brightwater.co.nz).

Conclusion / Future Opportunities

There has been a very positive synergy between the applied forest operations research work carried out in NZ and the implementation of innovations through both equipment development and application by industry. The focus on mechanisation and modernisation of steep terrain harvesting systems are showing potential for significantly improving both productivity and safety.

While the new developments presented in this paper each provide an opportunity for improvement, there remains a greater opportunity when integrating these individual components into an effective combined 'advanced steep terrain harvesting system'. Using the GIS based cable harvest planning software to identify both cable corridors and payload potential, this geo-referenced information could be uploaded into a cable-assisted felling machine application which shows exactly where and how to bunch the felled timber for most effective mechanised extraction using the grapple carriage systems. The onboard yarder monitoring system can then ensure that the productive potential is achieved safely. This data which includes payload and tensions can then be analysed and used for future updates of the harvest planning approach.

References

Amishev, D., T. Evanson and K. Raymond 2009: Felling and Bunching on Steep Terrain – A Review of the Literature. Harvesting Technical Note HTN01-07, Future Forests Research Limited, Rotorua.

Amishev, D. 2012: Mechanisation on Steep Slopes in New Zealand. Harvesting Technical Note HTN04-07, Future Forests Research Limited, Rotorua.

Berkett, H., and R. Visser 2012: Measuring Slope of Forestry Machines on Steep Terrain. Harvesting Technical Note HTN05-02, Future Forests Research Limited, Rotorua.

Evanson T. and D. Brown. 2012. Improved Grapple Control using a Grapple Restraint. Harvesting Technical Note HTN10-04, Future Forests Research Limited, Rotorua.

Evanson T. 2013. Hauler Vision System: Testing of Cutover Camera. Harvesting Technical Note HTN05-03, Future Forests Research Limited, Rotorua.

Harrill, H. and R. Visser 2012: Matching Rigging Configurations to Harvesting Conditions. Harvesting Technical Note HTN04-06, Future Forests Research Limited, Rotorua.

Harrill, H., and R. Visser 2014: Skyline Tensions and Productivity of a Motorised Grapple Carriage. Report FFR-H015, Future Forests Research Limited, Rotorua.

Marshall, H. 2012: On-board Machine Stability Information System. Harvesting Technical Note HTN05-01, Future Forests Research Limited, Rotorua.

McFadzean, S. and R. Visser 2013: Falcon Forestry Claw Grapple: Productivity and Ergonomics Harvesting Technical Note HTN05-06, Future Forests Research Limited, Rotorua.

Raymond, K. 2010. Innovative Harvesting Solutions: A Step Change Harvesting Research Programme. N.Z.J.For. 55 (3): 4–9

Raymond, K. 2012. Innovation to Increase Profitability of Steep Terrain Harvesting in New Zealand. Proceedings of NZ Institute of Forestry Conference, Christchurch, 1-4 July 2012.

Visser, R. 2013a. Tension Monitoring of a Cable Assisted Machine. Harvesting Technical Note HTN05-11, Future Forests Research Limited, Rotorua.

Visser, R. 2013b. Survey of Yarders Used in New Zealand. Harvesting Technical Note HTN06-03, Future Forests Research Limited, Rotorua.