Mechanising steep terrain harvesting operations

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Abstract

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. The mainstay of steep terrain harvesting for decades has been chainsaw felling, followed by cable yarding extraction using choker-setters, with subsequent processing on a landing involving skid workers. 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 hazards.

Most of the forests currently being harvested are on terrain that can be characterised as steep and difficult (Amishev, 2012). Cost-effectively harvesting this resource requires not only the need for improved operational efficiency to remain competitive in an international market, but also to address 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. Some innovations are developed by individuals or smaller equipment companies, but improving our steep terrain harvesting is also being supported by a coordinated R&D programme. The Harvesting theme of Future Forests Research Ltd (FFR) is a co-funded programme between industry participants and a competitive government Primary Growth Partnership (PGP) grant. 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, 2012).

This paper overviews a number of advances based on the mechanisation of our steep terrain operations. 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.

ClimbMAX felling machine with winch integrated into chassis

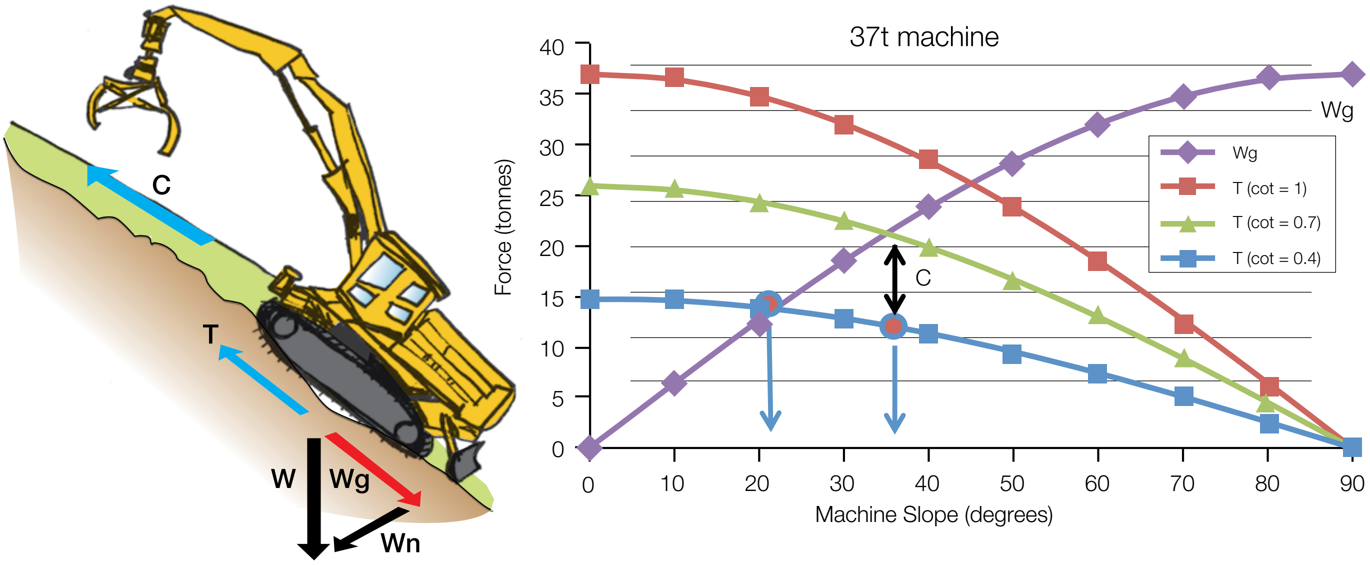

Figure 1: Basic force diagrams (left) can be used to illustrate the potential improved operating range on steep slopes dependent on soil strength (right). Source: From Visser 2013a

Extending ground-based system range

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 extend the operating limit of a 37 tonne machine. A machine will start to slide when the downslope force (Wg) exceeds the traction force that the tracks can generate through the soil. Traction (T) depends on the soil's coefficient of traction (cot) for the given machine type. Put simply, the greater the force the tracks/wheels can generate in the soil the steeper a machine can operate without slipping, the limit of which is indicated where the Wg line intersects the Traction T line. In the example shown in Figure 1, the 37 tonne machine would start to slip on a 22 degree slope if the soil had a cot = 0.4. By adding cable-assist, the Traction force T is augmented by the Cable force C. Adding a 10 tonne cable-assist force extends the theoretical operating range to 37 degrees, a considerable increase in operating range.

Cable-assisted harvesting machines are not new; in Europe they have been most commonly used for forwarders but are now also available for harvesting machines. However, New Zealand conditions include very steep (more than 50 per cent is common) and unstable terrain (geologically young and often highly erodible), in combination with relatively large tree size (more than three cubic metres is common), which has

Purpose-built self-levelling harvester (right) being cable-assisted by the winch mounted on the dozer (left) required larger felling machines than were commercially available. The ClimbMAX Steep Slope Harvester shown in the first photo, developed by Nigel Kelly and Trinder Engineering with the support of FFR, 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 New Zealand and Canada.

It complements other cable-assisted 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 as shown in the second two photos. With the largest risk of serious harm injury associated with motor-manual felling on steep terrain, a number of New Zealand forestry companies are actively encouraging their logging contractors to adopt these mechanised felling/bunching/shovelling systems that can work on very steep slopes.

A comprehensive research project looking at a range of forestry machines working on 'typical' terrain established that most exceeded the safety guidelines of 30 per cent slope for rubber tyred and 40 per cent for tracked machines (Berkett & 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 an on-board navigation application, HarvestNav, that provides the operator of any steep slope harvesting machine with information on harvest area terrain – see 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 as shown in Figure 2.

Mechanisation of cable yarder extraction

Most cable yarding rigging configurations in New Zealand still require the use of choker-setters to attach chokers to the felled trees for extraction (Harrill & Visser, 2012). Next to tree fallers, choker-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 & Brown, 2012). However, the mechanical grapple system

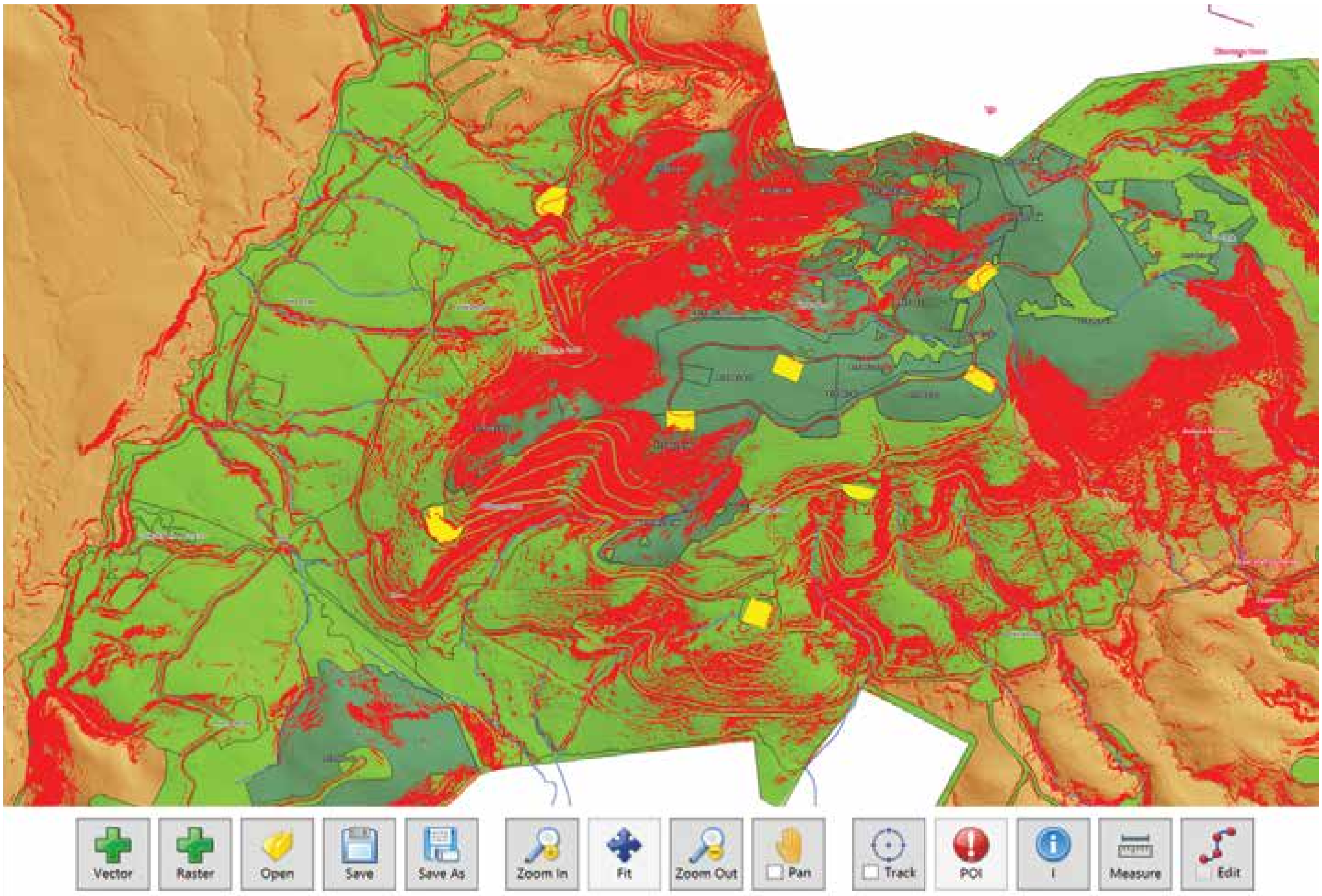

Figure 2: Screenshot of HarvestNav app that provides not only machine slope information, but allows the machine operator to plan the route through the stand to avoid exceeding slope limits

Motorised grapple carriages – Falcon Forestry Claw with internal motor (left) and hydraulically-powered Alpine (right)

is typically limited to terrain with good deflection, short extraction distances and good piece size.

Swing yarders are versatile, powerful and fast, but they are also expensive to purchase and operate. Two-thirds of New Zealand yarders are tower yarders (Visser, 2013b), which are not well configured for running skyline/mechanical grapple carriages. With improved control features, a powered grapple carriage can operate successfully on the existing tower yarders.

Two types of powered grapple carriages alternatives are now working in New Zealand as shown in the two photos above:

- The Falcon Forestry Claw is a two-tonne carriage housing an internal engine that powers the grapple. A comprehensive study, including scenarios of extracting motorised manually-felled stems and machine-felled stems (pre-bunched), showed that significant improvement in productivity can be achieved when working with an excavator/shovel in the cutover that 'feeds' the stems directly into the grapple (McFadzean & Visser, 2013).
- The second carriage is the Alpine which was developed in South Africa, but modified for New Zealand conditions. It is hydraulically-powered so relies on accumulated hydraulic pressure to operate the grapple. The advantage of a hydraulically-powered grapple is reduced carriage weight, with the disadvantage of needing to accumulate hydraulic pressure before the grapple can be actuated.

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'. This is a worker who 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 on 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 system provides the operator a view of the area directly under the carriage by either directly integrating the camera into the carriage, such as used on the Falcon Forestry Claw, or towing it behind the carriage on a separate rider block – see two photos below.
- 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

Camera mounted into a mechanical grapple carriage (left) and camera mounted in the cutover (right). Both cameras transmit a video signal back to the yarder cab to assist the operator with the grappling task below the carriage. Commercialisation of the CutoverCam camera system has been completed and the first commercial unit sold – see http://cutoversystems.com.

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.

The Cable Harvest Planning System (CHPS) has been developed to work in the ArcGIS environment – see 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 as shown in Figure 3.

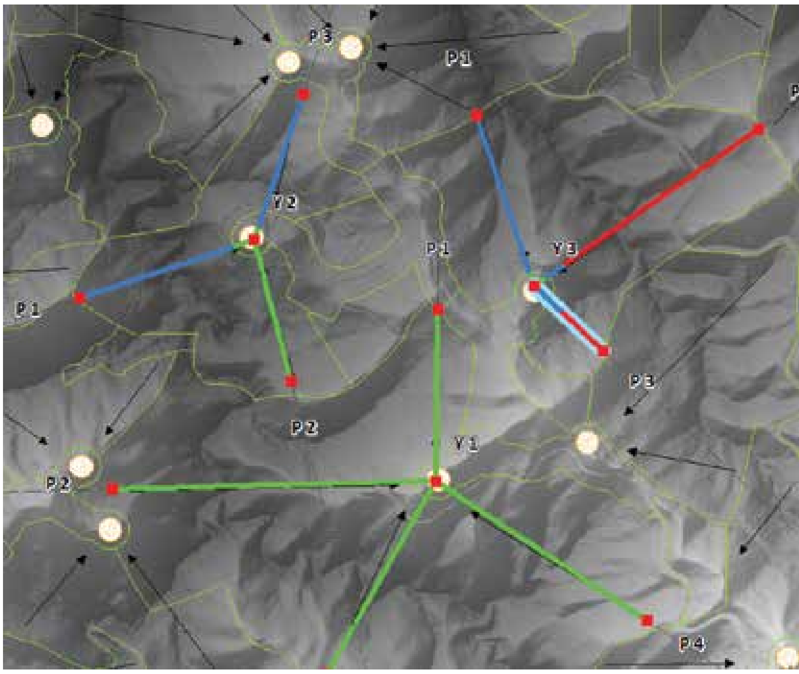

Figure 3: Example of the CHPS map interface which allows the harvest planner to identify landing locations and corridors. Corridor colours are used to denote payload limit ranges

Considerable work has been completed to improve our understanding of skyline tension/deflection/payload relationships. These mathematical relationships are often accurate for standing skyline with fully suspended loads, but 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 are 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 has highlighted the importance of not relying on just mid-span deflection/tension/payload, which is typically the design calculation for most software programmes.

Figure 4 shows a typical curve for a skyline tension cycle, including shock loading, which was measured for a motorised carriage operation (Harrill & Visser, 2014). Comprehensive tests on eight 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 such as the mainline. In Figure 4:

- High skyline tension occurs during the out-haul phase (purple) as the skyline is tightened to speed up carriage return
- Then tension occurs again when the skyline is raised to lift up the payload – start of green in-haul phase
- Finally it happens again as the carriage moves through mid-span.

Operational tension monitoring can be used for both immediate operator feedback with regard to both safety and payload optimising and 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 therefore allow for more advanced payload planning.

Automated control systems have long been a feature of the new yarders produced in Europe, but this new technology is now also being developed and retrofitted 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 retrofitted into the yarder cab – see 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) – see www.brightwater.co.nz. This makes it easier to change between configurations.

Future opportunities

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

The new developments presented in this paper each provide an opportunity for improvement, but there remains a greater potential when integrating these individual components into an effective combined

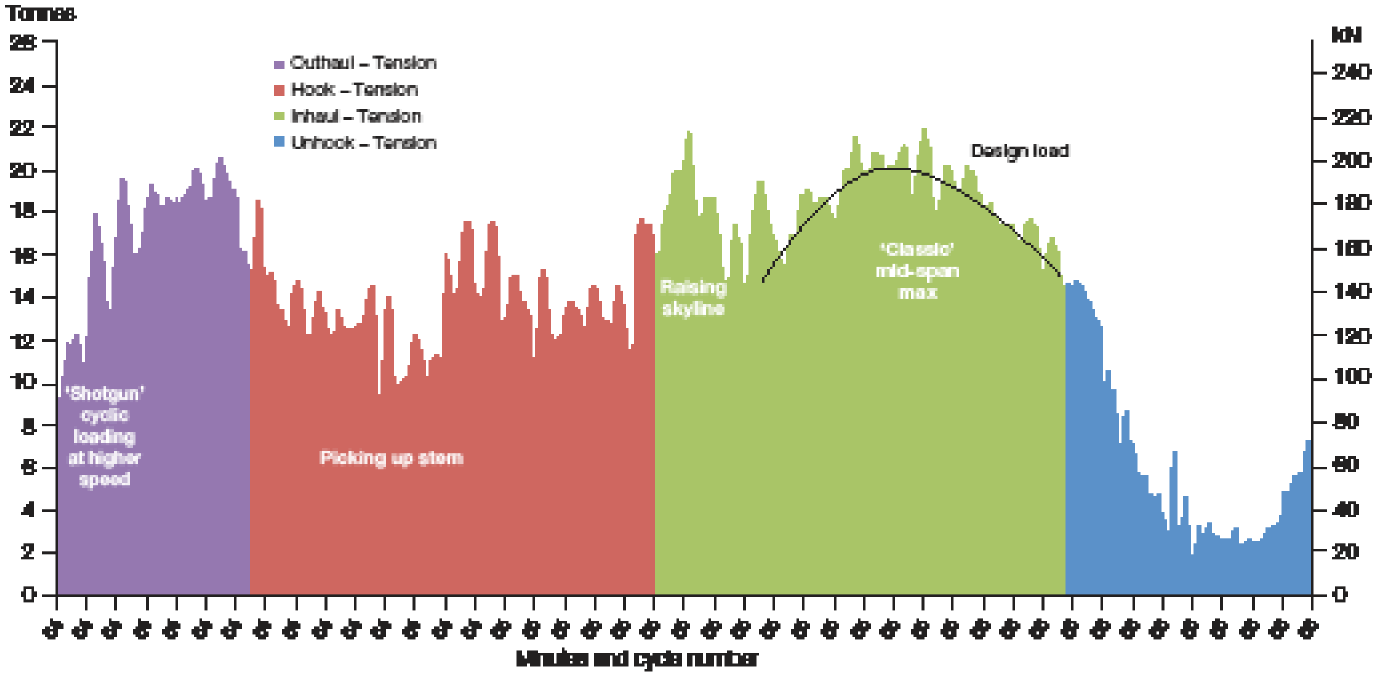

Figure 4: Skyline tension data showing the four phases of the extraction cycle of a motorised grapple carriage system: purple = out-haul; red = picking up stems; green = in-haul; and blue = dropping load at landing

'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 on-board yarder monitoring system can then ensure that the productive potential is achieved safely. These data, which includes payload and tensions, can then be analysed and used for future updates of the harvest planning approach.

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