FOREST GROWERS RESEARCH

Ministry for Primary Industries
Manatū Ahu Matua

STEEPLAND HARVESTING PROGRAMME

FINAL SUMMARY REPORT

30 September 2017

supported by forestgrowers commodity levy

Leadership in forest and environment management, innovation and research

Steep Land Harvesting Programme

Final Summary Report

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Acknowledgements: Steepland Harvesting is a Primary Growth Partnership between the Ministry for Primary Industries (MPI) and the forest industry led by Forest Growers Research Ltd (FGR). The programme is an alliance between the government, forest owners and forest management companies, engineering companies, harvesting contractors and research providers. Total funding is $7.60 million ($3.92 million from the forest industry and $3.68 million from government). FGR acknowledges the support of all stakeholders in the Steepland Harvesting programme.

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1. EXECUTIVE SUMMARY

1.1. Introduction

Seven years ago, the New Zealand forestry sector and the Ministry of Agriculture and Forestry, now Ministry for Primary Industries (MPI), identified steep country tree harvesting as the main bottleneck to greater profitability and safety in forestry. In 2010, Future Forests Research Ltd (now Forest Growers Research) formed a Primary Growth Partnership programme (PGP) with MPI to realise the vision in steep terrain harvesting of 'no worker on the slope, no hand on the chainsaw'. In other words to remove manual workers from hazards in steep terrain operations. This vision is now being achieved through the development and implementation of innovative mechanised and remote controlled harvesting technologies to realise substantial safety, productivity and cost reduction gains and improve worker safety in steep terrain harvesting in New Zealand.

The Steep Land Harvesting Programme was one of the first Primary Growth Partnership programmes launched, commencing in July 2010 between Future Forests Research Ltd (FFR) and MPI. It was originally a six year programme due to complete in 2016. In May 2016 a one-year extension was granted to strengthen the commercialisation of outputs of the programme. The programme was completed on 30 June 2017. Total programme funding was $7.60 million (excluding GST) of which MPI funded $3.68 million and the forest industry funded $3.92 million.

This report summarises the achievements of the programme against the original business case for the PGP investment.

Technical terms used in this report are described more fully in the glossary on page five.

KEY FACTS

- **Forest Growers Research** commercial partner
- **7 years** programme length
- **$7.6 million** total funding
- **$3.7 million** PGP funding
- **$3.9 million** Industry funding

1.2. Programme Objectives

The goals of the programme were to improve harvesting productivity and worker safety by developing and commercialising a range of new harvesting technologies in the tree felling and extraction phase of steep country harvesting operations.

The outcomes expected by the end of the programme included:

- A 25% reduction in steep land harvesting costs. This would create operational savings of $8.00 per cubic metre of wood produced.
- Zero lost time injuries during felling, breaking out and extraction phases of steep country harvesting.
- A 10% reduction in fuel costs.
- Developing and commercialising new machinery types for the harvesting industry for both domestic and export sales.
- Cumulative net economic benefits of $255 million by 30 June 2017.

HIGHLIGHTS

- **$6.18 /m³** lower cable harvesting costs (-17% of current costs)
- **30%** increase in cable harvesting productivity since 2010 (29.4 vs. 22.6 m^3/hr)
- **57%** of harvesting operations now using mechanised felling (up from 23% in 2009)
- **1/6** the number of serious harm injuries in 2016 compared to 2010
- **165** workers removed from hazardous manual roles (approx. 12% of workers)
- **$80 million** investment in new harvesting technology since 2012
- **$152 million** total economic benefits since 2010

1.3. Key Achievements

Notable achievements from the programme are the development and commercialisation of machinery and equipment designed to improve both safety and productivity on steeper slopes. In total the programme has driven 13 development projects that have produced 7 commercial products:

- ClimbMAX Steep Slope Harvester – a winch-assisted felling machine that can fell and bunch trees on slopes of up to 45 degrees. Prior to programme commencement 22 degrees was the accepted safe limit for tracked machines.
- HarvestNav machine navigation system – an on-board computer tablet-based navigation system that displays real time location and helps operators avoid hazards.
- Full Teleoperation – a control system for a commercial model tracked felling machine. The operator is located remotely in an operator console, providing improved working conditions and potential for extended working hours in safety.
- Cab Assist Backline – a teleoperation control system for a mobile tail hold machine. The yarder operator can shift the tail hold machine by remote control from the yarder cab, reducing operational delays.
- CutoverCam hauler vision system – a new model hauler vision system to provide the hauler operator full vision of the log extraction site.
- Alpine Grapple Carriage – a remote controlled light weight hydraulic log grapple designed to replace manual breaking out.
- Doherty Quick Coupler – an automatic hydraulic quick coupler for rapid switching between grapple processor head and log loading grapple.

In addition, the programme has developed 3 prototypes, in various stages of commercialisation, from pre-commercial model ready for market launch to early prototype, requiring further investment:

- Skyshifter Tail Hold Carriage – a prototype innovative twin winch skyline tail hold carriage that can remotely control the shifting of the hauler skyline, reducing operational delays and significantly improving cable logging productivity.
- Tension Monitoring ‘app’ – arising from the fundamental work by University of Canterbury in monitoring operating tensions of wire ropes in cable-assist and skyline rigging configurations, an application was developed to record and display rope tensions in the operator’s cab.
- Robotic tree-to-tree felling machine – a prototype concept for a radically new felling machine, which uses movement from tree-to-tree to traverse steep terrain.

Many of these products can be combined and operated as a new harvesting system that collectively result in lower harvesting costs and safer operations. FGR dubbed this system the Innovative Yarding System as illustrated in Figure 1.

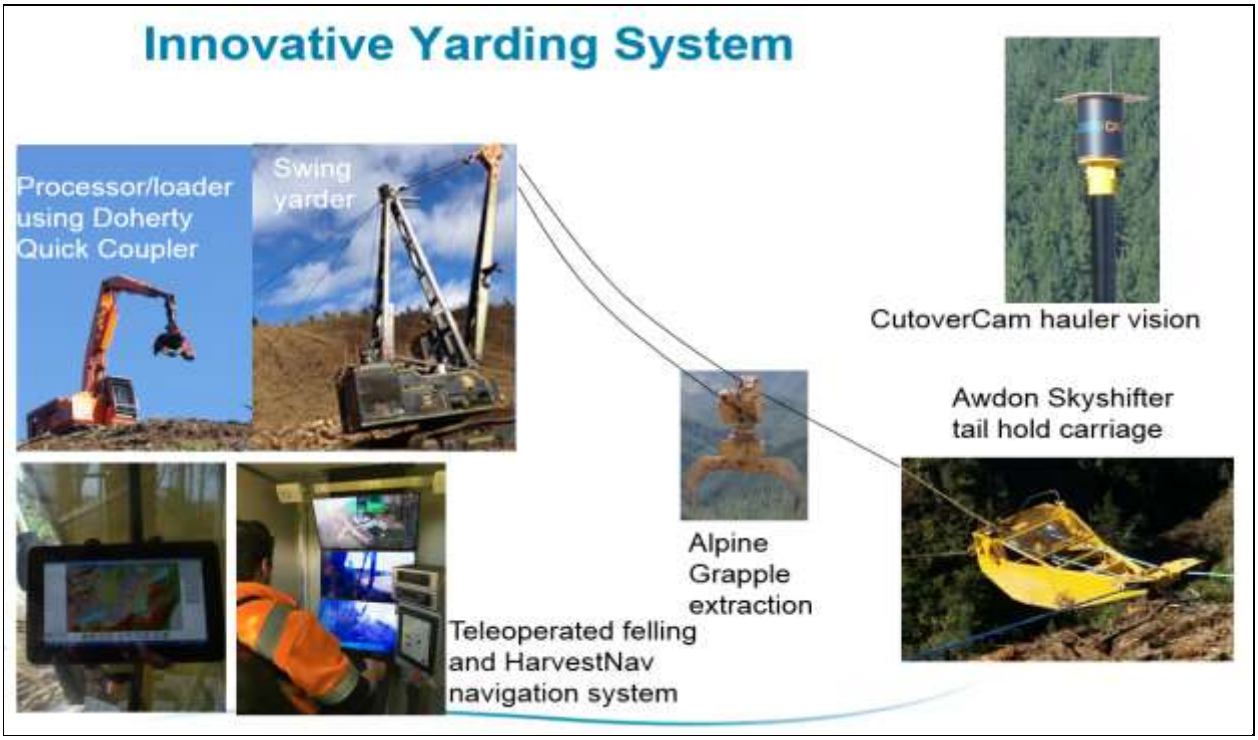


Figure 1: Innovative Yarding System

1.4. Outcomes

The programme has resulted in the successful commercialisation of new products and processes that improve the productivity and reduce the cost of steepland harvesting, and reduce dangerous manual labour roles. The major outcomes have been the implementation of new processes for winch-assisted felling machinery on steep slopes and increased industry uptake of grapple yarding as an improved method of cable log extraction.

As a result of these new processes, mechanised felling is now replacing manual tree fallers wherever possible in steep country forests. Since 2012 over $80 million has been invested by industry in new harvesters, winch-assist machinery, grapples, cameras and other equipment designed to enable safe work in tree felling and extraction. With this increase, the proportion of mechanised felling has increased from 23% of all harvesting operations in 2009 to 57% of operations in 2015. Approximately 165 workers have been removed from hazardous roles of felling and breaking out.

The sector wide economic benefits arising from the programme are estimated to total $151.6 million to 30 June 2017 against the goal in the business case of $255 million. These benefits comprise net operational cost savings of $71.3 million, and sales of New Zealand made forest harvesting machinery and equipment (domestic and export) totalling $80.3 million.

Spillover benefits include improving the safety and quality of the workforce environment, developing skills and training, and building technical capability in harvesting machinery manufacturing to future proof the industry.

These developments provide innovative harvesting solutions for steep country harvesting and fulfil the objectives of the original Business Plan of February 2010 – to improve productivity and safety on steep slopes.

The innovations developed by the programme have the potential to further transform forest harvesting and improve economic outcomes substantially for the forestry sector for many years to come.

This transformation will be dependent on further commercialisation and uptake of the forest engineering outputs post-programme. Continued strong support from forest management companies and contractors for increased mechanisation, plus on-going promotion of the work of FGR will support further adoption of these outputs.

BENEFITS

The cumulative net economic benefits to 30 June 2017 were:

- Operating cost savings of $71 million
- Machinery sales of $80 million
- Total cumulative programme benefits of $152 million.
- Compared to Business Case total benefits of $255 million by 2016/17.

On an annual basis the net benefits of the programme in 2016/17 were:

- Operating cost savings of $31m p.a.
- Machinery sales of $31m p.a.
- Total annual programme benefits of $62 million p.a. in 2016/17.
- Compared to Business Case annual benefits in 2016/17 of $86 million p.a.

1.5. Lessons Learned

The consensus amongst forest owners and the forest industry more generally is that the Steepland Harvesting PGP Programme has been successful. Key factors contributing to its success include:

1. A clear and compelling business case strongly supported by forest owners and industry members.
2. Effective programme governance and management supported by an industry-led Technical Steering Team has been a major factor in the successful achievement of outputs.
3. Adopting a 'fast-fail' approach whereby projects that are unlikely to succeed were stopped and funding reallocated to other projects with higher likelihood of success.
4. Widespread communication of programme progress and promotion of outputs to the industry through regional technical meetings, conferences, workshops and field demonstrations in order to drive uptake and adoption of outputs and delivery of outcomes. As a result of this industry-wide communication, the programme has been a catalyst for increased innovation in harvesting in New Zealand with new technology being developed and deployed, both from the programme and outside of the programme.

Areas where the programme could have improved its effectiveness include:

1. Resources should have been allocated to some projects earlier in the programme.
2. The extent of project management requirements, especially early in the programme, was underestimated, given the large number of projects underway.
3. Earlier engagement of expertise to assist with commercialisation aspects of each product development.
4. Having contractors represented on the Technical Steering Team would have achieved greater engagement from the contractor community. This would also have facilitated earlier identification of product champions, easier commercialisation and increased uptake of outputs.

2. OVERVIEW OF PGP STEEPLAND HARVESTING

2.1. Harvesting Terminology

Table 1: Glossary of harvesting terminology

Breaking out	Role carried out on hauler terrain where tree stems are hooked to cables for extraction by breaker-outs.
Breaker-out	Person who attaches wire rope strops to felled tree stems to enable extraction to the landing.
Carriage	Vehicle suspended on a skyline cable to which strops are attached.
Cutover	Area of hauler terrain where trees have been felled and extracted.
Faller	Person who fells trees with a chainsaw.
Feller buncher	Wheeled or tracked machine that fells trees and bunches felled stems together ready for extraction to landing by hauler.
Grapple Carriage	A carriage suspended on a skyline cable of a hauler that has a mechanical grapple to extract felled tree stems.
Hauler / Yarder	Machine equipped with a tower, winches and wire rope cables used for extraction of trees stems from cutover to the landing.
Landing	Flat site constructed in the forest to land extracted tree stems, to manufacture, sort and store logs, prior to truck loadout to customer.
Spotter	Person who can view the breaking out area and assist the hauler operator by radio communication to position the grapple during the extraction phase.
Strops	Short wire ropes connected to a carriage or cable rigging that are attached to tree stems to enable extraction.
Tail Hold	A tree stump or a machine (such as a bulldozer or excavator) used as an anchor point for the skyline cable or tail rope of a hauler.
Winch-assist	A machine (such as a bulldozer or excavator) with purpose-built winches and either single or dual wire ropes attached to a feller buncher that assists with traction on steep terrain.
Yarding corridor	The narrow swath of cutover spanning the length of the skyline cable, or tail rope, from the yarder to the tail hold, the width of which depends on the lateral yarding capability of the cable rigging system.

2.2. Background

On 30 October 2009 the Primary Growth Partnership (PGP) Investment Advisory Panel approved the first phase of a new PGP programme, “Innovative Harvesting Solutions”, and requested the submission of a full business plan by 1 February 2010. A presentation of the Business Plan was made to the PGP Investment Advisory Panel on 24 February, 2010. On 26 May 2010 the business plan for the “Innovative Harvesting Solutions” programme was approved by the Ministry of Agriculture and Forestry (MAF), now Ministry for Primary Industries (MPI).

The business plan for the PGP Steep Land Harvesting Programme detailed a six-year plan for the programme with a budget of $6.525 million (excluding GST) and identified cumulative net direct economic benefits of $169.1 million by 30 June 2016. These benefits would arise from cost savings over current practices, ACC injury claim savings and machinery sales (domestic and export). The plan also identified indirect benefits associated with: improving the safety and quality of the

workplace environment; building technical, scientific and engineering capability in harvesting machinery development; and further reducing the environmental footprint of harvesting in New Zealand.

The programme commenced on 1 July 2010. The contracting parties in this PGP programme were Ministry of Agriculture and Forestry (now Ministry for Primary Industries, (MPI)) and Future Forests Research Ltd (now Forest Growers Research, (FGR)). The contract for the Innovative Harvesting Solutions programme for steep country harvesting was signed by MAF and FFR on 16 November, 2010. After the Forest Grower Levy was introduced in 2014 and management of all forest growing research was moved to the NZ Forest Owners Association (NZFOA) as secretariat for the Forest Grower Levy Trust, FFR continued as the entity for this programme, with NZFOA providing management services to FFR under a management agreement.

An independent mid-programme progress review in November 2014 (van Rossen and Brown, 2014) noted that the effort, resources and communication required to make the transition from research output to commercial product had been underestimated. It was recommended that FFR engage external expertise to assist with the commercialisation of programme outputs. The Programme Steering Group actioned this recommendation and a review of all current commercialisation plans was undertaken (Todd, 2016). Subsequently a one-year extension to the programme, with a budget of $1.05 million, was approved in 2016 to assist with commercialisation of 6 programme outputs that were at pre-commercial stage.

2.3. Programme Vision

The scope of the Programme was harvesting on steep terrain and in particular on the felling, breaking out and extraction phases of harvesting. These are the parts of the value chain seen to have the greatest potential to deliver benefits.

The programme vision was low cost steep country harvesting operations carried out in safer and better working conditions by a well-trained, highly motivated workforce using sophisticated technology. This was encapsulated in the vision statement “no worker on the slope, no hand on the chainsaw.”

The programme aimed to improve the productivity and safety of tree falling and extraction of stems from steep land forests. Productivity and safety gains that had been achieved through mechanisation on flatter terrain had not occurred on steeper terrain and costs continued to increase. The programme aimed to extend mechanisation to harvesting on steep land, to remove operators from hazardous areas and to introduce new technology into harvesting operations.

The vision would be achieved through low cost steep country forest harvesting operations in New Zealand carried out in safer and better working conditions by a well-trained, highly motivated workforce using sophisticated technology.

2.4. Goals and Objectives

The primary goal was to reduce the cost of harvesting on steep country by introducing new technology that is more productive and cost effective compared with existing equipment. The secondary goal was to remove workers from the hazardous tasks of manual tree felling, breaking out and unhooking.

The programme outcomes are unchanged from the “Innovative Harvesting Solutions” Business Plan prepared for the Primary Growth Partnership (PGP) in February 2010. The total value proposition was to deliver steep country tree harvesting improvements that have a total net economic impact, from baseline 2010 figures, of $169 million by 30 June 2016 through:

- Reducing steep country harvesting cost per tonne by 25% ($8.00/tonne)
- Eliminating lost time injury (LTI) incidents in felling, breaking out and extraction phases of steep country harvesting operations which adopt this system

- Reducing current energy (diesel fuel) consumption in steep country harvesting by 10%
- Developing and commercially implementing three new machinery types for the forest harvesting industry (felling machine, grapple carriage and innovative yarding system) for both domestic use and export.

There would also be indirect benefits in developing technical capability in harvesting and machinery development; further reducing the environmental footprint of harvesting in New Zealand; and realising the substantial opportunity to increase establishment of forests on marginal lands, most of which are on slopes over 20 degrees.

With the one-year extension it was expected that cumulative net economic benefits would increase to $255 million by 30 June 2017. Expected annual net economic benefits were $85.8 million p.a. by 30 June 2017.

2.5. Programme Activities

To achieve these goals the programme invested in the following objectives, three of which were technology development projects, and one was focussed on commercialisation:

- Objective 1: Mechanisation on steep terrain
- Objective 2: Increased productivity of cable extraction
- Objective 3: Development of operational efficiencies
- Objective 4: Commercialisation and implementation (in the seventh and final year).

In addition, the programme management objective covered monitoring project progress against milestones, financial management and reporting. Over the duration of the entire programme there were seven development projects and 3 commercialisation projects with a total of 43 critical milestone steps identified to provide a critical pathway to the desired outcomes in steep country harvesting.

Objective 1: Mechanisation on Steep Terrain

This objective was aimed at improving the capability of machines to operate on steep country, specifically to replace manual tree felling which is one of the most hazardous roles in forest harvesting.

- **Project 1.1 Steep Slope Feller Buncher and Cable Assist Harvesting**: This project further developed the tractive capacity of ground-based felling machinery on steep slopes. The project culminated in the commercialisation of the ClimbMAX Steep Slope Harvester. In addition, fundamental research into the operating limits of the cable-assist harvesting systems was undertaken by the University of Canterbury, School of Forestry to extend the range of operation and reduce risks to the operator.

- **Project 1.1 HarvestNav machine navigation system**: Commenced as a decision support application for a computer tablet to provide operators of steep slope machinery with real-time information on machine slope and stability and reduce operator hazards. HarvestNav was later released as a commercial ‘out-of-the-box’ on-board machine navigation system.

- **Project 1.2 (Task A) Teleoperated Felling Machine**: This long term project aimed to employ remote control and teleoperation to a commercial model feller buncher, removing the operator from the machine on the steep slope, without sacrificing the worker’s productivity. The project commenced in 2011 with a concept design and a technical/economic feasibility analysis outlining the concept and proposed progression of the use of teleoperation in steep slope harvesting. The economic analysis demonstrated that teleoperation would become economically viable if it resulted in a relatively small increase in daily production (12 cubic metres per day or 6% on average cable logging productivity). This increase seemed realistic and the project gathered momentum in 2012 with the engagement of the first PhD student in the Mechatronics Programme at the Department of Mechanical Engineering, University of Canterbury. This work focussed on simulation of teleoperation of the hydraulic excavator-based harvesting machinery using a single teleoperated hydraulic circuit as a lab-based development platform for the first prototype. Despite

the fact that this research was highly technical and explored areas that are still a few years away from industrial manufacturing and commercialisation, this work contributed to making teleoperation of forestry machines feasible with off-the-shelf computing and networking hardware. Two 'real world' applications used part of this research: the John Deere 909 project, and the Volvo 290 mobile tail hold project. The first application converted a John Deere model 909 feller buncher to firstly remote control, then subsequently teleoperation. The second application converted a pilot hydraulics-controlled Volvo 290 excavator used as a mobile tail hold machine to enable remote control from the yarder cab.

- **Project 1.2 (Task B) Robotic Tree-to-tree Felling Machine**: This project developed an original concept for an alternative mobility system for a felling machine, using movement from tree-to-tree to traverse across steep terrain. The concept for a robotic tree-to-tree traversing machine (the 'Stick Insect'), was initiated by Scion New Zealand, and inspired by brachiating apes moving through the forest by using their arms to swing from branch to branch. Development of this design opens up opportunities for lighter weight, remote controlled machines to minimise ground disturbance on steep terrain. The development project was offered to the Mechatronics Programme at the University of Canterbury and the alpha prototype was built by four final-year engineering students in 2013. A second PhD student in the Mechatronics programme at University of Canterbury commenced in 2013 to develop the semi-autonomous brachiating robot for teleoperated steep terrain tree harvesting. The project was continued in early 2016, whereby the proof-of-concept prototype was demonstrated to the forest industry. Further investment is required to take this development further to commercialisation.

Objective 2: Productivity of Grapple Extraction

This objective was designed to provide technology which would improve the productivity of the extraction phase of cable logging, and ultimately to develop alternative systems to those traditionally used to extract wood from steep terrain.

- **Project 2.1 Advanced Hauler Vision System**: This project involved commercialisation of two camera systems, an option for a camera mounted on the grapple, and an option for a camera located in the harvested cutover. Trinder Engineers Ltd of Nelson completed development of a grapple camera system using an Ag-Cam camera mounted in a rugged box on the grapple of a cable hauler. The camera system located in the harvested cutover was commercialised as the CutoverCam hauler vision system.

- **Project 2.2 Improved Grapple Control System**: This project commenced in 2010 to develop an improved grapple control system whereby the grapple carriage could be remotely controlled. The project partnered with Alpine Logging Equipment Ltd of South Africa to modify and further develop the prototype Alpine Grapple Carriage for New Zealand conditions. This project also commenced fundamental work in cable rigging configurations and tension monitoring of different cable systems (including the Falcon Forestry Claw grapple developed by D.C. Equipment Ltd of Nelson).

- **Project 2.3 Innovative Yarding System**: Investigating alternative new extraction systems and methods to reduce cycle time, provide improved lift, and reduce operational delays, was aimed at developing a totally new concept yarding system. Innovative Yarding workshops were held in a number of regions throughout New Zealand and many concepts were generated and options explored. A common theme was the difficulty and cost of cable skyline shifting. This project developed an innovative twin winch tail hold carriage designed for rapid shifting of the skyline.

Objective 3: Development of Operational Efficiencies

In addition to development of new technology solutions in Objectives 1 and 2, this objective adopted a systems approach to integrate the various components to measure, monitor and improve operational efficiencies. Projects that undertook overall system feasibility analyses were included in this objective.

- **Project 3.1 Delimbing and Cut-to-Length Systems on Slopes**: Future operational developments and regulatory pressures were foreseen that could drive cutting tree stems to log length prior to extraction. This project aimed to further develop the winch-assisted harvesting

system to extend to delimbing and processing logs on the slope. This concept system would ensure residues (tree limbs, tops and offcuts) were dispersed around the cutover, creating a mat for machine travel, reducing environmental impact and eliminating the residue problem on landings. The project commenced with a technical and economic feasibility analysis.

- **Project 3.2 New Hauler Technology and International Monitoring**: This project investigated new yarder technologies internationally, supporting the development of other opportunistic projects and resulted in the Harvesting Technology Watch series of publications monitoring new developments in harvesting overseas, investigations into new European yarders such as the Koller K602 yarder, and the development of the Doherty automatic quick coupler.

- **Project 3.2 Harvesting Cost and Productivity Benchmarking**: This project continued the development of a comprehensive benchmarking database maintained by the School of Forestry, University of Canterbury. The database, comprises confidential harvest area production information, including terrain, forest stand, harvesting crew and cost data, contributed by industry co-investors. The database, which holds records of 1243 harvest areas dating from 2008 to 2016, is designed to record and monitor trends in productivity and cost factors over time. It can be used to benchmark performance of individual crews, companies or regions across a range of key cost and productivity variables. The industry will continue funding this database post-programme.

Objective 4: Commercialisation and Implementation

The final year of the Programme comprised commercialisation and technology transfer to the forest industry of six of the technology products developed in the Steep Land Harvesting Programme to ensure successful uptake and adoption.

- **Project 4.1 Product Pre-Commercialisation:** This task extended these technology products further down the path to market than intended in the original business plan, completing technical development to commercial stage of those products originally planned to be developed to prototype stage only (such as the Teleoperation Control System, CutoverCam, and Awdon Skyshifter), and those products that were additional to the original Business Plan (such as the HarvestNav, remote controlled felling wedge, and the Doherty quick coupler). It completed a business environment review of each product, and planned the development of an integrated system comprising some or all of the products (the Innovative Yarding System shown in Figure1).

- **Project 4.2 Securing Commercial Partners:** This project confirmed the small to medium New Zealand engineering companies that are the commercial partners responsible for sales, marketing and on-going support of the products. It provided business development support to these commercial partners, agreed appropriate intellectual property protection and strategies (branding, trademarks, patents etc.) with commercial partners, finalised improved commercialisation plans for each product, and identified “product champions” in the contractor community to participate in the technology transfer programme.

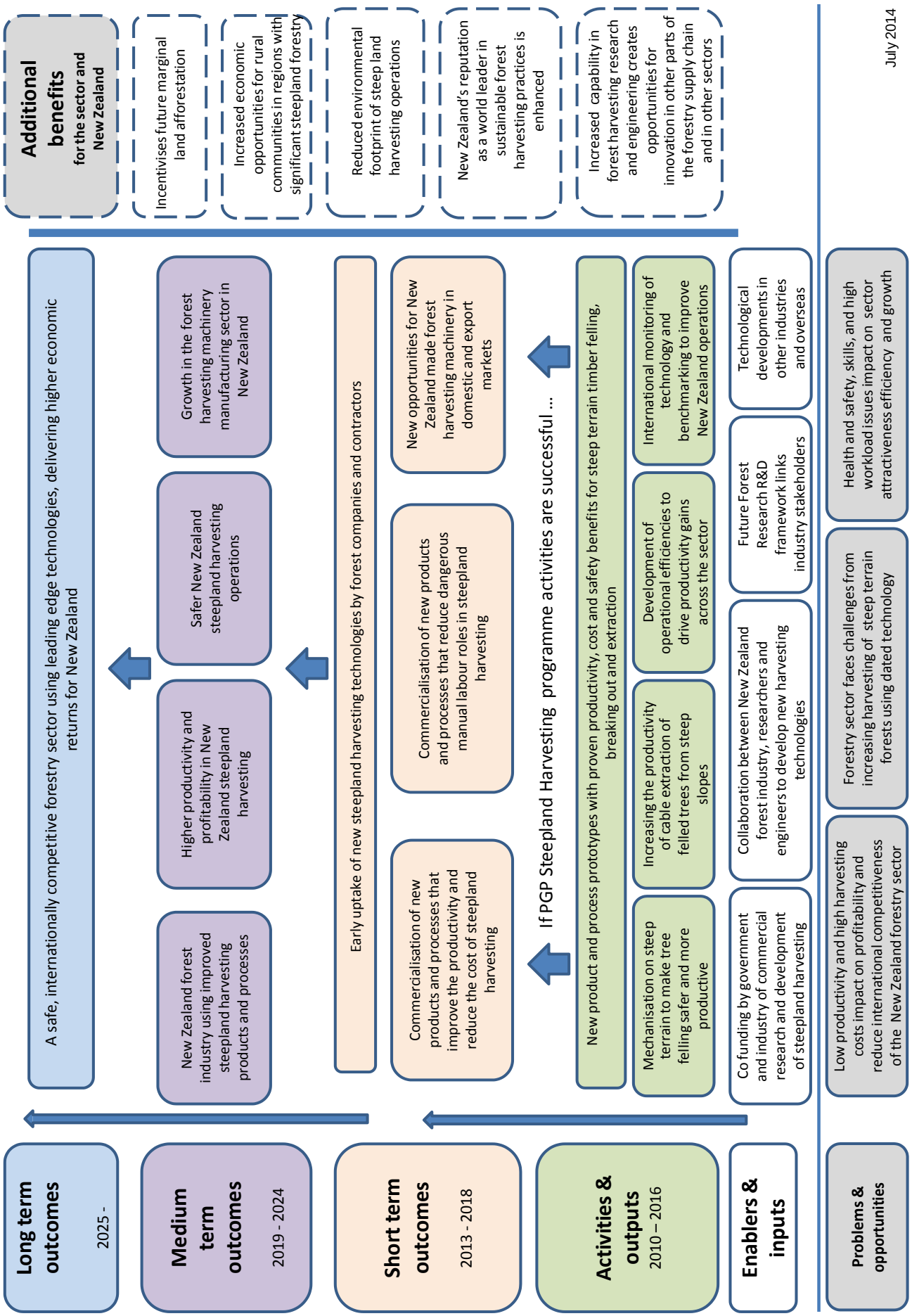
- **Project 4.3 Technology Transfer and Implementation:** This project completed further production trials to validate the productivity and safety benefits of the products, and transferred this technology to the forest industry at an industry trade show (HarvestTECH17) and through a series of field demonstrations of the products to ensure successful uptake and adoption by both contractors and forest owners.

Objective 5: Programme Management

FGR, as the co-investor company for this programme representing all the industry investors, has been committed to completion of this programme to the highest standards of effective programme management. Financial risks were managed to ensure industry funding was maintained through a combination of industry member fees and funding from the Forest Grower Levy Trust. Governance through the Programme Steering Group and FGR Board, and effective project management through the Technical Steering team and FGR management has ensured that project expenditure has been managed closely to achieve contract milestones and deliver the outputs of the programme. Technical risks in the programme were mitigated by the technical team using best practice R&D programme management processes, including:

- Development and implementation of Annual Plans, detailing delivery of each project in the programme, financial planning, progress to date and requirements to achieve project completion.
- Work Plans for each project with critical checkpoints to be achieved before progressing to the next stage of the project, and milestones related to quarterly progress payments.
- Monthly project progress review with Project Leaders.
- Quarterly meetings of the Technical Steering Team to provide technical input at the project level, provide valuable advice regarding design and development, and ensure the end-user interface continues to be strengthened.
- Quarterly reporting to the Programme Steering Group and FGR Board.

2.6. Outcome Logic for Steep Land Harvesting



3. PROGRAMME INVESTMENT

3.1. Programme Funding

Overall funding for the programme (Table 2) has effectively remained unchanged from the original Business Plan plus extension ($7.60 million vs. $7.57 million). Overall the budget has been stable which indicates the programme has been successful in attracting and maintaining industry contributions at expected levels.

PGP funding was within the approved budget at $3.68 million. Industry cash contributions were higher than budget ($3.40 million vs. $3.22 million) as industry in-kind contributions were under budget ($0.52 million vs. $0.67 million). Total industry funding was $3.92 million on a budget of $3.89 million.

Table 2: Programme Funding by Co-investor: Budget and Actual

Budget Funding ($) excl. GST								
Investor	**2010/11 Budget**	**2011/12 Budget**	**2012/13 Budget**	**2013/14 Budget**	**2014/15 Budget**	**2015/16 Budget**	**2016/17 Budget**	**Total Budget**
Industry cash	350,000	350,000	500,000	500,000	500,000	500,000	525,000	3,225,000
In-kind contributions	87,500	75,000	100,000	100,000	100,000	100,000	105,000	667,500
Industry total	437,500	425,000	600,000	600,000	600,000	600,000	630,000	3,892,500
PGP funding	437,500	425,000	600,000	600,000	600,000	600,000	420,000	3,682,500
TOTAL BUDGET	875,000	850,000	1,200,000	1,200,000	1,200,000	1,200,000	1,050,000	7,575,000

Actual Funding ($) excl. GST								
Investor	**2010/11 Actual**	**2011/12 Actual**	**2012/13 Actual**	**2013/14 Actual**	**2014/15 Actual**	**2015/16 Actual**	**2016/17 Actual**	**Total Actual**
Industry cash	369,459	375,690	351,178	542,755	506,991	711,484	537,798	3,395,354
In-kind contributions	60,675	43,945	81,688	67,213	100,000	65,318	107,442	526,281
Industry total	430,134	419,635	432,866	609,968	606,991	776,802	645,240	3,921,635
PGP funding	434,734	415,035	432,866	609,968	606,991	762,907	420,000	3,682,500
TOTAL ACTUAL	864,868	834,671	865,731	1,219,936	1,213,981	1,539,709	1,065,240	7,604.135

3.2. Governance and Management

The Programme Steering Group (PSG), provided governance for the programme and strategic oversight, including payment approvals. The PSG comprised two representatives of FGR (Mr Russell Dale, Chair, and Mr Peter Keach, later replaced by Mr Steven Couper) representing the forest industry investors, and two representatives of MPI (Mr Stuart Anderson and initially Mr Joseph Montgomery and later, Mr Robert Miller).

The FGR Harvesting Theme Technical Steering Team (TST) comprised 9 industry and science personnel and one representative of MPI. The TST met quarterly to review project progress, manage the delivery of projects, guide the direction of the programme technical research team and ensure effective end-user research interface and technology transfer. A total of 20 industry personnel represented FGR's industry co-investors on the TST over the duration of the programme.

Programme Manager, Mr Keith Raymond, led the technical team comprising researchers from Scion and University of Canterbury, forestry consultants, engineering company engineers and forest harvesting specialists. Recognising the need to move well beyond business-as-usual approaches in harvesting, the team incorporated diverse skills, such as mechatronics, design and industrial engineering. A team of 3 commercialisation specialists was led by Mr Geoff Todd, Managing Director of Viclink, the commercialisation office of Victoria University of Wellington. A total of 22 personnel participated on the technical team over the duration of the programme.

4. PROGRAMME ACHIEVEMENTS

4.1. Technical Outputs, Contributions and Awards

Over the course of the programme a total of 171 technical reports, refereed publications and conference papers have been published:

- 28 FGR Technical Reports
- 67 FGR Harvesting Technical Notes
- 13 FGR Harvesting Technology Watch reports
- 21 FGR Harvesting Programme Updates
- 42 Refereed publications and conference papers.

A total of 42 graduate and undergraduate students at University of Canterbury have been involved in studies contributing to the PGP Steepland Harvesting programme:

- 2 Doctors of Philosophy in Forest Engineering
- 2 Doctors of Philosophy in Mechatronics
- 5 Masters graduates in Forestry Science
- 2 Masters graduates in Science
- 16 Bachelor of Forestry Science and Bachelor of Engineering (Forestry) final year students
- 14 Bachelor of Engineering (Mechanical Engineering and Mechatronics) final year students
- 1 Bachelor of Computer Science final year student.

Four of the Mechanical Engineering and Mechatronics final year students from 2013, and their project supervisors, Dr Stefanie Gutschmidt of University of Canterbury, and Dr Richard Parker of Scion, were awarded the Ray Meyer Medal for Excellence in Student Design from the Institution of Professional Engineers New Zealand (IPENZ) in March 2014.

In 2011, Associate Professor Dr Rien Visser, University of Canterbury, School of Forestry was awarded the inaugural Future Forests Research Award for Communication and Sector Engagement, for his work in establishing the industry-wide benchmarking database for harvesting operations.

Mr Kerry Hill, Managing Director of Trinder Engineering Ltd, of Nelson, won the award for innovation that adds value to the forestry sector at the second annual Future Forests Research Awards in August 2012. The award recognised Trinder Engineering's joint development with Kelly Logging Ltd of the first commercial winch-assisted steep slope feller buncher,

Dr Paul Milliken of Scion was awarded the 2013 Future Forests Research Award for Innovation Adding Value to the Sector, for the development of a video camera system for use in steep country harvesting.

Dr Hamish Marshall from Interpine Forestry Ltd won the 2014 award for Innovation that Enhances Sector Value. This award was for the development of the HarvestNav on board machine navigation application for a tablet computer to improve the capability of machinery to work on steep terrain.

In 2015 the University of Canterbury Mechatronics team – Professor XiaoQi Chen, Mr Bart Milne and Mr Chris Meaclem – was awarded the Forest Owners Association Award for innovation that enhances sector value for the work on teleoperation and autonomous harvesting machines.

Programme Leader, Mr Keith Raymond, was awarded the Forest Owners Association 2016 Science Award for Contribution to a Science Team.

In terms of technology transfer activities, a total of 19 conferences, 13 field days and 11 workshops were held during the programme.

4.2. Engineering Products

Outputs of the PGP Steep Land Harvesting programme to date have been recognised by the forest industry in New Zealand as contributing to increased productivity and reduced exposure of workers to hazards on steep terrain. Technology products commercialised in the Steepland Harvesting programme are:

1. ClimbMAX Steep Slope Harvester

The first output in the steep terrain mechanisation programme was the ClimbMAX Steep Slope Harvester. In March 2009, the first prototype of this steep slope feller buncher using cable-assist technology, was designed and built by Kelly Logging Ltd and Trinder Engineering Ltd of Nelson. The further development of this prototype was a partnership with manufacturing partner, Trinder Engineering Ltd that provided leverage with commercial investment, which accelerated progress of the development. This early progress was valuable in creating a strong profile for the programme and generally promoted a spirit of innovation across industry stakeholders. The commercialised result of this project was the ClimbMAX Steep Slope Harvester.

The beta prototype (pre-production) harvester (ClimbMAX1) was completed in November 2011 and was commissioned in trials in Nelson, and demonstrated to the industry in September 2012. This prototype also included a new Trinder-designed felling head, equipped with high powered clamping force for handling windthrown trees and featured a retractable saw box that was designed to fell on slopes greater than 26°, and for shovel logging on slopes. This felling head has been a useful spin-off product from the project, and has now been licenced to John Deere, and marketed as the Waratah FL-95, purpose-built felling head for steep slope applications.

The first commercial ClimbMAX harvester (ClimbMAX2) was completed in October 2012 (Figure 2). In early 2013 this machine was studied during field testing in Marlborough prior to delivery to the customer. This unit was then sold to a contractor working in northern Hawkes Bay. After a period of commissioning, the machine was the subject of extensive production trials in June to December 2013 and the machine operating in Maungataniwha Forest was demonstrated to the industry in March 2014.

Figure 2: First commercial model ClimbMAX Steep Slope Harvester

Best Practice Guidelines were developed by the manufacturer in consultation with the Department of Labour (now WorkSafe NZ) and were incorporated into the revision of the Approved Code of Practice for Safety and Health in Forest Operations in 2012.

The ClimbMAX Steep Slope Harvester is now marketed by ClimbMAX Equipment Ltd. A total of 11 machines have been sold to customers in New Zealand, Canada and the U.S. This development has proven the concept of traction winch-assist systems for tracked feller bunchers on steep terrain and catalysed the development of many other winch-assisted felling machines. In total there are now 65 winch-assist machines (including the ClimbMAX) operating throughout New Zealand.

2. HarvestNav on-board machine navigation system

New technology to assist the mechanisation on steep terrain objective included the HarvestNav on-board navigation system for harvesting machines. This was an additional tool not originally planned for development in the Business Plan. The HarvestNav journey to commercialisation started as an 'app' that operates on a low-cost tablet computer mounted in the cab of a harvesting machine to give both safety and operational efficiency benefits. Using GPS and a digital terrain model based on LiDAR data, that shows detailed harvest area boundaries, slope, and restricted areas, HarvestNav allows the machine operator to not only track his exact location in the harvest block, but also to see the nature of the terrain ahead of the machine in real-time. The system also provides information on harvest area terrain around the machine including ground slope, boundaries, water courses and other exclusion zones, and gives the operator a warning if pre-set machine slope limits are exceeded.

The new HarvestNav system was launched in 2017 as an "out of the box" system (Figure 3), complete with pre-loaded software, harvest area map and mounting bracket. It is now available from Dr Hamish Marshall at Margules Groome Consulting Ltd.

Figure 3: HarvestNav on-board navigation system

3. Teleoperated John Deere 909 feller buncher and teleoperated mobile tail hold

Of all projects in the Programme this project, six years in development, pushed the boundaries of forest operations the most with the exploration of modern engineering technology. Teleoperation Control (remote control beyond line-of-sight) represents an important first step in having machines operating on steep slopes without exposing workers to potential risks, and will change the way tree felling will be undertaken in the future. Teleoperation of forestry equipment removes the person from the cab of the machine, improves the operator working environment (less work load and fatigue) and enables extended utilisation of machinery (working longer hours). In addition, teleoperation is opening the door to new lower cost machine designs that can be better adapted to operating on

slopes without the need to accommodate an operator on the machine. For example, cab-less machine designs which are smaller, lighter, lower capital cost and use less fuel.

Figure 4: Full teleoperation system for John Deere 909 feller buncher

Developed over the last three years by Dr. Paul Milliken, Daniel Lamborn and Allister Keast (part of the new start-up company Applied Teleoperation Ltd), the teleoperation control system was designed, built and installed on a John Deere model 909 (electric-over-hydraulic) feller buncher.

As a first stage in this project, in 2014 a hand-held remote-control system was installed for the John Deere 909. The initial field testing showed promise and the application of remote control to a tracked feller buncher on steep terrain was believed to be a world first, and was reported widely in the news media at the time.

The next stage of the project progressed to building an operator console to teleoperate the John Deere feller buncher, so the operator can sit in comfort, outside of line-of-sight and operate the machine (Figure 4). This full teleoperation control system was completed and installed in July 2016 in Ross Wood's John Deere 909 feller buncher in Nelson. This modular system was installed in Ian Harvey's John Deere 909 for the HarvestTECH17 Demo in the Bay of Plenty. This system is now available commercially.

In a second application of this technology, a remote-control unit (RCU) has been installed in a mobile tail hold machine (a Volvo EC290 excavator) also in Ross Wood's operation in Nelson. The Cab Assist Backline system has been designed to allow the hauler operator to move the backline excavator remotely from the cab of the hauler. Cameras have been installed in the tail hold excavator to enable full visibility around the machine, and the control system and monitor has been installed in the hauler cab. This system is now commercially available.

4. CutoverCam hauler vision system

Steep terrain and poor weather conditions often makes it difficult for the hauler operator to get a clear view of the breaking out area. Human factors, such as fatigue, eye strain from trying to focus over long distances, glare on sunny days and the eyes' ability to adapt to bright and shady patches in the cutover, all make it more difficult.

Designed with safety at the forefront, the CutoverCam hauler vision system was developed by Scion engineer Dr Paul Milliken for FGR (Figure 5). The CutoverCam is a portable camera system that uses wireless technology to transmit live video of the breaking out operation, and where the breaker-outs are, back to the hauler operator. This system is able to be set up anywhere in the cutover, and provides a clear view of breaking out or grapple functions on the screen mounted in the hauler cab.

The hauler operator remotely controls the camera – to pan side to side, tilt up and down and zoom in and out – using a joystick controller to gain a clear view of operations. Instead of relying on radio instructions or audio signals from a Talkie Tooter®, the hauler operator can control the extraction operation directly, and respond instantaneously, to ensure maximum safety.

Figure 5: New model CutoverCam

Another objective of the system was to offer the hauler operator, when grappling, a better view of the cutover to enable faster grappling time. Recent FGR feasibility studies have shown that the camera is beneficial in grapple carriage and rigging positioning, avoiding stem hang-ups and breakage on debris, stumps or other obstacles during extraction, reducing damage to stems and rigging and increasing the life of wire rope and strops. This saves considerable costs in hauler maintenance. Once operators have used the CutoverCam they do not want to return to the alternative of using a spotter or listening to audio signals only.

The prototype CutoverCam was initially marketed by Cutover Systems Ltd and 3 units were sold. The commercial model CutoverCam was designed and commercialised by Applied Teleoperation Ltd and was formally launched at the HarvestTECH17 Conference in Rotorua in June 2017.

5. Alpine Grapple Carriage

Breaking-out (manually attaching wire rope strops to felled trees ready for extraction) is one of the most hazardous roles in harvesting due to the risk from moving ropes and strops, swinging stems and dislodged debris on steep terrain. It is responsible for an estimated 40 per cent of serious harm incidents in forestry. One of the developments in the programme was to implement remote-controlled hydraulic grapple carriages to improve grapple control, increasing the productivity of cable extraction, and eliminating manual breaking out.

Commercial partner Alpine Logging Equipment Ltd, from George, South Africa, which specialises in manufacturing steep terrain yarding equipment, built the prototype Alpine Grapple Carriage, and provided it to FGR for field testing in 2012. Scion's harvesting and logistics team did the field trialling and recommended modifications to the Alpine Grapple to make it more suitable for New Zealand logging conditions.

The grapple is hydraulically driven through an accumulator that runs off one of the carriage sheaves. Hydraulic pressure is built up as the carriage moves up and down the skyline cable, and this is used to clamp the carriage in position on the skyline, and rotate and open the grapple arms. The grapple arms are closed around the stem load using the main rope. The skyline clamp is then released to pull in the load of stems to the log landing. The grapple is remotely controlled by the hauler operator,

so it can pick up stems easily and pull them out of steep gullies, avoiding the use of breaker-outs. This ultimately means a safer hauler operation.

Figure 6: Commercial model Alpine Grapple Carriage

The commercial model Alpine Grapple Carriage (Figure 6) works on 2-drum swing yarders and both 2-drum and 3-drum tower haulers. Being non-motorised, it is lightweight, low cost, and cheap to run. Its lightweight design and ease of control means it can be used on smaller cable harvesting machines, enabling more contractors to adopt this technology. A wireless grapple camera mounted on the carriage transmits high definition video back to a screen in the hauler cab, providing the operator with a clear view of the grappling operation for distances of up to 600 metres. Although the Alpine Grapple is manufactured in South Africa, a separate independent company, Logpro Ltd, was established to market and support the Alpine Grapple in New Zealand, and customise the technology to individual contractor requirements. Thirteen units have now been sold in New Zealand to date.

6. Doherty Quick Coupler Attachment

This is a quick coupling attachment to the boom of a base machine that will allow automatic switching between processor head and log loading grapple without the operator leaving the cab of the base machine.

This development increases machine utilisation, which is a key driver for lower logging costs. A mechanised hauler operation usually requires a minimum of three machines to do the job – hauler, processor and loader. When hauler production levels are low – such as working in difficult conditions (low volume forests, small tree size or long extraction distances), or where the mechanised processor production is constrained by limited landing size – operating costs are high, due to low machine utilisation.

In these situations of lower production levels, where machines have spare capacity and are not fully utilised, the number of machines can be reduced through doing more than one function, resulting in higher machine utilisation and lower operating costs.

The project commenced in 2013, to develop a quick coupling mechanism to allow the base machine to change quickly and safely from a processor head to a log loading grapple. Economic analysis showed that such an attachment would have the most advantage where production of the mechanised processor was constrained by operational factors to less than about 220 tonnes per day.

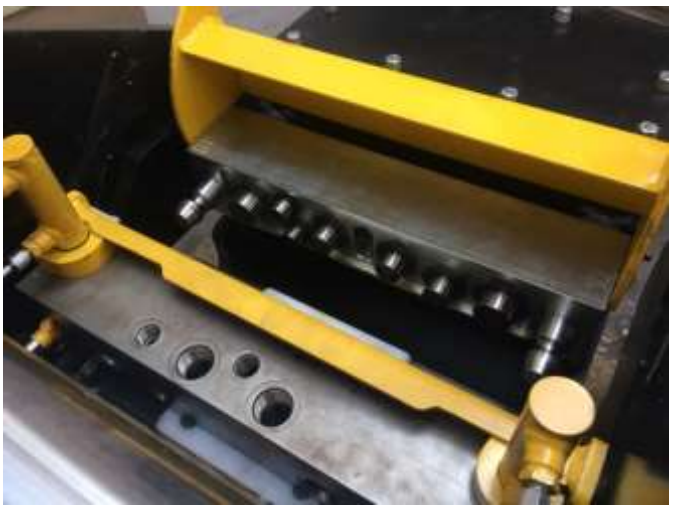


Figure 7: Close up of Doherty Quick Coupler attachment

A Quick Coupler attachment has been designed and built by Doherty Engineered Attachments Ltd of Mount Maunganui (Figure 7). Construction and workshop testing of the remote controlled automatic quick coupler has been completed. The first adopter contractor has been identified and has ordered the quick coupler to be installed. The Doherty Quick Coupler attachment is available from commercial partner, Doherty Engineered Attachments Ltd.

7. Awdon Skyshifter twin winch tail hold carriage (prototype)

Shifting the skyline is a time consuming, difficult and potentially hazardous task. This product is an innovative yarding carriage for remote controlled shifting of the cable yarder skyline. Developed by Don Scott of Awdon Technologies Ltd, Gisborne, the Skyshifter twin winch tail hold carriage was developed to reduce skyline shifting time and enhance grapple harvesting where pre-bunching of trees was not possible. A secondary objective of the Skyshifter is to enable safe logging at night, eliminating the need to do manual line shifts or move mobile tail holds.

Figure 8: Prototype Skyshifter tail hold carriage

The prototype Skyshifter tail hold carriage (Figure 8) was designed and built in 2016. Initial field testing of the prototype was completed in a forest in the Bay of Plenty. Recent field trials of the Skyshifter have shown that the carriage works well when each winch rope is secured to a tail tree, enabling the Skyshifter carriage to be raised clear of the ground to move sideways from left to right to move the cable skyline across the cutover. The Skyshifter is a prototype and is available for lease from commercial partner, Awdon Technologies Ltd.

8. Robotic tree-to-tree felling machine (prototype)

This product is an innovative remote controlled tree-to-tree harvesting machine that can traverse steep terrain without touching the ground (Figure 9). The prototype has been developed as a collaborative project between Scion and the University of Canterbury Mechatronics programme.

In 2013 the detailed design and construction of the alpha prototype tree-to-tree locomotion device was completed by four final-year University of Canterbury engineering students. The alpha prototype weighed 50 kg, had grippers at the end of each arm and could demonstrate movement between simulated trees in the laboratory. The prototype enabled the detailed mechanical and electronic analysis of the device moving controllably from tree to tree taking into account strength of materials, weight, gripper configuration and degrees of freedom of movement.

Figure 9. The robotic tree-to-tree machine at Bottle Lake Forest Park

Further development improved the design and control of the machine from 2014 -2016. The detailed design of the robot was further developed and refined, including joint displacement and velocity, machine and tool head coordinates, as well as accounting for the forces and actions required through kinematics and control theory. To ensure manoeuvrability in a forest environment, feedback controls and sensors were needed that could determine and correct for centre of mass and gravity, traverse time, and stability envelopes. The control software was re-written to control the robot using a PlayStation remote controller and on-board power source.

Testing of the robot was undertaken in a forest environment, and a field demonstration as a proof-of-concept was undertaken in Bottle Lake Forest in Christchurch in September, 2016. The objectives of this Steepland Harvesting project, to build and demonstrate the alpha prototype model, were achieved. It was however planned that trials with the prototype would ultimately guide the development of a full-sized felling machine. Further investment is required to take this proof-of-concept prototype to the next stage.

9. Falcon Tension Monitoring App (prototype)

Arising from the fundamental work by University of Canterbury in monitoring operating tensions of wire ropes in cable-assist and skyline rigging configurations, a tension monitoring computer application (‘app’) was developed for integration with a tension monitor to record and display the dynamic tensions in wire ropes used in forest harvesting operations, including both cable yarding and cable-assisted tree felling operations.

Designed and written by a final year Bachelor of Computer Science student, the tension monitoring ‘app’ was developed to display rope tensions in the operator’s cab (Figure 10). The developer then worked with a cable-assist machinery manufacturer (D.C Equipment Ltd) to enable tension data from

tension monitor on the Falcon winch-assist to be live-streamed into the operators cab in the feller buncher. Likewise when installed in a yarder, the skyline tensions from the yarder tension monitor would be streamed to the 'app' and displayed in yarder cab. The 'app' is currently a prototype, and will be commercialised by D.C. Equipment Ltd as the Falcon Tension Monitoring 'app'.

Figure 10: Display of wire rope tension using the Tension Monitoring 'App"

4.3. Outputs Against Objectives

The specific outputs of the development programme against the original Business Plan objectives are given in Table 3. All these outputs have been achieved to the stage envisaged in the original Business Plan or beyond. Additional outputs developed beyond the terms of the original Business Plan objectives are shown in Table 4. In total the programme has driven 13 development projects that have produced 7 commercial products and 3 prototypes that are in various stages of commercialisation.

Table 3: Summary of Outputs against original Business Plan objectives

Project	Name of Output	Planned commercial pathway (from original Business Plan)	Stage of development at programme completion
1.1	ClimbMAX Steep Slope Harvester	Development to commercialisation stage and sale of first unit by Year 4.	Commercial model built by Trinder Engineers Ltd, commercially available from ClimbMAX Equipment Ltd.
1.2 A.	Teleoperation Control System	Development of remote controlled steep terrain-capable machine to alpha prototype stage.	Commercial system developed for feller buncher and commercialised by Applied Teleoperation Ltd.
2.1	CutoverCam hauler vision system	Development of hauler vision system (camera, monitor, communication system) to beta prototype stage.	Commercial model available from Applied Teleoperation Ltd.
2.2	Alpine Grapple Carriage	Development of remote controlled grapple carriage system to simulation stage.	Commercial model available from Logpro Ltd, New Zealand agent for Alpine Logging Equipment, South Africa.
2.3	Awdon Skyshifter twin winch tail hold carriage	An innovative high production yarding system developed to alpha prototype stage.	Beta prototype built, tested and demonstrated. Available for lease from Awdon Technologies Ltd.
1.2 B.	Robotic tree-to-tree felling machine	Development of remote controlled (or robotic) steep terrain-capable machine to alpha prototype stage.	Alpha prototype built, tested and demonstrated by Scion and Univ. of Canterbury.

Table 4: Additional developments beyond original Business Plan objectives

Project	Name of Output	Planned commercial pathway (from original Business Plan)	Stage of development at programme completion
1.1	HarvestNav on-board navigation application	Additional development not originally planned for commercialisation.	Commercial system built and commercialised by Margules Groome Ltd.
1.2 A.	Teleoperation Control System	Additional development of remote controlled mobile tail hold not originally planned for commercialisation.	Commercial system developed for tail hold machine and commercialised by Applied Teleoperation Ltd.
3.2	Doherty Quick Coupler	Additional development not originally planned for commercialisation	Commercialised by Doherty Engineered Attachments Ltd, Mount Maunganui.
2.2	Falcon Tension Monitoring application	Additional development not originally planned for commercialisation	Prototype 'App' built by University of Canterbury and commercialised by DC Equipment Ltd.

4.4. Intellectual Property

A register of intellectual property arising from the Steepland Harvesting Programme is given in Table 5. This includes the number of sales to end of programme.

Table 5: Intellectual Property Register

Project	Name of IP	Owner of IP	Utilisation of IP
1.1	ClimbMAX Steep Slope Harvester	ClimbMAX Equipment Ltd, Nelson	Commercialisation by ClimbMAX Equipment Ltd. 11 units sold (3 in NZ, 1 to U.S., 6 to Canada)
1.1	HarvestNav on-board navigation system	Forest Growers Research Ltd.	Initially developed as a download from Interpine Group Ltd website. IP subsequently transferred to Margules Groome Ltd and commercialised. 31 app licences issued, and 18 units in operation. New model system launched by Margules Groome Ltd.
1.2 A	Teleoperation Control System	Forest Growers Research Ltd.	Licencing to commercial partner, Applied Teleoperation Ltd. Two RCU units sold (one for feller buncher and one for mobile tail hold).
2.1	CutoverCam hauler vision system	Forest Growers Research Ltd.	Initially licensed to Cutover Systems Ltd. Subsequently transferred to Applied Teleoperation Ltd. 3 initial units sold. New model launched by ATL
2.2	Alpine Grapple Carriage	Alpine Logging Equipment, South Africa.	Manufactured by Alpine Logging Equipment, and marketed in NZ by Logpro Ltd. 13 units sold in NZ.
3.2	Doherty Quick Coupler attachment	Doherty Engineered Attachments Ltd. Mt Maunganui.	Commercialisation by Doherty Engineered Attachments Ltd. First unit sold.
1.2 B	Robotic Tree-to-tree Felling Machine	Scion	To be licenced to commercial partner. Proof-of-concept prototype, not commercialised yet.
2.2	Falcon Tension Monitoring 'App'	Forest Growers Research Ltd.	Prototype built by University of Canterbury. Commercialisation by D.C. Equipment Ltd is on-going.
2.3	Skyshifter twin winch tail hold carriage	Awdon Technologies Ltd, Gisborne.	Commercialisation by Awdon Technologies Ltd is on-going. Prototype built and available for lease.

The management of intellectual property (IP) practices and procedures was designed to maximise the likelihood that the objectives of the programme would be achieved. Management of IP was

consistent with the overall objectives of Forest Growers Research Ltd and the Steepland Harvesting PGP programme. The IP agreements with the commercial partners in the programme maximised the availability to users and facilitated the uptake of innovative technology by the forest industry.

Patents were registered for three products developed by: ClimbMAX Equipment Ltd, Awdon Technologies Ltd and Doherty Engineered Attachments Ltd. The rest of the intellectual property is held in design and know-how in terms of applied engineering in the context of new harvesting equipment and machinery.

5. OUTCOMES

Outputs of the PGP Steep Land Harvesting programme to date have been recognised by the forest industry in New Zealand as contributing to increased productivity and reduced exposure of workers to hazards on steep terrain. There has been significant progress towards achievement of both short and medium-term outcomes, but slower than originally anticipated. This is reflected in the achievement of economic benefits to date (section 6).

5.1. Short Term Outcomes

The short term outcomes from the programme as set out in the Outcome Logic Model (Section 2.6) are:

- commercialisation of new products and processes that improve productivity and reduce the cost of steep land harvesting
- commercialisation of new products and processes that reduce dangerous manual labour roles in steep land harvesting
- new opportunities for New Zealand made forest harvesting machinery in domestic and export markets.

The timeframe for achievement of the short-term outcomes is 2018, only one year after programme completion. Progress towards delivery of these short term outcomes has been excellent. The programme has been extremely successful in developing technologies that improve the productivity and reduce the cost of steepland harvesting in New Zealand. Of a total of 13 development projects, 7 new products have been commercialised. This is a strike-rate of over 50%, significantly higher than most engineering development and commercialisation programmes.

- ClimbMAX Steep Slope Harvester
- HarvestNav machine navigation system
- Full Teleoperation of a feller buncher (product of Teleoperation Control System project)
- Cab Assist Backline (product of Teleoperation Control System project)
- CutoverCam hauler vision system
- Alpine Grapple Carriage
- Doherty Quick Coupler attachment

In addition, there are 3 prototypes in various early stages of commercialisation:

- Skyshifter twin winch tail hold carriage
- Falcon Tension Monitoring ‘App’
- Robotic Tree-to-tree Felling Machine.

5.2. Medium Term Outcomes

The medium term outcomes expected from the programme, as set out in the Outcome Logic Model, are:

- New Zealand forest industry using improved steepland harvesting products and processes.

“No worker on the slope, no hand on the chainsaw”

One objective of the Steepland Harvesting Programme was to introduce remote control and then full teleoperation of a steep slope felling machine. In June 2015, remote control with video feedback was successfully installed into a John Deere 909 feller buncher owned by innovative harvesting contractor Ross Wood, of Wood Contracting Nelson 2014 Ltd.

“At the start, I was a bit dubious about the advantage of remote controlling my machine,” says Ross. “As a result of the work done by Paul Milliken and Spencer Hill and the team, my mind has been opened to a whole raft of opportunities”.

“There is no doubt in my mind this will improve safety of steep slope felling operations more than what we have already achieved with our winch-assist system, and I see it really expanding the pool of potential employees for logging.”

- Higher productivity and profitability in New Zealand steepland harvesting
- Safer New Zealand steepland harvesting operations
- Growth in the forest harvesting machinery manufacturing sector in New Zealand

Use of Programme Products

The programme has resulted in the successful commercialisation and uptake of new harvesting products and processes as listed in Table 5. Since commercialisation of the ClimbMAX harvester in 2012 and widespread uptake of over 60 other winch-assisted machines over the last three years, the level of mechanised tree felling (as reported in the FGR Benchmarking database) has increased to 57% of all harvesting operations (up from 23% mechanical felling in 2009).

Profitability

To date the industry uptake of winch-assisted felling machinery on steep slopes, and increased uptake of grapple yarding as an improved method of cable log extraction, has achieved operational cost savings of $6.18 per cubic metre of wood harvested (based on actual productivity studies).

Early studies of the alpha prototype ClimbMAX harvester in 2009 showed an average 60% increase in the number of trees hauled per cycle with mechanically felled and bunched wood versus unbunched wood. Results also showed a 26% increase in daily productivity over the manual system. The logging cost benefits were around $3.00/m3 compared to the manual system with no steep slope harvester. This outcome of increased productivity and reduced harvesting cost was used in the benefits case.

Remote controlled grapple extraction has clear advantages over manual breaking out with chokers in terms of productivity and cost. Increases in productivity from grapple yarding were measured in a FFR study of the Alpine Grapple in 2013. In manually felled (unbunched) trees the productivity of the Alpine Grapple at haul distances of up to 250 metres exceeded that of the manual breaking out system by 35%. The cost of extraction was lower by $3.18 per cubic metre. This outcome of increased productivity and reduced harvesting cost was used in the benefits case.

Safer Operations

The spate of workplace deaths in 2013 spurred the New Zealand forest industry to improve safety performance immediately. In 2014 the industry set up an Independent Forestry Safety Review to consider ways to reduce workplace harm to forestry workers. This review made recommendations on key issues to be addressed, including:

- Improved leadership through the formation in 2015 of the Forest Industry Safety Council (FISC) with representation from forest management companies, contractors and workers.
- Launch of the Safetree website to elevate awareness, improve communication and boost safety resources.
- Setting up a comprehensive injury prevention programme based on risk assessment, improved incident data and accident investigation and review processes.

As a result of these initiatives, and developments in the Steepland Harvesting PGP programme and other developments outside the programme, forestry companies, harvesting contractors and local machinery manufacturers implemented the new traction-assisted mechanised harvesting technology. These machines now provide a safe alternative to manual tree felling with chainsaws by isolating workers from the key risks in tree falling (such as “hit by object falling from above” hazards).

Mechanised felling is now replacing manual tree fallers wherever possible in corporate forests. Since 2012 over NZ$80 million has been invested in new harvesters, winch-assist machinery, grapples, cameras and other equipment designed to enable safe work in steep slope forests. Approximately 165 workers have been removed from hazardous roles of felling and breaking out. These innovations are providing forest owners and contractors with solutions to improve productivity and reduce the exposure of workers to hazards on steep terrain.

The combined result of increased focus by WorkSafe, increased injury prevention funding and a step change in harvesting mechanisation, the number of serious harm incidents per year in forestry has dropped dramatically and constantly to less than one-sixth the number in 2010, from 170 incidents in 2010, to 79 in 2015, then down to 28 in 2016 (Table 6).

Table 6: Workplace serious harm incidents and fatalities in forestry (Source: WorkSafe NZ)

Year	Serious Harm Incidents (including fatal)	Fatalities
2010	170	4
2011	182	3
2012	194	6
2013	160	10
2014	107	1
2015	79	3
2016	28	4

Even more striking – the rate of serious harm incidents per million cubic metres of wood production has dropped to less than one-third of the rate in 2008 (Figure 11). This is measured against annual roundwood removals from data collected by Ministry for Primary Industries, and the number of serious harm incidents as recorded by WorkSafe NZ. Over this period annual forest harvest volumes have lifted from 20.5 million cubic metres per annum in 2008 to 29.5 million p.a. in 2015.

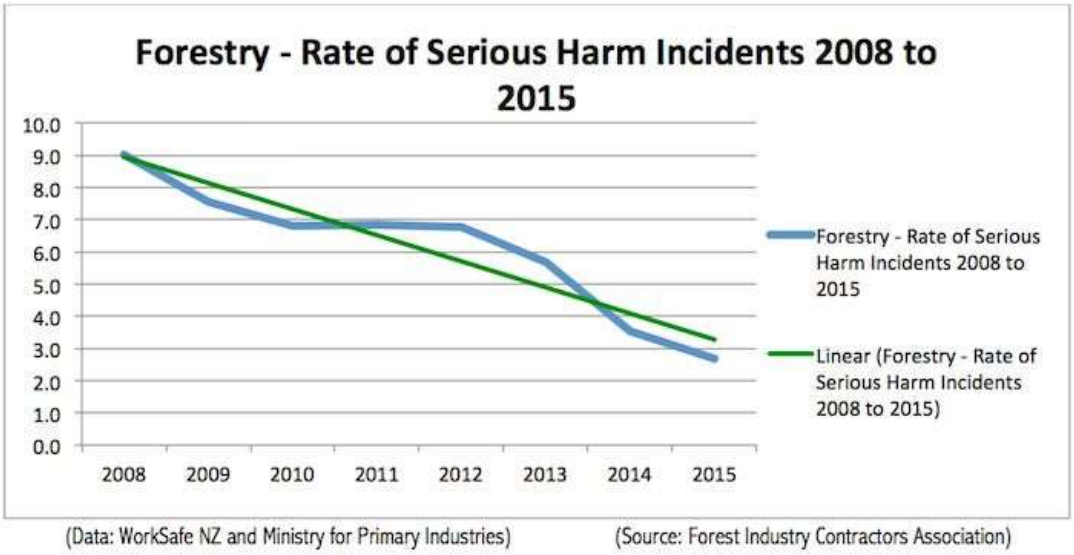


Figure 11: Rate of Serious Harm Incidents per million cubic metres production

Machinery Manufacturing
Sector wide benefits include the development and operation of 65 winch-assisted feller bunchers (including the ClimbMAX Steep Slope Harvester) in New Zealand, plus sales of 60 other winch-assist machines overseas. There are now four New Zealand companies manufacturing about 25-30 winch-assist machines between them annually. Other related benefits include development of new types of grapples and grapple camera systems. The use of grapples has more rapidly increased since 2012, when only 17 mechanical grapples (and no hydraulic grapples) were in operation, to latest estimates of about 75 hauler operations running grapples (50 hydraulic and 25 mechanical). There are now two manufacturers of remote controlled hydraulic grapples in New Zealand (D.C. Equipment Ltd.'s Falcon Forestry Claw and E.M.S. Ltd.'s Hawkeye).

5.3. Long Term Outcomes

Long term outcomes expected from the programme (out beyond 2025), as set out in the Outcome Logic Model, will be a safer, internationally competitive forestry sector, using leading edge technologies, delivering higher economic returns for New Zealand.

It is clear that there has already been considerable progress made towards achieving these long term objectives of the programme. As summarised in this report since the programme started in 2010 there has been a transformation in the use of mechanised harvesting technologies in the forest industry for which the programme has been an important catalyst. This has resulted in evidence of improved productivity, improved safety and economic benefits which are detailed in section 6.

6. BENEFITS

6.1. Economic Benefits

The original business plan envisaged direct economic benefits arising from:
- Reduction in steep land harvesting costs by 25%
- Zero lost time injuries during felling and breaking out on steep country
- Reduction in fuel costs by 10%
- Development of new harvesting machinery for domestic and export sale

Table 7: Economic Benefits Budget vs. Actual and Forecast

Benefit	Year	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19
Operating Cost Savings ($M p.a.)	Budget	0.0	6.1	14.3	25.0	38.4	54.5	65.4	78.3	95.0
	Actual	0.0	1.7	3.7	6.8	12.6	22.1	32.1	45.9	65.0
Fuel Savings ($M p.a.)	Budget	-0.2	-0.5	0.0	0.8	2.2	4.1	4.7	5.3	5.9
	Actual	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Injury Claim Savings ($M p.a.)	Budget	0.0	0.1	0.1	0.2	0.3	0.4	0.4	0.4	0.5
	Actual	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0
Annual Machinery Sales ($M p.a.)	Budget	0.0	1.6	3.4	5.3	7.9	11.6	16.3	26.9	33.3
	Actual	0.0	3.0	3.2	6.4	13.8	23.1	30.8	37.9	48.1
Total Net Benefits ($M p.a.)	Budget	-1.1	6.5	16.6	30.2	47.6	69.4	85.8	110.8	134.7
	Actual	-0.9	3.9	6.0	11.9	25.2	43.6	61.9	83.9	113.1
Cumulative Net Benefits ($M)	Budget	-1.1	5.4	22.0	52.2	99.8	169.1	255.0	365.8	500.5
	Actual	-0.9	3.0	9.0	20.9	46.1	89.7	151.6	235.5	348.6

Outputs of the PGP Steep Land Harvesting programme to date have been recognised by the forest industry in New Zealand as contributing to increased productivity and reduced exposure of workers to hazards on steep terrain. Cumulative sector wide benefits arising both directly from the programme and from related outputs total $151.6 million to 30 June 2017, from operational cost savings and machinery and equipment sales (Table 7).

No data was available at the level of detail required to calculate fuel savings in cable logging over the period. Likewise no data on the cost of injury claims was available from ACC at the level of detail required. No economic benefits have been claimed in these two areas.

All together the commercialisation of these new products and processes have resulted in cumulative net economic benefits of $151.6 million against a budget of $255 million. These benefits comprise cumulative operational cost savings of $71.3 million, plus domestic and export sales of New Zealand made forest harvesting machinery and equipment totalling $80.3 million.

The original business plan (plus one-year extension) envisaged annual net economic benefits of $85.8 million p.a. in 2016/17, as well as enhanced worker safety. It is estimated that as a result of this programme, annual net economic benefits total $61.9 million in 2016/17 (72% of target benefits). To date 165 workers have been removed from the hazardous roles of tree felling and breaking out. The annual rate of benefit gain from the programme is illustrated in Figure 12.

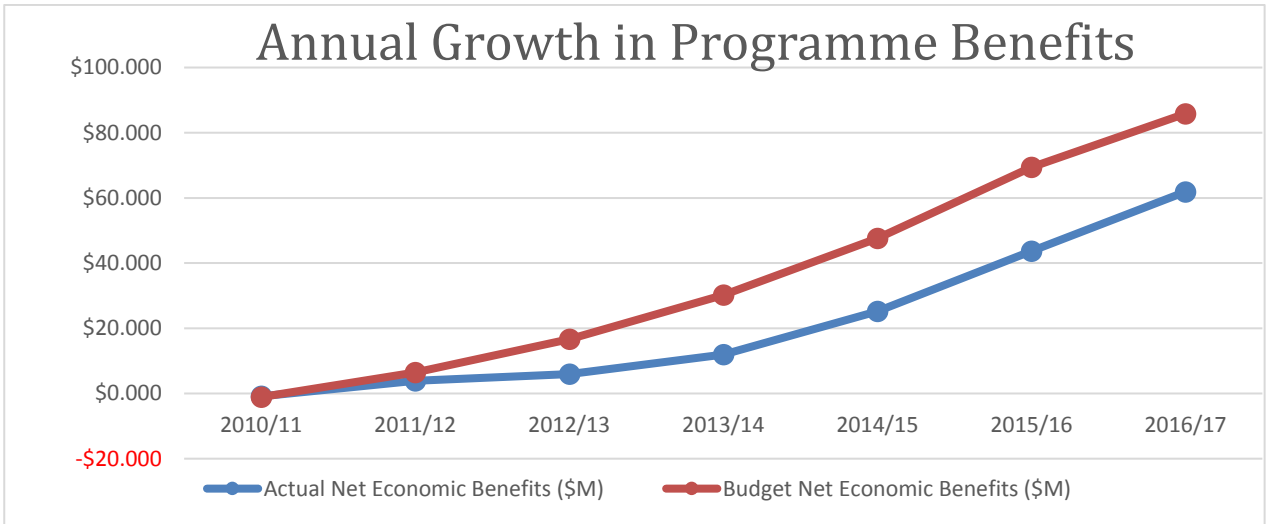


Figure 12: Annual Net Economic Benefits Actual vs. Budget

6.2. Forest Machinery Sales

Sector wide benefits include the development, commercialisation and sale of 65 winch-assisted feller bunchers (including the ClimbMAX Steep Slope Harvester) in New Zealand, plus sales of 60 other winch-assist machines overseas. There are now four New Zealand companies manufacturing about 25-30 winch-assist machines between them annually, with about half being sold overseas, particularly to British Columbia, Canada. These developments have been catalysed as a direct result of this PGP programme.

Other related benefits include development of new types of grapples and grapple camera systems. In a survey in 2011 only 10% of harvesting operators surveyed said they had used mechanical grapples within the last 5 years and a survey of yarders in 2012 found only 17 mechanical grapples in operation. Latest estimates are that at least 25% of hauler crews now run grapples (75 grapples in operation). One company (DC Equipment Ltd of Nelson) has built and sold 30 Falcon Forestry Claw grapple carriages and over 60 grapple camera systems, including a new product called Skylight. E.M.S. Ltd of Rotorua has launched a new hydraulic grapple called Hawkeye with an integrated grapple camera system. T-Mar Industries Ltd of British Columbia has also sold 6 grapple camera units in N.Z. and 40 grapple cameras in B.C.

As of June 2017 the following NZ-manufactured machinery and equipment is in operation:

- ClimbMAX harvesters – 11 units sold, 3 to New Zealand, 7 to Canada, 1 to the U.S.
- TractionLine winch-assist – 44 built in total, 23 operating in NZ
- Falcon winch-assist – 40 built in total, 22 operating in NZ
- Remote Operated Bulldozer (ROB) – 23 built in total, 10 operating in NZ
- Other NZ-made winch-assist machines – 7 built and operating in NZ
- Over 30 Falcon Forestry Claw and EMS Hawkeye grapples built and operating
- 18 HarvestNav navigation units in operation
- Over 60 hauler vision systems (including CutoverCam, Falcon and Hawkeye grapple cams)

6.3. Spillover Benefits

One of the major challenges identified in the original business plan was sustaining a strong, safe and healthy workforce. The outputs and ultimately desired outcomes from the programme relating to safety are very relevant to the current high level of focus on worker safety in the forestry industry, primarily in harvesting activities.

The outputs from the programme have not presented major new challenges to the forest harvesting industry in the area of skills and training. Spillover benefits from the programme have been a large number of training workshops undertaken by the University of Canterbury in working on steep slopes with cable-assist harvesting, and in professional development courses in forest engineering and harvest planning.

The programme has been successful in building technical capability in harvesting machinery development. The programme has supported the business development of four technology developers (Applied Teleoperation Ltd, Awdon Technologies Ltd, Logpro Ltd and Margules Groome Consulting Ltd) in addition to three machinery manufacturing companies (ClimbMAX Equipment Ltd, Doherty Engineered Attachments Ltd and D.C. Equipment Ltd). The programme has achieved a high level of recognition internationally through participation in international conferences, and strong industry collaboration with research organisations such as FPInnovations in Canada and Skogforsk, the Forestry Research Institute of Sweden. As a result of the programme and other sector developments, New Zealand has taken a global leadership role in the development of mechanised forest harvesting operations on steep slopes.

The largest spill-over benefit from improving the profitability of steep country harvesting that was identified in the original business plan was to realise the substantial opportunity to increase the establishment of forests on marginal land. Progress towards this goal has not yet been achieved, primarily for reasons not attributable to the Steepland Harvesting Programme, such as static log

prices, increasing harvesting costs (especially labour and machinery), high land prices and uncertainty around benefits from the Emissions Trading Scheme. Ultimately however, the improvements in harvesting technologies and reduced operating costs fostered by this programme will improve the economics of forestry and make it more attractive for new planting in marginal areas.

7. LESSONS LEARNED

7.1. Mid-Programme Progress Review

A mid-programme progress review was completed in November 2014 by Mr Rob van Rossen, Registered Forestry Consultant, and Professor Mark Brown, Director of Forest Industries Research Centre at the University of Sunshine Coast, Australia. This independent progress review of the programme made a number of observations and recommendations:

- Stakeholders throughout the industry have engaged positively in the programme. The programme has strong support from most industry members who have generally expressed satisfaction with programme management, programme reporting, progress against project plans and achievements from the programme.
- Programme governance and management, including financial governance, management and reporting, was of a high standard. This had also been noted in the MPI evaluation and audit of the programme
- The programme has been a catalyst for increased innovation in harvesting in New Zealand with new technology being developed and deployed, both from the programme and outside of the programme.
- It was clear that the programme was making progress towards delivering against the expected outcomes but the extent and timing of that delivery is still to be determined.
- The outputs and ultimately desired outcomes from the programme relating to safety are very relevant to the current high level of focus on worker safety in the forestry industry, primarily in harvesting activities.
- The outputs from the programme will not present specific new challenges to the forest harvesting industry in the area of skills and training.

The reviewers recommended the following:

- that a concerted campaign to enrol more direct contractor participation for the balance of the programme be initiated with the purpose of achieving greater engagement from this group to facilitate commercialisation and uptake.
- that external expertise be engaged to review progress with each product within the programme to date, and to assist with commercialisation aspects of each product development. The importance of external expertise in business development support and commercialisation was underestimated in the original programme, and this commercialisation expertise should have been engaged earlier in the programme.
- that all current work programmes be reviewed with a view to prioritisation such that as many outputs as possible are moved along the development path towards commercialisation, or at least to have enough momentum to continue in some form, by the end of this programme.
- that promotion of outputs and delivery of outcomes from the programme through workshops and field days be continued.
- that the emphasis be increased on operational trials for outputs at or near commercialisation for the balance of the programme.

The programme implemented all of the recommendations of the mid-programme progress review – in particular the programme was extended by one year to undertake the additional commercialisation work recommended.

7.2. Barriers to Uptake

A major challenge for FGR and the sector participants in achieving the goals of the programme has been the relationship with harvesting contracting firms which are contracted by forest owners and management companies to undertake harvesting operations. The industry is almost entirely subcontracted with arms-length business relationships between the parties.

Contractors play a critical role in the uptake and use of new technology and new methods, and finding the right mechanisms to secure contractor engagement in the programme and communication of outcomes to contractors has been an important component of the programme.

The independent commercialisation review completed in February 2016 (Todd, 2016) noted that successful commercialisation of technology in the forestry sector requires: involvement of early adopters in the product development process; demonstration of benefits, practicality and robustness; securing a champion in the harvesting contractor community; and getting the product into the contractors' hands through loan, lease, trials and demonstrations. The review noted that FGR had achieved this with all the successful projects in this programme.

In addition to the engineering development programme (primarily covered in Objectives 1 and 2, a third Objective, Development of Operational Efficiencies, focused on a Harvesting Technology Watch programme and a technology transfer programme to promote uptake of the outputs of the development programme by harvesting contractors and forestry companies. This has involved organising and participating in a total of 43 industry workshops, technical meetings, field demonstrations and conferences.

Another barrier to progress is that commercialisation of new technology is traditionally left to machinery and equipment manufacturers. Most machinery manufacturers are unwilling to take risks in machinery development, until other manufacturers have developed products and forestry companies and contractors had started to buy them. Relying solely on machinery and equipment manufacturers to develop and commercialise new technology is a high risk strategy for harvesting contractors due to the short term nature of their contracts and the pressure on margins at all times. This risk has led to a very conservative uptake of technology.

It was noted that without a collaborative programme of technology commercialisation, between forestry companies, contractors and machinery manufacturers, the forest industry would almost certainly deliver overall outcomes at a significantly slower pace than with this additional investment, and the likelihood is that some of the products developed within the Steep Land Harvesting Programme would not be fully commercialised.

The commercialisation review considered opportunities existed to:

- further leverage FGR resources by working with third party organisations to support technology developers in business development and further commercialisation of their products, including protection of intellectual property;
- improve the commercialisation plans for some of the early stage ventures initiated by FGR;
- involve early adopters (harvesting contractors) as product champions with a view to securing first buyers;
- facilitate the process of forest owners and contractors working together to implement innovations by sharing risk and productivity gains. It was noted that sharing this risk and reward between forest owners and their contractors would be a step change for the forest industry.

7.3. 'Fail Fast' Approach

The programme has attempted to 'pick winners' out of the myriad of new ideas and concepts generated as a function of the projects, workshops, industry technical meetings etc. held during the course of the programme. Some of the projects were additional to the original projects detailed in the Business Plan, and were seen as opportunistic developments that aligned closely to the goals

and desired outcomes of the programme. Not all of these projects were successful and there have been a number of failed projects, which were discontinued. It should be noted that several of these failed projects were additional tools not originally planned for commercialisation.

The programme applied a 'Fail Fast' approach to the screening and testing of product concepts whereby during the course of the programme, the Programme Manager and the Technical Steering Team recommended redistribution of resources between projects that were not achieving key milestones and other projects that had greater probability of success. Through the programme governance process the priorities for the programme were identified and the redistribution of resources within and between objectives reflected both these priorities and the potential for success of the projects.

For example early in the programme, the importance of Project 1.1 Steep Slope Feller Buncher was recognised and resources were front-loaded to accelerate this project. Opportunistic developments such as the HarvestNav on-board navigation application were included. Likewise once the initial feasibility and design work was completed in Project 1.2 Task A (Teleoperated Felling Machine) additional resources were allocated in Years 5-7.

The difficulties in identifying a suitable development project in the Innovative Yarding System in Objective 2, and the resources required for successful completion of the proposed project were recognised early and this project was downsized in 2015 to focus on the Skyshifter development only.

Conversely, in Objective 3 (Development of Operational Efficiencies), as a result of Project 3.2 Harvesting Technology Watch project, the opportunity to develop another new commercial product was recognised in 2013. As a result, the project to develop a quick coupler was commenced, and additional resources were allocated to design and build the first prototype.

7.4. Overall Observations

The FGR research team, supported by the analysis in this report, has recognised the following learnings from the Steep Land Harvesting programme:

- The programme has delivered benefits to New Zealand through an innovative investment programme that has been additional to existing initiatives. Without this PGP investment these initiatives would have been unlikely to proceed or at the very least would have proceeded at a much reduced scale and slower pace.
- Fine-tuning of projects was required as changes to existing operations were necessary for some projects to be completed. As the programme developed it was necessary to discontinue some projects that were unsuccessful and reallocate funding to other projects with higher likelihood of success. One example is the Delimbing/Cut to Length on Slopes project. Milestones were changed as more detail became available under the guidance of the Programme Steering Group.
- Programme outputs have been well promoted and communicated to the industry through a large number of technical meetings, conferences, workshops and field demonstrations in order to drive uptake and adoption of outputs and delivery of outcomes.
- Spinoff benefits from the programme have included the large number of training workshops undertaken by the University of Canterbury for those working on steep slopes with cable-assist harvesting, and in professional development courses in forest engineering.
- More direct contractor participation in the programme would have achieved greater engagement from the contractor community and facilitated easier commercialisation and increased uptake of outputs.
- Overall, progress has been achieved according to the schedule in the original business plan, and the annual plan for the one-year extension, with most milestones achieved on time. It is clear that the programme has delivered against the expected outcomes. The extent of that delivery has however been less than the total net economic benefits outlined in the original Business Case.

- The programme has achieved a high level of recognition internationally through participation in international conferences, and collaboration with strong industry collaboration with organisations such as FPInnovations in Canada and Skogforsk, the Forestry Research Institute of Sweden. As a result of the programme and other sector developments, New Zealand has taken a leadership role in the development of mechanised forest harvesting operations on steep slopes.
- The programme has the potential to substantially further transform the forest harvesting industry and improve economic outcomes in the forestry and forest products sector for many years to come. This transformation will be dependent on further commercialisation and uptake of the outputs of the forest engineering outputs of this programme, combined with strong support from forest management company members of FGR in order to further drive adoption.

8. POST PGP PROGRAMME ACTIVITIES

8.1. Further Activities

Further activities to promote commercialisation and uptake include:

- In addition to the programme, University of Canterbury has organised 27 cable-assist workshops across New Zealand (plus 3 in B.C. run on a cost recovery basis). Beyond the programme, the School of Forestry at University of Canterbury will maintain continuing professional development courses in forest engineering, harvest planning, LiDAR analysis in GIS systems, cable-assisted harvesting etc. which will foster uptake of the Steepland Harvesting Programme outputs.
- As a result of developments in New Zealand, FPInnovations in Canada have commenced a Steep Slope Initiative in winch-assisted harvesting. This will drive further exports of New Zealand manufactured winch-assist machinery and contribute to the expansion of the New Zealand machinery manufacturing sector, a key objective of the PGP programme.
- Continued commercialisation work of products arising from the programme, such as the teleoperated systems, the Skyshifter and the Doherty Quick Coupler.
- Further extension and promotion to forest industry stakeholders of the work of FGR through industry conferences and information dissemination.
- Continued funding by FGR of the University of Canterbury project in benchmarking harvesting cost and productivity.
- Continued funding of FGR through the Forest Grower Levy Trust to develop a new programme in forestry automation and robotics applied further down the forestry value chain to continue the momentum generated by this programme.

All these activities will promote further commercialisation and uptake of outputs from the PGP Steepland Harvesting Programme.

8.2. Post-programme Reporting

An annual programme outcomes report detailing progress towards achieving short term outcomes (to 2018) and medium term outcomes (from 2019 on) will be prepared by Forest Growers Research and submitted to MPI within one month of the periods ending 30 June 2018, 30 June 2019 and 30 June 2020.

8.3. Programme Evaluation

A requirement of the Primary Growth Partnership (PGP) Contract as detailed in the 2016/17 Annual Plan is that the Ministry for Primary Industries (MPI) will undertake a separate independent evaluation of the Steepland Harvesting PGP Programme. This evaluation will be funded by MPI.

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