FOREST GROWERS RESEARCH

2019 Annual Research Report

supported by forestgrowers commodity levy

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The last two years have been an exceptionally important period for forest growers.

On the one hand, the coalition government has shone a spotlight on plantation forestry – an industry which had previously operated in the shadows – especially with promotion of the One Billion Trees programme.

On the other hand, the administration of forestry's interests through the operation of a levy on harvested wood, and using levy funds effectively, has been strongly endorsed. Approximately $9 million per annum is now being collected for industry-good projects.

Geoff Thompson,
Chair, Forest Growers Levy Trust.

In what has been a favourable period for the industry, the Forest Growers Levy Trust (FGLT) conducted a referendum to ask eligible forest growers to renew the levy term, as required six-yearly under the Commodity Levies Act. The referendum was successful, with a vote of ninety percent by number, and in the high nineties by volume harvested, approving a further term.

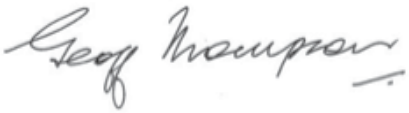
This second term will commence in November 2019 following approval from Cabinet. We now not only have a vote of confidence in the levy process but encouragement for the expenditure of levy funds into the future.

Over half of the available levy funds are spent on forest research. This category is recognised as the most important by the Levy Trust Board and the Forest Owners Association, which operates as the Trust secretariat. Research funding is managed under the capable direction of Russell Dale in Rotorua, and Research Committee chair Phil Taylor, a foundation member of the Levy Trust Board.

The growth in levy funds has occurred without an increase in the levy rate of 27c per tonne of wood harvested. The Board is committed to continuing this rate for 2020.

The Secretariat and Research Committee work closely with Scion and other research providers. Proposals submitted for research are carefully assessed, including screening by an advisory committee of growers of large and small forests, until a final decision is made by the Trust Board. Funding is allocated to ensure that the term of a research project is extended over a number of years if necessary. Results from the first six years of levy funding are now coming through and I am sure the substantial commitment to funding research will continue for many years.

Best Wishes,



Geoff Thompson
Chair, Forest Growers Levy Trust

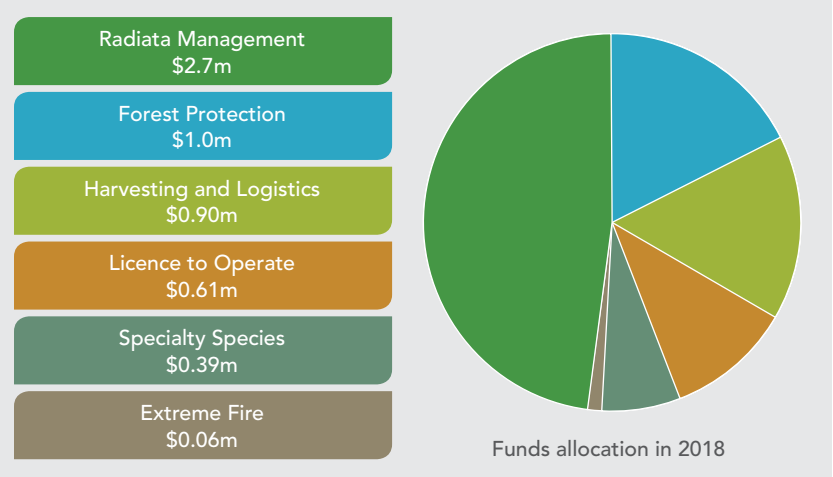
Introduction

Forest Growers Research plans and manages research partially or fully funded by the Forest Growers Levy. Levy contributions total some $5 - $6million per year and leverage much greater amounts from government, other research funders, and the forest industry.

(Left) Russell Dale, Research and Development Manager, Forest Growers Research, and (right) Phil Taylor, Chair, Forest Research Committee.

New Zealand's forest research is recognised as world-leading, and it is partly thanks to the long history of outstanding research that our forest industry occupies an increasingly important role in the country's economic and environmental well-being.

This year sees the culmination of two six-year research programmes – Growing Confidence in Forestry's Future (GCFF) and Healthy Trees, Healthy Future (HTHF). Both of these multi-million dollar programmes were ground-breaking in their cross-disciplinary approach to research, and in their level of industry involvement and governance. What started as an idea about how integrated forest research could be carried out has grown into a model producing outputs directly linked to industry needs.



Much of the science is awe-inspiring and step-change gains have been made – for example in tree genetics and phenotyping, unpicking the drivers of wood quality, understanding *Phyotophthora*-related diseases, and the use of a whole suite of aerial imagery across many aspects of research. Some findings have already been taken up by industry; many are set to provide tangible benefits to forest growers well into the future.

Our scientists receive international recognition for their work, but their achievements are made possible thanks partly to participation by some visionary members of forest industry. These people, who willingly commit time and resources from the boardroom to the forest, are acknowledged at the end of this report.

The **Forest Research Committee's (FRC)** role is in strategic planning, developing research proposals, and making recommendations to the Forest Growers Levy Trust on fund allocation. Members of the FRC are appointed based on their specific skills and knowledge, and they represent all forest growers. Other committees provide important input and include the Biosecurity, Environment, and Small and Medium Enterprises committees.

Programme Steering Groups (PSGs) exist for projects which receive funds from diverse sources. They have a programme governance role, and answer to the FGR Board. Members generally represent investors in the programme, including industry and government.

Technical Steering Teams (TSTs) are appointed to provide technical advice to, and interact with, scientists. They also often drive the uptake of research, because they have shared ownership of it. For example, many TST members host trials in their forests and provide support to scientists working on these trials.

We know our model is working well, and that we have laid strong foundations for the future of forest research in New Zealand. Earlier in 2019, forest growers produced a Science and Innovation Strategy, looking ahead to 2035. The strategy aligns closely with forest owners' 'Forestry Roadmap for Aotearoa New Zealand' (March 2019).

We identified three key strategic themes, which will provide focus in future research planning:

- **ensuring that we increase profitability from our main commercial species: radiata pine and Douglas-fir**
- **ensuring the long-term sustainability of commercial forestry through realising value from emerging species and developing new models for forestry**
- **future-proofing commercial forest growing in New Zealand.**

A strong science and innovation sector will continue to be an integral part of the New Zealand forest industry, and enable forest growers to respond positively and dynamically to the ever-changing environment in which they operate.

New Zealand's forest growers benefit from the work of dedicated scientists and support teams at our key research providers: Scion, the University of Canterbury, Lincoln University, Manaaki Whenua Landcare Research and the Marlborough Research Centre.

We trust you enjoy reading this report which gives some examples of the work being done under each main research theme. The support of the Forest Growers Levy Trust, forest owners, and other research funders is enabling forest growing research to make an increasingly important contribution to the forestry sector.

Finally, I would like to pay tribute to Phil Taylor, who is standing down after ten years as chair, first of Future Forests Research and then of the Forest Research Committee.

Phil has played a major role in shaping the development of our industry-centred research model, and, as chair of the Forest Research Committee, has provided sound guidance on the direction of forest research strategy and funding priorities.

Phil has made an immense contribution to the sector during this time. His passion and interest in the critical role that science and innovation plays in our sector is obvious. His ability to focus on the right issues, and lead the Forest Research Committee in making difficult decisions, has ensured that the industry has received significant value from its investment in research. His photography skills have also ensured a supply of impressive forestry images that have featured regularly in our publications and annual reports.

Russell Dale,
Research and Development Manager,
Forest Growers Research.

Radiata Management

Six years on – the GCFF legacy

Research into radiata pine has been dominated over the past six years by the Growing Confidence in Forestry's Future (GCFF) programme, which draws to a close at the end of 2019. The programme has received many accolades, and provided industry with information and tools to begin a move towards precision forestry: site-specific forest management using innovative science and technologies.

The Rangipo Accelerator trial.

"Results from the GCFF are really coming through now and there are clearly many areas that will be beneficial to Port Blakely, including the soil microbial and forest phenotyping work. Our challenge now as a mid-sized company is to mobilise our own resources and develop our productivity improvement plans so we can maximise the benefits coming out of the programme."

Aaron Gunn,
Technical Resources Forester,
Port Blakely Ltd and GCFF
Technical Steering Team.

New trials for old

The importance of long-term large-plot research trials has been reaffirmed through the GCFF. Trials established between 1987 and 1994 by the NZ Forest Research Institute, containing seedlots with different levels of genetic improvement growing at different stocking levels, continue to produce valuable data. Scientists have analysed and used the data in a number of ways, leading to increased understanding of many facets of growth, yield, wood quality, and management impacts in radiata pine.

New trials planted to replace those being harvested include a series of six large-scale Accelerator trials. These trials provide a facility for testing much of Scion's forest management science as the quest to increase radiata pine productivity and precision management continues.

In addition, the next generation of large-block genetic gain trials is already in the ground. These are a joint initiative between Forest Growers Research and the Radiata Pine Breeding Company. They comprise the best genetics available at the time of establishment and will provide an important resource for the forest industry and researchers alike. Data from these trials will also be used to update radiata pine growth models for the forest industry, and to check that predicted genetic gain is actually being realised.

Biuret being applied as part of a research project, Kaingaroa Accelerator trial.

"My main takeaway from my time here is just how efficiently a place like Scion works to answer questions. You've got a house full of experts with a clear mission and boundaries, but enough flexibility to think about things differently. The interaction with the forest industry is efficient too. It's about ten years ahead of where we are!"

Associate Professor
Jeff Hatten,
Oregon State University
(Visiting researcher 2019).

Growing confidence in forestry's future
Research Programme 2013-2019

Meteorological station, Central Kaingaroa Accelerator trial.

Key GCFF legacy	Major outcomes	Benefits to the forest industry
Fundamental advances in monitoring capability. Developed and applied a full suite of remote technologies to forest management.	Scientific applications of remote sensing include in phenotyping (describing the physical characteristics of both individual trees and whole forests), tree breeding, forest inventory and forest health.	Use of remote sensing tools and technologies becoming applied in both large and small-scale forests.
New understanding of critical biological functions and interactions. Significant advances in understanding how trees grow and what affects their growth.	Advanced gene-level understanding of radiata pine and application of this knowledge in many spheres. Beneficial microbial activity in forest nursery soils found to be negatively impacted by conventional nursery practices. Soil nutrient balances over multiple rotations better understood.	Shorter breeding cycles for genetically improved stock; faster deployment of site-specific genetics. Increased awareness of options for more precise use of chemicals throughout the rotation
Better options for precise and sustainable tree management. Involving the forest industry at all levels of the GCFF has kept the focus on precision forest management.	High-resolution models of tree growth, yields and financial outcomes under different silvicultural systems. Mid-rotation fertiliser trials including innovative applications.	Guidance on optimal silviculture (pruning and stocking options) to maximise financial returns. Guidelines under development for soil and crop analysis leading to site-specific mid-rotation fertiliser applications.
New systems to quantify wood quality and value. Greatly increased understanding of wood formation processes, variation in wood properties within and among trees, and the implications of different segregation options to deal with this variation.	New tools for assessing wood quality have been developed and tested. Model of tree growth and wood formation developed.	Greater understanding of how management practices that affect wood quality will lead to new management recommendations for forest growers.
New trials that will provide value for many years to come. Confirmed the enormous value of large trials during the GCFF, and have replaced new trials for old ones.	Six large-scale Accelerator trials have been installed to test new science: we will learn how fast we can grow trees through site modification, better site use, and better tree health.	Demonstration and proof of scientific advances for the industry to see, learn from, and apply.

The radiata pine SNP chip

Being able to describe the precise genetic make-up of trees is critical for rapid breeding advances. Natalie Graham is one of a team at Scion developing tools and techniques to accelerate breeding gains. In a major recent advance, Natalie and colleagues have developed a SNP chip for radiata pine.

The SNP (single nucleotide polymorphism) chip provides a relatively low-cost way of describing the DNA profile of large numbers of individual trees, and represents a very important development for tree breeders.

"Having this tool at an affordable price means we can introduce genomics tools into tree breeding, and this is where things get exciting," says Natalie.

"For forest growers, the SNP chip means we can focus on rapid improvement of selected traits, for example wood quality or resistance to diseases like red needle cast, so the product available to growers is going to get better and better, faster and faster."

Natalie Graham, Scion.

Radiata Pine Breeding Company, GCFF.

New tissue culture partnership established

Forest Growers Research, working closely with Scion, the Radiata Pine Breeding Company, and industry stakeholders, has set up a partnership to develop an automated tissue culture process. New technologies offer the potential to reduce the time to deploy plants from breeding and genomics programmes to less than ten years, possibly as short as six years. The value for the forest growing industry is significant: perhaps hundreds of millions of dollars if this can be achieved.

Researchers recently completed an end-of-rotation assessment of genetically-improved tree stocks planted in the early 1990s, and found value gains of 20-30% for the best genetic material available to growers at the time these stands were planted.

With such significant gains possible, getting improved genetic material into the forest quickly is important to maximise the return on the substantial investment being made in breeding and genomics. Genomics offers the potential to speed up the selection process, but the big gains and the introduction of new plant varieties depend on reliable and cost effective tissue culture to bulk up material, and this will be the focus of the new partnership.

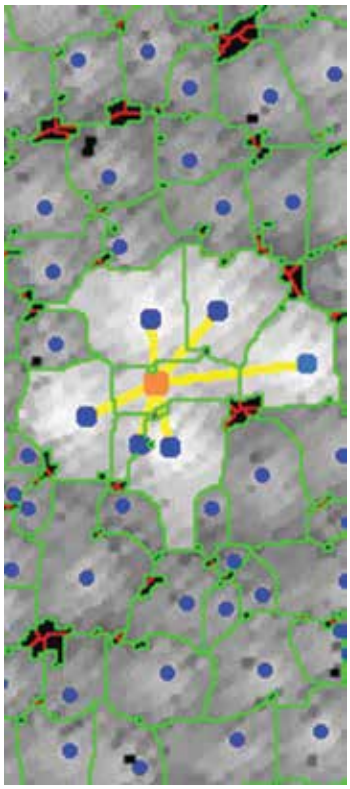
Forest Growers Levy Trust.

Nature versus nurture: using LiDAR to describe individual trees

Scion's Dr David Pont has developed a way of using LiDAR data to quantify the effects of competition and other site factors on the phenotype (physical characteristics) of individual trees. This advance is significant: David can now isolate the influence of genetics on phenotype from major environmental factors, including competition from neighbouring trees.

"The people who are really excited about this advance are geneticists," says David. "Being able to extract all the environmental noise from trial results means improved selections based on the genetic component of exceptional trees. Geneticists will have much more accurate information on the heritability of desired traits and will be able to accelerate the rate of genetic improvement.

"We now have the potential to develop a tool to interpret the effects of a tree's genetics in relation to specific site and silviculture influences," says David. "The next step will be incorporating this science into next-generation growth and yield models predicting log grades at the tree level."



LiDAR image of tree crowns showing how neighbouring trees are competing. LiDAR analysis such as this is enabling the effects of competition and other site factors on tree phenotype to be isolated from genetics. ▶

Low-input nursery practices

Scion's Dr Simeon Smaill is well-known for his research into ways to reduce both fertiliser and fungicide inputs in forest nurseries. Simeon believes that the high levels of chemicals conventionally used in nurseries suppress the activity of beneficial microbes associated with plant roots in the soil.

Dr Simeon Smaill at ArborGen's Tokoroa nursery.

In one operational-scale trial at ArborGen's Tokoroa nursery, fungicide input was reduced by 50%. The results in terms of tree growth and health were clear to see.

"The low-input seedlings were clearly better quality when they left the nursery gate," says Simeon.

Low-input seedlings have been planted out across some 50 trial sites nationwide, with some now 7-8 years old. Their survival and growth have varied between sites: the best-performing low-input seedlings are showing significantly better survival and growth rates than conventionally produced seedlings and in no case are the low-input seedlings performing worse than conventionally produced stock.

In another series of experiments, Simeon has been trialling a low-nitrogen fertiliser, 'biuret', in nurseries. Results of this work are also highly promising, with biuret producing faster-growing seedlings that are more efficient at acquiring nutrients and are also more tolerant to water stress.

From here, Simeon hopes to work with the nursery sector and forest growers to encourage collaboration that will continue to trial new, site-specific and low-input methods to produce high quality seedlings.

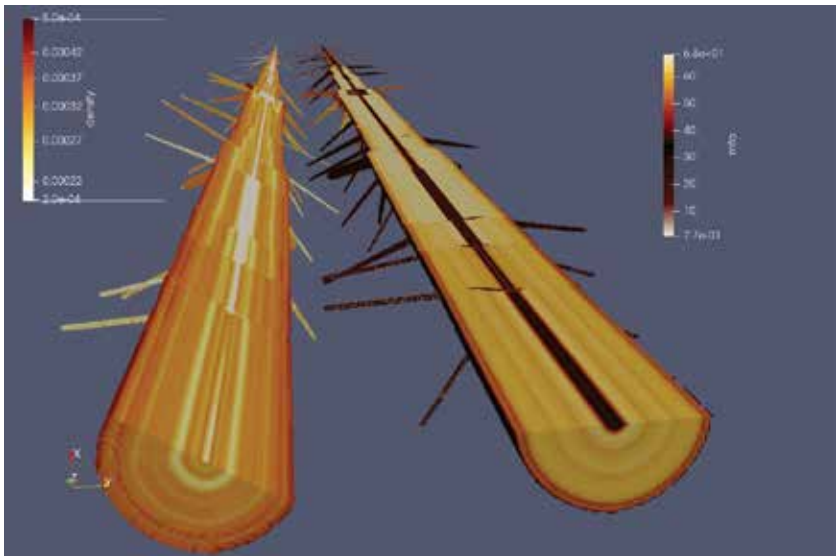
> *"None of us like using chemicals and Simeon has shown that you can reduce inputs in the nursery. It's important work and it is still early days. More work needs to be done."*
>
> Mark Ryan, Manager New Zealand Nurseries, ArborGen.

Modelling tree growth and wood formation

At present, forest growers lack detailed information on how factors such as site type and crop management affect timber properties. This is because, as yet, no-one really knows how trees grow from the inside.

Creating a model of internal tree growth and wood formation is a highly complex challenge, and has been taken up by Scion's Dr Damien Sellier. Damien has combined multiple computer models describing links between tree physiology, the growing environment, and wood properties and chemistry, and can now 'grow' the inside of radiata pine trees up to the age of around seven to eight years. Damien has tested the model using real trees, which was a big task, requiring multiple data sets from trees harvested in a Hawke's Bay trial, with encouraging results.

"We definitely understand a lot better now what is happening inside the stem and why," says Damien. "Ultimately the aim is to produce a tool that will enable growers to make the link between the quality of their product, and the growing environment. In future the hope is that they will be able to consider changes in management practices to improve timber quality."



Modelled outputs of stem density (left) and microfibril angle (right).

Alternatives to LiDAR for forest inventory

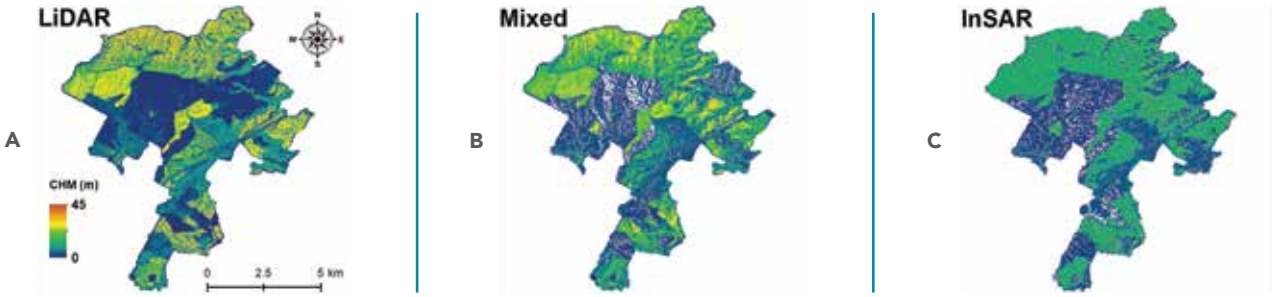
LiDAR is a valuable remote sensing tool, and provides very accurate information. It has its disadvantages, however – it is high cost (around $3 - 15 per hectare), is subject to lengthy turn-around times due to flight delays, and has long processing times.

InSAR (interferometric synthetic aperture radar) operates in the microwave region, so data capture is possible day or night, and regardless of cloud cover. It is also relatively cheap at around $0.16 per hectare. InSAR is already being used in other countries for forest data collection, but measuring New Zealand's forests does have some specific challenges, including very steep terrain and dense canopies.

Scion's Ellen Leonardo has recently compared InSAR and LiDAR data from Geraldine Forest, Canterbury. While LiDAR proved to be more precise than InSAR, the models derived from InSAR data for height and total stem volume were reasonably accurate, and could be improved by combining with data from other sources.

The Scion Geomatics team has also evaluated a third technique, satellite photogrammetry, for predicting forest inventory attributes. InSAR is the least expensive data source; satellite photogrammetry is more precise than InSAR, but it does not have InSAR's capability to create digital terrain models (DTM) over forests.

"InSAR may not be the most precise source of forest inventory information but it has its own advantages," says Ellen. "Forest managers should consider all factors when choosing the most suitable remote sensing system to use."



Canopy height models created using terrain and elevation datasets from different remote sensing technologies: (a) LiDAR only (b) mixed LiDAR and InSAR data sets, and (c) InSAR only.

Predicting site productivity: a new approach

A new tool to predict site productivity at high resolution has been developed at the University of Canterbury and is already enabling a more precise approach to forest management. The 'hybrid eco-physiological/mensurational model' has been developed by Professor Euan Mason, in collaboration with Swedish colleagues and several New Zealand forestry companies. By combining a suite of GIS-linked physical data about any given site, Euan has developed a way to accurately predict site index (and hence radiata pine growth) that does not require any inventory and is independent of genotype or silviculture. The model also indicates what factors are limiting productivity in different parts of a forest estate.

Model inputs include climate data from NIWA's virtual climate station network (VCSN), digital terrain and topographic information, and soils data. The model works by predicting radiation-use efficiency and underlying site productivity to produce site indices at 15m x 15m resolution. "Agriculture has been working at these levels of precision for some time," says Euan. "Forest managers now have a means of accurately predicting site productivity without measuring trees. It may allow them to better allocate alternative silvicultural regimes, and also understand where in their estates it might be feasible to increase productivity, for example by fertilising."

Several major NZ forest growers now have spatial layers developed by Euan for their own forests.

$ Forest Growers Levy Trust, Global Forest Partners, Nelson Forests Ltd, Port Blakely Ltd, Rayonier-Matariki Forests, Timberlands Ltd, Wenita Forest Products.

"I have used Euan's model to validate and adjust our site productivity layers that drive woodflow forecasts and thus the sustainable management of the Kaingaroa Timberlands estate. The model supports our efforts to improve productivity through site-specific deployment of genetics, silviculture and nutrient management. It also helps direct our soil and weather data acquisition programme."

Fred Schipper, Resource Planning Manager, Timberlands Ltd.

Applying fertiliser at mid-rotation

Trials to assess the cost-benefit of applying mid-rotation fertiliser have produced promising early results. The research is part of work aimed at gaining a much more precise understanding of trees' nutrient needs throughout a rotation, and evaluating the response to fertiliser supply.

Soil samples were taken at nine trial sites, from which growth-limiting nutrients were identified. A site-specific treatment and a standard urea (nitrogen) treatment were applied at each site, and tree growth responses have been measured for two years so far. Responses have been evaluated using the 'Forecaster' model. In 80% of cases, the site-specific treatment gave the greatest gains in stumpage, log grade and Net Present Value. On one site, predicted stumpage value increased by over $5,000/ha. Growers can expect to harvest earlier or take advantage of higher grade logs at the original harvest window, thanks to increased growth.

"We understand a lot more now about how the balance of key nutrients affects tree growth, and why growth slows during mid-rotation," says Scion's Graham Coker. "Basically, adding site-specific combinations of nutrients at the right time increases the carrying capacity of the site."

Graham is developing new regimes for identifying forest fertiliser requirements. A programme of foliar sampling at around years 4, 7 and 12 appears optimal, followed by late-rotation soil-sampling which would guide fertiliser applications for the following crop.

The industry is showing a keen interest in the work. "We already have keen forest managers coming to us, asking how to design mid-rotation fertiliser regimes," says Graham. "The days of growers simply shutting the gate once trees are established are coming to an end."

Trialling new UAV techniques for young-tree inventory.

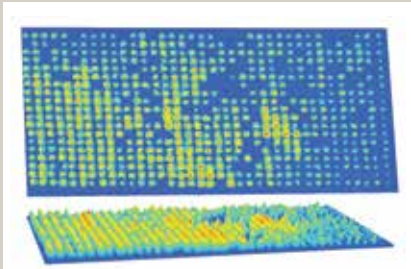
Using UAVs for young plantation inventory

Scientists looking at automated ways of counting and measuring young plantation trees have identified a UAV-camera-based, 'structure from motion' (SfM) technique as a highly promising method.

Scion's Dr Nathanael Melia explains: "The SfM process involves collecting video imagery and then feeding the overlapping aerial images into software. Complex algorithms carry out a range of feature recognition from different perspectives to create geolocation of features, and produce 2-D and 3-D outputs.

"We have succeeded in counting and measuring trees from around two to six metres in height using both SfM and UAV-based LiDAR. To date LiDAR has proved more accurate than SfM, especially in terms of measuring tree heights. SfM works well on clean sites, such as new planting on ex-grassland. We are looking at ways to increase tree-height accuracy on these sites, and developing methods of picking up trees in more complex sites like cut-overs."

The SfM technology is much cheaper and less technically complex than UAV-based LiDAR, the current industry standard for forest inventory. Nathanael is confident that ways to minimise the margin of error of SfM data can be developed, and forest owners could then potentially have a UAV-based tool for fast and cost-effective young tree inventory.



▲ Canopy height model.

▼ Tree peak detection and individual tree delineation model outputs.

Scion, ArborGen, Rayonier, Wenita Forest Products, Timberlands Ltd, Nelson Forest Ltd, University of Canterbury.

GCFF is a six-year (2013-2019) joint initiative between Scion, the Forest Growers Levy Trust, the forest growing industry and the Ministry of Business, Innovation and Employment. It has had an average budget of $5.1 million per annum.

https://gcff.nz

Licence to Operate

The forest industry needs a social licence to operate, and the research sector has a significant role to play in strengthening public approval of the industry's activities throughout the value chain.

The Helihawk slash grapple.

Cleaning the stream of slash – the Helihawk slash grapple

Mobilisation of woody debris ('slash') from wind-thrown trees, broken tops and branches, and residues from harvesting operations, is a high risk on steep, erodible terrain in intense rain storms. This debris blocks waterways and gets swept downstream, causing damage to the in-stream environment and to property, and risk to life.

The forest industry implemented a project to design, build and test a helicopter slash grapple to extract slash from streams before problems arise. The slash grapple, designed and built by Helihawk Ltd, was trialled in a steep, recently harvested radiata pine forest in the Gisborne region. The trial measured the cycle times and payloads of the helicopter using the slash grapple to grab loads of slash and spread it across the harvested cutover.

During the trial, the helicopter worked on different types of harvesting residues (old slash and logs, logs only, and fresh slash). Rates of slash extraction ranged from 16.2 - 18.5 tonnes per hour. The cost of extraction in the best conditions was $135/tonne. When spread across the volume of wood produced from the harvest area, the cost was only $1.05 per tonne of wood.

The research confirmed that helicopters are an effective but expensive method of slash extraction. In high-risk areas of steep terrain, this method of slash removal may well be preferable to manual slash extraction, which is very hazardous. It is also infinitely preferable to the cost of breaching resource consent conditions, or the risk of damaging debris flows.

Operating the Helihawk grapple in a steep gully.

"The grapple worked well in difficult operating environments – areas that would be too difficult or dangerous to clear otherwise – and the grapple productivity would likely increase the more hours the pilot operates it. It is best suited to clearing slash in the first three months post-harvest. I don't see it becoming a daily operation, more something to use in special or high-risk circumstances."

Hamish Macpherson, Operations Project Manager, PF Olsen Ltd.

Helihawk Ltd, Wairarapa Helicopters Ltd, PF Olsen Ltd.

Forest Growers Levy Trust.

Reducing tree breakage during felling

Trees often break when felled, and the broken pieces, which are usually too short or low-value to extract economically, are left where they fall, contributing to slash accumulation on the cutover.

FGR researchers compared two types of felling heads: (i) a 'dangle head' feller-director, and (ii) a 'fixed head' feller-buncher, to measure the difference in tree breakage rates between these two commercially available technologies.

Results showed conclusively that the fixed head machine caused less stem breakage than the dangle head. The average stem length of trees felled by the fixed head was 22.51 metres, compared to 16.05 metres for the dangle head. Analysis of the small-end-diameter distribution of the two samples showed a larger proportion of trees felled with the fixed head with smaller diameters, confirming that more of the total length of trees was harvested than by the dangle head.

TimberPro feller-buncher with Rosin KF800 fixed head.

Another trial showed that tree breakage could be reduced by changing the pattern in which trees are felled. Stems felled across the slope and uphill were longer than those stems that were felled downhill, indicating less breakage.

"While felling across the slope and uphill is difficult and hazardous for manual tree fallers, the same constraints do not apply to mechanical felling," says FGR's Keith Raymond. "This was a small sample however, and more work is needed to validate these initial findings."

Mechanised Cable Harvesting Ltd, Tasman Pine Forests Ltd, Nelson Management Ltd, Forest PhD Ltd.

Forest Growers Levy Trust.

Winning with Wildings

The major 'Winning with Wildings' research programme covers areas from invasion biology and ecology through social research to wilding management strategies and economics. The programme leader is Dr Duane Pelzer, Manaaki Whenua Landcare Research. The forest industry is contributing to work on wilding detection, herbicide application, and tree sterility. Social research has included surveys of both rural landowners and the general public to gauge their knowledge of, and attitudes towards, wildings.

Manaaki Whenua Landcare Research, Scion, Lincoln University, University of Canterbury, Nanyang Technological University (Singapore), Department of Conservation, Ministry for Primary Industries, Land Information NZ, NZ Wilding Conifer Management Group, CSIRO (Aus), NCAR (USA).

Ministry of Business, Innovation and Employment Endeavour Fund, Forest Growers Levy Trust.

Sterile Douglas-fir a real possibility

The forest industry is supporting research by Scion under the Winning with Wildings programme to develop sterile Douglas-fir so that planting in wilding-prone areas can continue. Scion's Dr Glenn Thorlby says good progress has been made, with the first potentially sterile seedlings in production.

Two techniques – transgenics (gene transfer) and gene editing – have been explored at Scion in the bid to create male-sterile Douglas-fir. Gene editing uses knowledge of the genetic make-up, or genome, of a species to tweak a gene that is already there rather than adding any new genes or DNA to control expression of a desired trait.

"Gene editing is likely to be the preferred technology," says Glenn. "Once we have succeeded in producing sterile trees, the next step will be to work with regulatory agencies to facilitate comprehensive field testing. After that an application will be made for their release to the forest industry."

Young trees engineered to be male sterile. These are the first set of plants produced and are growing in the contained glasshouse at Scion. Additional trees produced by gene editing and transgenics are at earlier stages in the production process.

Precision spraying using UAVs

UAVs have excellent potential for precision application of both herbicides and pesticides in forestry, including targeting individual trees – for example scattered wildings.

Scion's Dr Brian Richardson has been running trials to better understand the efficiency and effectiveness of spraying with UAVs. This research has included aspects such as quantifying rotor downwash, how operating factors (e.g. UAV speed, nozzle position, droplet size, meteorological factors) interact to influence the overall swath pattern, spray deposition and spray drift, and the overall accuracy and precision of the navigation systems.

A UAV designed specifically for spraying, the XAG, has been selected for further trials. "This UAV can be very precisely positioned and has a novel and effective approach to individual tree treatment," says Brian.

One goal scientists are working towards is to be able to programme a UAV to travel the shortest route around scattered trees such as wilding conifers (in theory already precisely located and measured by remote sensing technology), and accurately apply the minimum volume and dose of herbicide needed for each individual tree.

Dr Carol Rolando, a specialist in forest herbicides, is involved in this work. "Spraying individual trees is a completely different proposition to spraying large areas with a boom," says Carol. "A UAV does not have a big payload and may have to travel long distances between trees. We need to apply the minimum spray volume at the lowest dose rate possible. We are trialling various chemicals and adjuvants at different concentrations and on different-sized trees. Now we have confidence in some UAV technologies, we will move to field-scale trials this coming summer."

HeliResources, University of Canterbury, Plant Protection Chemistry, Aeronavics.

Ministry of Business, Innovation and Employment, Forest Growers Levy Trust.

Putting the XAG through its paces.

Dr Carol Rolando sets up plates to test spot-spraying accuracy.

World-leading insect detection

Researchers at Scion have developed some world-leading technology in the quest to quickly detect new unwanted insect pests close to entry ports.

Scion's lightweight portable electroantennogram (EAG) or 'cyborg' uses the sensors on a live male insect's antennae to detect females of the same species. The technology is incredibly sensitive, and in the lab has detected one nanogram of gypsy moth pheromones in a microlitre, one of the key achievements of the work to date.

The cyborg loaded with a male moth.

The prototype cyborg is mounted in a handheld device and uses wireless communications to send detection signals back to base. The prototype was designed for UAVs to carry and in the future the cyborg could be mounted on a UAV and sent to search for insects in tree canopies.

The focus so far has been on developing the cyborg to detect the gypsy moth – a known high-risk threat to the New Zealand forest and horticultural industries. "If we had an incursion of the gypsy moth now, it is plausible that we could use the cyborg to help detect it," says project leader Jessica Kerr.

Scion is collaborating with French and Canadian scientists, and Scion senior technician Brooke O'Connor has recently worked with the Canadian Forest Service to do some greenhouse and outdoor testing with gypsy moth and spruce budworm.

Brooke O'Connor testing the cyborg in Canada.

NRA, CNRS and LORIA (France); Natural Resources Canada (NRCAN).

Ministry for Business, Innovation and Employment Endeavour Fund, Forest Growers Levy Trust.

Testing water quality after mid-rotation fertiliser applications

Scion's Dr Brenda Baillie sampled water quality in forest streams in three forests with contrasting soil types before and after standard granular and experimental liquid foliar mid-rotation fertiliser applications. Samples were taken hourly on the day of application, and then with decreasing frequency thereafter.

The results showed that any impacts on water quality were short-term, and mainly confined to the day of fertiliser application. As anticipated, foliar fertiliser applications showed minimal impacts on water quality. Where increases in nitrogen and phosphorus concentrations in stream water were recorded, they occurred on the day of fertiliser application, several days after application, or during occasional rainfall events up to six months later. Concentrations of all nutrients were lower from liquid foliar fertiliser applications than standard fertiliser treatments.

"Water quality is a critical national issue in New Zealand and any innovations to improve forest productivity need to be within acceptable environmental limits. It is essential that the environmental impacts of mid-rotation fertiliser applications are monitored and understood," says Brenda. "These results will assist the forest industry in on-going improvement of environmental risk management practices and operational guidelines around aerial fertilisation."

Applying granular herbicide at mid-rotation.

Part of the GCFF programme (MBIE and Forest Growers Levy Trust).

Forest Health

FGR's forest health research team continues to make advances in the science and management of needle diseases, enabling better disease management, and selection and breeding for host resilience. Bioprotection – using natural organisms to increase tree productivity and resilience – is another important research area.

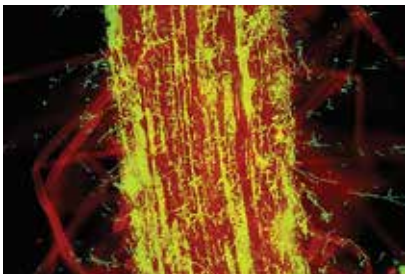
Dr Helen Whelan on-site in a Nelson forest.

Bioprotection: the power of natural soil fungi

Dr Helen Whelan, at Lincoln University's Bio-Protection Research Centre, leads forestry-related research into *Trichoderma* in New Zealand. *Trichoderma* are naturally occurring fungi which enter plant roots from the surrounding soil.

International research has shown that if the right beneficial *Trichoderma* fungi can be identified, isolated, and applied to plantation crops, there will be long-term protection from disease as well as enhanced vigour and stress tolerance.

Building on the promising findings of earlier small-scale trials, in 2018 Helen established a series of eight large-scale trials in forests in Gisborne, Northland, Bay of Plenty, Waikato and Nelson. Seedlings treated with the two best *Trichoderma* identified in the earlier trials were planted at low and high altitudes at each site. Monitoring for growth and tree health is already underway, and the forest owners hosting the trials are showing keen interest in the research.



Stained with fluorescent dye, *Trichoderma hyphae* growing in a radiata pine root.

Helen also has numerous other research projects on the go (see below), as owners of both small and large forests become aware of the good news story that *Trichoderma* seems to be.

> *"This research has huge potential. It could be a game changer. If we can get Trichoderma to increase canker resistance – we don't need to eliminate it all together – then that would be fantastic."*
>
> Patrick Milne, NZFFA Executive and Southern Cypresses Ltd.

PF Olsen Ltd, Timberlands Te Ngae Nursery, Juken NZ Ltd, Hancock Forest Management (NZ) Ltd, Nelson Forests Ltd, Rayonier-Matariki Forests.

Forest Growers Levy Trust.

***Trichoderma* Project**	**Early Results**
Testing the benefits of ***Trichoderma*** on hard-to-root radiata pine clones.	Significant improvement in the percentage of rootable cuttings following application.
Identifying ***Trichoderma*** that are adapted to warm and cold climates, and that increase drought tolerance.	Increased understanding of the root ***Trichoderma*** present in NZ plantation trees. Eventual outcome could be production of seedlings suited to particular sites.
Promoting Douglas-fir growth and health.	Greatly enhanced seedling growth in the nursery. D-fir highly compatible with ***Trichoderma*** applied.
Seeking canker resistance in cypresses.	Two small pilot trials underway – seedlings of three cypress species inoculated and planted close to a canker-infected ***C. macrocarpa*** shelterbelt.
Applying ***Trichoderma*** to established forest trees.	Application techniques being tested are stem and root injections and foliar sprays. Early results promising.

Healthy Trees Healthy Future

The Healthy Trees, Healthy Future research programme (HTHF) is a $10 million cross-sector programme studying *Phytophthora* diseases. The programme draws to a close at the end of 2019, with notable advances in both molecular research and science which will benefit the forest industry.

Red needle cast (RNC) disease of radiata pine.

Red needle cast: a significant challenge

Red needle cast (RNC) is now a widespread disease of radiata pine, caused by *Phytophthora pluvialis*. Growth losses of up to 40% have been recorded after a bad season. The HTHF team has put considerable research effort into understanding the biology of the disease, and developing tools and decision support for owners to assist in its prevention and management.

Key RNC Activity	Major Outcomes
Developing cost-effective control measures.	Copper identified as best control option with ongoing optimisation of timing and dose rates of aerial application from ongoing operational trials. Forest industry already applying copper in worst-affected areas, more guidance to come.
Detecting and monitoring RNC using remote sensing.	Capability of different remote sensing technologies to detect and monitor disease including satellite (RapidEye and Sentinel) and UAV alternatives analysed. New oblique imagery also under investigation: guidance on best options available for forest owners in this rapidly developing field.
Supporting forest owners' disease prevention and management decisions.	Two models to assist growers under development: (i) decision support for basic spray cost-benefit/prescriptions, and (ii) integrated predictive model, which will test spraying options for specific forests in different locations into the future.
Breeding for resistance.	RNC resistance data being used by tree breeders with latest genomics breeding technology to develop new radiata pine genotypes which are resistant to RNC as well as *Dothistroma* and *Cyclaneusma*. Resistant planting stock will be released via the Radiata Pine Breeding Company after full testing.

New *Phytopthora* species identified

A new *Phytophtora* species, *Phytopthora aleatoria*, discovered during a routine survey in a Nelson forest, has been formally recognised following identification by Scion and Plant and Food Research.

P. aleatoria is a soil-borne pathogen, and causes basal lesions on the stem and resin bleeding in radiata pine. The species has now been confirmed as being present on radiata pine across a range of sites in both the North and South Islands. While not yet giving cause for concern, formal scientific identification is an important first step in planning for the pathogen's control, should this become necessary.

"The point we want to make to forest growers is that a first critical step in ensuring good forest health is knowing exactly what pathogen you are dealing with," says Scion's Dr Nari Williams, HTHF programme leader. "*P. aleatoria* is a significantly different species from other *Phytophthora* associated with radiata pine, including *P. pluvialis* (the cause of red needle cast) and *P. cactorum* which impacts horticultural crops. We are looking to better understand the distribution and impact of *P. aleatoria* so that we can determine appropriate management strategies. New Zealand is not alone in trying to understand this group of highly damaging pathogens, with our international collaborations identifying several distinct pathogens impacting tree hosts which were formerly grouped with *P. cactorum*."

> *"This programme has not only enabled the development of knowledge, technology and research capability for red needle cast, but has also built a platform for dealing with other diseases either present or not yet present in New Zealand. This is important to ensure we continue to have a resilient forest industry."*
>
> Mike Baker, Technical Forestry Manager, Hancock Forest Management (NZ) Ltd.

▲ Branch dieback with a canker on a two-year old *P. radiata* tree in Nelson, associated with *P. aleatoria*.

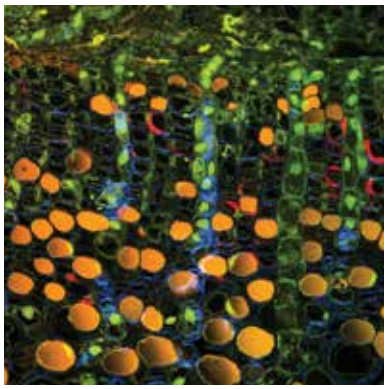
▼ Stem bleeding cankers associated with *Phytophthora aleatoria* on five-year-old *P. radiata* trees growing in Motueka Gorge, in the Nelson Region.

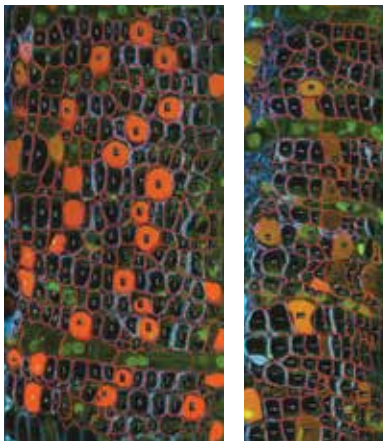
The inner workings of red needle cast

The most obvious signs that a tree is infected with red needle cast (RNC) are needle colour change and then defoliation. Researchers at Scion are exploring the associated impacts of RNC on the vascular tissue (phloem) responsible for transporting carbohydrates produced during photosynthesis from the crown to the rest of the tree.

Fluorescence microscopy was used to capture images of the phloem of radiata pine grafts infected with RNC and compared with uninfected grafts. The images showed a reduction in photosynthate carrying capacity but also changes in cell organisation in infected plants.

"Ultimately we hope to be able to quantify the productivity loss associated with the pathogen's presence depending on environment and silviculture," says Scion's Dr Damien Sellier. "The information will also contribute towards other models, including carbon transport, tree growth and wood formation."





▲ Cross-section of phloem (inner bark) of a control sapling (left) and an infected sapling (right).

◀ Cross-section of the food-conducting tissue (phloem) in a 1-year-old *P. radiata* graft. Orange cells are tannin-filled parenchyma cells. Rectangle-shaped cells are the pathway for sap and photoassimilates.

Fighting kauri dieback

Kauri dieback is caused by *Phytophthora agathidicida*, so the HTHF team's expertise in *Phytophthora* is proving valuable in a major collaborative project to control this disease.

An extensive kauri seed collection across the upper North Island was completed in 2018. Specialist tree climbers collected seed from over 600 trees. A portion of the seed from each tree is being raised by Scion in a specially commissioned kauri polyhouse; the remainder will go into a seed bank for use in future research, field trials or restoration.

Once the seedlings are 15 months old, they are transferred to Manaaki Whenua Landcare Research laboratories, where the first phase of work on identifying resistance is undertaken. Although it is very early days, the research gives hope for the future of one of New Zealand's most treasured native species.

A number of mana whenua (Māori) groups, Scion, Manaaki Whenua Landcare Research, Auckland University of Technology, Plant and Food Research.

Ministry of Business, Innovation and Employment, Kauri Dieback Programme.

Understanding environmental drivers of diseases

Douglas-fir growers in some parts of New Zealand have unfortunately seen the emergence of a new needle disease caused by *Phytophthora pluvialis*, the pathogen responsible for red needle cast (RNC) in radiata pine. Scientists in both New Zealand and US Pacific Northwest are keen to learn what environmental drivers are allowing the disease to develop, as well as how RNC interacts with Swiss needle cast *(Phaeocryptopus gaeumannii)* a well-established Douglas-fir disease in some regions.

Scion's Dr Mireia Gomez-Gallego worked with US colleagues to sample Douglas-fir over a range of climatic environments in both New Zealand and Oregon. The results showed that both pathogens are more abundant, and positively correlated, in New Zealand, compared with their home Oregon environment.

These studies started to elucidate a picture relating disease development to a winter temperature gradient, and found that at the low winter temperatures experienced in Oregon, the disease's development was inhibited, whereas winter temperatures in New Zealand Douglas-fir plantations are not cold enough to inhibit the disease. The findings will contribute towards enabling scientists to predict the areas at greatest risk of disease, both now and under various models of climate change.

Scion's Dr Mireia Gomez-Gallego collecting Douglas-fir needles in Oregon.

Specialty Wood Species

FGR research on specialty species is managed by the Specialty Wood Products Research Partnership (SWP). Species included are Douglas-fir, durable and non-durable eucalypts, and cypresses. The SWP aims to create an industry generating $350 million of exports by 2030, providing regional opportunities for employment, Māori forestry and wood manufacturing.

PhD student Daniel Boczniewicz assesses heartwood in 29-year-old *E. globoidea*.

Durable eucalypts: strategy 2020-2030

Durable eucalypt research and development are managed by the NZ Dryland Forests Initiative (NZDFI). The NZDFI team has recently produced a strategy looking out to 2030: 'Durable eucalypts: A multi-regional opportunity for New Zealand's drylands.' The strategy outlines how, through producing improved planting stock, developing markets and working with landowners, the NZDFI will move towards its vision of sustainable durable hardwood industries in the regions.

Planting a new trial at the Dillon's property, Marlborough.

PhD student Ebenezer Iyiola takes cores from *E. globoidea* to measure heartwood content of the young trees.

Focus areas: NZDFI strategy 2020-2030

- Identifying markets for durable eucalypts
- Modelling forest productivity and economic feasibility
- Working regionally to encourage new forests
- Breeding, propagation and trial management
- Educating growers on durable eucalypt forest management
- Industry partnerships to build support and capability.

The NZDFI established eight more demonstration trials in new regions in 2018 to extend the range of site types and climatic zones covered by its extensive trial network. Four new PhD students began research at the University of Canterbury in 2018 and 2019, with topics ranging from wood quality through growth modelling and physiology to essential oils. Over 30 post-graduate and under-graduate students have been involved in NZDFI work to date.

Peeling trials show durable eucalypts' potential for engineered wood

Durable eucalypts produce timber of relatively high stiffness, even at young age. Producers of engineered wood products such as laminated veneer lumber (LVL) are looking at options for new high stiffness LVL products that can't be made from radiata pine. These new products can open up more markets for LVL.

A recent trial run by the University of Canterbury (UC) involved rotary peeling of 15-year-old *Eucalyptus bosistoana* and *E. quadrangulata* logs at Nelson Pine Industries in Richmond. Logs were peeled, and the veneers returned to UC for analysis.

Results were encouraging, indicating for example the average stiffness of *E. bosistoana* veneer that was peeled is twice that of mature radiata. Also the peeling trial produced 80mm cores that could have a market as ground durable vineyard posts. In future the use of spindle-less lathes for the peeling process could greatly enhance veneer recovery from small logs.

The next phase of research at UC will look at suitable gluing techniques for the eucalypt veneers.

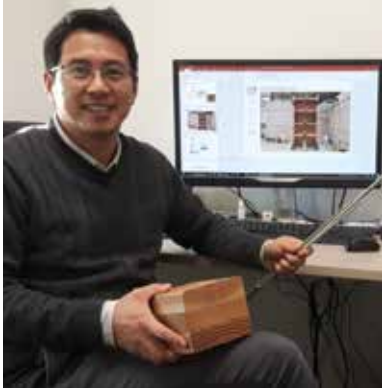
Logs ready for peeling at Nelson Pine Industries.

www.nzdfi.org.nz

> *"To increase resilience the forest industry needs to diversify away from a radiata pine monoculture. For us, durable eucalypts are a potential alternative, with applications in both engineered wood and solid wood product lines."*
>
> Sean McBride, Wairarapa Forest Manager, Juken NZ Ltd.

Representative veneers of 15-year-old *E. bosistoana* (left) and *E. quadrangulata* (right) grown in New Zealand.

Douglas-fir cross-laminated timber in building design



Engineering research at the University of Canterbury (UC) is investigating robust building design using cross-laminated timber (CLT) made from NZ-grown Douglas-fir. Earlier studies confirmed the strength properties of the product; the focus now is on developing efficient lateral-load resisting systems for CLT buildings to minimise earthquake damage. This requires strong and stiff CLT products and reliable connection systems between CLT panels.

The university's structural engineering team has been using the full height of strong reaction walls in the lab to test a four-storey C-shaped CLT wall structure. Long, self-tapping screws were used to connect the CLT panels. The team then applied lateral loads on the top of the wall structure to evaluate its performance under simulated earthquake conditions.

"We are very pleased with the results," says Dr Minghao Li, UC Department of Engineering. "The test wall achieved very high load-carrying capacity with these strong and rigid screwed connections. We have confidence that we can build strong CLT buildings with NZ-grown Douglas-fir."

The aim is to build a comprehensive database of the properties of Douglas-fir CLT, and the various connecting screws being tested, so that they can eventually be approved under the NZ Building Code. The research has received contributions from a wide range of both New Zealand and Australian sources.

▲ Dr Minghao Li with a sample of D-fir CLT and an example of the screws used to connect CLT panels.
◀ The CLT structure in the UC engineering lab, with PhD students and staff. Lateral loads are applied by the mechanism at the top right of the structure.

Genotyping Douglas-fir

Scion's tree breeders are working on Douglas-fir genetic improvement, with potential seen to increase both wood quality and tolerance to Swiss needle cast. One thousand superior trees have been selected from each of two large D-fir plantations, one in the North Island and one in the South Island. These trees will have their genotype described as a precursor to an accelerated breeding programme. Targets include shortening the D-fir rotation, increasing total recoverable yield, and increasing disease tolerance of plantation crops.

Investigating the sawing potential of young cypress

A new study is looking at whether young, unpruned cypress trees can be cost-effectively sawn into products suitable for high-value joinery and laminated timber markets. Thirty six logs from six trees each of 20-year-old *C. ovensii* and *C. lusitanica* trees were milled recently at Ruapehu Sawmills in the central North Island.

Scion's Rosie Sargent supervised operations: "The sawing went well, with a green recovery of 58% (the volume of wet timber compared to the volume of logs). The boards looked very good with the majority having small live knots, and very few black knots or holes", reports Rosie.

The wood will now air dry for the next few months before being graded.

Cypress boards after bandsawing, waiting to be edge-sawn.

"I've built three houses from macrocarpa – as a timber I like it a lot. Things need to be trialled, and there's nothing like trials in our own environment to test the viability of new genetics. In future people are going to prefer naturally durable timbers that don't need to be chemically treated."

Randal Cornish, Wairarapa farm forester and large-scale cypress trial host.

New trials aim to renew confidence in cypress

The winter of 2019 will see two different sets of cypress trials going into the ground – the culmination of work by Scion's tree breeders over several decades.

Breeders have identified a number of *Cupressus macrocarpa* genotypes believed to have good canker tolerance. Three large-scale trials will be planted at sites in the North Island and be fully monitored into the future. The aim eventually is to release new, canker-tolerant macrocarpa planting stock for growers.

Other trials involve a recently commercially released collection of 12 cypress hybrids. The hybrids are crosses between either *C. macrocarpa* or *C. lusitanica* with the more canker resistant *C. nootkatensis* to produce Leyland and Ovensii hybrids respectively. Scion has been trialling the new hybrids since 2014 with promising results, and in 2019 up to 60 farm foresters nationwide will plant research packs of 100 trees.

These small-scale trials are being managed by the Cypress Action Group of the NZ Farm Forestry Association, with the aim of renewing farm forester confidence in cypresses as a potentially high-value alternative to radiata pine.

Thermal modification of specialty species

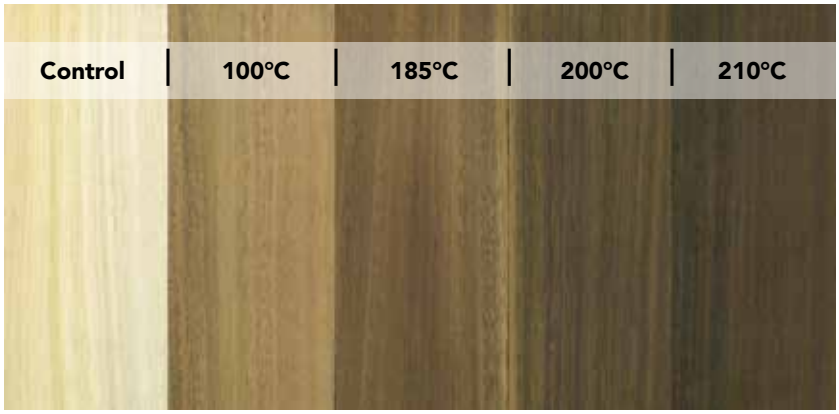
Scion's wood scientists have been looking at the potential of thermal modification to increase the market opportunities for three specialty species – *Eucalyptus nitens*, Douglas-fir, and cypresses.

The modification process involves heating the wood, sometimes in a steam atmosphere, in a lab-scale kiln. Temperatures range from 150°C – 210°C.

Benefits can include increased wood durability, enhanced dimensional stability, and darker wood colour. Problems can arise with wood becoming more brittle and cracking.

Most work has been done on *E. nitens*, which is mainly grown for low-value pulp and paper markets in New Zealand. The results have been mixed according to Scion's Rosie Sargent. "The major advantage of thermal modification in *E. nitens* is to increase its dimensional stability, meaning it would be more stable for uses such as indoor joinery and flooring than unmodified wood. The significant colour changes which occur at different temperatures may also appeal to some markets. Unfortunately, there is only a small increase in durability – not enough to allow for outdoor use."

Rosie reports that, by adjusting the heating technique, early problems with brittleness have been overcome.



Colour change of modified *E. nitens* boards at each modification temperature.

With cypresses, initial durability results are more encouraging, with the durability of both the non-durable sapwood and (relatively) durable heartwood increasing with thermal modification. Similarly, early tests on Douglas-fir suggest its durability may be enhanced by thermal modification.

SWP; Scion core funding.

Acknowledgements

The Specialty Wood Products Research Partnership (SWP) is a seven-year, $14 million industry/government partnership which runs from 2015 - 2022.

SWP members

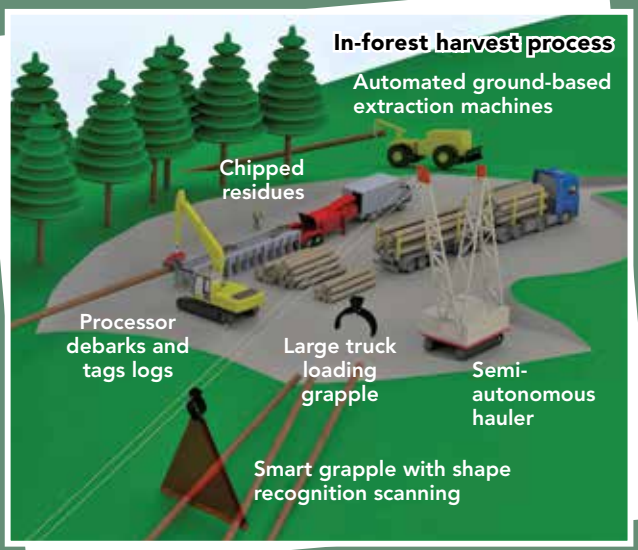
Ministry of Business, Innovation and Employment, Forest Growers Levy Trust, Southwood Export & Southland Plantation Forest Company, Juken NZ Ltd, Proseed Ltd, Ernslaw One, New Zealand Farm Forestry Association, Timberlands Ltd, Lake Taupo and Rotoaira Forest Trusts, Te Tumu Paeroa, Port Blakely Ltd, City Forests Ltd, Marlborough Lines, Vineyard Timbers Ltd.

SWP research organisations

Scion (which also contributes aligned core funding), University of Canterbury, Marlborough Research Centre.

Forest Harvesting

Levy-funded research is helping the industry's aim of moving to safe, fully mechanised harvesting on all site types to become a reality. The harvesting research programme has a strong history of industry involvement, and a second major government/industry research partnership will capitalise on this.



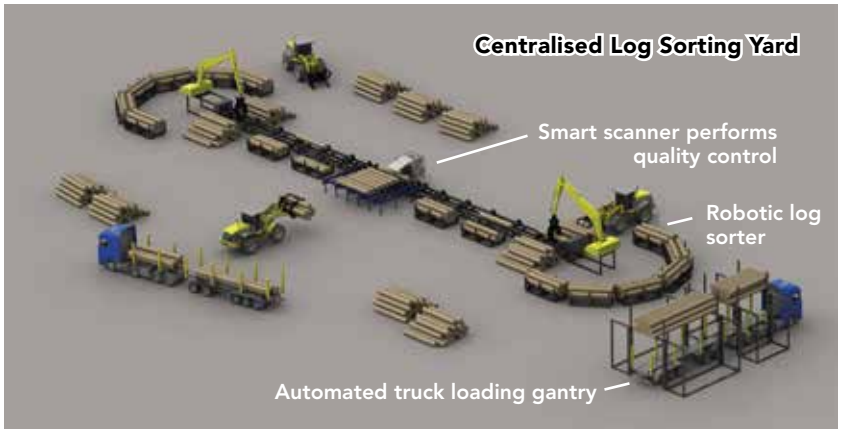
Forestry Work in the Modern Age

Forestry Work in the Modern Age: Te Mahi Ngahere i te Ao Hurihuri is an ambitious new Primary Growth Partnership (PGP), aimed at developing innovative automated harvesting and log handling systems. The programme follows on from the successful Steepland Harvesting PGP (2010-2017). It will complement the industry's rapid advance towards full mechanisation and will particularly benefit owners of smaller forests and woodlots.

A partnership between manufacturers, forestry companies and contractors will drive the design, build and commercialisation of a range of new technologies. The vision is to create a new harvest process, where fully mechanised and automated harvesting crews will manufacture logs, but no sorting will be done on the forest landing. Mixed grade logs will be transported to a separate, centralised log sort yard, with automated sorting and truck loading facilities. This will reduce total machinery and space requirements needed in the forest, reduce environmental impacts, and skim an estimated $6/m^3 off log production costs.

At the sort yard, logs will be scanned and sorted using robotic technologies. Logging trucks will be loaded by an automated loading gantry, reducing loading time. Benefits from sort yard efficiencies, including eliminating log weighing and scaling, reduced transport delays, and increased use of high productivity motor vehicle (HPMV) log transport, will add a further estimated $3/m^3 in cost savings for the grower.

The seven-year programme will be managed by Keith Raymond, FGR Harvesting and Logistics Programme Manager.



Five new forest technologies on the landing, and four sort yard technologies, have been identified for development. Prototype design will begin in late 2019 with manufacturing commencing in 2020, moving to commercialisation from 2022 onwards.

> *"Technology is coming on in leaps and bounds and the industry needs to keep up, so it's great to see research investment going into the right place. Also any cost reduction is a help to growers, and in these days of the National Environmental Standards, the less earthworks in the forest, the better."*
>
> Marcus Musson, Director, Forest360.

New technologies suit smaller forests and woodlots

In cable logging, felled tree stems are usually pulled up-slope to forest landings by haulers or 'yarders'. A 2018 survey of cable harvesting contractors confirmed that the industry is moving away from large tower haulers to swing yarders and smaller excavator-based yarders (often called 'shovel yarders'). These machines are more mobile, and require much smaller landings than tower haulers, and so are better suited to smaller forests on difficult terrain.

An innovative excavator-based yarder, the Alpine Shovel Yarder, was recently introduced to New Zealand by Alpine Logging Equipment Ltd, which will distribute the machine here and in Australia. The machine can work roadside in small inaccessible areas, or areas uneconomic to log with a large tower hauler or swing yarder. When coupled with a remote controlled hydraulic grapple, like the Alpine Grapple Carriage, the Alpine Shovel Yarder is suitable for uphill or downhill grapple yarding.

The Alpine Shovel Yarder in action.

FGR has an agreement in principle to collaborate with Alpine Logging Equipment to develop a prototype automated yarding system using the Alpine Shovel Yarder and Alpine Grapple Carriage as part of the 'Forestry Work in the Modern Age' PGP programme.

Integrated residue harvesting: a promising option

Forest residues are a common sight in harvesting operations. The highly mechanised harvesting and log sorting systems envisaged in the 'Forestry Work in the Modern Age' programme will provide options for salvaging forest residues such as offcuts and reject logs, as an integrated part of the harvesting process.

Harvest residues on site.

Clean woodchips suitable for heat and processing markets.

The proposed centralised log sort yards will have a concentrated volume of residues in one place and can be designed to have sufficient space to run a residue management system.

Over the past year, University of Canterbury (UC) researchers have reviewed integrated forest residue harvesting systems in North America and Europe. A range of technologies is used overseas to process residues alongside conventional harvesting and log sorting, producing uniform quality products. The research team believes that new residue processing infrastructure in log sort yards could be highly efficient, and capitalise on technology already developed and tested overseas.

Designing residue harvesting systems will have its challenges, however – not least in terms of meeting specifications of current markets and developing new markets. The impact of residue harvesting on mainstream log production, and the cost, value, and efficiency of the overall supply chain, are also fundamental factors to consider.

The PGP will fund three years' further research at UC into residue management and biomass processing options.

Partners:

Forestry Work in the Modern Age is a Primary Growth Partnership between the Ministry for Primary Industries and the forest industry. Total funding is $29.36 million, with 40% contributed by MPI, the remainder by industry.

Harvest industry benchmarking studies

The cost and productivity of harvesting operations has been recorded and reported over the last ten years, thanks to regular benchmarking surveys by Prof Rien Visser at the University of Canterbury (UC) School of Forestry. The annual surveys record the many attributes of harvesting operations, such as the stand and crop factors, and machinery and labour inputs. Data are provided annually by harvest planners from the industry, and enable productivity and costs to be tracked over time and by region, broken down by harvest system type.

A winch-assisted harvester heads down-slope.

Surveys of cable yarding and ground-based harvesting across the whole of New Zealand were also recently completed. These surveys confirm that new technology is being widely adopted by the harvesting sector. For example, around 50% of cable operations are now using either mechanical grapples or the new hydraulic grapple carriages to extract logs to the landing. Over 35% of operations on steep slopes are using winch-assisted felling machines. These changes, partly driven by the industry's desire to improve safety, will continue to trigger further mechanisation and automation along the value chain.

"The surveys are extremely beneficial internally for the industry – for example for benchmarking performance and for goal-setting on costs and productivity," says Rien. "On a broader scale, we can evaluate changes, such as the level of mechanisation and impacts of new technologies, over time." Rien says that few, if any, other countries have such good long-term data, and the New Zealand surveys are the envy of international colleagues.

Forest Growers Research, Forest Growers Levy Trust.

How to harvest and market your woodlot for profit

A new toolkit for woodlot owners is being launched, comprising a handbook and a linked on-line calculator. The handbook – 'How to Harvest and Market Your Woodlot for Profit' – is an updated edition of a booklet produced some 25 years ago by Dr Glen Murphy, of G E Murphy & Associates Ltd. This time round, Glen has teamed up with Prof Rien Visser at the UC School of Forestry. Data from the UC survey database have been used to underpin the resources.

> *"There is more money to be gained or lost at harvest than at any other time in the life of a forest," says Glen. "Owners need to be aware of the key steps and variables in what is a complex process."*
>
> Dr Glen Murphy, G E Murphy & Associates Ltd.

Woodlot owners can work through case studies, or enter geographic and other data about their own woodlot, into the online tool, and run harvesting scenarios. Indicative outcomes are generated – for example on gross revenues and all costs involved in getting logs from the forest to market.

Glen emphasises that the toolkit only provides a precursor to the information generated by harvesting professionals working on-site. "Our intention is to give woodlot owners a strong foundation from which to approach harvesting. From here they can work with professionals and engage in the process with more knowledge."

Forest Growers Research, Forest Growers Levy Trust.

Developing harvester simulator training

As forest harvesting becomes increasingly mechanised and automated, new entrants and existing crew need to be trained and upskilled so they can handle advanced and expensive equipment. A critical role in mechanised forestry is operating harvester-processors.

On a recent study trip to Finland, James Broadley, Toi Ohomai Institute of Technology forest management tutor, learnt about the comprehensive Finnish approach to training harvester operators using harvesting simulators. Toi Ohomai was an early adopter of simulators for use in its range of forestry courses.

Toi Ohomai's Richard Stringfellow oversees simulator training.

> *"I see many benefits for NZFFA members coming from the programmes managed by FGR. In particular the new PGP project on automation and robotics in log harvesting and sorting, and the concept of a centralised site, has the potential to lower harvesting costs for small-scale growers."*
>
> Neil Cullen, Vice-President, NZ Farm Forestry Association.

James' conclusion was that, in addition to operational skills, the key to high productivity was for operators to have a full understanding of value-recovery principles, and be part of a strong inter-linked communications chain involving wood-flow planners, supervisors, and contractors.

Forest Growers Levy Trust.

James Broadley using the Timberskills training package on the John Deere cut-to-length simulator.

Extreme Fire

The Scion Rural Fire Group works to develop the science and technology needed to understand and manage fire in rural landscapes. The risk of extreme fire is now a fact of life for New Zealand's forest growers; the challenge is to find ways to minimise that risk and protect life and property. The Rural Fire Group is mid-way through a five-year research programme, and outputs are already being delivered.

The Pigeon Valley ablaze.

Validating new theories of convective heat transfer

Work to validate new theories about convective heat transfer at the front of fires is underway at Scion, in collaboration with USA fire scientists. The team is undertaking a series of highly instrumented experimental vegetation burns, progressing through a series of fuel types. So far they have run two sets of successful crop stubble burns.

During the burns specialised UAV-mounted cameras recorded high definition video from all angles. For the first time it was possible to see how flame fronts pulsed regularly as the fires moved forward. University of Canterbury researchers produced ground-breaking infra-red imagery showing how heat travels ahead of flames.

Grant Pearce, senior fire scientist at Scion, says the burns have produced exciting results using new instrumentation. "Our initial results back the hypothesis that fire-induced turbulence above the flame zone pushes flames down and into the fuels, and ignites and spreads the fire almost by direct flame contact. This contrasts with conventional theory that fire is spread by radiative heat transfer."

The next phase will be to scale up the experiments, with burns planned in gorse and then wilding trees. This will allow scientists to investigate whether larger fires produce different results.

Experimental stubble burns at different scales.

Linking real-time decision support tools

By linking and automating several stand-alone satellite and ground-based tools into one real-time system, scientists will provide powerful decision support for fire operations teams and other emergency services.

Fire detection is the first component of the system: using satellite-based tools to detect new fire starts in reasonable time is now an achievable objective. Satellite data will be combined with other evidence such as 111 calls to confirm a definite fire start. This will trigger the second phase – collecting real-time high-resolution weather data from numerous sources and linking it into Scion's Prometheus fire growth model. Based on various site-specific data inputs, Prometheus predicts the direction and speed of fire travel. Scion's work has included developing the capability of Prometheus to run multiple simulations based on different weather scenarios. This work is nearing completion, with a prototype ready for testing over the 2019/20 fire season.

The third key component is the BlueSky smoke model, which is already in use. BlueSky was used extensively at the 2019 Pigeon Valley fires, and also during several hazardous waste fires in other parts of New Zealand. One output of BlueSky is videos which show forecasts of smoke movement, colour-coded to describe the smoke concentration in different areas. The videos can be posted on the internet to help guide decisions by authorities about evacuations, and trigger health warnings where smoke may affect residential or industrial areas.

By 2020 Scion expects to have a prototype of the complete tool-suite ready to trial with Fire and Emergency NZ (FENZ). FENZ is likely to eventually run the models as part of its day-to-day operations, giving it better, faster, information on fire occurrence, spread and potential impacts.

BlueSky outputs: smoke movement during the Pigeon Valley fires near Nelson, colour-coded to show concentration.

The Pigeon Valley fires: operational support

Scion's fire scientists are regularly called upon to join incident management teams when serious rural fires break out in New Zealand. During the February 2019 Pigeon Valley fires, Scion's Veronica Clifford was embedded in the FENZ-led incident management team. Veronica spent the best part of two weeks using tools developed by Scion and collaborators to help support fire operations.

The fires exhibited 'extreme fire' behaviour, burning with high intensity, producing flames up to 30 metres high, and throwing embers 500 metres or more ahead of the spreading flame front. At these levels of intensity, the fire was unstoppable using any of the fire-fighting methods available, so the fire-fighting strategy was a defensive one, evacuating people, protecting properties, and attempting to limit the spread of the fire around its boundaries.

> *"It was really good to get scientific expertise around how the fire was going to behave. In fact it's a shame they [Scion] weren't there right from the start of the fire. That is when their input would have most value."*
>
> Steve Chandler,
> Chief Operating Officer,
> Tasman Pine Forests.

The Pigeon Valley incident room.

During the fires, Veronica was running the Prometheus model together with data obtained from drone infra-red hotspot detection to predict the potential for fire flare-ups and escapes. This information was critical to decisions on evacuations and road closures, and the process for re-entry of evacuated properties. The Scion team also ran the BlueSky model frequently to produce smoke predictions that were used by fire, civil defence and public health agencies to inform the public of potential health issues.

Being part of the operational team during fires provides the best possible opportunity for Scion's fire research team to test their models under real conditions. The team has been asked by FENZ to provide a summary of the fire environment factors contributing to the Pigeon Valley fires, to assist the operational review of the incident. Back at base, the team also has the ability to 'reconstruct' fires after the event, which enables them to gain a better understanding of what happened and why.

Other fire research under the MBIE/levy-funded programme

- Investigating new fire-fighting tools and technologies: research includes developing smart thermal sensor networks, and investigating the potential for automation and robotics in some aspects of fire-fighting.
- Preparing rural communities for extreme fire: Scion is working with rural Māori communities to gain understanding of their attitude to protecting assets from fire, and assisting them to protect those assets in case of fire.

Scion, US Forest Service, San Jose State University, University of New South Wales, Canterbury University, Alberta Agriculture and Forestry (Prometheus), The Nature Conservancy, Te Tira Whakamātaki (The Maori Biosecurity Network), Fire and Emergency New Zealand (FENZ).

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http://www.ruralfireresearch.co.nz/, https://ruralfireresearch.wordpress.com/

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