FOREST GROWERS RESEARCH

Science Report

2023

supported by forestgrowers commodity levy

PAGE

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ISSN 2537-9305 (Print)
ISSN 2537-9313 (Online)

Forest Growers Research Ltd
99 Sala Street
Rotorua 3010

+64 7 921 1883
forestgrowersresearch@fgr.nz
www.fgr.nz

Foreword

A year ago the Forest Growers' Research conference was buoyant. International prospects were bright. The Minister of Forests was armed with funds for direct government investment. Our pandemic rebound had been unexpectedly speedy.

Our so-called 'social licence' was underpinned by the necessity of carbon capture. Changes in harvesting practices were expected to reduce the likelihood of another 'slash' discharge onto public and private property.

How times change. It would be idle to expand on Gabrielle's impact. China's tightening has cut harvesting to around 30% below last year's forecasts. The corresponding reduction in Forest Growers Levy Trust income for research and other investment will unavoidably hurt. We have some reserves and we can borrow to smooth cycles. But we owe it to the levy payers (and to ourselves) to try to focus cuts where there is most likely to be fat.

So let's consider where spending might be redirected. A long overdue unbanning of genetic 'engineering' should electrify New Zealand researchers. Still, politicians could choke or fail even when they think they are ending the ban. EPA permission hurdles could mean nothing much will change in practice and we continue to just watch the world pass.

> "We are treated as a woke laughing stock by some of the world's most influential science writers. Has it already affected your recruitment to New Zealand?"

Ending that irrational ban should not only open up new possibilities for control of pests and wildings. It should also boost your animal spirits. Will you be spurred to challenge other blights on the international reputation of our science and academia? We are treated as a woke laughing stock by some of the world's most influential science writers. Has it already affected your recruitment to New Zealand?

If your projects or careers need the 'accreditation' of coming from a reputable science country, you should be fighting cancel culture's gag on 'heresy' lines of research.

Why, for example, can I find no calculation of carbon sequestration by wilding pines? Why does policy subsidise the expensive planting of productive farmland, when DoC has vast lands that will plant themselves? Why has FGLT never been asked to fund a project to assess the relative costs of alternatives to the current ETS eligibility rules, to make sure they are genuinely targeted at maximising carbon capture and cutting global warming risks?

Some of the reforms promised by political parties will be extremely controversial. As a former MP, I urge you not to underestimate your own potential for influence. Some of you will have information that never gets through the filters of officialdom and media, but which could be of vital importance to politicians. Email them.

FGLT must now provide annually what is called a "Statement of Service Performance". In brief, we need to measure success or failure in the things we spend levy money on. Are we just doing things that seem a good idea, or are we actually achieving well-defined purposes? That question should be asked about all spending of other peoples' money. Remember this. We will want proposed success/failure measures for almost all grant applications.

Stephen Franks
Chair
Forest Growers Levy Trust

Introduction

Welcome to the 2023 Science Report which showcases some of the exciting research undertaken by Forest Growers Research in the past two years. In this report, the research highlights for 39 projects are arranged in subject sections representing key parts of the forestry value chain, from tree improvement, propagation and nurseries, to establishment, harvesting and transport, and managing for risk and uncertainty. Each feature is a snapshot of key outcomes and implications for the forest industry. The associated research programme and key collaborators who have brought the work together are also indicated.

Much has been achieved, with advances in tree breeding (*Pinus radiata* and a range of specialty species) and in propagation and nursery practices. We have increased understanding of the growing environment, including the microbiome, soil and site factors, made big gains in precision silviculture at establishment and for tending stands, and seen good progress in mensuration and tree modelling. Research outcomes in tree health, biosecurity and wildfire will help protect our forests, and there are numerous innovations in harvesting technology, transport and logistics, including in human factors and machinery maintenance. Finally, advances have been made in wood properties and product development, not only for *P. radiata* but also for specialty species.

"We have increased understanding of the growing environment, including the microbiome, soil and site factors, made big gains in precision silviculture at establishment and for tending stands, and seen good progress in mensuration and tree modelling."

Behind the scenes there have been several changes at FGR and within the wider research network. Paul Adams became the new Research and Development Director and Amanda Brake is the new Office Manager. At the board level, Brendan Slui, Dean Witehira and Ross Larcombe joined as three new directors following the departure of Barry Murphy, Kerry Ellem and Grant Dodson. Peter Berg continued as Chair of the Board. There were also a number of team changes in the Forest Research Committee. At the research programme level, we saw the conclusion of the seven-year Specialty Wood Products programme, and the commencement of the seven-year Precision Silviculture Programme (PSP). Brian Richardson joined as Programme Manager for the PSP and recently Claire Stewart has taken over this role on Brian's retirement.

All of this research and innovation is supported by forest growers across the country along with a multitude of teams and groups across the research network, from the FGR Board, Forest Growers Levy Trust Board, to the Forest Research Committee, Programme Governance Groups and Technical Steering Committees. These are listed at the back of the report.

One of the key features of Forest Growers Research's success is its ability to leverage co-funding, partnerships and collaboration with forestry-aligned research providers, who are well connected to today's challenges and future opportunities. FGR is supported by several key research providers who contribute to the successful delivery of research and results applicable to all forest growers. A range of government initiatives are enhancing research funding and collaboration: these include the Climate Emergency Response Plan (CERF) and the Forestry and Wood Processing Industry Transformation Plan (ITP). The Sustainable Food and Fibre Futures fund is also supporting a range of research across the primary sector and is co-funding the Precision Silviculture Programme.

New Zealand's forest growers, like other primary industry producers, continue to face external challenges – Cyclones Hale and Gabrielle in summer 2023, export market volatility, new biosecurity threats, and the increasing unknowns associated with global climate change. Our forests and forestry sector will be able to respond to many of these economic, environmental, social and cultural challenges only through proactive strategies, greater engagement and collaboration with stakeholders, improved training and education, and much larger financial investment in research. We must continue to look ahead, and provide tools for the industry to remain productive, profitable, and socially and culturally responsible.

Paul Adams
Research and Development Director
Forest Growers Research

Ian Hinton
Chair
Forest Research Committee

Forest Growers Research – portfolio of the major, multi-year research programmes

Programme	Aims	Partners / funding	Duration
21st Century Tissue Culture Partnership	Speeding up, and scaling up, deployment of top radiata pine genetics.	Ministry for Business, Innovation and Employment, Forest Growers Levy Trust, Strategic Science Investment Fund (Scion).	2020-2027
Precision Silviculture Partnership	Mechanisation and automation of forest nursery operations, forest establishment and young tree management.	MPI Sustainable Food and Fibre Futures fund, industry partners, Forest Growers Levy Trust.	2022-2029
Tree Root Microbiome Project	Investigating life in pine tree roots and surrounding soil, and to establish radiata pine as a model tree-root microbiome platform for global research.	Ministry for Business, Innovation and Employment Endeavour Fund, Forest Growers Levy Trust, Strategic Science Investment Fund (Scion).	2020-2025
Resilient Forests Programme	Increasing productivity, enhancing resilience, and managing risk and uncertainty in the radiata pine industry.	Forest Growers Levy Trust, Strategic Science Investment Fund (Scion)	2020-2026
Automation and Robotics Primary Growth Partnership Forestry Work in the Modern Age – Te Mahi Ngahere I te Ao Hurihuri	Increasing automation and robotics in forest harvesting, log transport, and sort-yard machinery.	Primary Growth Partnership between Ministry for Primary Industries, Forest Growers Research Ltd, nine forestry companies and ten machinery manufacturing partners.	2019-2026
Extreme Wildfire Research Programme	Understanding extreme fire behaviour; working with industry to develop strategies and tools to mitigate fire risk.	Ministry for Business, Innovation and Employment Endeavour Fund, Forest Growers Levy Trust. Department of Conservation, FENZ, Te Uru Rākau, NZ Defence Force, LINZ, University of Canterbury.	2022-2027
Specialty Wood Products Research Partnership	Instigate a high-value specialty wood products industry based on alternatives to radiata pine.	Ministry for Business, Innovation and Employment, ten industry partners, Forest Growers Levy Trust.	2015-2023

Technical Reports describing programme outputs are freely available on the Forest Growers Research website: fgr.nz

Tree Improvement

Advances in breeding durable eucalypts

The biggest novel tree breeding programme in New Zealand in recent years has been the work on durable eucalypts, led by NZ Dryland Forests Innovation (NZDFI), supported by the Specialty Wood Products Research Partnership (SWP) between 2015 and 2023.

Since 2008, NZDFI has established breeding and demonstration trials at over 40 sites. These include the eight trials established in 2018 under SWP to extend the research into regional environments.

While 11 species continue to be evaluated for overall productivity and site x species suitability, NZDFI's breeding investment has focussed on two species – *Eucalyptus bosistoana* and *E. globoidea*.

The NZDFI Science Team, led by University of Canterbury's Associate Professor Clemens Altaner, assessed key genetic traits of these species, including growth, form, and amount and durability of heartwood, to identify elite families and select plus-trees for seed orchard deployment and seed collection.

Using scion wood collected from plus-trees, Proseed NZ have successfully grafted and deployed these selections in seed orchards at their North Canterbury site. Seed from these orchards produced the first generation of XyloGene-branded genetically improved *E. bosistoana* and *E. globoidea* planting stock in 2021 under a separately funded but aligned Te Uru Rākau One Billion Trees (1BT) project. Proseed NZ's first *E. bosistoana* clonal stock were established in two Marlborough trials in 2018.

Demand for XyloGene seedlings is now out-stripping supply. "We are well underway," says Paul Millen, NZDFI's Manager. "We need greater seed production to ensure new durable hardwood forests can be planted, and to continue our genetic improvement work. Early growth of our improved trees demonstrates what we have gained from our long-term breeding investment."

^ *First generation* E. globoidea *seed being separated from seed capsules at Proseed NZ.*

< *First generation seed orchard* E. bosistoana *tree at Proseed NZ.*

Specialty Wood Products

Proseed NZ; University of Canterbury; Marlborough Research Centre; Te Uru Rākau.

NZDFI's many landowner trial hosts.

Radiata pine breeding update

The Radiata Pine Breeding Company (RPBC) continues its quest to deliver gains in desired growth, form, wood properties and disease resistance to industry.

The company's genetic gain trials are established nationwide, in forests belonging to RPBC shareholders, as well as in Australian shareholders' forests in New South Wales and Tasmania. RPBC tree breeder Mark Paget reports that analysis of a trial series which began in 2011-2012 is underway. Early observations are showing significant benefits in growth and wood properties when improved seedlots are grown: later trials are yet to be fully assessed.

The RPBC's large-scale genomics programme aims to reduce the breeding cycle from 17 years to 9 years while building gains into every cycle.

This programme, now fully operational, involves extracting DNA and genotyping 10,000 seedlings annually, selecting the best 10% or so based on their genetic profile, and taking these through to clonal (cuttings and somatic embryogenesis) test trials.

Phenotype data is required to implement genomic selection and RPBC continues to work with Scion to identify innovative approaches to measure individual trees for traits such as DBH, tree height, branching habit and dothistroma infection using remote sensing technologies. Cheaper and higher throughput methods for accurate phenotyping will help improve tree selections as well as more closely monitor new generation genetic gain trials.

To help foresters choosing germplasm, RPBC has developed a new selection tool, 'TopTree'. This app allows the user to alter the importance of traits at harvest and view ortet rankings based on their user-defined index.

RPBC shareholders, RPBC royalties, Forest Growers Levy Trust (genetic gains trials).

^ *An interactive screen from the RPBC Toptree app.*

^ *Two-year-old radiata pine in a breeding trial (established with clonal cuttings), in Wenita Forest Products Ltd Berwick Forest, Otago.*

Breeding gains for specialty species

The Specialty Wood Products Research Partnership (SWP), which ended in June 2023, included a significant amount of tree improvement work. The SWP focused on three established species/species groups – Douglas-fir, non-durable eucalypts and cypresses – as well as supporting the development of durable eucalypts, an emerging species group.

A primary aim for established specialty species was 'targeted breeding to enhance future wood supply, with a focus on wood quality and forest health'. Growers will benefit from the gains made by Scion's tree breeders and SWP collaborators in years to come.

One example is the work done on new *E. fastigata* selections for solid wood properties. Scion tree breeders assessed third-generation *E. fastigata* progeny trials and made new selections based on growth, form, and for the first time, wood stiffness – an important component, given *E. fastigata's* potential for use in engineered wood products. Stiffness was shown to have moderate heritability so could be included in the selections.

^ *Dr John Moore, Timberlands Ltd, marks up* E. fastigata *for the thinning and log splitting trial.*

However, *E. fastigata* logs are prone to splitting after harvest, resulting in poor sawn timber or veneer recovery rates. Following a thinning operation in an *E. fastigata* stand, a combined Scion/Timberlands team assessed the genetic basis of log- splitting and concluded that future selections for fast growth, combined with low log-splitting characteristics, should be possible.

Specialty species: breeding gains

Cypresses: canker-tolerant selections of *Cupressus macrocarpa* and *C. lusitanica* made; new trials established. New cypress hybrids produced and deployed in trials on farm forestry properties.

Douglas fir: new breeding targets for form, productivity and resistance to needle diseases (whilst maintaining wood quality) established by industry; new breeding selections made based on these. Initial genomics work completed as part of an aligned project.

Non-durable eucalypts: two fourth-generation *E. nitens* seed orchards established, with a focus on solid wood properties including wood density, growth strain, stiffness and drying properties. A new NIR-based model for predicting *E. nitens* wood shrinkage and cellulose content will enable early screening and selections for genotypes with improved drying characteristics.

Specialty Wood Products

SWP industry partners, NZFFA Cypress Development Group.

Propagation and Nursery

Tissue culture for the 21st Century

The 21st Century Tissue Culture Partnership is an industry/government funded programme which aims to speed up and scale up the production of the best radiata pine genetics, increasing their availability to all growers at a competitive price.

Now in its fourth year, the science team, based at Scion, and with partners in USA and Finland, continues to make good progress in developing techniques to select and nurture embryos from top radiata cell lines. Much of the science is still exploratory, but the overarching goal is to develop processes which deliver fit-for-purpose plants of known genetics to industry cost-effectively. Harnessing artificial intelligence and robotics to improve productivity is a key element.

The project is based around somatic embryogenesis (SE) – a micropropagation technique that starts by cultivating immature embryos extracted from green cones, or from cell lines stored in cryo-storage systems. Industry already uses a combination of SE and another micropropagation technique, organogenesis, but there are bottlenecks, and a lot of skilled manual labour is needed.

"We are making good progress on an alternative process to create a more direct route to produce plantlets and which will be more amenable to automation," says scientist Cathie Reeves. "At the same time, we are putting effort into improving the protocols that industry producers are more confident with. One of the things we're looking at is trying to get adventitious roots to form while the plantlets are still in the lab, rather than when they reach the nursery, which requires conditions in the nursery to be very tightly managed. It's not easy, but we've seen some positive signs. Using LED lights has shown to be beneficial, so we'll keep working on that."

Gains being made with work on the more direct route include shortening (and potentially removing) the germination period. With help from the National Resources Institute, Finland, the team is also trialling a Vivi tray system to help young plants transition to nursery conditions.

"We're focusing all the time on making things more efficient, reducing the time of everything," says Cathie. "We've set up a group with industry colleagues at Timberlands and Arborgen – that's been really fantastic, talking to people who actually do this for the forest industry."

> "If this project is successful, it will result in a massive step-change for forest growers. There are still some major challenges to be overcome. But getting some of these new clones that have awesome properties out to industry a whole lot quicker will be a game-changer."
>
> **Kevin Haine, PF Olsen Glenbrook Nursery Manager**

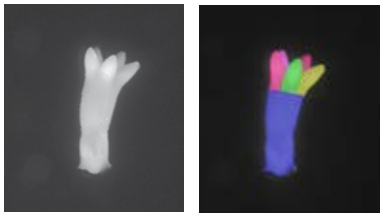
The Scion team is collaborating with Georgia institute of Technology on two aspects of research: (i) the use of temporary immersion bioreactors, which use a liquid nutrient and hormone system rather than a semi-solid system to feed the plants, and (ii) testing a fluidics system to grade and segregate embryos. Grading is currently done by human eye and is time-consuming and subjective. The fluidics system is high-speed, designed for a high throughput operating system, and provides another option as the programme develops.

An additional element is the introduction of artificial intelligence (AI) to grade embryos at an early stage, to improve germination success and reduce waste.

^ *Direct somatic embryos in micro-plugs in Vivi trays.*

A somatic embryo that failed to germinate (left), and one that germinated successfully.

"We can select the best embryos – those most likely to germinate – according to certain physical characteristics," says Scion data scientist Sam Davidson, who has used machine learning to train software to accurately identify the best embryos quickly and objectively. "AI is proving to be as good as a skilled technician. The next step will be to introduce some type of robotics to physically segregate the best from the rest."



Automated somatic embryo segmentation (right) using artificial intelligence.

Plans for the coming year including development of more sophisticated machine learning algorithms, and getting a lot more plants out into the nursery, to show industry the changes being made and that the project is making good progress.

21st Century Tissue Culture

Georgia Institute of Technology; Natural Resource Institute, Finland; ArborGen Inc;

^ Scion's Dr Jana Krajnakova and Dr Taryn Saggese inspect embryos in temporary immersion bioreactors.

Timberlands Ltd; Proseed NZ; Radiata Pine Breeding Company; Manulife Investment Management (NZ); PF Olsen Ltd; Rayonier-Matariki Forests.

Mechanised lifting of bare-root nursery stock

The labour-intensive task of lifting bare-rooted seedlings from nursery beds is ripe for mechanisation. An innovative 'block-lifting' tree lifter has been developed by Jonathan Sudano at Tree Nursery NZ in partnership with FGR's Precision Silviculture Programme.

The block lifter, which attaches to the rear arms of a small tractor and is controlled by the tractor's GPS, can lift a one-metre-length block of 8 -10 rows of trees at a time – around 120-150 trees. It can lift at least 20,000 seedlings an hour – the equivalent of ten people working flat out. Tree roots are mechanically trimmed, and trees then placed in a bin which holds 8,000-10,000 trees. Bins are lifted onto a trailer towed by the tractor and delivered to an indoor grading and packing line.

"The system involves minimal soil disturbance - it only requires one pass of the tractor," says Jonathan. "The roots and mycorrhizae are returned to the bed, keeping the organic matter there, and the site is left clean and ready for replanting."

While Jonathan stresses he has a good team of manual lifters, he envisages productivity gains once the system is fully operational, likely to be in 2024. "We're going to do more tests later this year on some spring onions we've got growing here – which are actually quite similar to pine seedlings," says Jonathan, who has designed the machine together with local agricultural engineers.

Automated seedling grading and packing is the next obvious step: another project to develop artificial intelligence-based tools to grade trees is on-going. Trials show that an AI system can be trained to select seedlings according to specific quality criteria, enabling rapid and consistent grading of stock. Initially designed for an in-shed conveyor system, the potential exists to embed this technology directly into a seedling-lifting machine, which would increase efficiency even further.

Precision Silviculture

Tree Nursery NZ; Timberlands Ltd; University of Canterbury; Contempo Lab.

Tree box tracking app for nurseries

A phone-based app to track trees from the nursery to the planting site is well on the way to being ready for use. The app, developed by tech company Integral, enables users to scan a unique GPS-linked identifier on each box of trees as they leave the nursery, and then at every stage of the journey including when the box reaches the planting site.

> "We've had examples of trees sitting in boxes for two months and then the client complaining that they didn't grow!"
>
> **Kevin Haine, PF Olsen Nursery Manager, Glenbrook Nursery**

The app is due to be tested at PF Olsen's Glenbrook Nursery, and nursery manager, Kevin Haine, can identify three immediate benefits the app will have for him.

"First, we'll have the information we need to find out what happened to the trees between leaving the nursery and planting. We've had examples of trees sitting in boxes for two months and then the client complaining that they didn't grow! So that will mean we can

resolve issues like this much more easily. Second, I'll know where my boxes are – I use around 70,000 boxes a year, so knowing where they are and getting them returned to the nursery more quickly will save money and increase efficiency. Third, because each box leaving the nursery can be tracked, it will mean we can trace boxes and trees very quickly if we have any biosecurity problems."

Kevin envisages a time when individual tree tracking becomes reality, where trees of known genetic origin are tracked from the nursery, GPS-located at planting and then monitored through their rotation and beyond.

Precision Silviculture

Integral Ltd; PF Olsen Ltd.

Nursery-applied Trichoderma promotes tree growth and health

Research quantifying the benefits of Trichoderma is progressing well under the watchful eye of Dr Helen Whelan, of Lincoln University. Trichoderma are beneficial fungi which enter the plant roots and do a similar job to mycorrhizae fungi. They are applied most effectively as a seed-coat dressing or liquid inoculant in the nursery.

Helen established a series of eight trials with inoculated radiata pine seedlings in 2018 in Gisborne, Northland, Bay of Plenty and Nelson, and five more in 2021 in South Otago and North and South Canterbury. The aim is to quantify the effect of Trichoderma on tree growth and health on sites with different growth potential.

Results from the 2018 trials show Trichoderma treatments significantly increased productivity (stem volume per hectare) by up to 40% across the sites, with the greatest gains seen in medium-growth-potential sites. Tree uniformity in terms of basal area and stem volume benefitted too, with average gains across all eight trials of 9-12%.

"Treated plants are also proving to grow bigger and stronger in the nursery," says Helen, "so a higher percentage are reaching production standard. This applies not only to inoculated stock, but also where stock are grown on fallow land treated before being brought into production."

Helen is currently evaluating the business case for producing a commercial forestry-specific Trichoderma blend. Numerous nurseries are already treating at least some of their seed with Trichoderma supplied by the research programme.

Forest Growers Levy Trust

Appletons Tree Nursery; ArborGen Ltd (Te Teko, Edendale, Kaikohe, Puha, Tokoroa Nurseries); City Forests; Ernslaw One Ltd; Juken NZ Ltd; Kauri Park Nurseries; Leithfield; Manulife Investment Management (NZ); Murrays Nurseries; OneFortyOne; PF Olsen NZ; Port Blakely Ltd; Proseed New Zealand; Rangiora Nursery; Rayonier-Matariki Forests; Rotorua Forest Nursery; Southern Cypresses Nursery; Tasman Pine Forests Ltd; Timberlands Ltd; Wenita Forest Products Ltd.

^ Dr Helen Whelan measuring a two-year-old radiata pine at Rayonier-Matariki's Ashley Forest, North Canterbury.

Microbiome and Soil Factors

Global connections in the tree root microbiome

The Tree Root Microbiome Project, led by Scion's Dr Steve A Wakelin, is exploring new territory, both geographically and scientifically. The project covers countries where radiata pine grows either naturally or as an introduced species. An international soil sampling initiative is underway: soil data are correlated with related environmental data and DNA information extracted from soil and root micro-organisms. Soil samples are sent from all countries to the Woodwell Climate Research Center, USA, to be analysed, while extracted DNA samples come to Scion.

"My role is to link environmental drivers to changes in the soil microbiome," says Scion's Sarah Addison. Sarah was recently part of a team who visited the Monterey region of California to collect soil samples from native radiata or 'Monterey pine' remnants there. A future trip will take Sarah to Mexico, to sample soils in native radiata pine populations in Guadalupe and the Cedros Islands.

People collecting soil samples around the world use a GPS-linked smartphone app to record the sampling site: the app also delivers environmental data for that site. Scientists can then look for links between climate factors – precipitation, temperature, hours of daylight and so on – and soil data, and the microbiome.

"We are at the end of sampling in New Zealand, and halfway through the Australian sampling programme," says Sarah. "We want to compare the microbiome data from radiata's home range with other countries, to see if there's a core microbiome that exists wherever radiata is in the world."

Micro-organisms living underground that comprise the tree-root microbiome play a critical role in the survival and health of trees and may well determine their response to environmental changes.

^ *Sarah Addison and Dr Steve A Wakelin collect soil samples from radiata pine in its natural home, Monterey, California.*

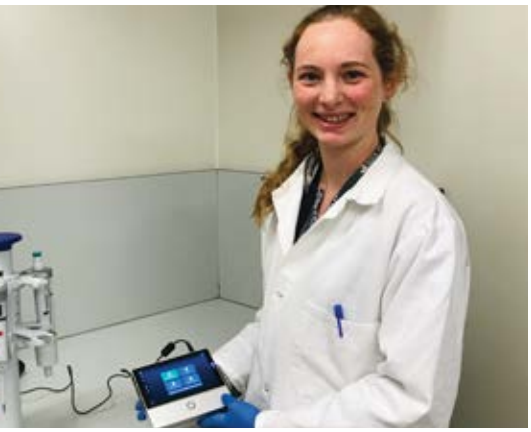
Tree Root Microbiome

Lincoln University; Victoria University of Wellington; Australian Plant Phenomics Facility; Hawkesbury Institute, University of Western Sydney; Woodwell Climate Research Center, Massachusetts; Wright State University, Ohio.

Identifying and sequencing new soil micro-organisms

Scion's Lottie Armstrong is on the hunt for new soil micro-organisms to build understanding of life under the soil surface around the roots of radiata pine trees. At present, only a small percentage of the microbes living in the soil have been described, leaving many knowledge gaps about the role of microbes in the ecosystem.

Lottie receives a small amount of all the soil samples collected from all around New Zealand as part of the Tree Root Microbiome Project. Focusing on less common and slower-growing species of micro-organisms, she has developed a method to isolate individual micro-organisms, grow them on in the lab,



^ *Lottie Armstrong with the minION sequencer – capable of sequencing long-read DNA sequences.*

and identify them. If they are thought to be new to science, the next challenge is to sequence their genome. By unpicking the genome, scientists can begin to understand the role of each micro-organism within the ecosystem.

"We wanted to be able to do the DNA extraction and sequencing in New Zealand," explains Lottie, "and to look at the whole DNA sequence of these new bacteria."

Until recently, samples had to be sent to the USA for sequencing but a new tool – a Nanopore minION sequencer – has been purchased by Scion and is enabling the sequencing to be carried out in-house, quickly and cost-effectively. The lab programme can now be scaled up, and it is likely that many new organisms will be discovered, and their DNA be sequenced. Once the new genomes are announced in scientific literature, they can be added to international soil micro-organism databases, reinforcing the global benefits of the Tree Root Microbiome Project.

Tree Root Microbiome

Uncovering the secrets of the holobiome

The whole radiata pine microbiome, or 'holobiome', comprises the tree and all the microbes living on and in it. Scientists want to better understand interactions between the tree and all its associated microorganisms, which are known to be intricately linked with tree health and resilience. The hope is that this will help predict trees' ability to cope with a warming environment.

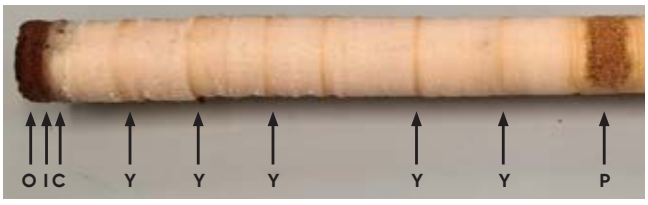
A team at Scion began by developing robust, reproducible sampling methods for investigating the microbiome of the individual parts of radiata pine trees, including needles, pollen and wood.

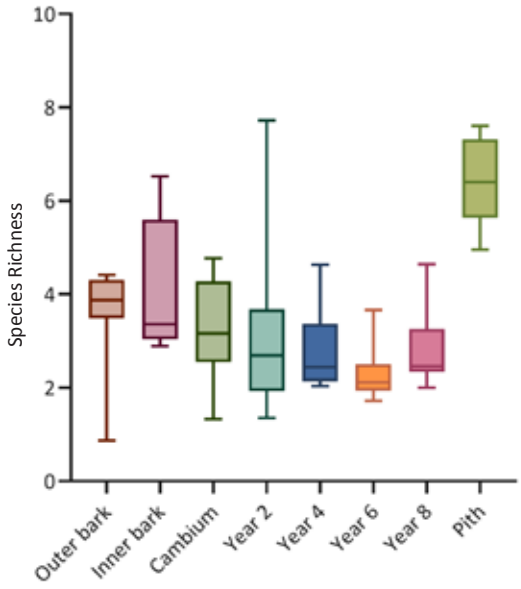
"The work we have done on sampling wood is probably the most interesting, because no-one has really looked at this before," says Scion's Dr Kathryn Walker. "We started by sampling one tree at different heights and separated the wood into outer and inner bark, cambium and rings of different ages. We found bacteria and fungi in all the different components." The sampling was repeated with more trees to confirm its validity.

Next the work is extending to look at the whole microbiome of specific trees, sampling both above and below ground elements, and exploring changes over time.

"We want to build up a picture of what microbes are present, how they are distributed on the tree and how they change over time with different environmental conditions, disease pressures, and management regimes. Ultimately the research could lead us to developing new tools for forest growers," says Kathryn, "If we can identify what a good community of microbes looks like, or the conditions that favour beneficial micro-organisms, we may be able to intervene to benefit trees."

Resilient Forests





^ *Analysis of the diversity of bacteria found in different sections of a tree core, ranging from the outer bark (O), through the cambium (C) and then each year's growth to the pith (P).*

Establishment

Using drones for precision release-spraying

Possible applications of UAVs in forestry are increasing at pace, and precision spot-spraying using this technology is already past proof-of-concept stage.

Working together with PanPac and SPS Automation, Scion's Robin Hartley and Dr Justin Nairn have overseen the first automated spot release-spraying trials completed as part of the Precision Silviculture Programme. The UAV was able to fly to a pre-determined GPS point (e.g. tree position) and deliver a precise dose of spray. There are, however, still a few challenges to be overcome before for the UAV technology could be considered fit-for-purpose, including:

- identifying an accurate tree location (not as easy as you would think!)
- optimising timing of spray release in relation to the target (on/off in relation to target whilst in continuous flight)
- optimising nozzle configuration and spray deposition patterns for release spraying of radiata pine.

Further trials in June 2023 with SPS Automation improved understanding of targeting efficiency and spray deposition. Ultimately the team is confident it will reach the point of being ready to develop a commercially deployable machine, and then will select an industry partner to work with to do this.

^ *SPS Automation's UAV platform on trial at Pan Pac's Glenmore Forest, Hawke's Bay.*

"I'm super-keen on it! My dream is that we'll do a pre-planting spot-spray with a drone, then after planting send a small drone out to find trees that need releasing and then send a bigger one out to spray them."

Sean Wright, Forest Manager, PanPac Forest Products Ltd.

Precision Silviculture

PanPac Forest Products Ltd, SPS Automation Ltd.

Testing hydrogel to extend the planting season

Hydrogels which retain moisture around tree roots can aid seedling establishment and growth, and potentially extend the planting season beyond its traditional winter window.

A trial to test a seaweed-based hydrogel was set up by a team from Scion together with Timberlands and contractors H.A.Fear. The hydrogel was applied, and the trees planted, using a mechanical 'M-Planter' in Tarawera Forest in March 2022. The site was renowned for its dry, difficult establishment conditions.

On this occasion the hydrogel had no significant effect on tree survival, and only a minor positive impact on early growth, perhaps because the weather was unusually wet around planting time. A second similar trial was planted with the M-Planter in December 2022 in collaboration with Rayonier-Matariki Forests to see whether hydrogel would increase survival over drier summer conditions. Again the trial was compromised by unseasonably wet weather, however, the team learned a lot about the operation of the M-Planter in wet weather and clay soils.

Research on hydrogels will continue because their use is closely aligned with mechanised planting. Extending the planting season is key to increasing planting machine utilisation, thereby improving the overall cost-effectiveness of mechanised operations.

Precision Silviculture

Timberlands Ltd.; Rayonier-Matariki Forests; H.A Fear Ltd.

^ *Preparing to plant hydrogel-treated seedlings with the M-planter.*

Managing the Growing Crop

SILVICULTURE

Trialling a battery-operated pruning tool

Pruning plantation trees is a physically hard job, and battery-powered pruners, already commonly used in horticulture and viticulture, may provide a way to make the job less strenuous.

Two contract pruners were tasked with using a battery powered 'Pellenc' pruning tool during a conventional 3.5 to 4-metre lift in Lake Taupo Forest. One pruner was inexperienced, the other highly experienced. Forme Consulting Group captured time and motion data from the operation, and physical data for each tree, for example the number and size of branches, prune height etc.

Forme's analysis found only a small difference in pruning time between the inexperienced and experienced pruner when using the pruning tool. They observed that less physical effort was needed. The experienced pruner especially reported he was less tired after using the tool.

However, pruning time per tree was over 30% slower with the battery tool. Its size and design meant it often slipped during cutting, and several attempts were needed to cut some bigger branches. Branch stubs were sometimes left that required double-handling using loppers, meaning both tools had to be carried.

The trial has shown that modifications to the tool are needed, and University of Canterbury mechatronics and mechanical engineering students are now rebuilding the cutting heads of both the Pellenc tool, and a second 'Infaco' tool. The new designs will be ready for testing later in 2023.

^ *Forme's Jack Palmer assesses a pruned tree.*

^ *Using the battery powered Pellenc pruning tool.*

Project manager, Tim Petro, was encouraged by the trial and reports that the contractor involved, Mahi Rakau, is keen to continue trialling the tools, not least because they hope to introduce a female pruning crew in the near future.

Precision Silviculture

NZ Forest Managers; Lake Taupo Forest Trust; Mahi Rakau (Contractor).

Battery-powered chainsaw trials

Replacing petrol chainsaws with battery powered ones could reduce carbon emissions from a typical waste thinning crew by about 6,580 litres of two-stroke fuel per year. Operator exposure to carbon monoxide fumes would also be eliminated.

Two makes of battery-powered chainsaw – a Stihl MSA300 and a Makita UC013GZ – were trialled in conventional waste thinning operations in the central North Island. Using a chest mounted camera and manual time study methods, data was collected on operators using both petrol and battery powered chainsaws. A Tango detector recorded exposure to carbon monoxide by petrol saws.

> "On-site management of batteries is the critical challenge. Each battery only lasts for 25-45 minutes, so operators might need to carry 12-13 batteries for a day's work (24-26kg). And flat batteries are no lighter than fully charged ones!"
>
> **Rob Prebble, FGR Project Manager**

Recording data showed there was little difference in felling time between the two types of saw, but operators preferred the longer bars and extra power of petrol saws when dealing with tricky felling jobs. Carbon monoxide peaks occurred while cutting in one place or in heavy undergrowth, but exposure did not reach dangerous levels because of their short duration.

A trailer was set up to facilitate overnight

^ *The specially adapted trailer, enabling 40 batteries to be charged overnight from one socket.*

^ *Chainsaw operator with camera and carbon monoxide monitor attached.*

charging of batteries which was very successful. It enabled all used batteries to be charged in one go overnight when the trailer returned to base. Other key observations included:

- chain bar oil use was considerably less with the battery saws, as the motor runs for much less time (i.e. only when cutting)
- fire safety is a concern - lithium-ion batteries will burn fiercely if ignited and no available extinguishers will put them out. Containment is the only option
- set up costs are higher for battery saws at over $12,000 for one saw plus batteries, compared to under $3,000 for a petrol saw (which is actually more powerful at 5-6kw vs 2-3kw).

Further trials are planned in smaller regeneration thinning operations later in the year, where tree size should be better suited to the battery saws. On-site battery distribution methods will be explored to improve continuity of work and reduce the weight operators will have to carry.

Precision Silviculture

Inta-Wood Forestry Services

FOREST MENSURATION / PHENOTYPING

Advances in autonomous forest measurement

^ *Scion's Pete Massam trials the backpack-mounted Hovermap laser scanner.*

Laser scanning technology which accurately describes and measures – or 'phenotypes' - individual trees is advancing rapidly. Forest managers and tree breeders are keen to adopt automated systems because of their relative speed and objectivity, but need to be certain that the systems are accurate.

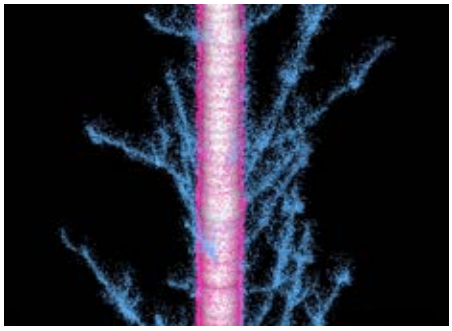
Scion's Robin Hartley and Sadeepa Jayathunga are working to validate the accuracy of laser scanners, and compared a backpack-mounted Hovermap scanner and UAV-mounted scanner with field measurements within three contrasting forest types. The Hovermap creates 3D models or 'point clouds' at densities in excess of 20,000 ppm² – much greater density than other available technologies.

"The backpack scanner measures tree diameters and stem volumes very accurately; canopy height measurements are also very accurate, although measuring suppressed tree heights is more challenging," says Robin. Robin is also making good progress in using laser technology to describe branching – another fundamental element of tree phenotyping.

"The end game here is to develop a freely available set of phenotyping resources that can be used by forest managers and others," says Robin. Robin leads the pan-industry Tools for Foresters group, who use and develop forestry technology and collaborate to share information and resources. (www.toolsforforesters.co.nz)

Resilient Forests; Transforming Tree Phenotyping (MBIE Endeavour Fund)

Manulife Investment Management Ltd; Timberlands Ltd; NZ Forest Managers Ltd.



< *Image of a tree stem derived from laser-scanner data.*

< *Hovermap laser scanner point cloud - forest stand level.*

Next generation tree modelling

"The tree is where it all happens," says Scion's Dr David Pont, whose specialism is in developing individual tree growth models derived from LiDAR data. Dave's earlier work included quantifying the effects of competition and other site factors on individual tree phenotype, or physical characteristics. This work benefited geneticists, enabling them to isolate the influence of genetics on phenotype from other major environmental factors.

"Going to tree level is pivotal, particularly when it comes to wood quality and wood properties," says Dave. "But genetic variability in seedlot trees, disease tolerance, response to competition – it all comes down to individual trees."

Dave is using individual tree ground measurements from a trial at Scion's Puruki Forest to validate a model derived from two LiDAR data sets. The model is producing excellent results in matching individual crown dimensions to tree height growth. Work to validate and extend the model's outputs to tree diameter and stem volume is on-going.

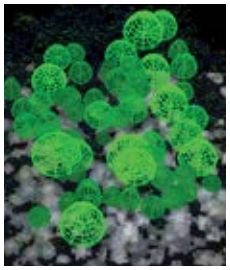
"Ultimately, phenotyping needs to reach this resolution, and LiDAR gives us the ability to do this at forest scale. If we can partition, and model, individual tree growth and properties, it opens the door to dynamic tree growth modelling and really does provide a platform to integrate different research areas."

An example of research area interrelatedness occurred recently, when individual trees identified as 'exceptional' during phenotyping work were investigated further, and shown to have particular soil microbiome characteristics, adding a further potential level of complexity for growth modellers.

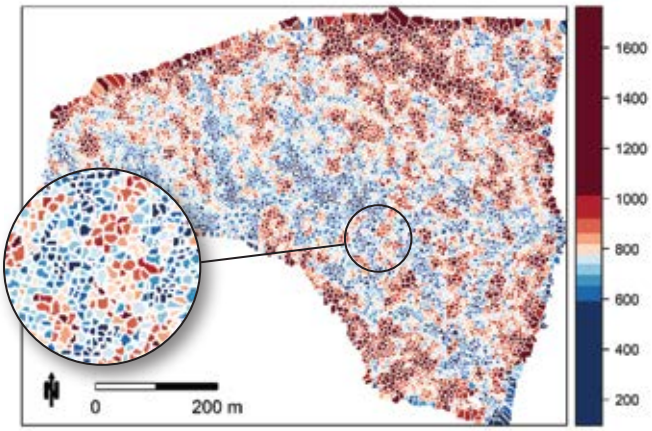
"It's a work in progress, and I am really pleased that industry sees the merits of supporting this research over the long term," says Dave.

Resilient Forests

Timberlands Ltd; Radiata Pine Breeding Company.



> *Whole tree models – a precursor to dynamic tree growth models incorporating genetics and environmental factors.*



^ *LiDAR-derived individual tree crowns at forest scale, showing crown-growth across the site.*

> *A permanent sample plot marked up in a hybrid cypress plantation.*

Getting to grips with alternative species growth rates

Growers need more information on the relative growth rates of alternative species, and the best way to obtain this is to establish permanent sample plots (PSPs) across a range of site-types and then measure trees regularly. Around 700 PSPs in alternative species plantings already exist, established nationwide over time. Ideally PSPs should be measured at short, set intervals so that growth of individual trees can be consistently tracked. Many existing PSPs have not been measured for at least ten years. Some also risk being lost through harvesting without the opportunity to assess the trees beforehand.

A comprehensive initiative to re-measure alternative species PSPs is now underway, led by the NZ Farm Forestry Association (NZFFA). All the main alternative species - cypresses, eucalypts, redwoods, cedars and poplars - are included, with new plots being established where gaps exist, for example in geographic location or trees of a certain age range.

> "Scion itself recommends that PSPs are measured once a year until trees are 11 years old, once every three years between 11-16 years, and once every five years when over 16. It is essential that we get back to measuring these trees regularly – otherwise, a wealth of information will be lost. Equally essential is that the data is shared with anyone who is interested, so that we build a collective knowledge base on these species."
>
> **Kees Weytmans, farm forester and NZFFA Special Interest Group member**

"This is a two-year project," says project manager Vaughan Kearns. "with a big input from members of the NZFFA's Special Interest Groups. Earlier work to re-measure coastal redwood PSPs helped stimulate a significant upturn in demand for planting stock, so we hope this will happen again once we can show just how well some of these alternative species are growing on the right sites."

The data will be delivered to Scion, and it is hoped will form the basis of new growth models and yield tables to assist growers.

Forest Growers Levy Trust; Te Uru Rākau; Forestry and Wood Processing Industry Transformation Plan.

NZ Farm Forestry Association; NZFFA Cypress, Poplar and Sequoia Special Interest Groups.

Control options for pine needle diseases

"Without copper sprays to control dothistroma needle blight, we would not have the forest industry we have today," says Dr Stuart Fraser, who is part-way through operational-scale trials in Kinleith and Whararata Forests to evaluate the use of copper to control red needle cast (RNC). A methodology has been developed for using multi-spectral aerial imagery for disease assessments, and tree sensors are monitoring individual tree growth and environmental conditions in sprayed and unsprayed areas.

Findings to date include that copper, sprayed at dothistroma standard rates, consistently reduces RNC severity. The impact of spray timing has yet to be tested under severe disease conditions, but more is being learnt about how RNC affects tree growth, so the cost-benefit of spraying can be analysed.

Copper has been used for routine control of dothistroma, a very different disease to red needle cast, for several decades. Conscious of the fact that copper does have some environmental questions hanging over it, Stuart and colleagues convened an industry stakeholder workshop to assess the interest in potential alternatives. Options discussed included alternative chemicals, biocontrols, genetic tools and silvicultural techniques. Participants concluded that a combination of new tools, some which are already available, others which need more development, could be needed. As a start, a review of alternative metal salts (which could be applied as sprays) has been completed, and lab-based trials looking at the impact of different chemicals on dothistroma have begun.

Resilient Forests

Manulife Investment Management Ltd; Juken New Zealand Ltd; Dothistroma Control Committee.

Modelling an intricate disease life cycle

Research to understand the fundamentals of the red needle cast (RNC) life cycle has quantified the climatic drivers of the disease. A Scion team, led by Dr Emily McLay, are now developing a process-based infection-risk model to predict how the disease will behave under different climatic conditions.

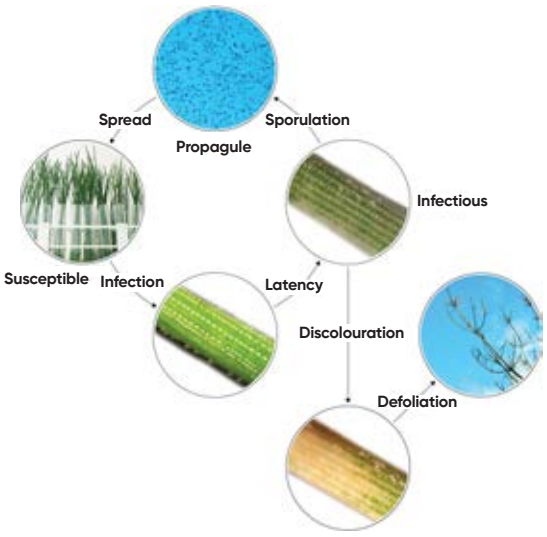
"RNC incidence is very variable both within and between seasons, and it can progress very quickly," says Emily. "By the time symptoms are visible, it's often too late to spray. Thanks to several years' field data collection, backed by lab experiments, we have a good understanding of how each phase of the disease's life cycle is influenced by climate, especially temperature and moisture. For example, we know that needle wetness is needed for the disease to spread, and what the temperature thresholds are for each life-cycle stage. We still have questions around how the disease survives when it is latent, and exactly how it spreads."

A prototype of the model, which is being designed to become a decision-making tool for forest managers, will soon be ready for testing. The team now needs to understand exactly what readily available climate data forest managers have, and how site-specific the data need to be to predict disease behaviour.

Resilient Forests

Rob Beresford, Plant and Food Research Ltd.

^ *The very rapid impact of a red needle cast infection.*



^ *Key times and processes in red needle cast's life cycle.*

Measuring tree growth and environment

A network of tree sensors is being deployed, first in Kinleith Forest in 2021 and then in Wharerata Forest on the East Coast later in 2023. The data gathered by the sensors, combined with tree health monitoring, are contributing to the red needle cast life-cycle model being built by Scion's plant health team.

Two types of sensors have been deployed by Dr Damien Sellier and colleagues:

(i) canopy sensors, located in the shaded part of the canopy where the red needle cast pathogen is found. These record environmental factors such as temperature, humidity and needle wetness

(ii) dendrometers, which are attached to individual tree stems, and monitor growth and sometimes, contraction.

"We will deploy our second-generation wireless sensors in December 2023 on the East Coast, where red needle cast is much more common," says Damien. "They measure precise stem movements, with live-streamed data delivered to me in Rotorua every minute."

The ideal scenario is that some sensors are attached to trees that become infected with red needle cast so scientists can monitor how the disease impacts growth, but as Damien says, "choosing trees that are going to be infected is a bit like playing bingo!"

^ *A dendrometer measuring precise tree stem expansion, and sometimes contraction, Kinleith Forest.*

Resilient Forests

French Embassy of New Zealand

INRA (Institut National de la Recherche Agronomique, France).

Understanding pathogen movement between forests

^ *Dr Kwasi Adusei-Fosu takes soil samples from a logging truck in wet conditions.*

Previous investigations into soil-borne pathogens, such as Phytophthora, suggest that inadvertent transport of infested soil or plant material can contribute to forest disease spread. A project to assess the risk posed by logging trucks operating in and across New Zealand's major plantation forests is under-way. The primary goal is to enhance biosecurity planning and preparedness so that, should a new disease incursion occur, the risk posed by logging trucks is understood and can be managed.

Scion's Darryl Herron has coordinated soil sampling from logging trucks servicing both North and South Island forests. "During dry weather, trucks carry tiny amounts of soil – we could only collect less than 20 grams in some cases," says Darryl. "In wet weather, it was easy to collect 1-2 kg samples from the muddiest trucks. Now our job is to analyse samples for pathogens that would be viable after transport. Pathogens move around in many ways, including by wind and water, so our main objective here is to understand what risks we might be dealing with."

The project is also recording logging truck movements between forests and their destinations. A network model will be constructed, to show how forests are connected in the logging truck network. If a serious soil-borne pathogen is ever detected in a forest, the model could help reduce the risk of its spread by managing logging truck movements in the area, for example by restricting logging operations to drier periods, introducing sanitations stations, etc. so that logging operations can continue with a lower risk of moving the pathogen around.

MPI Sustainable Food and Fibre Futures; Forest Growers Levy Trust

Rayonier-Matariki Forests; Ernslaw One Ltd.; many logging truck companies.

Strategies to beat eucalypt pests

Browsing insects are a major threat to some species of eucalypts in New Zealand. Two main beetle species– the eucalypt tortoise beetle *(Paropsis charybdis)* and a more recent arrival, the eucalypt variegated beetle *(Paropsisterna cloelia)* – are the focus of current research.

Paropsis charybdis has been recognised as an economic threat to large-scale *Eucalyptus nitens* plantations for some time. Scion's Dr Toni Withers has led an initiative to introduce a biological control agent. – *Eadya daenerys* – a native Australian parasitoid. After several years of intensive pre-release work, the first *Eadya* were released in late 2022 at three sites in Southland and the central North Island. Now it's a waiting game to see how they impact the target beetle populations.

Other work on eucalypt pests led by Dr Steve Pawson, University of Canterbury School of Forestry, has been part of NZ Dryland Forest Innovation's durable eucalypt programme. Research has established that some durable eucalypt species, and some families within species, exhibit greater tolerance to insect defoliation than others. Depending on heritability and whether a cost-effective assessment technique can be developed, pest tolerance could be incorporated into future breeding programmes.

At present defoliation can only be measured manually; researchers tested UAV-based LiDAR as a way of measuring defoliation, as this could greatly increase monitoring capacity. Results were promising but more LiDAR trials are needed to establish whether the technique can be refined to differentiate insect defoliation from other types of defoliation – for example caused by drought.

^ *School of Forestry PhD student Carolin Weser shaking insects off a eucalypt tree for counting and identification in the lab. Carolin is studying* Paropsisterna cloelia *ecology.*

Specialty Wood Products; MPI Sustainable Farming Fund; Strategic Science Investment Fund

Southwood Export Ltd; NZFFA Eucalypt Action Group, Oji Fibre Solutions (NZ) Ltd; NZ Forest Owners Association

University of Canterbury; University of Tasmania; University of Central Florida; Waikato University; Te Uru Rākau; Manaaki Whenua – Landcare Research; AgResearch; Forestry Tasmania; iFarm; PF Olsen Ltd; Forico.

EXTREME WILDFIRE

Experimental burns a world-first

Two new series of extreme wildfire burns were completed near Twizel in autumn 2023, as part of Scion's Extreme Wildfire research programme.

The burns follow on from experimental burns of stubble and gorse. This time a first series of burns involved burning radiata pine slash close to three commonly used types of house-cladding to test the vulnerability of the cladding to radiative heat; also to test new instrumentation.

A second series of nine experimental burns of various sizes were then completed, where the team achieved the objective of creating 'fire whirls' or fire tornadoes. Fire whirls occur during extreme fire events and creating them outside the lab with forest fuels was a world-first.

"We wanted to be able to measure fire whirls to help us better manage extreme fire," says Scion fire scientist Dr Hugh Wallace. "The whirls are usually caused by a combination of fuel and landscape, but in this case we shaped the piles of slash to cause the whirls to form."

Preliminary analyses have confirmed that the shape of fuel piles can greatly influence the build-up and intensity of fire whirls – information that will help predict wildfire behaviour.

Twenty-four scientists from Scion, US Forest Service, University of Canterbury's School of Earth and Environment and the US National Centre of Atmospheric Research were involved in the field work. Fire and Emergency New Zealand (FENZ) and Department of Conservation staff provided operational support. Each burn day provided FENZ with valuable training in incident management.

Extreme Wildfire

MBIE Endeavour Fund, Forest Growers Levy Trust

University of Canterbury; US Forest Service; US National Centre for Atmospheric Research; Hexion; Fire and Emergency NZ; Department of Conservation.

^ *Scientists and fire crew monitor fire whirl development in heavily instrumented radiata pine slash fires.*

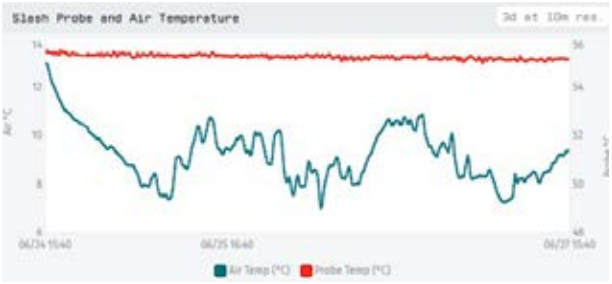
New slash sensor operational

A sensor which monitors temperature in slash piles has had extensive testing in forest environments to make it more robust and reliable. The sensor delivers temperature information via satellite to a smartphone app, giving forest managers time to act to reduce the risk of spontaneous combustion. The industry is very keen on the technology as slash pile heating is an ongoing challenge during and after harvest.

Two new communications networks will be trialled shortly in a bid to overcome some practical problems experienced with the first system.

"Instead of linking to a single stationary satellite, we are going to test an alternative system that links to swarm satellites," says Scion's Dr Richard Parker. "Another trial will use the cellular network – it's surprising how good cell coverage is in forests now. This makes things a whole lot simpler."

Six new sensors, some satellite and some cellular, will be deployed in forests in both the North and South Islands.



^ *Temperature data readings from a slash sensor and adjacent weather station, showing the much hotter temperature within the slash pile.*

^ *A slash pile which ignited spontaneously in a Northland forest.*

Richard is also investigating the relationship between slash pile temperature with the weather and has recently installed a weather station right beside a slash pile plus sensor in one forest, with a second weather station soon to be deployed. "There is still more to learn about how slash piles behave," says Richard. "The theory is that when a slash pile gets rained on, bacterial activity within the pile increases which causes it to heat up. But no-one has actually proved this."

> "The system is really valuable. It's an hour's travel each way to parts of the forest, so being able to check the pile temperature and know what the weather is doing from here – it just takes the guesswork out of things."
>
> **John Kerr, Forester, Wenita Forest Products Ltd.**

Extreme Wildfire

Wenita Forest Products Ltd; InFact Ltd.

Building for a wildfire future

As part of Scion's five-year Extreme Wildfire research programme, social scientists are investigating how decisions throughout planning, design and construction lead to homes being built with either higher or lower wildfire resilience.

As the climate warms, there will be increasing risk of wildfire in many parts of New Zealand. Meanwhile, new housing developments are springing up on the fringes of urban areas, creating more chances that humans will cause wildfires, and that more people and assets will be exposed to wildfires when they do occur.

During a recent case study to learn about how prepared people are for wildfire in the Queenstown Lakes District, Scion social scientists learned that what property owners could do to mitigate risk was often pre-determined by planning decisions.

"We need people to be making good decisions early on about wildfire risk," says Scion's Lisa Langer. "For example, houses are being built of flammable materials, close to flammable vegetation that is protected and can't be cleared, and roads are too narrow for fire trucks or for rapid evacuation in some high-wildfire risk areas."

Working with GNS Science, the Scion team have since assessed legislative and policy frameworks for managing wildfire risk and have prepared a draft White Paper. A key recommendation to government is that wildfire should be considered alongside other natural hazards at the planning stage of new developments.

^ *The urban-fringe damage left by the 2017 Port Hills fire.*

Plans include workshops with relevant professionals - planners, council staff, engineers, architects and landscape architects, to learn about their knowledge and planning processes. Two new case studies of wildfire risk planning for communities in Rolleston and Whangarei are underway, in collaboration with Fire and Emergency New Zealand (FENZ) and local authorities.

Extreme Wildfire

Fire and Emergency New Zealand; GNS Science; Queenstown Lakes District Council.

Harvesting and Transport

Hauler slash grapple prototype put through its paces

Moving slash away from watercourses and other high-risk areas is becoming a standard part of harvest operations. A solution to the challenge of how to do this on steep sites was recently trialled in a Whanganui forest, in the form of a hauler-mounted slash grapple.

The multi-tine slash grapple, designed and built by JDT Engineering Ltd, of Whanganui, was put through its paces by contractors Pomeroy Logging Ltd. The operation comprised a Thunderbird TMY50 cable hauler with a mobile tail hold and a Hawkeye Type B hydraulic grapple carriage, to which the slash grapple was attached.

During the trial the grapple successfully collected slash and tree stems up to 1.8 tonnes piece size, and moved it from an incised gully to a flatter area on the cutover, away from the waterway. Using the Hawkeye's camera to see the slash through the tines of the grapple, the hauler driver was able to pick it up and move it effectively in either direction along the skyline cable.

> "Eventually I'd like to see the design made available to any engineering company that is interested. The research has been funded by industry, so it would be fair enough just to make the CAD designs open source."
>
> **Marcus Musson, Forest360**

"We've proved the concept with that first trial," says project manager Marcus Musson, of Forest360. "The contractor found it easy to operate, so that was encouraging."

The prototype has been returned to the workshop for modifications to strengthen the frame and it will be back in the forest for some further field testing later in 2023.

^ *JDT Engineering's hauler slash grapple prototype.*

Forestry Work in the Modern Age – Te Mahi Ngahere i te Ao Hurihuri

Forest360; Pomeroy Logging Ltd.

Manufacturing partner: JDT Engineering Ltd.

Automated log tagging in the forest

Automating the process of individual log tagging, currently done manually for export logs, is a project objective in the Forestry Work in the Modern Age programme. Instead of attaching a paper tag to each log, a unique log identifier will be punched into the log end during log-making. This has many perceived benefits apart from reducing manual labour, including standardising log tracking and traceability, reducing costs associated with log stencilling and paper tags, and removing bottlenecks at ports and log scaling stations.

A multi-disciplinary project team comprising Otmetka AB, the Swedish technology developer, Engineering Services (Rotorua) Ltd, developer of the Woodsman processor, and Pocket Solutions Ltd, a mobile technology company, is developing, installing, and testing the new technology in three interlinked projects – log marking, reading the punch codes, and data management. The team is led by consultant Andy Dick, of Logjiztix Ltd, on behalf of FGR.

^ *An example of a punch code tag.*

The first prototype of the Otmetka log marker arrived in New Zealand in September 2022 and was installed on a Woodsman 750 processor provided to the project by Thomassen Logging Ltd. Otmetka sent a Swedish technician to New Zealand to work with the project team to get the log marker operating. The first successful log stamps were produced in April 2023; each stamp took less than one second, well within the acceptable cycle time to not affect processing productivity.

Pocket Solutions' role is to produce a system for scanning the log marks and managing data, with the aim being to develop a mobile scanner suitable for

^ *The Otmetka log marker prototype mounted on a Woodsman 750 head at the Kaingaroa Processing Plant (Timberlands).*

New Zealand forest conditions. The next stage of the project is to agree the design of Version 2 prototype of the Log Marker with Otmetka AB of Sweden.

Forestry Work in the Modern Age – Te Mahi Ngahere i te Ao Hurihuri

Manufacturing partners: Otmetka AB (Sweden); Otmetka NZ Ltd; Engineering Services (Rotorua) Ltd; Pocket Solutions Ltd.

Timberlands Ltd; Thomassen Logging Ltd.

Load securing and tensioning system reaches commercialisation

The Automated Log Load Securing project has three pieces of technology now at the commercialisation stage:

Chain thrower, which places the chains across the load automatically via remote control. This eliminates the risk of repetitive strain injuries to truck drivers, and opens up the task to a wider demographic of potential drivers to include people who are less physically strong.

Auto-tensioning winch which tensions the load securing chains and maintains the tension while the loaded logging truck is travelling. The winch eliminates the need for manual chain tensioning, reducing the risk of driver injury, and ensures loads are safe. There are other similar systems on the market, but this New-Zealand-designed winch operates at higher tensions than other models.

Load monitoring system – this part of the system measures the tension on each load restraint and transmits the tensions to the driver's cab. The shackle on each chain has a built in load cell and Bluetooth® transmitter to alert the driver to any loss of tension. The monitoring system is currently being tested by the log trucking industry.

The project has made excellent progress in the past year, according to project manager Ian Brown, of Woodhill Consulting Ltd. Ian emphasises that the three products can stand alone or operate together. "Although the likely total capital costs of around $68,000 per truck for all three elements may seem expensive, our cost-benefit analysis indicates the life-time costs will be about $6 per load, or 22 cents/tonne," says Ian. "Benefits include fewer injuries, extended driving careers, and better use of trucks as a larger pool of drivers become available.

> "We've started rolling out all three components of the system to logging truck companies now. It's early days, but feedback has been good so far. People seem to be keen to try all three elements, although not necessarily on the same truck."
>
> **Jared Silvester, Trinder Engineering**

Forestry Work in the Modern Age – Te Mahi Ngahere i te Ao Hurihuri

Manufacturing partners: Trinder Engineers Ltd and Waimea Engineering Ltd (Nelson).

^ *From left, Chain thrower, Auto-tensioning winch and Load monitoring system.*

Harvesting options for small forest owners

The drive for increased mechanisation in forest operations means fewer manual-based crews are available for thinning and harvesting in small forests. Forest owners now have limited choice when looking for crews with the right mix of equipment and operating knowledge to thin, fell and extract logs from small blocks at reasonable cost.

^ *A small-scale harvester-processor production thinning in a Southland radiata pine forest. (Contractor: John Fodie).*

In a series of case studies of small-scale mechanised harvesting operations throughout New Zealand, Forme Consulting Group was able to showcase what can be done with a bit of innovative thinking combined with appropriate-size machinery. The six studies include two different forwarding systems, a winch-assist ground-based harvesting system, a cable-harvesting system, mechanised production thinning, and mechanised thinning to waste operations.

^ *Forwarding harvested trees to the roadside.*

One example was a two-man mechanised production thinning operation in a small radiata pine forest in Southland, utilising a harvester-processor and forwarder. The Forme Group undertook a detailed time and motion study of the operation and a full operational cost analysis. They concluded that, in the right circumstances, mechanised production thinning could be an economically viable option for small growers, with a better financial outcome than conventional thinning to waste.

"Overall, the studies prove that mechanised contractors can work successfully in small forests, including on steep land," says Jack Palmer, of Forme. "We hope the studies will encourage owners and contractors to look at the options outside of the current large-scale machinery that tends to dominate harvesting and consider some of the small-scale alternatives."

Small-Medium Enterprises committee of FOA/FFA

Forest Growers Levy Trust

In-forest log debarking to meet market standards

Ever-stricter market requirements for chemical phytosanitary treatment of export logs are driving the alternative to remove all bark from logs. Being able to do this with a harvester-processor in the forest at the time of log manufacture has potential cost and environmental benefits.

FGR is partnering with Waratah NZ Ltd to develop a debarking head based on the successful Waratah processor design. Early fabrication was undertaken by Waratah's sub-contractor in Korea and the machine is now being machined and assembled in New Zealand. Initial field testing is scheduled for December 2023. If these in-forest tests and market analysis prove promising, Waratah NZ Ltd will commence the commercialisation of the radiata pine debarker technology.

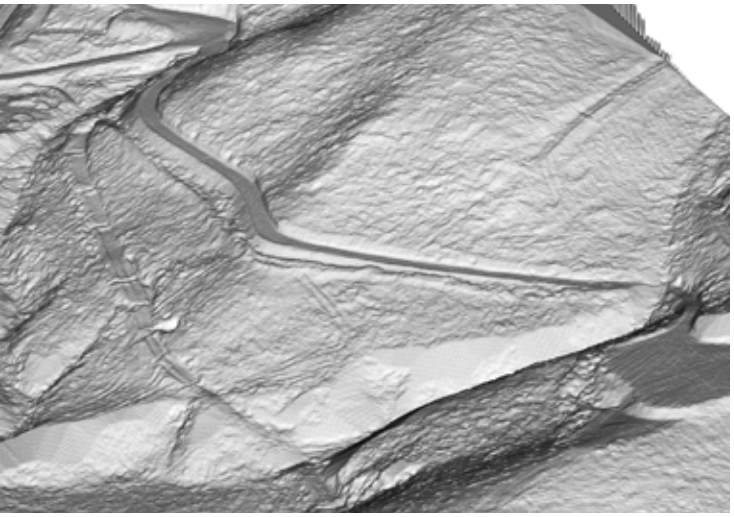
Later, the debarking head will include computer-vision technology plus artificial intelligence to measure the bark remaining on the log and provide feedback to the operator if the required debarking standard has not been met. This will ensure an objective measure of bark removal is achieved and minimise the risk of poor debarking jeopardising market access. The developers of this aspect of the project are Applied Teleoperation Ltd and Lincoln Agritech Ltd.

"There is a lot of background work going on," says FGR project leader Ian Brown. "We have installed cameras on a fixed debarker at the Kaingaroa Processing Plant, along with associated software to measure bark removal, and initial results are encouraging. We are going to run this for a while to get the bugs out of the system and then can install the bark measurement tool on the debarker head in the forest once that is ready."

Forestry Work in the Modern Age – Te Mahi Ngahere i te Ao Hurihuri

Manufacturing partners: Waratah NZ Ltd; Lincoln Agritech Ltd; Applied Teleoperation Ltd.

^ *Well-designed forest road in use.*



^ *LiDAR-derived digital terrain model of a near-completed road build.*

Improving forest road design on steep slopes

With the cost of constructing new forest roads commonly exceeding $200,000 per kilometre, good design and construction methods are imperative. Many roads in steep terrain forests are built on slopes of 25-35 degrees: the University of Canterbury School of Forestry's Professor Rien Visser and Dr Campbell Harvey are aiming to provide improved direction on best practice for road building in these conditions.

Their approach is two-fold:

- surveying experienced road engineers to collate varying construction approaches on slopes between 25-35 degrees
- using UAV-based LiDAR to capture terrain data before, during and after road construction, to capture all stages of construction and understand how roads are created in practice.

"We are trying to fill the gap between 'what should a good road look like, and how do we get there,'" says Campbell. "Road engineers are becoming much more attuned to the risks of slope failure. Standards are being raised, and roads cost more as a result. So we are rationalising, and finding out where we should be spending money to meet the required standards."

Campbell and Rien intend to encourage dialogue between forest road engineers and harvest planners to learn from each other's experiences. The best practice learnings could eventually be included in the next edition of the NZ Forest Road Engineering Manual.

Forestry Work in the Modern Age – Te Mahi Ngahere i te Ao Hurihuri

Major forest owners and forest engineers throughout NZ.

Calculating forest harvesting's carbon footprint

Measuring and reducing greenhouse gas emissions is important for the forestry sector, as it is in many other sectors. The New Zealand forestry sector is moving towards recording and reporting on greenhouse gas emissions from harvesting operations. To date there has been little formal recording of forest harvesting emissions, and more importantly ways for harvesting crews to reduce emissions.

Two final-year University of Canterbury Forest Engineering students, Dougal Shepherd, and Simon Smith, set about filling the information gap for their Honours research project. The scope was set to include only direct emissions - primarily the fuel used during harvesting operations plus crew travel to and from the forest. The students, supervised by Professor Rien Visser, developed a straightforward method for calculating emissions, available for the industry to use in future.

Information on fuel use was provided by 30 ground-based, 13 swing-yarder and 12 tower-yarder harvesting crews. Data analysis from the 55 crews showed tower yarder crews produce the largest emissions with 935 tonnes of CO_2 equivalent per annum (tCO_2e/annum). Related to wood production this relates to 14.7 kg CO_2e per cubic metre of timber harvested ($kgCO_2e/m^3$). Swing yarder and ground-based crews produced significantly lower emissions with 782 tCO_2e/annum and 693 tCO_2e/annum, which converts to 12.6 and 10.7 $kgCO_2e/m^3$ respectively.

Compared to previous studies, fuel consumption per cubic metre harvested has increased, mainly due to the increase in mechanisation, and higher proportion of steep terrain harvested, where fuel use is higher than manual or ground-based operations.

Forestry Work in the Modern Age – Te Mahi Ngahere i te Ao Hurihuri

Industry professionals (Lumen; Hiringa Energy; Z Energy; Manulife Investment Management Ltd; Logset; Total Oil NZ) and forest managers and harvesting contractors.

Augmented Reality – improving maintenance outcomes

Increased mechanisation has provided a new source of injuries in harvesting crews, with nearly 500 machine maintenance-related incidents reported between 2015-2019. Of these incidents, 185 resulted in injury.

Scion Human Factors scientists, Dr Richard Parker and Brionny Hooper, have been working with equipment manufacturer Waratah NZ Ltd and digital content developer StaplesVR to create an augmented reality (AR) tool to help train harvesting machine operators in safe machine maintenance practices.

Augmented reality superimposes virtual information on the real world (physical machinery and environment) to provide real-time visual instructions, helping technicians to easily identify components, understand their functions, and perform repairs more efficiently and safely.

The new AR tool provides step-by-step directions for routine maintenance and servicing tasks of the Waratah processor head, along with safety information. It is a screen-based alternative to a paper-based maintenance manual, whereby the user can manipulate the processor head position in real time.

^ *Augmented reality in-field servicing tool in action on a log landing.*

"It's like having a mechanic beside you," says Richard, who has been trialling the prototype. "We tested it against a paper-based system, and operators unanimously preferred using the screen. With the AR tool operators were able to find information they needed and complete tasks much more quickly than with the manual."

The tool has a fault-reporting module and records maintenance completed. It also generates awards for achievement. Richard and Brionny hope that eventually the AR tool will become part of the standard package provided with every Waratah processing head sold.

Forestry Work in the Modern Age – Te Mahi Ngahere i te Ao Hurihuri

Waratah NZ Ltd; StaplesVR.

Micro Innovation Challenge proves successful

Forestry workers with good ideas about ways to make their work safer or easier can apply for funding to help put their ideas into practice. Forest Growers Research has teamed up with the Forest Industry Contractors Association (FICA) and WorkSafe New Zealand to run a series of Micro Innovation Challenges.

Brionny Hooper is leading the team encouraging innovation. "Through many, many conversations with forestry contractors, I've learned that innovation is happening all the time across the industry. Countless clever ideas come from people on the ground. The Micro Innovation Challenge is about supporting this type of task-level innovation."

In November 2022 the first challenge had been completed, and by July 2023 a second round was underway. Entrants complete a simple on-line application to register their ideas. The selected winners receive a grant between $10,000-$25,000 to build and test a prototype.

^ *Slash grapple designed by Lucas Harper, Harper Logging Ltd.*

The first three projects selected were all practical ideas from forestry contractors. "Eventually we would like to set up a Micro Innovation hub for capturing ideas and helping innovators share their products," says Brionny. "Empowering people to contribute meaningfully to their work is known to be motivating, and to have health and wellbeing benefits. It's fantastic to be able to support our capable workforce in this way."

> "It's great to see the guys working at the coalface having the opportunity to get their ideas recognised. We've got engagement, with guys thinking innovatively about improvements. It's an excellent scheme."
>
> **Nathan Taylor, Mechanised Cable Harvesting Ltd, Tasman.**

Winners of the 2022 Micro Innovation Challenge

- Remote-controlled felling banner, enabling a felling machine operator to remotely close a harvesting site gate when operations are underway – *David Johnston*
- Quick-hitch slash grapple, designed to speed up and enhance operations to move slash to safe areas on logging sites – *Lucas Harper, Harper Logging*
- Mud mats, to create mud-free working platforms around skid sites - *Lukas Krkavec*

Forestry Work in the Modern Age – Te Mahi Ngahere i te Ao Hurihuri

Forest Industry Contractors Association; WorkSafe New Zealand; Forest Growers Research.

Wood Properties and Product Development

Productivity gains and wood properties

Dr Jono Harrington recently carried out a wood quality assessment in Puruki Forest, Scion's experimental forest in the central North Island nearing the end of its second rotation and renowned for its high productivity. The research was a preliminary investigation into how productivity gains achieved through site quality and improved genetics affect wood quality, and, by inference, product performance.

Jono carried out standard acoustic velocity tests, resistance 'Resi' tests and increment coring on three contrasting tree genotypes – GF7, GF30 and high-density genotypes. A total of 176 trees were tested. Both the velocity (a measure of tree stiffness) and density tests told a similar story – that GF30 wood quality was slightly poorer than the other two genotypes, meaning productivity had come at somewhat of a cost to wood quality. Whether or not this cost is industrially significant is yet to be addressed.

Jono believes that there are many questions to answered around matching wood quality characteristics with specific product requirements, and that data-driven simulation is possible and will enable this.

"There's been a lot of guesswork to date," he says, "which has worked OK but times are changing. In future forest growers will need to be very clear on what products they are targeting, and how they can evaluate wood quality in terms of those products. Predicting product performance has a role in risk mitigation, and in encouraging investment."

Resilient Forests

Boron and wood quality

Boron is an essential micronutrient for healthy plant growth, but its impact on wood quality is not clear. It is believed to help strengthen cell walls, so a deficiency could cause wood-quality issues including intra-ring checking, a significant concern to New Zealand wood processors.

Four trials were established nationwide in 2003 to look at how boron affects wood qualities, and Scion's Dr Jono Harrington recently undertook wood quality assessments at two of these trials, one near Taupo and one near Tekapo. The two sites are very different, according to Jono. Acoustic velocity measurements were taken, resistance was measured using the 'Resi' tool, and increment cores were taken back to the lab for analysis by Scion's Corebot.

The results confirmed that, as expected, site and genotype do influence wood quality, but the effect of boron was less obvious and interacted significantly with site and genotype.

Further wood quality analysis is needed to measure the fracture behaviour of wood – this strongly impacts intra-ring checking, and can be measured once the trials are harvested.

Resilient Forests

> Taking 12mm core samples for Corebot

^ Core profiles from Corebot - RGB, X-ray and near-infrared (NIR) hyperspectral images, from which density and composition can be derived across the tree diameter.

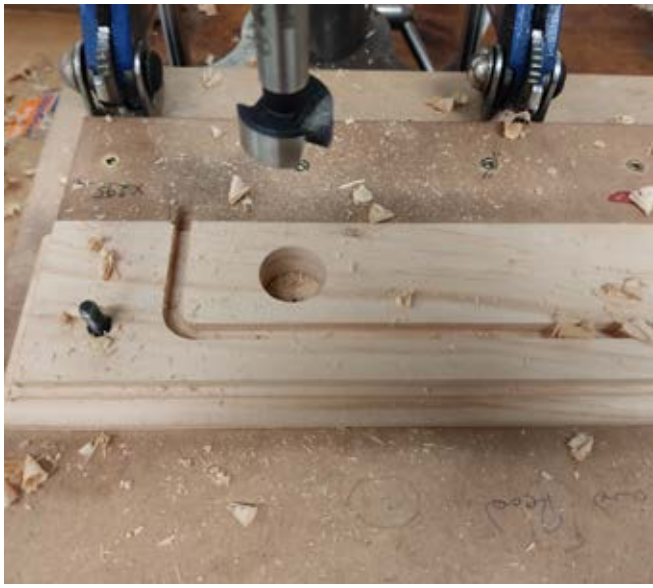
Machinability of *Eucalyptus globoidea*

Eucalyptus globoidea is one of two species selected by NZ Dryland Forests Innovation for genetic improvement work. It is recognised as being a versatile species, with class 2 durability, and good growth rates and tree form across a range of site types.

University of Canterbury School of Forestry Honours student Hamish Scown undertook six tests to assess the machinability of 28-year-old *E. globoidea* timber sourced from Banks Peninsula. He compared the results with the same tests on radiata pine. The radiata pine had an air-dry density of 460 kg/m³, compared to the *E. globoidea's* 723 kg/m³.

Hamish based his evaluation on an industry standard: the tests were planing, sanding, shaping (edging and grooving), boring, mortising and turning.

He found that the *E. globoidea* machined very well. Machinability was scored at various points in each operation, with the only low machinability scores occurring at certain points in some tests – for example as the tool exited the wood when grooving, boring and mortising. The *E. globiodea* proved more difficult to sand than the radiata pine, but adjusting the sanding technique overcame this problem easily.



^ *Testing the machinability of* Eucalyptus globoidea.

One key message from the study was that radiata-based solid wood processors can work with *E. globoidea* without any need to invest in new machinery. Hamish was supervised by Associate Professor Clemens Altaner.

Specialty Wood Products

Utilising young cypress timber

Thermal modification involves heating wood to temperatures of 180°C - 230°C in the absence of oxygen to alter the wood chemistry and properties. The aim is to increase timber durability and dimensional stability.

Scion's Rosie Sargent undertook thermal modification trials on *Cupressus lusitanica,* Douglas-fir *(Pseudostuga menzseii)* and *Eucalyptus nitens.* Early results for *C. lusitanica* heartwood and sapwood were especially encouraging, with improvement in both durability and dimensional stability. In a stakelet trial in a controlled environment, the *C. lusitanica* heartwood performed similarly to radiata pine treated with CCA to H3.2 standard. Further field trials are underway to assess longer-term durability.

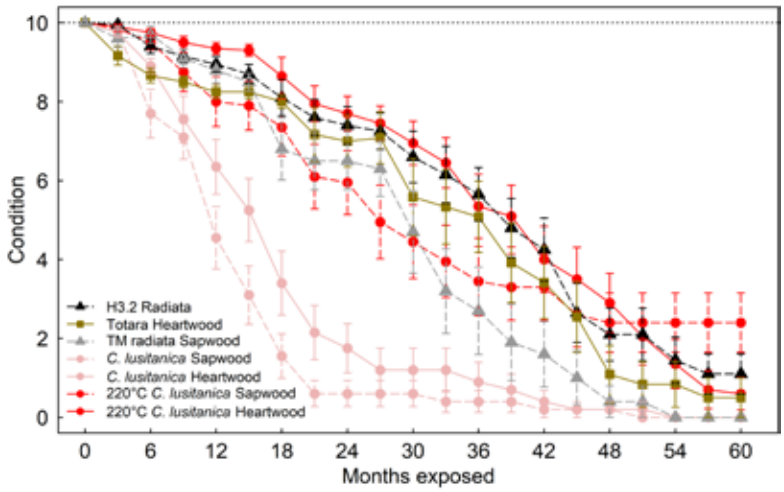
In a related project, wood from relatively young (20-year-old) *C. lusitanica* and a cypress hybrid, Ovens cypress, was sawn, air-dried and grade recoveries assessed. The Ovens cypress was also tested for bending strength and stiffness, reaching the overall standard of SG6.

Overall the two projects may increase opportunities for using relatively young cypress timber – for example from production thinning - with its high proportion of sapwood.

Specialty Wood Products

Ruapehu Sawmill (Vaughan Kearns).

^ *Cypress boards from 20-year-old trees awaiting grading and resawing, Ruapehu Sawmill.*



^ *Durability gains from thermally modifying* C. lusitanica. *(Dark red lines – thermally modifed* C.lusitanica *vs. light red lines – unmodified* C. lusitanica).

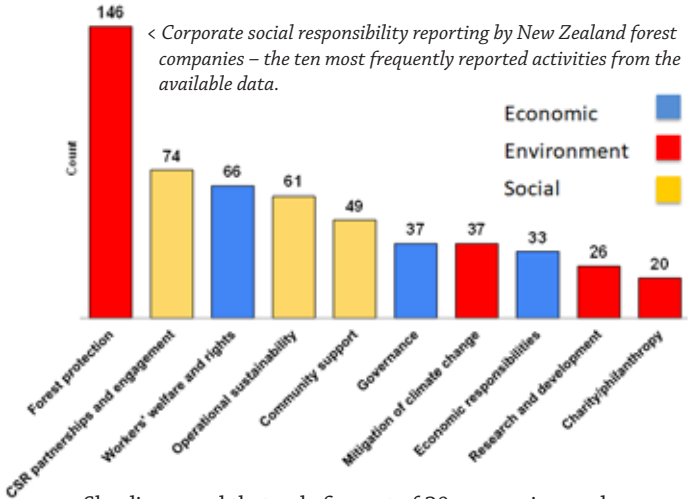
Managing for Risk and Uncertainty

Reporting social and environmental activities

The concept of corporate social responsibility (CSR) refers to a company's efforts to take responsibility for its impacts on society and the environment. Benefits likely to be derived from applying CSR include enhanced reputation, customer loyalty, and better employee satisfaction.

In the corporate world, CSR is likely to be applied from the top down by management, whose aim is to make certain values and behaviours part of the company culture and brand. Corporate social responsibility differs from a company's social licence to operate which is defined by stakeholders and the community from the bottom up.

Scion's Dr Grace Villamor has been looking at the application of CSR internationally and comparing this with its adoption by New Zealand's corporate forestry sector. Grace reviewed company reports and websites of 20 of New Zealand's largest forest owners, including two Māori trusts. Her aim was to establish how many forestry companies report publicly on their social and environmental impacts, as well as on their efforts to improve their performance in these areas.



< Corporate social responsibility reporting by New Zealand forest companies – the ten most frequently reported activities from the available data.

She discovered that only five out of 20 companies produce an annual local or New Zealand-wide sustainability report. These reports all varied in their scope, covering a range of economic, environmental and social activities.

"It's important to remember that a lack of reporting doesn't necessarily mean a lack of CSR activity on the ground," says Grace, "but we've learnt that CSR reporting is really not part of New Zealand forest company culture."

Grace then held two workshops to canvas environmental foresters about their attitudes to sustainability reporting. Participants agreed that companies are conscious of the growing pressure, both nationally and internationally, to report on their social and environmental activities; also that there is increasing awareness that forest certification is no longer enough.

Some participants voiced concern that to publicise what they are doing could be counter-productive in some way. Foresters would like to share the many good stories they have, but are cautious, and don't know how to best communicate with the public, especially the media.

Overall, participants agreed strongly that a new framework or set of standards is needed to enable consistent reporting. Company managers, rather than operational foresters, are the people likely to be making decisions on adopting and reporting CSR, and bringing these people into the conversation is a future challenge for Grace and her team.

Resilient Forests

NZ Forest Owners Association Environment Committee.

"It's important that we report on environmental and social aspects – the good things, and the challenges we are dealing with. If we don't provide information about what we're doing out there, we're not doing ourselves any favours.
And it's good to have the information at hand – good for the staff, who take pride in their achievements, and good for stakeholders, our Board, local Iwi, even local politicians so that they can stick up for us when we need them to.
At Timberlands, we'll have our first Sustainability Report out soon. We have some restorative goals out to 2050, so we can report annually on progress towards our targets.
But there's a case for a collective industry approach - as a region or even nationally we could identify some key metrics or indicators, and then there would be some commonality in how we all report."

Colin Maunder
Sustainability Manager, Timberlands Ltd.

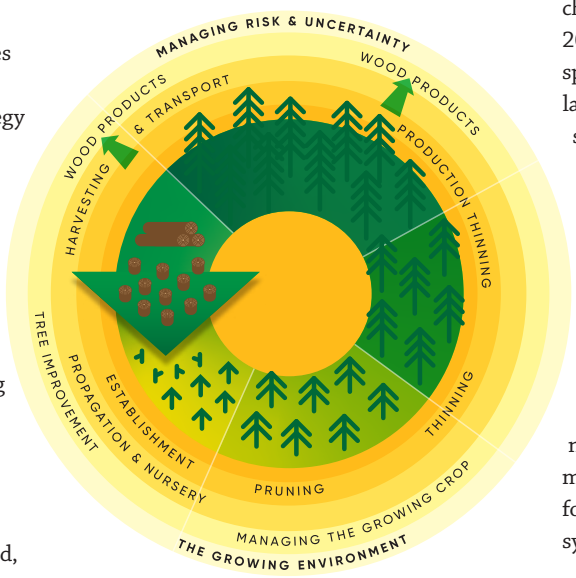
Future Research

The forest industry must be proactive in preparing for the future. Investment in science and research is a key pathway to help us do this. The forest industry's roadmap to 2050 focuses on five key goals: productivity, value, people, carbon, and our licence to operate. Underpinning our research direction is the industry's Forest Growing Science and Innovation Strategy 2020-2035, which continues to provide the framework for industry-funded research. The strategy has three key themes:

- increasing profitability from radiata pine and Douglas-fir
- ensuring 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.

There are six current industry-funded, multi-year research programmes. Five programmes are mid-term (Automation and Robotics Primary Growth Partnership, Tissue Culture for 21st Century Forests Partnership, Resilient Forests Programme, Tree Root Microbiome Partnership, and the Extreme Wildfire Research Programme). One programme commenced in 2022 (Precision Silviculture Sustainable Food and Fibre Futures Partnership) and a seventh programme, the Specialty Wood Products Research Partnership, has just been completed. All the current programmes fit within the context of a familiar forestry cycle, dominated, justifiably, by radiata pine. Within this apparently conventional structure, there is some truly innovative and world-leading research happening. We must continue to explore and embrace new technologies and systems and improve our understanding of our core business.

Some 'unstoppable trends' were identified by forest industry representatives at a workshop in 2021 – climate change, emerging carbon markets, societal expectations, biosecurity



^ *Idealised forestry cycle showing the stages of conventional management and the associated themes of research and development.*

threats and China's influence. And in 2022, the Forestry and Wood Processing Industry Transformation Plan – Te Ara Whakahou- Ahumai Ngahere (ITP) provided a new vision of our future forest industry which includes:

- reducing carbon emissions by providing bio-alternatives
- increasing domestic wood processing
- increasing export earnings from value-added wood products
- increasing wood used in mid-rise and commercial construction
- planting of alternative species increases to 20% of all planting by 2030.

Both our own Science and Innovation Strategy and the Industry Transformation Plan reiterate the need for diversifying the forest industry, and future research must embrace this change of direction. The forests of 2050 are expected to exhibit greater species diversity, a reduced reliance on large coupe clear-felling, be more site-specific and use precision silviculture, and produce a more varied range of products feeding into diversified markets.

The 2015-2023 Specialty Wood Products Research Partnership made good initial progress towards kick-starting an alternative species wood products industry. FGR's role now is to develop the case for a new multi-year research programme focusing on diverse species and forest systems.

The first stage is to develop a 'case for change' that articulates the risks and the need for change and secures wider industry support for transformation. This will encompass a new vision for the industry, evolving from one which relies on a single species feeding a limited number of product streams into a more diversified, resilient, profitable, and valued growing and processing industry. This industry will continue to make a significant contribution to the economic, environmental and social fabric of New Zealand.

An important feature of the new programme is that it will consider and complement other key strategies and research programmes already in place. It is anticipated that the new programme could get underway in 2024.

Our People

Forest Growers Research Management

Paul Adams
Research & Development Director
paul.adams@fgr.nz

Amanda Brake
Office Manager
amanda.brake@fgr.nz

Russell Burton
Programme Manager
21st Century Tissue Culture
russell.burton@fgr.nz

Marco Lausberg
Programme Manager
Specialty Wood Products
marco.lausberg@fgr.nz

Keith Raymond
Programme Manager
Automation & Robotics
keith.raymond@fgr.nz

Claire Stewart
Programme Manager
Precision Silviculture
claire.stewart@fgr.nz

Forest Growers Research Board

Peter Berg - *Chair*
Berg Forests

Ross Larcombe
PF Olsen Group Holdings Ltd

Brendan Slui
Rayonier-Matariki Forests

Dean Witehira
Timberlands Ltd

Forest Research Committee

Ian Hinton - *Chair*
Timberlands Ltd

Mike Baker
Manulife Investment Management Ltd

Angus Gordon
NZ Farm forestry Association

Aaron Gunn
Port Blakely Ltd

John Hura
NZ Forest Managers Ltd

John Schrider
NZ Farm Forestry Association

David Turner
Sequal Ltd

Sandra Velarde
WSP New Zealand Ltd

Debbie Ward
Ministry for Primary Industries

Julian Elder
Scion, Observer

Henri Ballieres
Scion, Observer

ACKNOWLEDGEMENTS
FGR acknowledges the input of all research providers, industry supporters, and others who contribute to our world-class programme of forest research.
FGR also thanks researchers and others for use of photos and images in this report.
Thanks to Phil Taylor for cover photography.

PROGRAMME GOVERNANCE GROUPS

Specialty Wood Products

Peter Berg - *Chair*
Berg Forests

Paul Adams
Forest Growers Research Ltd

Phil De La Mare
Ernslaw One Ltd

Doug Gaunt
Scion

Angus Gordon
NZ Farm Forestry Associaton

Bruce Manley
University of Canterbury, School of Forestry

Graham Manley
Southwood Export Ltd

Sean McBride
Juken New Zealand Ltd

Shaf van Ballekom
Proseed NZ

Alison Slade
Ministry of Business, Innovation & Employment

Automation & Robotics

Bryce Whitcher - *Chair*
Bryce Whitcher Ltd

Andrew Widdowson
Manulife Investment Management Ltd

Brendan Slui
Rayonier-Matariki Forests

Elizabeth Heeg
Ministry for Primary Industries

Guy Tapley
Ministry for Primary Industries

Paul Adams
Forest Growers Research Ltd

21st Century Tissue Culture

Alison Stewart - *Independent Chair*
The Foundation for Arable Research

Paul Adams
Forest Growers Research Ltd

Emily Chapman
Ministry of Business Innovation and Employment

Andrew Cridge
NZ Forest Research Institute Ltd

Craig Ford
Timberlands Ltd

Mere George
Mere Waihi Consultants Ltd

Greg Mann
ArborGen New Zealand Unlimited

Darrell O'Brien
Radiata Pine Breeding Company Ltd

Shaf van Ballekom
Proseed NZ

Mark Wilson
Lifetech Laboratories Ltd

Precision Silviculture

Ian Boddy - *Chair*
IKB Consulting

Paul Adams
Forest Growers Research Ltd

Ross Larcombe
PF Olsen Ltd

Elizabeth Heeg
Ministry for Primary Industries

Ian Hinton
Timberlands Ltd

Mike Baker
Manulife Investment Management Ltd

Boonkiang Tan
Ministry for Primary Industries

PROGRAMME TECHNICAL STEERING TEAMS

Specialty Wood Products

Marco Lausberg - *Chair*
Forest Growers Research Ltd

Clemens Altaner
University of Canterbury
School of Forestry

Jack Burgess
Port Blakely Ltd

Mark Dean
Ernslaw One Ltd

John Filmer
Southwood Export Ltd

Shawn Foster
Southwood Export Ltd

Vaughan Kearns
NZ Farm Forestry Association

Paul Millen
Millen Associates Ltd

John Moore
Timberlands Ltd

Rosie Sargent
Scion

Brendan Smith
Juken New Zealand Ltd

Andrea Stocchero
Scion

Toby Stovold
Scion

Automation & Robotics

Keith Raymond - *Chair*
Forest Growers Research Ltd

Alec Cassie
Wenita Forest Products Ltd

Andy Costello
Aratu Forests Ltd

Damon Wise
Panpac Forest Products Ltd

Dan Fraser
Forest Enterprises Ltd

Ian Wilson
ForestPHD

John Hornby
Ministry for Primary Industries

Leigh Smith
Rayonier-Matariki Forests

Mark Forward
OneFortyOne New Zealand Ltd

Mac Owen
NZ Forest Managers Ltd

Melissa Evans
Timberlands Ltd

Pat Bethel
PF Olsen Ltd

Graham Douglas
Juken New Zealand Ltd

21st Century Tissue Culture

Russell Burton - *Chair*
Forest Growers Research Ltd

Sai Arojju
Radiata Pine Breeding
Company Ltd

Mike Baker
Manulife Investment
Management Ltd

Kevin Haine
PF Olsen Ltd

Jude Redington
ArborGen New Zealand Unlimited

Christine Te Riini
Timberlands Ltd

Dianna Te Riini
Timberlands Ltd

Paul Schroeder
Proseed NZ

Resilient Forests

John Moore - *Chair*
Timberlands Ltd

Paul Adams
Forest Growers Research Ltd

Sai Aroiju
Radiata Pine Breeding
Company Ltd

Andrew Clarke
Ernslaw One Ltd

Peter Clinton
Scion

Acacia Farmery
Rayonier-Matariki Forests

Aaron Gunn
Port Blakely NZ Ltd

Emily McLay
Scion

Mark Paget
Radiata Pine Breeding
Company Ltd

Simon Papps
Manulife Investment
Management Ltd

Mark Self
Ernslaw One Ltd

Grace Villamor
Scion

Helen Whelan
Lincoln University

Precision Silviculture

Don Aurik
OneFortyOne New Zealand Ltd

Jack Burgess
Port Blakely Ltd

Thomas Crosse
NZ Forest Managers Ltd

Neil Cullen
NZ Farm Forestry Association

Tor Drummond
Juken New Zealand Ltd

Alfred Duvall
Port Blakely Ltd

Sean de Haas
ArborGen New Zealand Unlimited

Melissa Evans
Timberlands Ltd

William Grogan
Aratu Forests Ltd

Daniel Laffey
Ernslaw One Ltd

Marsh Hudson
Hudson Strategic Ltd

Hamish Macpherson
PF Olsen Ltd

James McEwan
Wenita Forest Products Ltd

Al Panckhurst
Ministry for Primary Industries

Rob Schoonderwoerd
Rayonier-Matariki Forests

Mike Thornton-Pay
City Forests Ltd

Ngaro Tumai
Manulife Investment
Management Ltd

Graham West
NZ Farm Forestry Association

Sean Wright
PanPac Forest Products Ltd

FGR 2023 Science Report Production: Harriet Palmer Design: Lloyd Creative Printing: Greenlees Print

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supported by forestgrowers commodity levy