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

Newsletter

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forests · products · innovation

Welcome to the latest update of the six-year 'Growing Confidence in Forestry's Future' (GCFF) research programme (October 2013 - September 2019). The programme is half way through its third year of activity and research projects initiated at the start of the programme back in 2013 are starting to bear fruit. Items highlighting the progress to date are featured in this edition of the newsletter.

March 21 was the International Day of Forests http://www.un.org/en/events/forestsday/. This coincided with World Water Day (March 22). These international events highlighted the importance of the interconnectedness of forests and water resources both in terms of quantity and quality, and their significance for human well-being. Water resources are not a strong focus of GCFF but they are being touched on and activities in this area will be reported in future newsletters.

Peter Clinton *(Programme Leader)*
and the research team

Research update

Improving our ability to predict fertiliser response in planted forests

The inability to predict growth responses to nitrogen fertilisers has been a significant barrier to the use of these products in planted forests. Cost-effectiveness is also an overriding issue in the forestry sector. If the returns from nitrogen addition cannot be predicted reliably from past history or existing site indicators, such as foliar nutrition, it is not practical to use fertilisers.

Recent research conducted within the GCFF programme is shedding new light on this problem. Analysis of growth, nutrition and climatic data from several existing fertiliser trials has determined that metrics describing soil phosphorus and moisture availability can produce relatively accurate predictions of growth. Although these metrics were not particularly effective at predicting the initial response to fertiliser application, within three to five years after fertiliser was added they consistently explained nearly 80% of the observed variation in fertiliser growth response.

This research suggests that returns on investment in nitrogenous fertiliser use should be able to be predicted with much greater confidence. It also provides forest owners with opportunities to modify a site to improve growth responses to nitrogen fertiliser use. Additional work is planned within the GCFF programme to expand the scope of this research.

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New spray treatments are showing some early promise

Research into new and practical options for increased growth of mid-rotation stands has given some early insight into possible new options. An initial foliar screening trial has shown gains of up to 20% increased volume growth as measured part way through a regular growing season.

In response to a range of spray treatments applied using operational methods, six different products significantly improved seedling growth compared with a standard urea application of 435 kg/ha after four months of growth.

The seedlings were grown in a relatively fertile soil media, so one wouldn't necessarily expect a large response to fertilisers. Despite this, 46% of treatments were better than the untreated controls. This suggests that even highly fertile sites may respond if the product, application rate and timing is well matched with plant requirements.

The implications of this initial study are:
- Liquid applications of nitrogen and phosphorus products to the foliage of radiata currently provides strong evidence of increased cost efficiency compared with the short term response to conventional operations.
- Testing the best treatments in mid-rotation trials will help to prove if gains shown in this work are transferable to larger trees.
- These results are indicative of trends after four months and further measurements will be required to reinforce these research initiatives.

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FOREST OWNERS ASSOCIATION

NEW ZEALAND FARM FORESTRY ASSOCIATION

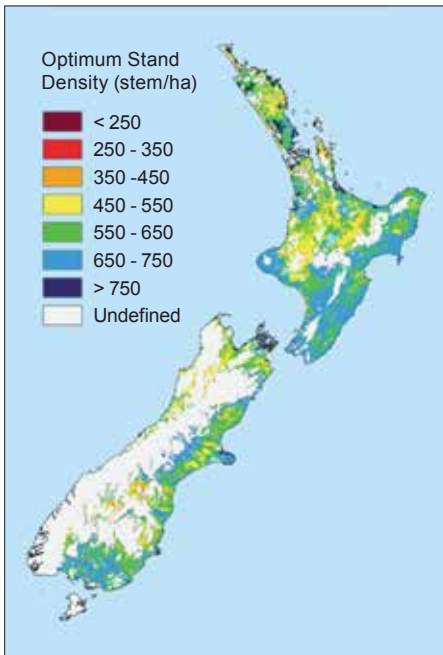# Spatial optimisation of plantation productivity and value

Figure 1. *Spatial prediction of optimal stand density for a structural grade regime across New Zealand.*

Two of the key end-uses for forest plantation products are clearwood timber, where the lower branches of the trees are removed (pruned) and structural grade timber (unpruned trees). Forest managers in many plantation growing regions have to determine the relative profitability of growing for clearwood or structural grade to ascertain whether pruning will be cost effective. Regardless of the regime chosen, managers also need to determine the final crop stand density that will maximise value. We have developed a model that allows spatial prediction of optimal end use and final crop stand density.

Example output from the model for a structural grade regime is shown in Figure 1. The predicted stand densities are far higher than current final crop stand densities in most regions.

Analyses also show that pruning profitability in New Zealand has declined markedly over the last two decades, primarily in response to reductions in the pruned log premium. The most profitable areas for pruning were found to be located in regions where 300 Index ranges from moderate to high and Site Index is relatively low.

The developed model suggests there is considerable scope for increasing plantation value through optimising stand density by site to values that are higher than those generically prescribed. The model also highlights sites where pruning is likely to be most profitable.

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UAV developments support GCFF

Unmanned Aerial Vehicles (UAVs) are an exciting and rapidly developing technology that is set to transform many fields of research and facets of our everyday lives. Anticipated advantages for the forest industry include enabling high-resolution site specific forest management, revolutionising data collection and providing a fresh perspective on forest operations. Data collected by UAVs will enrich and augment current data and provide a mechanism to fill gaps in our knowledge about our forests.

Scion has recognised this potential and invested in a UAV programme to develop and deliver the benefits of


this emerging technology to the forest industry. Scion's heavy lift craft is equipped with a laser scanner that is capable of collecting very dense point clouds, and numerous sophisticated sensors.

The UAV research programme is focussed on de-risking the technology for the forest industry and developing data collection procedures and methods to extract meaningful metrics from the extensive datasets collected. Within GCFF, the UAV has been deployed to develop methods for monitoring disease expression and for fine scale phenotyping of the forest accelerator trials and genetics trials. Scion's Jonathan Dash recently presented our UAV developments at a prominent UAV conference at the University of Queensland where it was apparent that the rapid progress in the past 12 months has placed Scion's UAV research amongst the world's leaders in the field of forest assessment and monitoring.

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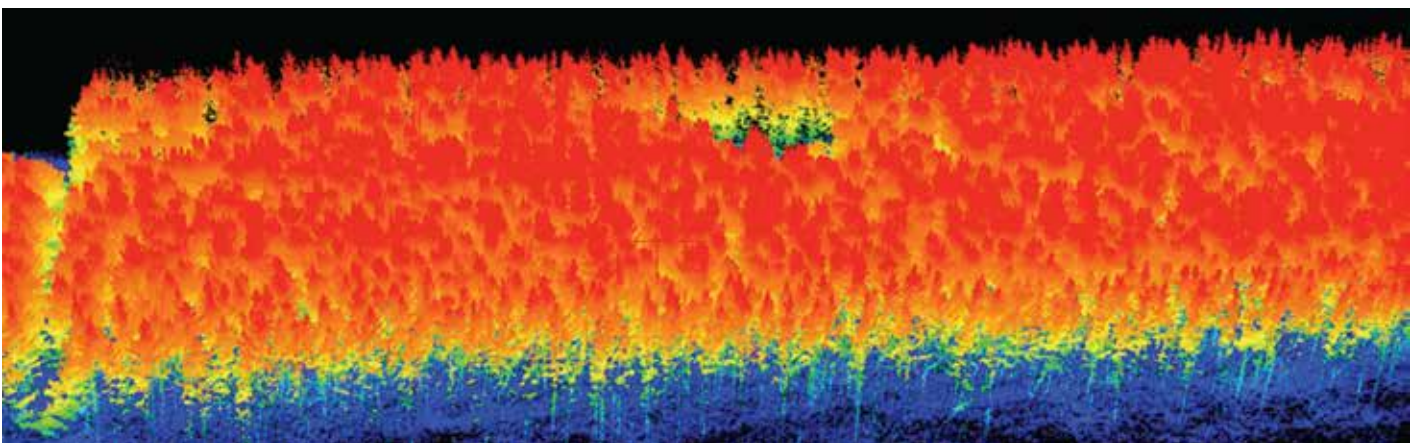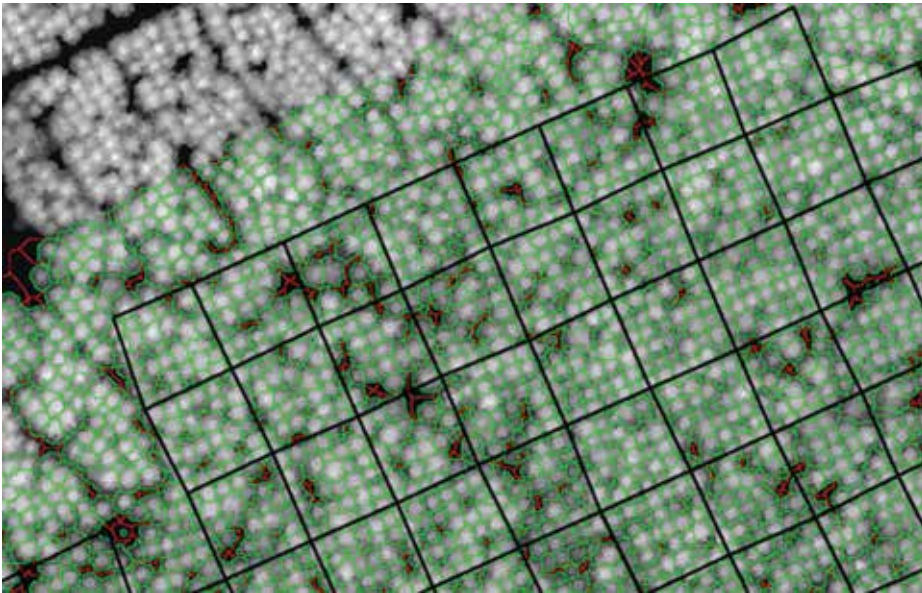
A greyscale image created from LiDAR was used to delineate more than 2000 individual tree crowns, outlined in green, in a genetics trial at Kaingaroa forest.

Remote sensing for phenotyping trees

Methods to characterise individual trees using remote sensing are powerful phenotyping tools for tree breeders, showing the effects of genetics, environment and silviculture on tree growth and quality.

Capability development in this area is being carried out as part of a post-graduate research project involving Scion's Geomatics, Forest Genetics, and Tree Growth and Quality groups. David Pont recently submitted his PhD thesis *Assessment of Individual Trees Using Aerial LiDAR in New Zealand Radiata Pine Forests* to the University of Canterbury. David found the methods he assessed allows accurate estimation of individual tree heights and diameters from aerial LiDAR, with potential applications in phenotyping trees for tree breeding programmes. The project was supervised by Justin Morgenroth (University of Canterbury), Michael Watt (Scion), and carried out in collaboration with Heidi Dungey of Scion, Forest Genetics Group.

The research results have been presented at four international conferences. Strong interest and recognition have been generated by these presentations, along with presentations and a technical report to forestry sector groups and governmental agencies. Most recently, an invited keynote speech was given at the Forest Genetics for Productivity Conference in Rotorua (15-18 March 2016). The conference was hosted by the Forest Genetics Group of Scion. Further presentations based on this research are scheduled, including the international WoodQC conference in Quebec in June and the annual GCFF conference and the associated Phenotyping Cluster Group meeting in May. Scientific papers from this research are also being prepared.

New developments supporting the GCFF programme and new research initiatives are already underway. One project, in collaboration with John Moore of the Tree Growth and Quality group, will evaluate the ability to estimate tree growth and wood quality characteristics using remotely sensed data from a trial incorporating genetics and silvicultural treatments. Data collection for the trial includes conventional ground measurements, LiDAR and multispectral imagery from the Scion UAV, hand-held LiDAR scans taken from the ground, and intensive measurement of wood properties on discs being carried out using the DiscBot (profiled in the November newsletter).

For more information, please contact *david.pont@scionresearch.com*

New frontiers in forest soil research

Scion's ability to examine the composition of soil microbial communities and understand how their activity can affect forests has vastly expanded with the GCFF programme's support of soil molecular research. The use of advanced next-generation sequencing techniques has enabled scientists to identify genes that give soil microbes the ability to enhance forest performance through increasing stress tolerance and making nitrogen more available. This research also includes studies of how site properties affect populations of important mycorrhizal fungi and identifying the environmental factors that most influence the abundance and activity of these beneficial soil microbes.

Current molecular research in the GCFF programme is exploring how radiata genotype influences the activity of soil microbes. The initial results suggest that this interaction can help explain why some genotypes are more tolerant to harsh conditions than others. This research will also be applied across different forest species, helping to improve understanding of how some tree species can establish more rapidly in marginal land than others.

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A trial exploring variations in the structure and activity of the soil microbial community associated with different radiata genotypes under stressed conditions.

Developing NuBalM into a nutrient management tool for the forestry sector

Improved ability to manage soil nutrient dynamics is critical to the ongoing success of the forestry sector in New Zealand. The GCFF programme and the Forest Growers Levy Trust have supported activities that will enable Scion's NuBalM (Nutrient Balance Model) platform to be utilised by sector stakeholders to achieve this goal.

A series of workshops provided potential NuBalM users with a forum to identify what they want the model to do, as well as gathering input from regional councils and experts in land management systems to determine how the model might be implemented and supported. A roadmap for the future development of NuBalM has been produced based on this engagement, and is already being acted on.

One of the key issues identified was ensuring that NuBalM retain a focus on stand-level predictions of site productivity and nutrient balance, with the development of new stand alone systems to convert multiple stand level predictions into a set of outputs for an entire forest. The development of another system to help landscape level planning by integrating the outputs of NuBalM with other land management systems (e.g. OVERSEER) is also planned, allowing stakeholders to compare and manage nutrient use across multiple land uses.

For more information, please contact *simeon.smaill@scionresearch.com*

New nursery management trials at Tokoroa Arborgen

The generous provision of in-kind support by Arborgen has enabled the GCFF programme to install two operational scale trials at the Tokoroa Arborgen nursery. These trials cover 2.4 km of seed bed, and are testing the impacts of alterations in nutrient use and fungicide exposure on seedling health and growth. Although final results will not be known until the seedlings are harvested in winter, interim measurements suggest a number of positive results are likely. If these findings hold, this trial could lead to substantial savings for nursery managers without compromising seedling quality when leaving the nursery gate. To determine if the differences in nursery management affect performance in the field, a large number of small trials will be established around New Zealand to monitor post-nursery performance over several years.

For more information, please contact *simeon.smaill@scionresearch.com*

New methods allowing substantial reductions in fungicide use have had no measurable negative effect on seedling health and growth over the first 8 months of the trial.

Cumulative effects of herbicide use project

Dr Dan Neary from the USDA Forest Service spent five months at Scion in 2015 on an OECD fellowship. Dr Neary worked with Dr Brenda Baillie on the development of a model to assess the cumulative effects of herbicide use (terbuthylazine and hexazinone) on water quality in the Rangitaiki River catchment over a two year period. The results indicated that the risks to both human and aquatic ecosystem health were very low. Concentrations for both herbicides were below detection limits for most of the modelling period. The analysis indicates that landscape-level forestry herbicide application programmes implemented with best management practices do not pose any additional risk to water quality.

This project supports on-going research on the forest industry's 'licence to operate' and provides a baseline to assess potential risks for any future intervention strategies to improve productivity that involve more intensive herbicide use.

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Engagement

Product Quality Innovation Cluster Meeting, Rotorua, 25 November 2015

The Product Quality Improvement Cluster meeting included presentations on: what does the upcoming wood availability picture look like; use of remote sensing to determine future resource availability; Resi – a new tool for assessing standing trees; drivers of wood quality variability – what we have learned from the silvicultural breeds trials; understanding the implications of segregation decisions on return to log; and, discrete event simulation – an approach for modelling the implications of decisions along the supply chain. The cluster group also visited the new Scion DiscBot tool which can assess various wood quality criteria.

Developing good practice for steepland forestry field day and workshop, Gisborne, 11-12 November 2015

A field trip and workshop 'Developing good practice in steepland forestry' was held as part of the sustainability cluster activities. Around 70 participants

addressed questions of: how effective are we at mitigating debris flow and sediment; what are the real or important impacts of debris flow; should we be worried about nutrient loss; how could we modify our harvesting or planting management to minimise risk; and, what should be included in a risk management analysis? A workshop summary has been circulated to participants and will be published in an article.

LiDAR/Phenotyping Innovation Cluster Meeting, Christchurch/ Rotorua, December 2015

The cluster meeting was well attended by about 20 participants and included an update on LiDAR providers, technologies and projects; results from recent UAV related projects; fixed wing smart plane UAVs for mapping cutovers; and discussion around other potential projects.

Puruki field trip.

Site productivity field trip to Puruki, April 2016

A field trip to the Puruki Forest in the central North Island highlighted some of the benefits of inter-agency collaborative research into forest productivity, tree health, nutrition, tree water use, and stream water quantity and quality, work that has been ongoing since 1968. The research site incorporates three paired catchments, including native forest, pasture, and radiata pine. The pine catchment was converted from pasture to forest in 1973, and harvested and replanted with second rotation pine forest in 1997. An overview of the research undertaken at this designated research site was followed by more detailed sessions on the hydrology and productivity of the pines.

The first focus area featured biomass production and allocation of growth to needles, branches, stems and roots; nutrient uptake and cycling; nitrogen supply from the soil and changes in streamflow in relation to pine leaf area development. Export of nitrogen and phosphorus from streams draining the 35 ha pine catchment, adjacent pasture and native forest catchments is providing valuable information of the effect of land use on water quality, and on the longevity of soil fertility improvement effects (a legacy of a farming history) on radiata pine productivity, and flow-on effects on stream water quality.

The second focus area compared stand productivity in second rotation trials at Puruki with growth rates achieved in the first rotation. The large gains in growth rate found in the second rotation stands were a result of planting genetically improved seedlots at a fertile site where foliar diseases had resulted in severe defoliation of first rotation stands. The improved tree health of the genetically improved seedlots deployed at Puruki resulted in greater needle retention and increased leaf area index that was evident in LiDAR images of the site. Growth gains were further amplified by the ability of improved seedlots to support high final crop stocking levels without resulting in high rates of tree suppression and mortality evident in less improved seedlots included in the second rotation trials. The productivity gains evident in second rotation stands planted with improved seedlots were achieved while applying appreciably less copper spray than required previously to control a commonly occurring foliar disease, *Dothistroma*.

Research results are being transferred to end users through the development of carbon and nutrient cycling models. These models have recently been integrated into the NuBalM modelling as part of the plan to facilitate improvement in the nutritional management of New Zealand's plantation forest estate within environmental limits.

The field trip was well attended with about 30 participants and included members from forestry companies and researchers.

GCFF contributions to the Forest Genetics for Productivity Conference (IUFRO), Rotorua, March 2016

Topics at this conference relevant to modern tree breeding ranged from practical requirements for breeding trees to quantitative and molecular genetics and the importance of phenotyping. Experts talked about the challenges, the future and issues that we need to think about when determining how to deliver the next wave of genetic gain to industry, as well as the use of tools to measure trees and forests across the landscape.

The GCFF programme was well represented at the conference with several programme scientists presenting research based on the GCFF programme. Simeon Smaill outlined the impact of climate change on the likely new risks that future rotations of radiata pine could face. He highlighted that although we can readily breed trees for specific known threats, the nature and extent of the conditions that climate change will precipitate cannot be readily predicted. Therefore breeding for trees with enhanced general tolerance to

stress will become increasingly important. Dean Meason presented on the influence of site factors on growth and physiology of *Pinus radiata* genotypes, and Dave Pont on the use of LiDAR for phenotyping trees.

The post conference field trip from Christchurch to Queenstown via Haast

Pass provided several opportunities for the overseas participants to view a range of forestry-related activities, including Douglas-fir seed orchards, black woods, harvesting of Sitka spruce, wilding control and native timber sawmilling.

Craigieburn Forest Park – Discussing the issue of Wilding Conifers.

Scion interactions with the New Zealand Farm Forestry Association, April 2016

Six Scion scientists recently travelled to Hokitika to participate in the 60th Annual New Zealand Farm Forestry Association Conference. The conference attracted 200 delegates from New Zealand and Australia. The outcomes of various GCFF projects were presented, including the latest work on nutrient balance modelling (NuBalM) and the potential to use this in riparian management; new information regarding

the maintenance of forest productivity over multiple rotations; and the importance of seedling properties to the establishment of a productive forest stand. The presence of the Scion staff was very well received, and the organisers of the next conference have already been in contact with Scion to begin planning the GCFF content that will be presented in 2017.

International links

A COST Action (European co-operation in science and technology) proposal titled as Payments for Ecosystem Services (Forests for Water) has been approved for funding by the EU Framework Programme in early 2016. The proposal development was led by Gregory Valatin of Forest Research UK. Richard Yao was invited to serve as a secondary proposer when the two met

in the New Frontiers in Forest Economics Conference in China, in August 2015. Richard presented the research on the validation and enhancement of the Forest Investment Framework (FIF), which provides a spatial economic framework to demonstrate the full value of planted forests, at the conference.

The four-year COST Action project aims to develop flexible, incentive-based

mechanisms that could play an important role in promoting land-use change to deliver water quality targets. This project will provide a great opportunity for Scion to collaborate with European, American and Chinese institutions in the area of payments for ecosystem services, ecosystem service valuation, and land-use change research.

Prosperity from trees *Mai i te ngahere oranga*

Looking ahead

Innovation cluster meetings

- **Forest Genetics 101 workshop:** 11 May 2016, 9 am – 1 pm, Auckland. Agenda and online registration are available at http://gcff.nz/news-and-events/. For enquiries contact Emily Telfer at *emily.telfer@scionresearch.com*, phone (07) 343 5401.
- **Phenotyping/LiDAR Innovation Cluster Meeting**: 11 May 2016, 2 - 4.30 pm, Auckland. Agenda and online registration are at http://gcff.nz/news-and-events/ For general cluster enquiries contact Mike Watt at *michael.watt@scionresearch.com*, phone (03) 364 2987 ext 7823.
- **Product Quality Improvement innovation cluster** on issues related to wood quality and resource characterisation. November 2016, Rotorua (TBC).
- **Sustainability workshop** on steepland erosion and debris flow mitigation experiences, mid-2017 (TBC).

3rd Annual GCFF programme conference: 12-13 May 2016, Novotel, Auckland. Agenda and online registration are available at http:// cff.nz/news-and-events/

5th Forest Ecosystem Services (FES) National Forum, Te Papa, Wellington, 24 May 2016. Agenda and online registration are available at http://gcff.nz/news-and-events/.

Annual FOA research conference, Napier, 12-13 October 2016.

NuBalM workshop, Oct/Nov 2016 (TBC).

4th Annual GCFF conference, March 2017, Dunedin (TBC)

Selected recent publications related to the GCFF programme

1. Dash JP, Watt MS, Bhandari S, Watt P. (2016). Characterising Stand Structure using combinations of airborne laser scanning data, RapidEye satellite imagery and environmental data. *Forestry*, 89 (2).
2. Dash JP, Pont D, Brownlie R, Dunningham A, Watt MS, Pearse G. (2016). Remote Sensing for Precision Forestry. *New Zealand Journal of Forestry*, 60 (4) pp15 – 24.
3. Donaldson LA, Nanayakkara B. (2015). Xylem parenchyma cell walls lack a gravitropic response in conifer compression wood. *Planta*, 242:1413-1424.
4. Kimberley MO, Cown DJ, McKinley RB, Moore JR, Dowling LJ. (2015). Modelling variation in wood density within and among trees in stands of New Zealand-grown radiata pine. *New Zealand Journal of Forestry Science*, 45:22.
5. Legg M, Bradley S. (2016). Measurement of Stiffness of Standing Trees and Felled Logs using Acoustics: A Review. *The Journal of the Acoustic Society of America*, 139, 588-604.
6. Monge JJ, Parker WJ, Richardson JW. (2016). Integrating Forest Ecosystem Services into the Farming Landscape: A Stochastic Economic Assessment. *Journal of Environmental Management* 174, 87-99.
7. Marden M, Rowan D. (2015). The effect of land use on slope failure and sediment generation in the Coromandel region of New Zealand following a major storm in 1995. *New Zealand Journal of Forestry Science*, 45:10.
8. Nanayakkara B, Riddell MJC, Harrington JJ. (2015). Screening for compression wood p-hydroxyphenyl to guaiacyl ratio in Pinus radiata clones using pyrolysis gas-chromatography mass-spectrometry (Py-GC/MS). *Holzforschung*, 70, 313-321.
9. Pearse G, Watt MS, Morgenroth J. (2016). Comparison of optical LAI measurements under diffuse and clear skies after correcting for scattered radiation. *Agricultural Forest Meteorology*, 221, pp61.
10. Phillips CJ, Marden M, Lambie S. (2015) Observations of "coarse" root development in nine young exotic trees from a New Zealand plot trial. *New Zealand Journal of Forestry Science*, 45:13.
11. Sabatia CO, Burkhart HE. (2015). On the use of upper stem diameters to localize a segmented taper equation to new trees. *Forest Science*, 61, 411-423.
12. Waghorn MJ, Whitehead D, Watt MS, Mason EG, Harrington JJ. (2015) Growth, biomass, leaf area and water-use efficiency of juvenile Pinus radiata in response to water deficits. *New Zealand Journal of Forestry Science*, 45, 3.
13. Watt MS, Dash J, Bhandari S, Watt P. (2015) Comparing parametric and non-parametric methods of predicting Site Index for radiata pine using combinations of data derived from environmental surfaces, satellite imagery and airborne laser scanning. *Forest Ecology and Management*, 357, 1-9.

To learn more about the research projects in the programme:

Contact Dr Peter Clinton at peter.clinton@scionresearch.com

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