The GCFF research team has had a busy summer with ongoing trial measurements, preparations for new trials, workshops and the annual GCFF conference held in Rotorua on April 4 - 5. At the same time, team members have been preparing detailed proposals for the MBIE Endeavour fund and two proposals: "Detecting and navigating social conflict along value chains: safeguarding New Zealands's economic future" and "Connections matter for enhancing interactive ecosystems" were submitted in early March and if successful would start in October 2018. Further proposals are being developed for submission in early 2019. If these proposals are successful, the work will start in October 2019.

The Government's Billion Trees programme is turning the spotlight on forestry. In particular, the nursery research component of the GCFF programme and forest ecosystem services are attracting increased interest. Our work on GxExS will also provide new understanding to assist with decisions on genetics, stocking and where to plant trees.

The GCFF team are planning a number of workshops for the remainder of 2018 that will focus on using soil and tree nutrition data and segregation. We will also hold a follow up on the Napier phenotyping workshop to discuss progress on the forest phenotyping platform. In additions, we have also been invited to host an international workshop on forest phenotyping in Rotorua as part of the International Plant Phenotyping Network conference in Adelaide in October. GCFF team members will also be attending the NZFFA conference in Nelson in May, and the Forest Ecosystem Services (FES) Forum in Wellington in May.

One of the cool achievements of the GCFF programme is what we think is the first use of an UAV to apply experimental fertiliser treatments to plots in mid rotation stands. This capability has opened new doors for research and we are now examining the use of UAV's to get more value from our network of research trials.

This newsletter contains stories about a range of current research activities, highlights some of the engagement and collaboration activities and upcoming events. We look forward to seeing you at the GCFF conference, the NZFFA conference and the FES forum.

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

Research updates

New mid-rotation fertiliser initiatives growing value

Nine mid-rotation trials have been established over the last two years at sites ranging from Topuni in the far north and Berwick in the south. Once sites were located, 30 permanent sample plots (each 0.04 ha) were established at each site and soil nutrients were collected as a basis for fertiliser recommendations.

In Spring, fertiliser bags weighing up to 350 kg were lifted by helicopter into designated plots at different sites. The bagged granular fertiliser was placed at plot centers for hand spreading.

Waiting for the helicopter to drop the fertiliser into the plots at Golden-Downs site for hand spreading later that day. From left to right David Glogoski, Craig Brown, Max Novoselov, Matt Scott and David Henley.

The team would especially like to thank the forest industry folks who helped by organising or cutting access tracks into the sites and plots. Without this, the H&S risk would be much greater and the on-going site assessments much less efficient.

The trials are a sound platform for investigating fertiliser responses at a scale not previously achieved. We have seen significant gains at three of the five sites after the first growing season and expect greater gains over the next couple of years. More soil samples will be collected to check on changes in soil properties.

This trial series, in combination with the other GCFF field trials, will enable us to develop a more detailed understanding of nutrient uptake and the importance of balanced nutrition for tree growth. Ultimately, forest managers will be able manipulate soil health for more profitable gains. Working closely with forest growers through the programme Technical Steering Committee ensures that a wide range of new ideas are being tested and new data are available to better predict fertiliser responses in the future and safe guard the industry's license to operate.

For further information, please contact Graham.Coker@scionresearch.com
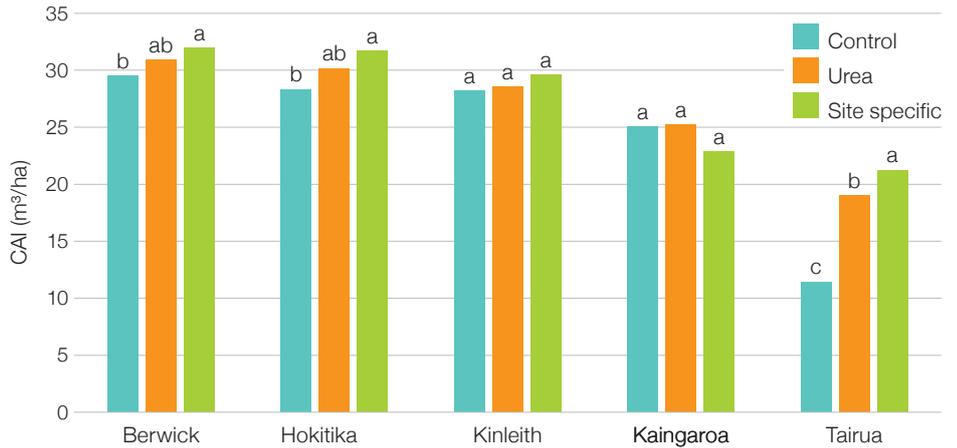

Photo: Paul Adams – Rayonier.

One of the two crews during fertiliser spreading at the Topuni site. From left to right Priscilla Lad, Mark Miller, Rodrigo Osorio and Graham Coker.

White dotted lines indicate the location of narrow access pathways cut in the thinning slash at the Flagstaff site as an example across sites.

Current annual increment, one year after treatment.

Nitrogen leaching trial in Kaingaroa Forest

Scion soil scientists, in collaboration with Prof. Brian Strahm from Virginia Polytechnic Institute and State University, have recently finished installing a nitrogen leaching trial in Kaingaroa forest. Nitrogen movement through the soil will be monitored using soil sampling (isotope tracer) as well as resin lysimeters and leachate collectors at depth (1m and 2m soil depth). The trial incorporates the different surface forms created by spot mounding (inter-rows, mounds and windrows) and different levels of nitrogen (N) fertiliser application (0, 250 and 500 kg N ha⁻¹). The results of this trial will inform the timing and rate of N application to the adjoining Accelerator Trial. The trial is in a young *Pinus radiata* stand on a low-fertility Immature Orthic Pumice Soil; fertiliser use could significantly improve productivity at this site, and the leaching study will be a key step towards understanding how to do so in a sustainable manner.

For further information, please contact Loretta.Garrett@scionresearch.com or Amanda.Matson@scionresearch.com

Stephen Pearce and Loretta Garrett preparing the scaffolding for the soil pits.

Amanda Matson installing lysimeters in a soil pit and completed pit directly after fertiliser application (inset).

Progressing sector-led biuret trials

Timberlands and Rayonier/Matariki have launched their own pilot trials with biuret based on successful results of the biuret trials carried out within the GCFF programme to determine the extent of any potential nutritional and growth benefits to their forest estate.

Scion scientists have provided support to both companies in terms of the design and implementation of the trials, and will continue to assist with measurement collection and data analysis. The scale of the trial means aerial application is needed, and Scion staff worked with Timberlands to develop a suitable methodology for this process. In addition, Scion is helping Timberlands explore the environmental footprint of biuret compared to the other treatments through the installation of resin lysimeters to track nitrogen within the treated areas.

The Rayonier/Matariki trial was established in a recently planted stand, and also tests the effect of biuret compared to more conventional nitrogen fertilisers. This trial will provide a useful comparison to the Timberlands trial, which focusses on older trees.

If the results of the trials are satisfactory, a process will need to be initiated to enable the production of biuret in New Zealand. This is not a technical challenge, and will significantly improve the current price model and the value proposition.

The development of these trials serves as an example of how GCFF results can be tested within the sector to determine if a piece of successful research can be converted into a practical treatment within the forest.


Loretta Garrett installing resin lysimeters into a soil pit in the Timberlands biuret trial.

For further information about this research and the opportunities to establish operational trials, please contact Simeon.Smaill@scionresearch.com, Loretta.Garrett@scionresearch.com or Amanda.Matson@scionresearch.com

Phenotyping for Precision Forestry

The Phenotyping Platform under development at Scion aims to link information from a number of sources to derive knowledge about the drivers of tree growth, and provide the tools to optimise forest management in support of precision forestry. Phenotyping relies extensively on the application of remote sensing and image analysis to characterise forest stands and trees. Remotely sensed data are analysed to produce phenotypic measures that embody complex interactions between genetics, environmental influences, and silviculture. Current research is focussed on the use of airborne laser scanner (ALS) data, but methods to utilise a wider range of sensors and platforms, such as colour and hyperspectral images captured from UAVs and satellites, are also under development. In the future, the Phenotyping Platform will also integrate developments such as characterising wood properties using the DiscBot, and monitoring seedling responses in nursery experiments.

Teasing apart the interactions of genotype, environment, and silviculture (GxExS) will allow the selection of superior breeds, matching them to sites, and tailoring silvicultural management to maximise production goals. Traits of interest include, growth, form, disease and wood quality. The current prototype platform includes developments at two contrasting levels of resolution, tree-based and area-based, and is primarily focussed on characterising tree growth.
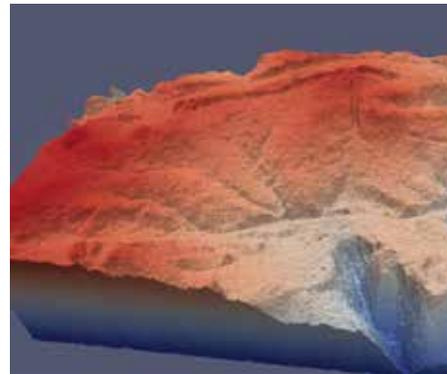
*Micro-terrain model extracted at 0.2 m resolution from LiDAR.*

Tree-based phenotyping is characterising individual trees using a set of 50 crown metrics. These tree-based methods, developed using ALS data, were recently shown to also be capable of utilising point cloud data from UAV-borne LiDAR or colour image sensors. Data are analysed at 0.2 m pixel resolution, providing the ability to characterise individual tree crowns and micro-site terrain features, and is typically applied at the stand or trial level. Terrain features such as exposure, slope, wetness, ruggedness, and insolation have been extracted from ultra-high resolution digital terrain models and correlated with tree growth, form, disease, and wood quality traits. Methods to analyse ultra-high density point clouds from UAV and hand-held laser scanners were also recently developed, with the potential to better characterise traits such as stem form and branching. The current focus of tree-based phenotyping research is to quantify and isolate the effects of competition and environment on the growth of individual trees, allowing accurate identification of trees of exceptional genotype within forest stands. DNA testing can then be applied to those trees and exceptional parents identified to improve the gene pool used in future breeding. Tree-based phenotyping methods also aim to develop deeper understanding of the fundamental interactions of genetics, micro-site, tree spacing, and silvicultural treatments. Phenotyping at the tree level is the ultimate goal, but is also computationally and analytically demanding.

The area-based analysis of ALS, widely used for forest inventory, is being applied to derive estimates of mean height, TSV, basal area, and stocking as phenotypic measures at the patch level, across a whole forest. These data are being assembled together with stand records, information on seedlots, and environmental spatial layers. The ALS data are processed with 25 m pixels, while stand records, seedlot, and environmental data are effectively limited to stand level (approximately 500 m pixels). Area-based phenotyping can therefore be effectively applied to characterise stand-level performance, identifying superior combinations of seedlots, stands, and silviculture. This approach will allow managers to maximise production by identifying best-performing seedlot, site, and silvicultural combinations within their forest.

Tree-based phenotyping will ultimately enable true precision forestry right down to the individual tree and micro-site level, requiring a long-term research and development horizon. In the interim, area-

based methods can deliver valuable near-term gains by providing forest managers with a tool to optimise seedlots, sites, and silviculture in stand-level precision forestry. Future developments will see the integration of a wider range of sensors, platforms, data sources, and analytical methods to develop a Phenotyping Platform enabling precision forestry at ever-increasing resolution, accuracy and scope.
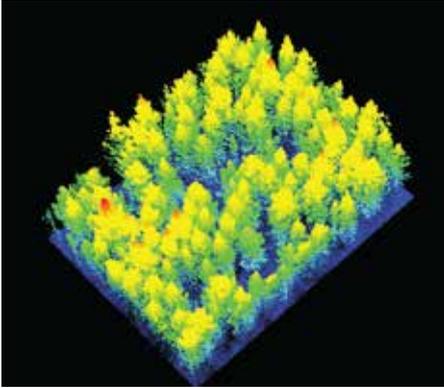

Ultra-high density UAV LiDAR used for tree detection and phenotyping.

So what can you expect at the end of the GCFF programme? The area-based phenotyping will be demonstrated in a case study on at least one forest, where we hope to estimate the projected gains in forest productivity from the research. We will also work with interested GCFF members to show how the area-based methodology might be useful, identifying the data that will need to be collected and how we can work towards using this approach in individual businesses. Workshops are planned in the next financial year for this purpose.

Individual-tree phenotyping has been achieved for growth (height) and diameter at breast height (DBH), and preliminary work on stem form will be carried out by the end of the GCFF programme. Individual-tree phenotyping for stand inventory purposes is now possible, and we have also shown that the accuracy needs to improve for breeding purposes. Two further and very significant challenges remain – individual-tree inventory across the whole forest and accurate in-forest phenotyping for breeding and genomics.

Fingerprinting has been a much more challenging target than we expected. We were assured from the manufacturers that the technology developed in animals for an approximately 100 marker fingerprinting panel was ready for application in plants.
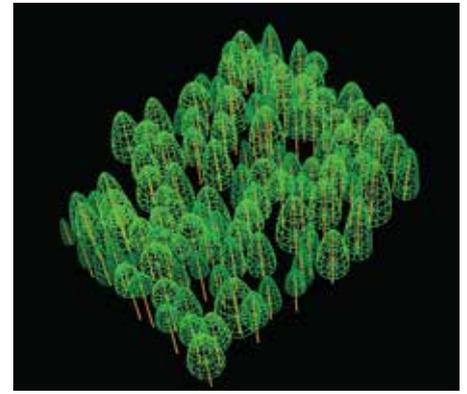
Phenotypic metrics extracted from LiDAR representing tree height, DBH and TSV.

Unfortunately this was not the case and we lost two valuable years trying to make this work. At the moment we have the capability to do more expensive classical genotyping, which supports the phenotyping research. Simultaneously, we are exploring solutions for cost-effective operational fingerprinting and we intend to demonstrate the fingerprinting of exceptional trees identified using LiDAR prior to the completion of the GCFF programme.

For further information, please contact Heidi.Dungey@scionresearch.com or David.Pont@scionresearch.com

Engagement

The FOA Environment Committee and Waikato Regional Council trip to Puruki Forest

A Scion delegation led a field trip attended by Forest Owners Association Environment Committee and Waikato Regional Council members to Puruki Forest at the request of the FOA Environment Committee. Tree productivity, soil chemistry, and stream water quantity and quality have been examined in inter-agency projects at this long term monitoring site, funded through multiple research programmes since 1968. Data from this radiata pine forest have helped underpin the development of NuBalM (Nutrient Balance Model) in the GCFF programme, and a number of other GCFF funded projects have utilised the site. The topics discussed included:

- Advances in predicting water use within forests
- Variations in nutrient export during the life of a forest rotation
- Results of a recent study into rainfall infiltration and movement through forest soils
- NuBalM nutrient balance model and its implementation to understand nutrient cycling processes at Puruki Forest

Peter Beets addresses the Puruki field trip attendees.

- Future development and applications of NuBalM
- Monitoring of soil nitrogen pools at Puruki Forest
- Likely future fertility of Puruki Forest
- Changes in foliar nutrition at Puruki Forest through time.

The audience was highly engaged with the various topics with questions and discussion punctuating the presentations throughout the field trip. Scion has received positive feedback from both the Environment Committee and the Waikato Regional Council regarding the value of the information provided, and their interest in any future events of this nature.

For more information about this trial site and the research described above, please contact Peter.Beets@scionresearch.com, Dean.Meason@scionresearch.com, Simeon.Smaill@scionresearch.com or Loretta.Garrett@scionresearch.com.

Collaboration and international linkages

A high level delegation from the Beijing Forestry University (BFU) led by President Weiming Song visited Scion at the end of January 2018 and a MOU was signed between the two organisations. Another outcome from the visit was that John Moore and Peter Beets were invited to attend workshops at BFU. John will attend a workshop on precision-based non-destructive testing technologies for evaluating wood quality of forest resources organised by the Beijing Forestry University and D5.01.09 of IUFRO. Peter has been invited to a workshop at BFU hosted by the international journal "Forest Ecosystems".

The GCFF team will continue to develop links with their Chinese colleagues through co organising sessions and events at the 4th International Congress on Planted Forests in Beijing, China on 23-27 October 2018.

Amanda Matson will be visiting Drs. Marife Corre and Edzo Veldkamp in the Department of Tropical and Subtropical Soils, University of Goettingen, Germany. She will give a presentation about Scion and her research in the GCFF programme while she is there. She will also work on data analysis on tree-stem greenhouse emissions from her previous studies there.

Looking ahead

Upcoming GCFF events

1. 4-6 April 2018. 5th Annual GCFF conference 'Current innovations and opportunities in forest management and productivity', Rotorua (includes LiDAR/Phenotyping cluster workshop).
2. 8-9 May 2018. Forest Ecosystem Services National Forum, Wellington.
3. Product Quality Improvement Innovation Cluster, date & location TBC (Presenting a range of options available to forest managers and wood processors for segregating at the stand and tree scale)
4. 30 May 2018. (TBC) Professional development workshop on Forest Productivity (incorporating a visit to Forest Accelerator trial), Rotorua.
5. July 2018. Two workshops on site specific management based on soil and foliage information. North Island venue (Rotorua) and South Island venue (location TBC).
6. 9-14 September 2018. IUFRO Extension & Knowledge Exchange (EKE) working party conference. (GCFF RA4 aspects integrated), Christchurch.
7. 8-9 October 2018. International Forest Phenotyping workshop, Rotorua. (a satellite meeting of the International Plant Phenotyping Network (IPPN) conference 2-5 October in Adelaide)

Other

1. 6-9 May 2018, NZFFA conference, Nelson
2. 16-18 October 2018 Annual FGR conference https://fgr.nz/programmes/conferences/

Selected recent publications related to the GCFF programme

1. Dickson A., Nanayakkara B., Sellier D., Meason D., Donaldson L., and Brownlie R. (2017). Fluorescence imaging of cambial zones to study wood formation in *Pinus radiata* D. Don. Trees. *Structure and Function*, **31**(2): 479-490.
2. Dash JP, Watt MS, Pearse GD, Heaphy M & Dungey HS (2017). Assessing very high resolution UAV imagery for monitoring forest health during a simulated disease outbreak. ISPRS *Journal of Photogrammetry and Remote Sensing*, **131**, 1-14.
3. Gallart M, Adair KL, Love J, Meason DF, Clinton PW, Xue J, Matthew H &Turnbull MH (2018). Host Genotype and Nitrogen Form Shape the Root Microbiome of *Pinus radiata*. *Microbiology Ecology*, **75** (2), 419-433.
4. Kimberley MO, Watt MS & Harrison D (2017). Characterising prediction error as a function of scale in spatial surfaces of tree productivity. *New Zealand Journal of Forestry Science*, **47**:19.
5. Pearse GD, Morgenroth JA, Watt MS & Dash JP (2017). Optimising prediction of forest leaf area index from discrete airborne lidar. *Remote Sensing of Environment*, **200**, 220–239. https://doi.org/10.1016/j.rse.2017.08.002

Note: Results of this programme and related work are often published in the New Zealand Journal of Forestry Science which has open access and publications are easily accessible through their website http://www.nzjforestryscience.com/. Summary abstracts of other subscription only journal publications are typically available online through the individual journal's websites and full information can be accessed by getting in touch with the authors directly. The GCFF website https://gcff.nz/publications/ provides the appropriate links to access the published information.

To learn more about the research projects in the programme:

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

Visit the programme website www.gcff.nz

To receive our newsletter and information on upcoming GCFF events go to www.scionresearch.com/subscribe and sign up.

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