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

Newsletter

SCION

AUGUST 2019 ISSUE 10

The GCFF Programme winds up in September 2019. This is our second to last newsletter reporting on a range of activities. Contributors to the programme have been busy running workshops for industry and preparing scientific papers for publication. Highlights in this newsletter include stories on tree level phenotyping, nutrition and soil health and a report on the 2018 GCFF conference. Our final newsletter will feature a mixture of flashbacks and key highlights from the last few months of the programme.

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

Research updates

Tree level forest phenotyping

Tree height, diameter, and volume are phenotypes – observable characterisitics – and the process of estimating these is phenotyping. Remote sensing data acquired using airborne laser scanning is being analysed to detect trees and estimate their individual heights, diameters, and stem volumes; in other words, to phenotype individual trees.

This capability is being applied in a project to develop methods to identify exceptional trees in operational forest stands. The vision is to use remote sensing to phenotype and rapidly screen hundreds of thousands of trees in order to detect exceptional individuals. Exceptional trees are those showing notably superior or inferior growth. Those trees are the outliers, and we would like more of those showing superior growth in our future forests, and less of those showing inferior growth.

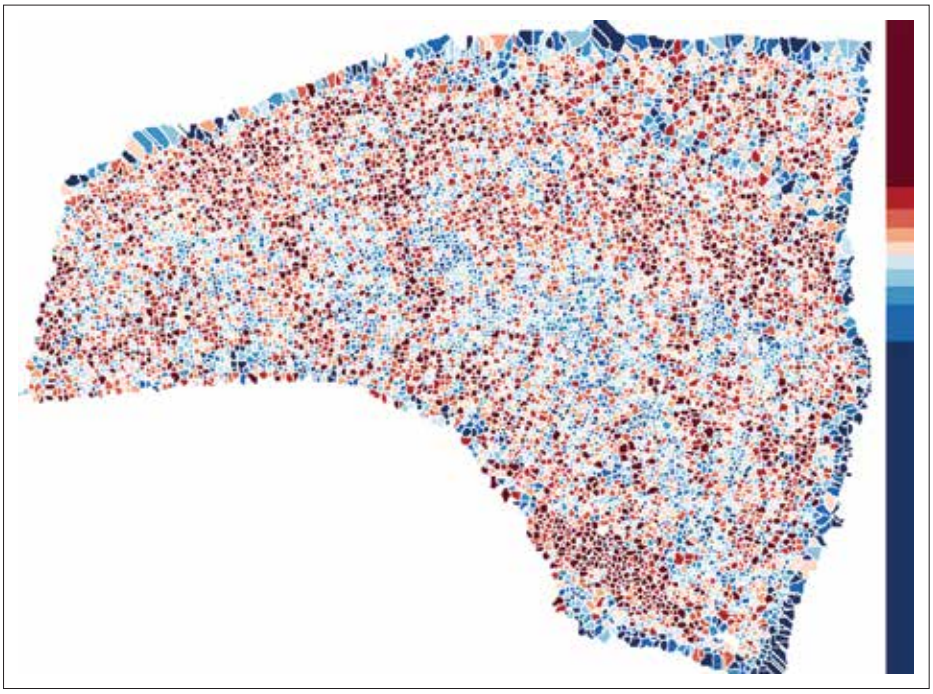

Figure 1. *Map of an operational stand showing detected individual tree crowns coloured to represent one of the derived phenotypic measures – tree height. Localised areas of superior height growth are visible and were related to aspect.*

Earlier analyses of phenotypic data showed that key drivers of individual tree growth were the combined effects of genetics, local microsite, and inter-tree competition. Prototype methods are being developed to separate and quantify these effects from tree-level phenotypic data. The methods are currently being developed using data from a mature operational forest stand. Like most typical forest stands, the trees have mixed genetics (a seedlot), and there is significant environmental variation due to varying elevation and aspect. This is providing real-world conditions for development and testing of the methods.

A total of 10,882 trees were detected and phenotyped in the 35 ha test stand. A plot of the phenotypic data showed obvious areas of superior and inferior growth (see Figure 1). This variation represents localised micro-site effects on growth, with superior growth occurring on northern aspects. Analysis quantified the site effects, as well as inter-tree competition, to more accurately estimate the genetic component of observed tree growth.

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Candidate trees were then selected and visited on the ground to collect DNA for genetic analysis to identify superior parents from the breeding pool. Such research can ultimately lead to the development of improved breeds, matched to sites and regimes, optimising performance across a forest.

There is also scope for applications of this research beyond tree breeding. The methods could be extended in future developments to relate individual tree performance to stand density, soil fertility, and disease. This information could support precision forestry by optimising management operations such as planting, thinning, and fertilisation across the forest. There is even current interest in using the methods to identify beneficial soil microbes by sampling soil near trees exhibiting improved growth not attributable to site or competition effects.

The phenotyping and analytical methods being developed can therefore support development of improved breeds, precision forest management, and can provide tools for researchers in a range of areas, including soils and microbes, forest management, growth modelling, and forest health.

The research team includes: David Pont, Heidi Dungey, Toby Stovold and Natalie Graham.

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Latest results from the Accelerator Trial series

An analysis of tree growth at the three oldest Accelerator Trials has been presented to the GCFF Technical Steering Team. Some highlights were:

- **Southern Kaingaroa –** the application of a small dose of biuret continued to enhance tree diameter and height growth. It was also found that trees treated with biuret suffered less damage from dothistroma.
- **Rangipo –** cultivation carried out as standard practice to prepare the site for afforestation has resulted in reduced growth compared to the stock that was planted into undisturbed pasture. Cultivation was also found to increase the incidence of dothistroma.
- Across all three sites, genotypes that were resistant to dothistroma also tended to exhibit strong growth rates, indicating the importance of this trait for forest performance.

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Example of the variance in tolerance to dothistroma observed across genotypes at the southern Kaingaroa site.

Will maintaining balanced nutrition of trees enhance the disease resistance of pine?

The association between tree nutrition and the occurrence and severity of red needle cast (RNC) in radiata pine is being investigated by GCFF contributors Jianming Xue, Graham Coker and Amanda Matson. Mineral nutrients are essential not only for plant growth and development, but also affect plant-disease interactions. In general, plants with optimal nutrition resist or tolerate diseases better than malnourished plants. Mineral nutrients are often viewed simply as plant food necessary for better plant growth and yield. Although disease resistance is also controlled by genetics, mineral nutrition can have an influence on plant resistance or susceptibility to pathogens and pests. In addition, some disease-resistant genes in plants will only activate via specific environmental stimuli like nutrients.

Nutrient-pathogen interactions are not well understood for key commercial tree species. However, it is understood that plant nutrient status may affect disease susceptibility by changing metabolic pathways that create a more favourable environment for disease. Plants with optimal nutritional status have the highest resistance (tolerance) to pests and diseases. Susceptibility increases as nutrient concentrations deviate from this optimum. Since the roles of mineral nutrients are well established in host-disease interaction of many crops, tree growers may also better utilise the opportunity of such interactions for improved disease and pest control by achieving balanced tree nutrition through fertiliser applications and other best management practices.

Little work has been conducted on the effects of optimised tree nutrition on disease development, and there are no detailed studies simultaneously linking tree nutritional status, disease susceptibility, and expression of induced defense responses for RNC and other diseases of radiata pine. Therefore, a better understanding of the association between tree nutritional status, disease development and defense chemistry in radiata pine will be helpful in providing new management options in the future.

As a proof of concept, a study is underway

Manipulating the nutrition of radiata pine seedlings in the glasshouse.

in a glasshouse fogging chamber using pine seedlings growing with different nutritional supplies (e.g. control, multiple nutrient deficiencies, balanced nutrition, excessive nitrogen). Initially, we manipulated the seedling nutrition of radiata pine in the glasshouse (See the photo). Once the required nutritional status of pine seedlings for each treatment was met, all individual pots were moved into the fogging chambers and inoculated with RNC spores for 28 days. The results from this study will be used to guide future field work and to develop a decision support system for forest nutrition management and disease control of radiata pine forests.

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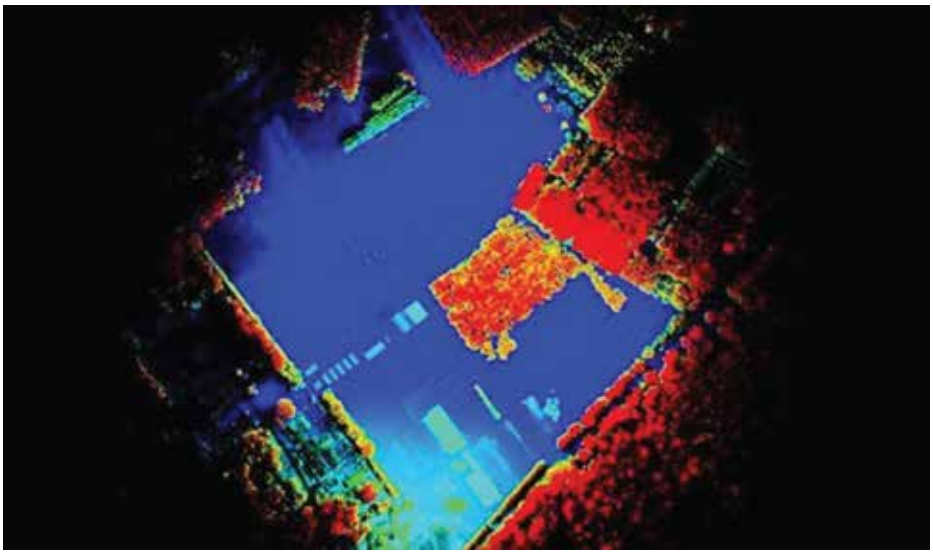
Scion has a new top-of-the line lidar scanner – the Riegl MiniVUX-1 UAV Snoopy V-series manufactured by LidarUSA

The new sensor has a finer resolution and accuracy than our previous scanner and, perhaps most importantly, has an increased range. Being able to capture data at greater than 60 m above ground (and up to 120 m) means flying UAVs within visual line of sight (VLOS) is much easier, and the UAV is safely clear of tree tops.

Scion arranged a training session to learn how to get the most out of the new acquisition. LidarUSA sent out one of their trainers from Alabama, USA, and some of our partners (University of Canterbury, Interpine Innovation, and Pilbrow Surveying Ltd) who are also looking at adopting this technology were invited.

The system has been applied operationally for data capture, and the Geomatics team have been putting it through a series of trials to assess the optimal settings for various types of data capture.

This system will be used for GCFF research to assess a variety of stands, including the GCFF Accelerator Trials (between age 1 and age 4), and for some mature genetics trials, so that we can ascertain the value that this type of data could add to the industry.



Scion's nursery in 3D modelled from data captured 60 m above ground.

Soil health

The assessment of soil health (or quality) is internationally recognised as an important tool to understand ecosystem function including the productive potential of planted forests. Endpoints can include chemical, physical, and biological metrics, but holistic assessments would include coverage of all these. Despite the fundamental importance of biological species and processes in many soil ecosystem services, the explicit inclusion of biological assessment in soil health testing in New Zealand is generally absent.

Within the GCFF programme, the Systems Ecology team at Scion undertook a survey-based study to determine the relative value of soil ecosystem services to plantation forestry stakeholders. This work was supported by French intern student, Mr Mathis Richard.

Across all survey respondents, a very high importance was placed on the ability of soils to sustain forest production across subsequent forest planting rotations. Interestingly, this was valued more highly ($p<0.05$) than maximising short-term production, even by forest owners. Māori placed greater importance on forest ecosystem resilience, provenance and kaitiakitanga (sense stewardship of resources), water quality, and harvest of

food and/or medicines from forests than non-Māori (all $p<0.05$).

These results demonstrate inherent cultural differences in the importance of forest ecosystem services that soils support. It is important that these differences are understood and integrated into future soil health testing schemes to reflect the needs of all stakeholders. Ultimately, this work will help increase the sustainability of planted forest ecosystems in New Zealand, ensure the forestry sectors social licence to operate, and add value to forest products by demonstrating environmental and cultural stewardship of forest products.

This work was presented at the New Zealand Soil Science Society conference and a full manuscript has just been accepted for publication in an international peer-reviewed journal.

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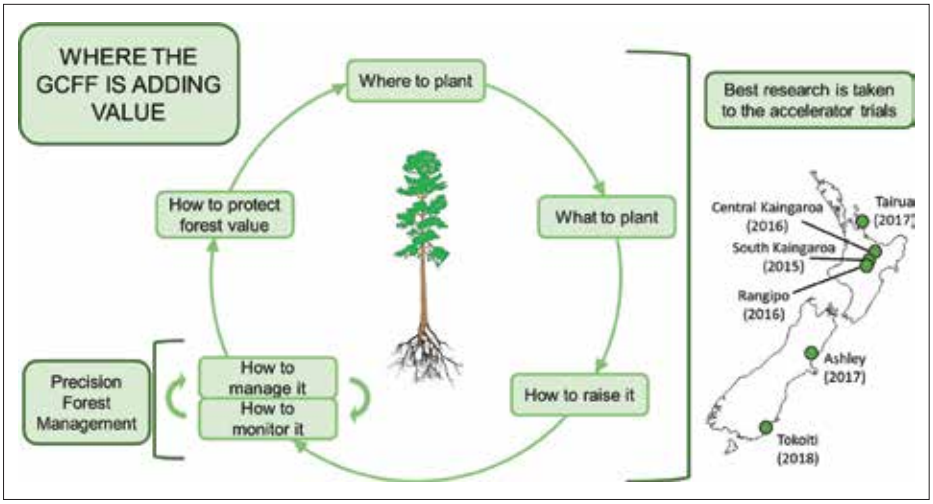
Engagement

Reporting on GCFF progress at the 2018 Forest Growers Research Conference

The impact of the GCFF programme on current and future forest productivity was discussed in a presentation given by John Moore, Loretta Garrett, Mike Watt and Simeon Smaill at the 2018 Forest Growers Research Conference (Tauranga 16-18 October). The presentation illustrated how different components of the GCFF Programme were contributing to five key elements of forestry: Where to plant, what to plant, how to raise the stock you will plant, how to manage and monitor your forest, and how to protect the future value of your forest. The final discussion showed how these different research areas are being combined in the management of the Accelerator Trials. The trials have been established at six locations to identify pathways to sustainably maximise productivity.

Simeon Smaill received the FGR Research Award for "Innovation that Enhances Sector Value" based largely on work undertaken in the GCFF Programme, some of which is described in the presentation.

A recording of the full presentation can be viewed at https://fgr.nz/programmes/conferences/2018-fgr-annual-conference/gcff-what-have-we-learnt-to-date/, and a copy of the presentation can also be downloaded from this site.



Central structure of the GCFF presentation at the 2018 Forest Growers Research Conference.

Scion scientists at the New Zealand Society of Soil Science conference

The national soil science conference (Napier, December 2018) was attended by Sarah Addison, Peter Beets, Yeganeh Eslami, Loretta Garrett, Priscilla Lad, Amanda Matson, Dean Meason, Simeon Smaill and Jianming Xue. The theme of the conference was 'Diverse Soils – Productive Landscapes', with sessions on soil quality/function, hydrology, carbon, contamination/remediation and greenhouse gases.

The Scion presentations incorporated several projects that are part of the GCFF Programme. These included soil factors that have the greatest effect on New Zealand forest productivity, nutrient retention and loss from a nitrogen leaching trial, integrating 'biology' into forest soil quality assessments, using soil natural capital in the Accelerator Trial network, the effects of forest ecosystem management on soil biodiversity and function, and quantifying soil microsite variation and its impact on forest productivity.

The Scion team had a great time at the conference, meeting and talking with attendees and developing new opportunities for future collaboration.

Staff update

Retirement

Peter Beets retired and left Scion after 44 years of service. Over his career, Peter has become something of a national treasure, not least for his contribution to carbon and climate change research in New Zealand.

"Peter has won the respect of government and industry for his work on measuring and modelling biomass carbon, water and nutrient cycling in both plantations and indigenous forests. He is perhaps best known for his underpinning research for the Ministry for the Environment which led to the implementation of the national carbon inventory of New Zealand's planted and natural forests as well as foundational work for New Zealand's Emission Trading Scheme for the Ministry for Primary Industries.

Along the way he has won a Nobel Prize for his work with the Intergovernmental Panel on Climate Change, as well as Scion's own Science Excellence Award.

What we will miss most, I suspect, is Peter's passion and commitment to science excellence. He has never lost the enthusiasm and drive for science inquiry and a love of forests. He has maintained that rare ability to feel equally at home in Wellington's rarefied policy world while getting his hands dirty undertaking research out in the forest.

I hope you will join me in thanking Peter for his huge contribution to Scion and in wishing him all the best for his future adventures."

Dr Julian Elder,
Scion Chief Executive

New staff

Three new staff members have recently joined the Forest Systems team at Scion. They have been busy settling in and identifying new research opportunities and are very excited about contributing to research that will underpin the New Zealand forestry sector.

Dr Thales West. Thales has a background in Forest Engineering and PhD in Environmental Modelling & Economics (University of Florida). He holds a position of Forest Carbon Scientist at Scion, part of the Land Use Economics and Climate team. His research focus is on forest carbon dynamics, forest management, land-use/cover change, natural resource economics, spatial and statistical modelling, and payments for environmental services.

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Dr Grace B. Villamor. Grace is a socio-ecological systems scientist in the Land Use Economics and Climate team. Her research interest is in decision-making of land managers affecting ecosystem services using agent-based land-use models and participatory game simulations. She has more than 30 peer-reviewed papers on the topics of land use change, market-based mechanisms, climate change adaptation/mitigation, and application of modelling tools such as agent-based models. She has more than 10 years of experience with development research organizations (e.g., World Agroforestry Centre, Center for International Forestry Research), which aim at utilising research outcomes for development. Her current research in Scion is focused on developing negotiation support system tools for incorporating trees on farms.

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Dr Alan Jones. Alan has just been appointed as a research leader for the Enabling Environments team within Forest Systems. Previously, Alan was a Research Manager with Earthwatch UK and an Honorary Research Associate with Oxford University. He has experience in plant ecology, climate change and carbon inventory. He has a passion for science impact, communication and the interface between policy and research.

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Collaboration and international linkages

Taking GCFF research to the world

GCFF research was well represented at the Fourth International Congress on Planted Forests (Beijing, October 2018). Scion staff covered topics including the role of planted forests as providers of vital ecosystem services, a re-evaluation of breeding targets to increase the resilience of future forests, carbon and nutrient management, and opportunities to utilise soil microbes as drivers of forest productivity. Scion scientists developed and led several sessions. A lack of international research in several areas that have been strongly developed in the GCFF Programme was evident. Nursery management is one example, with discussion of the progress made in New Zealand being met with considerable interest.

Tim Payn presenting on planted forest ecosystem services research at a Sub-plenary session of the Congress.

Jeff Hatten joined Scion for a six month sabbatical

Jeff hard at work in a soil pit located in H. J. Andrews Experimental Forest, Oregon.

Jeff Hatten worked with the Scion soil science team from February to July, 2019 on issues relating to the management of soil nutrition in radiata pine and Douglas-fir forests, and the stability of soil carbon stocks in planted forests. Jeff was based in Christchurch with his family for most of his stay in New Zealand.

Jeff is an Associate Professor of Forest Soils in the Forest Engineering, Resources & Management Department at Oregon State University (OSU). He earned a BSc degree in Environmental Science from Western Washington University and PhD degree in Forest Resources from the University of Washington. Jeff's research focusses on forests soils and the source of sediment in managed settings that include intensively managed forests, prescribed fire, and other less intensively managed settings. Jeff has actively participated in the Division of Forest Range and Wildland Soils of the Soil Science Society of America and is currently the outgoing chair for the division.

5th International Plant Phenotyping Symposium, Adelaide, Australia

The 5th International Plant Phenotyping Symposium (IPPS) brought together a diverse, multidisciplinary community of plant scientists, agronomists, ecologists, engineers, biostatisticians and computer scientists to share their new knowledge. The event also aims to foster international collaboration to form new partnerships and develop new research projects. Maxime Bombrun and Elspeth MacRae attended the Symposium and successfully proposed that the IPP Network establish a Forest Phenotyping group. Scion is now organising the first meeting of the Forest Phenotyping working group at the next IPPS Symposium in Nanjing, China (23-26 October). https://ipps2019.plant-phenotyping.org/program_ipps2019

Collaboration with international PhD student

Carol Rolando and Brenda Baillie have been invited to co-supervise a postgraduate PhD student from the Nelson Mandela University, South Africa. The student will study the environmental fate of chemicals used in South Africa the South African forest industry. The student (Noxolo Ndlovu) has visited Scion to gain experience in field trial design and sampling techniques. She assisted with field measurements at the mid-rotation fertiliser water quality trial in Berwick and with lysimeter sampling in Kaingaroa with Amanda Matson.

Looking ahead

Upcoming GCFF events:

1. 14 October 2019, LiDAR/Phenotyping innovation workshop, Te Papa, Wellington
2. 15-16 October 2019, Annual/end of programme GCFF conference (15th October) combined with the annual Forest Growers Research (FGR) conference (16th October), Te Papa, Wellington.

More information and online registration for these events can be found at https://fgr.nz/

Selected recent publications related to the GCFF Programme

Refereed journal publications

1. Addison SA, Smaill SJ, Garrett LG, Wakelin SA. (2019). Effects of forest harvest and fertiliser amendment on soil biodiversity and function can persist for decades. *Soil Biology and Biochemistry* 135: 194-205.
2. Dargahi M, Newson T, Moore J. (2019). Buckling behaviour of trees under self-weight loading. *Forestry: An International Journal of Forest Research*. doi:10.1093/forestry/cpz027
3. Dash JP, Moore JR, Lee JR, Klápště J, Dungey HS. (2019). Stand density and genetic improvement have site-specific effects on the economic returns from Pinus radiata plantations. *Forest Ecology and Management* 446:80-92. doi:10.1016/j.foreco.2019.05.003
4. Dash, JP, Pearse, GD, Watt MS. (2018). UAV Multispectral Imagery Can Complement Satellite Data for Monitoring Forest Health. *Remote Sensing* 10(8), 1216; https://doi.org/10.3390/rs10081216
5. Gallart M, Love J, Meason DF, Coker G, Clinton PW, Xue J, Jameson PE, Klápště J, Turnbull MH. (2019). Field-scale variability in site conditions explain phenotypic plasticity in response to nitrogen source in *Pinus radiata* D. Don. *Plant and Soil*. pp 1-16. doi.org/10.1007/s11104-019-04237-0
6. Gasser E, Schwarz M, Simon A, Perona P, Phillips C, Hübl J, Dorren L. (2019). A review of modeling the effects of vegetation on large wood recruitment processes in mountain catchments. *Earth-Science Reviews* 194: 350-373.
7. Ma P, Han X-H, Lin Y, Moore J, Guo Y-X, Yue M. (2019). Exploring the relative importance of biotic and abiotic factors that alter the self-thinning rule: Insights from individual-based modelling and machine-learning. *Ecological Modelling* 397:16-24. doi:10.1016/j.ecolmodel.2019.01.019
8. Meason DF, Baillie BS, Höck B, Lad P, Payn T. (2019). Planted forests and water yield in New Zealand's hydrological landscape – current and future challenges. *New Zealand Journal of Forestry* 63: 33-39.
9. Moore J, Lin Y (2019). Determining the extent and drivers of attrition losses from wind using long-term datasets and machine learning techniques. *Forestry: An International Journal of Forest Research*. doi:10.1093/forestry/cpy047
10. Nanayakkara B, Dickson A, Meason DF. (2019). Xylogenesis of *Pinus radiata* D. Don growing in New Zealand. *Annals of Forest Science* 76:74. doi.org: 10.1007/s13595-019-0859-2.
11. Pearse GD, Dash PD, Persson HJ, Watt MS. (2018). Comparison of high-density LiDAR and satellite photogrammetry for forest inventory. ISPRS *Journal of Photogrammetry and Remote Sensing* Volume 142, August 2018, Pages 257-267.
12. Rey F, Bifulco C, Bischetti GB, Bourrier F, De Cesare G, Florineth F, Graf F, Marden M, Mickovski S, Phillips C, Peklo K, Poesen J, Polster D, Preti F, Rauch HP, Raymond P. Sangalli P, Tardio G, Stokes A. (2019). Soil and water bioengineering: practice and research needs for reconciling natural hazard control and ecological restoration. *Science of the Total Environment* 648: 1210-1281.
13. Rodríguez-Gamir J, Xue J, Clearwater MJ, Meason DF, Clinton PW, Domec JC. (2018). Aquaporin regulation in roots controls plant hydraulic conductance, stomatal conductance, and leaf water potential in *Pinus radiata* under water stress. Plant, Cell & Environment. doi: 10.1111/pce.13460
14. Telfer E, Stovold T, Graham N, Ismael A, Dungey H. (2019). From seed to harvest – factors affecting genetic worth of radiata pine stand over its rotation. *New Zealand Journal of Forestry*, Vol 64, 32-36.
15. Tóth A, Yao RT. (2019). Cultural Ecosystem Services and Water Quality Improvement provided by Forest Landscapes in New Zealand. Rotorua: Scion. 23 p. ISBN 978-0-473-48088-2 (print), 978-0-473-48089-9 (digital). DOI https://doi.org/10.15414/2019.9780473480899
16. Watt MS, Pearse GD, Dash JD, Melia N, Leonardo EMC. (2019). Application of remote sensing technologies to identify impacts of nutritional deficiencies on forests. ISPRS *Journal of Photogrammetry and Remote Sensing* 149, 226-241.

17. Yao RT, Palmer D, Hock B, Harrison D, Payn T, Monge J. (2019). Forest Investment Framework as a Support Tool for the Sustainable Management of Planted Forests. Sustainability, Volume 11.

18. Yao RT, Scarpa R, Harrison DR, Burns RJ. (2019). Does the economic benefit of biodiversity enhancement exceed the cost of conservation in planted forests? Ecosystem Services, 38, 100954.

Technical notes

1. Coker G, Dowling L, and Moore J. (2019). Preliminary economic outcomes of the GCFF mid-rotation fertiliser trials. Tech Note GCFF TN-026.

2. Dash J, Watt M, Hartley R. (2019). Testing UAV-borne Riegl Mini VUX-1 scanner for phenotyping a mature genetics trial. Tech Note GCFF TN-023.

3. Graham N, Ismael A, Stovold T. (2019). DNA fingerprinting to reconstruct parentage from trees in the forest – a second proof of concept. Tech Note GCFF TN-024.

4. Hartley R, Melia N, Estarija HJ, Watt M, Pearse G, Massam P, Wright L, Stovold T. (2019). An assessment of UAV laser scanning and photogrammetric point clouds for the measurement of young forestry trials. Tech Note GCFF TN-028.

5. Murphy G, Moore J. (2019). Application of a wood-properties-based, techno-economic model in assessing the effects of stand density and seedlot on stumpage value in two Pinus radiata silviculture-breeds trials. Tech Note GCFF TN-025.

6. Smaill S, Garrett L, Matson A. (2019). The accelerator Trial series – update on progress to June 2019. Tech Note GCFF TN-022.

7. Xue J and Coker G. (2019). The Role of Micronutrients in Controlling Plant Diseases - Knowledge gaps and future research for tree species in particular. Tech Note GCFF TN-027.

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 www.gcff.nz/publications provides the appropriate links to access the published information.

Acknowledgements and links. This research programme is jointly funded by the Ministry of Business, Innovation and Employment (MBIE(CO4X1306)) and the Forest Growers Levy Trust, with the support of the NZ Forest Owner Association (FOA) and the NZ Farm Forestry Association (FFA). In addition to this newsletter, the programme website provides links to technical reports and peer reviewed science publications (http://gcff.nz/publications). Further information is also available on the Forest Grower's Research (FGR) website – http://fgr.nz/

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

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