Prosperity from trees - Mai i te ngahere oranga

Highlights

scion™
FORESTS · PRODUCTS · INNOVATION

Annual 20
Report 20

A female cone of radiata pine at an early stage of development magnified about 40x using fluorescence microscopy.
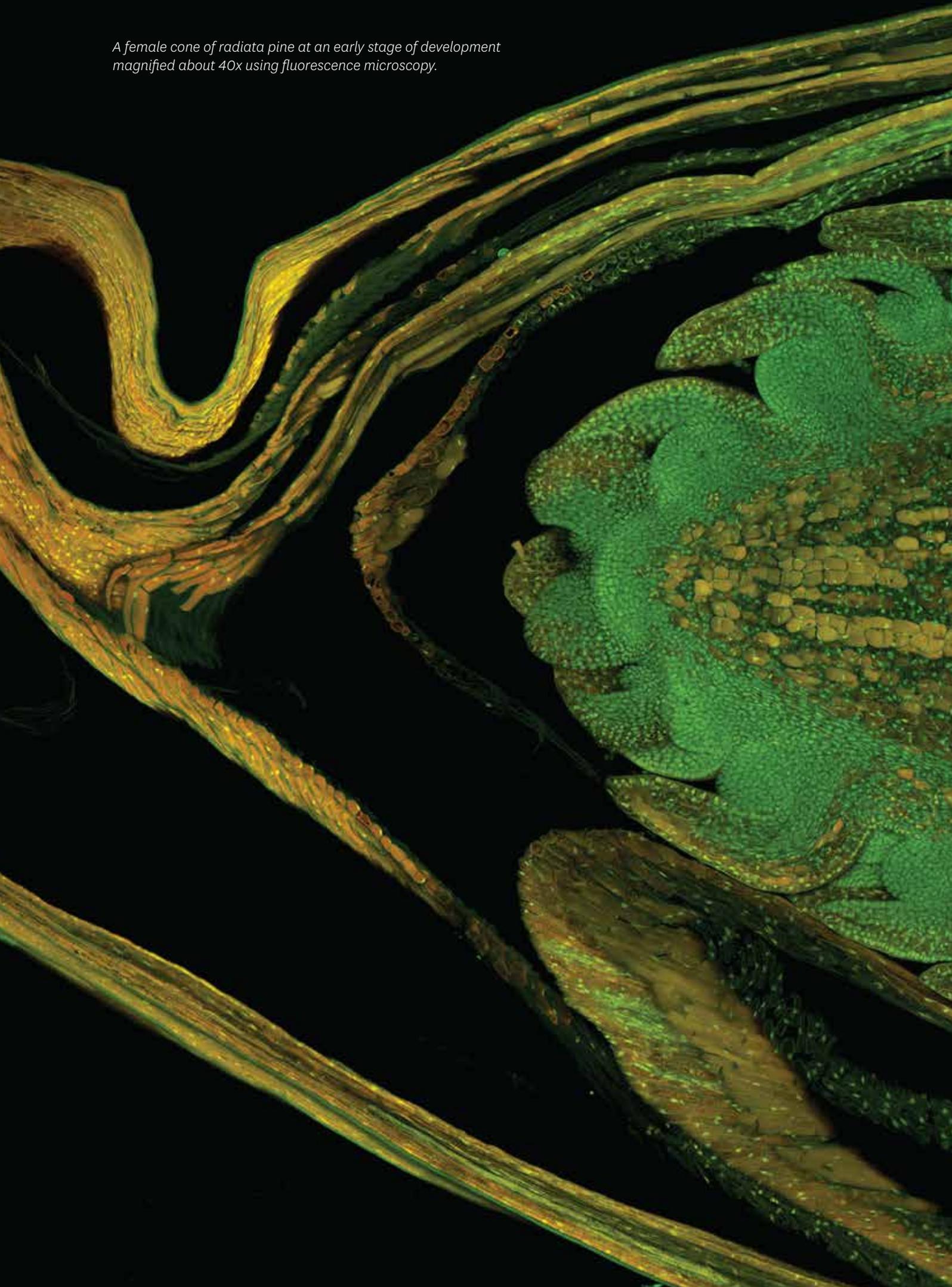
Right tree,
   right place,
right purpose

Annual Report 2020 Highlights

Presented to the House of Representatives pursuant to section 44 of the Public Finance Act 1989.

Our Annual Report is presented in two parts – Highlights (Part A) and Reports and Financial Statements (Part B). Together, both documents fulfil our annual reporting responsibilities under the Crown Research Institutes Act 1992 for the year ended 30 June 2020.

The Reports and Financial Statements (Part B) includes the employment and environmental reports, directors' report, performance targets and financial statements.

Our Annual Report is also available in digital format at www.scionresearch.com/annual-reports

Contents

Partnering

Collaborating

Delivering

Sharing

Excelling

Enhancing

Achieving

At a glance

Operating revenue

$57.9m

Last year: $55.9m

Total comprehensive income

$5.5m

Last year: $1.7m

Return on equity

11.8%

Last year: 3.9%

A low-volume, sustainable industry for Northland is achievable by harvesting single or small groups of farm-grown tōtara and leaving larger tōtara to thrive. **Page 24**

Full-time equivalent staff

320

285 Rotorua **3** Wellington **32** Christchurch (includes fixed term, student and postdoctoral staff)
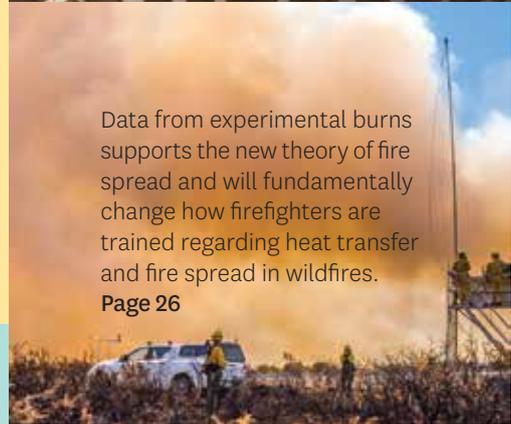
Data from experimental burns supports the new theory of fire spread and will fundamentally change how firefighters are trained regarding heat transfer and fire spread in wildfires. **Page 26**

Published refereed papers

154

88.42 rolling 5-year weighted average H-index
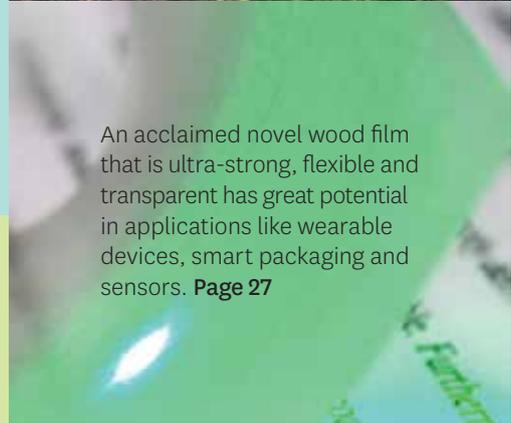
An acclaimed novel wood film that is ultra-strong, flexible and transparent has great potential in applications like wearable devices, smart packaging and sensors. **Page 27**

Commissioned reports to users

313
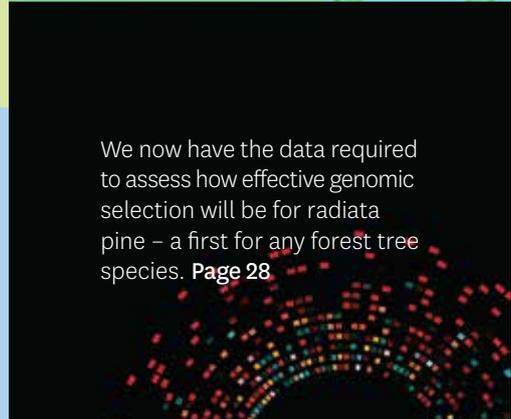
We now have the data required to assess how effective genomic selection will be for radiata pine – a first for any forest tree species. **Page 28**

Vision, mission and strategy

Our core purpose

"To drive innovation and growth from New Zealand's forestry, wood product and wood-derived materials and other biomaterial sectors, to create economic value and contribute to beneficial environmental and social outcomes for New Zealand."

Our vision

Prosperity from trees - Mai i te ngahere oranga

Our mission

Enhancing New Zealand's prosperity, well-being and environment through trees - Kia piki te ora, te taiao me te whai rawa o Aotearoa mā te ngāherehere

Trees are remarkable, renewable resources. Planted as forests, and used in products and materials, trees have a powerful potential to be at the heart of a low-carbon, biobased future New Zealand.

Our strategy, *Right tree, right place, right purpose: Scion Strategy to 2030*, sets out three research impact areas that focus our expertise to deliver on our aspirations for New Zealand and supporting the Government's goals.

Our research impact areas are:

Forests and landscapes. To grow healthy, resilient forests that are planted primarily for their standing-forest benefits.

High-value timber manufacturing and products. To grow healthy, resilient forests that produce trees for high-value manufacture into products that capture an increasing share of the global high-end market for timber.

Biobased manufacturing and products. To grow healthy, resilient forests that replace petrochemicals and non-sustainable materials with products from trees and other biomaterials.

Chair and Chief Executive overview

An opportunity to reshape our country

In casting back across Scion's 2019-20 year, it is hard to look beyond the enormous impact of the COVID-19 pandemic that engulfed us so suddenly and so totally.

These 1 in 100-year events bring devastating impacts to people and economic systems, yet as massive disruptors they provide rare catalysts for change. Many businesses have been forced to reset to survive. Sector by sector, such resets could see New Zealand reshape as an entire nation.

New Zealand's post-COVID-19 economic rebuild will be huge. It could also be transformative, and Scion can help steer the way. Through transformation in the forestry sector, Scion is helping lay a path that leads to an innovative, low-emissions economy bringing multiple benefits regionally and nationally.

Changing direction takes purposeful intent. It is hard and needs a clear path to a sought-after goal. Like most nations, New Zealand's post-COVID-19 economic rebuild will be huge. It could also be transformative, and Scion can help steer the way. Through transformation in the forestry sector, Scion is helping lay a path that leads to an innovative, low-emissions economy bringing multiple benefits regionally and nationally.

Our work over the past year contributed to this transformation through supporting the forestry industry meet its productivity goals, developing nurseries of the future, co-innovating with Māori, creating new bio-industries outside of forestry and modifying manufacturing techniques.

Research highlights illustrating this work, and described in this report, include working with the Radiata Pine Breeding Company to achieve a first for radiata pine. We found that it is possible to predict tree diameter and density using only genetic marker information. Also, DNA fingerprinting technology (the SNP chip) was used to reconstruct and validate over 14,000 records of the breeding pedigree. This is the first pedigree validation undertaken at this scale in forest trees.

Our remote sensing research achieved another industry first by successfully trialling the use of a drone flying independently of an operator beneath the tree tops in a pine forest along a flightpath it had mapped itself. This trial could provide forest managers crucial detail about their trees beneath the canopy. A forest industry consultancy has taken up the technology and offers it as a service.

The six experimental burns carried out by our rural fire research team in March alighted international attention. Fire scientists from Australia and America contributed to what are the most observed burns in New Zealand to date. With the use of drones to gather data, the research team captured never-before-seen insights into wildfire.

In Reporoa, Ecogas broke ground on New Zealand's first large-scale food waste to bioenergy facility that was backed by our research. When finished in 2022, the plant can turn 75,000 tonnes of

food waste from homes and businesses across the North Island into heat, biofertiliser and biogenic carbon dioxide that will be used to grow tomatoes.

Scion is a key player in the Rotorua community. Our priority in the past year was to uplift the connection between Scion and mana whenua at strategic and operational levels. We look forward to a formal memorandum of understanding with mana whenua, who will have a permanent presence on site and take part in the cultural narrative across the Rotorua campus. In partnership with Rotorua Lakes Council, pou (posts) will be carved on site for installation along the road that will become our new public entry to the innovation hub, which will be completed in spring 2020.

A visually striking building, the innovation hub showcases the latest in engineered timber within its unique and challenging structural form. The hub

has already attracted a lot of interest from industry and the public with mounting requests to visit. Investment in the hub demonstrates our commitment to transforming the New Zealand economy, especially in the regions. With our partners, we will give life to our strategy's goal "transitioning New Zealand to a circular bioeconomy".

Scion's "Strategy to 2030" was finalised just prior to COVID-19 lockdowns, and we are very pleased to have Minister Woods recently reaffirm her support of our strategy.

While we are optimistic about how Scion can help make a difference to New Zealand's post-COVID-19 future, we are very aware of how challenging this will be for us. The 2020 Endeavour Fund results were disappointing and heightened the need for a long-term funding solution for Scion. During the year, a joint MBIE/Scion team worked on this pressing funding problem, with

the work well on track until delayed by COVID-19. The Scion board is strongly committed to our strategy but very mindful that without a permanent funding solution we will not be able to achieve it and the aligned priorities of the Government.

Owing to lower than normal revenue expectations and the uncertain impacts of COVID-19, costs were managed with extreme restraint during 2019-20. COVID-19 support provided at the end of the financial year therefore resulted in a one-off strong profit result. Revenue of $57.9 million was $1.9 million (3.5 per cent) up on last year's revenue of $55.9 million and net profit after tax of $5.4 million was $3.8 million (232 per cent) up on last year's profit of $1.6 million.

The year was defined by COVID-19, and so we wish to express our pride in Team Scion for adapting responsibly and efficiently to a new, challenging way to work and live. To the Scion leadership team and to our hard-working staff, we say a sincere thank you. And to our customers and partners, we thank you all for your support and contribution to Scion throughout the year.

We are privileged to lead Scion in the momentum towards a low-carbon, biobased future for New Zealand.

A visually striking building, the innovation hub showcases the latest in engineered timber within its unique and challenging structural form. The hub has already attracted a lot of interest from industry. Investment in the hub demonstrates our commitment to transforming the New Zealand economy, especially in the regions.

Dr Helen Anderson
Chair

Dr Julian Elder
Chief Executive

Partnering

Tihei mauri ora,

Ko te oranga ngahere te kaupapa e whakatōpu ai tātau ki Te Papa Tipu. Koia te poutokomanawa i whakaara ake, ka mutu, e tū tehetehe tonu ai ki te manawa o Titokorangi.

Ko te rākau tērā e whakarewaina tahitia tātau ki ngā rangi o anamata.

E kī a nei te kōrero "Ko te amorangi ki mua, ko te hāpai ō ki muri".

Nō reira,

Kia toitū te mana, kia toitū te whenua, kia toitū te ao,

Tēnā koutou, tēnā koutou, tēnā koutou katoa.

Mauri ora.

Behold here, the breath of life.

The life of the forest is what draws us together and into Te Papa Tipu. It is the central pillar erected in the beginning which still stands at the heart, and in the mana of Titokorangi. It is trees that hoist us up into the skies of the future, so it is said "Those who rise to greatness, do so on the shoulders of giants."

Therefore,

Let the mana of the people prevail, so that the land prevails, so that the entire world can prosper, flourish and prevail.

Greetings to you all.

Life be in us.

Co-innovation and partnering with Māori

The mihi (opposite) heralds the beginning of a new era for Scion and acknowledges the special space that is Te Papa Tipu and which has always been at our heart. Our distinctive campus in Rotorua connects us to tangata whenua, the inherent mātauranga of our Māori-Moriori research partners and staff, and the diverse nature of local indigenous ways of thinking and being.

Also, the mihi signals our intent to show leadership as a Crown research institute to advance Māori knowledge and science alongside the traditional keepers. We recognise ancient knowledge as a heritage of cultural, scientific, national and global significance, and ensure it is included as a distinctive knowledge system contributing to Aotearoa New Zealand's sustainable future.

We are pursuing a holistic view of the contemporary and customary interests of Māori to their forestlands, indigenous species and relative futures that considers plantation pine forests on Māori land, the care and regeneration of trees in ngahere and the potential of new mosaic planted forests and the communities of people that design and care for them. Giving credence to a Māori worldview and approach to forestry in its many forms and broader purposes is the role of the Māori Forestry Futures team.

Our three pou

Three pou were forged over the past year for our mana-enhancing Māori strategy, to be launched in the new financial year. The pou are mana whenua at Te Papa Tipu, Māori cultural competency and the Māori forestry roadmap.

Mana whenua at Te Papa Tipu

The unique connection between Scion and Ngāti Taeotu, Ngāti Te Kahu and Ngāti Hurungaterangi hapū was enhanced over the past year through shared residence, in kaupapa related to the Te Papa Tipu Innovation Park campus redesign, specifically:
- Cultural guidance and input into the innovation hub design features and cultural elements;
- Engaging design and carving skills of pou whakairo to be erected along Titokorangi Drive (previously Long Mile Road) in partnership with Rotorua Lakes Council; and
- Working alongside Scion in resource consenting processes, such as the current Storm Water Resource Consent.

An onsite location for a mana whenua representative was offered and taken up part-time to establish a meaningful partnership. Mana whenua leadership at hui, wānanga and special events now ensures that tikanga and kawa (protocol) are appropriate. Collaboration over managing other onsite tenant relationships also reached a good outcome. As the relationship continues to evolve we expect increased levels of whakawhanaungatanga, opportunity sharing and participation among the campus community.

Māori cultural competency

Scion's work has the potential to transform and improve the future treatment of our lands, waters and air, and the lives of all people visiting, living, and working in New Zealand. As we move towards the vision we pursue with our partners and stakeholders, the future will see us carrying out even more research, science and innovation in communities, on Māori-Moriori land, with indigenous trees and other forms of life from the natural world.

It is crucial that we keep all our staff culturally safe, equip them for quality engagement and demonstrate our commitment to working in a quality way with tangata whenua. They also need to have experiences affirming that working with mātauranga and Māori-Moriori can be a personally rewarding and expansive experience.

2019 Innovator of the Year Ian Taylor was invited to talk with staff during Māori Language Week. This talk was one of many cultural interactions that inspired staff to take up He Waka Eke Noa – Scion Te Reo 101 professional development course delivered onsite. Ian shared his story from childhood to the success of the team at Animation Research Limited

and his work with the Tuia 250 project. Ian's key messages were the value of mātauranga Māori knowledge, the intersection of science, creativity and mātauranga, being bold in the face of uncertainty and embracing innovation storytelling.

A cultural competency needs assessment initiated a matrix of training, and 135 staff participated in these training modules. Scion's own waiata *Te Papa Tipu E* sharing the Scion kaupapa was composed by staff.

Māori forestry roadmap – tomorrow's forestry

Evidence shows that a global circular bioeconomy aligns strongly with Te Ao Māori. Pre-Treaty land use and practice used knowledge that had developed with te Taiao, the systems of land and sky, for more than 700 years. Established to set a future pathway for Māori forestry, the overarching aim of the Māori Forestry Roadmap is to contribute to the processes and practices of a globally unique transition towards a future bioeconomy, championing customary kaitiakitanga practice in a whole-of-systems approach inside the primary sector, with Māori forestry leadership.

The roadmap looks at what it will take to: expand exotic forestry, indigenous forestry and wood manufacturing pathways; build new forestry models to optimise Māori land; and conceptualise and revitalise a Māori Bioeconomy by 2030.

Our Māori partnerships

These projects show how the work and hopes of our Māori partners endures through our research, science and innovation.

Prioritising well-being in papakainga housing

Much of the housing affordability discussion centres on supply and demand of houses, land cost and availability, and finance and regulatory processes. Too often, 'affordability' is not considered from a quality and building life-cycle perspective. Instead it is linked solely to construction and compliance costs and thus dissociated from high-quality construction, building performance, and human health and well-being.

"Toitū te Kainga, Toitū te Ora, Toitū te Tangata" (Healthy Homes, Healthy People) was a collaborative project funded by the Building Better Homes, Towns and Cities National Science Challenge (MBIE) and led by Toi Ohomai Institute of Technology. Built on the Matekuare Trust's plans for papakāinga development on ancestral whenua at Tāwhitiwhiti, Te Whaiti, Eastern Bay of Plenty, the project aimed to develop modular prefabricated housing design and construction solutions that would improve life-time affordability and provide a high-quality indoor environment for the health and well-being of the Matekuare Whānau.

Scion applied building physics principles and used hygrothermal (heat and moisture flows) modelling targeting healthy indoor living parameters to optimise the thermal envelope of the innovative Tallwood prefabricated construction system. The collaboration between Scion, Tallwood and the Toi Ohomai construction team lead to mock-ups (models) used to test the buildability of the proposed housing plans. The results of the hygrothermal modelling and the mock-ups, together with the indoor quality and health monitoring conducted by Toi Ohomai and Unitec, were shared with the whānau in a series of hui and wānanga.

"The concept of papakāinga began as a dream of the Matekuare Trust, but is fast becoming a reality. With the research team's support, the original ideas from whānau have been converted into a formally planned village that is now laid out on the ground, with some services in place. Tallwood, Scion and Toi Ohomai have created and tested plans for housing that will be healthy, genuinely affordable over a life time, while still functioning efficiently in the extreme conditions in the region. It's something that whanau across the country deserve to know about." *Hinerangi and Tony Goodman on behalf of Matekuare Whānau.*

Partners: Matekuare Trust and Toi Ohomai

Kaunaki Kōrero Tua Teru: Building science capability to contribute to a sustainable Chatham Islands

What can New Zealand learn from carrying out a waste stocktake on Rēkohu (the big island in the Chathams archipelago) as we establish a national bio-circular economy?

A Vision Mātauranga Capability Funded (MBIE) project made good progress

towards developing a Rēkohu waste resource map of the current and expected future state. Through the project, circular economy principles and drivers are demonstrated to the Rēkohu community leading to improved understanding and practice of tracking, waste management and utilisation. Rēkohu stakeholders will be linked to current mainland waste reuse, recycling and reduction initiatives.

This immersion in circular economy-related science and technology will benefit the Hokotehi Moriori Trust, the Rēkohu community by enabling future research or implementing projects for Moriori businesses in the move towards a circular/zero-carbon economy model. The project will also develop the science capability of Harina Rupāpera (Ngāti Rangitihi, Ngāruahinerangi) he pukenga mo ngā mahi para kore (a developing specialist in waste minimisation).

Partners: Hokotehi Moriori Trust and the Chatham Islands community

Marc Gaugler (Materials & Polymer Scientist) talks to Maui Solomon (Chair Hokotehi Moriori Trust) about reprocessing options for nylon rope debris washed up on the Chatham Island coastline.

Te Urunga o Kea: A Climate Change Strategy for Te Arawa

Hui were held with key strategic stakeholders and with local, regional, national and international individuals and collectives. A scoping exercise over the past year found no current iwi climate change strategies in the region developed by Te Arawa interest groups. More recently, the Eastern Bay of Plenty Regional Council released a draft climate change strategy for comment.

At localised levels, particularly amongst marae and hapū groups, strategies are emerging. Discussions included climate change adaptation and disaster risk reduction (marae preparedness), establishing and strengthening alliances, social mobilisation through education, creative and youth initiatives, exploring circular economies, land use change and biodiversity.

From these discussions a Te Arawa Climate Change Strategy was developed and includes research priorities. The strategy document reached first draft stage and is currently under review with iwi strategy expertise.

A highlight of the year was the Te Arawa Climate Change Strategy Team, led by Scion's Marie McCarthy and supported by iwi researcher Lani Kereopa, receiving a gold status award from MBIE, the funder.

Partners: Te Arawa Climate Change Working Party

One billion trees science and kaupapa Māori-Moriori partnerships

Over $20 million in One Billion Trees Partnerships funding was applied for in the last 12 months with the support of Scion. Partnering trusts and communities have received $7 million to date.

These partnerships provide evidence-based insights and are developing the valuable contributions made by mātauranga and science to the success

of the Government's flagship tree planting programme. In coming years, the impact of these partnerships will be measured not only in seedlings planted but also directly to 200+ new jobs, accelerated seedling production, increased survival rates of planted seedlings, new high-value indigenous forestry value chains and improving the decisions of landowners and funders.

Nursery Research Scientist Craig Ford discusses indigenous coastal grass propagation with Maui Solomon of the Hokotehi Moriori Trust.

Forests for whenua Māori

The new tupu.nz website to support Māori landowner decision-making and whenua Māori applications includes fact sheets for carbon, timber and diversified-mixed product forests co-developed by Scion for Māori land use.

Scion worked with Te Puni Kokiri project managers to design information flow for the website, which was launched in March 2020. Scion supports Te Puni Kokiri's work to put land use development information in one place.

Partner: Te Puni Kokiri

Tane's tamariki

Over 100 children flooded the Scion campus last October to enjoy the final instalment of a forestry science learning programme funded by MBIE's Unlocking Curious Minds fund. The programme was open to tamariki from shareholder whanau of forestry trusts from across Rotorua and Taupō districts.

During the eight-day school-holiday programme the students learned about the lifecycle of tuna (eels), toured a geothermal electricity generation plant, flew drones, experimented with dry-ice, wrote letters to Papatuanuku and landowners, learnt how trees reproduce and filter forests, built robots for scrimmage and protected forests against disease. They also planted kūmara tipu (runners) in a māra kai (garden) from which over 50 kilograms of tubers were harvested in February.

Filtering water through forest carbon at Scion.

Relationships were strengthened with the partnering trusts as well as Te Rangihakahaka School of Science, Whakarewarewa School, Contact Energy Wairakei Geothermal Plant, Ngāti Hikairo Tuna Restoration and Te Whare Wananga o Awanuiarangi. A golden

tōtara sapling was gifted by Lake Taupō Charitable Trust to commemorate the STEM relationship between the science community and the children.

Partners: Lake Taupō Charitable Trust, Lake Taupō Forests Trust

Kāuta: He hononga mo te tangata manaaki (Traditional hearths: Bringing people together)

Once central to Māori hospitality and hosting, the traditional marae kitchen has all but vanished from Māori culture and our New Zealand heritage owing to non-compliance with building regulations.

This project aims to reinstate kāuta traditions by calling on the living memory of kaumātua who were raised with this tradition and the tikanga that embraced it. At the time of writing, close to 40

interviews were completed and a video narrative was being planned.

Waitangi Wood, who leads the science capability project on behalf of the hapū, said "We were surprised to learn that even 50-year-olds had no memory of kāuta on marae, so working with the expertise and networks of Scion as a FENZ adviser to reinstate the mātauranga of a cookery as a safe and justifiable hospitality space

has been very satisfying for us."

In the next stage, kāuta specifications that meet New Zealand's flame-heat regulations and building standards will be written and tested on new kāuta building plans. The project is due to end in 2021.

Partner: Tau Iho o te Po Trust and kaitiaki in Kaipara and Northland

Rēwena bread packaging

Scion introduced Koa Holdings Ltd to Massey University and helped draft a successful Vision Mātauranga Capability Funding application. Underway since

June 2019, the project is developing the science capability between the Māori partner and the two research institutions.

The project aims to scale up the production of rēwena bread, develop a Māori-led DNA-supported provenance and devise a novel food packaging solution. This is a circular project that combines the expertise of mātauranga Māori with science to revitalise Māori kai traditions.

Partners: Koa Holdings Ltd and Massey University's School of Food and Advanced Technology

Healthy trees, healthy future

The year saw the end of the six-year "Healthy trees, healthy future: Enabling technologies to combat *Phytophthora* diseases" programme.

The multi-organisation team says New Zealand is now better able to respond to the threat of the *Phytophthora* pathogens that are affecting trees in horticulture, forest plantations and natural ecosystems thanks to the protocols, baseline data, inoculation systems, analysis pipelines, modelling capacity and germplasm resources they established.

Part of the programme led the establishment of a kauri seed collection from hundreds of mature trees across the range of kauri. Working with 14 mana whenua groups from Kaitaia to Tauranga, the team created a significant resource for future screening and kauri research. While the HTHF programme has finished, the relationships and the work have not.

During this year, the team found the exciting result that there appears to be widespread tolerance to kauri dieback among the trees we could test. Scion is continuing discussions with mana whenua to determine the desired priorities for the next phase of work.

The model of Māori engagement within the programme was recognised by both the research partners and the mana whenua partners as a new way of working in biosecurity and specifically in the kauri dieback space. The science translation and cross-cultural relationships built up during the programme will endure into the future and contribute to long-term solutions to protect New Zealand's precious tree species.

Partners: Healthy trees, healthy future (HTHF) kauri dieback mana whenua

Collaborating

Collaborating for impact

Scion's international and national reach is wide and deep. Through multi-disciplinary collaborations and networks our scientists are at the forefront of the latest thinking, novel approaches and technological advances. Maintaining and building on these linkages is critical for Scion to remain innovative and competitive in the domestic and global markets. Our presence and influence in key networks is well recognised as shown in the examples below.

Scion formal long collaborations - institutes and organisations

- Australian Synchrotron (Australia)
- Chinese Academy of Forestry (China)
- EPSO (European Plant Sciences Organisation Belgium)*
- Food and Agriculture Organisation of the United Nations
- Fraunhofer IGB Stuttgart (Germany)
- Innovawood (Europe)*
- INRAe (Institut National de Recherche en Agriculture, Alimentation et Environment) (France)
- International Energy Agency (Bioenergy Technology Collaboration Programme) (France)*
- IUFRO (International Union of Forest Research Organisations) (Austria)*
- NZ-China Food Protection Network (China)
- University of Tasmania (Australia)
- VITO (Belgium)
- VTT (Finland)

*Associations

Scion key science interactions (multiple and multi-year programmes, 2-3 different science areas)

- Australasian Bioplastics Association*
- Chinese Academy of Agricultural Sciences (China)
- CNRS (France)
- Embrapa (Brazil)
- ETH (Switzerland)
- Forestry and Forest Products Research Institute (Japan)
- Georg-August University of Gottingen (Germany)
- Georgia Tech (USA)
- GO!PHA (Germany)*
- IAWA (Netherlands)*
- Jiangnan University (China)
- KIER (Korean Institute of Energy Research (Korea)
- LUKE (Finland)
- Mendel University (Czech Republic)
- Nanjing University (China)
- Notre Dame University – Louaize (Lebanon)
- Oregon State University (USA)
- Pine Chemicals Association (USA)*
- San Jose State University (USA)
- Swansea University (UK)
- Swedish University of Agricultural Sciences (Sweden)
- Swiss Federal Research Institute WSL (Switzerland)
- Synthetic Biology ARC (Australia)
- Tall Timber Hub (Australia)
- Teagasc (Ireland)
- Technical Institute of Denmark (Denmark)
- Thünen Institute (Germany)
- United States Department of Agriculture (USA)
- University of British Columbia (Canada)
- University of Florida (USA)
- University of Lisbon (Portugal)
- University of Montpellier (France)
- University of New South Wales (Australia)
- University of Queensland (Australia)
- University of Southampton (UK)
- University of Warwick (UK)
- University of Washington (USA)
- University of Wurzburg (Germany)
- US Forest Service Missoula Fire Science Laboratory (USA)
- US Forest Service Pacific Northwest Laboratory (USA)
- Virginia Polytechnic and State University (USA)
- Zhejiang Agriculture and Forestry University (China)

PlantEd (COST)

Scion's membership of the European Plant Sciences Organisation (EPSO) enabled participation in a pan-European Cooperation in Science and Technology (COST) action called PlantEd "Plant genome editing – a technology with transformative potential". We are part of a working group contributing to the ongoing discourse on the regulatory frameworks in the European Union and other relevant countries, their potential applicability for plant genome editing, and providing future-oriented solutions if necessary.

Policy in the gene editing space is moving very quickly, and the working group has submitted to the European Commission on the importance of legal shifts to enable gene editing in Europe. The commission is currently re-evaluating its position on gene editing and new breeding technologies.

Georgia Tech

Scion collaborated with Georgia Institute of Technology (Georgia Tech) in the United States to develop two different engineering projects.

One project was the G2RT project (Generation 2 Reinvented Toilet, funded by the Bill & Melinda Gates Foundation) where Georgia Tech led joint activities. Together we shaped the thinking around hydrothermal processing (the basis of one of the toilet processes), overall process integration and detailed characterisation of toilet inputs for the overall design specification.

The second project was to develop the experimental fluidics system for sorting somatic embryos of radiata pine and the first generation of customised temporary immersion bioreactors with the gas phase control. This technology development is part of the 21st Century Tissue Culture partnership programme with the forest growing industry that aims to speed up reproduction of tree breeds.

Relationships with Japan

Scion interacts with several Japanese companies as well as government entities through both global bioeconomy activities and strategic interactions with specific Japanese-owned companies in both countries.

The Japan New Zealand Business Council invited Scion to present at its annual conference "Pathways to Progress" on 'Forests and the bioeconomy' in the infrastructure and investment plenary session.

The conference was held last September in Kashiwa-no-ha. A 'smart city', Kashiwa-no-ha was an ideal venue with its emphasis on the environment, healthy living, creativity and communications.

The Business Council extended a second invitation to be one of seven speakers at the Japan Chamber of Commerce and Industry (JCCI) trade mission to New Zealand and Australia, which was a one-day event in Wellington, February 2020. The topic again was 'Forests and the bioeconomy', with around 80 Japanese members of the mission attending.

VITO collaboration

Scion and VITO (Flemish Institute for Technological Research in Belgium) signed the second five-year term of their formal collaboration agreement. The collaboration includes joint funding of postdoctoral fellows, a focus on biomass processing (especially lignin and hemicellulose), joint research on renewable and recyclable materials (with an emphasis on plastics and biopolymers) and scale-up of these technologies. In addition, Scion was invited to sit on the board of a scale-up VITO biopilot plant for lignin.

Biosecurity excellence in port communities

A collaborative project pioneering a field of biology, biodiversity and ecology in industrial areas (ports) is now well underway and helping to develop new surveillance and monitoring tools for these high-risk areas.

The five-year Better Border Biosecurity (B3) project Biosecurity Excellence in Port Communities - jointly led by Scion and AgResearch - has completed its third year and is focused on two goals: to develop and implement better ways to understand, measure and influence biosecurity awareness in port communities, and understand the constraints and opportunities to better target pathway interventions, surveillance and eradication practices in and around port environments.

The project's work is taking place at the Port of Tauranga where Scion researcher Dr Carl Wardhaugh has collected 253,582 invertebrates using a range of trapping methods.

The collection tested the effectiveness of eight invertebrate trap designs that will help inform the development of surveillance programmes to sample

invertebrates at seaports and other high-risk points of entry.

The key questions answered so far through this work are: which traps, or combination of traps, collect the broadest spectrum of beetle species, (used as a proxy for some invertebrates) and what trapping intensity is needed to confidently sample most species in the area, including rare species.

Carl's findings indicate continuous or regular trapping as new species were collected throughout the year and light traps performed best in collecting a broad range of species. Pitfall traps were able to provide ground-based species sampling and are especially good at capturing high-risk groups such as ants.

Scion is a science partner in the B3 collaboration along with Plant & Food Research, AgResearch, Manaaki Whenua

Scion entomologist Dr Carl Wardhaugh with an insect light trap used at the Port of Tauranga.

and the Bio-Protection Research Centre. End-user organisations are the Ministry for Primary Industries, Department of

Conservation, the Environmental Protection Authority and the horticultural, cropping, forestry and pastoral sectors.

Scion joins XLabs

Helping organisations go circular is the intent of New Zealand's first circular economy lab, an initiative of Circularity in partnership with Auckland Tourism, Events and Economic Development (ATEED).

The strength of the highly collaborative XLabs programme is that it has been designed by circular economy practitioners and engages experts to mentor businesses making the shift. Scion's Dr Florian Graichen was invited to participate as an expert panelist.

The programme comprises a series of weekly workshops, and Scion material scientists Dr Dawn Smith and Marc Gaugler presented during the 'How might we grow our World' themed workshop day. They helped participants to understand how innovative materials such as bioplastics can fit into the circular bioeconomy. Their intent was to spark thoughts and ideas and get attendees excited about new possibilities, rather than offering solutions at this early stage.

"It was a positive experience," says Dawn. "The audience was very engaged and had a lot of questions – sometimes hard

questions. It was great to be able to engage with different groups who described their own journey to change their businesses to operate in a circular manner."

Scion has embraced circular bioeconomy thinking in New Zealand for some time and built up deep technical knowledge and established domestic and international networks that are invaluable in helping to fast-track industry initiatives. Our involvement in the inaugural XLabs was a great way to help connect New Zealand companies with partners that can help to realise their initiatives.

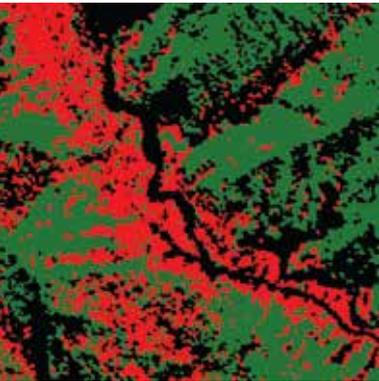www.scionresearch.com./?a=70356

Delivering

We're protecting and nurturing the forests that you love.

We're finding cutting-edge ways of building with timber here and around the world.

We're developing tomorrow's products from today's trees to contribute to a biobased future.

Delivering

Detecting tree disease from space

Researchers have developed a method to monitor red needle cast from satellite imagery.

Their goal was to produce maps that accurately showed areas of possible red needle cast infection. Satellite imagery of three forest areas with known red needle cast infections were used to test out their approach.

Scientists created a method to recognise red needle cast in satellite imagery by defining what unhealthy foliage looks like, i.e. clusters of pixels with the same specified characteristics.

The model performed well, with accuracy of detection varying between 60 to 93 per cent. Accuracy is expected to improve as researchers add more locations and trial more advanced techniques to identify the unhealthy foliage. Results will be verified from field samples, processed in the laboratory to confirm the pathogen's presence and avoid false detection.

This simple and repeatable methodology will be used in Scion's pathogen monitoring programme in 2020. Thanks to this new method, the range of the annual red needle cast monitoring will increase substantially.

To read the full story on this research, visit
www.scionresearch.com/2020redneedlecast
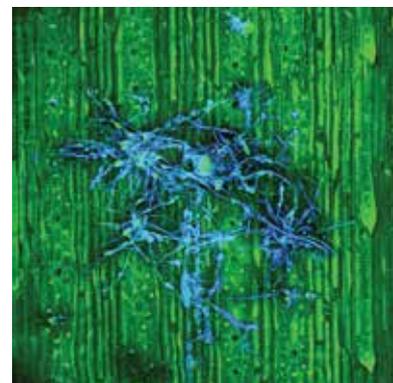
Delivering

Our roadmap to a world without plastic waste

Plastic is not the problem, it's what we do with it. This has been Scion's consistent message as we focus on the plastic issues facing New Zealand.

As part of clarifying and accelerating this discussion, Scion's Chief Science and Innovation Officer Dr Elspeth MacRae was a panellist on the *Rethinking plastics in Aotearoa New Zealand* report for the Office of the Prime Minister's Chief Science Advisor.

This landmark report was launched with a commitment from government to set goals to shift away from low-value and hard-to-recycle plastics such as PVC and polystyrene, and from single-use packaging such as beverage containers.

Scion has also begun developing a New Plastics Economy (NPEC) roadmap for New Zealand's plastic industry. The New Plastics Economy is a circular economy initiative with plastic-specific goals. It was started by the Ellen MacArthur Foundation, who invited countries, companies and organisations to commit to ridding the world of plastic waste using circular economy principles.

New Zealand's unique roadmap will focus on our plastics industry for a solution-focused, rather than a government-led approach.

Plastics New Zealand, Packaging New Zealand, WasteMINZ and the Sustainable Business Network have joined forces with Scion in this project. Together, we will chart New Zealand's path towards a NPEC.

To read more about our path to a NPEC, visit www.scionresearch.com/2020plastics

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Funders Ministry for the Environment
Collaborators Packaging New Zealand, Plastics New Zealand, The Sustainable Business Network, WasteMinz

Delivering

Sustainable land use analysis for the Hawke's Bay

Afforestation is a powerful remediation approach for reducing erosion. The Hawke's Bay Regional Council and the Hawke's Bay Regional Investment Company approached Scion and our collaborators to understand what environmentally and economically sustainable afforestation could do to combat erosion in their region.

The Right Tree, Right Place study saw researchers strategically analyse the 12 per cent of land in the Hawke's Bay considered vulnerable to erosion. They assessed suitable afforestation options from commercial exotic forests through to exploring possibilities for permanent native forests.

The study also took into account the added value from benefits to the environment from planting. These benefits included sequestering carbon, the reduction of sediment and nutrients in waterways, and the benefits to terrestrial and aquatic biodiversity. Results show strategic afforestation is potentially a worthwhile investment for the Hawke's Bay Region.

Hawke's Bay Regional Council CEO James Palmer says, *"The data-driven Right Tree, Right Place (RTRP) programme project has reinforced that owners of the land need to see the social, environmental and financial benefits of afforestation and how it might impact local communities.*

"We will use the insights gained from the RTRP project to partner with landowners to optimise the mix between permanent forest and tree crops and pastoral farming, to knit together a more diverse patchwork of land use with greater resilience and ecological integrity and function."

To learn more about this study, visit
www.scionresearch.com/2020afforestation

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Funders   Hawke's Bay Regional Council, Hawke's Bay Regional Investment Company, Te Uru Rākau
Collaborators   PF Olsen, AgFirst, Fresh Perspectives Insight, RedAxe Forestry
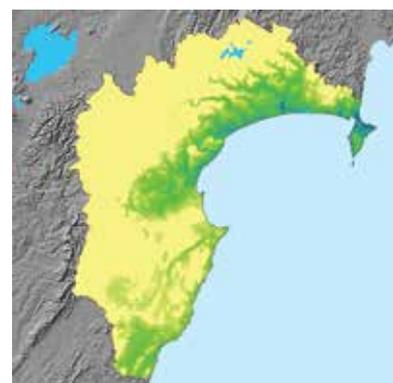
Delivering

A drone that can sense its way through a forest

If volume equals value in forestry terms, the lower stem is one of the most important, yet least accessible parts of the tree for airborne remote sensing. Until now, that is.

Flying above the canopy, unmanned aerial vehicle (UAV) scanners cannot reliably map tree stems. On the ground, GPS error prevents conventional laser mapping. SLAM technology (Simultaneous Location and Mapping) is the solution. It can create 3D maps from sensors without GPS. Attached to a UAV, this technology can navigate around a forest unpiloted. All the while, the sensors are collecting a highly detailed point cloud dataset of the forest environment that is immediately available after the scan, avoiding expensive and time-consuming data processing.

Over the past 18 months, Scion has conducted forestry trials with the manufacturers of a range of mobile SLAM scanners, including GreenValley International and GeoSLAM. And in November 2019, Scion and Emesent successfully completed a world-first and trialled Hovermap technology beneath the forest canopy. Results from the trial show that there is tremendous potential for SLAM technology to detect tree stems and take detailed measurements including location, diameter, height, stem volume, branching and stem defects, all of which determine the value of wood in the trees.

Forward thinking forest industry consultants, Interpine, have now taken up the technology and have begun to offer it as a service.

"We look forward to working alongside Scion to provide a pathway to implement SLAM-based LiDAR technology in the forestry sector. Together our teams will continue to extend what can be done with this game changing technology," says David Herries, Director and General Manager of Interpine.

For more information on this landmark research, visit www.scionresearch.com/2020slam

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Funders   Strategic Science Investment Fund, Forest Growers Research, Radiata Pine Breeding Company, Ministry of Business, Innovation and Employment

Collaborators   Emesent, Interpine, GreenValley International, GeoSLAM, Survey Solutions Ltd

Delivering

North Island food waste goes circular

Food scraps from over 500,000 homes are set to be transformed into renewable clean energy and biofertiliser.

Ecogas is a new venture that will see food waste collected from throughout the North Island and transported to Reporoa located in the centre of the North Island. There it is processed via anaerobic digestion. This system turns food waste into biogas, heat, usable biogenic carbon dioxide and biofertiliser. Scion scientists have proudly been involved in de-risking the key technologies, since 2016, and will continue work with Ecogas on commercialisation of science and technologies.

Ecogas will own and operate what will be the new utility anaerobic digestion plant. The site will be a commercial showcase, sitting on two hectares of farmland beside Turner and Grower Global's five hectares of tomato-growing greenhouses. Greenhouses will be heated by biogas produced from the digestion process; and CO_2 will be pumped in to enhance plant growth. Approximately 75,000 tonnes per annum of manufactured biofertiliser will also be applied onto more than 1500 hectares of productive farmland, replacing imported and manufactured synthetic fertilisers. Construction of the facilities began in August 2020.

Earlier Scion research based on derisking this technology has led to a new agreement to begin long-term pilot plant operational trials. Scion will take a science advisory role for this project over the next five years and explore additional biotech products with Ecogas.

Andrew Fisher, Managing Director and Owner of Ecostock (shareholder of Ecogas) recognises the need for quality research and development, saying, *"Long-term research and relationships are vital to the long-term success and adoption of biotechnologies in New Zealand. The Scion team helped us prove this technology and educate New Zealand industry. Scion will continue to be an important link between industry, government and other research bodies as we look to build a nationwide network."*

To read more about the benefits of anaerobic digestion, visit www.scionresearch.com/2020foodwaste

Funders	Ecogas, EcoStock Supplies Ltd, Bioresource Processing Alliance
Collaborators	Plant and Food Research

Delivering

A sustainable tōtara industry for Northland

Abundantly growing tōtara on Northland farms could support a viable new industry for the Northland economy, according to a two-year study.

The study found that a low volume (3000 m³), sustainable industry is achievable by harvesting single or small groups of tōtara and leaving larger tōtara to thrive.

This farm-grown tōtara timber project has had great support from local iwi partners, who will be involved with the commercial side of the proposed industry. With their help, the industry's predicted revenue of $3.5 million will stay in Northland communities. New regional jobs will also be created through sawmills, silviculture, log transport, cultural use and many other indirect opportunities.

In time, this project could become a great example of a resource-led value chain returning benefits to the local community.

Tapuaetahi Incorporation are owners of one of the farm harvest sites for the Northland Tōtara project. Executive Manager, Mariao Hohaia says, *"The project has helped us realise that the tōtara stands across our areas should be actively managed, not just for the ecological improvements but also for future prospects from a nascent industry of this taonga, with a cultural narrative that is uniquely Te Tai o Tokerau. Now, we are looking to replant our small 18-hectare pine and gum stand in tōtara."*

For the full story on Northland's farm-grown tōtara potential, visit www.scionresearch.com/2020totara

Funders	Te Uru Rākau, Northland Inc., Northland Regional Council, Kiwinet, Scion
Collaborators	Te Taitokerau Māori Forestry Inc., Tane's Tree Trust (and their Northland Tōtara Working Group), Northland Inc., Te Uru Rākau

Delivering

Unlocking the benefits of bark

Over 2 million tonnes of bark are produced by New Zealand's forestry industry every year. It is an underutilised resource, which could be worth $400 – 600 million annually if put to use.

Pine bark is a rich source of polyphenols, terpenes and resin acids that have unique functional and structural properties including antioxidant, antibacterial and waterproofing properties.

New technologies and integrated processing are needed to recover all the potential value from bark. Scion is setting out to create new processes and products through our highly collaborative Bark Biorefinery programme.

Industry involvement is key to building a successful value chain around a New Zealand bark biorefinery. Over 20 organisations from across New Zealand came to the table at the Bark Biorefinery Industry Workshop in November 2019. Their participation helped initiate an industry engagement strategy for the programme.

Mark Glenny, Innovation Research Manager from Resene, attended the industry workshop. He says, *"Sustainability is important to Resene, and one way we can make a big impact is to source more sustainable and renewable raw materials. The bark biorefinery project gives us the opportunity to do this, and we're excited about the potential product streams the project could create. The industry workshop gave us the chance to discuss the various approaches to achieving this alongside a wide range of other businesses."*

For more information on what has been extracted from bark, and the possible uses, visit www.scionresearch.com/2020bark

Funders Ministry of Business, Innovation and Employment
Collaborators VTT (Finland), Fraunhofer IGB (Germany), ITQB NOVA University of Lisbon (Portugal) and University of Auckland
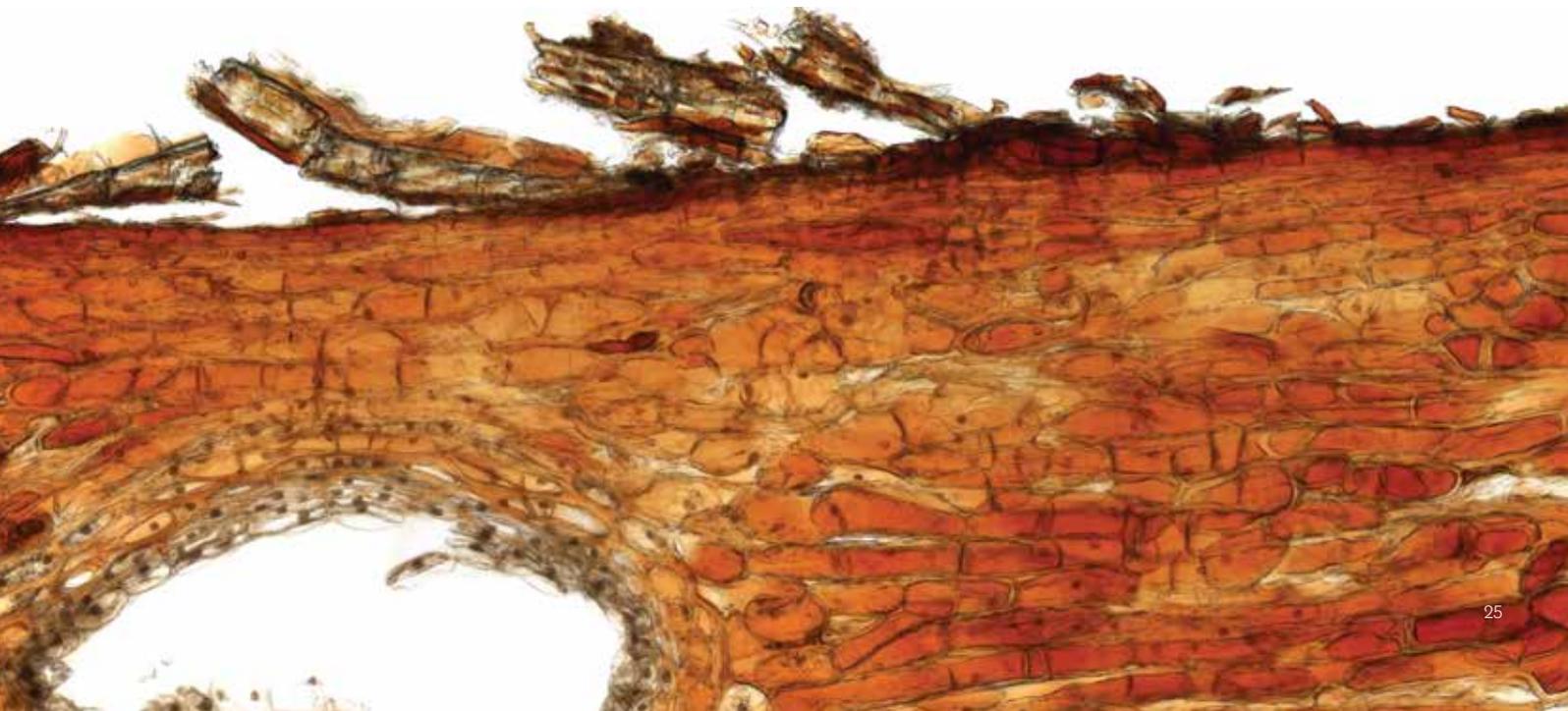
Delivering

Never-before-seen insights into fire

Six experimental burns carried out by Scion's Rural Fire Research team have resulted in never-before-seen insights into fire behaviour.

The burns are part of a series of experiments in differing vegetation types, designed to test a new theory of fire spread based on convection.

The six burns conducted in gorse scrub in the Rakaia Gorge, were highly instrumented with over $1 million in specialist camera equipment. Infra-red and visual footage captured by drones has provided new insights into the patterns of up- and down-drafts created by the fire front. The data collected across these fires, and experimental crop stubble fires undertaken in 2018-19, have both supported the new theory of fire spread. The next step will be to test it in standing wilding pines.

Fire and Emergency New Zealand, Integrated Risk Manager Darrin Woods says, *"The learnings from Scion's research burns will contribute to firefighter and community safety by changing the way we predict and respond to wildfires. The burns are also an invaluable opportunity for firefighters to practice their skills and observe extreme fire behaviour while in a highly managed environment."*

For the full story on our extreme fire research programme visit, www.scionresearch.com/2020fire

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Funders Ministry of Business, Innovation and Employment, Fire and Emergency New Zealand, Forest Growers Research, New Zealand Defence Force and the Department of Conservation, in-kind support from Federated Farmers

Collaborators United States Forest Service, San Jose State University and University of Canterbury

Delivering

A new wood that is transparent and flexible

Scientists have created a new wood film that is ultra-strong, flexible and 80 per cent transparent. The wood film is the result of a chemical treatment that removes lignin/hemicellulose from thin layers of wood that are then compressed and dried.

The material becomes 20 times thinner and 25 times stronger than the original wood and mechanically stronger than materials such as steels, alloys and plastics (strength-to-weight). It can be produced sustainably and is easily recyclable and biodegradable.

New functionality can be added to the material's surface via printing or coating, with functional nanoparticles or hydrophobic molecules, for example. It has already been used in conjunction with a biobased conductive ink to create wood-based flexible circuits that could be used for a wide range of applications, such as sensors, smart packaging and wearable devices.

The potential of this product has already been recognised by industry, receiving a highly commended award in the Wood and Fibre Products Technology and Innovation category in the 2020 Resene Timber Design Awards.

To read the full story on our new wood film, visit www.scionresearch.com/2020woodfilm

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Funders Strategic Science Investment Fund
Collaborators ETH Zurich

Delivering

Genomic selection testing gives breeding programme green light

New Zealand's specialist supplier of elite radiata pine genetics, the Radiata Pine Breeding Company (RPBC), can now confidently begin implementing genomic selection into their breeding programme, thanks to new methods performed by Scion.

With over 10,000 trees genotyped, Scion and the RPBC have the data required to assess how effective genomic selection will be for radiata pine – a first for any forest tree species.

Scion researchers found that it is possible to predict tree diameter and wood density using only the marker information.

Predictions were even possible for different types of radiata pine found in the breeding programme.

Mark Paget, RPBC Tree Improvement Manager, says, *"The next steps for the RPBC is to implement operational genomic selection in the breeding programme to increase the rate of genetic gain for key growth, disease and wood property traits."*

To read more about their testing and results, visit www.scionresearch.com/2020genomics

Funders Radiata Pine Breeding Company, Ministry of Business, Innovation and Employment

Delivering

Making modified wood more colourful

Kebony is a world leader in the modified wood market and major users of New Zealand-grown radiata pine. The company specialises in wood treated with an ecofriendly biobased solution that when applied to softwoods, such as radiata pine, modifies the wood to increase durability properties and give it a dark brown colour. This treatment makes softwoods a robust option for outdoor decks, cladding, furniture and joinery.

Scion has long been undertaking research in this area. Our technology can produce durable wood without adding colour. This gives the added benefit of being able to apply a variety of colours later in the process, which offers significant new marketing opportunities.

Scion has now partnered with Kebony who are looking to expand the colour range of their modified wood products. Together, we have begun trials at their pilot plant in Norway.

Kebony's Chief Technology Officer, Per Brynildsen, says, *"Kebony will always have a strong interest in research that can offer innovations in the field of biobased chemistry for wood enhancement, and Scion's inventions could present very interesting new features in Kebony's product offering."*

Bringing this technology to the commercial scale will create more demand for New Zealand-grown radiata pine, while opening exciting possibilities for future onshore processing in New Zealand.

For more information on our work with Kebony, visit www.scionresearch.com/2020modifiedwood

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Funders Strategic Science Investment Fund, Ministry of Business, Innovation and Employment
Collaborators Kebony

Delivering

Tree pedigrees reconstructed

Tracking tree pedigrees is important in radiata pine tree breeding to maximise genetic gain and minimise inbreeding.

In the 70 years since the radiata pine breeding programme was established, breeders have only been able to rely on paper-based records of tree identity and pedigree.

For the first time, Scion and the Radiata Pine Breeding Company (RPBC) have used genomics tools to determine the real relationships among trees and the real tree identities to update and improve the radiata pine breeding pedigree.

Scion scientists carried out pedigree reconstruction using DNA fingerprinting based on single nucleotide polymorphisms (SNPs). They were able to validate or improve over 14,000 pedigree records.

This has created an immediate improvement to pedigree records, and an increase in the accuracy and reliability of the breeding values of their genetically improved radiata pine.

The RPBC is keen to realise these gains. Tree Improvement Manager, Mark Paget says, *"The joint research effort into genomics of the past few years is now starting to bear fruit and the RPBC is very keen to start translating this to increased genetic gains in the production forest."*

To learn more about their results, visit
www.scionresearch.com/2020treepedigree

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Delivering

3D printing PPE for COVID-19 health workers

At the height of New Zealand's COVID-19 response, Scion joined a group of Rotorua companies pooling their talents to manufacture face shields for Lakes District Health Board (DHB).

In late March 2020, Scion was informed that the DHB was temporarily short of protective face shields for staff working at Rotorua hospital and in the wider community where they could be exposed to the coronavirus.

Working together, Scion and Kilwell Fibretube came up with a design that met the needs of the DHB, which provided clinical input and advice.

The team came up with a design for a modified Prusa face shield, consisting of a 3D printed headband manufactured by Scion and Kilwell, a Perspex shield cut by High Duty Plastics, and an elastic band at the back that was provided courtesy of AJ's Emporium and the DHB. A total of 215 visors were delivered to the DHB.

Dave Gower-Rudman, DHB Facilities Manager said the visors were modified after infection control recommendations and are now robust, fully re-usable and fit for purpose.

"At the time of receipt there were very few options available for eye protection. Even goggles and safety glasses could not be sourced in sufficient quantities. The receipt of these locally made visors was both well received and excellently timed", said Dave.

To learn more about the 3D printed face shields, visit www.scionresearch.com/2020faceshields

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Funders	Scion, Lakes District Health Board
Collaborators	Kilwell Firetube, High Duty Plastics
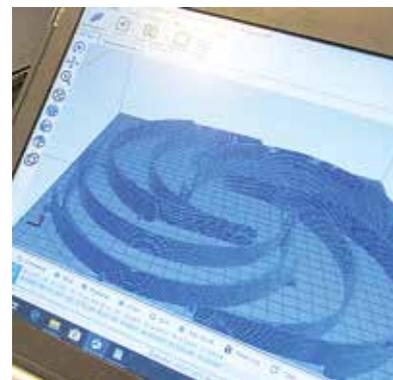
Sharing

Science papers

154 Refereed papers published

88.42 Rolling 5-year weighted average H-index

www.scionresearch.com/2020publications
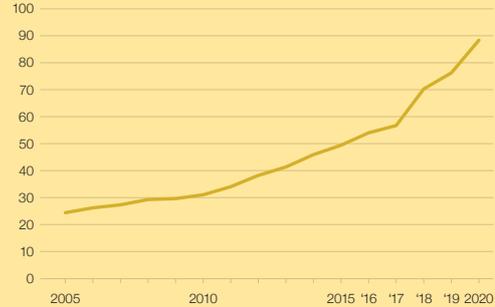
Collaborations

75 Publication collaborations with international research institutions

27 Publication collaborations with other New Zealand institutions

25 Formal collaborations with Māori

6 National Science Challenges

Tech transfer

7,418 Research-specific website visitors

313 Commissioned reports

240 Publications on technical information and research results

218 Presentations on technical information and research results

35 Popular articles and videos

14 Research specific newsletters

Communications

304 Media mentions

1,392 Subscribers to *Scion Connections*

2,260 Twitter followers

6,170 LinkedIn followers

22,500 Minutes watching Scion YouTube videos

60,436 New visitors to the Scion website

Excelling

Forest Growers Research Science Awards (October 2019)

Communication and Sector Engagement - Dr Amanda Matson. Amanda's skill set includes a great ability to communicate the research she's doing on what's going on under the ground in a pine forest, particularly the movement of soil nutrients.

Innovation that Enhances Sector Value - Dr Graham Coker. Graham's study is using foliar fertiliser applications to see what works to enhance tree growth and when it's best to apply those nutrients.

Collaboration to a Science Team - Loretta Garrett. Lorretta is the scientist everyone wants on their team according to her colleagues. Her work has varied from productivity trials to measuring nitrogen transfer in forest soils.

Young Scientist - Dr Stuart Fraser. Stuart is a recent recruit to working in New Zealand to combat forest tree diseases, such as the threat of myrtle rust and Dothistroma needle blight.

Science of International Quality - The Phenotyping Team from Scion and the University of Canterbury School of Forestry. This large team has been pulling together diverse science areas – such as genetics, remote sensing, computer modelling – to make huge world leading gains in finding, identifying, analysing and using the genetics of individual super-trees in Timberlands and Lake Taupo forests.

New Zealand Biosecurity Awards (November 2019)

These awards recognise and celebrate outstanding contributions to protecting our country. Scion staff were part of the Myrtle Rust Research Consortium, which won the Bio-Protection Research Centre Science Award for its integrated and rapid response to myrtle rust.

https://rb.gy/5eodwd

Science New Zealand National Awards (November 2019)

L to R: Drs Rezanavaz and Richardson, Hon Dr Megan Woods (Research, Science and Innovation Minister), Dr Dawn Smith & Marc Gaugler representing the Extrusion Plus Team.

Dr Brian Richardson was acknowledged with a **Lifetime Achievement Award** for a career in biosecurity research.

Brian has made many significant contributions both domestically and internationally to biosecurity research as well as pest-, vegetation- and sustainable forest-management. He has established extensive collaboration networks, including the USDA Forest Service where he received a technology transfer award for his research on spray modelling software, used to determine pesticide drift and efficacy.

Dr Roya Rezanavaz won an **Early Career Researcher Award** for her leadership on a project working with Kai Rotorua and Rotorua Boys High School.

Excited by the possibilities of additive manufacturing (3D printing) and plant-based bioplastics led an Unlocking Curious Minds project with kūmara at its heart. The project provided students with a practical way of engaging in science and technology using their own cultural heritage and bridging western science and mātauranga Māori. Through creating and 3D-printing models of kūmara they harvested, the students connected their ancestors, traditional agriculture and science.

The Team Award was bestowed on Scion's **Extrusion Plus Team**, who developed a technology platform to convert biomass from primary industries

into renewable natural materials to replace fossil fuel-based ingredients.

Low-value biomass, such as sander dust, kiwifruit hair and skin, seashells, grape marc or bark were compounded with biobased polymers to create biocomposites than can be extruded or reshaped into a new form for use in further manufacturing, such as injection moulding. A big advantage of the technology is its versatility. Extrusion and additive manufacturing (3D printing), lend themselves to both using biomaterials and possibilities for mobile, distributed manufacturing.

Timber Design Awards (April 2020)

Dr Qiliang Fu and the transparent wood film team were highly commended in the Wood and Fibre Products Technology and Innovation category in the New Zealand Wood – Resene Timber Design Awards 2020.

www.scionresearch.com./?a=68724

Packaging Innovation and Design Awards (May 2020)

Dr Kelly Wade won the Young Packaging Professional of the Year Award at the 2020 Australasian Packaging Innovation Design Awards.

Kelly is a materials scientist from Scion's packaging research team and was nominated for his work on biomimicry and nature-inspired sustainable packaging solutions. Using his knowledge of biomaterials, he is exploring biomimetic solutions to redesign and strengthen corrugated board boxes before they start to fail. This is valuable work given box failures in supply chains cost New Zealand and international companies billions of dollars in damaged goods.

www.scionresearch.com./?a=68934

2019 Scion Employee Recognition Awards

New Zealand Individual/Lifetime Achievement Award - Dr Brian Richardson

New Zealand Science Team Award - Extrusion Plus Team: Dr Dawn Smith, Marc Gaugler, Dr Marie Joo Le Guen, Ross Anderson, Beatrix Theobald, Dr Alankar Vaidya, Stephanie Weal, Eva Gaugler, Dr Yi Chen, Dr Meeta Patel and Dr Roya Rezanavaz.

Early Career Researcher Award - Dr Roya Rezanavaz

Roger Newman Award for Science or Engineering - Dr Tara Strand

Scion Science Individual Achievement Award - Kane Fleet

Recognition for Funding Success Award - Bark Biorefinery Team: Dr Warren Grigsby, Dr Dawn Smith, Dr Stefan Hill, Dr Laura Raymond, Peter Hall and Rob Lei.

Recognition of Publication Success Award - Dr Steve A. Wakelin

Customer Engagement Award - Craig Ford and Paul Keech

Support Excellence Award - IT Team: including Alec Martin, Narissa Tuawhiorangi, Jenny Simpson, Linda Andrews, Wendy Applegate and Sharon Burrell.

Scion Values Award - Jamie Bridson

Health and Safety Award - Christine Dodunski

Enhancing

On campus

We are upgrading our Rotorua campus to provide inspirational workspaces and flexible, fit-for-function facilities that reflect the world-class scientific work we are doing here at Scion. Construction activity was ongoing around us as our innovation hub took shape.

This impressive building displays timber technology designed using sustainable building principles. Here Scion will showcase what can be made from sustainably grown wood, both now and in the future. A first worldwide, the predominant feature of the three-storey building is the unique diagonal grid (diagrid) timber structure. Diagrids are an efficient way to provide strength and stiffness and require less material than traditional structures. A wrap around coloured curtain wall clads the building in colours that reflect the forest canopy.

Completion was delayed by COVID-19 lockdowns. We now look forward to occupying the building in spring and opening the doors to the public in early 2021.

Nursery Technician Ngarimu Mana demonstrating paper pot production, for seedling and cutting propagation, using an Ellepot production line. Scion has the machine on loan for research trials, and significant industry interest in the technology has resulted.

Nursery industry representatives were welcomed to an open day at our new research nursery facilities in December 2019. The pilot scale operation shows how a modular, automated, lean-flow, environmentally sustainable propagation facility could work in New Zealand conditions.

This new facility allows Scion to lead new propagation-based research aimed at speeding up our ability to grow high-quality indigenous trees. Research findings will be publicly available, helping nurseries around New Zealand increase their indigenous tree production and help to achieve the One Billion Trees goal.

Volunteering

Scion staff came together in December 2019 to volunteer for a day in our communities. This opportunity for whakawhanaungatanga (strengthening relationships) across Scion and into the community was a tangible way to make a difference in the cities where we work and reside.

Spades aplenty at Ohinemutu Village gardens on the shores of Lake Rotorua.

In Rotorua we partnered with kaitiaki at Ohinemutu Village on their vision for a 'food forest' as they work towards food sovereignty. A second day of volunteering took place at Whakarewarewa Living Village (which backs onto the Scion campus) where staff freshened up the paint on an historic church and whānau bathhouse.

Our Christchurch team joined the Orana Wildlife Park team to clean, garden and create enrichment toys for the zoo animals. They also wrapped children's presents for a charitable trust.

The three days gave Scion a way to support business and community enterprises. Internally, this volunteering project continued efforts towards building cultural capability, an understanding of local context through experience and a place for reciprocity where knowledge can be shared as part of the volunteer experience. Those involved agreed that the days were very satisfying and marked the beginning of meaningful relationships with our local communities. Ongoing volunteer opportunities in 2020 will extend the vision, maintain and build on relationships established during this inaugural activity.

Many hands helped paint the church at Whakarewarewa Village.

Achieving

Meeting our science and innovation goals

Impact Area 1

Forests and landscapes
Goal: To grow healthy, resilient forests that are planted primarily for their standing-forest benefits.

Key performance indicators	Achievements

By 2020, Scion, in collaboration with key industry, Māori, and government stakeholders will have initiated an R&D portfolio that achieves impact through accelerated propagation from tissue culture and nursery practice, and productivity gain and greater resilience from genetics and tree improvement.

The first year of the seven-year Tissue Culture Partnership project focused on contracting and establishing capability. The project aims to improve the effectiveness, efficiency and economic viability of tissue culture propagation methods for radiata pine using temporary immersion (TIM) bioreactors and a fluidic sorting system to separate and process viable embryos to produce small plants. The project involves industry through Forest Growers Research and collaborators Georgia Tech (GT), USA, and Natural Resources Institute Finland (LUKE).

Scion now has 48 TIM bioreactors and a new facility. Travel restrictions imposed by COVID-19 delayed installation of the systems that control the TIM bioreactor, but this work is proceeding with virtual assistance.

Scion's research nursery was upgraded with a state-of-the-art propagation facility. An industry open day showcased the new facility to the nursery sector in December 2019.

To help indigenous tree nursery production capacity, a large work programme commenced, and several nursery productivity trials have started to produce results.

Studies into the potential effectiveness of genomic selection (GS) have led to the Radiata Pine Breeding Company and Scion proceeding with implementation of GS.

By 2021, Scion will have a research platform to accelerate the delivery of ecosystem services from production and conservation forests through sustainable vegetation management practices that support continuous licence to operate. We will partner with key stakeholders Te Uru Rākau (TUR), Forest Owners Association (FOA), LandCorp, Māori, Department of Conservation (DOC) and regional councils to enable the success of a range of tree establishment programmes.

Together with TUR, FOA, Pāmu/Landcorp, DOC, regional councils, Tuhoe Tuawhenua Trust and Te Toa Whenua Trust an MBIE Endeavour Fund proposal "He nuku heu heu: Forest vegetation management drives tree establishment success" was submitted in March 2020 and successfully passed the science excellence assessment. The proposed programme aims to accelerate knowledge around establishment of planted indigenous forests in highly modified environments. The proposal integrates local knowledge (mātauranga) for planted indigenous-forest systems with national and international expertise in ecophysiology, vegetation/weed ecology, indigenous-forests systems, ecological modelling, remote sensing, precision spraying and biotechnology.

A TUR one billion trees programme on use of herbicides for establishment of planted indigenous forests was funded in 2020 enabling development of expertise and knowledge around herbicides that can be used safely with weeds common to forestry situations.

By 2020, working with Māori entities, cultural values have been integrated with Forest Investment Framework output to make land use decisions.

Not completed. Incorporation of cultural values into the Forest Investment Framework is ongoing work supported by the appointment of a specialist in this research area.

By 2021, Scion continues to be recognised as having contributed to New Zealand's ongoing national and international carbon reporting obligations.

Scion analysed national forest inventory data from natural and planted forests to produce revised estimates of the carbon stocks and stock changes in forests for use in greenhouse inventory reporting and policy development. Reports were prepared for MPI and MFE assessing options for reporting net carbon stock changes in forests under the Paris Agreement. New Zealand's accounting approach for wood products, together with the resulting stock changes, were published in a peer-reviewed journal for the first time.

By 2021, Scion in partnership with Māori have co-developed a breeding plan for at least one indigenous forest species.

A hui was held with mana whenua in June 2020 to plan next steps in co-developing planting options for kauri on their whenua, which may lead to a co-developed kauri breeding programme.

By 2021, the impacts of insect pests and pathogens on tree species grown for their standing benefits have been evaluated and research programmes to mitigate those effects have been started.

Scion has collaborated for the last three years with the apiculture industry and the Regional Council River Managers Forum to improve the health of willows, which protect erosion-prone land, are a food source for honey bees, provide animal shelter and amenity values. The invasive pest giant willow aphid creates honeydew that attracts wasps. When gathered by honey bees it creates a bitter crystal honey reducing honey quality and food for the honey bee brood. With support from MPI's Sustainable Food & Fibre Futures Fund and co-funding from the NZ Honey Industry Trust and Zespri International, Scion delivered an aphid parasitoid, *Pauesia nigrovaria*, for biological control. In the year, 23 separate releases were carried out at 15 locations, with establishment confirmed already at two of the sites.

Targeted field sampling of manuka, kauri, tōtara, rimu and kahikatea plantations and revegetation projects started in 2019 to assess pest and pathogen risk. A native fungus *Junghuhnia vincta* and an exotic pathogen *Phytopythium vexans* were found attacking kauri for the first time. Other new pathogen records were made, including *Phytopythium litor* on kahikatea. This exotic pathogen has attacked other woody hosts and agricultural crops since it was first found here in 2008. The findings suggest that risk from new pests and pathogens to native tree establishment remains significant.

Frequent monitoring of myrtle rust at two native forest sites near Rotorua continued, showing that the disease was still spreading within and between sites and having a significant impact on endemic *Lophomyrtus* (ramarama). Despite a very dry summer, myrtle rust caused death of *Lophomyrtus* seedlings and dieback of older trees. The disease was observed on foliage, stems, flowers and fruits. New monitoring sites were established in Auckland and Taranaki regions. Pilot studies in two native forests showed greater disease severity on *Lophomyrtus* growing in more open situations than those under canopy. Plantings of native myrtle species in trial field conditions confirmed ramarama and pohutukawa susceptibility but no symptoms observed on mānuka and kanuka.

By 2023, the Forest Investment Framework has been implemented to span three dimensions (time, space and risk), integrated with other land use models, and includes at least three new ecosystem services and five new forest productivity surfaces. The framework includes a protocol to integrate Māori cultural values in the decision making process.

Under the 2014-2019 "Growing confidence in forestry futures" MBIE-funded programme, we developed four new ecosystem services (ES) functions - biodiversity enhancement, water footprint, avoided nitrogen and recreation – to add to the Forest Investment Framework's three-existing ES functions - timber viability, carbon sequestration and avoided erosion. The seven spatial ES functions now enable a comprehensive quantification and valuation of the multiple benefits of current and future forests in New Zealand.

By 2023, Scion has provided the underpinning science to support and enhance licence to operate through environmental certification and to meet regulatory requirements, particularly in relation to Douglas-fir wilding spread and pesticides use.

Research examining terrestrial arthropod biodiversity in plantations that aims to improve plantation forestry's licence to operate started in 2019. The first year focussed on 15 plots established in radiata pine and native remnants within the forest. Iwi gave their blessing for entry to Pukemako, one of the native bush sites. An exciting find already was the rare and unique New Zealand beetle *Brounia thoracica* in a native remnant in northern Kinleith. Until recently, this odd little beetle was known from just seven specimens collected over the last 150 years. In February 2020, three specimens were found, indicating pine forests and native remnants can hold unexpected biodiversity.

Through our research under the MBIE-funded "Winning against wildings" programme, Scion provided new detection and mapping approaches that are efficient and highly accurate thereby allowing mapping of local and regional wilding infestations as the future basis for control planning and monitoring. Our thought leadership sparked multiple authorities to develop operational remote sensing-based mapping approaches based on our research and guidelines to support their wilding control efforts across the country.

Impact Area 2

High-value timber manufacturing and products
Goal: To grow healthy, resilient forests that produce trees for high-value manufacture into products that capture an increasing share of the global high-end market for timber.

Key performance indicators	Achievements

By 2020, Scion will have implemented new genomic screening tools to characterise the underlying genetic traits for the Radiata Pine Breeding Company (RPBC) elite germplasms and other production germplasm with the goal of identifying desirable tree genetics and the associated improvement in deployment of these genetic traits.

The RPBC /Scion-developed radiata pine SNP Chip was used to gather genotyping data from 20,000 trees to identify the real pedigree, and we reduced inconsistencies to <5 per cent which is a great result.

A retrospective assessment of the accuracy of genomic selection across populations, families and trial series (a first study at this scale for any forest tree) was completed. Preliminary results suggest that both wood density and tree diameter can be predicted across populations.

We determined that the predictive ability for tree diameter in the cloned elites series was nearly doubled with a genomics-corrected pedigree. This means that for some populations, incorporating genomic relationships will significantly enhance both pedigree and breeding value accuracies.

Maps produced from our linkage mapping study will be a valuable resource for applications including the selection of marker panels for genomic studies and de novo whole genome assembly.

By 2020, the full value of planted forests, including key ecosystem services will have been communicated to forest managers, regional and central government agencies at the National Forest Ecosystem Services Forum.

The 2020 National Forest Ecosystem Services Forum was postponed from May 2020 to December 2020 owing to COVID-19. The full value of planted forests will be presented at this forum, but the focus will be on the quantification of water related ecosystem services and carbon sequestration to align with the forum theme "Planted forests, climate change, water and people connections".

The full value of planted forests was quantified and valued using the refined Forest Investment Framework and results were presented at two conferences: IUFRO World Congress, October 2019, Brazil, and later that month at the NZ Forest Growers Conference in Wellington.

By 2020, the key outcomes from the multi-year GCFF programme (i.e. new knowledge on optimising right tree, right place, right purpose, improved genetics, silvicultural models and management methods) will have been communicated at national industry events to large forest owners and the many small Farm Forestry Association members.

After six years the forestry industry's flagship research programme "Growing confidence in forestry's future" (GCFF) was completed. A key outcome of the programme was a fundamental shift towards precision forestry. More precise management decisions are being made: sensor technologies are providing newly available phenotypic data; the right fertilisers are being applied to add the best value with lower environmental impact; industry and researchers are working together towards common goals. Confidence has grown as forest growing companies now know that 60 years of managing trees on their sites is not impacting their long-term productive capacity. Forests are more productive and resource efficient, providing the raw material for value-add processing. Forest growers and policy makers now have a better basis to make strategic decisions around investment and forest policy underpinning the Government's goals of "right tree, right place, right purpose".

The relationship between industry and researchers has strengthened over the past six years, as the benefits of sustained fundamental research are being realised through regular interaction. The GCFF programme was replaced with a new programme focused on resilient forests, which is supported by government's Strategic Science Investment Funding provided by MBIE and by Forest Growers Research. The level of industry support increased to $2.6 million per annum.

A legacy of the GCFF programme is the new "Forest Flows" MBIE Endeavour-funded programme. It stems from a 2017 GCFF workshop on forestry and water-related issues that identified key issues facing the forest growing sector.

By 2020, an integrated land use framework including timber and non-timber values has been proved and used in validating forestry investments under the billion trees initiative.

Scion developed integrated land use models, maps and reports for the Hawke's Bay Regional Council that will enhance decision making for afforestation on erodible landscapes.

The project aimed to inform landowners of forestry options for their land and to guide investment decisions by the council. Information is provided on (1) landscapes that are suitable for commercial forestry versus landscapes that should be retired (e.g. plant and leave), (2) which tree species or forest systems have potential to be established across a landscape, and (3) a calculation of not only timber values from a plantation, but also an estimate of non-timber values (e.g. avoidance of erosion or biodiversity).

The work was undertaken with PF Olsen, AgFirst, and Fresh Perspective Insight.

By 2020, Scion has worked with Māori, and at least one Māori entity is active in building a new vertically integrated high-value wood manufacturing enterprise.

Scion joined with Te Arawa Primary Sector (TAPS) to identify, integrate and evaluate opportunities for adding value to the food and fibre produced on land they administer in the Bay of Plenty. Central to this ongoing collaboration is the role of wood and wood byproducts to generate regional manufacturing opportunities.

By 2021, new fundamental knowledge is developed around wood natural durability, wood permeability and treatability for both radiata and non-radiata species. This new knowledge will be then be used in targeted wood modification, durability and drying solutions.

A new method was implemented to extract the cellulose/hemicellulose matrix from wood while maintaining the wood three-dimensional structure. The delignified substrate will be used to develop innovative material from wood by re-composing the cellulose/hemicellulose matrix with resins and biopolymers.

A new theory of surface tension was proposed to explain collapse in wood during drying.

A Patent Cooperation Treaty was filed for one of Scion's wood modification technologies in September 2019. We continued to work with a European wood modification company to deliver this technology.

A domestic company is trialling our Thru-Colour technology and evaluating interior applications for this technology in its international markets.

By 2021, Scion, with science collaborators, government, and industry partners with non-traditional urban stakeholders, has developed a platform of high-value wood products to provide better performing, higher amenity built-environments in terms of affordability, performance and sustainability, e.g. tall timber buildings, prefabrication etc.

Research for a review paper in preparation showed that without an integrated circular city approach, a focus on one individual activity area (like waste reduction, energy efficiency, food production, pollution) can impinge on another area's ability to succeed. Most circular city approaches around the world tend to focus on individual activities, which while useful do not provide a complete view on how to achieve a truly circular city where everything needs to work together from resources, economies, social and other systems.

By 2023, tools, novel forest management approaches and new plant material will be embedded into New Zealand's forests and forestry practices to support the industry's target to increase radiata pine MAI from an average of 20 m³ ha-1 yr to 35 m³ ha-1 yr and in a way that enhances the sustainability of forest growing in New Zealand.

Forest growers typically apply granular fertiliser, primarily nitrogen-based products, to address nutrient deficiencies. New Scion research demonstrated that less fertiliser is applied with better plant uptake via foliar application. Experimental rates as low as 16 kg N ha^{-1} vs traditional application rates of 200 kg N ha^{-1} have shown promising economic and environmental outcomes.

The importance of previous land use on soil properties and forest productivity was highlighted in a national study into the drivers of site productivity. After adjusting for the effects of climate, site productivity was found to be negatively related to the soil C/N ratio and positively related to the size of the soil organic matter pool. This resulted in a 20 per cent gain in productivity, commonly known as the 'farm effect'. These findings add to the knowledge of soil and climate drivers of radiata pine productivity.

Phenotyping extends beyond the study of growth characteristics. We examined the variation in nitrogen source preference of different radiata pine clones in situ. Some of the clones we tested showed positive growth responses to an organic nitrogen fertiliser while others only showed a growth response to inorganic nitrogen fertiliser, suggesting that specific clones could be selected for planting in nitrogen-sensitive areas.

Using new DUALEM technology to remotely assess soil physical properties, we quantified the interaction between microsite, genotype, nitrogen fertiliser and climate, and identified specific genotypes more sensitive to drier soil conditions. This ability to rapidly map forest soil physical properties over a large area can help account for previously unexplained variation in tree performance due to differences in soil properties.

New insights into real-time patterns of tree growth and water use will help us better understand and prepare for the impacts of future climate change. We have combined data from an extensive, low-cost network of environmental and sap-flow sensors with the DUALEM map of soil physical properties across one of the large forest accelerator trials, to show that some genotypes use significantly less water than others with minimal impact on growth.

By 2023, the forestry industry, land owners, and central and regional government have adopted new tools, approaches and technologies developed to mitigate impacts from the increasing risk to New Zealand's forests from pests (insects, pathogens, weeds), fire and wind in our changing environment (climate, trade and tourism), and to mitigate risks and take advantages of opportunities from climate change.

A Lucid interactive key to identify all indigenous and most common exotic myrtle species was developed with Manaaki Whenua – Landcare Research. This MPI-funded work provided a field tool to support myrtle rust management.

Scion, as part of the Better Border Biosecurity (B3) collaboration, started research for the "Tauranga Moana Biosecurity Capital" initiative. Our aim was to test the effectiveness of eight insect trap designs to support insect surveillance programmes at seaports and other high-risk points of entry.

To better support eradication programmes, machine learning options for processing electroantennogram data from a prototype for gypsy moth were promising.

Lagrangian coherent structures (atmospheric 'rivers') successfully predicted movement of smoke and insects across the Tasman.

Long-term disease monitoring identified key seasonal weather variables driving red needle cast outbreaks. Combining ground-based monitoring with high-resolution satellite imagery allowed an investigation into wider landscape drivers. Preliminary results suggest greater disease severity at sites on slopes with south-facing aspects. A modelling framework was developed to incorporate this data into epidemiological and growth impact models that can be scaled from the tree to the forest.

Scion worked with forest nurseries to characterise populations of oomycete pathogens in soil and roots of *Pinus radiata* using high throughput DNA sequencing. The data will help understand the movement of pathogens between seed orchards, nurseries and forests. In addition, differentiating populations of viable and non-viable oomycetes present in nursery soils was made possible using environmental RNA, resulting in a better indicator of biosecurity risk.

Gorse scrub burns at Rakaia Gorge, Canterbury, were successfully completed in March, as the second phase of testing the new convective fire spread theory.

Kāuta: He hononga mo te tangata manaaki (Traditional hearths: Bringing people together") is a mātauranga Māori project developing engineering design requirements for a contemporary kāuta (traditional open, internal/external fireplaces used for cooking and heating on marae and/or papakainga). This project engaged Māori, scientists and regulatory agencies, resulting in skills transfer, scientists learning Māori culture and gaining cultural knowledge of how to engage Māori in scientific projects. www.scionresearch.com./?a=70326

By 2023, Scion has provided tools, new biotech and genetic solutions, new plant material (e.g. germplasm) and competitive niche wood products that will increase the confidence of growers of Douglas-fir, eucalypts, cypresses, redwoods and indigenous species to increase plantings of these species by at least 50 per cent over 2018 plantings.

Key data from project trials in selective harvesting of farm-tōtara, along with milling and drying trials, demonstrated the operational and environmental viability of producing high quality farm-tōtara timber. Business and financial models, and market feedback, indicated promising and sustainable business opportunities from this resource. Next steps and recommendations will appear in the final report due August 2020. The two-year project received good publicity across print, radio and television media outlets over its duration.

The invasive eucalyptus variegated beetle *Paropsisterna variicollis* is creating significant defoliation in eucalyptus plantations, especially those with ground-durable timber properties being developed by NZ Drylands Initiative and those with short fibre used at a mill. Via a collaboration between molecular researchers and overseas entomologists we found that the New Zealand beetle was unique, but most similar to one shared between Western Australia, Tasmania and Victoria. This research paves the way for biocontrol of this pest in the future and resulted in its name change to *Paropsisterna cloelia*.

Ongoing: New technologies such as automation, robotics, sensors, new digital technology have been implemented in the cities/buildings/products/processing and forest growing value chains, demonstrating improved efficiency, cost reduction, improved safety, and better living and working environments.

Sensors that detect the presence of the fire front in a vegetation fire were developed and successfully demonstrated at Scion's experimental burns. The sensors can use a satellite or terrestrial radio network and can remotely activate water sprinklers to protect valuable assets (buildings, infrastructure) in the path of the fire.

Early work with Forest Growers Research on the "Forestry work in the modern age" Primary Growth Partnership developed a preliminary supply chain model that simulates a new automated harvesting system. The programme is currently working to demonstrate improved efficiencies and economic benefits of the new system.

Functionality of Scion's tree-to-tree robot was improved with the addition of a working electric chainsaw. The chainsaw-armed robot successfully demonstrated cutting 15 cm diameter stems. Our robot was presented as an example of the silviculture future at the 52nd International Symposium on Forestry Mechanization, Hungary.

The AI 'seedling detection using deep learning' project identified that the use of convolutional neural network may be a powerful tool for mapping seedlings, having been demonstrated to detect individual nursery seedlings with an accuracy of 91 per cent.

Beyond visual line of sight technologies (for drone operations) were identified to be of most benefit to large forest companies. The technologies have a few gaps to overcome, which are in the control and communication links and the detect and avoid systems.

Emesent Hovermap™ laser scanning technology was successfully evaluated for its applicability for research and operations. We found that the data captured by the technology was of superior quality and qualified it for research use.

Data issues in 3D scans of forests are now addressed with our development of state-of-the-art deep learning techniques.

The Gates Foundation Toilet Challenge Phase 2 was completed and successfully demonstrated the potential role of wet oxidation technology into a low cost, off-grid re-invented toilet. Scion was invited into the next phase of the project, led by Georgia Tech and collaborating with world-class institutes around the world, culminating with a presentation by Scion staff to Bill Gates.

Ongoing: Support forest growing, wood products and building industries to grow and develop by addressing domestic/international standards, regulations and market specifications.

Our commercial testing services exceeded our commercial target by 30 per cent and provided significant benefit to the wood and fibre sectors, and our engagement with the wood durability sector showed dramatic growth.

Progress was made on the three New Zealand timber building standards NZS3602, NZS3603 and NZS3640, which after many years have now been through the final committee vote. With a few modifications and approval from the NZ Standards Approval Board these standards now will be published. Work continues on the Australia/NZ Standards - AS/NZS1604 and AS/NZS1605.

Our Bioenergy Team delivered eight commercial contracts mainly focusing on biomass availability and costs, and processing options for companies, government departments and regional development agencies.

Impact Area 3

Biobased manufacturing and products
Goal: To grow healthy, resilient forests that replace petrochemicals and non-sustainable materials with products from trees and other biomaterials.

Key performance indicators	Achievements
By 2020, at least six new polymeric material products with renewable content have been developed to prototype stage using existing (e.g. extrusion, injection moulding) and emerging technologies (e.g. 3D printing or electrospinning), and two of these prototypes have been incorporated into new product offerings by firms.	Scion's composite programme aims to produce novel, high-performance, eco-friendly functional material. This year we created a fully biobased, wood-derived electronic circuit, a conductive 3D printable elastomeric bioplastic and a biobased aerogel for water depollution. Our lignin nanofibre electrospinning and carbonisation technology, developed with commercial partner Revolution Fibres, was adapted to produce conductive biobased inks contributing to packaging industry engagement. Our range of biodegradable bioplastic (PHA) materials was expanded by incorporating the microbial cell biomass as a filler. This lowers the cost of the PHA resulting in cheaper products such as bread clips or germination tubes. A PHA commercialisation workshop organised by Scion brought together New Zealand companies with a strong interest in PHA to explore product and manufacturing possibilities. As part of the Science for Technological Innovation National Science Challenge, we formed keratin-lignin copolymers for the first time using green chemistry principles. This resulted in materials that can be 3D printed and which retain their inherent responses to external stimuli such as moisture. Scion led and successfully completed a six-year MBIE Endeavour funded research programme for BPN (Biopolymer Network Limited). The programme sought to incorporate New Zealand bioresources into new industrial resin, foam or packaging products for industry uptake. Scion modified bark for use as a functional additive for BPN's Zealafoam™ technology. Scion also supported the uptake of the ZealaFoam® technology by expanded polystyrene manufacturers locally and internationally. Scion-developed materials and technologies underpin two technologies now marketed by our partners from EPL. Vine clips, carefully designed to both protect the vines then degrade naturally into the soil, were made using EPL's biodegradable polymer PolyDegrade™. Building on this work and material, plant protectors made from a unique blend of natural resources are now available from EPL. Biofuels can also be made from wood using thermal reactions, such as pyrolysis. However, relatively high levels of oxygen-containing chemicals such as catechols are also created and need to be removed. An enzyme-based system was developed to convert bio-oil-derived catechols into corresponding muconic acids, which could be used as precursors for producing nylons and new biopolyesters.
By 2020, two different genetically modified biotech tree lines have been developed and existing trees evaluated to determine their viability as alternative feedstocks for producing high-value chemicals and/or processability for fibre or bioenergy.	Trees that were genetically modified to be more easily processed, by altering the monomer composition of lignin, were harvested and their performance evaluated. Biochemical analysis showed that modified lignin was present at high levels in needles and bark but at a lower level in wood. The modified wood showed minor improvements in paper characteristics and enzymatic saccharification. This indicates that wood with greater levels of modified lignin is likely to yield economic and environmental benefits. Trees in two growth-related trials, initiated reproduction at a younger age than anticipated and had to be felled to meet the conditions of our EPA approval prior to growth differences becoming apparent. Trees with other cell wall modifications are progressing through to field trials.

By 2020, Scion has identified technology innovations to deliver the Biofuels Roadmap outcomes and has secured funding to progress them.

The Biofuels Roadmap indicated that heavy goods transportation and aviation needs liquid biofuels to decarbonise. This need was recognised in the Ministry of Transport's Green Freight initiative, which considered incentives and mandates to encourage biofuels use. Concern from MBIE and the Parliamentary Commissioner for the Environment on the impact on biofuels implementation in New Zealand if Marsden Point refinery was to close (one of the scenarios being considered in the Strategic Review of the Refinery) resulted in Scion being asked to produce a brief report addressing a range of questions on the topic.

The impact of COVID-19 slowed progress with the NZ Biojet consortium, and funding was not secured. A trans-Tasman group, Sustainable Aviation Fuel Alliance ANZ, was set up with contributions from airlines, airports and research groups to promote the development of sustainable aviation fuels.

By 2020, Scion and commercial partner(s) have developed a viable and New Zealand-specific biorefinery business case including Scion-developed high-value bioproducts and cost-efficient technology platforms for commodity fibres and bioenergy, including criteria for new short-rotation forest trees systems.

Three key papers were published to the biorefinery business case. They covered the effect of pretreatment on the production of liquid biofuels (by thermal routes); production of biomass briquettes with greater energy density that are less likely to break down during transport; and studying nano-scale energy efficient process for future application to large-scale energy systems.

Requests for information increased from government departments and other organisations, and we elevated our position within the International Energy Agency Bioenergy Group.

Our partner Ecogas secured funding to convert food waste to biomethane and is about to break ground on a plant that processes 75,000 tonnes per annum of food waste into energy and fertiliser products. Scion also secured a five-year agreement to provide science services to this venture.

To enable non-destructive identification of radiata trees for high fibre production a high throughput novel core scanning method (Corebot) was developed where cores are scanned using both NIR and X-ray. Results showed significant differences in lignin and cellulose content, which is notable for pulping operations to produce fibres where a 1 per cent change in cellulose content has a substantial impact on pulping efficiency.

By 2020, Scion has worked with Māori, and at least one Māori entity has included new biobased materials in their product portfolio.

With MBIE's Unlocking Curious Minds funding, Scion worked with Kai Rotorua and Rotorua Boys High School to bring kūmara history to life via science and technology. In Scion workshops, students made 3D models of kūmara they had harvested, and the models were 3D printed with a biopolymer.

Another Unlocking Curious Minds project underway engages students from local schools to assess the issues, scale and possible sources of plastic pollution along the Kaituna River catchment.

In a two-year collaboration with the NZ Institute for Minerals to Materials Research and Māori weavers we are assessing how the properties of cabbage tree and harakeke fibres prepared using mātauranga Māori and paper-pulping methods affect the properties of bioplastic composites.

By 2022, New Zealand has new industries using new high-performance products enabled by Scion-developed technologies (on-demand degradable plastics, green electronics, biobased composites, lignin products and

Scion chaired the Safe and Sustainable Packaging and Materials Forum in Auckland in March 2020 attended by central and regional government, waste providers, brand owners and consultants. It was agreed that change is necessary, everyone must take responsibility, and both compostability and recyclable materials have a place.

As part of our work on biobased printable electronics to inform packaging performance, five data loggers were compared by monitoring a shipment of apples from Hastings to

new compounded materials containing biopolymers), using existing (e.g. extrusion and/or injection moulding) and emerging technologies (e.g. 3D-printing or electrospinning).

Antwerp, Belgium. Overall, they all produced relatively similar temperature records, but the humidity results varied among them. The loggers and their software interfaces had different advantages and disadvantages.

The packaging team is now a partner in an international APPTI (Alliance for Pulp & Paper Technology Innovation) programme between Miami University (USA), RISE (Sweden), Massey University and Scion on producing a model of box behaviour capable of accounting for factors including creep and vibration.

We are supporting ESR's AIM2 MBIE Programme (Aotearoa Impacts and Mitigation of Microplastics). Our activities include quantifying microplastics distribution, assessing direct and indirect impacts of plastics and determining methods of reducing the impacts and the amount of plastic in the environment.

By 2022, Scion has identified commercial opportunities that have led to drop-in replacement of coal with wood residues or wood-based solid fuel products to generate heat in industrial processes. This will help drive a 1 per cent reduction in GHG emissions per annum from the sector, aligned with the New Zealand Energy Efficiency and Conservation target.

Scion continued working with the Energy Efficiency and Conservation Authority (EECA) on biomass availability and cost of supply to eight commercial entities requiring heat for processing. With BusinessNZ we also assisted EECA on their modelling of different energy demand scenarios out to 2060 and the impact on GHG emissions.

Both bark and bark processing residues were assessed for their characteristics suitable for use as biofuel briquettes. From this evaluation, an understanding of briquette manufacturing conditions including consolidation temperatures and pressures were determined to ensure satisfactory briquette durability (weathering) and performance.

By 2023, Scion has demonstrated the feasibility of converting forest and other biobased materials through distributed and mobile processes into chemicals and biopolymers and has identified a group of interested industrial partners to progress one of the technologies to pilot/demonstration scale.

Several proof-of-concept projects are underway such as BPA (Bioprocessing Alliance)-funded work to assess the feasibility of using brewers' spent grain and hemp hurd/straw as feedstock for a reactive extrusion-based process to produce biochemicals. Working with commercial companies we developed reactive extrusion-based processes for the manufacture of selected high-value biochemicals

Scion supported an AgResearch-led international initiative exploring new ideas for grassland production systems to increase export value and generate new job opportunities, while reducing environmental impacts. This work includes leading Irish research organisations (Teagasc, AMBER and the BEACON Bioeconomy Research Centre), and investigations began around alternative and complementary uses for pasture as a feedstock for a green biorefinery. Irish researchers visited Scion in October 2019.

Ongoing: Provide evaluation of benefits and risks to increase engagement and stakeholder support for biotech for forestry and other bioproduct industries and ensure quantified outcomes for biotechnology applications are presented to the forest industry, government and other key stakeholders to facilitate an informed decision on future implementation.

We received the final report from Colmar Brunton on our public survey of opinion and presented results at the annual Forest Growers Research Conference. The key result of achieving potential sterility in Douglas-fir through gene editing was reported in the Forest Growers newsletter with commentary that the law on biotech plants needs revision. The public survey indicated that while the public is not generally well informed on the GMO debate they were most generally in favour of using gene editing to combat wilding conifers. These results were also submitted to the Waikato District Council on the Waikato District Plan revision together with other organisations regarding GMO organisms in the Waikato. The hearing was held in late January 2020, and we are awaiting a decision.

We have demonstrated the ability to carry out gene editing by directly introducing CRISPR protein complexes into radiata, which is the first time for radiata to our knowledge. This is the key step in development of transgene free gene editing. A hybrid approach has been used where editing has been carried out by CRISPR protein co-delivered with a transgene that enables selection of the edited trees. Ongoing work is focussed on delivery of the protein without the selectable marker.

Ongoing: Support bioproducts and bioenergy industries to grow and develop by (a) addressing standards that create artificial barriers to products accessing markets or applications, (b) developing technologies and IT systems that allow bioproducts to be traced within the value chains they are transacted in and for their source to be verified, and (c) ensuring environmental compliance for regulators and customers.

Scion contributed to Cawthron-led research to develop a marine biosecurity 'toolbox' by testing eco-innovative digital technologies combining 3D scanning and printing of natural environments, and by developing cost-benefit models and decision support systems.

Our Biodegradation Plant was contracted by four companies with >20 companies requesting quotes for compostability testing towards their environmental compliance obligations.

Scion joined forces with Plastics New Zealand, Packaging New Zealand, WasteMINZ and the Sustainable Business Network to develop a New Zealand specific New Plastic Economy Roadmap. Completion of this two-year Waste Minimisation Fund funded programme is due in mid-2021.

Another WMF two-year project "A practical study of compostable materials in NZ composting systems" started. The project will quantify how a range of different packaging materials degrade in different composting facilities.

Financial results summary

	2018 Actual	2019 (Restated) Actual	2020 Budget	2020 Actual
Revenue, $m	56.74	55.94	51.23	57.88
EBIT, $m	3.03	1.87	-3.99	6.02
EBIT Margin	5.3%	3.3%	-7.8%	10.4%
Reinvestment, $m	1.43	1.12	1.45	1.99
EBIT-R, $m	4.46	2.99	-2.54	8.01
EBIT-R Margin	7.9%	5.3%	-5.0%	13.8%
Total Assets, $m	57.13	55.92	55.59	65.07
Return on Equity	5.7%	3.9%	-7.0%	11.8%
Pre-reinvestment Return on Equity	8.2%	5.7%	-4.4%	14.7%
Equity Ratio	71.6%	73.5%	73.3%	75.1%
Dividend, $m	-	-	-	-
Gearing	0.0%	0.0%	0.0%	0.0%

Revenue: Includes science research, contract work for government and commercial clients, royalties and licence fees.

EBIT: Earnings before interest, tax and restructuring costs.

EBIT Margin: EBIT ÷ revenue.

EBIT-R: EBIT before reinvestment where reinvestment are amounts approved by the Minister.

EBIT-R Margin: EBIT-R ÷ revenue.

Return on Equity: Net profit after tax ÷ average shareholders' funds, expressed as a percentage.

Equity Ratio: Average shareholders' funds ÷ average total assets.
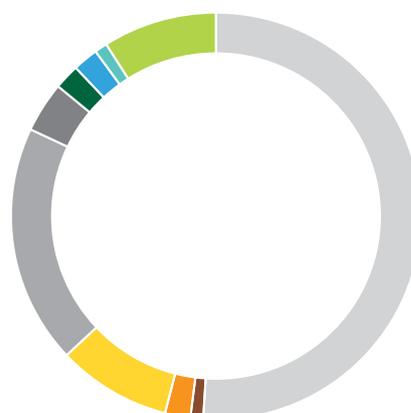
Gearing: Financial debt ÷ financial debt plus shareholders' funds.

(The Minister of Finance and the Minister of Science and Innovation each hold 50 per cent of the shares on behalf of the public.)

Where our revenue comes from

Ministry of Business, Innovation and Employment (SSIF)	41%
Ministry of Business, Innovation and Employment (Other)	24%
Government departments	13%
Other commercial	22 %

How our revenue is spent

Employee remuneration	51%
Training and recruitment	1%
Consumables	2%
Depreciation and amortisation	9%
External services and contractors	19%
Premises costs	4%
Travel	2%
Other operating costs	2%
Non operating costs	-1%
Net profit before tax	11%

Our full Reports and Financial Statements are presented in Part B of the Annual Report. www.scionresearch.com/annual-reports

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