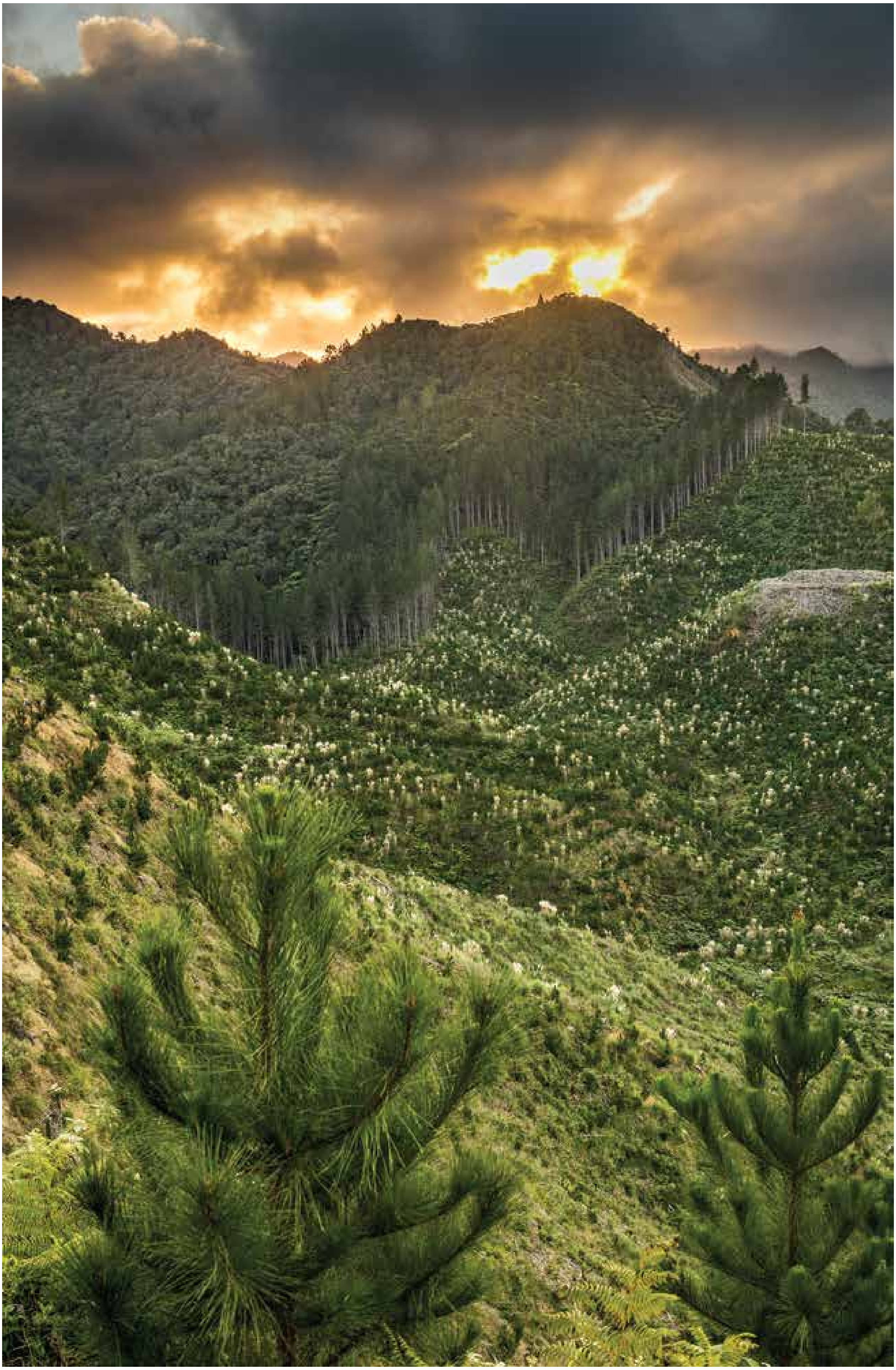
FORESTRY UNLEASHED

scion™
FORESTS ▪ PRODUCTS ▪ INNOVATION

Annual Report 2018
Highlights



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Annual Report 2018 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.

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

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SCION AT A GLANCE

Operating revenue

$56.7m

Last year: $51.9m

Total comprehensive income

$2.3m

Last year: $2.3m

Return on equity

5.7%

Last year: 6.2%

Full-time equivalent staff

321

288 Rotorua
1 Wellington
31 Christchurch
1 Dunedin

(includes fixed-term, student and postdoctoral staff)

Published refereed papers

131

70.46 rolling 5-year weighted average H-index

336

commissioned reports to users

OUR VISION IS

Prosperity from trees - *Mai i te ngahere oranga*

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.

More than seven decades of science and technological innovation delivery makes Scion uniquely placed to unleash the power of forestry to build economic value and achieve better environmental and social outcomes for New Zealand.

Our responsibility as a Crown research institute is to work with industry, government and Māori to achieve four national outcomes for New Zealand. These are:

- Increase the value and productivity of New Zealand forestry, wood products, wood-derived and other biomaterial sectors
- Protect and enhance market access and manage risk
- Increase renewable energy production and energy security from forest biomass
- Enhance benefits from forestry-based ecosystem services

From these outcomes, we organised our year's work in seven areas of science impact as shown on page 7.

CHAIR AND CHIEF EXECUTIVE OVERVIEW

Powering our country through trees

This time last year we determined that forestry's time had come, and aptly named our annual report "Unleashing the power of forestry". One year on, we have taken the title "Forestry unleashed" to reflect changes across the board from global to local. Much has happened this year to set Scion, and the forest industry, on the road to more surely drive 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".

We strongly believe that forestry, and all that we can make from trees, has great potential to achieve our mission in very significant ways. We know that our purpose is highly aligned with many government objectives, such as increasing afforestation to one billion trees in a decade and a zero carbon emissions economy by 2050. Scion, too, is well aligned to supporting Māori achieve their long-term aspirations for their land and their people.

Through planting the right trees in the right places for the right purposes, long-term good for New Zealand economically, environmentally and socially will be attained.

Many Māori entities are directly or indirectly linked to forestry or can utilise forest products, like using packaging as part of commercial enterprises. This year, three partnerships involving Scion were supported by the new Provincial Growth Fund: Ngāti Whare, who received Crown backing of $5.8 million to underpin the development of their state-of-the-art nursery at Minginui; the Northland Tōtara Industry Pilot programme to test the proposition of building a full sustainable value chain industry in Northland based on farm-grown tōtara; and the recent announcement to explore establishment of a kauri sanctuary at Takou Bay led by Ngāti Rēhia. Seeing Māori/Scion partnerships grow and deepen is encouraging. Together we are identifying new opportunities and pathways forward, and enjoying rewards that will evolve into sustainable benefits for our country Aotearoa.

During the year we embarked on a strategy refresh, designed to lift our thinking above our current framework so we could indeed see "the wood for the trees". The process was important for us to really understand what Scion is about and what opportunities are ahead for New Zealand. In the process, we set out our aspirations for our country in 2050. To help us get there, we concentrated on more immediate goals, which we were delighted to present in our new strategy "Right tree, right place, right purpose: Scion strategy to 2030" published in June and available online. Our job now is to formulate the action plan to deliver on this strategy so that through planting the right trees in the right places for the right purposes, long-term good for New Zealand economically, environmentally and socially will be attained.

Last year, we celebrated 70 years of science impact. A year on, we have much to be proud of. Our research highlights presented in this annual report cover just a small portion of the total contribution we, and our iwi and industry partners, have made towards making forests the powerhouses of the future.

A milestone achievement was completion of the world-first draft assembly of the radiata pine genome, announced at the Forest Growers Research Conference last October. This marked the beginning of a new era of precision forestry for this species, which comprises 90 per cent of all New Zealand planted forests.

Scion's involvement in the myrtle rust incursion response was intense during the year both as leaders of specific projects and as collaborators in multi-disciplinary and multi-organisation programmes. We are leading a new approach to engagement with Māori and interest groups to create a baseline for long-term monitoring and surveillance of myrtle rust, and we lead a social science theme to the myrtle rust response. Also, development of a smartphone app – the Myrtle Rust Reporter – was led by Scion. Launched in November, the bilingual app enables citizen scientists to log and monitor Myrtaceae plants.

Scion is a key player in the kauri dieback response via a highly collaborative research programme. In the last six months, technologies have emerged from the consolidation of research conducted since 2013 covering breeding, management and research approaches. This work will be showcased at the upcoming Healthy Trees, Healthy Future conference in August.

Optimising radiata pine stand density could increase the net value of the plantation estate by $1.7 billion. Using productivity indices our scientists developed a model that predicts the optimum final crop stand density to produce structural grade timber. Using this model they were able to develop productivity maps covering the whole country. The model will be released later in 2018 for use by forest owners and managers to plan targeted operations optimising stand density and maximising the value of their crop.

How forests can power our country was well illustrated in the launch of the *New Zealand Biofuels Roadmap* in February by the Minister of Energy and Resources. The roadmap, which includes forestry as a feedstock, is stimulating discussion on domestic large-scale production and use of liquid biofuels as a key first step to make industry and policy makers aware of the options, and their advantages and disadvantages.

Financially 2017-18 has been a strong year. Revenue growth of 9.3 per cent to $56.7 million (budget $54.6 million) provided a net profit after tax of $2.3 million (budget $1.7 million).

During the year we sparked the interest of the public in the potential of forestry to shape a sustainable future through three interactive exhibitions: 'Science in the City', in the Rotorua CBD; at Science New Zealand's event at Te Papa, Wellington, celebrating 25 years of Crown research science; and a three-month 'Science in the Forest' encounter at Rainbow Springs Nature Park in Rotorua open to all the park's international and domestic visitors. All exhibitions included talks by scientists on a broad variety of topics.

Our plans to create a permanent showcase for the public at our Rotorua campus are taking shape. Detailed design of an innovation hub was largely completed during the year, and construction will commence by the end of this calendar year. The innovation hub will be the new entry point to Scion and will include a public café and exhibition area, while also housing Scion staff and tenants. The hub is one part of our extensive campus redevelopment to upgrade our aged buildings and provide modern, flexible facilities to reflect our world-class work. During the year we refurbished an entire office floor, now occupied by several teams, and started work on another floor.

Financially 2017-18 has been a strong year. Revenue growth of 9.3 per cent to $56.7 million (budget $54.6 million) provided a net profit after tax of $2.3 million (budget $1.7 million). On the back of investment into property, plant and equipment totalling $8.6 million, Scion's cash balance reduced from $15.5 million to $13.9 million (budget $7.3 million). This positions Scion well for reinvesting back into the organisation, such as through the construction of the innovation hub and other significant science and building infrastructure planned over the coming five years.

We sincerely thank all our staff for their hard work and commitment to Scion in a year where we faced new challenges and prepared for exciting opportunities. Our customers and partners also receive our thanks for contributing to our successful year.

Special acknowledgements go to former general managers Keri-Anne Tane and Emeritus Professor Alison Stewart for their contributions to Scion and the executive team. We congratulate both on their new leadership roles.

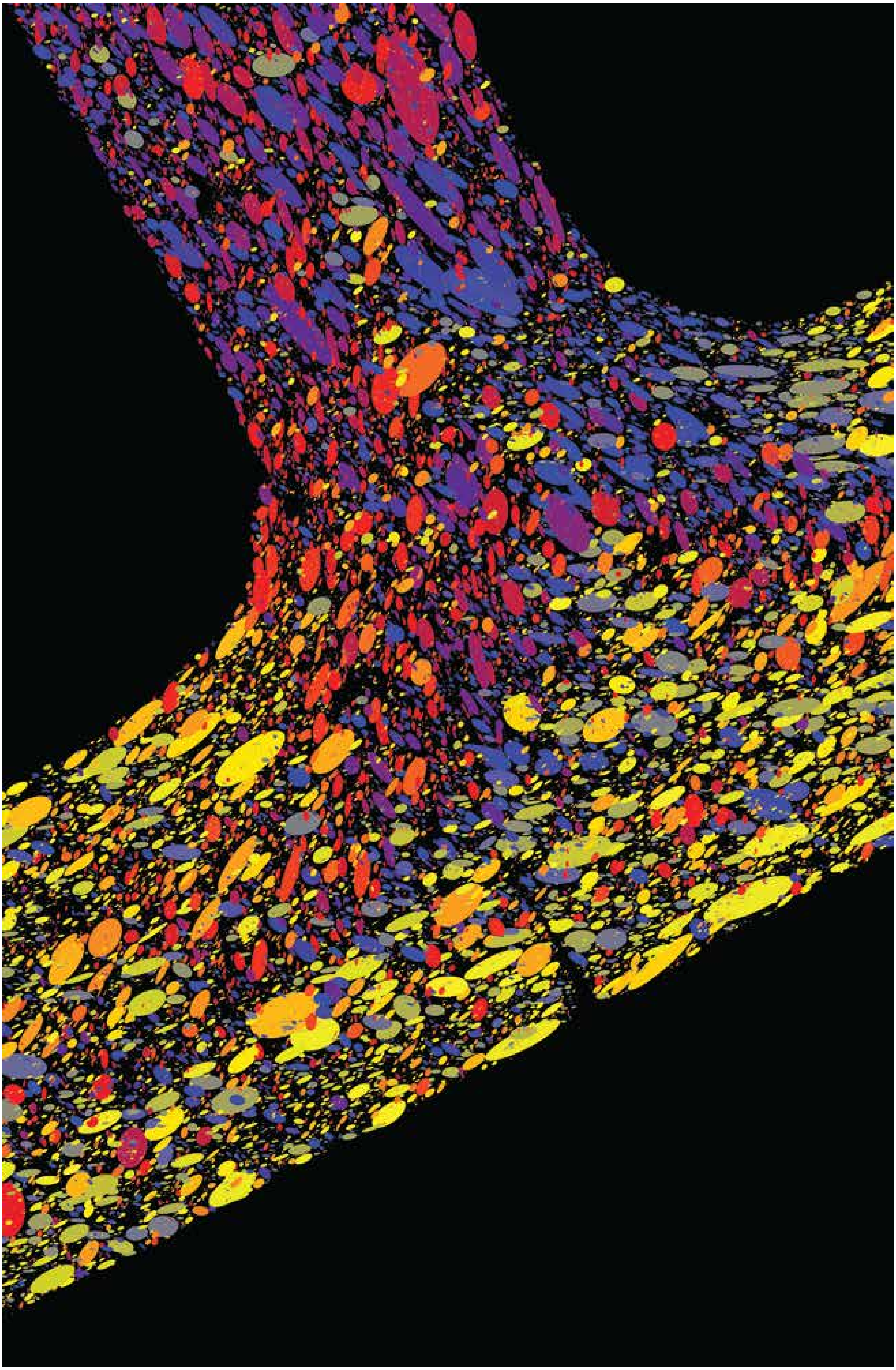
During the year, we welcomed two new Directors, Stana Pezic and Greg Mann, to the Board. We were also delighted to welcome Adriana Botha as General Manager People, Culture and Safety, Arron Judson as General Manager Marketing and Partnerships and Dr Bart Challis as Chief Operating Officer (from 30 July 2018).

For the last nine years, Tony Nowell has served as Scion Chair. We take this opportunity to extend a very sincere thank you for his stellar leadership and direction for Scion in a period of significant change in the country's science system and in the forest industry. We welcome Dr Helen Anderson as our new Chair from 6 August 2018.

The year 2017-18 was one of change, but welcome change that poised Scion and all our partners to deliver on our new strategy. We believe that trees planted as forests can be at the heart of a low-carbon, biobased future New Zealand. We are very excited by Scion's role in seizing and shaping opportunities for forestry and manufactured products from forestry to benefit all New Zealand, regional economies and the Māori economy.

Dr Helen Anderson
Chair

Dr Julian Elder
Chief Executive



Plastic composite reinforced with Scion's engineered wood fibre (licenced and sold as Woodforce).

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

Unleashing the power of forestry to create economic, environmental and social value for New Zealand through these areas of impact:

IA1 Increase value from plantation forested land

IA2 Increase the resilience of forests to biotic and abiotic risks

IA3 Sustain licence to operate and standards across the forest industry value chain

IA4 Diversify forests and local manufacturing to support regional growth

IA5 Increase the use of wood and fibre products in the built environment

IA6 Manufacture and apply biorefinery products from wood fibre, waste and other materials

IA7 Use more forest biomass to improve New Zealand's energy security and reduce emissions

INCREASE VALUE FROM PLANTATION FORESTED LAND

World first radiata pine genome draft completed

At 25 billion base pairs, the radiata pine genome is an enormous puzzle that had never been put together until now. A research team led by Scion scientists completed a world first draft assembly of the radiata pine genome, marking the beginning of a new era of precision forestry for a species critically important to New Zealand.

This is important work that will underpin the future of the New Zealand forest industry.

The process was not without its challenges. The research team led by Dr Emily Telfer since 2015, and including Dr Richard Winkworth from Massey University and Dr Jill Wegrzyn from the University of Connecticut, were initially going to use the genome of the already sequenced loblolly pine from the USA as a reference to help put the radiata pine genome together. But because the radiata genome is so large, it had to be broken down into 100 smaller data sets, which would have extended the computer assembly run time to eight years.

Not to be discouraged, Emily and the Forest Informatics Computer Science team, led by Melissa Evans, set about acquiring one of the most powerful computers in New Zealand. With six terabytes of RAM, 72 2.4Ghz Xeon cores and 250 terabytes of direct attached storage, a *de novo* draft assembly was completed in September 2017.

"The potential benefits of unlocking the radiata pine genome are game changers for forestry. With better understanding of the genome, scientists can begin to develop markers for breeding and gene selection, carry out functional genomics for understanding complex gene interaction and begin comparative evolutionary studies," says Emily. "This technology will also give scientists the ability to respond faster to biosecurity incursions and the environmental challenges of climate change.

"And it's great news for the forestry industry as this means accelerated breeding with genomic selection, and, after further study and annotation of the genome, we can begin to understand how specific genes impact a tree's performance and resilience. This is important work that will underpin the future of the New Zealand forest industry."

The genome assembly began in 2013 led by Dr Phil Wilcox and Lucy Macdonald, with input and guidance from the international conifer genomics community. The assembly also benefits the international scientific and forest growing community. Radiata pine is the backbone of New Zealand's forestry industry. It is also the most widely planted pine in the world and is grown commercially in Australia, Chile, Spain and South Africa.

The research team is now working to reduce the number of pieces of the puzzle by joining long sequences together. A type of sequencing technology called PacBio is being used to run the process. The next steps are to identify genes and regulatory regions that influence the growth and resilience of radiata pine.

Massey University, University of Connecticut

Strategic Science Investment Funding

https://bit.ly/2M6UE6a

New spatial models could add $1.7 billion in net value to forests

Growing unpruned structural grade timber is the silvicultural regime of choice in half of New Zealand's forests. According to research, most of that forest estate's final stocking rate is below the optimal stand density.

Nationwide, there is approximately $1.7 billion in net value to be gained from optimising final stocking. Scion is helping to realise this value by developing a set of simple models that can be used by most of New Zealand's structural grade forest growers.

"If proven to be successful, this will be a substantial step in the direction of precision forestry and the optimisation of the growing capacity of our sites."

Aaron Gunn,
Technical and Resources Manager, Port Blakely

Scion scientists used the productivity indices Site Index (SI) and 300 Index (I_{300}), and rotation length, harvest costs and log value, to develop a model that predicts the optimum final stand density (S_{opt}) for a standard structural grade regime. Using this model they have been able to produce a map of S_{opt} covering the whole country.

The average predicted S_{opt} for growing structural grade logs across New Zealand was found to be over 700 stems per hectare. The current final stand density for structural grade regimes averages around 500 stems per hectare, so there is definite scope for increasing the volume of high-value log products.

Research Leader Dr Michael Watt explains, "This research is applicable to structural regime forest growers all around the country. Already, we've had widespread interest from forestry companies and consultants who want to use the model to spatially predict the optimum final crop stocking within their estates."

One such forest manager is Aaron Gunn, Technical and Resources Manager at Port Blakely. He says, "As a direct result of this research, we are currently evaluating the potential for using high resolution LiDAR derived SI and I_{300} layers to define optimal final crop stockings for structural grade regimes at one forest site. If proven to be successful, this will be a substantial step in the direction of precision forestry and the optimisation of the growing capacity of our sites."

The model will be released later in 2018 by Forest Growers Research. Further work is already underway to extend the modelling approach to optimise final crop stocking for clearwood regimes that have a lower S_{opt} than structural regimes. Work is also in progress that will allow forest managers to compare the value of clearwood and structural grade regimes at the site level.

Ministry of Business, Innovation and Employment and the Forest Growers Levy Trust as part of the Growing Confidence in Forestry's Future research programme

https://bit.ly/2J8vy1h, https://bit.ly/2zoqshX

IA1

Forestry meets machine learning

When it comes to forestry, phenotyping – the act of quantifying and describing a forest's physical, physiological and biochemical properties – presents a special variety of new challenges. Now, thanks to advances in remote sensing technology, accurate assessment of forest characteristics and growing conditions is possible. The next challenge is making the best use of this data.

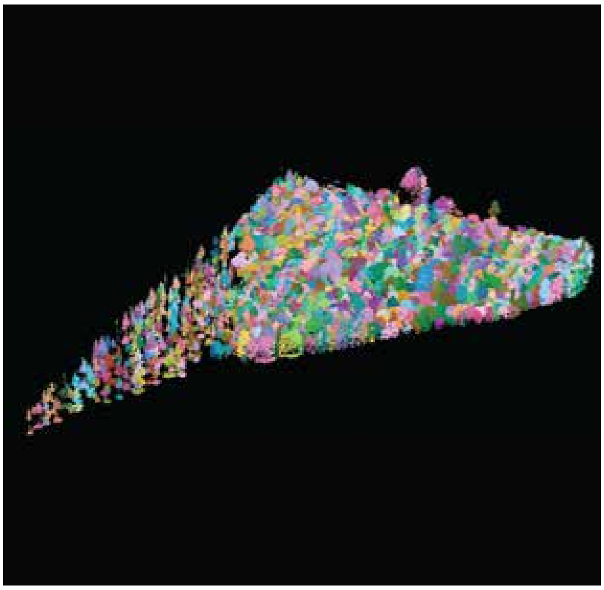
Combining phenotype with genetics and forest management data creates very large, noisy and complex datasets. This year, Scion developed and implemented new methods based on machine learning to analyse these complex datasets and identify trends in growth patterns for different genotypes in different environments.

The significant challenges with forest phenotyping are caused by the size of the forested areas and the length of the forest rotation. This leads to a large amount of data over highly varied landscapes with differing terrain and localised climatic conditions. When you add technical challenges, including collecting data from trees that can be physically large and are often planted in remote locations, the complications mount quickly.

"The development of a successful phenotyping platform will ... enable us to identify greater opportunities to improve the productivity and value of our forest estate."

Paul Adams,
Forest Estate Manager, Rayonier Matariki Forests

Scion's new forest phenotyping platform includes the development of new concepts of describing forest characteristics across large areas. The team has assembled stand management, genetic, soils, terrain, and climatic datasets (supplied by Timberlands) for the purpose of accurately describing the growing conditions experienced by crop trees. In the last year, New Zealand's largest plantation forest has been characterised for forest phenotype and terrain characteristics and the techniques developed during this process have been extended to other large forests. This compilation of information results



in extremely large datasets that can have more than a billion records.

Scion's new machine learning techniques simplify this data, analysing the huge volume and turning it into applicable information that will be invaluable to forest growers, tree breeders, investors and other researchers. As an industry, forest growers will be able to make best use of our existing forests by maximising their profitability and enabling investors to have greater confidence in investing in regional infrastructure. This research could also significantly increase the speed with which new discoveries about tree growth are made and speed up the deployment of new genetic material.

This work begins to open up a world of potential for the forestry industry. Paul Adams, Forest Estate Manager at Rayonier Matariki Forests explains, "The development of a successful phenotyping platform will significantly improve our understanding of the linkages between genotype, environment and silviculture. This will enable us to identify greater opportunities to improve the productivity and value of our forest estate."

The next steps for this research includes expanding the phenotyping concept to describe every tree in a forest.

Timberlands
Ministry of Business, Innovation and Employment and the Forest Growers Levy Trust as part of the Growing Confidence in Forestry's Future research programme

IA2

INCREASE THE RESILIENCE OF FORESTS TO BIOTIC AND ABIOTIC RISKS

Myrtle rust research response

When myrtle rust arrived in New Zealand in 2017 it was all hands on deck for many of the country's research providers. Scion is part of a multi-disciplinary research team focused on learning what we can about myrtle rust in New Zealand, conserving the susceptible species and developing effective ways to manage it.

Achieving a robust research baseline

Over the year since myrtle rust was discovered, a number of new and diverse research programmes have begun.

Scion is leading a new approach to engagement with Māori and interested groups including horticulturalists, conservation groups, government departments, regional councils and science groups. The focus of bringing these groups together is to create a consistent approach to the long-term monitoring and surveillance of myrtle rust. This will ensure that all groups are using the same measures New Zealand wide, creating a reliable baseline that can be compared against overseas data. Work to develop a system and tools to complete this surveillance and monitoring will take place next year.

The team also has begun collecting seed from exotic and native Myrtaceae around New Zealand and is working closely with mana whenua around the country to obtain seed from taonga species in accordance with local tikanga. The germplasm of these plants is retained by mana whenua and either stored on their behalf or returned to them. Future work will see engagement with iwi and seed collection undertaken across the nation.

Some of this seed is being sent to Australia to test against the same strain of myrtle rust as is present in New Zealand because currently testing cannot be done in New Zealand. Seed is also being sent to South Africa and South America where different strains of myrtle rust are present.

"By sending our seed to our southern hemisphere neighbours, we can compare our material against theirs and gauge how susceptible New Zealand's myrtles are," says Research Leader Dr Beccy Ganley.

Back on the home ground, Scion is working with Plant and Food Research and Manaaki Whenua, preparing comprehensive reviews investigating the potential for resistance breeding and control methods suitable for New Zealand conditions.

Scion is also leading a social science theme to the myrtle rust response. By exploring engagement and social licence, we are gaining a new perspective on the response to the initial incursion, and how it might be improved going forward into long-term management or for future incursion responses.

Dr Rebecca Martin, Ministry for Primary Industries Myrtle Rust Research Programme Coordinator, and Senior Adviser, Conservation, says: "Scion's highly collaborative and multi-disciplinary research programme is integral to New Zealand's understanding of both the impacts of myrtle rust over the long-term here, but also how we manage and deal with those impacts. This essential research programme, along with the inter-linked themes led by Plant and Food Research, will help deliver improved management tools and greater understanding for myrtle rust's behaviour and impacts here, and will help to enable all New Zealander's to protect their taonga and iconic myrtle plants, and their associated species and ecosystems."

These projects are an important beginning in what promises to be a hard fought battle for New Zealand's beloved Myrtaceae plants.

Plant and Food Research, Manaaki Whenua, Will Allen Associates, Biosecurity Research Ltd, AgResearch, Massey University, AsureQuality

Ministry for Primary Industries, Ministry of Business, Innovation and Employment

IA2

The Myrtle Rust Reporter app

The Myrtle Rust Reporter (MRR) app lets every New Zealander help officials monitor how myrtle rust is affecting Myrtaceae across New Zealand.

"The app gives us the potential to create a biosecurity surveillance army that includes a diverse audience – and not least because the app is bilingual and available in te reo Māori."

Dr Steve Pawson,
Research Leader, Forest Protection, Scion

The smartphone app was developed to help detect the spread of myrtle rust and went live in November 2017. Dr Steve Pawson, who led the development of this app, says, "This app allows users to record a dozen potential host plants in their community and monitor these specific plants. Users are encouraged to check these plants regularly and look for tell-tale yellow spores on new growth."

The MRR app goes one step further than Scion's existing citizen science biosecurity surveillance app (NZ Eucalyptus Pests). Instead of logging a myrtle rust infection and that being the end of it, the MRR app encourages citizen scientists to select uninfected plants, log them in the app and return to them over time, allowing users to continue to monitor plant health and report symptoms of myrtle rust if they see them. This point of difference will help biosecurity officials to gain a better understanding of how myrtle rust will affect different species in different climates and conditions.

"The app gives us the potential to create a biosecurity surveillance army that includes a diverse audience – and not least because the app is bilingual and available in te reo Māori," says Steve.

On the first day the app was launched, an app user recorded a myrtle rust infection in a new area, unknown to biosecurity officials at the time. Since then, there have been another 38 confirmed myrtle rust observations. It has been installed over 800 times, with over 400 observations from ~90 reporters.

Available for Apple and Android devices: scionresearch.com/myrtlerust

Te Tira Whakamātaki (Māori Biosecurity Network)

Northland Regional Council, Envirolink, Biological Heritage National Science Challenge, Ministry for Primary Industries

New national forest biosecurity surveillance system

Biosecurity officials report an average of three new pests and diseases establish in New Zealand every year. Understanding how exotic species make their way here is the best chance we have to detect and eradicate them before they can become permanently established. New Zealand's new national Forest Biosecurity Surveillance (FBS) system has been designed by identifying high biosecurity risk areas for the introduction of overseas tree pests and pathogens.

Work to overhaul the existing forest health surveillance system and develop the new national forest biosecurity surveillance system began in 2015.

Using a new model, a team from Bayesian Intelligence and Scion has addressed the risk of biosecurity incursion across seven import pathways (sea vessels, used vehicles, used machinery, sea containers, wood packaging, wooden furniture, live plants), and the movement of people.

The new model estimates the relative probability of introduction of a selection of potential invaders at main entry points such as sea and airports, and all other locations in New Zealand. These 'introduction risk' probability maps are in turn used in an optimisation model, co-developed by AgResearch and Scion scientists, which works out the best allocation of surveillance effort. For any defined budget, the optimisation process defines which types of survey should be performed within each area, and what resources should be allocated to maximise detection efficiency.

Insect species transported as eggs or pupae, which can remain undetected and survive during long distance transportation, represent significant biosecurity threats. For example, the gypsy moth family has members of high-concern to forestry. They are not yet established in New Zealand, but the moth egg masses are regularly intercepted at our borders.

The model estimated the risk of introducing this pest via each of these pathways (cars, containers, sea vessels), taking into account the volumes and spatial redistribution of items transported, as well as their estimated rates of infestations. Overall, it estimated that the probability of egg hatching, and the escape of caterpillars, is principally at ports, followed by critical locations in the container pathway (such as container cleaning sites) and the imported cars pathway (car registration sites and car yards).

This new pathways-based approach to biosecurity risk evaluation and surveillance is a departure from the traditional view that tree health surveillance should be conducted in the forest. The new model recommends that 90 per cent of surveillance efforts should be focused on urban and peri-urban areas, however the data that went into the model did not cover all pathways and some surveillance effort will also go into monitoring the forest estate. Following these recommendations, the team has carried out a feasibility trial and completed a five year plan for rolling out surveys on a fully operational nationwide scale.

PHOTO: PORT OF TAURANGA

David Cormack, Chair of the Forest Owners Association Forest Biosecurity Committee, says, "The forest industry has been surveying its estate under the Forest Health Surveillance system since the 1950s to detect new pests and pathogens, monitor forest health and provide trade assurances. The Forest Biosecurity Surveillance system is specifically designed to detect harmful pests and pathogens early enough so that eradication is still an option, rather than long-term management.

"We have confidence in the science and look forward to rolling out the FBS over the next few years."

CEBRA, Bayesian Intelligence, AgResearch, Ministry for Primary Industries, Forest Owners Association

Ministry for Primary Industries, Forest Growers Levy Trust, Strategic Science Investment Funding, Better Border Biosecurity

https://bit.ly/2uzXmXe

SUSTAIN LICENCE TO OPERATE AND STANDARDS ACROSS THE FOREST INDUSTRY VALUE CHAIN

Is that biodegradable?

To really consider the true environmental impact of products and materials we need to know how they are made, and what they are made of. Equally important is how products and materials are disposed of and if they end up in the environment, how they break down. To help evaluate product performance at the end-of-life, Scion has designed and built a unique-to-New Zealand biodegradation facility for measuring the aerobic biodegradation of materials such as plastics, paper and wood under a range of standardised environments.

Given the international emphasis on sustainability and the rise of biodegradation claims, these tests will become increasingly important to assure environmentally conscious companies and consumers that products are indeed able to biodegrade as claimed. Scion's biodegradation facility has recently been upgraded to provide more accurate data, verified according to international compostability standards.

Lou Sherman, Technical and Service Leader, says, "When it comes to compostability claims it is important that materials have been validated to biodegrade in a composting environment. International standards have been developed for both home and industrial composting conditions. Our facility is able to follow these standards by measuring the carbon dioxide respired by microbes as they consume the test material."

"I'm really excited to be able to work with Scion on their testing regime to fit in with international standards so that I can get my compliance completely independently verified."

Owen Embling,
Managing Director, Convex Innovative Packaging

A number of different standards are tested. Scion's facility can ensure there are no excessive heavy metals (lead, mercury and arsenic) left in the environment. It checks the disintegration by looking at the size of the decomposed particles, ensuring they properly breakdown, rather than just break into smaller pieces. It also can measure for

Dr Gerty Gielen (left) and Lou Sherman examining the samples degrading in the new biodegradation unit.

ecotoxic residues from the broken down materials that could affect the health of the microbes in the environment.

In addition to composting, the facility can test how a range of materials might degrade in different environments such as soil or sea water.

Lou says, "Having this facility in New Zealand will give kiwi companies access to knowledge and equipment around compostability and biodegradability enabling them to compete in and ensure access to an international market which is demanding reliable data to back up sustainability claims".

That is an experience that Owen Embling from Convex Innovative Packaging can relate to. He says, "Something that is really important to us and our customers, is that we can't be seen to be making greenwash claims. If we state that we have a compostable pack, we need to be sure that it is actually compostable.

"I'm really excited to be able to work with Scion on their testing regime to fit in with international standards so that I can get my compliance completely independently verified."

The biodegradation testing facility was tailor-made to test the biodegradabiliy of a range of materials in different environments. It has capacity to test up to 17 different samples (in triplicate) under controlled temperature, moisture and air-flow conditions.

Strategic Science Investment Funding

IA4 DIVERSIFY FORESTS AND LOCAL MANUFACTURING TO SUPPORT REGIONAL GROWTH

Softwood trees with hardwood properties

A current research project aims to modify radiata pine lignin to make it more like that of hardwood lignin to improve processing efficiency.

The research contributes to our ambitions to grow New Zealand's bioeconomy, and one way is to make bioproduct processing easier and more efficient than the existing alternatives. Using trees for pulp, paper and biorefining is a key example. To make use of wood fibres, they need to be separated from the lignin that glues them together. The softwood trees that grow so well in our planted forests contain a type of condensed lignin that is much more difficult to separate than the syringyl (S)-rich lignin found in hardwood trees.

Lignin is a complex polymer that provides strength and structure in trees. In softwoods like radiata pine, the lignin contains mostly guaiacyl (G) units. Lignin made up of G units is more condensed and difficult to process. This, together with their high lignin content, makes softwoods more difficult and energy demanding when producing high yields of refined biomass for pulping and biorefinery use.

By contrast, hardwoods, which contain syringyl (S) units, are easier, cheaper and cleaner to process while retaining their desirable wood fibre qualities.

Scion produced a small crop of young radiata trees modified to contain S-lignin, based on an initial proof of concept that showed softwood cells could produce the novel lignin.

These trees formed a field trial that allowed the S-lignin radiata to grow in a forestry setting where Scion's team could collect data and carefully monitor the trees' growth and performance.

Strategic Science Investment Funding

https://bit.ly/2LF8xoA

Molecular biologist Lorelle Phillips monitors a crop of seedlings in Scion's containment facility.

IA4

From log to laminated veneer lumber

The use of laminated veneer lumber (LVL) is becoming more popular with designers and architects. Because LVL is created by layering different veneers atop each other, there is a wide variety of process combinations to choose from, but with each combination the structural qualities of the overall LVL varies. It is crucial for manufacturers to know if their available wood will produce LVL that satisfies their customer's needs. Now, with a new software tool developed by Scion, LVL manufacturers can gauge whether their LVL will likely meet a customer's performance requirements, without the need to conduct expensive mill tests.

"JNL can see the benefit of this tool to model potential structural finished product output yields..."

Brendan Smith,
Technical Services – Product Manager, JNL Group

Dr Wayne Schou, lead developer of the LVL stiffness computer model, holding a LVL sample made with radiata pine.

One of the most important design properties of LVL is bending stiffness. To test the full range of LVL properties, manufacturers have had to process logs and create an LVL sample to check its performance. However, this approach can be expensive and is not always practical in a production setting when trying to assess a wide range of veneers and LVL process options.

Scion was engaged via the Specialty Wood Products Partnership to create a computer model that can determine the bending stiffness range from individual veneers and use that information to calculate the overall LVL section stiffness. It is used as a guide to assist decision making on the likelihood that a forest/log/veneer could meet customer performance requirements and determine what the LVL manufacturing process implications might be.

The computer decision model uses information uploaded about the individual veneer stiffness properties or log pith to bark stiffness profiles and the customer performance/purchase requirements. The user can then explore different LVL process options, and the manufacturer can efficiently use the wood available to them while meeting their customer's needs.

Brendan Smith, Technical Services – Product Manager for the JNL Group, says, "JNL can see the benefit of this tool to model potential structural finished product output yields, and in being able to determine the required input product mix from two or more distinct log fibre resources. This would enable an increased surety of supply of the required structural grade for the manufacturer's market, with less potential for arising non-targeted lower grades."

This software model will save time and money by eliminating unsuitable veneers early in the process. If the model shows that the tested LVL would perform within requirements, then detailed mill studies would be carried out.

As with any model, it is only as good as the input data. The next step to develop the model is to generate and upload more stiffness data for a range of forest/log/veneers.

Specialty Wood Products Partnership

IA5

INCREASE THE USE OF WOOD AND FIBRE PRODUCTS IN THE BUILT ENVIRONMENT

Colourful timber

Staining or painting timber is the traditional way to add colour to wooden products, but that colour is only surface deep. Any scratching or resurfacing can remove the colourful layer and affect the aesthetic of the wood. The full thickness colour technology developed by Scion fixes colourful dye throughout timber in a range of bright colours.

The full thickness colour technology colours every fibre in a piece of timber ... when coupled with wood hardening, the improvements could increase the value of New Zealand's soft pine-based wood product industry.

The full thickness colour technology colours every fibre in a piece of timber. At present there is nothing like this product on the market and, when coupled with wood hardening, the improvements could increase the value of New Zealand's soft pine-based wood product industry. This would also increase onshore processing and spread benefits across regional New Zealand through job creation.

Calling the technology 'full thickness colour' is not something the research team take for granted. Dr Elizabeth Dunningham explains the team has been working with a variety of different dyes over six years to achieve what is now a consistent, bright and non-leaching colour suitable for anything from furniture to flooring.

"Initially we focused on natural dyes that had softer hues but they wouldn't fix in the wood. We turned to a range of commercially available food dyes, then fabric dyes, and over the first three years, looked at four types/classes of colourants and 36 individual colouring agents in all."

The research team is now looking at combining the colour technology with wood hardening technology. The added properties would make New Zealand's soft radiata pine more competitive in a wider variety of interior applications especially uses that require higher resilience such as skirting boards and outdoor furniture.

Market research results showed that the unique look of the full colour thickness wood was interesting to all stakeholders interviewed, especially those from international markets. The biggest advantage of the full colour thickness product was the unique 'look'. Described as naturally translucent and grainy, the guaranteed consistency of this look was a positive feature, as was the ability to pre-colour wood that could create potential for increased efficiency in the manufacturing process.

$ Strategic Science Investment Funding

MANUFACTURE AND APPLY BIOREFINERY PRODUCTS FROM WOOD FIBRE, WASTE AND OTHER MATERIALS

Boxes made to last

“New Zealand’s economy relies on exporting products worth billions of dollars to distant markets, and packaging plays a huge role in maintaining the value of these products,” says Technical and Service Leader Lou Sherman.

“Two per cent of all packaging fails. For large companies, transporting millions of products to local and international markets, failure can be costly. We’re helping to prevent box failure by creating a new testing procedure to ensure boxes can withstand real life conditions.”

Some products are stored in boxes for over a year before they reach the consumer. In that time they may be stored on a pallet, be subjected to a constant load and exposed to different ranges of humidity. These environmental changes can increase the likelihood of box failure.

The standard test for corrugated boxes is called a box compression test (BCT). It measures the load under which the box will fail when crushed at a constant rate. This approach has been used for many years to ensure box performance compliance even after the material or box design has been changed. However, it does not accurately mimic the conditions that boxes in real supply chains are exposed to. Typically a box is subjected to a constant load, the box height changes over time, which is known as ‘creep’, and can eventually fail. Cyclic humidity, such as that experienced in cool stores, is known to accelerate creep, making humidity an essential part of an improved and more realistic box testing process.

Scion has one of the few facilities in the world that can measure box creep. Our ‘WHITE’ room (WHITE stands for weight, humidity, interval, temperature and experiment) simulates supply chain conditions by applying a constant load to the boxes while the humidity is cycled. The packaging is then monitored over time and compared to different box specifications.

“Because Scion’s box testing facilities are able to evaluate corrugated box designs before they are put into service, many millions of dollars can be saved ...”

Russell Allan,
Managing Director, Aurelia Group Consulting

Working alongside industry, Scion ran experiments on two types of boxes, which were identical except for their different corrugated mediums (the inner paper in the corrugated flute). These boxes were tested both for BCT and for creep. The BCT method indicated that both types of boxes performed the same. However, creep testing gave very different results. This discovery could reshape how we test corrugated box performance and, thanks to Scion’s unique testing facility, New Zealand-based companies have an advantage in being able to conduct creep testing locally.

Russell Allan, Managing Director of paper and forest product company, Aurelia Group Consulting, says, “The survival performance of corrugated boxes in the supply chain remains one of the most challenging and important areas of packaging research and testing. Because Scion’s box testing facilities are able to evaluate corrugated box designs before they are put into service, many millions of dollars can be saved due to lower packaging cost and increased product yield to market. Scion’s facility also allows companies that need to test their packaging in simulated field applications, to do that without having to invest in expensive equipment or lengthy trials.”

Strategic Science Investment Funding

https://bit.ly/2OSa6ld

To market with new wood and bioplastic 3D printer filament

New Zealand is in a strong position to make 3D printing of biopolymers and composites one of the success stories of our emerging bioeconomy. An abundant variety of renewable feedstocks could be converted into biobased filaments and ultimately renewable high-value products. Imagin Plastics, a 3D printer filament manufacturer, is leading by example with new 3D printer filament that contains a Scion-made wood and bioplastic compound. The filament is 10 per cent by weight New Zealand pine and is 100 per cent biobased and compostable.

The advantages of 3D printing and the strengths of New Zealand's economy are a combination for success. Geographically isolated, New Zealand relies on importing and exporting goods. A thriving 3D printing industry would enable innovative and localised production that could function within our existing manufacturing network. This new industry could also bring the manufacture of some imports onshore and create new opportunities for manufacturing businesses to export higher value products.

Project leader Dr Marie Joo Le Guen observes the Imagin Plastics wood-fill filament as the 3D printer prints a sample piece.

For Imagin Plastics, the product will serve the growing share of their customers interested in sustainability and biobased plastics, in addition to being a truly kiwi-made product that was designed, developed and manufactured in New Zealand.

"Being able to work closely with Scion to see a research project over the line and make it to market is an asset to 3D printing in New Zealand."

Ben Blakley,
National Sales and Technical Manager, Imagin Plastics

Imagin Plastics National Sales and Technical Manager Ben Blakley says, "As FDM (fused deposition modelling) 3D printing grows across all sectors we want to have high-quality options for our clients, and biobased materials is a good one. Being able to work closely with Scion to see a research project over the line and make it to market is an asset to 3D printing in New Zealand."

Dr Marie Joo Le Guen, who led the project says, "This product is a great example of research and industry collaboration, and how it could strengthen New Zealand plastic manufacturing industry through innovation".

The wood within the plastic is a waste stream from the wood milling industry. It is a sustainable resource that would otherwise be discarded or burnt.

A 100 kg supply of the Scion-made compound has been prepared for Imagin Plastics to manufacture the filament, which is now for sale on their website imaginplastics.co.nz

The product was officially launched on 1 May in Auckland at EMEX 2018. EMEX is New Zealand's largest technology trade show for the manufacturing, engineering, machinery and electronics industries.

https://bit.ly/2Okuo5H

IA7

USE MORE FOREST BIOMASS TO IMPROVE NEW ZEALAND'S ENERGY SECURITY AND REDUCE EMISSIONS

Moving to a biofuelled New Zealand

There are a lot of questions about how we might power New Zealand with biofuels. How do we encourage biofuel use? Which biofuels? Where will we grow the feedstock? But despite the lack of clarity and risks around establishing a brand new, large and complex value chain, we know that powering the country with biofuels is within our reach.

The *New Zealand Biofuels Roadmap*, a new study by Scion's bioenergy specialists, was released in February 2018. The aim of the roadmap was to present options that would stimulate discussion on biofuels, as a first step to make industry, policy makers and the general public aware of the options, and their advantages and disadvantages.

The roadmap team chose the Bioenergy Value Chain Model (BVCM) to visualise alternative biofuelled futures. The model was developed by the Energy Technologies Institute in the United Kingdom and modified for use in New Zealand. It considers the entire value chain, from where and when to grow the different feedstocks, which processing technologies, where to site them and which fuels to produce, then balances these variables to find the lowest cost solutions for different scenarios.

They modelled over 50 different scenarios to produce some very interesting findings. In one future scenario, the BVCM model used any combination of feedstocks, technologies and final fuel mix to calculate the lowest cost to achieve 30 per cent substitution of liquid fuels. In this example, greenhouse gas emissions would be reduced by 5 million tonnes per year (compared with 2015 levels), which would be equivalent to removing half the cars off the road and, as a country, we would be more energy independent and be able to cut our oil imports by 30 per cent.

The regions where biofuel feedstocks are grown and processed would also prosper. When limited to growing feedstocks on non-arable land only, the forests in the Gisborne region would need to increase in size by 50 per cent and the area would be home to four pyrolysis and four upgrading plants requiring a nearly $1 billion in capital and creating 1000 jobs. Northland and the Central North Island are also important areas for biomass production and would benefit from regional growth in many of the scenarios run by the model.

The broad conclusion of the study is that biofuels are part of the solution for decarbonising transport in New Zealand, particularly for the marine, aviation and heavy transport sectors, which are hard to electrify. A biofuelled New Zealand can also create a wide variety of benefits for the climate, our economy and for regional New Zealand. The country would import less fossil oil, making New Zealand more energy independent. And our goods and services would continue to to access international markets as 'green pressure' (the demand for reduced carbon footprints) grows.

The Biofuels Roadmap is a considered and thorough piece of work that shows why and how New Zealand can transition to a low-carbon transport fuel future says Z Energy Chief Executive Mike Bennetts.

Z Energy CEO Mike Bennetts (left) with Energy and Resources Minister Hon. Dr Megan Woods and Scion's Dr Paul Bennett at the roadmap launch.

"All the pieces required for our country to transition aren't crystal clear, but this study shows we have enough of a biofuels four-lane highway for us to start driving down," he says.

"We may have to swap lanes somewhere, but to get to that level of precision now is impractical. We should use this roadmap as a call to action. How many more reports do we need to bring a closed-loop domestic biofuel production system into being that doesn't adversely affect food supply chains?

Nine companies; six associations/industry bodies, four government departments and four research organisations.

Strategic Science Investment Funding

https://bit.ly/2mJKIBt, https://bit.ly/2vPLTTM, https://bit.ly/2F208va

Drop-in biofuels offer compelling benefits for New Zealand.

CO-INNOVATION AND PARTNERING WITH MĀORI

Ko te manu e kai i te miro nōna te ngahere. Ko te manu kai i te mātauranga, nōna te ao.

The bird that eats the miro berry owns the forest, the bird that feasts on knowledge owns the world.

"The Ministry of Business, Innovation and Employment estimates Māori enterprise is worth nearly $40 billion, and growing faster than the economy as a whole"[3]. Forestry is increasingly part of that burgeoning economy. Also, Māori are part of the revitalisation of land and culture with an increasing focus on tree planting as part of restoring the land and improving the resilience of regional communities.

The Government's increased focus on the regions and trees has had a positive and powerful impact on activities within many partnerships between Māori entities and Scion.

Although many Māori entities are embedded in major programmes being managed by Scion, some partnerships have a unique character and could be pioneering future development of forestry. Examples include forest diversification, indigenous forestry and forest products, land use and a greater focus on community resilience as summarised below.

Stephen Karepe checking the miro seedlings growing at Minginui Nursery.

A step change in indigenous tree propagation

Last year, we reported on the partnership between Ngāti Whare Holdings Ltd and Scion. When Ngāti Whare approached Scion for expertise to design and build a modern nursery in the village of Minginui Te Whaiti they came with a two-fold vision: to produce indigenous trees to replant 640 hectares in the Whirinaki Valley and to initiate employment in the village.

After a 45-year struggle for Minginui to survive after the New Zealand Forestry Service closed, the iwi's nursery is the new heart of the community and contributes a great deal to Ngāti Whare's present sense of well-being. Recently the Government announced an investment of $5.8 million to underpin the nursery and all it represents for this region, and to support the Government's goal to plant a billion trees in 10 years, ensuring that many of those trees are indigenous.

The nursery is also responding to the enormous interest in indigenous trees by piloting an approach for mass propagation of indigenous trees. Mere George, General Manager of Ngāti Whare Holdings, says, "What's really exciting

[3] Stuff May 21 2018 https://www.stuff.co.nz/business/industries/104060829/the-maori-economy-continues-to-grow

about the technology is that we might be able to facilitate native forestry. It's as though the downfall for the community was the cutting of native trees and logging of native timber, but now, the thing that might revive the village is going to be the nursery and effectively replanting the areas that were logged way back then. It has come full circle."

New sustainable industries based on indigenous trees

The role of indigenous trees in building resilient communities is also being advanced with the work in Te Tai Tokerau where on-farm grown tōtara is being evaluated for its commercial potential in high-value applications with the vision of a sustainable new industry in Northland. This is a partnership across many organisations: Scion, Te Tai Tokerau Māori Forestry Collective, Tāne's Tree Trust, Northland Inc., Ministry for Primary Industries and the Ministry of Business, Innovation and Employment (Provincial Development Unit).

Diversifying forests

Rotomā No 1 Incorporation (Rotomā) is a Māori owned entity with substantial investment in pine forests on the shores of Lake Rotomā. The entity is exploring new operating approaches ranging from eco-tourism to forest diversification. An important part of developing this vision is the secondment of Scion scientist Lania Holt into the company and evaluating the option to grow the Chilean (gevuina) hazel and European hazel as part of a diversified forest. Rotomā Chair, Nelson Meha says, "A key attraction of this project is the ability for my committee to explore alternative options to pine, whether it be gevuina or eco-tourism. We need to understand what else is out there and what the potential social, environmental and financial benefits could look like".

Te Urunga o Kea – Te Arawa Climate Change Strategy

Climate change research and strategies gained prominence with the release of the New Zealand Interim Working Party Report (December 2017) and the call for submissions from our government in response to the Paris Climate Agreement global negotiations. A notable factor in the Interim Working Party Report was the absence of an overarching New Zealand strategy and iwi participation. The latter is being addressed by the Iwi Leaders Group who acknowledge that Māori are at an early stage in developing adaptation plans and strategies for climate change.

In parallel, Te Arawa have formed Te Arawa Climate Change Working Group and, in association with Scion, are developing a climate change strategy followed by a research strategy and a prioritised plan.

Scion Social Scientist Marie McCarthy is a member of the working group. She says, "The work connects community to science, to government directions and across global social typologies in an applied conceptual research framework developed from a Te Arawa cultural values framework. There is a need to be at the interface of RS&T as a planned and strategised iwi contributing to the primary objectives of Te Arawa Lakes Trust where the quality of the water is such 'that you can see the footsteps of the kōura (fresh water crayfish)', where the land is maximised and the people are up-skilled and mobilised".

Taking the latest technologies into the forest

Supported by the Vision Mātauranga Capability Fund and working through Ngāti Tūwharetoa scientist Ben Aves, the productivity of clonal radiata pine stock and non-clonal stock in the Lake Taupō and Lake Rotoaira forests was tested. The forest trusts are committed to employing the latest capability and technologies in forest management. Ground-based tree growth analysis, augmented with an airborne laser scanning survey of forest trees, was used to derive a 3D data-point cloud using light detection and ranging technology (LiDAR). From the combined analyses of field and LiDAR data, results confirmed that clonal stock perform better than non-clonal stock within the trusts' forests in every aspect.

Te Hiku Economic Development Platform

Scion is involved in an economic development project for Te Hiku lands, which is a research project in the Mauri Whenua Ora programme within Our Land and Water National Science Challenge.

The research partners are three of the five Te Hiku iwi that settled a Treaty claim in 2014 including Ngai Takoto, Te Rarawa and Te Aupōuri. Te Hiku iwi have had significant land assets returned to them under settlement, including 20,000 hectares of pine forests and several farms.

A framework is being developed to enable these organisations in their long-term investment planning. The main development issues the iwi are trying to solve are (1) improving the resilience of forestry and agricultural assets by looking at diversifying into higher value products and (2) empowering the iwi with ownership and control of down-stream processing, distribution and market channels.

A key research issue that emerged from these discussions is the inadequacy of current research and industry models to analyse multiple land blocks with multiple land uses for owners with multiple (and often conflicting) objectives. Although Te Hiku Platform is based on the forestry sector, the intention is it can be adapted to other sectors.

Bartons Gully, Waiapu catchment, East Coast taken by Tui Aroha Warmenhoven, Ngāti Porou.

Adaptive governance approaches

The Ministry of Business, Innovation and Employment-funded programme Weaving the Korowai, led by Scion, has been using innovative approaches to improve outcomes for Māori specifically in restoration of degraded landscapes and in local economic development. This is using a co-ordinated agency approach aligned to the aspirations of Ngāti Porou. Based on the Waiapu Catchment on the North Island's East Coast, this research has used 'serious game' approaches and social network analysis to identify shared pathways to lead to best outcomes for all parties. For example, building partnerships that are based on a clear understanding of the context in which decisions are made and the livelihoods of local people.

COLLABORATING TO MAKE THE WORLD A BETTER PLACE

Around the world

Developing and growing the circular bioeconomy was a common theme running through the international conferences, research collaborations and science exchanges that Scion participated in over the past year. Being active at an international level allows us to contribute to world-leading thinking and research, and to bring the best of new science and technology to New Zealand.

Plenary session co-chairs Dr Elspeth MacRae (Scion) and Waldermar Kütt (European Commission) at the 2018 Global Bioeconomy Summit.

Manufacturing and Bioproducts General Manager Dr Elspeth MacRae co-chaired a plenary session on international collaboration in bioeconomy innovation agendas at the Global Bioeconomy Summit held in Berlin. Also Elspeth was contracted to review the Helmholtz Bioeconomy programme of work as part of the four-yearly review of all research at Helmholtz, the largest funder of research in Germany. The review included leading edge, global research on industrial biotechnology, plant phenotyping and biomass feedstock research.

The year saw Scion's relationships with international partners grow. Formal collaboration agreements and specific joint research projects are in place with many, and a number of partners were included as collaborators in 2017-18 funding proposals.

As part of our ongoing partnership with the VTT Technical Research Centre of Finland, which started in 2016, Executive Vice President Dr Anne-Christine Ritschkoff and Vice President Dr Tiina Nakari-Setälä visited to strengthen cooperation and promote our common vision for the bioeconomy and circular economy. One topic of discussion was our first joint project – adapting VTT's hemicellulose technology to use different polymers from New Zealand-grown radiata pine to make new packaging products.

Scion's work with VITO Flemish Institute for Technological Research in Belgium has continued to expand over the last two years. Taking advantage of VITO's experience in sustainability in the built environment, Scion Sustainable Architect Andrea Stocchero visited VITO at the EnergyVille center in Belgium. In return, VITO Sustainable Built Environment Researcher Sofie de Regel was seconded to Scion for four weeks. During that time, Sofie and Andrea met with stakeholders in the New Zealand building industry value chain. The conversations and insights are being collated to summarise New Zealand's best practice, barriers and gaps to define how Scion and VITO can support a wider sustainability uptake within the built environment.

Scion and VITO are also delving further into the use of enzymes to produce biopolymers and other high value products from wood residue. With Scion's strengths in analytical chemistry and polymer characterisation and VITO's in ester production using commercial enzymes, the two organisations are a good match. VITO Biological Engineer Dr Karolien Vanbroekhoven spent a month at Scion working with industrial biotechnology Research Leader Dr Christophe Collet. While in Rotorua, she worked on defining a new research project building on the research of the first joint sponsored post-doctoral fellow Elias Feghali.

"Our continuing work with VITO on lignin technologies has been particularly satisfying," said Elspeth. "The success of our joint post-doctoral fellow has prompted VITO to propose investing more and for both parties to fully fund an exchanging postdoc for further work."

"Scion's research fits on multiple levels including applying circular economy thinking in construction and the built environment, and our clean technology strategies."

New Zealand and Germany celebrated 40 years of science collaborations in November 2017 at an MBIE-hosted event. Scion was one of six featured organisations. Science Leaders Drs Paul Bennet and Florian Graichen met the German president Frank-Walter Steinmeier and discussed bioenergy and the potential for bark biorefineries.

Bark biorefineries were also the subject of a visit to Fraunhofer IGB in Stuttgart. Florian and Research Leader Dr Warren Grigsby met Fraunhofer staff to progress joint research including scaling-up the technology, raw material logistics and options to widen the scope of the project.

Manufacturing and Bioproducts Science Leader Dr Florian Graichen presented Scion's packaging work at the Innovation and Sustainability Conference 2017: The Circular Economy for Consumer Goods, in Korea. Florian reported he was able to spend time discussing disruptive thinking and design, biomaterials and sustainable brands, all very relevant topics for Scion.

Florian also attended the Circular Economy sessions at G-STIC – Global Sustainable Technology and Innovation Conference in Brussels. The conference, hosted by VITO and international partners, had a focus on accelerating the development, dissemination and deployment of technological innovations as part of achieving the United Nation's Sustainable Development Goals (UNSDGs).

Florian reports it was a conference with a difference, with discussions on a policy and political level, rather than about science. "Scion's research fits on multiple levels including applying circular economy thinking in construction and the built environment, and our clean technology strategies," said Florian. "Single use plastics were also highlighted as a huge issue."

Sustainable wood for a sustainable world was the topic of a global meeting held at the UN's Food and Agriculture Organisation (FOA) headquarters in Rome. Sustainable Architect Andrea Stocchero presented on and contributed to discussion on how societies benefit from sustainable wood value chains and the challenges that prevent their contribution to sustainable development. All UNSDGs were identified as relevant in some form for forests and forest products.

Andrea was also invited to present at a follow up meeting in Rome, February 2018. Entitled "Halting Deforestation and Increasing Forest Areas", this initiative was led by the Collaborative Partnership on Forests with other international organisations including the FAO. Andrea presented on how construction and the tree-based value chains address the UNSDGs.

The New Zealand-China Food Protection Network (NZCFPN) has been very active. Technical and Service Leader Lou Sherman is on the leadership team. Lou, with the University of Otago, organised a workshop in China last July with topics that included food contact safety, antimicrobial packaging, sustainable materials and smart packaging. Another workshop was held at Scion in February to help local exporters understand changes to Chinese food contact regulations. Professor Hu from Jinan University was the guest speaker. The next NZCFPN engagement coincides with Scion's biannual packaging convention in August. Three Chinese experts have been invited to talk on topics including antimicrobial packaging, food contact testing and fibre-based packaging.

Scion's Andrea Stocchero (second left) at the Sustainable Wood for a Sustainable World meeting in Rome, October 2017.

Closer to home

Protecting our environment, whether from pests or pollution, describes much of Scion's collaborative work with other Crown research institutes during 2017-18.

The discovery of myrtle rust prompted a multi-pronged research response, with Scion working with AgResearch, Plant and Food Research, Manaaki Whenua, NIWA and others. A framework for strategic science activities that took into account, short, medium and long term research was developed and the work is underway.

Scion has also been working with AgResearch and Lincoln University's Agribusiness and Economics Research Unit to work out how much weeds cost the country's pastoral, arable and forestry sectors. This is thought to be $1.658 billion a year.

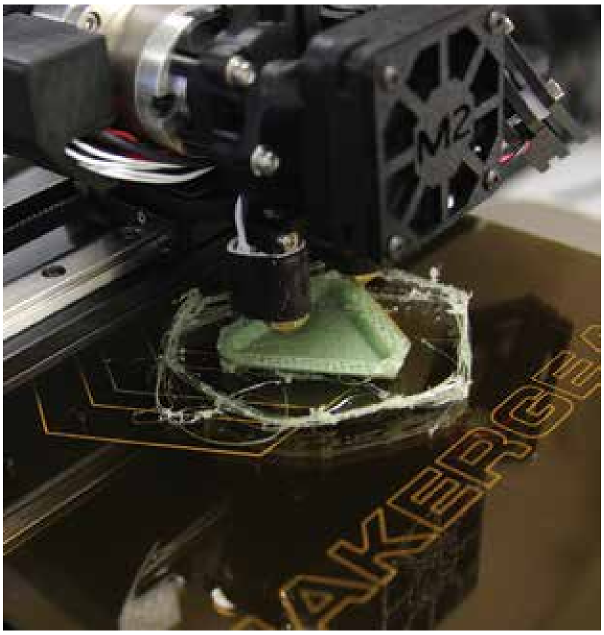
How microfibres degrade in water is the subject of new research with AgResearch. Microfibres produced from washing clothes, for example, end up in the sea and marine life. Scion is using its specialist biodegradation unit to compare how wool, a natural protein-based fibre, breaks down in sea water, compared to synthetic fibres such as polyester.

Scion is working with a number of partners on the Healthy Trees, Healthy Future (HTHF) research programme, which is dedicated to combatting kauri dieback and related diseases. These include Manaaki Whenua, Plant and Food Research, Massey University, University of Auckland, Auckland University of Technology, Kauri Dieback Programme, Tangata Whenua Rōpū and local iwi.

Kauri seed collection for 2018 took place in February and March. Pathologists from Manaaki Whenua, kaitiaki from Te Roroa and Kawerau a Maki and others collected cones from healthy trees growing near infected trees in the Waipoua and Waitakere Forests. The cones from 92 trees are now at Scion. Seed from the cones has been sown under strict hygiene protocols in the Scion Nursery kauri polyhouse.

Dr Nari Williams, HTHF Programme Leader, explains: "We are hoping to find natural resistance to kauri dieback in some of these seeds. When they are old enough, our collaborator Manaaki Whenua will infect a selection with the pathogen. Some of the trees from last year's crop have survived the six-month trials, which is starting to look exciting."

Scion is also involved in six National Science Challenges: Building Better Homes, Towns and Cities; New Zealand's Biological Heritage; Our Land and Water; Resilience to Nature's Challenges; The Deep South and Science for Technological Innovation (SfTI).



Scion is leading the spearhead project additive manufacturing and 3D and/or 4D printing of bio-composites under the Materials, Manufacturing and Applications portfolio of SfTI. The challenge's logo is an icosahedron (20-sided solid shape). Building on the 3D-printed logo presented to the Minister of Science and Innovation last year, a floating version has been developed by ESR.

The four in 4D refers to time. 4D objects and materials can change shape after manufacture. This can be on exposure to stimuli such as heat, humidity or wear. An example could be window shades that automatically open and close, depending on temperature or light intensity.

The annual industry workshop on 3D/4D printing was held at Scion in June 2018. Participants from research institutions and industry were able to see and handle samples and new materials, and discuss where the research might go. For many, it allowed them to think freely and to consider possibilities that they had not thought of before.

Lab Manager Tracey Bowers with Scion's bioreactor.

ACHIEVING OUR SCIENCE AND INNOVATION GOALS

Meeting our targets as set out in our 2017-2022 Statement of Corporate Intent

Impact Area	Leading indicators	Achievements
IA1 Increase value from plantation forested land	By 2018, improved growth models made available to industry to support better silvicultural management.	All 17 silviculture breeds trials have been assessed. We have empirical evidence of the impacts that genetic improvement and stand density have on stand value. Forest managers have used these results to develop their own productivity and silvicultural strategies.
	By 2019, a model conifer species has demonstrated proof of concept achievement of sterility.	Modified plants have been made but not developed through to shoots yet.
	By 2019, a phenotyping platform has been used to identify outstanding trees for at least one key trait leading to better site species matching and increased estate-level productivity for at least one end-user.	A whole-forest phenotyping platform was developed and implemented across a major forest. The original phenotyping platform concept was refined to incorporate machine learning methods, and the approach is currently being expanded to additional forests and datasets through our Vision Mātauranga partnership with Lake Taupō and Rotoaira Forest Trusts.
	By 2019, next generation genetics will have delivered new trees with an additional 15% genetic gain compared with the average improvement of 2012 deployed genetic seedlots.	Genomic-estimated breeding values (GeBVs) were generated for key traits and non-key traits in three Radiata Pine Breeding Company (RPBC) populations. Scion/RPBC have joined international Conifer SNP consortium to develop cheap, robust genotyping tools ("SNP Chips"). Using this chip, a further 20K individuals will be genotyped in the next 2 years, demonstrating commercial implementation of this technology and resulting GeBVs in the breeding programme. While GeBVs have been estimated, demonstrating the ability to deliver 15% genetic gain, the physical delivery of 15% genetic gain has not yet been achieved, but has been rolled into the ongoing work programme.
	By 2020, four biotech tree lines with modified productivity traits are being developed by field trials and reported to stakeholders.	Field trial monitoring and data collection from four lines was carried out.
	By 2020, first phase of ecosystem services assessment and evaluation completed and presented to industry.	Scion engaged with key contacts at MPI, Statistics NZ and Australia National University. Day 2 of the Forest Ecosystems forum focused on developing a framework for a New Zealand forestry satellite system that incorporates key ecosystem services.
	By 2022, new forest management regimes are adopted by industry to ensure capture of value from forest ecosystem services such as carbon capture and sequestration.	A SLMACC project progressed on new management options for steeplands, exploring transition from clearfell radiata regimes to other lower impact or risk forest types. The team worked with forest companies to identify case study sites for testing theoretical new silvicultural regimes.

	On-going: The Forestry Library, Permanent Sample Plots (National Forest Tree Database) and Tree Genetic Archives remain viable and provide valuable information about the national forestry position for New Zealand.	Permanent Sample Plots (PSP) measurements were completed for the 2017-18 year. Despite some location and forest ownership records being incomplete, data was collected from 150 plots across six species and stored on the PSP database available for Scion projects (subject to forest owner approval).
	On-going: The forest sector continues to adopt best practice remote sensing and analytical methodology developed by Scion.	In collaboration with HoloLens app development company Taqtile, we delivered a VR/mixed reality proof of concept for a forestry company, which provided a new perspective and understanding of how mixed reality technology could be used to enhance harvest planning, management practices and crew safety. Two significant advances were made around use of remotely sensed data within forest inventory and communicated to the forest sector: development, and testing of voxelised metrics from LiDAR data and subsequent implementation in the widely used LAStools. This research showed that voxelised metrics were more accurate than standard LiDAR metrics for predictions of key inventory variables. Secondly, a major study was completed showing that low cost photogrammetric point clouds from satellite are as accurate as standard LiDAR metrics for predictions of key forestry inventory.

Impact Area	Leading indicators	Achievements
IA2 Increase the resilience of forests to biotic and abiotic risks	By 2018, policy makers and forest growers are accessing Scion's knowledge of climate change impacts and resultant implications to provide guidance in managing risk and adapting to impacts of climate change.	Scion made a significant submission on the Productivity Commission's draft low carbon economy report. The billion tree initiative stimulated significant new discussions with the Ministry for Primary Industries (MPI) and we have also been involved with a number of Biological Emissions Reference Group projects focussing on trees on farms and their climate benefits.
	By 2018, MPI has adopted a validated helicopter spot spraying protocol for pest eradication.	The development of a protocol for helicopter spot spraying is effectively completed. A summary report/protocol outlined the key results and recommendations on implementing this technique during appropriate future incursion responses.
	By 2018, Rural Fire Authorities have adopted activity restriction triggers for high fire risk activities and implemented these within their strategic fire management plans.	Stubble burns near Darfield were successfully completed with data collected from nine burns in collaboration with national and international partners. This forms a key part of testing the convective fire spread hypothesis and subsequent development of a new fire spread model based on this theory. If validated this will globally change wildland fire science and deliver significant impact by improving forestry fire risk management processes around the country, including forest fire risk guidelines (being developed by NZ Forest Owners Association) and new preparedness plans (being developed by Fire and Emergency NZ).

	By 2018, options to reduce the impact of *Phytophthora* on radiata pine, kauri and one horticultural species have been identified.	Kauri seed collections from healthy-looking trees in infected areas were completed and seed is germinating in the kauri hygiene facility. Screening trials have shown variation in susceptibility to the kauri pathogen and that result is very promising. Spray trials have indicated that copper can control red needle cast in radiata pine.
	By 2018, Scion will have developed new molecular tools, and field tested at least one, to enable early identification resulting in more timely and appropriate response to unwanted forest pests or pathogens.	High-throughput detection assays for *Phytophthora pluvialis* and *P. kernoviae* were developed with Slipstream, greatly increasing the efficacy and capability of our research. These assays will be used in inoculum quantification in the coming financial year as well as several other projects.
	By 2018, Scion will have developed a dynamic decision support tool that enables rapid screening of potential pest species to improve industry and MPI's readiness to respond to future unknown incursions.	A primary mathematical/epidemiological model was developed, and a paper published in the ANZIAM Journal. The model is being extended with experimental and field data to introduce environmental and genetic variability. Average seasonal oscillations in spore development and mortality as well as needle health have been predicted from available field monitoring data. Smartphone app: following extensive stakeholder consultation, a comprehensive software requirements document was tendered. A contractor will be assigned in August to deliver a prototype Android and iPhone app with backend integration with iNaturalist NZ. This will enable vastly improved industry participation to conduct surveillance and join response actions. Additional spinoff programmes via Envirolink funding will ensure regional councils have a tool to manage invasive weeds.
	By 2019, options to reduce the impact of *Phytophthora* on radiata pine, kauri and one horticultural species have been identified.	High-throughput detection assays for *Phytophthora pluvialis* and *P. kernoviae* were developed with Slipstream. Early and effective detection greatly increases options for infection impacts.
	By 2019, research pathways towards the development and implementation of low spread or sterile genotypes of Douglas-fir have been identified and alternative mechanisms to reduce seed production from existing Douglas-fir stands have been trialled.	Three different constructs designed to engender sterility (and associated controls) were developed and have been transformed into Douglas-fir. Plants transformed with the first of these constructs (male sterility) are now in the GMO glasshouse while others remain in the tissue culture pipeline. Tissue culture techniques were developed for embryogenesis and cryopreservation for Douglas-fir, providing a clear path to deliver transformed lines.
	By 2019, new tools have been used for pest detection or targeted spraying in at least one pest eradication or pest management operation.	The development and testing of the Cyborg surveillance system (mobile electroantennogram (EAG)) is continuing with the help of engineering company Infact and colleagues from INRA in France. Version 3.0 of the prototype was completed and five dose response trials validated our anticipated improvements. A noticeable increase in signal strength and sensitivity was observed.

	By 2020, Scion will have identified radiata pine germplasm with improved drought resistance.	The genetic variation in plant growth, photosynthetic ability, water use efficiency and drought tolerance among elite radiata pine clones was examined. Needle $\delta^{13}C$ was identified as a potential trait for selecting genotypes with improved water efficiency and better growth performance under dry conditions. Such information will be useful for selecting drought tolerant germplasm. A draft publication was written.
	On-going: The National Forest Herbarium and the Forest Health Collections and Databases remain viable and provide valuable information on the national forestry position for New Zealand.	2,093 specimens were imaged in 2017-18. All Myrtaceae specimens have now been imaged. To date, 11,716 out of 30,336 specimens (39%) in the collection have been imaged. The database has been actively curated this year. The online website and database had 702 unique page views during the year. An interactive lucid key to wilding pines was also completed.

Impact Area	Leading indicators	Achievements
IA3 Sustain licence to operate and standards across the forest industry value chain	By 2018, with industry, progress a programme of work focussed on the design and commercialisation of modern harvesting tools, value chain approaches and labour productivity.	The Harvesting Primary Growth Partnership Business Case was accepted by MPI. Discussions are now underway with Forest Growers Research on the detailed work programme for the "Human Factors" theme and a value optimisation project on super skid sites led by Scion.
	By 2019, in partnership with key collaborators, Scion is developing and testing two robot prototypes to be deployed autonomously in the forest to undertake silviculture operations such as pruning and thinning.	FP Innovations have funded a project to be shared between the FPI Wildfire Operations Research Group and Scion to modify the current tree-to-tree machine to cut small diameter (approx. 10 cm) black spruce for fire thinning operations.
	By 2020, Scion will have implemented a learning review process with key agencies (FISC) designed to develop an understanding of human action(s) in context in order to facilitate the development of a learning culture and to improve organisational and individual resilience in high risk environments (harvesting).	Scion successfully developed and delivered two Maximising Incident Learning Opportunities Workshops to build industry capability to conduct effective learning reviews for working in high-risk environments. Highly positive feedback led to four more workshops in the new financial year with the Forest Industry Safety Council and Worksafe.
	By 2018, the benefits and risks of genetic modification research will have been quantified and presented to the forest industry, government and other key stakeholders for an informed decision on its future.	Wider communications undertaken included presentations, industry meetings and site visits. Abstracts prepared for the QMB2018 satellite meeting on Applied Genetic Technologies in which gene editing and public engagement will be a focus.

	By 2018, Scion will have supported the forest industry's licence to operate as FSC certified through research that underpins minimisation of pesticide use in forests, including development of improved tools for managing spread of conifers beyond the forest boundary.	A series of studies examining factors affecting uptake of triclopyr and dicamba were completed and will inform recommendations for boom and spot spraying operations.
	By 2019, Scion and its research partners will have supported the implementation of the National Environmental Standard for plantation forestry.	After development of a prototype for the erodeNZ app and presentation at various conferences, the NZ Forest Owners Association/NZ Farm Forestry Association Joint Resource and Environment Committee decided not to proceed with the app. Following the recent Tolaga Bay and other storm events and resulting debris flows we are discussing the possibility of accelerating this programme with MPI and potentially enlarging it with support from the Forest Growers Levy Trust.

Impact Area	Leading indicators	Achievements
IA4 Diversify forests and local manufacturing to support regional growth	By 2018, Scion and iwi tangata whenua and other partners will have secured external investment supporting the commercial opportunity associated with Northland tōtara.	Achieved in full with the Northland Tōtara Industry Pilot being formally initiated in May 2018. This included Scion, Te Tai Tokerau Māori Forestry Collective, MPI, Tane's Tree Trust, Northland Inc. with support from the Provincial Growth Fund.
	By 2018, a conceptual framework has been developed for the economic assessment of alternative forestry options, focused on indigenous forestry and Māori land holdings.	Scion, in partnership with Ngāti Porou and Manaaki Whenua, developed a framework to analyse risk and uncertainty of alternative forestry options using ecosystem services with market values in the Waiapu catchment, East Coast. Three planting options were analysed: mānuka for honey, mānuka and later maturing tōtara for timber, or mānuka then tōtara followed by an understory of medicinal kawakawa. Using a 1% discount rate all options were profitable. Such a low discount rate is appropriate in the specific circumstances, with few land-use alternatives in the highly erodible country, the community's attachment to the land, and desire to provide for future generations.
	By 2018, Scion will have developed tools and models for the forest products value chain that will be in use to determine where to intervene in order to maximise benefits from the existing forest resource. This work will have created better connectivity between growers and processors, and between small-scale forest growers.	Scion and its collaborators developed two models that focus on identifying opportunities to improve the forest products value chain. The first, called SEGMOD, focuses on quantifying the economic impact of segregating stand and logs based on their internal wood properties. The second, called Primary Value Chains, focuses on regional value chains. The model was applied in a regional case study to determine the impact of investments in traditional and emerging processing technologies on the optimal use of the forest resource and overall economic returns.

	By 2019, two lines of biotech trees will be harvested and processed to determine their viability as alternative biorefinery feedstock (production of high value chemicals and/or processability for fibre or bioenergy). The investment case will have been presented to potential commercialising partners.	Work slightly delayed owing to biological needs. S-lignin trees were harvested in June, and many facets of future analysis coordinated for top quality publications. Also, a second line of lignin modified trees was analysed and the presence of the new, active gene was confirmed.
	By 2019, Woodscape has been upgraded to reflect both new products and new knowledge developed for current technologies. Assessments have been made to the business case stage, and for the development of a new or substantially enhanced wood manufacturing operation.	The WoodScape model had Monte Carlo risk analysis added to it, as well as calculation of an extended range of financial metrics (IRR and NPV). Additional processing technology options were added (acetylated wood, furfurylated wood and full colour thickness wood) these were used in the development of business cases for the further development of these products.
	By 2019, Scion will have provided tools, 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 5% over 2014 plantings.	We created, and demonstrated, a software tool that predicts the stiffness of LVL produced from a mix of eucalypt and radiata logs with a known density profile. Also found was that the density of *Eucalyptus fastigata* veneers needs to be measured to be able to measure stiffness accurately. Value-added chemical modifications did not progress owing to problems with equipment supply.
	By 2019, solutions for novel pre drying/drying for three difficult-to-dry species have been identified then trialled at full-dimension material scale to produce dry, check/collapse-free full-size timber. Processing costs have been estimated. The information is being used by a partner company to establish the commercial feasibility of this new approach to drying.	Collapse caused by internal stress is a problem in *E. nitens* timber. A model created in 2016-17 to predict levels of collapse in boards from measurements made in standing trees was tested by comparing a set of *E. nitens* trees predicted to collapse with a set thought unlikely to collapse. Similar levels of collapse were seen for both sets. The underlying properties leading to increased collapse are thought to be not well correlated with the measurements taken in the standing trees. Experimental work from 2016-17 was analysed and showed that dewatering *E. nitens* using supercritical CO_2 prior to a short period of oven drying significantly reduced levels of collapse compared to conventional drying from green timber. Oscillatory treatments had no effect on checking and collapse.
	By 2019, at least two regional councils have integrated Scion's forest economics and ecosystem services approaches into landscape level planning for multiple land uses.	A new research programme proposal 'Connections Matter' was submitted to the Ministry of Business, Innovation and Employment but was not successful.
	By 2019, Scion's information will have contributed to New Zealand's national	The Environmental Fact Sheet series launched in 2017 is proving very popular with forestry stakeholders. Companies

	and international reporting obligations and the New Zealand Freshwater National Objectives Framework.	and councils are using the sheets widely to provide facts on various environmental issues. The debris flow sheet is particularly topical. These fact sheets are available from the planted forests portal, the NZ Forest Owners Association and Scion websites. More sheets are intended.
	By 2019, Scion is collaborating with Māori organisations to develop forestry options that meet their economic and social aspirations.	Organisations involved in a VM project (Māori and forest management) came together to move the project to developing a business model. Scion is providing technical support in this phase. The indigenous nursery project was boosted by a funding injection from the Government to support regional growth and the Government's billion tree planting initiative.
	By 2020, using adaptive governance approaches, the barriers and obstacles facing Māori in the development and implementation of alternative land uses will have been described and new governance approaches developed and tested with key agencies.	Game-based approaches to support greater awareness of the challenges facing Māori in developing new opportunities were developed and tested with community members and key agency representatives (reps). Feedback was positive, and findings fed back to MPI and other bodies. Regional fora were held with community members, regional council officers, senior politicians and agency reps to map a way forward based on community aspirations. Scion was invited to help shape a future plan in partnership with MPI (and contractors) to guide future action by the Joint Governance Group and ways in which progress may be mapped.

Impact Area	Leading indicators	Achievements
IA5 Increase the use of wood and fibre products in the built environment	By 2018, Scion will have demonstrated and secured external investment to enable at least one new modified wood product to compete in high-margin market segments.	A patent was drafted for filing on Scion's novel Furfuryl alcohol modification of timber technology, and a commercialisation strategy formed. A biobased modification technology for use as a wood preservative has completed 2-year field trials. It has performed well to date (i.e. minimal or comparable durability to industry standards) and corrosion of fittings was evaluated to be similar to use of other preservatives. Commercial interest has been expressed.
	By 2018, Scion will have produced thermally modified wood samples from at least three species, large enough for market place testing. Durability, stability and structural performance have been assessed and a commercial feasibility explored. The information is being used by an investor company to establish the commercial feasibility of the modified wood process.	Scale up of *Cupressus lusitanica* thermal modification was delayed until end of the year owing to wood supply difficulty and required kiln upgrade. Property tests have not yet been completed. The properties of lab-scale samples of *C. lusitanica*, tōtara and *Eucalyptus nitens* were compared. Preliminary commercial feasibility of the thermally modified *E. nitens* for interior flooring was conducted with a mixed response. A more detailed assessment is in progress.
	By 2019, Scion will have progressed a novel wood modification that	There seems to be no competitive advantage for full thickness colour only treatment, but there might be a better market

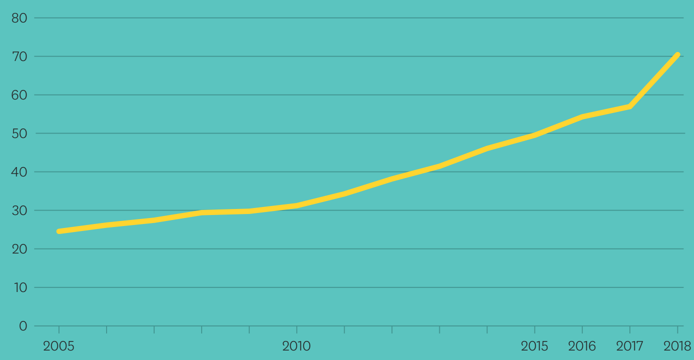
	incorporates some of the key attributes identified in the business cases to a pre-commercial stage.	proposition for colour and hardness. Although underway, work to improve understanding of the significance of wood emissions from modified wood on indoor air quality was delayed because an international collaboration was not secured. Modified and unmodified samples from four wood species were analysed, and a report is due.
	By 2019, Scion, with *Building better homes, towns and cities* science and industry partners, will have developed a platform to provide better performing, higher amenity built environments in terms of affordability, performance and sustainability. This platform addresses the wider impacts of intensive living on the urban environment.	The Toi Ohomai project, in which Scion is a major partner, was very well received and led to a design meeting where construction and prefab options were put forward. A proposal for the first building acoustic project was completed. The waste water scoping project was completed. Our work introduced a vision of a decentralised, circular economy-based future for New Zealand's urban environment, as a think piece report to this national science challenge.

Impact Area	Leading indicators	Achievements
IA6 Manufacture and apply biorefinery products from wood fibre, waste and other materials	By 2018, Scion will have aligned a cluster of organisations (including industry, government and research organisations) to pursue an integrated biorefinery concept (combining bioenergy and bioproducts) and together have developed a joint roadmap.	Interested global players and several New Zealand commercial interests were brought together to understand the concept of a bark biorefinery and its position globally and for New Zealand. A later workshop was held in June with one of the international partners and New Zealand industry. Under the Bioprocessing Alliance, a proof of concept study showed that low value sawdust can be successfully converted to value-added products such as protein feed and a selective adsorbent with high adsorption capability.
	By 2018, a patented technology has been produced at industrial scale and partners have been found for commercial uptake.	Exciting improvements to our bioadhesives formulations were achieved, and licensing discussions held with some big brand companies. Similarly a large range of companies have been approached for interest in Scion's coatings technologies.
	By 2018, 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).	Three techniques were evaluated to produce a bio-polyester nanocomposite, and one progressed for composite production in order to be characterised. Significant improvements on conductivity of Scion's lignin carbon nanofiber technology was achieved through global partnerships. With partners Waikato and Victoria Universities, we created two novel PhaC sequences. One sequence is not found in nature and represents an entirely new PhaC enzyme that can be engineered for further activity and specificity enhancements. Also, we identified eight enzymes with aromatic substrate specificity that show the production of a polymer-like substance in vitro.
	By 2019, at least two of these polymeric material prototypes are incorporated	We developed a formulation that is being sold by a company for use in 3D printing. Commercial electrospinning

	in new product offerings by firms.	trials were undertaken to investigate spinning of lignin combinations and formulations.
	By 2019, Scion will have assisted a commercial packaging company to develop boxes with improved performance in coolstores.	A 'WHITE' Room test to examine the creep performance of two box types with the same box compression strength test and size but different core material was completed, and results shared with industry.
	By 2019, new high performance products (packaging, composites and new compounded materials containing biopolymers) developed by Scion in collaboration with commercial partners are supporting the development of new industries in New Zealand and providing direct revenue to New Zealand.	Offshore evaluation of coating technologies was conducted. A concept was advanced for a niche compound manufacturing company to address risk aversion among New Zealand companies.
	By 2020, Scion and commercial partner(s) have developed a viable and New Zealand-specific biorefinery business case based on Scion-developed high-value bioproducts and cost efficient technology platforms for commodity fibres and bioenergy.	A project with VTT on plastic film progressed and now needs further work to become financially viable. A Bioprocessing Alliance project, with Plant and Food Research, commenced to investigate production of wood-based molasses for animal feed.

Impact Area	Leading indicators	Achievements
IA7 Use more forest biomass to improve New Zealand's energy security and reduce emissions	By 2018, Scion will have supported a group of firms in one region to develop a value proposition, based on industrial symbiosis using wood energy, outlining the benefits/risks across economic, social and environmental criteria, enabling them to make an informed decision for action.	The project progressed well towards wrap up in September 2018. A full process model for a site was developed and integrated at least two biorefinery processes into the site model. A workshop was held with stakeholders on the opportunities from symbiotic use of waste from neighbours' processes. Planning started for public engagement at end of the programme.
	By 2019, Scion will have identified, and reached national alignment, around the Implementation Roadmap for Biofuels in New Zealand. Technology barriers, acceleration options and policy interventions will be identified.	The NZ Biofuels Roadmap documents were launched by the Minister of Energy and Resources in February resulting in good media pick-up and pleasing commercial and government interest. Scion's profile was raised significantly through subsequent presentations on roadmap modelling, and we gained recognition for capability in climate change mitigation modelling.
	By 2020, Scion and commercial partner(s) will have developed a viable and New Zealand specific biorefinery business case based on Scion's high-value bioproducts and commodity (fibres and bioenergy) platforms.	Several projects made good progress and three manuscripts were published in peer reviewed journals as well as a contribution to a book chapter on PHA bioplastics from organic waste, and drafting of a position paper on a new forestry application for gaseous emissions.

PURSUING EXCELLENCE AND REACHING OUT



Science papers

131 Refereed papers published
70.46 Rolling 5-year weighted average H-index

www.scionresearch.com/ar18/publications

Collaborations

89 Publication collaborations with New Zealand and international research institutions
15 Formal collaborations with Māori
6 National Science Challenges

Tech translation

2049 Research-specific website visitors
307 Presentations on technical information and research results
336 Commissioned reports
190 Publications on technical information and research results
25 Events sponsored
24 Popular articles and videos
14 Research specific newsletters

Outreach

95	Days of public exhibitions
1389	Subscribers to *Scion Connections*
1277	Followers on Twitter
3165	Followers on LinkedIn
21,200	Minutes watched of Scion YouTube videos
47,926	Unique visitors to the Scion website

Science New Zealand National Awards 2017

Lifetime Achievement Award - **Dr Dave Cown**
Team Award – **Biosecurity Team**
Early Career Researcher Award - **Dr Nari Williams**

https://bit.ly/2PhaRDL

FINANCIAL RESULTS SUMMARY

	2016 Actual	2017 Actual	2018 Budget	2018 Actual
Revenue, $m	49.60	51.90	54.65	56.74
EBIT, $m	2.28	3.01	2.13	3.10
EBIT Margin	4.6%	5.8%	3.9%	5.5%
Reinvestment, $m	1.35	1.37	1.55	1.43
EBIT-R, $m	3.63	4.38	3.68	4.53
EBIT-R Margin	7.3%	8.4%	6.7%	8.0%
Total Assets, $m	48.11	54.20	52.67	57.13
Return on Equity	5.2%	6.2%	4.3%	5.7%
Pre-reinvestment Return on Equity	7.8%	8.8%	7.1%	8.2%
Equity Ratio	75.1%	73.5%	73.3%	71.6%
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% of the shares on behalf of the public.)

Where our revenue comes from

Ministry of Business, Innovation and Employment (SSIF)	31%
Ministry of Business, Innovation and Employment (Other)	24%
Government departments	8%
Other commercial	36%
Interest	1%

How our revenue is spent

Employee remuneration	47%
Training and recruitment	2%
Consumables	3%
Depreciation and amortisation	7%
External services and contractors	23%
Premises costs	5%
Travel	4%
Other operating costs	2%
Non operating costs	2%
Net profit before tax	5%

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

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