ScionConnections

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Greg Steward, Scion's longest serving indigenous forestry researcher, inspecting the foilage in a 9-year-old planted kauri stand.

Indigenous forestry renewed

New Zealand's early forest industry was based on our indigenous forests. Over time, many of those forests disappeared, new sources of wood were sought and interest in indigenous trees languished. Indigenous trees were believed to be unsuited to planted forestry, being too slow growing and no match for the impressive growth that can be achieved with radiata pine. However, that's not necessarily the case. Scion's Greg Steward has spent more than four decades researching New Zealand's indigenous trees for production forestry, and what he has learned may surprise you.

Beginnings

Planting of indigenous species began from as early as the mid 1800s. A 1919 review of kauri forestry revealed results that Greg has also observed: in managed plantations, kauri had significantly better growth than many exotic alternatives.

Despite these results, a pessimistic view of planted indigenous forestry had become embedded, based on early measurements and observations of growth rates in indigenous species that were contradictory and bleak. The prevailing assumption was that planted indigenous trees would have to resemble old growth forests to maximise clean timber and heartwood, and indigenous species would need hundreds of years to achieve this size.

Surprising results

Greg's research into indigenous forestry dispels many of the old assumptions. He says, "indigenous forestry has been plagued by anecdotal conservatism".

Weaving numerous sets of kauri growth data together, a pattern began to emerge of faster growth than was previously considered possible on sites within and

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Are you ready to take the circular bioeconomy journey?

In previous editorials, I have described my vision for a New Zealand where my grandchildren, and theirs, can thrive because being environmentally sustainable is mainstream. It is the way city and country people live in 2050. To get there, we need our economy to shift back to the future where growing our resources takes over from taking raw resources from the ground.

An imperative is a national bioeconomy strategy for New Zealand. This strategy must be cross-sectorial, involving players in all sectors, to ensure all opportunities and challenges are identified. And adopting multi-sector thinking makes sense for New Zealand because of our size and relative ease of integration.

Already New Zealand has the setting and ingredients for a bioeconomy. We have plenty of land (relative to population), water, primary industries, strong biological sciences and we are not overly invested in fossil-fuel based manufacturing.

As a country we can embrace a move from an oil-based economy to a plant-based one more easily than other countries, and we have our own cultural stories that strongly connect us to the land. A bioeconomy encompasses the production of renewable biological resources, and their conversion into food, feed, biobased products and bioenergy via innovative and efficient technologies.

We need to go a step further and think 'circular bioeconomy', which is where industrial systems are designed to minimise waste and make the most of biological resources (or biomass).

New Zealand's largest source of biomass is planted forests, with plenty of low-value leftovers from the harvest and processing of trees. Adding value to slash and piles of bark is a tangible example of an opportunity that would contribute to the circular bioeconomy.

Scion has been applying a sustainable design approach, conducting biobased R&D for many years, and we have developed many biobased solutions to enable a circular bioeconomy. I was awed by what I saw when I arrived here less than three years ago and yet frustrated by why our science wasn't being taken up.

Globally Scion is recognised as a leader in the circular bioeconomy approach and we have strong international science networks and active research collaborations. We're now working hard on gaining this same recognition at home, and signs are positive. For instance, we lead a research programme to demonstrate bark biorefinery technologies that can convert millions of tonnes of bark into high-value materials and products. We are pulling together a national roadmap for the future of plastics. We have delivered a biofuels roadmap for New Zealand and produced regional 'industrial symbiosis' case studies.

> ... we need our economy to shift back to the future where growing our resources takes over from taking raw resources from the ground.

I am committed to seeing Scion become a key enabler in transitioning New Zealand to the circular bioeconomy. We have well-established scientific expertise in developing bioproducts from renewable resources. We have an open campus, unique pilot facilities and plenty of space to expand this important work for New Zealand and deliver world-class impact.

As an innovation nation, New Zealand can shine in addressing global problems and ensuring a sustainable future for our citizens.

We can redesign our cities and the urban environment using circular bioeconomy principles. Not only should 'wood first' and circular sustainable approaches be key principles, but cities literally could be green with high-rise buildings covered in trees and shrubs.

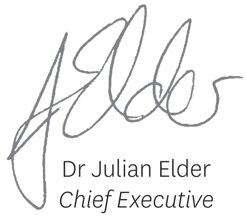
> Vertical forests will happen ... world leading experts on sustainable urbanisation see future cities being truly clean and green.

Vertical forests will happen. China already has several vertical forest projects where nature is an essential element of architecture. Such forest cities will absorb thousands of tonnes of carbon dioxide and pollutants. World leading experts on sustainable urbanisation see future cities being truly clean and green.

De-centralised manufacturing close to renewable resources will boost our regions. Advanced manufacturing technologies are reducing the need to manufacture at scale and ideally suit a future of vibrant regional communities with farming, forestry and manufacturing existing symbiotically.

Through redesigning our cities and industries we can transform New Zealand to a sustainable way of living that is beneficial socially, environmentally and economically. This will require a national strategy and bold corporate leadership.

I am ready for this journey, Scion is ready. How ready are you? I welcome your feedback.



Dr Julian Elder
Chief Executive

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PHOTO: LUKE MARSHALL IMAGES AND NELSON AIRPORT LTD.

The recently opened Nelson Airport terminal is a great example of a new timber construction with engineered wood products that are storing carbon long-term.

Locking up carbon long-term in timber buildings

Over their entire lifecycle, New Zealand buildings are responsible for approximately 20 per cent of the country's greenhouse gas emissions (Thinkstep, 2018). When you also consider that emissions from the construction sector increased 66 per cent in the decade to 2017 (Stats NZ), it's evident that the building and construction sector has a lot to do to improve their emissions profile. As such, the search is on for ways to mitigate some of those carbon dioxide emissions, or to avoid them entirely. One way is to build with wood.

It is scientifically recognised and widely accepted that using wood instead of alternative construction materials greatly reduces greenhouse gas emissions and fossil fuel consumption during the product manufacturing and building construction stages. Wood processing releases very little carbon, unlike other materials that emit high quantities of CO_2 into the atmosphere.

In addition to lowering greenhouse gas emissions, building with wood stores carbon sequestered by trees when they were growing.

Scion Sustainable Architect, Andrea Stocchero, and University of Canterbury Emeritus Professor, Andy Buchanan, suggest quantifying how much carbon is stored in each timber building so that the storage benefit can be accounted for and recognised with possible incentives. This would help policy makers that want to encourage wood product use in construction.

Storing carbon in buildings

Sustainably harvested wood used in construction can store carbon for a long time, decades and even centuries, depending on the building's lifespan. And as the building industry begins to implement circular economy principles, which include design for recycling and re-use of building materials, this time could grow considerably.

Andrea and Andy say that a cubic metre of wood (e.g. radiata pine) with a weight of 500 kg contains approximately 250 kg of carbon (C), which is equivalent to 920 kg of carbon dioxide (CO_2) sequestered from the atmosphere. When this wood is used for building construction, that CO_2 equivalent (CO_2-e) quantity is locked in building materials until the end of their life.

For example, a typical New Zealand timber framed home with a floor area of 200 m² contains about 30 m³ of wood and therefore locks up 27 tonnes of C_2-e.

The Scion Innovation Hub, currently under construction within Scion's Rotorua campus, is a bigger example. It is a three-storey building containing 455 m³ of structural wood, storing approximately 418 tonnes of CO_2-e. This storage is equivalent to the emissions from 160 return flights from Auckland to London. Impressively, it took only 35 minutes for New Zealand radiata pine to grow the same amount of wood used in the Innovation Hub.

Building with wood for a low-carbon future

Building with wood is an important measure as New Zealand strives to meet the goals set in the Zero Carbon Bill, the Paris Agreement on Climate Change and the UN Sustainable Development Goals.

Andrea and Andy say that building with wood has become increasingly achievable, even for medium-density and tall buildings up to 15 storeys and more.

And there is little reason not to build with wood. Andy confirms, "new wooden buildings are attractive and functional buildings. They can have similar or better safety and performance than buildings built with other construction materials".

Andrea agrees, saying, "building with wood is a great option both for long-term carbon storage and for the broader social, economic and environmental advantages that wood provides on top of other technical, functional and biophilic benefits."

Doug Gaunt, Scion Wood & Fibre Team Science Leader, says, "the most important thing the world can do now is to reduce greenhouse gas emissions by sequestering and storing CO_2 from the atmosphere. Trees are well known to be an efficient sequestrating mechanism and timber used in building provides long-term storage. We urgently need to get timber buildings as the mainstream construction option."

Andrea continues, "it is time to encourage and incentivise people to build with wood as it is a tangible contribution to both the New Zealand and the global carbon balance".

FOR FURTHER INFORMATION on carbon stored in the built environment contact Andrea Stocchero at andrea.stocchero@scionresearch.com

Solving the mysteries of forest hydrology

Irrigation, population growth, urbanisation, agriculture – these are all factors that are increasing the demand on New Zealand's freshwater resources.

Water quality is also under pressure from pollution, floods and droughts that are expected to increase in frequency with climate change.

Where do forests fit into this picture? When planted in the right place, we know they can help to protect the land and water from the effects of storms and floods. But we do not know how forests affect water resources at other times of the year, especially during dry months and droughts, or how that might change between tree species. Scion has just begun a bold new research programme that intends to find out.

Need for new research

There is a desperate need for new forest hydrology research. Most of the forest hydrology models used in New Zealand today are based on a small number of studies conducted in the 1960-70s. Also in use are algorithms developed for agricultural soils, which are very different from forest soils. Presently, there's no way to know how accurate these current models are, and a lot has changed since the data was initially gathered.

> The bold goal of this programme is to create a new biophysical forest hydrology model by combining cutting edge remote sensing techniques with terrestrial based measurements.

Now is our opportunity to ensure that new forests, including the 500,000 ha of new forests that could be planted through the One Billion Trees programme, are strategically situated where they can enhance water resources into the future.

Forest flows

Scion is leading a new 5-year research programme called 'Forest Flows', supported by MBIE. The programme aims to create a biophysical model of forest hydrology that accurately predicts water retention and release for entire catchments, while also providing data on changes in water quality over time. This will ensure that New Zealanders have a sustainable water supply, a reliable source of high-quality drinking water, and that our land uses preserve social and cultural values.

This programme seeks to protect primary sector productivity and improve water quality, flood mitigation and current/future demands for rural/urban users by qualifying water storage and release by planted forests. It will also quantify the positive and negative impacts of planted forests on water resources, including any potential impact resulting from intensification of planted forest management. It will determine whether some tree species and forest types are better at flood mitigation than others and identify planted forests that have the potential to be passive water reservoir systems.

The bold goal of this programme is to create a new biophysical forest hydrology model by combining cutting edge remote sensing techniques with terrestrial based measurements. The inclusion of remote sensing technology will give the team the data needed to scale their model, going from tree, to stand, to forest, to catchment and will be applicable to forests all over New Zealand. These extrapolations are only possible after detailed analysis linking the fine scale field measurements to the remote sensing data. Achieving this will be a breakthrough for hydrology research internationally.

Ten years down the track this could mean that tree species planted as part of the One Billion Trees programme, or for carbon sequestration, timber and non-timber products are spatially optimised by catchment to maximise water ecosystem services.

The remote sensing techniques that will be used include lidar, hyperspectral imagery and p-band radar. P-band radar is a new technology that can penetrate the ground and pick up variation in water content.

Tools

After the model is created and can accurately predict hydrology fluxes, the research team plans to create tools for assessing the combined ecological and economic implications of land use decisions on the provision of water services. These tools have a huge potential impact on policy setting and land use planning.

Working with stakeholders, including iwi, central and regional government, landowners and industry, the research team will create a framework for a web-based decision-making tool. It will incorporate biophysical, economic, social and ecological considerations that allow stakeholders to plan for optimal water use, yield and nutrient levels according to their priorities.

Paradigm shift

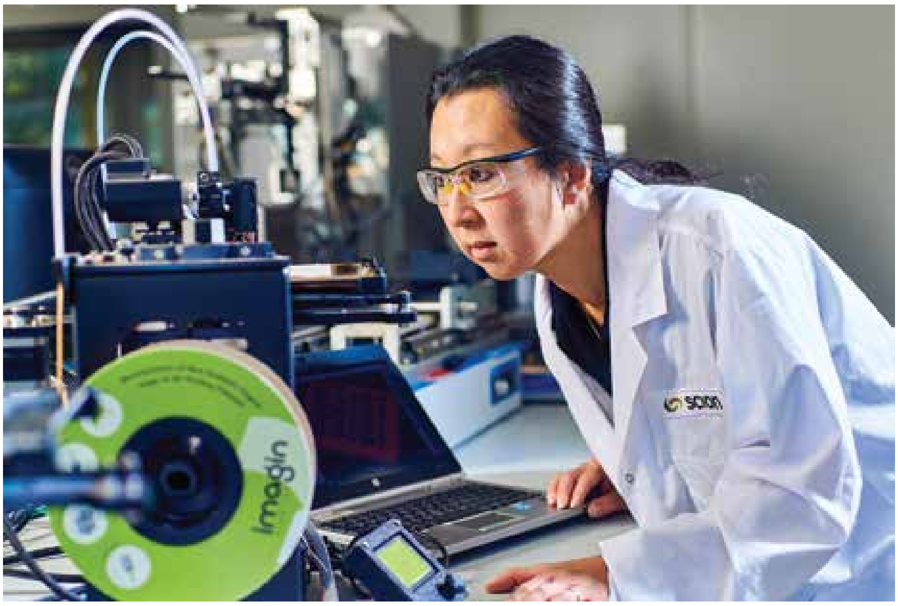
Forests are increasingly seen as a competitor for water by downstream users, and this is only likely to increase with the large-scale afforestation planned in the One Billion Trees programme. This research programme hopes to turn that around and prove how strategically situated forests can substantially increase water resources, further mitigating flooding, and enhancing future primary-sector productivity with increased water flow during drier months.

Ten years down the track this could mean that tree species planted as part of the One Billion Trees programme, or for carbon sequestration, timber and non-timber products are spatially optimised by catchment to maximise water ecosystem services. We envisage that new forests will be used as low-cost water-storage alternatives to dams and passively supply water to downstream users during dry months, while mitigating overland flow during storms.

Collaboration

The boldness of this project is only possible with a huge range of collaborators from across New Zealand and the world. New Zealand based collaborators include NIWA, XERRA, and the Universities of Auckland and Waikato, with international, trans-Pacific collaborators from Remote Sensing Solutions, Meter Group, Virginia Tech and the Universities of Massachusetts and Southern California (USA), CSIRO and Whitegum Forest and Natural Resource (Australia), and ARAUCO (Chile).

FOR FURTHER INFORMATION on the Forest Flows research programme contact Dr Dean Meason at dean.meason@scionresearch.com



Research Leader Marie Joo Le Guen is printing a sample using Imagin's wood bioplastic filament that contains a Scion-made compound.

Biobased additive manufacturing

Additive manufacturing (AM), including 3D and 4D printing, encompasses some of the most promising technologies currently available.

News stories regularly appear featuring exciting creations or innovations from houses to human hearts, all made possible with AM technologies. Scion anticipates that AM will continue to be one of the biggest and most influential technologies worldwide. As New Zealand transitions to a circular bioeconomy AM will be a core manufacturing technology going forward.

New Zealand has particularly promising arguments for using AM in our journey to a circular bioeconomy. Our small nation is rich in renewable natural materials that can create the new polymers, composites and other performance filaments that are needed to replace the fossil-based products currently in use.

Scion has 20 years of research and development experience in biomaterials and 10 years in AM; this is forming the basis of a new, innovative manufacturing sector for New Zealand.

Field leading capability

Scion has recently appointed its first Research Leader for Additive Manufacturing - Dr Marie Joo Le Guen. Marie Joo is recognised as one of New Zealand's leading experts in the 3D printing of biobased materials and she has an impressive industry and national and international academic network. The role will see Marie Joo work with a wider team within Scion and our national and international partners to develop both 3D and 4D printing filaments incorporating renewable resources.

Marie Joo has also been a key contributor in projects with significant additive manufacturing elements including the Science for Technological Innovation National Science Challenge's (SfTI NSC) 3D/4D printing spearhead project. Scion's Biopolymers and Chemicals Science Leader Dr Florian Graichen is a co-leader in this project with Dr Kim Pickering from the University of Waikato. Other partners of the multi partner and multidisciplinary collaboration include AgResearch, GNS, Auckland University of Technology, Victoria University of Wellington, Massey University and University of Auckland.

The spearhead project aims to harness New Zealand's natural resources, such as biopolymers, plants and wood fibres to create new, more environmentally friendly materials and products. Their work includes developing biopolymers for 4D printing, which adds a functionality (i.e. a new dimension) to the 3D printed object such as shape memory. Besides manufacturing the materials, the challenge will design printing processes that can cope with and preserve the natural functionalities of the renewable materials. These new properties could be used to make anything from buildings to furniture.

New research projects

This year, Scion has been successful in securing two new research projects supported by the SfTI NSC seed fund.

Dr Angelique Greene is leading a programme to explore self-cleaning molecular sponges for chemical sequestration. Her work will develop a new method of chemical separation. She plans to create a molecular sponge that uses electrically controlled mechanical motions to selectively trap waste products in one environment and release them cleanly for further processing without saturating the sponge.

Dr Kelly Wade will be leading a project with the AM team to delve into the field of biomedical AM by developing 3D printable polymers containing biologically-active antimicrobial enzymes. He will be working on 3D printable medical devices, such as catheters and orthopedic implants that contain anti-bacterial enzymes, reducing the need for antibiotics while maintaining sterile conditions on the devices. The research will combine recently identified enzymes that remain stable at elevated temperatures with lower temperature 3D printing techniques.

Looking ahead

Looking to the future, our vision for AM includes cross-disciplinary opportunities with other advanced related technologies such as robotics, virtual and augmented reality, and artificial intelligence. For example, the SfTI NSC spearhead teams for 4D printing and robotics are collaborating to identify innovation opportunities on the interface of these two futuristic research domains.

Coupling this highly adaptive technology with the innovative kiwi-mindset, a small but young manufacturing sector, and easy production near supplies of biomass is a recipe for success. This technology will also bring new opportunities to decrease reliance on some imported materials, while increasing exportable products. These factors and more are the reasons to make AM the next big manufacturing direction in New Zealand.

FOR FURTHER INFORMATION on our additive manufacturing research contact Dr Marie Joo Le Guen at mariejoo.leguen@scionresearch.com

Did dinosaurs dine on *Phytophthora* - infected plants?

It's highly likely they did, based on the information decoded from the genes of *Phytophthora kernoviae* samples collected in New Zealand and Chile.

As part of the Healthy Trees, Healthy Future research programme, Scion plant pathologists working with an international team sequenced and compared the genomes of *Phytophthora kernoviae* from Chile and New Zealand.

Both countries share common ancient plants that seem to have co-evolved with *P. kernoviae*. Scientists believe both the Chilean and New Zealand populations have descended from an ancient Gondwanan population.

The supercontinent Gondwanaland existed around 550 to 180 million years ago and its remnants today make up parts of Australia, New Zealand and South America with fossil records that show dinosaurs roamed the land.

A Parasaurolophus, a type of herbivorous ornithopod dinosaur of the Hadrosaur family, stands in a forest of fir trees with a floor of ferns.

Genetic secrets

Examining genomes can reveal close and more distant family relationships that give us clues as to how long an organism has existed, where it might have originated, and how it has evolved with time.

The genes within the populations of an organism change with time due to mutation, natural selection, geographic isolation and other evolutionary processes. Comparing the genomes from different populations lets us identify closely related strains with very similar genomes and more distant relatives and track the changes through populations.

FOR FURTHER INFORMATION
on our Healthy Trees, Healthy Future programme contact Dr Nari Williams at nari.williams@scionresearch.com

Indigenous forestry renewed

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outside the species' natural range. Greg used this data to develop robust models of growth in planted stands. These models have shown that planted kauri stands aged 20 to 60 years were 20 times more productive than natural stands. His work has blown the estimated kauri crop rotations of hundreds of years out of the water.

Greg also found that if kauri is grown quickly, the wood quality does not diminish, unlike some exotic species. Reiterating the good news, Greg goes on, "we're getting these great results before we've had an opportunity to apply selective breeding, which would improve performance again. There is so much opportunity here".

Tōtara too has way surpassed initial expectations for crop rotations. Following research exploring growth, density and wood quality, estimations have been updated to a 60 to 80-year rotation, which is where Douglas-fir started in New Zealand and could be further reduced with research into breeding and management.

These findings give Greg hope for the future of indigenous forestry. "We need to unlock the economic opportunity in indigenous forestry, which will give people the confidence to invest while also helping to protect the future of our indigenous trees."

Current research

Support has been provided from the One Billion Trees programme to remeasure progress on the old establishment trials. "We are looking at lessons we can learn from these trials, both good and bad."

Research is also taking place in Northland with tōtara on private land. The most recent results (2019) are very promising, showing that self-seeded trees on farms growing without management or selective breeding still produce a high volume of good quality recoverable timber. However, Greg acknowledges there are still big gaps in our knowledge. "We desperately need species specific models on growth and productivity," he says.

The three ages of forestry

In Greg's opinion, there have been three ages of forestry in New Zealand. Forestry began with early land clearance, the second stage could be called the age of radiata pine, and the third age is what we are transitioning to now. Greg's vision of the future includes a diverse forestry estate, with many different species that are planted for a variety of reasons.

Now approaching the last years of his career, Greg says he's excited to see what Te Uru Rākau will achieve. And when asked what he's most proud of in his 44 years of resolute and determined belief in indigenous forestry, he says, "maintaining the beating heart of where forestry started".

FOR FURTHER INFORMATION
on our indigenous forestry research contact Greg Steward at greg.steward@scionresearch.com

Hemp products for the circular bioeconomy

A hemp revival is gaining momentum, and it is easy to see why. There is no shortage of applications for hemp. From food to bioplastics and even biocomposite construction materials like 'hempcrete' (hemp fibres and lime), it is clear this fibrous plant has a lot of potential. Scion is poised to help hemp growers, product designers and innovative brands to cultivate and use this plant in new sustainable products matching the requirements of a circular bioeconomy.

Optimising harvest

Scion scientist Dr Stefan Hill has begun developing a fast and inexpensive way to help hemp growers pick the best time to harvest. The test will screen samples of hemp for the chemical signature of selected phytochemicals such as CBD (cannabidiol).

This kind of testing is widespread in the wine and fruit juice industries, where goods are tested to ensure that there are no dangerous contaminants in the products, and to certify that products have not been counterfeited and filled with cheaper substitute materials (e.g. beef mixed with cheaper horse meat sold as pure beef).

The test uses NMR (Nuclear Magnetic Resonance) technology. The NMR will show a spectrum or pattern of chemicals for each sample tested. These results can then be assessed for any patterns from known products (such as horse meat in the example above) to ensure that there are no missing ingredients, or whether any unwanted ingredients are present.

Using hemp as a sample, Stefan will be looking for the presence of CBD, to ensure that the hemp crop is ready to harvest. This will allow growers to maximise their harvest value. This test promises to be much cheaper than the existing alternative methods such as GC-MS and LC-MS.

Hemp R&D at Scion

Scion can also test hemp products by other means to assess their environmental credentials and has capability to develop new products. Scion began developing our expertise in natural fibre processing 13 years ago, including post-harvest treatments of hemp fibres and their preparation to suit composite manufacture for the automotive industry within international networks (e.g. Canada, Germany).

Our facilities can test the biodegradability and compostability (DINCERTO accredited), as well as the mechanical properties of hemp. These assurances are vital to organisations looking for green products that are genuinely eco-friendly.

Scion's current hemp extracts research is being carried out in our in-house testing facilities in collaboration with industry partner Rua Bioscience, and using the cannabinoid testing services of R J Hill Laboratories.

Stefan says, "With research, innovation, and collaboration, hemp will be an important building block in New Zealand's emerging circular bioeconomy."

FOR FURTHER INFORMATION on our hemp research and capabilities contact Dr Stefan Hill at stefan.hill@scionresearch.com

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