ScionConnections

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Stephen Pearce takes tree measurements using a Haglöf vertex and enters the data into an Allegro data manager.

New Zealand's most productive forest

New Zealand has a small number of 'experimental forests' reserved for research. The Scion-managed Puruki Experimental Forest (Puruki) is the jewel in the crown. Data and models from Puruki underpin almost every management decision modern forestry companies make today; something never even imagined at the time the forest was established.

Given our changing climate, it is urgent we understand the functions of forests in a wider landscape. Forests are central to New Zealand's solution for improving water quality, carbon storage, landscape multifunctionality, and biodiversity. Experimental forests are necessary to demonstrate possibilities at scale, to provide data that validates our models, and to help researchers understand impacts of a warming climate on forest health, resilience and productivity. They are also a place to demonstrate new and sustainable forestry practices that can shape and transform future forest management, leading to new forest designs tailored to products, for example, short rotation species for biobased plastics or fuels.

Long-term access to experimental forests like Puruki is essential to carry out the science that will help to realise New Zealand's opportunity for more biobased products and answer key questions for our nation's future.

The beginning

Puruki forest is located in the central volcanic plateau of the North Island. The forest is part of the Purukohukohu Experimental Basin established in 1968 in response to a call by the United Nations Educational, Scientific and Cultural Organisation (UNESCO) initiative to address a global decline in freshwater resources.

An ambitious programme of long-term research was established to understand the effects of land use change on local hydrology and derived volcanic soils. The land that is now Puruki forest was converted from pasture to forest in 1973, then harvested and replanted with second rotation pine forest in 1997. The second rotation is now 24 years old and approaching harvest.

Highlights from 50 years of research

For over 50 years Puruki forest has been continuously studied. In that time, research undertaken at Puruki has expanded into areas well beyond the original objectives

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Seeing what's possible from wood

For some time, I have been talking about the huge opportunity in front of New Zealand coming from the world's shift away from petrochemicals and fossil fuels towards a sustainable circular bioeconomy.

I wish there was a clear route towards grabbing this opportunity and setting in motion the incentives, pathways, investment and infrastructure to realise it. Scion estimates this opportunity to be $30 billion per annum in 10 years. Just imagine what that would look like.

Around the country are many examples of innovations driven by passionate people that show we can do this at small scale, and as a nation of small businesses such innovators may provide the waves we need to get a tidal change.

Here at Scion, there is a new wave of visitors coming to see what is possible from wood – a fantastic renewable resource.

When our innovation hub, Te Whare Nui o Tuteata, was officially opened on 31 March guests could see the versatility and beauty of wood as a structural building element, and they could see how wood can be transformed into innovative uses that could become mainstream in a circular bioeconomy.

The attending government Ministers expressed real excitement about what Te Whare Nui o Tuteata demonstrates, with the Prime Minister Jacinda Ardern saying "Te Whare Nui o Tuteata is one of the most striking and unique structures I've seen in a long time, and really shows what's possible with timber. Traditionally in New Zealand, we've built large commercial buildings out of steel and concrete. This building showcases what can be done with trees".

Our knowledge, and now our experience, validates that wooden buildings perform wonderfully. They provide an enjoyable working environment, can be designed to result in low damage from earthquakes and be highly fire resistant, and store carbon for the life of the building. With New Zealand radiata pine forests growing the timber needed for this one building in just 35 minutes, Te Whare Nui o Tuteata is a great example of the future of sustainable buildings.

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>
> Jacinda Ardern,
> Prime Minister

From my observations, the 'wow' factor is felt by all who enter its doors, take in the unique diagrid frame then look up the triple height atrium that leads to the custom-designed wooden ceiling. It's quite something - inspired by the structure of the radiata pine genome with lighting reflecting the Matariki night sky. To one side of the ground floor is a small, but fascinating interactive exhibition (about the clever work Scion and partners do) that captivates visitors, and on the other side of the floor is a public café that encourages people to linger and enjoy the experience of being in a building where wood is the hero.

I'm a fan of wood, trees and forests because they offer so much for New Zealanders' well-being in many ways. I'm constantly surprised that the potential of forests to transform our economy is not recognised. We, at Scion, are helping to broaden thinking, expand horizons and turn aspirations into reality. As my colleagues and I embark on our 'pathways to impact' work to implement our Strategy 2030 we aim to bring many along with us on this journey.

Creating economic, environmental and social prosperity from New Zealand's forestry, wood products and wood-derived materials and other biomaterials is Scion's reason for being. We are committed to enabling our core purpose outcomes for New Zealand that will result in a vibrant mosaic across our regional landscapes and find innovative use of resources in ways that are both renewable and recyclable. As champions of a circular bioeconomy for New Zealand we will continue to chase the $30 billion opportunity and help New Zealand meet its climate change targets and "build back better".

Dr Julian Elder
Chief Executive

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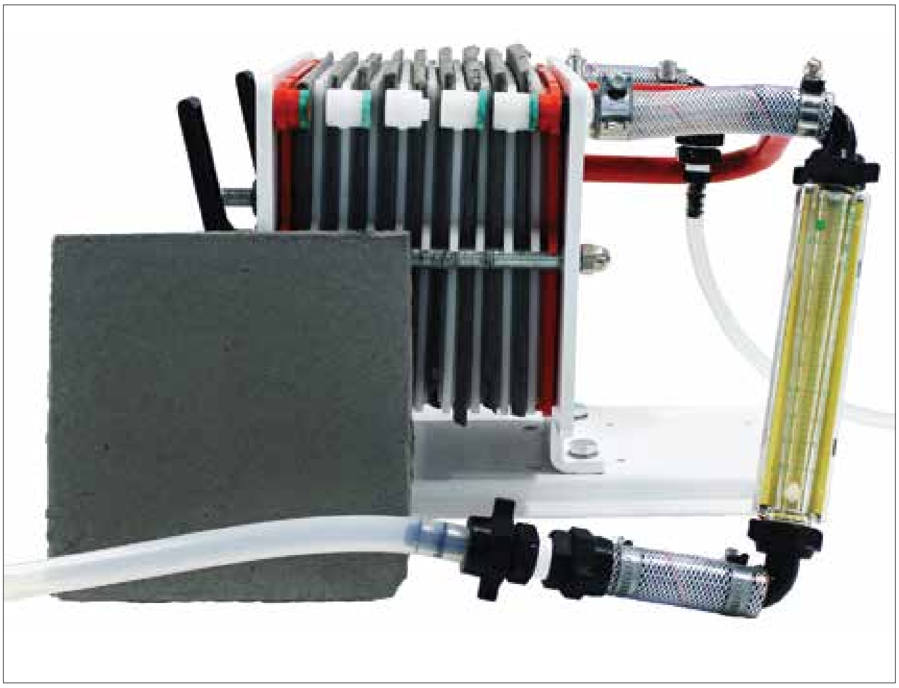
Te Whare Nui o Tuteata – open daily to the public. *www.scionresearch.com/te-whare-nui-o-tuteata*



The filters are embedded with MIPs and designed to fit in industry-standard plate and frame filter systems.

Collaboration creates highly specified filters

Ligar – a leader in molecular extraction technology and Scion have combined their expertise to create food grade filters so precise they can capture specific molecules.

The collaboration has seen Scion's pulp and paper engineering expertise united with Ligar's experience in molecular extraction to produce the paper-based filter embedded with molecularly imprinted polymers known as MIPs.

MIPs

A MIP is a polymer material with a unique impression in it, like a footprint left in the sand which only fits a chosen molecule and can also recognise it from the way the molecule behaves, e.g. charge. MIP technology has been around for some time and is well proven.

The ability to selectively capture and filter material at molecular scale is very useful in concentrating, refining and purifying processes. MIPs can be used to recover highly desirable molecules (valuable metals, for example) for sale or re-processing, and in extracting molecules that are not wanted in the final product (e.g. removing unwanted flavour producing compounds in wine).

There are many industries that can and do make use of such high specialised functionality. However, the integration of the MIPs into the paper-based filter has enabled new applications because of its efficient and functional design.

Paper-based solution

MIPs traditionally come in powder form and are mixed into the material to complete the desired recovery/extraction and must then be filtered out. Incorporating MIPs into a paper-based filter designed by Scion scientists, combines the removal and filtration steps into one efficient process.

The fibres in the paper-based filters hold the polymer in place allowing them to work efficiently. Importantly, the fibres in the plates do not capture anything in the filtration process, ensuring the filters can continue to be used in highly selective applications, including food contact applications.

Naturally aligned for biorefining

Beyond the success of the filter plates there is potential for Scion and Ligar to benefit from working together especially in biorefining. The biorefinery concept is comparable to today's petroleum refineries, which produce multiple fuels and products from petroleum. A biorefinery uses renewable biomass feedstock to be transformed into fuels, power and value-added chemicals. One of the biggest challenges of biorefinery processes is separation and purification of the products. Usually a suite of technologies are used to obtain the purified products – and MIPs could play a key role here.

Scion has long been involved in developing biorefinery processes and there are many applications for Ligar's established industrial scale separation technology. One example is in the potential for MIPs to pre-concentrate processed biomass, a step that could decrease processing volumes and reduce costs and increase the economic viability for some processes.

Scion's General Manger for Forests to Biobased Products Dr Florian Graichen says, "We are excited to work with an innovative partner like Ligar on a strategically important part of our 2030 journey – establishing advanced biorefining in New Zealand. Partnerships are critical for us to achieve our big impact aspirations for New Zealand and biorefineries will form an important part of this strategy, moving towards a circular bioeconomy while meeting the Government's goals for an environmentally and economically sustainable future New Zealand".

The impact of a successful biorefinery network in New Zealand is enormous. Scion's work in the MBIE-funded bark biorefinery project estimates that the high-value materials created could earn between $400-600 million per annum, contribute $1.8 billion to New Zealand's GDP and add several thousand new jobs by 2050. Bringing Ligar and Scion's mutually beneficial technology together will be critical in turning these possibilities into reality.

FOR FURTHER INFORMATION on our work with MIP embedded filters, contact Dr Florian Graichen at florian.graichen@scionresearch.com

Soil percussion auger – taking an intact soil core down to 1 metre, which tells us the nutrient stocks on site in the soil.

Sustaining forest productivity: A 30-year study

A 30-year experimental monitoring of forest ecosystem nutrient levels and forest productivity over a complete rotation has been completed by Scion researchers. The results show that soil nutrient levels and forest productivity can be maintained with site-specific management – specifically through the retention of forest harvest residues and the forest floor at low-fertility sites.

Around 15 percent of New Zealand's planted radiata pine forests are now in their third or fourth rotation. A consistent supply of nutrients is essential to ensure the long-term productivity, health and sustainability of these forests. This is not a new issue, with concern being raised more than 40 years ago.

Effects of removing harvesting residues

Harvesting a forest includes removing the main stem but can also include removal of harvest residues (slash) and even the forest floor, a scenario which is becoming increasingly more plausible as biomass for bioenergy and biofuels are emerging as ways to diminish our reliance on fossil fuels. Understanding the consequences of these practices from one rotation to the next is necessary to ensure our forests stay productive into the future.

New Zealand is part of a global network of "Long Term Site Productivity" trials investigating the sustainability of intensive forest management harvesting practices and the pressures placed on soil resources. The first whole-of-rotation results have now been reported for forests around New Zealand.

Six experiments were planted between 1986 and 1994 throughout New Zealand. Harvesting treatments included removing the stem only, removing all forest residues (or the whole tree) and removing the whole tree and the forest floor. Soil samples were taken at all the sites before harvest and mid rotation. However, forests at Burnham and Kinleith were cleared at mid rotation for dairy conversion and the Golden Downs site was abandoned due to severe wind damage. Forests at Woodhill, Tarawera and Berwick all reached harvest age and soil samples were taken once again.

Most of the nutrients at the sites were held in the soil, but the amount varied considerably from site to site. For example, the sandy soil at Woodhill contained 1,000 N kg/ha while the fertile soils at Berwick contained 12,000 N kg/ha down to 1 m soil depth. At sites like Woodhill, low soil nitrogen levels meant a much greater percentage of the total nitrogen was present in the forest floor litter and therefore the effect of disrupting forest floor was likely to be greater.

As expected, more carbon and nutrients were removed when the forest floor was disturbed, which can happen during harvesting and preparation for planting.

However, by the end of the rotation, the forest floor had recovered. The one exception was forest floor removal at the Woodhill site where the soil is sandy and low in nutrients. There, removing the forest floor had a long-term impact on soil carbon and nitrogen. However, the removal of large amounts of nutrients in harvest residues and forest floor had no effect on wood quality. These results suggest the soils and forest floor were generally able to supply adequate amounts of nutrients and, with time, the nutrient stocks were replenished.

Effect of adding fertiliser

Fertiliser application was also part of the trial, with the intention of removing any nutrient limitations caused by the harvesting treatments. Consequently, very large amounts of nitrogen were applied over many years. This contrasts with the typical practice of applying no fertiliser, or up to 200 N kg/ha if trees are considered short on nitrogen.

> Adding fertiliser increased early rotation productivity, mitigating the effect of removing the whole tree and whole tree plus forest floor.

Adding fertiliser increased early rotation productivity, mitigating the effect of removing the whole tree and whole tree plus forest floor. Fertiliser was especially effective at sites like Woodhill and Tarawera where carbon and nitrogen stocks were initially low. Although the added nitrogen could be used to counteract the negative effects of forest floor removal, further research is required to ascertain the amount required to offset forest floor removal.

Predicting nutrient levels

The nutrient balance model, NuBalM, was developed as a part of this work. NuBalM can predict nutrient levels over multiple rotations and is being used to support precision nutrient management and improve productivity and underpin sustainable forest management. The model also has wider application. For example, it can also be used to predict nitrogen that could then be leached under new land use scenarios, and this approach supports a pathway to engage with the OverseerFM land use model (the principle agricultural modelling system).

Applying what we have learnt

The results from this work are already being used by the forestry industry to develop and implement site-specific nutrient management plans. Understanding the potential effects of forestry residue removal on some sensitive sites allows for site specific harvesting (and preparation) plans that ensure residues are retained and evenly spread.

NuBalM is also being used to predict the cumulative effects of repeated harvest removals and to calculate how precision nutrition could be used to maintain or increase productivity. Some companies have also begun soil sampling and installing fertiliser trials.

NuBalM can be used to identify sites with greater fertility and that have the capacity to cope with intense harvest residue removal and sites where harvest residues should be retained. Knowing where forestry residues are available for use is vital for planning new forests and new processing plants in New Zealand to utilise forestry biomass in the move towards a carbon-neutral bioeconomy.

Microbial communities

These trials also provided the framework that supported several novel explorations of the soil microbial community present in New Zealand planted forests, and how their activity might influence tree health and productivity. Site treatments of removing the forest floor, and adding fertilisers at sites low in nutrients, were seen to reduce microbe diversity. These findings have contributed to expanding the scope of research exploring the potential to use the microbiome – microbes intimately connected with trees – to increase the resilience of planted forests to disease, drought and other stresses.

Sustainable future forests

New Zealand is the first country to complete and report on a full rotation of the Long Term Site Productivity harvest removal experiments, largely due to the rate at which radiata pine grows in this country. The work supports the pathway to a more sustainable forest industry as the global demand for wood and fibre places greater pressure on forest soils.

> This work also demonstrates the sustainability of planted forestry in New Zealand, which is essential for public acceptance of commercial forestry, and to meet the requirements of external bodies such as the Forest Stewardship Council.

The ground-breaking work has added to our understanding of how forest ecosystem nutrient pools change over a rotation and over many rotations. The forest floor has been confirmed as an important store and source of nutrients, particularly on low nutrient sites, where retaining the forest floor is essential to maintain long-term nutrient supply. The monitoring strategies developed and deployed (NuBalM) give the industry new capability to predict critical soil fertility thresholds before they are reached and also to develop site specific management practices to preserve soil fertility and maintain forest productivity.

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Funders include the Forest Growers Levy Trust, the New Zealand Forest Owners Association and the New Zealand Farm Forestry Association with historical input from the New Zealand Forest Service and numerous forest companies at the time of establishing and early management of the experiments.

FOR FURTHER INFORMATION on the forest harvesting trials contact Loretta Garrett at loretta.garrett@scionresearch.com

Our model was tested over 16 ha and identified 13,295 planted trees and delineated 1,541 blocks of native forest, both with high accuracy.

Managing newly planted forests and indigenous biodiversity with AI

Scion is working with remote sensing specialists Indufor on an artificial intelligence-powered model that uses remotely sensed data to help manage newly planted radiata seedlings and indigenous biodiversity.

How it works

Together, Scion and Indufor have created a process that can transform remotely sensed data into a model to identify radiata seedlings and pockets of indigenous forest. This data can be used to understand seedling survival rate, while also gaining a clear picture of the indigenous biodiversity on site.

High-resolution aerial imagery (5 cm) is processed through a trained deep learning model, which then identifies, maps and draws polygons around the newly planted radiata seedlings and pockets of indigenous forest.

The new model offers many advantages. Unlike earlier models, it needs much less data to train it. The approach is also much lower cost per unit area than UAV-based imagery and has been successfully used over large areas of afforested land. The team is now exploring the potential to use the 3D point cloud generated alongside the aerial imagery during the data generation process. The point cloud data could potentially be used to characterise the biomass, height and density of the indigenous forest identified on each site.

Understanding biodiversity

Indufor is using this model now to help foresters map the exotic and indigenous species growing on their land, and they have seen a great demand for this type of service. In addition to assisting foresters to monitor the establishment of their newly planted radiata seedlings, it aids them in identifying indigenous forests on their land and how to integrate them within the landscape appropriately, e.g. seeing how big and far apart forest fragments are and what steps could be taken to join them up.

Mapping also helps answer key questions about the biodiversity carrying capacity of the indigenous forest, for instance, can the existing fragments support indigenous bird species that help spread tree seeds? Knowing this could help land managers to understand what activities are required to help their pockets of indigenous forest to expand and connect.

The future

With more development, the team hopes to update the model to identify the indigenous species mix within a stand, painting a much richer picture of the biodiversity and biomass. This capability would help answer long-term planning questions, such as, is there a good mix of tall woody species and shrubs on the land? Do I need to carry out predator control and plant native species to increase the value of the existing forest?

With more development, the team hopes to update the model to identify the indigenous species mix within a stand, painting a much richer picture of the biodiversity and biomass.

Scion project lead Dr Grant Pearse says, “There’s a lot in favour of this model; it’s cost-effective, scalable and accurate. We hope that with a little more development we could accomplish a lot more”.

Dr Pete Watt, leader of Indufor’s resource monitoring team, says, “We are excited to leverage this promising technology and further explore how we can use it to accurately map planted and native forests across landscapes”.

Forests, both native and exotic, are vital to New Zealand’s long-term climate change response, and this technology could play a role in ensuring those efforts are successful.

FOR FURTHER INFORMATION on our machine learning work, contact Dr Grant Pearse at grant.pearse@scionresearch.com

"Hatching" a kiwi to demonstrate 4D printing and controlled plastic degradation.

Controlled degradation with 3D-printed enzyme-embedded plastics

Enzymes embedded into plastic objects can be triggered to break down the plastic at the end of the object's life.

This enzymatic technology offers a new way to ensure that compostable plastics biodegrade quickly in an environmentally friendly way.

Embedding enzymes

Scion materials scientists have been working on the problem of developing cost-effective ways for mass producing enzyme-embedded plastics. The challenges include the use of heat during plastic processing. Many enzymes are denatured at higher temperatures and lose their activity. And the enzymes need to be embedded into the plastic, which up to now has been accomplished by encasing the enzyme and plastic using toxic solvents or the use of additional protective layers around the enzyme.

The solution developed by the team is deceptively simple. They mixed solid enzyme with finally ground polycaprolactone (PCL), a biodegradable polyester with a low melting point, and used 3D printing techniques to mimic industrial thermoplastic processing where plastic is heated to or past its melting point then shaped (extruded, moulded or blown).

Promising results

The chosen enzyme, in its solid state, was found to be very heat stable. During testing, samples heated to 130°C for two hours retained most of their activity.

Printed films made by the research team broke down in aqueous conditions with the rate of degradation dependent on the amount of enzyme added to the plastic. After one week, 400 mm thick plastic films containing 1% by weight of the enzyme had lost 70% of their original weight.

Read the full story at www.scionresearch.com/degradableplastics

FOR FURTHER INFORMATION on controlled degradation contact Dr Angelique Greene at angelique.greene@scionresearch.com

New Zealand's most productive forest

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of the experimental forest. Key research includes land use comparison with pasture and native forests for water yield and quality, soil carbon and nutrients and targeted forestry research on forest health, nutrition and disease, biomass allocation, solar radiation impacts on growth, leaf area and carbon stocks, and spatial variability of rainfall and water yield. This data has gone on to provide invaluable information for the development of New Zealand's key forestry models including the forest carbon predictor, and nutrient balance model.

Data from Puruki has also been used for hydrological modelling and water quality. One of the key findings showed that there was less nitrogen and phosphorus exported from pine forest than pasture or indigenous forest. This work additionally provided evidence that planted forests both reduce flooding and regulate water flow.

The former land-use of the site has also contributed to interesting findings. The fertile ex-pasture land has helped create one of the fastest growing forests in New Zealand. Puruki had a 54 percent increase in productivity from one rotation to the next, making it 63 percent more productive over the second rotation compared with the national average (all species) for post-1989 planted forest. The results come from a combination of a fertile site, healthy planting stock and high stocking densities. Research has also shown Puruki to have 16 times faster carbon sequestration than natural forest regeneration. If all forests grew like Puruki, less land would need to be converted to trees to meet New Zealand's net emission targets.

Conclusion

As plans are made to harvest the second rotation and plant a third, there are new opportunities to capture end of rotation and harvest data, and improve our understanding of forest productivity, carbon sequestration, hydrological modelling, water quality, and certain biodiversity values.

The demands on New Zealand's forests are changing and researchers need a series of long-term forests to provide the data that will enable environmental, economic, social, and cultural opportunities for all New Zealanders. Puruki, close to Rotorua, can be the centrepiece of this trial series and can continue to contribute to future forest and catchment level management strategies.

FOR FURTHER INFORMATION on the research undertaken at Puruki Experimental Forest contact Loretta Garrett at loretta.garett@scionresearch.com

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

Trialling insect traps at the Port of Tauranga

Scion scientists have trialled a selection of insect traps to increase detection of invasive species before they can establish in New Zealand.

A team led by Dr Carl Wardhaugh trialled eight types of surveillance traps at New Zealand's Port of Tauranga to determine optimal trap types to sample a broad spectrum of the insect fauna. These traps captured flying and crawling insects using chemical lures, attractive lights, and passive methods that trap insects inflight or while crawling. The insect catch data and effectiveness of the various traps will inform the design of surveillance programmes at seaports and other high-risk points of insect entry.

Insect sampling was undertaken during four one-week-long periods over the course of a year (Feb, May, Sep, Dec) to assess seasonal differences in the activity and diversity of insect species.

Findings

In total, the eight trap types caught over 250,000 invertebrates including over 46,000 beetles and happily, no new-to-New Zealand species were observed among the 211 species identified. UV-light traps collected the largest proportion of beetle species (~84 percent) and were complemented by pitfall traps that collected ground fauna, especially ants. A small number of light traps operating for a relatively short amount of time could potentially sample the vast majority of species resident in a given area.

Next steps

Given the large volume of invertebrates collected, manually identifying species for potential insect incursions presents a significant challenge. Traps with cameras and image recognising machine learning software are currently under testing and could help to overcome this hurdle.

Another promising avenue is the use of eDNA that will allow for the mass sequencing of samples. Both approaches are limited to existing data (imagery and genetic sequences), however, both are rapidly evolving fields. With further development, both approaches have the potential to allow for the rapid identification of new exotic species.

Read the full story at www.scionresearch.com/trialtraps

FOR FURTHER INFORMATION on this work contact Dr Carl Wardhaugh at carl.wardhaugh@scionresearch.com

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