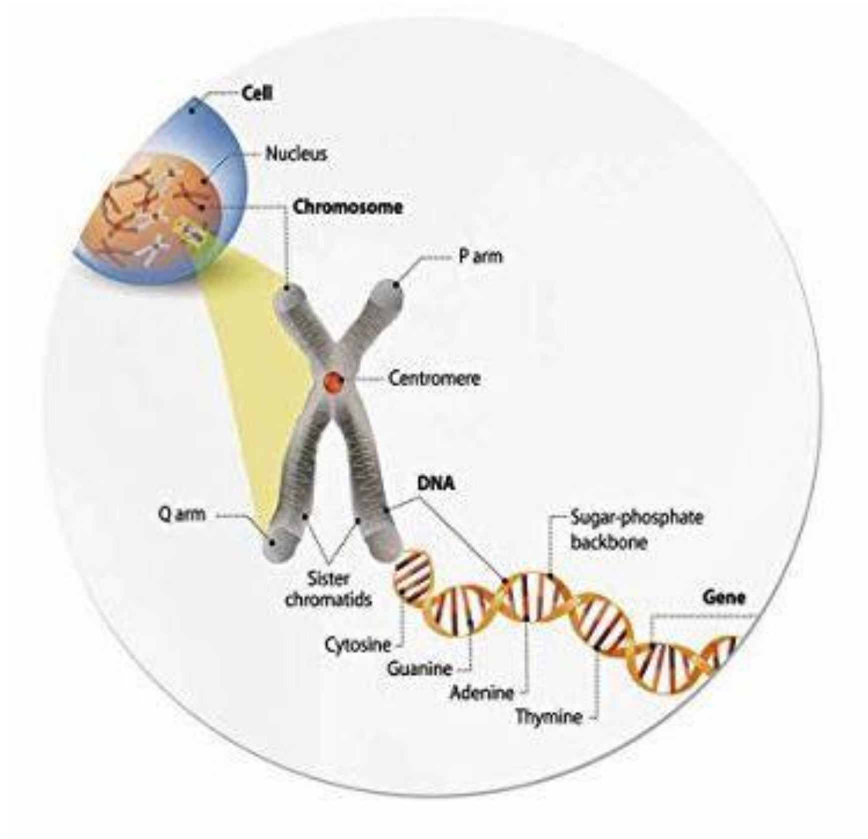
Useful Tool in a Forest Manager's Toolbox

Genetic modification (GM) research and deployment in plantation forestry with lessons from Australian agriculture, New Zealand, and south-east United States forest industries.



Source: sciencephoto.com

GOTTSTEIN AWARD PROJECT REPORT

GAVIN MATTHEW

JOSEPH WILLIAM GOTTSTEIN MEMORIAL TRUST FUND

The Joseph William Gottstein Memorial Trust Fund was established in 1971 as a national educational Trust for the benefit of Australia's forest products industries. The purpose of the fund is *"to create opportunities for selected persons to acquire knowledge which will promote the interests of Australian industries which use forest products for the production of sawn timber, plywood, composite wood, pulp and paper and similar derived products."*

Bill Gottstein was an outstanding forest products research scientist working with the Division of Forest Products of the Commonwealth Scientific Industrial Research Organization (CSIRO). Tragically he was killed in 1971 photographing a tree-felling operation in New Guinea. He was held in such high esteem by the industry that he had assisted for many years that substantial financial support to establish an Educational Trust Fund to perpetuate his name was promptly forthcoming.

The Trust's major forms of activity are:

1. **Fellowships and Awards -** each year applications are invited from eligible candidates to submit a study programme in an area considered of benefit to the Australian forestry and forest industries. Study tours undertaken by Fellows have usually been to overseas countries, but several have been within Australia. Fellows are obliged to submit reports on completion of their programme. These are then distributed to industry if appropriate. Skill Advancement Awards recognise the potential of persons working in the industry to improve their work skills and so advance their career prospects. It takes the form of a monetary grant.
2. **Seminars -** the information gained by Fellows is often best disseminated by seminars as well as through the written reports.
3. **Wood Science and Forest Science Courses –** each year the Trust organises week-long intensive courses in wood science or forest science for people working or studying in the Australian forest industries.
4. **Study Tours -** industry group study tours are arranged periodically and have been well supported.

Further information may be obtained by writing to:

J.W. Gottstein Memorial Trust Fund,
P.O. BOX 346
Queanbeyan NSW 2620
www.gottsteintrust.org

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ABOUT THE AUTHOR

The author in front of Rayonier Advanced Materials plant at Fernandina Beach, Florida, US.

Gavin Matthew has over 20 years of diverse experience in industry policy advocacy, natural resource and forest management, wood processing and consulting. Gavin holds a Bachelor of Science (Forestry) degree and a Bachelor of Economics degree, both from the Australian National University, and a Graduate Diploma in Applied Finance and Investment.

Gavin is a Senior Policy Manager* with the Australian Forest Products Association (AFPA)[1]. AFPA is the peak national body for Australia's forest, wood, and paper products industry, representing the industry's interests to governments, the public and other stakeholders on the sustainable development and use of Australia's forest, wood, and paper products.

**Readers please note that the views and observations expressed in the following document are the author's alone.*

ACKNOWLEDGEMENTS

I would like to personally thank the Gottstein Trust for providing the financial support to undertake this study tour and AFPA for allowing me the time to undertake the travel. I also want to acknowledge and thank the many people who assisted in this project through arranging introductions, and those that I visited and interviewed for being generous with both their time and their expertise.

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[1] *See www.ausfpa.com.au*

EXECUTIVE SUMMARY

The intent of this project is to explore whether, with the appropriate policy settings, research and regulatory controls, we can utilise genetic modification (GM) technologies in plantation forestry in Australia, to address future increasing wood fibre demand and other looming challenges. This analysis will be informed by learnings gained from existing GM technologies used in New Zealand (NZ), south-east United States (US), and Australian agricultural crops.

This report details the status of the GM issue, the main policy and regulatory drivers, and potential benefits and outcomes from relevant GM technologies research and deployment for plantation forestry. This information was gathered via meetings, discussions and site visits with relevant company representatives, key researchers, industry associations and policy makers.

This paper is intended to be a broad observation of the topic compared with a detailed scientific piece on GM technologies and their application. The thinking is that understanding Australia's social, environmental economic, political, and regulatory environment in relation to potentially deploying GM technologies for commercial tree species and gaining learnings from similar countries, is as important as the science.

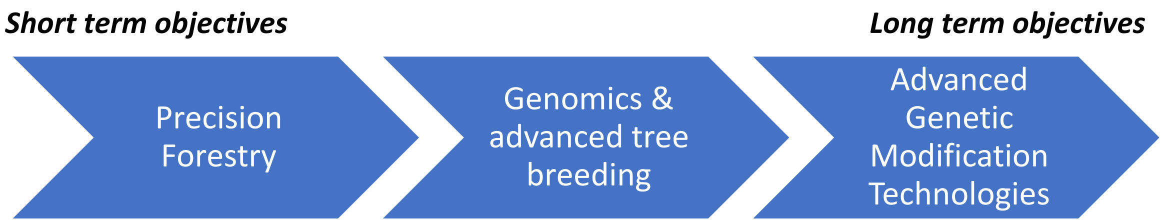
We know we need advances in climate adaption, yield, productivity, wood characteristics, and pest and disease resistance of our forest plantation resource — the recent bushfires, myrtle rust and giant pine scale incursions are sobering examples of the ongoing challenges/threats — to protect our entire industry, keep up with demand and keep industry competitive, but policy makers in Australian are not currently considering the utilisation of more advanced GM technologies in plantation forestry.

At the beginning of this project I wanted to explore three (3) challenging questions for our renewable forest industries in Australia: **Is advanced GM technology for us? What needs to change? How can we change it?**

In short, I came to the following conclusions which are developed further in this paper:

- **Is advanced GM technology for us?**
  In the long term, yes, especially with looming market, climate change and biosecurity risks. However, it is argued that progressing a GM technology framework in Australia needs to be as part of an integrated tree improvement strategy to reduce risk, increase our trees and forests resilience to known and emerging threats, and increase commercial benefit.

  A Strategic Plan would be needed that could be temporally broken up into short term (application of precision forestry techniques), medium term (improvements in advanced tree breeding, precision forestry techniques and investment in new technologies, wood products and wood product solutions, while preparing the regulatory and social purpose ground for implementing a GM technology plan), and in the longer term (advanced GM technologies being researched and deployed for key commercial tree species).



- **What needs to change?**
  A Strategic Plan is the essential first step, to establish an advanced GM technology framework for commercial tree species. Actions must include:
  - Stakeholder engagement and communication strategy, including social purpose.
  - Cost/benefit analysis undertaken to inform the Strategic Plan.
  - Sustainable Forest Management (SFM) certification engagement.
  - Political advocacy and engagement at both Federal and State government levels.
  - Regulatory engagement with the Office of the Gene Technology Regulator and State government regulators.
  - Whole-of-industry commitment to progressing a GM technology strategy, R&D program and workplan.
  - Establish an industry position/role to coordinate and progress a GM technology strategy and workplan.
  - Ongoing collaborative industry funding commitment with matched government funding will be needed for a targeted R&D program. The funding required will be magnitudes greater than currently expended by our forest growers.

- **How can we change it?**
  - Concerted political and industry will, and commitment need to be coupled with large investments in funding and resources, collaborative effort and communication, and R&D and policy work. A program is anticipated to have a long timeframe of more than 10 years.
  - However, initially our forest industries need to wring more value out of the existing tree stock by use of precision forestry, and currently accepted gene technologies along the gene intervention spectrum (including advanced tree breeding and genomics), plus investment in in new technologies, wood products and wood product solutions. Significant gains can be achieved in a shorter timeframe of less than 10 years.

KEY OBSERVATIONS*

Some of the key observations[2] made during my exploration of this subject include:

1. GM technology spans a broad spectrum of intervention from long-used tree breeding techniques, through GM technologies that improve existing gene stock (e.g. gene marker assisted selection) to complex advanced GM technologies that result in GM organisms.

[2] *Note: these are the author's specific observations based on a view of Australia's specific political, social, and regulatory environment.*

2. Many challenges (and opportunities) face Australia (e.g. climate change, energy certainty, biosecurity threats, increasing market demands and land-use competition) which will impact on our renewable forest industries. Yet, our industries have huge potential to address these challenges. We are already using technologies along the GM spectrum and as the challenges (and opportunities) grow for Australia, we need to be prepared to apply the best solution.

3. There are significant and cost-effective gains to be made by industry in applying well-known and off-the-shelf precision forestry methods, and advanced tree breeding techniques in both new plantations and existing plantations, as Australia is still only a few generations into existing breeding programs. These gains can be made while strategically preparing the policy, social and technological 'ground' for advanced GM technologies.

4. Advanced GM technologies are a complex and diverse area of research and development.

5. Applying GM technology is more complicated than just accessing science and applying the technology. Understanding the commercial and biological trade-offs in deploying GM technologies, understanding the issue that you are trying to address with an appropriate approach, increasing social acceptance, and having the necessary regulatory approvals in place, are all essential inputs to success.

6. Australia's plantation trees need advances in climate adaption, yield, productivity, wood characteristics, and pest and disease resistance to protect our supply chain, meet increasing wood fibre demand, and stay internationally competitive.

7. Wood product manufacturing innovation (e.g. Engineered Wood Products (EWP), panel products, and Laminated Veneer Lumber (LVL)) can complement a longer strategy of GM technology deployment. By bridging the gap between the existing resource and the improved resource but also better utilising the resulting wood characteristics after a tree improvement plan has been implemented.

8. With the ongoing importance and high uptake of Sustainable Forest Management (SFM) certification schemes in Australia, provisions relating to the utilisation of GM technologies in plantation forestry contained in these standards are important. There is no doubt that if any advanced GM technology program and potential deployment is to be successful, then a level of social acceptance needs to be achieved and incorporation into existing SFM certification schemes acceptance of this is a major step.

9. Agricultural industries have paved the way in Australia by progressing GM technologies and deploying resulting material, predominately for food chain. Australian forest industries can learn a lot from these long-running and sophisticated GM technology programs.

10. The general scientific consensus is that responsible GM technologies used to date pose no greater risk to human health or the environment than similar products derived from traditional breeding and selection processes, which are already accepted for food and fibre product uses.

11. How benefits and controls around GM technology are communicated to industry, the public, and policy makers is important to increase levels of social acceptance around GM technologies, especially how the key perceived risk mitigations are communicated.

**Further observations are contained in this Report*

US photo: Southern pine needles.

CONTENTS

1. AUSTRALIA'S FOREST PLANTATION CHALLENGES

Australia's forest plantations are a renewable and sustainable resource that can store significant amounts of carbon dioxide (CO_2) in standing timber and innovative wood, paper and bioproducts, and for many years afterwards by the recovery and recycling of these renewable products. New plantations support employment, economic activity, environmental and social outcomes in key regions around Australia.

In 2018–19, Australia's total commercial plantation area was 1,933,400 hectares[3], a decrease of 9,300 hectares (0.5 per cent) from 2017–18 (**see Figure 1**). These plantations are located within the 15 National Plantation Inventory (NPI) regions close to associated regional processing facilities resulting in the formation of distinct regional forest industry hubs (**Figure 2**).

Figure 1 – Australia's total and new forest plantation area

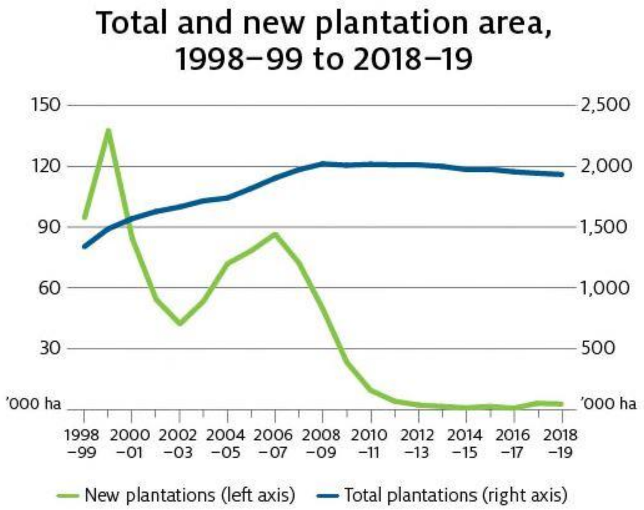
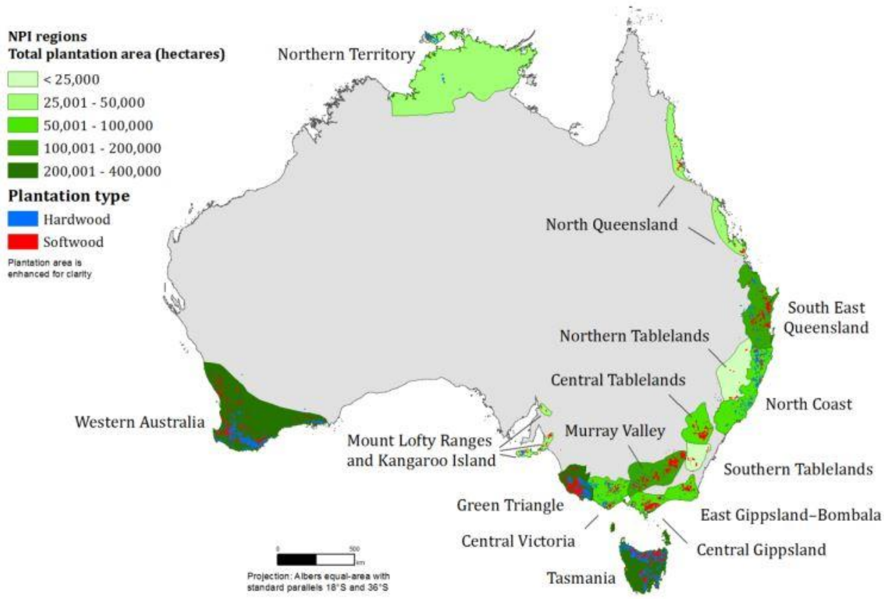


Figure 2 – Australia's 15 National Plantation Inventory (NPI) regions



[3] *Source:* https://www.agriculture.gov.au/abares/forestsaustralia/plantation-inventory-and-statistics

Australia has a large land mass, however a smaller (yet still significant) amount of land can support commercial-quality forest plantation production based on current land use, water availability and productivity potential. A changing climate's impact on that available land, including more frequent, longer duration and more intense droughts (e.g. decreased land productivity) and extreme weather events (e.g. cyclones and bush fires), increased biosecurity threats (e.g. from pests and diseases), and also new opportunities like potential bioenergy residues, will impact on productivity and the viability of the forest product industries that they underpin **– more on those issues later.**

Softwood plantations are managed primarily to grow sawlogs that are processed into products, such as building and construction materials. Softwood pulp logs produced from thinnings and lower quality parts of the tree are used to produce engineered wood products, landscaping products, and pulp and paper products.

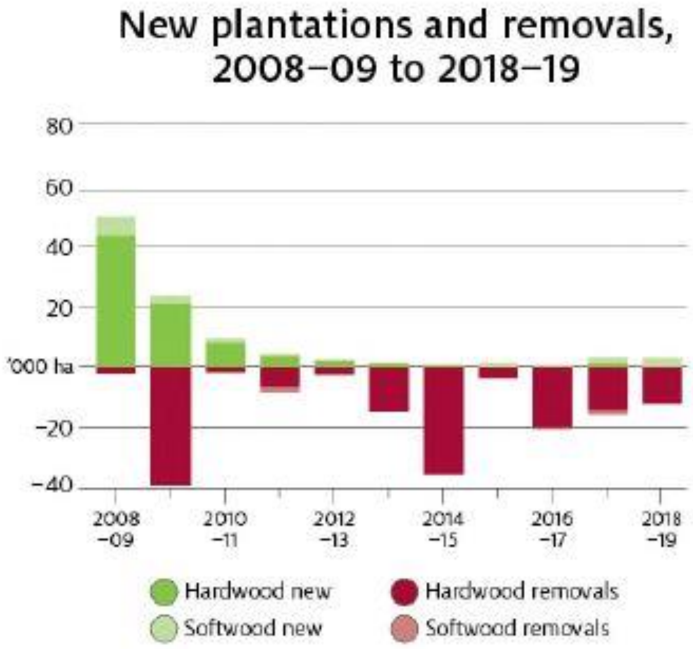
Hardwood plantations are managed primarily to grow pulp logs for products such as woodchips and paper. An increasing amount of hardwood plantations (~ 18 per cent) are being managed to produce sawlogs and engineered wood products to be processed into products such as flooring, panels, decorative and structural timbers.

It should be noted that the existing plantation estate is not static due to the ongoing process of renewal via harvesting of mature hectares and then replanting those hectares with new trees. For example, in 2018–19 a total of 58,500 hectares of plantations were harvested and then replanted, comprising 24,600 hectares of replanted or coppiced hardwood plantations (42 per cent) and 33,900 hectares of replanted softwood plantations (58 per cent). This constant cycle of renewal is important for applying R&D innovation and tree improvement techniques.

Softwood and hardwood plantations provide more than 80% of the domestic fibre inputs for our national forest product industries and markets. However, investment in new plantations in Australia has effectively come to a standstill and significant marginal hectares are being removed from the national estate (due in part to poor productivity, stranded assets, and competition by other land-uses).

According to ABARES figures over 66,000 hectares have been removed or converted back to agriculture from Australia's plantation asset over the last 5 years (**see Figure 3**). Timber sawmillers, engineered wood products (EWP) processors and pulp & paper manufacturers (many who are based in regional Australia) see an uncertain future without long-term access to quality timber resources. This uncertainty has been enhanced by recent devastating bushfires impacting large areas of plantation and future timber supplies.

Figure 3 – New forest plantation areas and removals in Australia.



Observation 1: ***Forest plantations provide more than 80% of the domestic fibre inputs for our national forest product industries. However, investment in new plantations in Australia has effectively come to a standstill and significant marginal hectares are being removed from the national estate. This is especially concerning considering the changing climate's impact on available land in Australia, including more frequent, longer duration and more intense droughts and extreme weather events, increased biosecurity threats, and opportunities like potential bioenergy residues.***

2. WHY DO WE NEED RENEWABLE TREES AND WOOD PRODUCTS?

As Australia's population grows, and with global demand for timber expected to quadruple by 2050[4], the challenge to meet this growing demand will become increasingly difficult under current settings. From high-rise and commercial timber building construction to replacing plastics, chemicals and energy sourced from fossil fuels with new and emerging wood-fibre based materials, global demand for renewable wood and fibre is only going to increase.

The many social and environmental benefits of trees are well known and documented. Forest plantations can provide multiple carbon abatement benefits, through the carbon stored in the forest and harvested wood products, the substitution of more energy intensive products with wood products and the use of woody biomass for renewable bioenergy.

Wood fibre is an amazing natural, renewable, recyclable, and sustainable resource. Policy makers should recognise that renewable forest industries can play a significant role in storing carbon in trees and products, reducing greenhouse gas emissions, converting fibre into bioproducts (that substitute for products sourced from fossil fuels), and transitioning to a lower carbon future.

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[4] *The World Bank, 2016 – Forests Generate Jobs and Incomes, available at www.worldbank.org.*

Plantations are vital to the growth of downstream processing in wood, paper and emerging bio-based products, and essential if we are to have a global–scale, internationally competitive industry delivering vital regional jobs in the future. Forest industries also provides stable, long-term employment in regional and rural towns around Australia.

Forest products industry is one of Australia's largest manufacturing industries with an annual turnover around $25 billion. It contributes around 0.5% to Australia's gross domestic product and 6.6% of manufacturing output[5]. Around 80,000 people are directly employed along the industry value chain in the growing and processing of our forest products with a further 100,000 jobs supported through flow-on economic activity.

Box 1 – Forest industry supply chain multipliers

a. *Forest plantation job multiplier*

For every 100 hectares of forest plantation in Australia, it has been shown that around 1.5 direct jobs are created in management, harvesting, haulage and processing[6]. Noting that many of these jobs are regionally based and important for the economic well-being of these regions.

b. *Construction industry supply chain multiplier*

The Australian Bureau of Statistics (ABS)[7] estimates that for every $1 million spent on construction output around $3 million in output would be generated in the economy as a whole, giving rise to 9 jobs in the construction industry and 37 jobs in the economy as a whole from all effects.

The integration of trees into productive agricultural landscapes can take many forms, including timber belts, plantations, woodlots, wide-spaced tree plantings and the sustainable management of new and existing stands of native vegetation and regrowth, including sustainable native forest management.

By careful planning and location in the landscape, these sustainable practices can assist with:

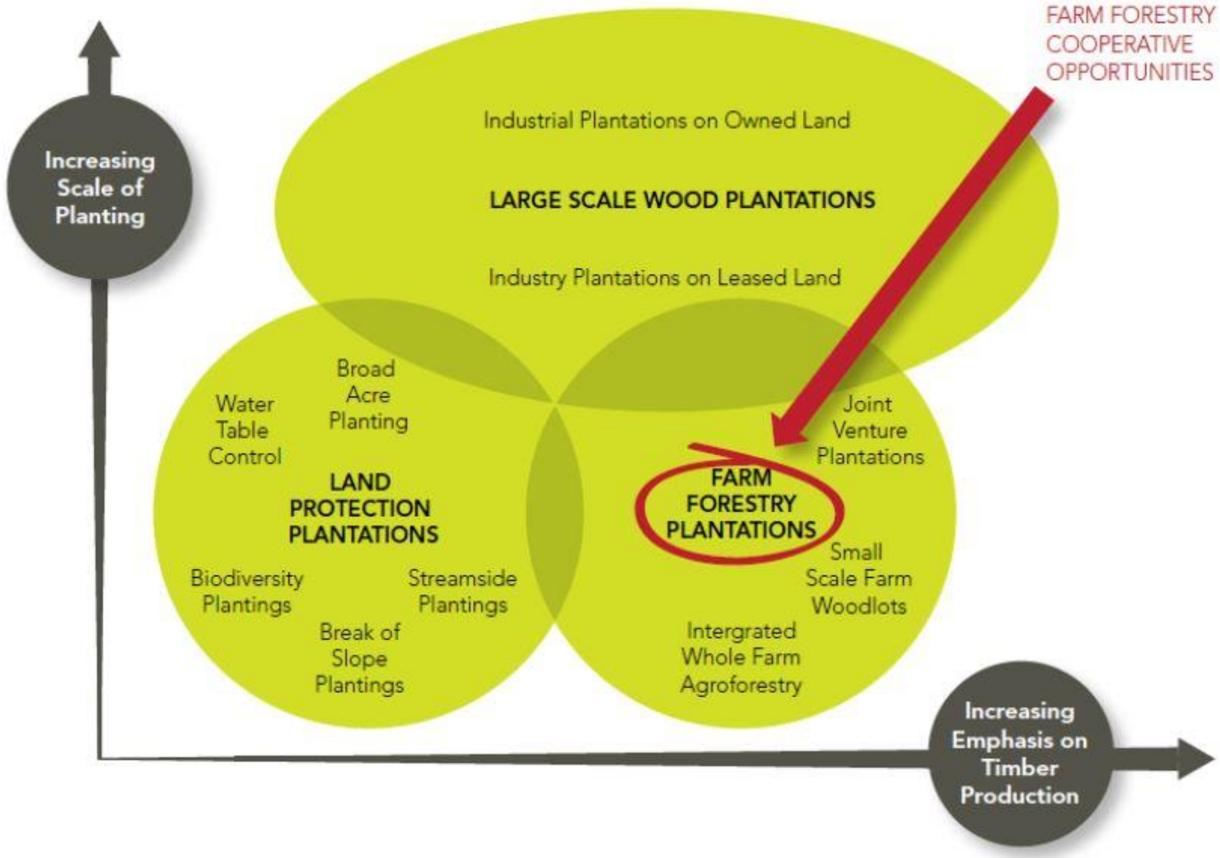
- reducing salinity
- improving water quality
- enhancing habitat restoration/revegetation (e.g. mine sites)
- continual improvement of soil management
- waste-water management

[5] https://www.agriculture.gov.au/abares/research-topics/forests/forest-economics/forest-wood-products-statistics
[6] Bureau of Resource Sciences 2015
[7] https://www.abs.gov.au/Ausstats/abs@.nsf/94713ad445ff1425ca25682000192af2/ed6220072793785eca256b360003228f!OpenDocument

Incorporating commercial tree planting and forestry activities into farming systems (**see Figure 4**) can also:

- provide farm income diversification (e.g. renewable timber products)
- improve agricultural productivity enhance carbon sequestration and lower net carbon emissions
- generate soil conservation and water quality benefits

Figure 4:



Forest industry participants will remember, if not for our long and successful history tree breeding and genetic selection programs, Australia would not have come close to two million hectares of softwood and hardwood plantations productively growing around Australia.

We know we need advances in climate adaption, yield, productivity, wood characteristics, and pest and disease resistance of our forest plantation resource — the recent bushfires, myrtle rust and giant pine scale incursions are sobering examples — to protect our entire industry, meet increasing demand for renewable wood fibre, and keep industry competitive, but policy makers in Australian are not currently considering the utilisation of more advanced GM technologies in plantation forestry.

Observation 2: ***Forest plantations provide products that are natural, recyclable, and renewable. Australia's forest plantation trees need advances in climate adaption, yield, productivity, wood characteristics, and pest and disease resistance to protect our entire industry, meet increasing wood fibre demand and stay competitive. Policy makers in Australian need to consider the utilisation of more advanced GM technologies in plantation forestry.***

3. GENETIC MODIFICATION (GM) TECHNOLOGIES SUMMARY

GM technologies (also known as genetic engineering) provide ways to make changes to genes (e.g. genes are the working subunits of deoxyribonucleic acid (DNA) with each gene containing a set of instructions). Traditional biotechnology has been practised for centuries around the world. We have used conventional breeding to create new crops, new breeds of livestock and pets.

Gene technology is a modern branch of biotechnology that allows direct modification or removal of a gene, or the transfer of a gene from one species to another. When plants, animals and other organisms are changed using gene technology they are known as genetically modified (GM) organisms.

Box 2 – Key GM technology related terms:

Gene: *A sequence of DNA that encodes a function or trait within a cell of an organism, usually in the form of a protein that performs the function. The gene is transcribed to a matching sequence of RNA, which is then translated to a protein.*

Genetic modification (GM): *The process of altering an organism's genes or DNA.*

Genetically modified organism (GMO): *A live and viable organism whose genes have been modified. For regulation by the OGTR, in Australia the term 'genetically modified organism' has a precise legal definition under the Gene Technology Act 2000. A GMO can be an organism that has been modified by gene technology; or an organism that has inherited particular traits from an organism (the initial organism), being traits that occurred in the initial organism because of gene technology.*

GM product: *The non-living outcomes of gene technology, usually in the form of foods and textiles.*

GM technologies: *All applications of genetic modification, including biological entities and derived, non-living products.*

To a geneticist, genetic modification means a modification in the organism's genetic material. This heritable form of variation of course is caused by mutation. Mutation can be natural or induced. For years, plant breeders have used induced mutation breeding to create favourable traits in plants as well as other organisms. Tree breeders can screen progeny for certain traits of interest and can also select against detrimental traits. However, if the modification includes the introduction of a gene from another organism, then this process is known as **transgenic**.

A rapidly developing gene editing technique is **CRISPR (or Clustered Regularly Interspaced Short Palindromic Repeats)** a process that edits a short sequence of DNA within an organism. No new or foreign DNA is introduced.

Genomics is a rapidly developing branch of science focusing on the structure, function, evolution, mapping, and editing of genomes. A genome is a specific organism's complete set of DNA, including all of its genes. Genomics focuses on the collective characterization and quantification of genes and involves the sequencing and analysis of genomes through uses of high throughput DNA sequencing and bioinformatics to assemble and analyse their combined function and structure. Access to computers and massive increases in processing power is underpinning rapid advances in genomics.

Research and development in forest genomics has lagged that of other agricultural systems. However, forest genomics are poised to enter a very productive phase owing to the advent of next-generation sequencing technologies, genetic diversity in forest trees, and the need to mitigate and adapt to the effects of climate change and other challenges.

Box 3 – a genomic R&D project in Australia

Australian forestry has begun to utilise the exciting developing technology of genomics, including a project announced in 2019 (of an up to $1 million) under the National Institute in Forest Products Innovation (NIFPI) Mt Gambier research centre to the Tree Breeding Australia Ltd (TBA)[8] for the development of state-of-the-art genomic resources for pine breeding to enable single-step genomic selection.

Single nucleotide polymorphisms, frequently called SNPs (pronounced "snips"), are the most common type of genetic variation in an organism. Each SNP represents a difference in a single DNA building block, called a nucleotide. SNPs occur normally throughout an organism's DNA. These variations may be unique or occur in many individuals. Most commonly, these variations are found in the DNA between genes. They can act as biological markers, helping scientists locate genes that are associated with certain traits (e.g. disease resistance etc).

Observation 3: GM technologies are a complex and diverse area of research and development. Forest genomics has lagged that of other agricultural systems but globally is poised to enter a very productive phase owing to the advent of next-generation sequencing technologies, genetic diversity in forest trees, and the need to mitigate and adapt to the effects of climate change and other challenges.

[8] http://www.stba.com.au/

4. SPECTRUM OF GENETIC INTERVENTION

GM technology is a complex area of science and it should be appreciated that there is a spectrum of genetic intervention from basic tree selection and breeding to complex GM technologies and transgenesis. In forest science circles, basic interventions that are not considered to be GM technologies include: **in vitro fertilization; selective tree breeding; natural processes such as, conjugation, transduction, and transformation; and polyploidy induction**[9].

Australia has a long and successful history of tree breeding research and deployment in plantation forestry to improve productivity and focus on desired traits. See **Figure 5** below for the major forward progress already made on Monterey Pine - *Pinus radiata* (a key forest plantation species).

Figure 5 – advanced tree breeding impact on a key commercial tree species.

Natural Monterey Pine (original stock)

Monterey Pine (improved stock)

An example of this success is [Tree Breeding Australia Ltd (TBA)][10] which is a national body which manages the Australian tree improvement programs for Radiata Pine (Pinus radiata) and Blue Gum (Eucalyptus globulus) and provides genetic evaluation services in forest trees. TBA was originally established in 1983 to develop improved genetics for plantation forestry (it was renamed and incorporated as TBA in 2019).

TBA is based in Mount Gambier but has expanded to service member companies in Western Australia, South Australia, Victoria, New South Wales, ACT, Tasmania, QLD and New Zealand. TBA also has clients in Sweden and China who operate with a range of tree species. TBA has consolidated genetic resources developed over more than sixty years by private companies, State and Federal governments in order to breed better genetics more cost effectively.

In partnership with the Animal Genetics and Breeding Unit (AGBU), TBA developed TREEPLAN® an analytical system for genetic evaluation. The system is routinely used for the Australian cooperative tree improvement programs. TREEPLAN® genetic evaluation system provides an integrated solution to managing data and regularly producing breeding values for improved profit.

[9] https://www.responsiblewood.org.au/standards/australian/australian-standards-4708-forest-management/
[10] http://www.stba.com.au/

TREEPLAN® system is innovative in that it can use all performance data and pedigree information available to produce robust genetic values for all tree production regions in Australia. TREEPLAN® system of genetic evaluation has dramatically changed the way TBA tests and identifies elite material for industry use.

The systematic approach enables TBA to undertake breeding activities every year and update TREEPLAN® breeding values regularly to assist in identifying the best material for use in industry deployment programs. As seen in Box 3 above, TBA is undertaking a project linking advanced tree breeding with genomic technologies to better target improvements this refine TREEPLAN®.

Box 4 - Radiata Pine Breeding Company (RPBC) hybrid radiata pine breeding program

In October 2019, the Radiata Pine Breeding Company (RPBC) in New Zealand announced it would coordinate a Hybrid breeding program looking to cross Radiata pine with Pinus attenuata to produce a fertile Hybrid, producing similar timber and wood products to Radiata pine, from trees that flourish on harsher sites.

"The Hybrid can be looked at as a genetic continuum of the existing Radiata pine genetic resource and the Hybrid genes will extend the site range of radiata pine, as well as providing improved options for managing the impacts of climate change," said RPBC Chairman, Dr Ross Dickson.

"The programme will develop the potential for effective commercial forestry on higher elevation and exposed sites particularly in the South Island, as well as sites with similar attributes elsewhere in New Zealand and Australia." The modest, but well defined and well structured, breeding and research programme proposed in the Hybrid space was brought to the RPBC by the NZ industry.

Source: Radiata Pine Breeding Company[11]

Box 5 - Hybrid southern pine breeding program in QLD

Several species of pines (genus Pinus) occur in the southern and south-eastern regions of the United States and are together known as 'southern pines'. Among these species the principal commercial pines are loblolly pine (P. taeda) and slash pine (P. elliottii). These species were introduced for testing in Queensland, beginning with loblolly pine in 1917. From the 1940's Caribbean pine (P. caribaea var. hondurensis) from Central America was also introduced. The aim was to determine the most suitable species for establishing a commercial forestry plantation program in the south-eastern coastal lowlands on soils of low nutritional status supporting relatively low-grade eucalypt forest.

[11] https://www.rpbc.co.nz/

Genetic improvement of Caribbean pine began in Queensland in the 1950s leading to the development of both a superior pure breed and to an inter-specific hybrid breed with slash pine which, since the mid-1980s and through three generations, has gradually replaced the single specie strains in southern Queensland, on poorly drained sites in coastal central Queensland, and also in northern New South Wales.

Source: Brown, AG (Compiler) 2017[12].

However, these initial techniques only go so far to address some of the key looming issues that the forest industries must address in the future, including tree/forest extinction events. There is an existing lack of policy direction and accompanying research in Australia, for the utilisation of more advanced GM technologies in plantation forestry to produce reliable quality wood fibre for multiple benefits.

In varying degrees with varying success, New Zealand, south-east US, and other trading nations, have been developing GM technology in the plantation forestry of our key competitive species. This is still very much a live issue and these countries continue to develop policy and regulatory structures that seek to address both the science and concerns about the use of GM with the intent to deploy the resulting genetic material infield with significant productivity increases and other benefits. However, it has not been smooth sailing in any of these jurisdictions due to commercial, social, political, regulatory, and other constraints (*these are explained more below*).

Observation 4: ***Australia has a long and successful history of tree breeding research and deployment in plantation forestry to improve productivity and focus on desired traits. Major gains in productivity, timber characteristics and health can be achieved by using digital technology coupled with precision management on both new plantations but also the existing plantations in Australia. However, to address long term challenges, there is a lack of policy direction and the accompanying research in Australia for the utilisation of more advanced GM technologies in plantation forestry.***

5. GM TECHNOLOGIES IN AUSTRALIA AND REGULATORY STRUCTURE

In what is an odd contrast, advanced GM technologies are widely used in Australia: in agriculture, in research, in health and medicine, in education, and industry.

Advanced GM technology is a heavily regulated area. You cannot create, use or import a GMO in Australia unless you have the appropriate approval. When GM technology is used to create a genetically modified plant or other living thing (an organism), the use of a genetically modified organism (GMO), is regulated by the Gene Technology Regulator (the Regulator). The Regulator is an independent statutory office holder responsible for administering the Gene Technology Act 2000 (the Act) and corresponding state and territory laws.

[12] http://era.daf.qld.gov.au/id/eprint/5800/1/Southern%20pines_for%20eRA.pdf

The Regulator is appointed by Australia's Governor-General only with the agreement of most or all jurisdictions. In administering the GM technology regulatory system, the Regulator has responsibility to protect the health and safety of people, and to protect the environment, by identifying risk posed by or as a result of GM technology, and by managing those risks through regulating certain dealings with genetically modified organisms (GMOs).

In Australian agriculture, there has been significant progress with GM research and deployment for key agricultural crops ranging from cotton to canola with multiple goals to increase yield, increase herbicide tolerance, increased oil, plant stress tolerance and address pest and disease threats.

Three GM crops are grown in Australia: canola, cotton (***see more detailed case study in Box 6 below***) and safflower. There are experimental field plantings in Australia of GM banana, barley, ryegrass, mustard, sugarcane, and wheat. In the past there have also been trials of rice, clover, maize, poppy, papaya, pineapple, and grapevines.

There are currently 63 research trial sites registered under the Regulator, testing various GMOs around Australia. These ongoing trials include sorghum (yield), wheat (yield and drought tolerance), sugarcane (herbicide tolerance), barley (yield), canola, cotton (insect resistance and herbicide tolerance), and bananas (disease resistance).

Box 6: Case study on GM cotton research and deployment in Australia

GM adoption has led to a dramatic change in pest resistance of cotton with a corresponding decrease in pesticide use resulting in significant environmental benefits and cost savings. Australia, Mexico and the USA were the first countries to commercialise biotech cotton in 1996/97 (source: ICAC, 2015).

According to Cotton Australia[13], GM cotton has been commercially grown in Australia since 1996, more than 99% of the cotton grown in Australia contains GM traits. The use of biotechnology in cotton has made a significant contribution to the dramatic reduction in insecticides applied to Australian cotton crops. There has been a 97% decrease in insecticide use since 1992, coinciding with the introduction of Bt cotton and strong integrated pest management (IPM). The Australian cotton industry's Environmental Toxic Load (ETL) for bees decreased by 18.2% from 11 to 9 in the four years to 2018.

GM cotton plants are either herbicide-tolerant, resistant to the major caterpillar pest Helicoverpa spp., or both. GM cotton that provides resistance to Helicoverpa spp. is known as Bt cotton. Bt cotton produces proteins that are toxic to the specific Helicoverpa spp. pest when it eats the plant. Herbicide-tolerant cotton, Roundup Ready®, was commercially released in Australia in 2001. The Roundup Ready® cotton is resistant to the herbicide glyphosate. Herbicide-tolerant crops are not harmed by the herbicides applied to the weeds around them, providing growers with greater flexibility in weed control options, decreased use of residual herbicides and soil tillage. This has environmental benefits through reduced herbicide run-off and reduced soil erosion.

[13] Cotton Australia, Biotechnology, and cotton factsheet. https://cottonaustralia.com.au/fact-sheet

GM Cotton Research and Deployment framework

The commercialisation and ongoing monitoring of Bt cotton in Australia involves the technology provider, growers, scientists, and government regulatory bodies. These stakeholders are also involved in the development and ongoing review of ecologically based stewardship strategies that aim to delay the evolution of resistance to Bt cotton. Each genetic trait is individually assessed on a case-by-case basis by the Office of Gene Technology Regulator (OGTR), Food Standards Australia New Zealand (FSANZ), and the Australian Pesticides and Veterinary Medicines Authority (APVMA).

R&D funding

The Cotton Research and Development Corporation (CRDC) works with industry to invest in research, development, and extension for a more profitable, sustainable, and dynamic cotton industry. In 2020-21, cotton growers and the Australian Government co-invested $18.7 million through the CRDC into 300 research projects in collaboration with around 100 research partners. CRDC is funded through an R&D levy, which all growers pay (the levy equates to $2.25 for each 227 kilogram bale of cotton; or $4.06 per tonne of exported seed cotton), with the Government matching the funds dollar-for-dollar. (Source: https://www.crdc.com.au/)

GM cotton benefits

Other environmental, social and economic benefits of biotechnology in cotton include: increased populations of beneficial insects and wildlife in cotton fields, reduced pesticide run-off, improved farm worker and neighbour safety, more time for farmers to spend with their families, a decrease in labour and fuel usage, improved soil quality, reduced production costs, increased yield, reduced risks and further opportunities to grow cotton in areas of high pest infestation.

50% more cotton is produced worldwide today on the same amount of land as compared to 40 some years ago (source: Cotton Inc., 2014). There are financial benefits for cotton farmers using biotechnology. Graham Brookes, Director of PG Economics UK told the National Press Club in an address in 2012, "Since 2010, the total farm income gain derived by Australian cotton farmers from using this technology has been $395 million, an average of about $180 per hectare."

Some lessons

It is also interesting to note that significant amounts of cottonseed used in the food chain is produced than the more commonly known cotton lint which is used in fibre chain. Cottonseed is consumed by humans as oil and livestock as a feed source. The comparison between using GM technologies in either trees or cotton in the fibre chain is a useful one, both are crucially important fibres used in many essential products. Obviously, GM advances and deployment in cotton are significantly ahead of even the discussion in application of GM technologies to commercial tree species in Australia. Especially notable with GM cotton as it is both a food and fibre chain discussion and with commercial trees it is a fibre chain discussion.

Source: https://cottonaustralia.com.au/

Several other Australian government regulators also oversee work with GMOs, depending on the use of the GMO, including:

- *Australian Pesticides and Veterinary Medicines Authority (APVMA)* handles veterinary products and agricultural chemicals produced in, or used on, crops.
- *Department of Agriculture, Water and the Environment* handles quarantine; all animal, plant and biological products that could pose a risk if they were imported; import permit applications.
- *Food Standards Australia New Zealand (FSANZ)* handles food issues, including labelling and mandatory pre-market safety assessments for GM foods.
- *National Industrial Chemicals Notification and Assessment Scheme (NICNAS)* assesses the risk of industrial chemicals and provides information to promote their safe use.
- *Therapeutic Goods Administration (TGA)* handles medical issues (including GM and GM-derived therapeutic products).

CropLife Australia[14] is a national industry association that represents the innovators, developers, manufacturers, formulators and registrants of crop protection and ag-biotechnology products. Croplife Australia details some of the estimated benefits of deploying GM include:

- The increased productivity of GM crops has meant an additional 357.7 million tonnes of corn, 180.3 million tonnes of soybeans, 25.2 million tonnes of cotton and 10.6 million tonnes of canola have been produced around the world between 1996 and 2015.
- Australian farmers with access to crop biotechnology over the last 20 years have financially benefited too – they have gained $1.4 billion of income benefits.

Another good example of the regulatory review that could underpin change in consideration of GM technologies is the recent gene editing laws under review in Australia. Australia's GM technology legislation is a scientific risk-based scheme. The Office of the Gene Technology Regulator has proposed amendments to the Regulations to ensure the legislation keeps pace with technological change, and the level of regulation is appropriate given the potential risks.

The proposed amendments address risks to human health and safety and the environment for the purposes of the gene technology legislation. It is seen that there is currently legal uncertainty about the regulation of new technologies, including genome editing techniques, and these amendments will explicitly capture most genome editing techniques that requires regulation under the legislation.

One CRISPR random repair technique, known as SDN-1, is proposed to be excluded because SDN-1 organisms present no different risk than organisms carrying naturally occurring genetic changes. Organisms modified using SDN-1 cannot be distinguished from conventionally bred animals or plants, and there is no evidence that they pose safety risks that warrant regulation.

More detail on Australian agriculture's GM technology approach can be found in **Attachment 1**.

[14] *https://www.croplife.org.au/*

***Observation 5:* Agricultural industries in Australia have paved the way in establishing GM technologies and deployment predominately for food and fibre, in the case of cotton. Australian forest industries can learn a lot from these long-running and sophisticated GM technology programs.**

6. ARE GM PRODUCTS CONSIDERED SAFE?

There is significant regulation and research undertaken to attempt to address the concerns surrounding the use of GM technologies. The general scientific consensus, supported by scientific organisations such as the World Health Organization[15], the US National Academy of Sciences[16] and the Royal Society of London[17], is that after more than 20 years of commercial use, the GM technologies used to date '*pose no greater risk to human health or the environment than similar products derived from traditional breeding and selection processes*.'

Nonetheless, GM technologies and products continue to be treated with caution by governments, regulatory bodies and the public, and their impacts on human and animal health and the environment are closely scrutinised. Some GM products researched and deployed in Australian agriculture have an over 20-year history and have addressed safety and risk issues over that period.

GM technologies as they relate to fibre chain products (not food chain products) are discussed in this paper – the contrariness of the perception of increased concern about deploying GM fibre products from trees compared to (more acceptable in Australia to date) GM food products should not be lost on the reader and is **further explored later in the paper and in Box 6 (the cotton case study) above.**

***Observation 6:* The general scientific consensus is that the GM technologies used to date pose no greater risk to human health or the environment than similar products derived from traditional breeding and selection processes (which are generally accepted for both food and fibre chain product uses).**

7. GM MORATORIUMS

Outside the many ongoing research trials, GM plants currently approved for commercial deployment and cultivation in Australia are cotton, canola, safflower, and carnations[18].

There are moratoria (temporary suspensions) on growing commercial GM crops in South Australia, Tasmania, and the Australian Capital Territory *(see examples below)*. New South Wales and Victoria also have moratoria in place, but GM cotton and GM canola are exempt, and both are grown in these states. Western Australia and Queensland grow GM cotton and GM canola. The Northern

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[15] https://www.who.int/foodsafety/areas_work/food-technology/faq-genetically-modified-food/en/
[16] https://www.nap.edu/catalog/23395/genetically-engineered-crops-experiences-and-prospects
[17] https://royalsociety.org/topics-policy/projects/gm-plants/
[18] http://www.ogtr.gov.au/internet/ogtr/publishing.nsf/content/9AA09BB4515EBAA2CA257D6B00155C53/$File/11%20-%20Genetically%20modified%20(GM)%20crops%20in%20Australia.pdf

Territory does not grow cotton or canola, so GM varieties of these crops are not farmed. GM safflower grown for industrial applications is exempt from current moratoria, and is grown in Victoria, New South Wales, and Western Australia.[19]

South Australia: Under the *Genetically Modified Crops Management Act 2004 and Regulations*, the moratorium on the commercial cultivation of GM food crops was to be in place until 2025. The SA genetically modified food crop moratorium exists for trade and market access purposes.

However, in 2018, an independent review of South Australia's moratorium on the cultivation of Genetically Modified (GM) food crops was undertaken by Emeritus Professor Kym Anderson AC. It was envisaged once completed the review would enable better informed policy decisions regarding GM food crops in South Australia. The Review's Terms of Reference is included in **Attachment 1.**

The SA review was not to consider aspects of gene technology which are covered under commonwealth legislation, these include: human health; safety; and environmental impacts. 216 submissions were received. The Review Report was publicly released by the SA Government on 20 February 2019 finding conservative estimates the cost to farmers of the GM moratorium since 2004 is up to $33 million, and if extended to 2025, farmers face losing at least another $5 million. Further it found that investment in agricultural science has suffered under the moratorium and the GM moratorium has discouraged both public and private investment in research and development in this state. The SA Government then considered Professor Kym Anderson AC's report and the 19 findings.

On the 19th August 2019, the SA Liberal government announced via media release[20] the decision to lift the Moratorium on mainland SA but will retain it on Kangaroo Island. In response to the original moratorium reasoning of marketing and trade advantage, the Anderson Review found the GM moratorium in South Australia provided no price premium compared with GM crop growing neighbouring states. The SA Government stated that this '*reform will help increase farm profitably and drought resilience, create job opportunities in our regions, grow the state's economy and attract greater research investment.'*

Subsequently on the 11 October 2019, the SA Minister for Primary Industries announced via media release[21] that new regulations were gazetted that from 1 December 2019 SA farmers could use GM crops on mainland SA but not on Kangaroo Island starting from the 2020 season.

Tasmania: In March 2019, Tasmanian's were invited to comment on the latest review of Tasmania's moratorium on Genetically Modified Organisms (GMOs). Previous reviews had found no reason to change Tasmania's moratorium. Building on Tasmania's reputation in the global marketplace for producing premium products that are safe, clean and reliable is a key to growing

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[19] *Australian Academy of Science - https://www.science.org.au/files/userfiles/learning/documents/genetic-modification.pdf*
[20] *https://www.timwhetstone.com.au/lifting_stifling_gm_moratorium_gives_farmers_a_choice*
[21] *https://premier.sa.gov.au/news/mainland-sa-farmers-to-have-choice-with-new-gm-regulations*

the value of agriculture to $10 billion per annum by 2050. The Review's Terms of Reference is included in **Attachment 1.**

Tasmania's current moratorium was to expire in November 2019. Comments closed in April 2019. On the 7th August 2019, the Premier of Tasmania announced by media release that Tasmania's moratorium on Genetically Modified Organisms (GMOs) will be extended for another 10 years. [22] The review was carried out by the Tasmanian Department of Primary Industries, which received 76 submissions, with an '*overwhelming number of respondents in favour of extending the moratorium*'.

Box 7 – Moratoriums can be perceived to have a marketing advantage

What is interesting about the Tasmanian review is the way the outcome to extend was promoted i.e. 'Tasmania's GMO-free status is an important part of the Tasmanian brand, offering a marketing advantage for our high quality, high value primary industries and is a key component in Government's goal to grow the annual value of our agricultural sector to $10 billion by 2050.'

This indicated that a perceived marketing benefit can be achieved by promoting GMO-free products as compared to other products participating in the market. Obviously political and marketing concerns are being overlayed over the necessary science that would underpin the decision to remove a moratorium. Contrast this outcome to the recent SA review and part-lifting of their moratorium. With this history, it is proposed that discussions around acceptance of GM advances in commercial tree crops will be more challenging in Tasmania than other Australian jurisdictions.

Observation 7: ***From the ongoing debate surrounding GM moratoriums, it is obvious that additional overlays need to be considered (including political, social, and marketing concerns), not just consideration that deploying GM technologies is possible and safe from a scientific viewpoint.***

8. WHAT ARE THE BENEFITS OF GM PRODUCTS?

GM technologies are an extension of traditional breeding technologies by offering (sometimes only promising) a more precise and targeted way to obtain the same kinds of outcomes. GM technology applications could help Australia respond to the significant environmental changes from climate change and other challenges, including more frequent, longer duration and more intense droughts and extreme weather events, increased biosecurity threats, and opportunities like potential bioenergy residues and crops.

On a commercial scale, genetic modification can improve individual tree characteristics, including traits such as: pulpability, wood quality (e.g. strength, stiffness and density), increased carbon storage, herbicide resistance, pest and disease resistance, environmental stress tolerance (e.g. cold, drought), and reproductive function.

[22] http://www.premier.tas.gov.au/releases/gmo_free_status_creates_markets_for_tasmanian_products

With both global and Asian Pacific Region demand for timber products expanding rapidly it is obvious that Australia will play a key role in supplying both fibre and food to these critical markets. It will also need to do this effectively from less land and with growing uncertainty and risk from ongoing climate change impacts. With the help of GM technologies, it is possible to produce organisms and products better adapted to changing environments.

Potential benefits include:

- Herbicide tolerance for more cost-effective weed management and insect resistance.
- Reduced use of insecticides and residual herbicides.
- Increased yields, allowing land managers to grow more product without needing more land.
- Increased incomes
- Reduced CO_2 emissions per tonne of product.
- Improved nutritional value for food.
- Increased tolerance to climate change impacts including drought, bushfires etc

Observation 8: ***GM technologies offer land and forest managers many benefits in a changing world especially considering Australia's geopolitical position and role in the rapidly growing Asian Pacific region. GM technologies can help us respond to the significant environmental changes from climate change and other challenges. With the help of GM research, it is possible to produce organisms and products better adapted to changing environments.***

9. IS GM TECHNOLOGY A SOLUTION FOR LOOMING CHALLENGES IN AUSTRALIAN PLANTATION FORESTRY?

With an expanding population in Australia and in the Asia Pacific region, aging housing stock and high forecast demand for new housing and other wood-based products over the next few decades, the demand for wood fibre will significantly increase. To successfully meet this demand our renewable forest industries will need to change and adopt new approaches or potentially capitulate to our international wood fibre competitors.

Additionally, as trade becomes more global and interconnected, new pests and diseases will emerge on a more regular basis to threaten our relatively long-lived plantation forestry assets. Recent examples of these threats, that will need more innovative solutions than we have now, include:

- the myrtle rust incursion that directly effects myrtaceous plant species including our hardwood plantations
- the recent giant pine scale incursion that threatens our softwood plantations
- the effects of climate change impacting on increased extreme weather events (including bushfires, drought, and cyclones), tree mortality, productivity, and land and water availability
- environmental issues such as salinity mitigation, erosion control and water quality (e.g. the Great Barrier Reef issue)

Both high quality tree breeding and advanced GM technologies can potentially provide a powerful tool to address these challenges.

It is evident that New Zealand (for softwood plantations) and south east US (for softwood and hardwood plantations) and other countries are probably 10-15 years ahead in terms of developing and adopting a strategic plan for GM technology utilisation in plantation forestry. This includes our key competitive species (both *pinus and eucalyptus* species). They have:

- developed forward thinking policy settings
- thought about appropriate regulatory checks and balances
- continued to undertake long-term, controlled GM research on key plantation species
- started the approval process of deployment of genetic material to meet the significant fibre demand challenges, optimise land-use, and address the threats of new pests and diseases

***Observation 9:* To address the supply challenges facing our renewable forest product industries, having the scientific know-how to develop a GM program and a strategy for deployment is only a part of the solution, it must also be both cost-effective compared to other approaches and gain a level of social acceptance or address social objections to be both sustainable and successful.**

SOCIO, ECONOMIC & ENVIRONMENTAL CONSIDERATIONS

10. APOCALYPSE (JUST NOT) NOW!

A compelling reason for investing in advanced GM technologies is to prepare for, or mitigate, a potential tree/forest extinction event caused by the adverse impacts generated by climate change, including cataclysmic bushfires and increased predations by pests or diseases. In these circumstances, can advanced GM technologies come to the rescue? Should they?

In the US in 2018, at the request of several U.S. federal agencies and the U.S. Endowment for Forestry and Communities, the National Academies of Sciences, Engineering, and Medicine formed a committee[23] to “examine the potential use of biotechnology to mitigate threats to forest tree health.” Experts were asked to “identify the ecological, ethical, and social implications of deploying biotechnology in forests, and develop a research agenda to address knowledge gaps.”

The committee looked at the following four key case studies to illustrate the breadth of forest threats:

1. The Asian emerald ash borer which causes severe mortality in five species of ash trees. First detected on U.S. soil in 2002, it had spread to 31 States as of May 2018.
2. Whitebark pine, a foundational species in high elevations of the U.S. and Canada, is under attack by the native mountain pine beetle and an introduced fungus. Over half of Whitebark pine in the northern U.S. and Canada have died.
3. A native fungal pathogen (e.g. *Septoria musiva*) has begun moving west, attacking natural populations of black cottonwood in Pacific Northwest forests and intensively cultivated hybrid poplar in Ontario.
4. The infamous chestnut blight, a fungus accidentally introduced from Asia to North America in the late 1800s, has wiped out billions of American chestnut trees.

[23] *https://www.newspronto.com/news/the-conversation/56084-ca*

The committee found that researchers could insert genes that help a tree tolerate or fight an insect or fungus pest but making a biotech tree would not be easy. Trees are large and long-lived, which means that research to test the durability and stability of an introduced trait will be expensive and take decades. Plus, not nearly as much is known about the large complex genomes of trees. They also found that because trees need to survive over time and adapt to changing environments, it is essential to preserve and incorporate their existing genetic diversity into any new biotech tree. Even an advanced biotech tree will need a deliberate breeding program to ensure long-term survival. For these reasons, they recommended increasing investment not just in biotechnology research, but also in tree breeding, forest ecology and population genetics.

During my visit to south-east United States, the ongoing impact of fusiform rust and the importance of GM technologies and advanced tree breeding techniques was evident. Fusiform rust is a widespread and damaging disease of loblolly pine (*Pinus taeda*) and slash pine (*P. elliottii*). Caused by the fusiform fungus (*Cronartium quercuum f. sp. fusiforme (Cqf)*), the disease leads to rust galls or cankers on the main stem and branches of host trees. Rust galls can either kill or effect wood quality and yield by causing deformed and broken stems in young trees.

Over many years research has identified pines with improved genetic resistance to the disease, allowing production and planting of resistant seedlings in areas at risk. Currently, anticipated improvements in resistance will not eliminate all physical and financial damages from the disease. However, it is estimated that substantial financial benefits yet remain for additional R&D including genomic tools.

Back in Australia compelling recent examples of looming threats include:

- the relatively recent myrtle rust incursion that directly effects myrtaceous plant species including our commercial hardwood plantation species
- Giant Pine Scale (GPS) (*Marchalina hellenica*) a scale insect that sucks the sap of pine trees. GPS is native to the eastern Mediterranean region and is known to occur in Crete, Georgia, Italy, Russia, and Turkey. GPS was reported for the first time in Australia in late 2014 in amenity pine trees east of Melbourne and Adelaide. To date GPS has not been found in other parts of Australia, nor has it been detected in any commercial pine plantations. It does pose a significant economic threat to Australia’s softwood plantation industry and amenity trees. GPS is slow to spread without human intervention. The movement of infected wood, mulch, and machinery is the primary way it spreads long distances.

Observation 10: ***A compelling reason for investing in advanced GM technologies is a potential tree/forest extinction event caused by the adverse impacts generated by climate change, including bushfires and increased predations by pests or diseases (such as myrtle rust and GPS in Australia).***

11. ROLE OF TREES IN CLIMATE CHANGE ADAPTATION

Governments have a major role to play in climate change adaptation policy and implementation. Our renewable forest industries are both adversely impacted by and can play a significant positive role in adaptation to climate change.

Although there are many similarities between agricultural pursuits and the forestry sector. Forestry does have unique characteristics, due in part to the long timeframes between establishment and harvest. Natural forests and plantations are vulnerable to harm from both extreme weather events (e.g. bushfires, cyclones) and long-term effects of a changing climate such as more frequent drought, especially as a dry-land land-use activity.

Forecast long-term trend changes in rainfall, temperature and weather patterns can produce both positive and negative productivity affects and other impacts depending on industry sector (e.g. short-rotation hardwood plantations for pulp products compared with long-rotation softwood plantations for structural timber products) and geographic region (e.g. Northern Australia tropical zones compared with southeast Australia temperate zones).

A changing climate imposes significant challenges and some opportunities for the forest and forest-based industries in dealing with these changes. Forestry activities can also enhance agricultural productivity through beneficial impacts on pasture, crop, and animal production, primarily through provision of shade and shelter, nutrient cycling, and soil conservation.

Agriculture and forestry are not necessarily mutually exclusive and there exists a continuum of tree planting and forestry activities across the landscape at a range of scales and tree densities. These activities are undertaken for a range of production and environmental purposes, such as salinity and riparian plantings and shelter belts through to farm woodlots and plantations used primarily for wood production.

It is for these reasons that well targeted forestry activities can be complementary to a broad range of farm level and landscape management objectives. This is particularly relevant given current climate change impacts and previous tree clearing and land use practices that have resulted in land degradation at a range of national and regional scales, including dry land salinity, invasive weeds, soil erosion and water quality reduction.

It is well known that tree plantations yield the benefits of wood production and carbon sequestration but also provide significant other benefits such as water quality and soil conservation, salinity control, biodiversity and agricultural productivity (e.g. shade and shelter for livestock). These additional benefits are also important in the context of land management strategies (e.g. to reduce soil run-off into the Great Barrier Reef).

In collaboration with relevant researchers, industry practitioners and companies involved in climate change adaptation responses, the Australian Forest Products Association (AFPA) managed a three-year project to enhance the industry's ability to reduce the harmful effects of, and exploit the opportunities from, a changing climate. This work was supported by funding from the Australian Government.

The 'Plantation Forest Industry Climate Change Adaptation Handbook'[24] was prepared as part of the project to promote awareness of future climate change scenarios and relevant adaptation management options and strategies, which can be used to improve adaptive capacity in dealing with climate change.

Figure 6 – Relationship between climate change impacts and adaption responses[25]

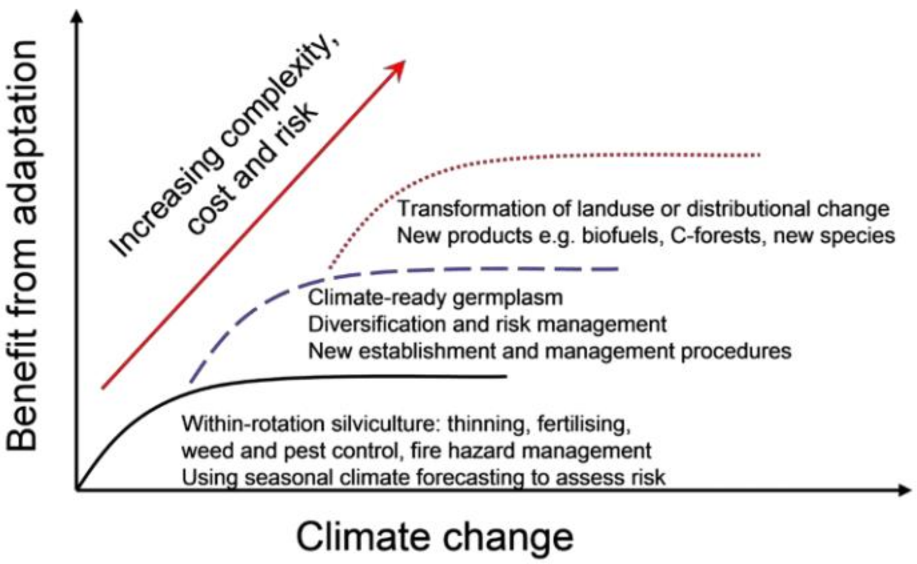

Figure 13: Relationship between climate change impacts, adaptation responses and the potential benefits from adaptation (Pinkard et al 2010, adapted from Howden et al 2010).

Figure 6 is analogous with my proposed approach to development and implementation of GM technologies to commercial trees in Australia. That is a progressive approach from fully implementing the benefits from precision forestry techniques on existing and new trees, to advanced tree breeding and improvement technologies, to developing an appropriate GM technology plan.

Observation 11: ***A climate change adaptation framework should be adopted by industry. It should include recognition of forest industry benefits and support projects that will consider and address climate adaptation options for the forest industry and broader processing issues.***

[24] *https://ausfpa.com.au/wp-content/uploads/2017/05/Plantation-Forest-Industry-Climate-Change-Adaptation-Handbook.pdf*
[25] *Pinkard et al 2010 adapted from Howden et al 2010*

12. GM TECHNOLOGY AND FOREST MANAGEMENT CERTIFICATION

One current constraint with utilisation of GM technologies in plantation forests is related to forest management (FM) certification. The objective of a forest management certification standard is to provide forest managers with environmental, economic, social, and cultural criteria and requirements that support the sustainable management of forests. FM certification standards are nominally voluntary (although increasingly important for access to some markets) and can be utilised by forest managers who are seeking independent, accredited third-party certification of their forest management system and practices.

Currently both the Responsible Wood/PEFC and FSC schemes have black letter provisions firmly against the commercial use of GM trees.

Certification is a very important driver for forest management practices in Australia with more than 80% of the 2 million hectares of plantations in Australia are certified to either Responsible Wood's standard endorsed via the Programme for the Endorsement of Forest Certification (PEFC) or the Forestry Stewardship Council (FSC) standard or both.

It should be noted that basic tree improvement/breeding interventions that are not considered to be GM technologies by existing international credible certification schemes include: **in vitro fertilization; selective tree breeding; natural processes such as, conjugation, transduction, and transformation; and polyploidy induction**[26].

(a) Responsible Wood standard and GM technology

Responsible Wood/PEFC standard includes the following provision (under Criteria 3.8.2):

> **The forest manager shall not use genetically modified trees.**
>
> ***Note:*** *The definition of genetically-modified trees are 'trees in which the genetic material has been altered in a way that does not occur naturally by mating and/or natural recombination, taking into account applicable legislation providing a specific definition of genetically modified organisms.'*
>
> The following techniques are considered as genetic modification resulting in genetically modified trees (EU Directive 2001/18/EC):
>
> - recombinant nucleic acid techniques involving the formation of new combinations of genetic material by the insertion of nucleic acid molecules produced by whatever means outside an organism, into any virus, bacterial plasmid or other vector system and their incorporation into a host organism in which they do not naturally occur, but in which they are capable of continued propagation.
> - techniques involving the direct introduction into an organism of heritable material prepared outside the organism including micro-injection, macro-injection, and micro-encapsulation.

[26] *Responsible Wood's AFS FM standard AS 4708:2013 - https://www.responsiblewood.org.au/*

- cell fusion (including protoplast fusion) or hybridization techniques where live cells with new combinations of heritable genetic material are formed through the fusion of two or more cells by means of methods that do not occur naturally.

The following techniques are not considered as genetic modification resulting in genetically modified trees:

- in vitro fertilization;
- selective tree breeding;
- natural processes such as, conjugation, transduction, and transformation; and
- polyploidy induction.

Following a revision in the Responsible Wood standards in 2016 a directive was distributed that detailed: All Certification Bodies and Responsible Wood Certificate Holders are to consider the policy on the exclusion of genetically modified organisms listed in Clause 3 (Terms and Definitions) of AS4707 Chain of Custody for Forest Products under "Controversial Sources", **extended to 31st December 2022**.

(b) FSC standard and GM technology

FSC's Policy for the Association of Organizations with FSC indicates:

That FSC will only allow its association with organizations that are not directly or indirectly involved in the following unacceptable activities:

- Illegal logging or the trade in illegal wood or forest products
- Violation of traditional and human rights in forestry operations
- Destruction of high conservation values in forestry operations
- Significant conversion of forests to plantations or non-forest use
- Introduction of genetically modified organisms in forestry operations
- Violation of any of the ILO Core Conventions

However, on its website, FSC clarifies that research into GE trees does not constitute a breach of the Policy of Association.

The FSC Australia SFM standard in force from February 2019 provides:

10.4 The Organisation* shall* not use genetically modified organisms* in the Management Unit*.

10.4.1 *Genetically modified organisms** are not used.

Verifiers:

- *Documentation of seed origins.*
- *Documentation of compliance with any state/federal regulations such as the Office of the Gene Technology Regulator*

Genetically modified organism[27]: An organism in which the genetic material has been altered in a way that does not occur naturally by mating and/or natural recombination.

Examples of genetic modification covered by this definition include the following:

- Recombinant DNA techniques using viral or bacterial vector systems.
- Techniques involving the direct introduction into an organism of heritable material such as DNA prepared outside the organism, including microinjection and microencapsulation.
- Cell fusion (including protoplast fusion) or hybridisation techniques where live cells with new combinations of heritable genetic material are formed through the fusion of two or more cells by means of methods which do not occur naturally.

The following techniques are not considered to result in genetic modification, on condition that they do not involve the use of recombinant DNA molecules or GMOs as recipient or parental organisms:

- in vitro fertilization,
- conjugation, transduction, transformation or any other natural process,
- polyploidy induction,
- mutagenesis,
- cell fusion (including protoplast fusion) of plant cells where the resultant organisms can also be produced by traditional breeding methods.

Clones, hybrids formed by natural processes, or the products of traditional tree breeding, selection, grafting, vegetative propagation or tissue culture are not GMOs, unless produced by GMO techniques.

FSC-POL-30-602 clarifies the risks make it necessary to apply strict and obligatory safeguards for field research trials of GMOs in forestry. As a precaution, in the absence of such agreed and implemented safeguards, FSC does not endorse the certification of forests containing or using GMOs in research or management.

As a result, provisions contained in these two internationally credible SFM certification standards relating to the utilisation of GM technology in plantation forestry are incredibly important when considering a strategic plan for GM technology, research and deployment.

Observation 12: ***With the ongoing importance and high uptake of SFM certification schemes in Australia, provisions relating to the utilisation of GM technology in plantation forestry contained in these standards are incredibly important. But are these provisions science-based or emotive views? There is no doubt that if any advanced GM technology program and potential deployment is to be successful then a level of social acceptance needs to be achieved and SFM certification schemes acceptance of this is a major step.***

[27] *Source: Based on FSC-POL-30-602 FSC Interpretation on GMO (Genetically Modified Organisms.*

13. GM TECHNOLOGY PROTESTS AND SOCIAL CONCERNS

GM is a challenging social acceptance issue for many primary industries, especially in Australia. Previous small-scale GM field trials both in Australia for agricultural crops and in New Zealand for GM radiata pine trees, established by the research company Scion, have been attacked by protestors.

Food versus fibre - The notion of directly modifying genes to change attributes would seem to be much more challenging in agriculture as the public tend to focus far more intently on food related crops rather than plants grown for fibre. Yet the breakthroughs in pesticide reduction, increased yield, disease resistance and so on have been so compelling that many agricultural food crops continue to move this way.

An example of the GM fibre discussion comes from former Deputy Prime Minister and leader of the National Party, John Anderson who was reported in August 2015 saying *"I remember it was only a little while ago that green activists wanted to tell us that GM cotton was going to destroy every food producing area in the country and everyone was dying of cancer and this was a great blot on the horizon," he said. "But now we hear nothing about the evils of cotton and we don't even hear people complaining about the fact that Australian cotton is virtually all GM. "The savings in chemicals, and therefore I'd argue the environmental benefits as well as economic benefits are huge, just huge. "Now if those benefits are there for GM cotton, dare I suggest, and it's fairly obvious, they're going to be there too when it comes to feeding people in the future and doing it in a more sustainable way with other GM crops."*

So, it is difficult to understand the direct and vehement opposition to GM technology being applied to plantation trees in many countries, including Australia.

One of the key concerns given by people is controlling the risk of uncontrolled spread of GM trees within or outside the gene pool. There has been research work (e.g. conducted on poplars, eucalyptus and pines) undertaken to both understand and control the risk of uncontrolled spread of GM trees with different molecular approaches being developed including male and/or female sterility. The long vegetative period of trees versus other crops has made this research more difficult to achieve rapid outcomes and as a result stakeholder confidence in controls.

Observation 13: ***Confidence should be established that potential GM plantation trees would have no impact or potential incursion into neighbouring crops or land. This stems from the fact that trees are not equivalent crops to the neighbouring land grown for food. Rather, they are long lived tree crops grown for fibre, with many genetic safeguards built into their basic genome that will prevent chances of cross-pollination between trees and to also induce sterility to stop the potential spread of genetic material from the GM trees. As a result, increased social acceptance should be easier to achieve if confidence is built through successful communication.***

14. IMPORTANCE OF COMMUNICATION AROUND GM TECHNOLOGIES

How the benefits and controls around GM technology are communicated is incredibly important as found by University of Adelaide researchers in a study of women's attitudes towards genetically modified (GM) foods.

The study found that when it comes to controversial science issues, scientists need to rethink their approach to engaging the public. The results of focus groups conducted by University of Adelaide researchers showed that if scientists continue to present "just the facts", most people won't engage or modify their thinking – even if those people are highly educated.

Findings included, women who had backgrounds in plant science said the lack of evidence of harm meant that GM food was safe to eat. However, women in health sciences said it was a lack of evidence of safety that made them cautious about consuming GM food. These perceptions are based on two very different concepts of risk, despite both groups being highly educated in science. For women without science backgrounds, GM food presented 'unknown' risks, and hence was to be avoided. There was a range of other issues apart from the science, a major one being a general lack of trust of science.

***Observation 14:* The way and the how benefits and controls around GM technology are communicated to industry, the public and policy makers is incredibly important to support social acceptance around GM technologies, especially how the key perceived risk mitigations are communicated.**

15. GM TECHNOLOGY RESEARCH IN NZ and SOUTH-EAST US

The concerns detailed above are the very ones that should be (and have been elsewhere) addressed by highly regulated research and tightly controlled field trials of potential GM trees.

In NZ, Scion (the forest industry R&D body) has been conducting GM tree research since 1992. The objective of the research is to produce a tree that has several good characteristics including high growth and other commercial characteristics. This research involved non-native, economically important forestry species both in the laboratory and in field trials.

From 1996 to 1999, Scion undertook field trials with genetically modified radiata pine to establish that the science could be conducted in accordance with NZ GM regulatory, risk management and environmental standards.

Scion reports that on a commercial scale, genetic modification can provide significant value by improving individual tree characteristics, including traits such as: pulpability, wood quality (e.g. strength, stiffness and density characteristics), increased carbon sequestration, herbicide resistance, pest and disease resistance, environmental stress tolerance (e.g. cold, drought), and reproductive function.

The NZ Environmental Protection Authority in 2010 approved an application from Scion to further study genetic modification of forestry species on a 4-hectare containment site in Rotorua. The research will field test radiata pine with genetic modifications for genes for commercially important traits such as tree growth and wood quality.

NZ has been looking at GM technologies for commercial trees for over 20 years demonstrating that deploying advanced GM technologies with appropriate approvals and regulation is not a quick process.

More detail on NZ current approach can be found in **Attachment 2**.

In south-eastern US, the main player in GM development in forestry is ArborGen, a global provider in forest biotechnology (operating in US, Brazil, NZ, and Australia). ArborGen states that it has a fully integrated technology platform for introducing, testing, and commercialising trees and has conducted nearly 900 field trials containing roughly a million trees.

One of Arborgen's GM technology focus has been on tree genomics. Being able to identify genetic markers related to the variation in phenotypes (the composition of an individual's characteristic traits) offers the potential to genetically improve forest tree species at a much faster pace than traditional breeding approaches. In recent years, the genomes of several tree species have been sequenced including Populus (Poplar), Eucalyptus (Eucalypts), and Pinus (Pine).

Another key focus is on developing biotech trees, such as a freeze tolerant tropical Eucalyptus product which is currently going through a review process for deregulation in the United States. This tree combines the fast-growing and highly desirable fibre quality characteristics of a proven Eucalyptus variety grown in Brazil with the ability to withstand freezing temperatures, targeted at the south-eastern United States.

More detail on south-east US approach can be found in **Attachment 3**.

Observation 15:* *Australian plantation forestry can learn a lot from the other countries in their efforts to progress GM technologies R&D programs and deployment. More formal work could be undertaken to fully scope the steps other similar countries have taken.

16. INDUSTRY DRIVERS

a) Global timber demand challenge

As Australia's population grows, and with global demand for timber expected to quadruple by 2050[28], the challenge to meet this growing demand will become increasingly difficult under current settings. From high-rise and commercial timber building construction to replacing plastics, chemicals and energy sourced from fossil fuels with new and emerging wood-fibre based materials, global demand for renewable wood and fibre is only going to increase.

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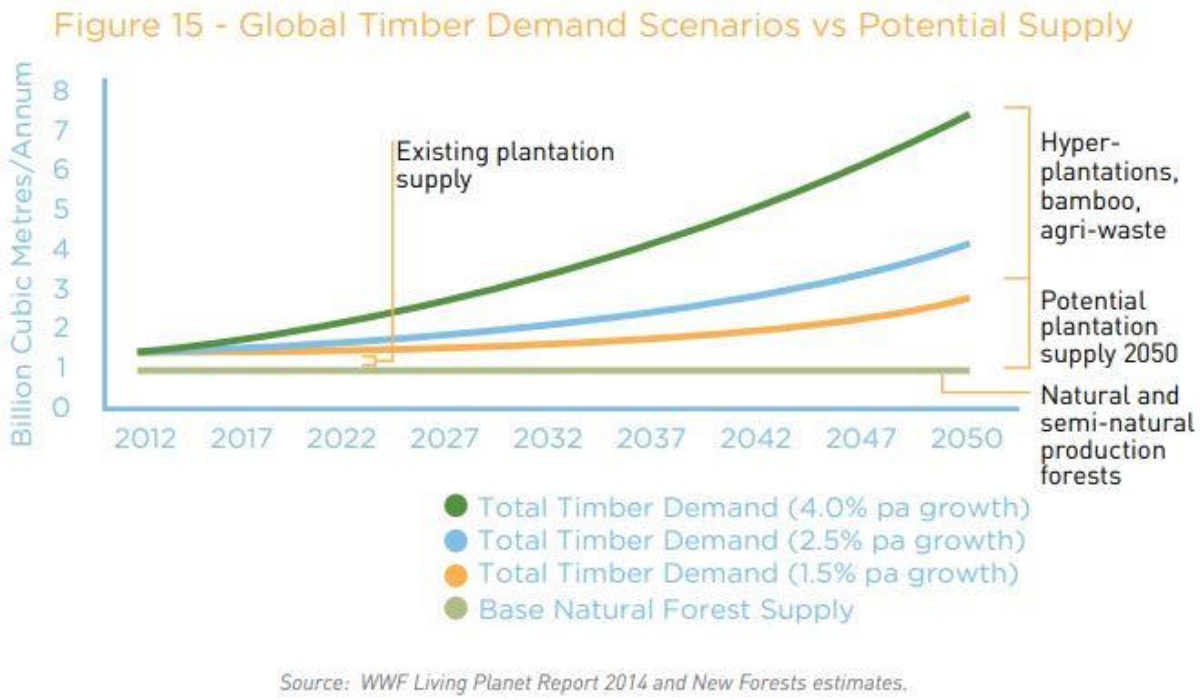
[28] *The World Bank, 2016 – Forests Generate Jobs and Incomes, available at www.worldbank.org [16 August 2018].*

Figure 7 shows the increasing global timber demand challenge and is reproduced from New Forests 2015 report [Timber Investment Outlook 2015-2019](https://www.newforests.com.au/wp-content/uploads/2015/07/New-Forests-Timberland-Investment-Outlook-2015-2019.pdf).[29]

Figure 7.



As noted in the report, '*This conceptual analysis indicates that if industrial roundwood demand exceeds a growth rate of 1.5% per annum, then conventional timber plantation investment is unlikely to meet the supply gap. It would then be reasonable to expect that new innovations and increased investment in genetically modified trees, high yielding hyper-plantations like bamboo, and higher levels of agricultural waste collection would emerge to bridge this gap. This also seems to point to a convergence of forestry and agribusiness as ever more productive crops and biomass plantations seek to meet human needs from a finite land base.*'

New innovations in, and sources of, wood fibre will need to emerge to bridge this wood fibre demand gap. GM technology can potentially provide a powerful tool to address these challenges.

b) Emerging Timber Market Drivers (Quality and cost/productivity drivers)

A strategic policy, quality R&D and controlled deployment approach to the use of GM technologies and precision techniques in plantation forestry could:

- increase wood fibre volumes per hectare in the longer term adding significant value and growth opportunities for both Australian industry and to sustainably meet the burgeoning demand for fibre in the Asia Pacific region.
- increasing competition for productive land. Changes to land-use in Australia from agriculture production to commercial trees. Land costs are high. Achieve higher timber yields off the same land area.

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[29] *https://www.newforests.com.au/wp-content/uploads/2015/07/New-Forests-Timberland-Investment-Outlook-2015-2019.pdf*

- improve the wood fibre characteristics to better meet traditional market demand and new emerging markets such as bioenergy, biofuels and biochemicals.
- mitigate impacts from pests and diseases and the effects of climate change in Australia.

c) *Plantation ownership changes*

Another significant trend has occurred in Australian plantation forestry and that is the changing ownership of the existing plantation forestry assets. These relatively new global timber fund owners and institutional investors recognise that productivity gains of the forest estate are vital and have the resources and international connections to have an innovative and long-term view to achieve these changes. See **Figure 8** below for changing trends over time.

Figure 8

Table 8 Plantation area, by state/territory and ownership, 2018–19

State/Territory	Unit	Private	Public	Joint a	Total
New South Wales	'000 ha	123.6	261.8	7.9	393.2
Victoria	'000 ha	415.9	2.5	0.1	418.5
Queensland	'000 ha	230.4	0.1	0.0	230.5
South Australia	'000 ha	150.6	16.2	0.0	166.8
Western Australia	'000 ha	233.5	79.5	46.9	359.9
Tasmania	'000 ha	258.4	35.1	16.2	309.7
Northern Territory	'000 ha	47.4	0.0	0.0	47.4
Australian Capital Territory	'000 ha	0.0	7.4	0.0	7.4
Total	'000 ha	1,459.9	402.6	71.0	1,933.4
Proportion of ownership	%	75.5	20.8	3.7	100

a Includes some small areas for which ownership details were not reported.
Note: Totals may not tally due to rounding.
Source: ABARES

Box 8: GM technology in Brazil

The emphasis of the GM program in Brazil (South America) to date has been on increasing wood fibre yield with FuturaGene's testing resulting in an approximate 20% increase in yield compared to the equivalent conventional variety.

Increasing yield provides many significant economic, environmental and social benefits including increased competitiveness for industry, and using less land to produce more wood fibre will include lowered carbon emissions from reduced transport, reduced chemical use and more land for other uses such as food production.

FuturaGene also reports that from 1970 to 2010 wood fibre yield in Brazil has increased from 21 m3/ha/year up to 44 m3/ha/year and GM technology can take this figure higher again; and that for every 1% increase in yield across the estate it reduces Suzano Pulp & Paper's and requirement by 4,400 hectares.

FutureGene is a leader in plant genetic research and development for the global forestry, biopower and biofuel markets. With facilities in Brazil, China, and Israel, FuturaGene is a wholly owned subsidiary of Suzano Pulp and Paper - http://www.futuragene.com. Not also that Brazilian National Technical Biosafety Commission (CTNBio) is the agency responsible for biosafety regulation in Brazil based in Sao Paulo - http://www.ctnbio.gov.br.

Observation 16: ***New global timber fund owners and institutional investors in Australia recognise that productivity gains of the forest estate are vital and have the resources and international connections to have an innovative and long-term view to achieve these changes. New innovations and sources of wood fibre will need to emerge to bridge a global demand gap. GM technologies can potentially provide a powerful tool to address these challenges.***

17. GM TECHNOLOGY AND THE 'COMPLEX' PINUS RADIATA GENOME

Obviously one of the most important commercial tree species in Australia is *Pinus radiata*. Tree breeding R&D and processes for improving *Pinus radiata* are very well developed and sophisticated with high quality seedlings with advanced traits being produced every generation. However, what is not well appreciated is that *Pinus radiata* is both an incredibly old and complex (e.g. an 'obese' DNA sequence) tree species. It has a lot of 'redundant' genetic material in its genome that makes it difficult to sequence and apply more advanced GM technologies (e.g. transgenic GM processes), especially for desirable, yet complex and interrelated genetic traits like growth.

Pinus radiata has around 25 billion base pairs of genes compared to around 3 billion base pairs for the human genome and around 640 million pairs of genes for eucalypt species. This has made GM technology advancements for *Pinus radiata* much slower to be developed and realised around the world, whereas there have been more advancements in (relatively) younger and less complex species, such as the key commercial eucalypts. This complexity makes the decision tougher on which tree species (Pinus radiata or eucalyptus) to focus GM technology research funds on.

Box 9: NZ assembles the radiata pine genome[30]

Late in 2017, in a world first, NZ scientists completed a draft assembly of the radiata pine genome. Dr Emily Telfer, who led the project, says, "The completion of the genome assembly means that we now have an instruction book for how a radiata tree grows, it's the foundation we need to begin the task of deciphering what each of the base pairs of DNA relates to in physical terms."

At 25 billion base pairs, the radiata pine genome is eight times bigger than the human genome. Following assembly, the next steps for scientists are to understand each piece of the genome and the role it plays in tree growth and resilience.

[30] *https://www.scionresearch.com/about-us/news-and-events/news/2017/radiata-pine-genome-draft-assembly-completed*

The sheer size of the genome was a large challenge to researchers. Now armed with this knowledge, the forestry industry could breed trees with their desired characteristics – hastening the current method of selective breeding that can take decades to produce superior trees. This marks the beginning of a new era of precision forestry for a critically important species via the use of genomics and other GM technologies.

Observation 17: ***What is not well appreciated is that Pinus radiata is both an incredibly old and complex tree species. It has a lot of 'redundant' genetic material in its genome that makes it difficult to sequence and to apply more advanced GM technologies to, especially for desirable, yet complex and interrelated genetic traits like growth. This complexity makes the decision tougher on which tree species (Pinus radiata or eucalyptus) to focus GM technology research funds on.***

OPPORTUNITIES

18. PRECISION FORESTRY ADDS VALUE TO EXISTING PLANTATIONS

Like many other industries overtime our renewable forest industries are at the crossroads, the future is filled with challenges, but also with many opportunities. When we combine the significant increasing wood fibre demand in the South East Asia region, the challenges from new pests and diseases, the need to adapt to climate change, and the ongoing policy, economic and social constraints to establishing new plantations in Australia, the policy area we aren't talking about enough is increasing the productivity of the replanted estate.

This is peculiar because it was the phenomenal science-supported breakthroughs in the breeding of the radiata pine which gave us the world-class softwood plantation asset we have today in Australia. As an example, back in the 1960's and 1970's there was genetic gain of up to 33% in volume from the first generation by using basic tree breeding techniques.

It is well known that digital technology is revolutionising industries around the world. Forestry is seen by some to have lagged other industries in the adoption of digital technology. This perception and the reality are certainly changing. Studies have shown potential (and actual) productivity increases in general agriculture of 5 to 25 percent[31] annually using digital technology coupled with precision management. Potential gains are not merely in the future for forest products but are being realised by early movers today.

However, inspired in part by advances in agriculture, forest managers globally have begun using advanced technologies to improve forest-management outcomes (widely called "precision forestry"). Precision forestry is enabled by use of a wide range of emerging technologies, such as drones, laser scanning (lidar), and increasingly advanced equipment. But it is not simply the adoption of digital technologies.

[31] *Autumn Quarter 2018, Farm Policy Journal Vol 15 #1, Richard Heath AFI, 'An analysis of the potential of digital agriculture for the Australian economy'.*

For forest managers, it involves a paradigm shift, from broad management prescriptions to a system with digital data capture and planning, granular management prescriptions, and tight operational control including feedback of outcomes.

Each of the precision forestry technologies offers improvements to forest management by:

- tighter control of operations with improved data collection
- increased selectivity of prescriptions to match site and needs, for instance, soil nutrients and the genetic material of seedlings planted
- automation of operations, from nurseries to wood logistics
- optimized decision making with advanced analytics
- better management of biodiversity (flora and fauna) which delivers better environmental and social outcomes

Australia has just under 2 million hectares of existing forest plantation assets with around 70,000 hectares of that being harvested and replanted with new genetic stock every year. Major gains in productivity, survival and health and productivity can be achieved by using digital technology coupled with precision management.

Observation 18: ***Major gains in productivity, survival and health can be achieved by using digital technology coupled with precision management on both new plantations but also the existing plantations in Australia. It is obvious that if improved productivity and value realisation is the primary goal of the forest manager the first investment should be in precision forest management of the existing forest estate.***

19. NEW WOOD PRODUCTS AND WOOD PRODUCT SOLUTIONS (E.G. APPLICATION OF ENGINEERED WOOD PRODUCTS)

Another way of ensuring wood products continue to evolve and meet changing market demands while managing risk is investing in new wood products, wood product solutions and technologies further down in the supply chain while still utilising the same (or slowly changing) wood fibre from our forests.

An obvious example is in the construction industry. Wood is a natural product with natural variation of its mechanical and appearance properties. Alternative construction materials such as steel and concrete are engineered products that have more consistent mechanical and appearance properties. Builders and consumers naturally demand more certainty around their products including properties, appearance, and stability.

New wood product innovations such as LVL, Glulam and CLT are examples of engineered wood products (EWPs) that increase certainty of mechanical and appearance properties. EWPs can cross greater spans, build high-rise buildings, and form part of total building solutions. These EWPs utilise the existing wood fibre and the investment timeline is reasonably short.

As noted previously, forestry is long-term investment. Improvements to the initial feedstock either by precision forestry and/or GM technologies, will take a significant time to flow through into the wood products we sell into the market.

Observation 19: ***Wood product innovation (e.g. EWP, panels and LVL etc) can work hand in hand with a long-term strategy of GM technology deployment. Together this would bridge the gap between the existing resource and the improved resource but also better utilising the resulting wood characteristics after a tree improvement plan has been implemented.***

20. CARBON AND NEW PRODUCTS WILL DRIVE VALUE AND PURPOSE

Climate change and emissions reduction are one of the great policy issues of our time. The Australian government has committed to reduce the nation's emissions by 26-28 per cent on 2005 levels by 2030.

As Australia and the world ramp up efforts to drastically reduce emissions, our renewable forest industries can play an even greater role in Australia's transition to a greener, low-carbon emission economy. Deployment of GM technologies can also play a positive role in grasping these opportunities and the pricing of carbon benefits (especially as they are generally front-ended where the costs of establishing trees are the most) will be a great benefit to offset the increased costs of new R&D and seedling costs related to the application of GM technologies.

In June 2018, AFPA launched the *"18 by 2030 – Forest Industries help tackle Australia's climate change challenge"* initiative which lays the foundation for how our forest industries can further contribute to tackling climate change.

The document outlines how Australia's forest industries can remove an additional 18 million tonnes of $C0_2$ equivalent per year from 2030 (on top of the carbon already stored by our forests), with the right policy settings. In the lead up period from 2019 to 2030, 115 million tonnes of $C0_2$ equivalent can also be stored.

Australia's forest industries are pledging to remove over 18 million tonnes of CO2-e per year by 2030, by:

- **Building Block 1:** Storing carbon in new forest plantations.
- **Building Block 2:** Replanting existing forest plantations to maximise on-going carbon storage.
- **Building Block 3:** Increasing the use of wood products in the construction of new detached residential houses, multi-rise apartment and commercial buildings to offset emissions.
- **Building Block 4:** Reducing emissions from our processing and industrial facilities by being more energy efficient and using renewable bioenergy (both electricity and renewable heat) instead of fossil fuels.
- **Building Block 5:** Reducing emissions in transport by replacing fossil fuels with renewable biofuels.
- **Building Block 6:** Reducing emissions by supporting the use of sustainable biomass for cofiring in existing coal fired power stations or standalone or cogenerating bioenergy plants.

This ambitious but important goal can only be achieved through the right mix of policies across all levels of government to maximise the carbon-storing and emissions reduction potential of our renewable forests and forest products. The 18 by 2030 climate change challenge document can be found here. AFPA's associated 18 by 2030 website with more information is here.

The effectiveness and scale of carbon storage under Building Block 1 and Building Block 2 could be supported initially by implementation of precision forestry principles and ultimately by GM technology deployment.

Observation 20: ***Climate change and emissions reduction are one of the great policy issues of our time. Deployment of GM technologies can play a positive role in grasping carbon opportunities and the pricing of carbon benefits will be a great benefit to offset the increased costs of new R&D and seedling costs related to the application of GM technologies. The effectiveness and scale of carbon storage under Building Block 1 and Building Block 2 could be supported initially by implementation of precision forestry principles and ultimately by GM technology deployment.***

21. OPPORTUNITY COST OF NOT PROGRESSING GM TECHNOLOGIES

It is obvious that GM technology R&D and deployment is resource intensive with long development timeframes and needs a lot of regulatory approvals and social acceptance. However, due to increasing risks including market and climate change impacts the benefits from successful deployment are also potentially high.

The opportunity costs of not have a strategic approach to deploying GM technologies in Australia include:

- Long timeframe to put a successful GM technology framework for key commercial trees species especially as markets and biosecurity risks move quickly
- Lack of necessary expertise in Australia increasing potential cost of R&D and deployment
- Losing good R&D experts to other countries
- Lack of stakeholder exposure and social acceptance of GM technologies for key commercial trees species
- Being significantly behind international competitors in GM technologies
- An ad-hoc approach to political and social concerns against deployment of GM technologies for trees
- Lack of regulatory approvals needed to progress R&D and necessary knowledge

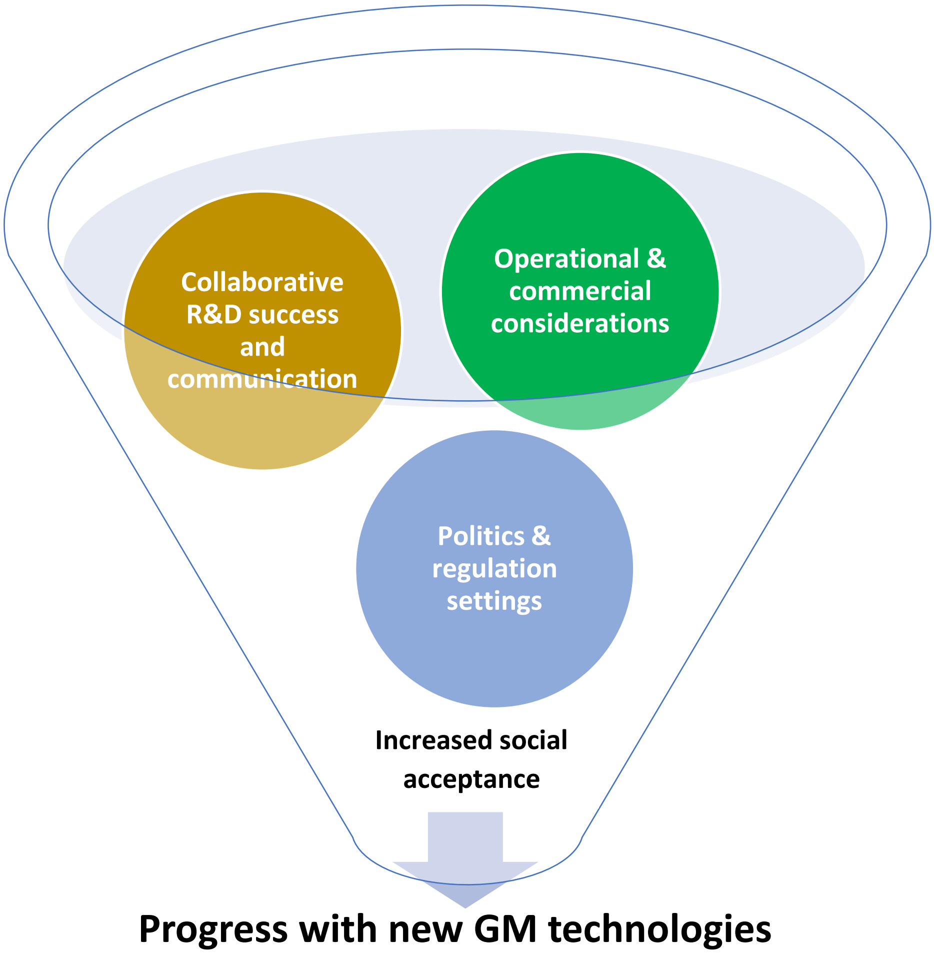
Observation 21: ***GM is resource intensive, has long development timeframes, and needs a lot of regulatory and social approvals but the benefits from successful deployment are also potentially high. There are many opportunity costs of not putting in place a strategic framework for progressing GM technologies for commercial tree species in Australia.***

22. POLICY ENVIRONMENT

What needs to change? A strategic plan to establish a GM technology framework for commercial tree species needs to be developed and changes/actions must include:

- Stakeholder engagement and communication strategy including social purpose.
- Cost/benefit analysis undertaken to inform the Strategic Plan.
- Sustainable Forest Management (SFM) certification engagement.
- Political advocacy and engagement at both Federal and State government levels.
- Regulatory engagement with the Office of the Gene Technology Regulator and other State regulators.
- Whole-of-industry commitment to progressing a GM technology strategy and workplan.
- Establish an industry position/role to coordinate and progress a GM technology strategy and workplan.
- Ongoing collaborative industry with matched government funding will be needed for the necessary R&D program. The funding required will be magnitudes greater than currently expended by our forest growers. For example, in 2020-21, cotton growers and the Australian Government co-invested $18.7 million in R&D (this being down from around $24 million five years ago).

Figure 9 – graphic representation of the inputs to a policy advocacy strategy to implement a GM technology strategy



Observation 22: ***A strategic plan (including a cost-benefit analysis) to establish a GM technology framework for commercial tree species needs to be developed and changes/actions identified and progressed.***

23. OPERATIONAL AND ADVOCACY STAGES

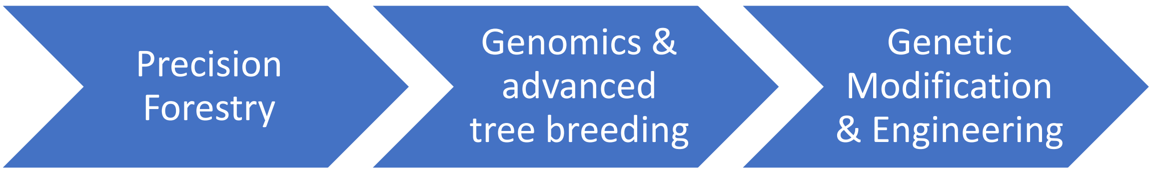
So, is GM technology for us? In the long term yes especially with looming market, climate change and biosecurity risks. However, I argue progressing a GM technology framework in Australia needs to be as part of an integrated tree improvement strategy to reduce risk, increase our trees and forests resilience to known and emerging threats, and increase commercial benefit. A strategy could be temporally broken up into short term (application of precision forestry techniques), medium term (improvements in advanced tree breeding, precision forestry techniques and investment in new technologies, wood products and wood product solutions while preparing the regulatory and social purpose ground for a GM technology plan), and in the longer term (GM technologies being researched and deployed for key commercial tree species). See **Figure 10**.

How can we change it? Concerted political and industry will and commitment needs to be coupled with large investments in funds and resources, collaborative effort and communication, and R&D and policy work. However, initially our forest industries need to wring as much value out of precision forestry and accepted gene technologies along the gene intervention spectrum (including advanced tree breeding and genomics) plus invest in in new technologies, wood products and wood product solutions.

Figure 10 – operational and advocacy/social objectives and strategy over time.

(a) Operational objectives and strategy

Short term objectives ***Long term objectives***



(b) Advocacy and social engagement objectives and strategy

Short term objectives **Long term objectives**

Observation 23: ***A GM technology framework in Australia needs to be as part of an integrated tree improvement strategy to reduce risk, increase our trees and forests resilience to known and emerging threats, and increase commercial benefit.***

ATTACHMENT 1: ADDITIONAL AUSTRALIAN INFORMATION

Below are the Terms of Reference (ToR) for the two recent moratorium reviews. It is useful to show the types of issues that governments and stakeholders look at when considering GMO and GM technologies.

SA Government GM moratorium review (2018)
Under the terms of reference, the SA Government Review looked at:

- Assess available evidence on the market benefits of South Australia's moratorium on the commercial cultivation of GM crops.
- Assess the degree of awareness of South Australia's moratorium amongst key trading partners and food production businesses operating in South Australia and other Australian states.
- Where there is evidence of market benefits resulting from the moratorium, examine whether it is possible to retain such benefits for industry using systems of segregation in the supply chain, having regard to segregation protocols adopted in other jurisdictions.
- Consider evidence from South Australian businesses and industry, market and trade data, the experience in other Australian and international jurisdictions and other relevant evidence to inform the analysis.
- Explore whether there are potential innovations likely to be available for commercial adoption by South Australia's agricultural industries prior to 2025 that would justify a reconsideration of the moratorium on grounds of economic benefit to the state.
- Quantify where possible the economic costs and benefits of maintaining, modifying or removing the moratorium, not limited to but including on-farm impacts, food manufacturing, supply chain costs and impacts on research and development investment in South Australia.

TAS Government GM moratorium review (2019)
Under the terms of reference, the TAS Government Review looked at:

- The potential market advantages and disadvantages of allowing or not allowing the use of gene technology in Tasmanian primary industries, including food and non-food sectors
- Domestic and international gene technology policy relevant to primary industries
- Research and development relevant to the use of gene technology in primary industries
- Any other relevant matters raised during the review
- Under the National Gene Technology Scheme, Tasmania regulates a moratorium on GMOs for 'marketing purposes' and accordingly this is the focus of the review
- Other aspects of gene technology which are regulated by the Australian Government, including human health, safety and environmental impacts are not part of the review

Office of the Gene Technology Regulator and GMO Records (see http://www.ogtr.gov.au/)

The Office of the Gene Technology Regulator is the key regulatory organisation that regulates GM technologies and resulting GMOs. The regulatory process includes:

- Accreditation of both the organisations that research GMOs and the facilities that research GMOs
- Licence to work with GMOs and import GMOs

- Guidelines on transport, storage and disposal of GMO material
- Licence to field trial GMOs
- GM crops grown in Australia are approved for commercial release only when the Regulator found that the GM crops were as safe for human health and the environment as non-GM versions.
- The decision of the Regulator to approve release of any GM crop is based on a comprehensive risk assessment and risk management plan for each application. These documents and other details of the licences can be accessed through the GMO Record.
- The OGTR monitors scientific and other literature for any new information relevant to GM crops, and the Regulator has the power to vary, suspend, cancel or transfer licences.
- All GM crops and other GM organisms in Australia must be authorised by the Regulator. Significant fines and even imprisonment can result from anyone having anything to do with GM crops which are not authorised. This includes growing crops, importing crops, transporting crops – even destroying GM crops without permission.

What is the GMO Record?

- The term 'GMO Record' is shorthand for Record of GMO Dealings (Part 9, Division 6, the Act).
- The GMO Record contains information on all genetically modified organisms (GMOs) approved by, or notified to, the Gene Technology Regulator (the Regulator) or specified in an Emergency Dealing Determination.
- The purpose of the GMO Record is to provide the Australian public with ready access to information about GMOs in Australia.
- Australia was one of the first countries in the world to make such a comprehensive record available to the general community.
- The GMO Record is a very important part of the openness and transparency of the regulatory system for GMOs that has been operating in Australia since 21 June 2001.

What is a Genetically Modified Organism (GMO)?

- Definition: The full definition of a GMO appears under section 10 of the *Gene Technology Act 2000* (the Act). A GMO means:
  a. An organism that has been modified by gene technology; or
  b. An organism that has inherited traits from an organism, where the traits occurred in the initial organism because of gene technology.

What are dealings with a GMO?

'Dealing' in relation to a GMO is defined in the Act as meaning:

- conduct experiments with the GMO
- make, develop, produce or manufacture the GMO
- breed the GMO
- propagate the GMO
- use the GMO in the course of manufacture of a thing that is not the GMO
- grow, raise or culture the GMO
- import the GMO
- transport the GMO
- dispose of the GMO or

- possess, supply or use the GMO for the purposes of, or in the course of, any of the above.

Under Part 4 of the Act, all dealings with GMOs are prohibited unless they are:

- an Exempt Dealing (these are not listed on the GMO Record)
- a Notifiable Low Risk Dealing (NLRD)
- licenced as:
  - a Dealing Not involving an Intentional Release (DNIR) of a GMO into the environment
  - a Dealing involving an Intentional Release (DIR) of a GMO into the environment
  - an Inadvertent Dealing
- included on the GMO Register
- an Emergency Dealing Determination.

What GMO dealings are listed on the GMO Record?

The GMO Record contains information about:

- NLRDs
- all licences granted by the Regulator, including those for
  - DNIRs
  - DIRs
  - Inadvertent Dealings
- dealings with GMOs included on the GMO Register
- GMO dealings authorised by an Emergency Dealing Determination made by the responsible Australian Government minister

Map of active agricultural GMO field trials in Australia from the Office of the Gene Technology Regulator website (see here).

ATTACHMENT 2: NEW ZEALAND

In NZ, I visited the Scion research facility at Rotorua (topics: GM pine field trials). **Thanks to Dr Heidi Dungey, Glenn Thorlby and Lynn Bulman of Scion.**

Scion has been conducting genetically modified tree research since 1992. This research involved non-native, economically important forestry species both in the laboratory and in field trials. http://www.scionresearch.com/, including:

- initial research involved exotic, commercial forest plantation species both in the laboratory and in field trials.
- from 1996 to 1999 Scion undertook field trials with GM radiata pine to establish that the science could be conducted in accordance with all regulatory, risk management and environmental standards.
- in 1996, the Environmental Risk Management Authority (ERMA) was established, and in 2000 ERMA granted Scion approval for certain field trials with radiata and spruce over a 20-year period. The experiments to date have been purely to assess environmental safety. They found no evidence of adverse environmental impacts.
- in December 2010, ERMA granted conditional approval for Scion to field test GM radiata pine in outdoor containment, for both environmental impact assessments and commercial traits.
- introduced genes and other relevant DNA sequences will be obtained from naturally occurring organisms such as bacteria, fungi, and plants (including pine). No genetic elements from humans, or New Zealand indigenous flora and fauna was used.
- trees will be assessed for expression of the new genes, herbicide tolerance, improved growth rate and wood quality traits. Environmental impacts will also be assessed by monitoring the microorganisms and insects living in association with pines.
- in April 2012, a field trial of GM radiata pine trees planted in a secure site at Scion's Rotorua campus was deliberately destroyed.

I have also spoken to the NZ Forest Owners Association (topics: national industry policy and drivers of GM research and deployment). *The New Zealand Forest Owners Association (FOA) represents the owners of New Zealand's commercial plantation forests.* *http://www.nzfoa.org.nz/.* **Thanks to David Rhodes CEO of NZ FOA.**

Additionally, I have researched the operations of Environmental Protection Authority (EPA), Wellington (topics: national regulatory settings of GM research and deployment). *The EPA is the government agency responsible for regulatory functions concerning New Zealand's environmental management. http://www.epa.govt.nz/.*

Box 10: NZ 2018 discussion paper 'The use of gene editing in primary industries'

The Royal Society Te Aparangi's new discussion paper – '*The use of gene editing in the primary industries',* explores the relevant considerations, risks and potential benefits for five scenarios of how gene editing could be used for primary production sectors including agriculture, forestry and horticulture.

These papers explore five scenarios of where gene editing could be used in New Zealand's primary industries to: reduce environmental impact (reduce wilding pines); respond to insect pests and environmental stress (improve forage grass); speed up innovation (develop new apple varieties faster); protect taonga species used in the primary industries (protect Mānuka from disease); and provide new human health benefits (remove potential allergens from milk)

A multidisciplinary expert panel and reference group had been brought together to explore the wider social, cultural, legal, and economic implications of gene editing in New Zealand, incorporating Maori perspectives and broader cultural contexts.

The society also held three workshops around the country to discuss the potential use of gene editing in the primary industries with the panel and reference group members, and gauge New Zealanders' views.

A scenario the paper discusses is using gene editing to make manuka resistant to disease, due in part to the potential risks of myrtle rust and kauri dieback diseases. Generating the question should NZ use gene-editing to create new varieties of manuka that are resistant to disease?

Another scenario is to use gene editing to make exotic conifer trees, such as Douglas fir, sterile, as wilding trees were a big problem in New Zealand, outcompeting native species, costly to remove and can contribute to pollen allergies. Gene editing could halt the production of cones and pollen in these species. Source: https://www.royalsociety.org.nz/

NZ photo 1: mature *P.radiata* trees from improved stock located at Scion's facility at Rotorua.

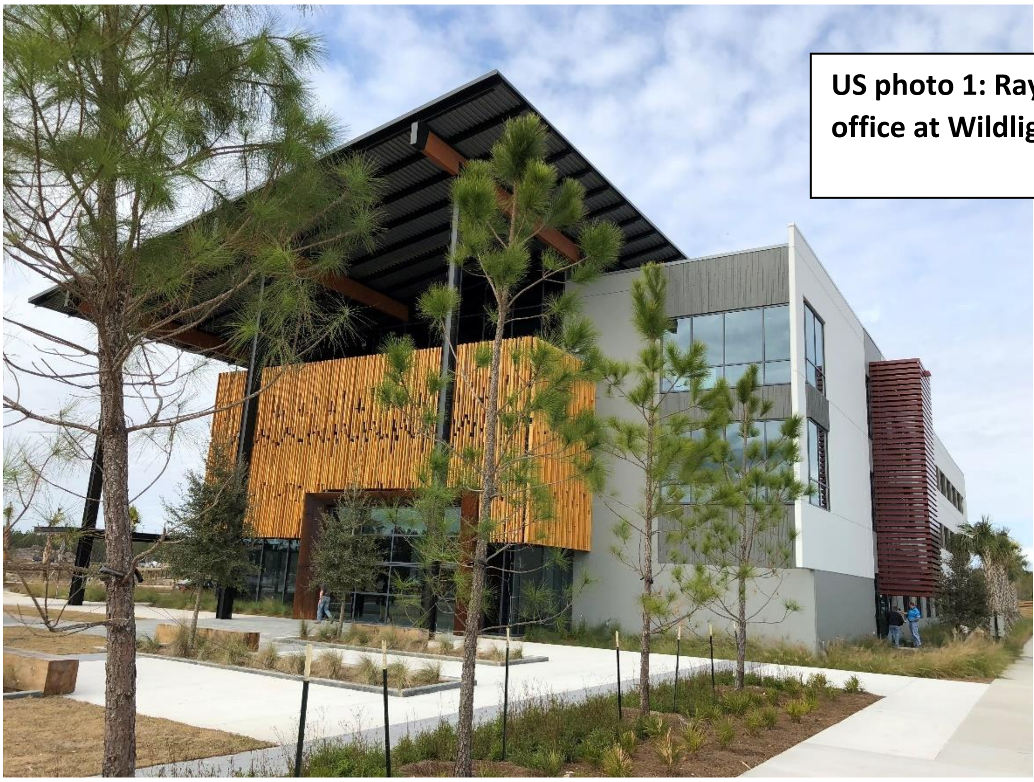
NZ photo 2: Seedlings and cuttings of improved material at Scion's facility at Rotorua.

NZ photo 3: security measures in place for field trails of *P.radiata* from GM technologies located at Scion's facility at Rotorua.

ATTACHMENT 3: SOUTH-EAST US

In Florida, I visited Rayonier's new head office, real estate arm, tree improvement offices, nursery and operations and sustainability staff based out of Wildlight Yulee. See https://www.rayonier.com/about-us/company-snapshot/

Rayonier's strategy is to increase its timberland holdings while upgrading the quality by evaluating every acre, divesting nonstrategic timberlands and re-investing in strategic timberlands. Our 2.7 million acres of working forests, located in eleven U.S. states - focused in the U.S. South and U.S. Pacific Northwest - and New Zealand, provide wood for use in a variety of markets, from pulp to lumber, paper, oriented strand board (OSB) and other wood-based products. Rayonier is committed to the responsible management of every acre. In the U.S., we voluntarily subscribe to the Sustainable Forestry Initiative® program, which includes independent third-party audits of our practices. In New Zealand, all our forests are 100% certified by the Forest Stewardship Council, a not-for-profit organization that promotes responsible management of the world's forests.



US photo 1: Rayonier new head office at Wildlight Yulee, Florida.

I also visited the Rayonier materials plant at Fernandina, Florida US. See https://rayonieram.com/facilities/fernandina-plant/.

In 2014, Rayonier Inc. divided its land resources businesses from its performance fibers business, creating two independent publicly traded companies. Rayonier is now a global forest products company with products ranging from lumber, paperboard and newsprint to high-yield pulp and high-purity cellulose. They have expanded our international footprint to include global manufacturing operations in Canada and France in addition to our U.S. operations.

Thanks to Josh Sherrill, Tom Fox, Dan Roach from Rayonier US.

US photo 2: Rayonier materials facility at Amelia Island, Fernandina.

US photo 3: Non-GMO branding on milk in US (Food v Fibre!)

US photo 4: Non-GMO branding on juice in US (Food v Fibre!)

I visited ArborGen at their state-of-the-art R&D facility located in Ridgeville, South Carolina. See https://www.arborgen.com/about-arborgen/. Note that Arborgen has operations in NZ and Australia. See https://supertreeseedlings.co.nz/. Arbogen is a leading Global Supplier of Conventional and Advanced Genetic Tree Seedlings Exclusively for the Forestry Market - ArborGen is committed to effective, sustainable forestry solutions that improve the productivity of well-managed, working forests to meet the challenges facing the global commercial forestry industry.

Thanks to Mike Cunningham, Les Pearson, Eric Gulledge and Andrew Baum etc from Arborgen US. Arborgen's major areas of focus has been on:

a. **Tree genomics.** Is the study of a given organism's DNA, gene sequence, and function. Genomic tools have been a major research and development emphasis for agronomic plant and animal species to improve yield and quality, reduce disease, and improve nutrition. The genomes of forest trees are large and diverse making it challenging to identify the DNA variation and underlying genes that affect the appearance and performance of the trees. Forest trees have been the focus of many breeding programmes for genetic improvement for over 50 years but these species still remain highly diverse. Being able to identify genetic markers related to the variation in phenotypes (the composition of an individual's characteristic traits) offers the potential to genetically improve forest tree species at a much faster pace than traditional breeding approaches. In recent years the genomes of several tree species have been sequenced including Populus (Poplar), Eucalyptus (Eucalypts), and Pinus (Pine). This work has been led by collaborating scientists at various Federal facilities, Academic institutions and other Industry groups. Key breeding traits targeted are growth, straightness, branching and fusillarium rust resistance.

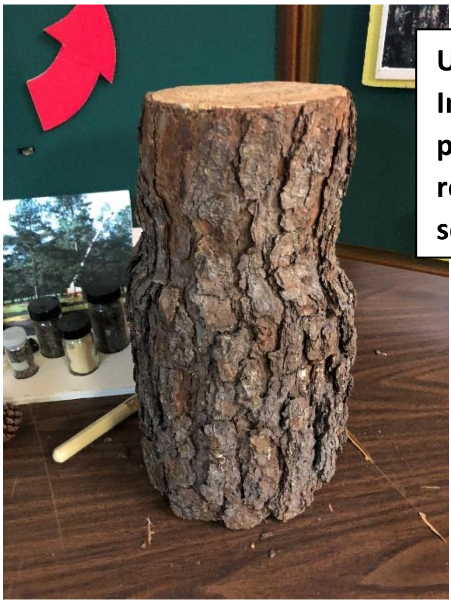
b. **Biotech trees.** Arborgen has a fully integrated technology platform for introducing, testing and commercialising trees. Arborgen's freeze tolerant tropical Eucalyptus product (AGEH427) is currently going through the government review process for deregulation in the United States. This tree combines the fast-growing and highly desirable fibre quality characteristics of a proven Eucalyptus variety grown in Brazil with the ability to withstand freezing temperatures. Eucalyptus is typically harvested after seven years of growth in countries like Brazil, yielding an average of 17 green tons per acre per year. Arborgen's first-generation freeze tolerant tropical Eucalyptus, targeted at the south-eastern United States, is designed to have growth and quality traits comparable to Eucalyptus in Brazil and to grow in areas significantly farther north than the areas in which conventional tropical Eucalyptus is currently grown. Other traits ArborGen continues to research include improved growth and wood quality, increased density and drought tolerance as well as bioenergy possibilities. Several of Arborgen's projects are in conjunction with academic collaborators including the BioEnergy Science Centre (BESC), University of Georgia and University of Florida.


US photo 5: Charleston SC

US photo 6: Everything is bigger in the US (including the trucks) reflects US support for their vehicle manufacturing industry and the cheap price of fuel (US $0.70 per litre at that time)

US photo 7: The pinecones of the different species of southern pines

I visited South Carolina Forestry Service (SCFS) operations in Tillham SC and head office located in Columbia. See https://www.state.sc.us/forest/scmiss.htm. South Carolina Forestry Service (SCFS) has about 350-employees and is charged with protecting and enhancing South Carolina's forest resources. Forest firefighters are based in every county for quick response to wildfires, and project foresters are available to assist landowners throughout the state. Three regional dispatch centers coordinate state-wide forest protection. The Commission operates five state forests, and a modern forest nursery which grows over 17 million containerized and bareroot seedling species for S.C. landowners. The Commission continues to provide a range of educational programs to better inform the state's citizens concerning the wise use and management of South Carolina's forest resources. **Thanks to Tim Adams, Scott, Mike Sheely, Herb, Edgar and Russell from SCFC US.**



US photo 8: Improved southern pine grafted to older rootstock for use in seed orchards.

US photo 9: SCFS office at Columbia

US photo 10: Disc-saw on wheel mounted feller buncher in southern pine harvesting operation

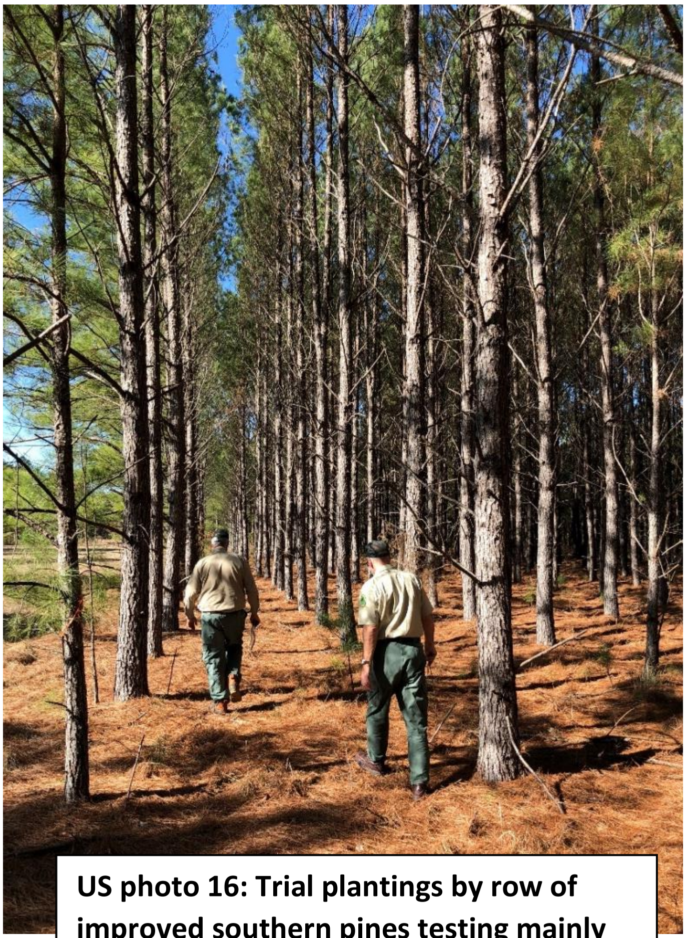
US photo 11: Seed pollinator bag used in seed orchards.

US photo 12: Southern US native river trees with epiphytic Spanish moss.

US photo 13: Grapple skidder in southern pine harvesting operation

US photo 14: Grafted seed orchard with protection from pest predation.

US photo 15: Failed plantings of frost/cold intolerant eucalyptus in SC



US photo 16: Trial plantings by row of improved southern pines testing mainly for growth and rust resistance.

US photo 17: (L) row of low rust resistance and (R) row of high rust resistance southern pine provenances