Coding for Change

Navigating adoption of gene editing in the New Zealand primary sector

By Rachel Baker

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Executive Summary

Gene editing is poised to reshape the New Zealand primary sector, offering opportunities to adapt to climate change, enhance environmental sustainability and boost productivity. With advancements in more precise, faster, and safer gene editing techniques, new legislation has been proposed to align New Zealand's gene technology regulations with those of its trading partners and other agricultural trading nations. It is essential for New Zealand to adopt a balanced approach that harnesses scientific innovation and collaboration while maintaining public trust and market access.

Adoption of gene editing in New Zealand has the potential to transform specific segments of the agricultural value chain, such as scientific research, the biotech sector, and plant breeding. In other segments it will serve as an additional tool to address often complex challenges. In these situations, its impact may be more incremental due to the time to achieve sufficient scale that generates outcomes of significance. It will be essential for expectations to be managed to ensure that the government, primary sector, and public have realistic views on the potential benefits as well as limitations of this technology. Primary sector and government research will play an important role in independent monitoring and reporting of outcomes.

In developing regulatory framework, New Zealand has the opportunity to implement Environmental, Social, and Governance (ESG) principles and adopt a holistic approach that includes evaluations of economic, societal, and environmental impacts alongside standard safety and risk assessments. This expanded method would necessitate case-by-case evaluations, which would be more demanding for both regulators and applicants. However, it would ensure a more comprehensive and balanced assessment, enhancing public, sector and trade confidence.

It is vital that the primary sector assumes a leadership role at a regulatory level to ensure that impacts and opportunities to agriculture are forefront of mind. Coordination and development of production sector strategy frameworks for gene technology will help identify research and innovation pipelines, opportunities and risks, and timelines to commercialisation for end-users.

Early engagement between government, sector organisations, farmers, growers, Māori and the public will be vital to align shared values, listen to concerns and shape what the acceptable role of gene technology should look like. Presenting relatable examples to enable the building of knowledge and development of informed opinions, rather than an expert 'top down' approach is vital. Not all will be in favour of regulatory change and these perspectives must be respected.

There needs to be a focus on investment to drive innovation including leverage of public-private partnerships and international collaboration. The challenge will be to enhance scientific capability, capacity, and confidence during uncertain times for the science sector in New Zealand.

A 'fast follower' approach to gene technology legislation will help New Zealand balance scientific opportunities with the trust of trading partners and the public. By carefully navigating the adoption of gene editing, New Zealand can enhance its primary sector's productivity and sustainability while simultaneously enhancing its global competitiveness.

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Acknowledgements

Being awarded a Nuffield scholarship has given me the privilege of gaining first-hand a global perspective of food production, but more importantly, of meeting and connecting with many amazing people around the world involved in bringing food from the farm to the plate. It has been a truly inspiring journey of learning and personal development for which I am eternally grateful.

I wish to sincerely acknowledge and thank the New Zealand Rural Leadership Trust, Chair Kate Scott and her fellow trustees, for awarding me what is a once-in-a-lifetime opportunity, and to Lisa, Lyndsey and Annie of New Zealand Rural Leaders for their fantastic organisation and support, always with a smile. Hamish Gow has also been a great source of knowledge and an enthusiastic catalyst for challenging thought conversations over the course of the year.

My Nuffield scholarship was made up of the following:

- The Rural Leaders New Zealand "Value Chain Innovation Program" doing a 'deep dive' tour of the North Island's food sectors and supporting industries.
- Attending the Nuffield 2024 Contemporary Scholars Conference (CSC) in Brazil (Mato Gross du Sol state), followed by a small group post-tour in Sao Paulo state.
- A Global Focus Programme (GFP) six-week tour of Indonesia, France, Denmark, California and Chile with 11 other Nuffield scholars from Australia, Ireland, Brazil, Chile and Zimbabwe.
- Personal study travel to Ireland, Italy (to attend the Food & Agriculture Organisation of the United Nations World Food Forum), Netherlands, United Kingdom and Washington State, USA.

I would like to thank the numerous people who so generously gave of their time to host, present, share contacts and be interviewed. It's the face-to-face conversations and experiences from which you learn the most - there is always an open door here for you in New Zealand. I would like to thank the country hosts for an outstanding GFP programme and my fellow GFP scholars for the best fun-filled learning crew I could have hoped for, you are all friends for life. And to my fellow inspiring 2024 New Zealand scholars Jenna, Carlos and Pete whom I shared the journey, I look forward to what you do next.

And most importantly, I would like to thank my husband Rowan and children Alice, Emma and Harry for their love and support during my Nuffield year, you mean the world to me. And to our families, particularly my sister Fiona, and our friends in our wonderful community, for always being in support. It truly does take a village.

Objectives

In my year of Nuffield travels, it was apparent that agri-food producers globally are facing many of the same challenges. The economic model of producing food from the land is increasingly complex, more volatile and in some cases uncertain, amid a changing climatic, social and political landscape. Despite this, there is optimism in abundance and confidence in the application and advances of science and technology, to continually improve and adapt.

One such application that has the potential to transform agri-food systems globally is gene editing. My interest was piqued as the New Zealand government signalled a change in legislation during my Nuffield year, and many of the countries I visited were either cultivating genetically modified crops or changing legislation to enable it in the future. This framed my study objectives to:

- Gain an international perspective on the use of gene technologies and the changing legislative and regulatory environment.

- Understand potential opportunities and risks for using gene editing technology in New Zealand.

- Identify useful framework for navigating change with new scientific technologies such as gene editing.

While the scope for gene editing encompasses plants, microbes, animals and even human medicine, the general focus of this project has been on pastoral and crop examples, as these are already grown commercially in many countries and adoption of these in New Zealand is likely to supersede the commercial application of gene editing in livestock.

Nuffield Contemporary Scholars Conference, Brazil, June 2024. Photo source: Author.
Tour of sugar cane and citrus plantations in Sao Paulo State.
Brazil is the world's largest sugarcane producer and exporter. Sugarcane is primarily used to produce sugar and ethanol for biofuel. Genetically modified sugar cane (resistant to sugarcane borer) was approved for commercial use in Brazil in 2017.

Chapter 1: Introduction

Primary export production is vital to New Zealand's economy, providing export revenue and employment for a country of 5.2 million people. The food and fibre sector accounted for 81% of NZ's export goods in the year ended 30 June 2024, generating $53.3 billion in export revenue, of which $23.2 billion was dairy, $11.3 billion meat and wool and $7.1 billion horticulture[1].

With a small domestic market and unsubsidised production, New Zealand primary production is highly attuned to global market signals and maintaining its position as a trusted and preferred partner to key markets, customers and consumers. Main trading partners for primary produce are China (32%), United States (12%), Australia (8%), European Union (6%) and Japan (5%) and a total of fifteen free trade agreements (FTA) are currently held which accounted for over 70% of New Zealand's trade in 2023. [2]

Innovation and adaption have long been key to maintaining New Zealand's global competitiveness as it has transitioned through distinct phases over the past century, driven by evolving economic, environmental, and social imperatives. In a post-World War era, the general focus was on maximising production from fertile soils and a temperate climate to meet the growing demands of counter-cyclical European markets. This was characterized by an increase in farming scale and the intensive use of natural resources to boost output. However, the removal of agricultural subsidies in the 1980's, combined with unfavourable interest and foreign exchange rates, exposed the limitations of solely volume-based strategies. The sector shifted towards enhancing productivity through on-farm efficiency, product differentiation and supply chain restructuring. In recent decades, the need to address environmental concerns and obligations as well as societal expectations has instigated a shift to sustainable farming practices that minimise environmental impact. Automation and technological advancements, improved management techniques, and genetic improvements from focused breeding programmes have all contributed to implementing change.

Globally the business of producing food globally to meet a growing world population and burgeoning middle class has become more complex, compounded by the impact of Covid-19, climate change, geopolitics and conflict on supply chains. Primary producers and agricultural businesses have had to balance economic viability and environmental stewardship in an increasingly prescriptive regulatory environment, under the spotlight of government and public. For example, there have been increasing demands on livestock farmers from global buyers and multinationals to reduce emissions as part of their focus on Scope 3 decarbonisation. Policy initiatives, such as the European Union "Farm to Fork Strategy" to reduce pesticide use by 30% by 2030, are tightening the guard rails on management practices. Innovation is needed to navigate this complexity in the pursuit of multiple and complimentary solutions.

The development of new gene editing techniques, such as CRISPR, has created possibilities to accelerate adaptation to climate change and address national and global food security and sustainability commitments. This has hastened a review of gene technology policy and regulation in many countries where current legislation is no longer considered fit for purpose.

New Zealand has some of the strictest gene technology legislation in the world and has lagged behind its trading partners and agricultural producing countries in reviewing it. This is

[1] Situation and Outlook for Primary Industries (SOPI) December 2024

[2] Situation and Outlook for Primary Industries (SOPI) December 2024

understandable, with a high reliance on market access for trade, and a value proposition built around production systems and product integrity.

The New Zealand National party included review of gene editing legislation as part of its election campaign and enacted its pledge when it formed a coalition government in October 2023. Keen to provide the scientific community and primary sector with the opportunity to employ gene editing to help solve challenges and drive economic prosperity for the country, New Zealand is now embarking into new territory as policy makers, food producers, consumers and citizens navigate this 'code for change'.

Global Focus Programme group visit to Terranova Ranch, California, USA. Photo source: Author.

Chapter 2: The Science

The scientific techniques used to modify an organism's genome have developed over time, becoming more precise, efficient, available and cost-effective. Associated terminology has also evolved to distinguish these new modification techniques from those used historically. Broadly, differentiation of techniques relates to the preciseness of the technique used, the amount of genetic change that has been made and whether foreign DNA has been introduced.

Genetic modification (GM) involves the modification or deletion of an organism's genetic code and may involve temporary or permanent insertion of foreign DNA material into an organism's genome using DNA technology, creating a genetically modified organism (GMO). Genes can be transferred from a sexually compatible species (termed cisgenesis) or between different species (termed transgenesis). Traditionally this process involved often random or untargeted insertion of genes from different species to produce desired traits, such as pest resistance. Genetic modification is typically broader in scope and can result in the creation of organisms with entirely new properties.

Example of genetic modification

Insect resistant corn, known as 'Bt' corn is modified to include genes from the bacterium *Bacillus thuringiensis* which produces a protein that is toxic to insects.

Herbicide tolerance (HT) corn is modified to include a bacterial gene that prevents susceptibility to weedkillers, such as glyphosate. Corn can have 'stacked' traits which have resistance to both insects and herbicide.

In 2020, 92% of corn planted in the US was GMO.[3]

Gene Editing (GE) refers to a group of technologies that enable scientists to make highly precise, targeted changes to the DNA of an organism's genes (the part of the cell that determines heritable characteristics of individuals). Changes can be the addition, removal, replacement or alteration (e.g. silencing) of genetic material at specific locations which is expressed as traits such as pest resistance, drought tolerance and enhanced nutritional value.

[3] GMO Crops, Animal Food, and Beyond | FDA

A good analogy of gene editing is "being a bit like editing a document. Scientists can find a specific "word" or "phrase", in this case a DNA sequence or gene, and then delete it, change it for another "word" or add additional "words" to improve it"[4].

CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) is a new gene editing technique that has revolutionised gene technology. CRISPR-Cas9 was discovered in 2012 by American scientist Jennifer Doudna, French scientist Emmanuelle Charpentier, and refined by American scientist Feng Zhang.[5] They identified that a bacterial enzyme defence system against invading viruses could be adapted to modify the DNA of living organisms by targeting specific DNA sequences. Popular metaphors used to describe CRISPR is a pair of genetic scissors, effectively a 'cut-and-paste' tool at a molecular level[6] or malware in that CRISPR can search for any chosen 20-character line of genetic code and corrupt it.[7]

There has been a long-running legal battle over the patent for CRISPR-Cas9 which was awarded in the US to the Broad Institute (Zhang) but has been repeatedly appealed by the University of California (Doudna) and Charpentier who were awarded the Nobel Prize in Chemistry in 2020 for developing the technology.[8] Other CRISPR enzymes have since been discovered and patented.

The CRISPR technique was far more precise than previous techniques and carried a lower risk of off target effects, was faster and more affordable. These modern techniques are often described as 'precision gene technologies' or 'precision breeding techniques' (PBT) to differentiate them from earlier techniques of genetic modification.

Some CRISPR gene edits to an organism's existing DNA can be very small and indistinguishable from a conventionally bred organism or naturally occurring mutation. This has prompted a review of GM legislation in many countries to differentiate between gene editing and genetic modification and the associated regulatory approach (see Chapter 4).

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4 https://www.technologynetworks.com/genomics/articles/genetic-modification-techniques-and-applications-382001

5 Gene editing | Definition, History, & CRISPR-Cas9 | Britannica

6 Wielding the genetic scissors | EMBL

7 Why the 'molecular scissors' metaphor for understanding CRISPR is misleading

8 Ongoing CRISPR Patent Dispute Complicates Licensing but Hasn't Deterred Gene-Editing Investment - BioSpace

Example of gene editing

One of the world's most common banana varieties, Cavendish, which comprises 99% of all exported bananas and an estimated 80 per cent of global production, is under threat due to susceptibility to a new variant of Panama disease, known as TR4. [9] [10] Panama disease is caused by the soil borne fungus *Fusarium* which causes plant wilting and death.

English biotech company Tropic has developed a QCAV-4 Cavendish banana using CRISPR gene editing technology[11] using a gene from a wild banana that is resistant to Panama disease.

Tropic estimates there are 400 million people worldwide whose livelihood and nutrition depend on the banana sector.

In February 2024, Food Standards Australia New Zealand (FSANZ) approved the commercial growth of the QCAV-4 banana.

"We have moved a banana gene from one banana to another. There's nothing scary. The gene was already present in Cavendish … it just doesn't work so we have put in a version that works."

"We're going to need these sorts of technologies to cut down on pesticides, but also as we're getting into a much more challenging climate, we've got to be able to generate new cultivars that are able to cope with all these new conditions."

Professor James Dale, leader of the banana biotechnology program at the Queensland University of Technology[12]

[9] What We Can Learn From the Near-Extinction of Bananas | TIME
[10] Panama disease Tropical Race 4 - DAFF
[11] Gene-Edited Bananas: Tropic's Solution to Global Threats | Tropic
[12] Genetically modified banana resistant to Panama disease given approval for Australian consumption - ABC News

Chapter 3: Global Uptake of GM

3.1 Commercial Cultivation

Twenty-seven countries have approved GM crops for cultivation since the first plantings in 1996. In 2023, 206 million hectares was planted in genetically modified crops globally, about 13.4% of the world's farmland area.[13]

The top five countries in terms of planted area in 2023 are the United States, Brazil, Argentina, India and Canada, collectively representing 91% of the world's GM crops. These countries have large scale or broadacre cropping of soya bean, maize, cotton and/or canola. Over 70% of GM crops are fed to food producing animals[14], such as livestock or poultry, but also for human consumption, fibre and biofuel production.

Drivers for using gene edited crops has been to increase yield and reduce the likelihood of crop failure, through increased tolerance to specific insect pests and disease, increased tolerance to herbicides (specifically glyphosate based), or both (referred to as 'stacked' traits).

top 10 countries by area	gm area (ha.)	% change	top 10 countries by area	gm area (ha.)	% change
1 USA	74.4	-0.4	6 Paraguay	4.3	+8.2
2 Brazil	66.9	+5.9	7 South Africa	3.3	+3.6
3 Argentina	23.1	-1.4	8 China	2.8	-7.9
4 India	12.1	-2.3	9 Pakistan	2.3	+33.3
5 Canada	11.5	+1.5	10 Bolivia	1.5	+7.0

Figure 1. 2023 Top 10 Countries by GM Planted Area. Source: [AgbioInvestor-GM]

Global growth in GM planted area increased by 1.9% in 2023, with greater areas of maize, soya bean and canola offsetting a decline in cotton areas. The rate of growth is slowing as the GM area in some of the early adopting countries has reached relative maturity. The exception is Brazil which increased by the most area, adding 3.7 million hectares of GM crops in 2023.

13 https://doi.org/10.1016/j.jia.2024.09.012

14 Van Eenennaam, A.L. GMOs in animal agriculture: time to consider both costs and benefits in regulatory evaluations. *J Animal Sci Biotechnol* **4**, 37 (2013). https://doi.org/10.1186/2049-1891-4-37

Figure 2. Global Map of Countries growing GM crops. Source: ISAAA (2019)[15]

[15] https://www.isaaa.org/resources/publications/briefs/55/executivesummary/brief55-fig1.jpg

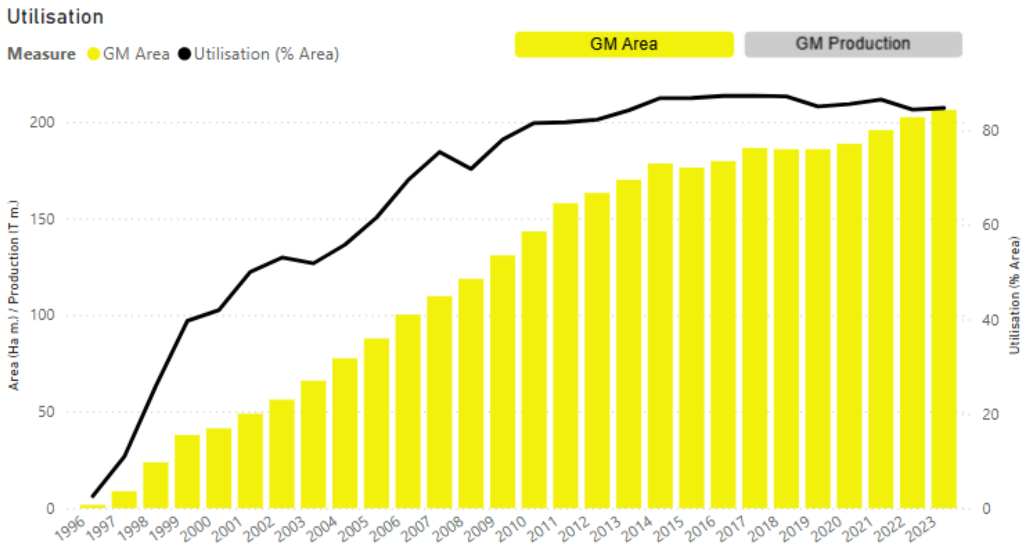

Figure 3. Annual Global GM Planted Area (hectares)
Source: [GM Production - AgbioInvestor-GM]

The USA has been the largest adopter of GM crops globally. In 2020, GMO soybeans made up 94% of all soybeans planted, GMO cotton made up 96% of all cotton planted, and 92% of corn planted was GMO.[16] The use of stacked herbicide tolerant and insect resistant varieties, has increased rapidly and now dominate the market. USA GM crop area declined by 0.4% in 2023 as result of lower soya bean, cotton and sugar beet areas.

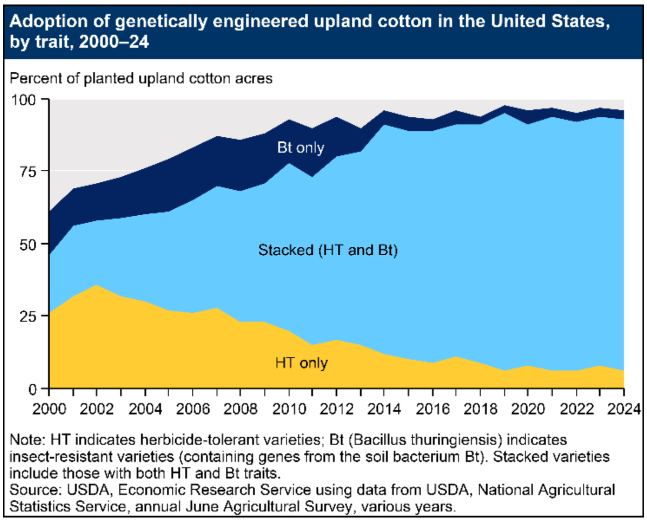

Figure 4. Adoption of genetically engineered cotton by trait in the US 2000-2024[17]

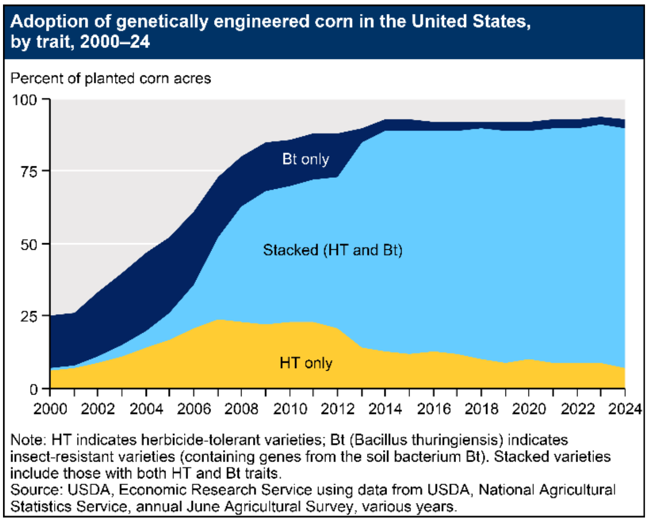

Figure 5. Adoption of genetically engineered corn by trait in the US 2000-2024

[16] GMO Crops, Animal Food, and Beyond | FDA

[17] Adoption of Genetically Engineered Crops in the United States - Recent Trends in GE Adoption | Economic Research Service

In Brazil, the second-largest adopter, 99% of soya bean and cotton crops grown are GM, and 95% of corn crops.[18] The first GM crop sown commercially in Australia was in 1996 in New South Wales. This was an insect resistant variety of cotton developed under licence.[19] However, at that stage Australia had no nation-wide legislation to regulate the commercial cultivation of genetically modified crops. By 2016, 98% of Australia's planted area of cotton was GM, either insect-resistant or herbicide-tolerant or both, and in 2017 GM canola accounted for 23% of planted canola in New South Wales, Victoria and Western Australia.[20]

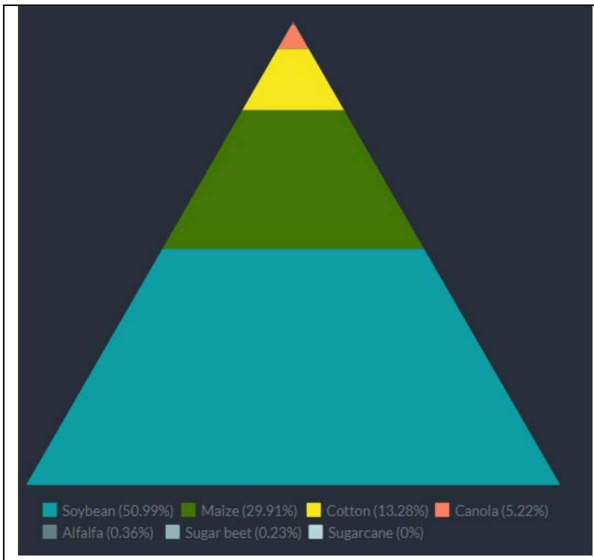

Figure 6. Proportion of GM crops planted globally 1996-2023. Source: AgbioInvestor-GM

Soya bean accounts for 51% of GM crops planted globally from 1996-2023, followed by maize/corn (30%), cotton (13%) and canola (5%).

Soya bean crops are used to make livestock e.g. cattle, and poultry feed, soybean oil (for human use or biofuel) and ingredients for processed foods, such as lecithin, emulsifiers and proteins. Genetically modified soyabean is currently the most important source of feed protein within the European Union[21] where about two-thirds of the protein source is from GM soyabean.

Maize or corn accounts for 30% of GM crops grown and is predominantly used for livestock and poultry feed and biofuel with a small amount processed for human food.[22]

The author attended the Science and Innovation presentations at the Food & Agricultural Organisation of the United Nations (FAO) World Food Forum (WFF)conference in Rome 2024. The narrative was that a focus on sustainability should not be at the expense of food security and the impact of the "3 C's" – Covid-19, Climate Change & Conflict - has highlighted the vulnerability of many countries to food and energy security. Adapting to climate change and reducing the likelihood of crop failure in developing countries is critical. Nineteen developing nations — including India, Pakistan, Paraguay, Brazil, Bolivia, Sudan, Mexico, Colombia, Chile, Vietnam, Philippines, Honduras and Bangladesh — now account for 53 percent of the world's acreage in GM crops.[23] In 2023, areas in Pakistan, Ethiopia, Indonesia, Vietnam and Kenya increased proportionally the most on the previous year as these countries start planting GM crops. [24]

[18] USDA FAS-GAIN Releases Agri-biotech Updates in Brazil- Crop Biotech Update (December 14, 2023) | Crop Biotech Update - ISAAA.org
[19] biotech-aus-policy-snapshot.pdf
[20] ISAAA 2016, Global status of commercialized biotech/GM crops: 2016, ISAAA brief no. 52, International Service for the Acquisition of Agri-biotech Applications, Ithaca, NY
[21] Prevalence of Genetically Modified Soybean in Animal Feedingstuffs in Poland - PMC
[22] The GMO High-Risk List: Corn - The Non-GMO Project
[23] Developing nations lead growth of GMO crops - Alliance for Science
[24] AgbioInvestor-GM

3.2 GM Regulatory Approvals

Approvals for the commercial use of GM are for cultivation, human food products or feed for food producing animals e.g. livestock or poultry.

From 1996 to 2019, there were 4,485 regulatory GM approvals granted globally of which 47% were for food, 34% were for livestock feed and 19% were for cultivation (refer Table X.)

Rank	Country	Food	Feed	Cultivation	Total
1	United States	183	178	178	539
2	Japan*	186	177	130	493
3	Canada	147	138	144	429
4	Brazil	111	111	106	328
5	South Korea	157	148	0	305
6	Philippines	116	114	14	244
7	Mexico	188	29	14	231
8	Argentina	77	69	75	221
9	European Union	100	101	4	205
10	Australia	118	18	39	175
	Others	732	431	152	1315
	TOTAL	2115	1514	856	4485

Figure 7. GM Approvals to 1996-2019 by Country. Source: ISAAA[25]

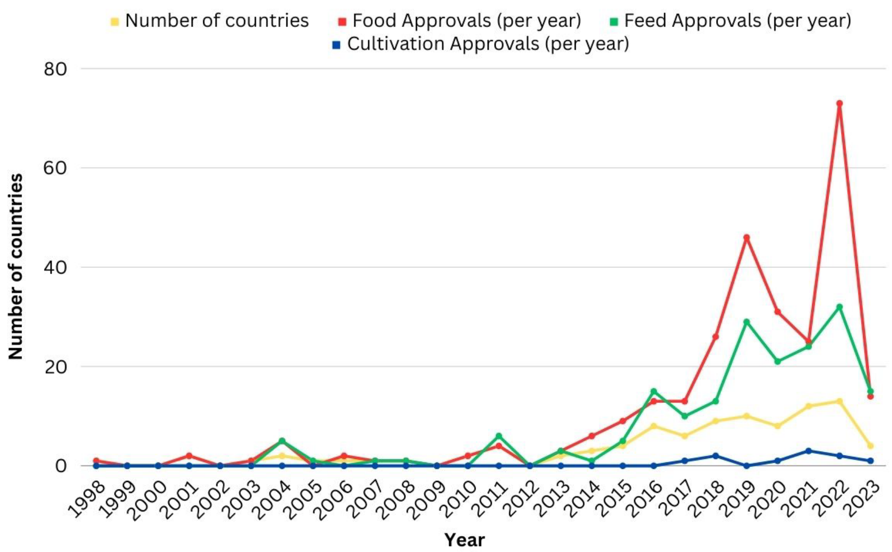

Figure 8. Number of country approvals for GM crops by year (ISAAA[26])

[25] https://www.isaaa.org/resources/publications/briefs/55/executivesummary/brief55-fig1.jpg

[26] [Highlights from the GM Approval Database | Science Speaks - ISAAA.org]

Food approvals by country have trended higher than feed and cultivation approvals, peaking in 2022. From 1998 to 2023, Colombia had the highest number of food approvals, while the European Union and Argentina topped feed and cultivation approvals, respectively.[27] This reflects the increasing application of GM in ingredients in processed food and imported food versus more stringent regulation of cultivation. Approvals of feed for food producing animals have trended steadily upwards since 2015.

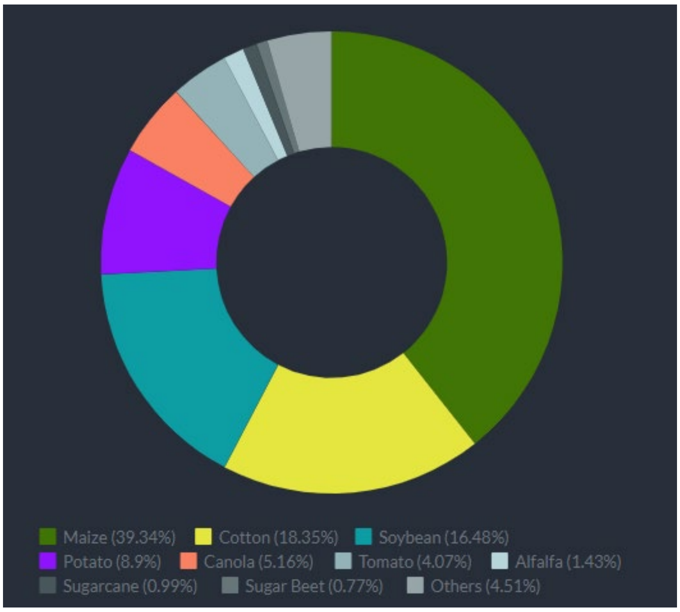

Figure 9. Global cultivation approvals by proportion
Source: [Downloads - AgbioInvestor-GM]

Globally, the number of approvals is highest for maize/corn (39%), followed by cotton (18%) and soyabean (16%) (Figure 9.)

In 2023 there were 65 new approvals of GM species globally, of which 49.32% was corn, 32.31% soya bean and 7.69% cotton. China approved 24 new GM safety certificates in 2023, which included the first herbicide-resistant cotton and gene-edited soya bean permitted into the country.[15]

[27] Countries Approving GM Crop Cultivation | Science Speaks - ISAAA.org

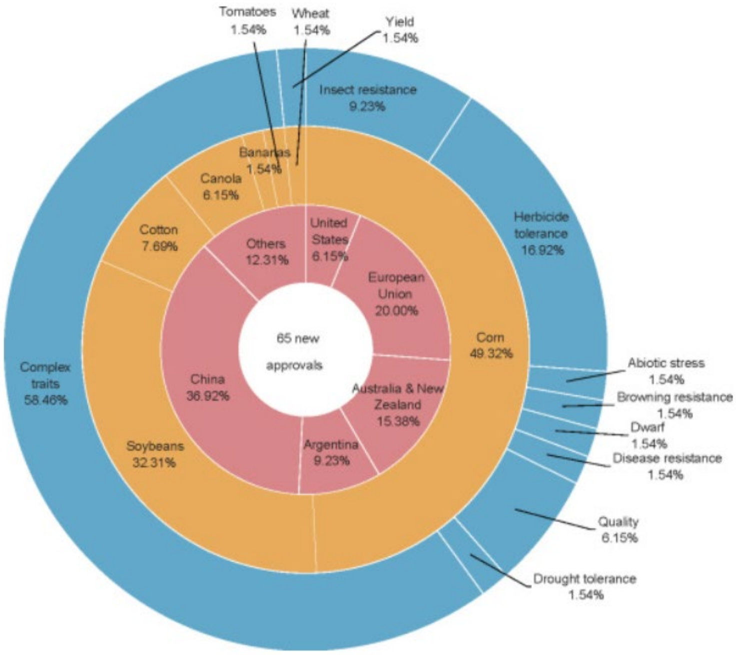

Figure 10. New GM approvals during 2023 of GM species (yellow), traits (blue) and countries (red)[28]

From December 2023 to August 2024, the European Union had the highest number of approvals (52 approvals), with 26 approvals for food and 26 approvals for feed.[29] As of October 2024, over 30 countries had granted cultivation approvals to genetically modified crops.

There are currently eleven GMO plants approved by Food Standards Australia New Zealand (FSANZ) for use as an ingredient in food sold in New Zealand, including varieties of soybean, wheat, potato, corn, rice and a banana resistant to Panama disease.[30] No GM crops are approved for cultivation in New Zealand under current HSNO (Hazardous Substances and New Organisms Act) legislation.

3.3 Export trade of GM crop products

GM crop products are not an insignificant component of exports from the large-scale GM production countries, in particular the United States, Brazil, and Argentina (see Figure 11). Soya bean, corn, cotton and canola are exported for livestock feed, food processing and biofuel generation, in many cases to countries where cultivation is not approved.

[28] Trends in the global commercialization of genetically modified crops in 2023 - ScienceDirect
[29] ISAAA GM Approval Database: Mapping Updates from Global Biotech Crop Approvals | Science Speaks - ISAAA.org
[30] Current status of genetically modified foods applications | Food Standards Australia New Zealand

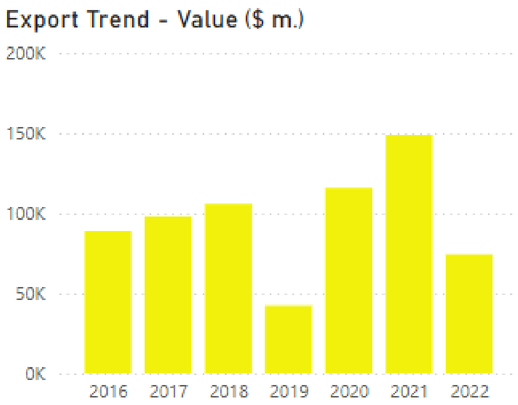

Figure 11. Annual Value of GM exports (US$m).
Source: [GM Production - AgbioInvestor-GM]

Countries and regions in Asia, including China, the Republic of Korea and Japan are significant importers of GM crops due to their high demand for food, limited land resources, and large populations. The EU imports over 30 million tonnes annually of soya bean and soya bean products from the USA and South America of which 90-95% is GM, 10-20 million tonnes of maize products of which 20-25% is GM and 2.5-5 million tonnes of canola of which nearly 25% is GM, mostly for livestock feed. [31] [32]

Dairy cows being supplementary fed in the Netherlands. The EU imports GM feed, predominantly soyabean products, from the USA and South America for feeding to livestock. Photo source: Author

[31] INFOGRAPHIC_EB_MS_GMO_April2017_web_Drieluik_Infographic_Europabio

[32] https://www.isaaa.org/resources/publications/briefs/55/executivesummary/brief55-fig1.jpg

3.4 Public Perception & Concerns about GM use

If we look back at the history of GMO, controversy was fuelled by historical association with the American company Monsanto and its herbicide product glyphosate. Monsanto, originally a chemical and pharmaceutical company, suffered reputational damage with its manufacture of plutonium for the Nagasaki bomb, supply of herbicides used in the Vietnam War ("Agent Orange"), and manufacturer of flame retardants that were found to be carcinogenic.

Monsanto transformed into an agri-biotech company, developing genetically modified (GM) crops and patenting these technologies. These included "RoundUp Ready®" seeds released in the 1990's that were genetically modified to confer resistant to the herbicide glyphosate, enabling farmers to spray glyphosate on their crop for weed control without killing the crop.

Monsanto lost public trust and confidence when glyphosate was considered a possible human carcinogen in 2015 by the World Health Organisation and they subsequently lost a lawsuit in 2018 against "RoundUp Ready" by a cancer claimant, with Monsanto later found to have tried to manipulate the case[33]. This fuelled mistrust in powerful multinational companies and their potential control of global food systems and the increased use of glyphosate that GM herbicide-resistant seeds appeared to encourage. In Chapter 8, research has shown these themes of concern around transparency, safety, inclusion and equity are still highly relevant to the public of today.

General concerns around the use of gene technologies and genetic modification include:

- 'Gene flow' or the introduction of new genetic material into a population, for example by pollen or seed dispersal, which introduces traits into susceptible populations. Strict regulatory requirements around isolation distances and buffer zones are designed to prevent this.
- Cross-contamination of GM into non-GM food products, for example at processing.
- Safety to human health.
- Traceability and consumer choice through food labelling.
- Negative environmental impact e.g. biodiversity, toxicity, increased use of chemicals.
- Unintended consequences of gene manipulation.
- Unethical or immoral use of the technology.
- Animal welfare - research suggests people are more averse to gene editing in animals than plants for ethical reasons, with animal welfare the main concern.[34]

The regulatory process needs to be transparent (publicly available) and provide assurance that its assessment considers such concerns in granting approvals.

[33] Monsanto ordered to pay $289m as jury rules weedkiller caused man's cancer | Monsanto | The Guardian

[34] Genetic engineering of animals: Ethical issues, including welfare concerns - PMC

Chapter 4: The Changing Landscape

4.1 Global GM Legislation and Regulation

“Science progress and policy process are usually not aligned.”
Science Researcher interview, Wageningen University, Netherlands

Broadly, regulation of GM distinguishes approvals between cultivation, importation and exportation, and consumption as human food or feed products e.g. livestock and poultry.

Risk assessment and quality assurance systems inform the regulator about safety and the ability to cause harm to humans (e.g. allergenicity, toxicity), animals (e.g. welfare) and the environment (e.g. cross-contamination, possible adverse effects) and provide freedom of choice for the consumer (labelling and traceability) in making their decision.

The United Nations (UN) Cartagena Protocol on Biosafety is the international guiding definition which has been used by most country governments in their legislation governing GM crops. The Cartagena Protocol definition of a ‘living modified organism’ (LMO), which includes GM organisms, is that it meets two requirements:

1. The plant contains a novel combination of genetic material, and
2. The genetic material was introduced using modern biotechnology

At the time of drafting the Cartagena Protocol in the early 2000’s, the legal definition of ‘modern biotechnology’ was a means of clearly separating certain biotechnology techniques from those that were considered more traditional, namely plant breeding, selection and conventional mutagenesis techniques.

The risk assessment and management strategies for permitted release and commercialisation of GM crops are defined by individual country legislation. These differ from country to country but broadly, regulation and risk management are orientated to one of the following approaches:

1. Process
2. Tiered risk
3. Trait

Process risk assessment is where regulation is triggered by the processes or techniques involved in the development of the organism. New Zealand’s current GM legislation is regulated under the HSNO Act 1996, administered by the Ministry for the Environment. All organisms created using gene editing or modification techniques are defined as GMO regardless of what the specific genetic changes are or the traits that these genes encode. As GMO, they are prohibited from being developed, field tested, knowingly imported or released prior to regulatory approval. The regulatory approvals process is extensive with a significant administrative and evidential requirement and has been termed an ‘effective ban’ on the release of GMO.

The tiered risk approach is triggered by how much genetic change has been made and how far removed the modification is from what could be produced in nature or using a traditional breeding method. It assumes that, from a scientific perspective, genetically modified organisms, where no new DNA has been introduced into the genetic material of an organism, are unlikely to pose a greater risk than similar organisms produced with traditional breeding techniques. The risk assessment is proportionate, with significant degrees of change triggering a higher tier level (tier 3) requiring greater administrative and evidential requirements, and those with changes that could be obtained via conventional methods triggering a lower tier level (tier 1) requiring only notification to the regulatory authority.

The US, EU, UK, Australia, Japan, India, Argentina and Norway operate this approach. China indicated in 2022 that it would loosen regulations and move to a case-by-case approach from its previous process risk management approach.[35]

The trait-based approach to regulation is only used in Canada. If the trait is classified as a new or novel genetic organism, the GMO is regulated under existing product-orientated legislation. If the trait is defined as 'non-novel' it is seen to pose no greater threat than that which currently exists in the open environment and is exempt from risk management.

Gene editing (or precision breeding) technologies such as CRISPR are challenging legislation definitions as to whether they fit the definition of GMO because the method of introducing small changes to the DNA is not discernible from changes than can occur during conventional breeding or in nature[36], they just occur faster. Therefore, if genetic material is not defined as novel or 'new' because there is no introduction of foreign DNA and the plant is genetically indistinguishable from a conventionally bred counterpart, some countries are reducing their regulatory oversight to being notifiable only or exempt from regulation.

In 2019, Australia's Office of the Gene Technology Regulator ruled that CRISPR-edited plants are not considered genetically modified (GMO) if they don't contain foreign DNA. This reduced the degree of regulatory oversight and aligned with regulation in other countries such as the USA and Brazil.

"Brexit" was a catalyst for change in the United Kingdom (UK) and in 2023 parliament passed the Genetic Technology (Precision Breeding) Act with Royal Assent.[37] The narrative suggests a desire to lead globally in gene editing technologies:

"The Genetic Technology Act is fantastic news for British consumers and farmers. Precision breeding technologies are the future of food production, not just at home, but around the world, and this Act will put our nation at the forefront of this revolution."
Mark Spencer, Food Minister, United Kingdom[38]

England then joined the USA, Australia and Japan in classifying targeted gene edited changes that could have occurred naturally or through traditional selective breeding, as 'non-GMO' and thus not subject to GMO regulation.

In 2023 the European Commission adopted a proposal for a new regulation of new genomic techniques (gene editing) in plants as part of a package of legislative proposals to support the EU's "Farm to Fork" and Biodiversity strategies.[39] This included an exemption from GMO legislation for new genomic technique (NGT) plants that could occur naturally or by

[35] China: Crops / Food - Global Gene Editing Regulation Tracker
[36] Frontiers | Global Regulation of Genetically Modified Crops Amid the Gene Edited Crop Boom – A Review
[37] Genetic Technology (Precision Breeding) Act 2023 - Parliamentary Bills - UK Parliament
[38] Genetic Technology Act key tool for UK food security - GOV.UK
[39] New techniques in biotechnology - European Commission

conventional breeding. Information on these plants would be provided through labelling of seeds, in a public database and through plant variety catalogues. Under EU legislation, each of the 27-member state retains the right to decide on the cultivation of GM crops in its territory.

The Ukraine War has prompted a widening of EU focus on sustainability to include food and energy security. When grain imports into the EU were beginning to be severely impacted by the conflict, Spain's Agriculture Minister Luis Planas proposed lifting the EU's ban on genetically modified grains. "This is a warning call for us to think about having the capacity to provide food security to our 450 million citizens. We need the European Union to add flexibility to grain import rules" challenged Minister Planas,[40] a proponent of gene technologies.

[40] Russia-Ukraine War Latest: EU Might Consider Grains Import Waiver - Bloomberg

Figure 12. Global Regulatory Landscape for Gene-Edited Crops. Source: ISAAA[41]

[41] [Updates on Global Regulatory Landscape for Gene-Edited Crops | Science Speaks - ISAAA.org]

Chapter 5: New Zealand & GM

5.1 Legislation Review

"There hasn't been a ban, but there have been barriers. We have been operating under HSNO legislation and there have been a lot of changes both in science and risk assurance since then."
Dr Emily Parker, Professor of Biology at Victoria University of Wellington, and Science Advisor to MBIE[42]

New Zealand's gene technology laws were set over 25 years ago and were understandably precautionary to an emerging technology with a controversial reputation in export markets.

The use of CRISPR gene editing technologies is deemed genetic modification under current legislation because they are classified as 'new organisms' under the Hazardous Substances and New Organisms (HSNO) Act. This puts them under the regulation of the Environmental Protection Agency (EPA) and Food Standards Australia New Zealand (FSANZ) for consideration of applications to import, develop or release GMOs into NZ.[43]

The stringent legislation and regulatory requirements mean no GM crops are cultivated in NZ. However, gene editing and genetic modification research has occurred in tightly controlled laboratory conditions in New Zealand, led by the Crown Research Institutes (CRIs) Plant & Food Research, AgResearch and Scion. Historically, field studies have been conducted in crops and forage species by Crop & Food, the predecessor of Plant & Food Research, but these effectively ceased following a breach in containment of a brassica crop in 2009[44]. HSNO legislation has proven a significant barrier to conducting field trials, and there is currently only one field trial currently being undertaken in New Zealand, by Scion in Pinus radiata[45]. Other GM research programs, such as the AgResearch GM forage programs, have progressed to field trials in Australia and the United States[46],[47].

With the availability of more precise and safe genetic technologies, and applications that could contribute to addressing challenges of human health, climate change and environmental degradation, the New Zealand government announced a draft Gene Technology Bill in December 2024 [48] with Science, Innovation and Technology Minister Judith Collins outlining potential benefits for the country:

"Gene technology can deliver enormous benefits for New Zealand, including access to better cancer treatments, and increased productivity for farmers through such things as disease-resistant and drought-resistant grasses and tools to help meet emissions targets. This all adds up to greater economic gains for the country as a whole."

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[42] NZ Dairy Exporter, Episode 48
[43] Genetically modified organisms | EPA
[44]https://www.nzherald.co.nz/nz/gm-trial-axed-after-crop-error-is-exposed/WO565QITZVFNFEMUI2XZAZ375A/#google_vignette
[45] https://www.scionresearch.com/science/genetic-engineering
[46] https://www.agresearch.co.nz/news/hme-ryegrass-making-steady-progress/
[47] https://www.agresearch.co.nz/our-research/high/
[48] Parliamentary press release, 17 December 2024 Gene Technology Bill passes first reading | Beehive.govt.nz

"Restrictive rules and time-consuming processes have made research outside the lab almost impossible, and these changes will allow New Zealand to catch up to global best practice."

"The Gene Technology Bill will enable science to grow and ensure gene technologies are managed proportionate to their risk."

New Zealand's Ministry of Business, Innovation and Employment (MBIE) will be the lead agency for regulatory work, alongside the Ministry for Primary Industries, Ministry of Health, Ministry for the Environment and Department of Conservation. MBIE will be supported by:

1. A Technical Advisory Group (TAG) of 12 scientists and researchers
2. A Māori Focus Group to convey Māori rights and interests for inclusion in policy advice
3. An Industry Focus Group to consider the regulation's impact on trade, market access, branding, competitiveness and consumer perceptions

Aligning New Zealand regulation framework with trading partners and peers to minimise compromising trade agreement conditions and market access is imperative in an increasingly geopolitical and protectionist world.

5.2 Farmer & Public Sentiment

A recent survey of farmer insight into genetic technologies was conducted by Beef & Lamb New Zealand (B+LNZ) in August 2024[49] and its findings were compared with a sponsored survey of the general public by research firm Primary Purpose in May 2024.

The majority of farmers surveyed (69%) declared they knew 'not that much' (57%) or 'nothing' (12%) about the use of gene technologies in the growing of food. A minority (31%) said they knew 'a fair amount' (27%) or 'a lot' (6%).

This was similar to the general public survey where 50% said they knew 'not that much', 19% said they knew 'nothing' and 30% declared they knew 'a fair amount' (25%) or 'a lot (6%). This indicates a significant knowledge gap exists in both farming communities and the general public about gene editing and genetic modification.

Over half of farmers (53%) supported the use of growing food in New Zealand, with 18% opposed and 29% unsure (Figure 13). The general public were more evenly spread across the responses, with 34% in support, 31% opposed and 34% unsure. Of the farmer respondents, males were more likely to support its use (60%) than females (33%), those farming 5,000 or more stock units were more supportive (64%) and across stock types, dairy farmers were most supportive (74%) than beef farmers (44%).

[49] https://beeflambnz.com/sites/default/files/2024-08/GMO-results.pdf

Regardless of how much you know, generally do you support or oppose the use of gene technologies in growing food in New Zealand?

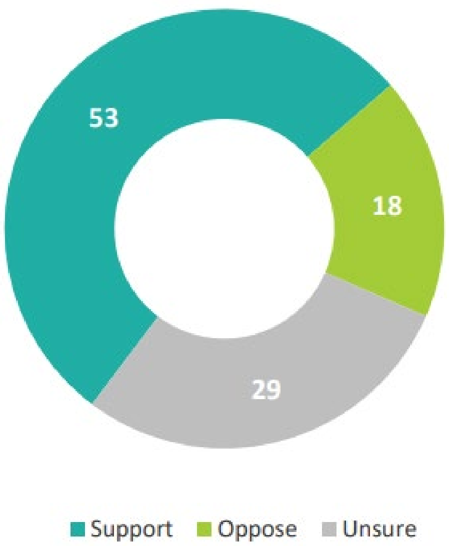

Figure 13. Beef & Lamb NZ Climate and GMO Farmer Survey report, August 2024[50]

Which of the following option aligns closest to your view as to how New Zealand should approach gene technologies for growing food?

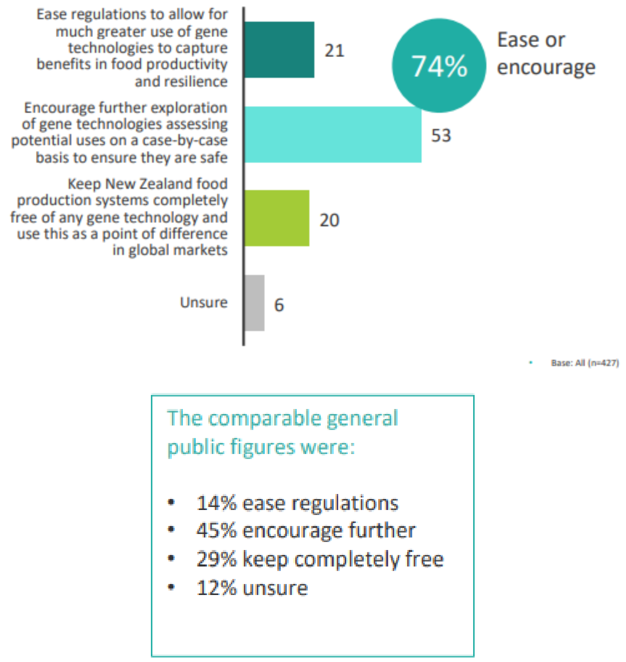

Figure 14. Beef & Lamb NZ Climate and GMO Farmer Survey report, August 2024

Regarding views on how New Zealand should approach gene technologies for growing food (Figure 14), 74% of farmers either supported easing regulations for greater use (21%) or encouraged further exploration if they were assessed on a case-by-case basis (53%). The general public were 59% in support of easing regulations (14%) or encouraging further use (45%). Twenty percent of farmers surveyed and 29% of the public wanted to keep New Zealand food systems completely GE-free, a not insignificant proportion.

[50] https://beeflambnz.com/sites/default/files/2024-08/GMO-results.pdf

How concerned are you about various potential risks of using gene technology?

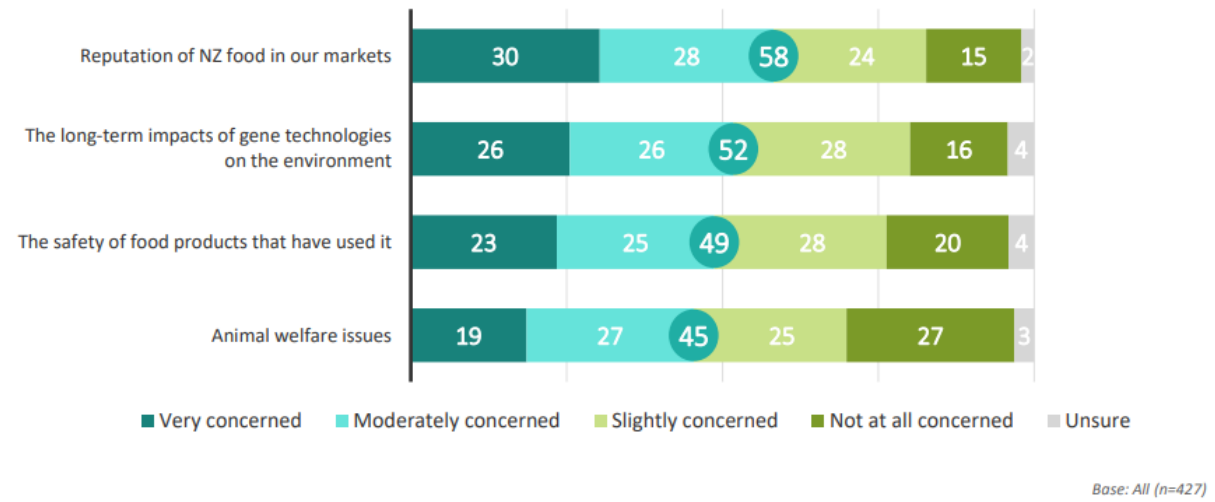

Figure 15. Beef & Lamb NZ Climate and GMO Farmer Survey report, August 2024

Unsurprisingly, farmers ranked impact on reputation of New Zealand food in markets as their greatest concern (58%), followed by the long-term impact of gene technologies on the environment (52%). The general public in the Primary Purpose survey were more concerned about the safety of food products that used gene technology (62%) and the impact on the environment (61%) and animal welfare (59%) than the farmer survey responses.

5.3 Māori Perspective & Involvement

Māori owned and operated agribusinesses make up a significant proportion of New Zealand agribusiness with over half of Māori owned land and around 15 percent of Māori businesses agriculture focused.[51] The largest proportion of the Māori agriculture asset base is in sheep and beef farming ($8.6b) and dairy ($4.9b), with increasing investments in horticulture.

A February 2024 comprehensive study into Māori perspectives on gene editing[52] indicated that Māori perspectives on genetics have evolved since the early days of debates on genetic modification but there is still a wide diversity of views. There was general support for a cautious approach to explore how gene editing might deliver positive outcomes for Maori communities and businesses. While integration with international regulation was recognised, there was concern that the risk of global-focused criteria may exclude indigenous values as mere minority concerns.

Science New Zealand, representing the Crown Research Institutes (CRI), advocated for a review of New Zealand regulation and legislation in their February 2023 paper on Gene Technologies[53]. They also highlighted the important role of Māori and the Wai 262 Taumata

[51] https://www.mpi.govt.nz/dmsdocument/60865-2023-Briefing-to-Incoming-Ministers-Agriculture
[52] https://www.nature.com/articles/s42003-024-05896-1
[53] SNZ-GE-Positioning-Paper-Feb-2023.pdf

Whakapūmau claim[54] (relating to flora and fauna) that reinforces the need for a Te Tiriti-led partnership in ensuring that the rights and interests of Māori are protected and promoted as New Zealand investigates and uses techniques that change the genetic makeup of organisms.

Significant agribusiness involvement, as well as fulfilling a kaitiaki or guardianship role of natural resources and a partner in the Treaty of Waitangi, Te-Tiriti o Waitangi, mean that Māori have an important leadership role to play, on many fronts, as conversations and decisions about gene editing in New Zealand progress.

5.4 Framework Fit for Purpose

In considering the development of regulation in New Zealand, the author was referred to the Norwegian Gene Technology Act[55] which includes sustainability, societal benefit and ethics in its regulatory assessment, as well as health and environmental risk. For cases involving deliberate release of GMOs, authorities place considerable emphasis on whether the release is of benefit to society and promotes sustainability. This holistic assessment means that in practice, more stringent requirements apply to GMOs than equivalent non-GMOs. However, regulation could be less stringent for such examples and be notifiable or exempt (which is the case with regulatory change in many countries as previously mentioned).

Considering the various regulatory approaches globally and the best approach for New Zealand, a holistic regulatory framework seems appropriate for permitted release applicants. This would include the scientific and risk assessment for human and environmental safety, but be extended to assess the economic, environmental and social (ethical and moral) impact to the New Zealand primary sector, trade, the country, and its people. This would in effect be applying principles of ESG (Environmental & Social Governance) to regulation, with the intention of focusing research and applicants on solving for these challenges.

A holistic framework would address farmer and public concerns and is supported further by a key finding from the Biological Heritage National Science Challenge 2024 research report "Genetic Technologies and Our Environment" [56] which stated:

"Fundamentally, New Zealanders saw the possible introduction of gene technology into the environmental management architecture to be less about the technologies themselves, and more about the social, economic and environmental factors."

In developing framework fit for purpose, the primary sector must play a significant role in the development of regulation and assessment for permitted release decisions due to the potential impact on trade, social licence and on-farm productivity.

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[54] Wai 262 - Taumata Whakapūmau

[55] Bioteknologira˚det. (2018). The Gene Technology Act - Invitation to Public Debate. Retrieved from http://www.biote knolo girad et.no/ filar kiv/2010/07/gente knolo gilov en-engel sk-hele-for-web-v-2.pdf

[56] Reporting | TalkingEcoGeneTech

Chapter 6: Opportunities for New Zealand's Primary Sector

6.1 The Leading Edge of Biotech Innovation & Collaboration

"New Zealand at its best, is leading at the front edge."
Tony Martin, CEO, Prevar

New Zealand needs to continue to innovate through world-class scientific research and technology development to give its food producers the ability to remain a preferred supplier of quality food that is sustainably and ethically produced. Gene technology has the potential to transform biotech's contribution to New Zealand's agricultural value chain through research, on-farm implementation, the export of intellectual property (IP) and international collaboration. Using gene editing, New Zealand could enhance its value proposition in the marketplace due to the pace of new varietal offerings, improved quality, and ethical and sustainability claims. Some examples that are already underway:

ZeaKal: A biotech innovation company

"The world's most important crops require tools beyond the code in their genomes today."
ZeaKal[57] is a biotech company which evolved as a spin-out from researchers at AgResearch (a NZ Crown Research Institute) and has developed gene editing technology ("PhotoSeed™") to enhance plants' ability to photosynthesise. By increasing capacity to harvest more sunlight, fix more CO_2 and use less water, up to 50% higher growth rates can be achieved with forecasted yield improvements by as much as 20%.[58] Developed for NZ pastoral systems, this technology can increase metabolizable energy by 1 MJME/kgDM thus increasing performance and reducing CO_2 emissions and nitrogen losses from livestock. There are applications for many plant species globally, with IP licences held by partner AgResearch (pastoral) and ZeaKal (row crops). "PhotoSeed™" is not commercially available under current New Zealand HSNO legislation.

"It's almost a disruptive technology because it [licence fees] could potentially add billions of dollars to our [New Zealand's] GDP." Dr Greg Bryan, ZeaKal

The first Zeakal product to market is "PhotoSeed ™" soybeans which have improved energy density and carbon capture. Photo: Field of soybeans on a farm in Oklahoma, U.S.,Encyclopedia Britannica

[57] Plant Trait Technology | Home - ZeaKal
[58] AgResearch - ZeaKal - a New Zealand Research Commercialisation Success Stories

Biotech International Collaboration

"We are looking forward to working alongside OSF and Prevar to better understand how we can apply our gene discovery research in this new and fast-changing commercial setting. This in turn will help us support New Zealand's horticulture sector in making decisions on how they could apply this to future-proof the sector."
Professor Richard Newcomb, Chief Scientist at Plant & Food Research

In January 2025 New Zealand's Prevar and Plant & Food Research entered into an R&D partnership with Okanagan Specialty Fruits (OSF) of Washington State, USA. OSF have commercialised an Arctic® apple brand which has gene-edited existing varieties to prevent browning when cut or bruised. OSF supply packets of pre-sliced apple to the US elementary and secondary school food programmes. This collaboration brings together a US innovator in commercial fruit bioengineering (OSF) with New Zealand's world-leading apple scientists and breeding programmes.

Visiting Okanagan Specialty Fruits in Washington State for Nuffield study into gene editing

6.2 Accelerated Plant Breeding Programmes

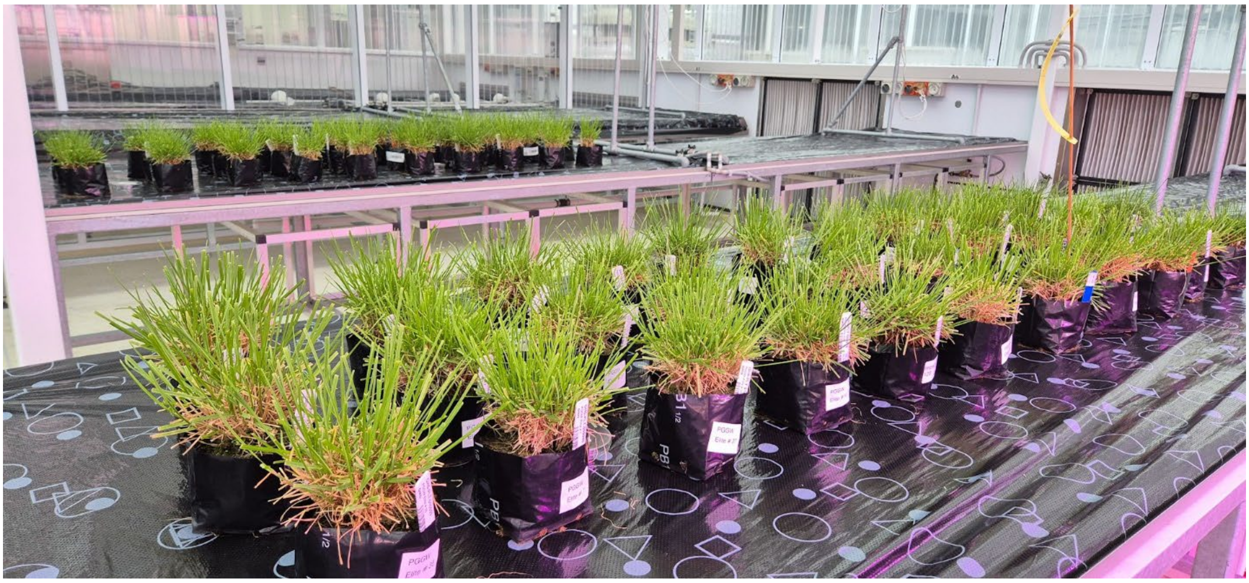
"We have all the tools we need. Using these sophisticated editing tools we can cross plants ten times faster than with traditional breeding. As great as they are, I just don't think our traditional breeding techniques will be fast enough for climate change." [59]
Professor Andrew Allan, Plant & Food New Zealand

New Zealand plant breeding programmes are world-class resulting in development of new and superior genetic lines that have been successfully commercialised in-country and sold or licensed commercially overseas.

Gene editing will enable acceleration of plant breeding programmes because they will effectively short-cut the crossbreeding cycles for some traits. This will shorten the time to selection and commercialisation. The potential earlier revenue generation from new varieties and licence agreements should be attractive to investment from both public and private sectors.

The Plant Variety Rights Act (PVR) in New Zealand provides a term of protection of 20 years, or 23 years for 'woody' plants (e.g. grape vines, trees and rootstock) to provide incentive for plant breeding innovation[60] through the opportunity to hold exclusive propagation rights and get a return on investment during that period. Major overseas jurisdictions relevant to New Zealand PVR offer similar or slightly longer periods of protection of 20-30 years. PVR of gene edited plants didn't appear to be raising concerns with plant breeders where regulation was changing:

"Plant breeders here don't have concerns and don't forsee any issues at this stage. We will continue to keep in close dialogue with them. Their biggest question is 'who will we pay the [Intellectual Property] licence to?'"
Dr. Janet Talling, Head of Genetic Technologies & Farm Tenancy, DEFRA, UK



Gene edited ryegrass trials, AgResearch laboratory, New Zealand. Photo source: Author.

[59] Andrew Allan: the potential for new breeding technologies · Plant & Food Research
[60] Information sheet: What are Plant Variety Rights?

Breeding Apple Trees with Blackspot Resistance

Breeding apple trees is a slow process, limited by a long juvenile stage which means it can take up to 20 years to commercialise a new variety. By shortening the selection process, plant breeding is faster to respond to changing pest and disease challenge and consumer preferences.

Black spot or apple scab is a fungal disease that causes circular black or brown spots on fruit and is more prominent in warm, wet weather. Fungicide spray applications (16-30x) are required each season for black spot control.[61] The economic impacts of black spot arise from direct fruit losses, grading out diseased fruit and market access risks from fungicide residues. Many markets, including China and Taiwan, have strict phytosanitary requirements related to blackspot.

Using rapid flowering gene technology to shorten juvenility, black spot resistant apple trees would be bred faster and made available to orchards earlier than conventionally bred trees. Modelling by PWC for The Aotearoa Circle[62] calculated a gene edited black spot resistant apple orchard would use a total of 225 fewer sprays over the theoretical 9 year delay it would take to develop the same black spot resistance through selective breeding.

Kiwifruit Psa Outbreak

A recent example of a biosecurity threat in the New Zealand primary sector was the 2010 Psa-V bacterial outbreak in kiwifruit. Psa-V is caused by a *Pseudomonas sp.* bacteria which causes leaf spotting, cane dieback and in extreme cases, vine death.[63]

Analysis in 2012 by Lincoln University's Agribusiness and Economics Research Unit (AERU) expected the disease to cost the kiwifruit industry between $310 and $410 million in net present value terms in the five years following the outbreak, approximately $500 to $600 million over ten years and over a 15-year period between $740 and $885 million.[64]

Fortunately for growers, a gold kiwifruit cultivar that had desirable traits and an increased tolerance to Psa-V had already been identified in selected breeding programmes and was fast-tracked into full commercial production (marketed as Zespri™ SunGold™'). The use of

[61] Climate change impacts on plant diseases affecting New Zealand horticulture
[62] Modern Genetic Technology: Applications in Aotearoa Food and Fibre Production. 2024. The Aotearoa Circle. Modern Genetic Technology — The Aotearoa Circle
[63] Psa-V - KVH
[64] The_Costs_of_Psa_V_to_the_New_Zealand_Kiwifruit_Industry__Wider_Community_Report.pdf

gene editing in future could enable accelerated insertion of disease protection genes into cultivars that have desirable traits. This would enable a shorter timeframe to commercialisation and not reliance on luck that a resistant variety is already in the conventional breeding pipeline.

Photo source: Zespri™ website

6.3 Beneficial Pastoral & Horticultural Traits

"Gene editing offers the potential to produce a step change in NZ primary industry productivity, biosecurity and speed of innovation."[65]

Gene edited traits have the potential to enhance the productivity and environmental performance of New Zealand pastoral farming, arable and horticulture sectors. The ability to perform research field trials in New Zealand through changed regulation could open up the following opportunities:

- Tolerance to climate change such as extreme weather conditions (e.g. drought), reduced rainfall, longer heat periods, milder winter conditions.
- Reduced insecticide use and/or reduced herbicide use. Noting future resistance to chemicals and limited 'new' chemical releases pose increased pest and disease risk.
- Reduced methane emissions and urinary N production in grazing ruminants.
- Improved animal performance through improved digestibility and metabolizable energy levels.

NZ's primary sector is vulnerable to the threat of pest and disease on productivity, revenue and market access. The magnitude of this risk is enormous. A 2019 NZIER report into the role of crop protection products in land-based sectors calculated the NZ economy would lose between $7.5 billion to $11.4 billion without crop protection, with horticulture and the pastoral sectors most affected. [66] Gene editing has the potential to confer resistance to certain pest and diseases and reduce the amount of chemical treatment and control required, improving environmental outcomes and reducing emissions associated with application.

[65] Front. Plant Sci., 12 September 2018 Sec. Plant Biotechnology Volume 9 - 2018 | https://doi.org/10.3389/fpls.2018.01323
[66] NZIER-Report.pdf

Example: High Condensed Tannin White Clover (Hi-CT)

AgResearch scientists are trialling a gene edited white clover with partners PGG Wrightson Seeds and Grasslanz Technology. A gene has been edited from another species of clover to boost the expression of condensed tannins which occur naturally in the leaves, which could significantly reduce animal emissions and leaching reduction and improve production performance outcomes. Field trials have been conducted in the US and more recently in Australia. Potential benefits include a reduction in GHG by 5-10%, methane reduction by >16%, reduced N leaching and N_2O losses and improved animal performance.[67] A change in regulation settings could allow field trials to commence in New Zealand so data can be collected under New Zealand conditions.

Photo source: AgResearch website

6.4 Beneficial Animal Traits

New Zealand's dairy, beef and sheep sectors have relatively sophisticated livestock breeding programmes focused on improvement of animal performance under New Zealand conditions. For example, the dairy industry has utilised 'DNA-proven' genomic testing for bull selection which provides faster rates of genetic gain than conventional progeny testing for 'daughter proven' bulls.

DairyNZ, New Zealand's levy-funded dairy industry-good organisation which oversees the national breeding index for New Zealand dairy cattle, has identified potential applications of gene editing for beneficial animal traits[68] including:

- Disease resistance
- Heat tolerance
- Reduced greenhouse gas emissions
- Reduced bloat and ryegrass staggers
- Polledness (no horns)

[67] High condensed tannin (HiCT) white clover - AgResearch
[68] Gene technologies - DairyNZ | DairyNZ

6.5 Responsive to Customer & Consumer Preferences

Gene editing could enable a faster pathway to meet some customer and consumer expectations and preferences, if market research supports delivery would increase market share and/or attract a premium. These could be improved nutritional value, lower environmental footprint and/or enhanced customer experience.

Food waste could also be reduced using gene editing. An example is the non-browning apple (previously mentioned in Chapter 6.1) which has the potential to reduce food waste in retail and food service through prolonged shelf life and enhanced customer experience. Food waste is a significant contributor to food security and an environmental burden globally, and a loss of potential revenue for farmers and growers. In 2022, according to the UN Environment Programme (UNEP)[69], 19% of food available to consumers was wasted at the retail, food service, and household level, in addition to the 13% of the world's food lost in the supply chain estimated by the Food and Agricultural Organisation (FAO)[70]. Food and organic waste contribute 9% of NZ's biogenic methane emissions and 4% of GHG emissions. [71]

6.6 Predator Control

Opportunities will likely exist for gene editing predator control of mammalian pests such as mice, rats, stoats and possums. Possum control has multiple benefits for agriculture as they are a vector for tuberculosis and a threat to biodiversity as they target native flora and fauna.

In an interview with Predator Free NZ, Predator Free 2050 Ltd Science Director Dan Tompkins stated "Overhauling the regulation of gene editing and other genetic technologies may have consequences for predator free in the mid to longer term. For the short term, research into such is already underway in contained laboratory settings in New Zealand under current regulations. We still have several years of work in containment to go for application to mammal pests."[72]

Chapter 7: Risks for New Zealand's Primary Sector

7.1 Market Access

As an export nation, maintaining market access is vital for the sector. New Zealand's main trading partners China, USA, Australia and Japan already enable gene editing technology, so it is unlikely that there will be a barrier at trade level and more likely a marketing challenge to customers and consumers.

Early communication must be had by government trade officials and exporters about New Zealand's changing legislation, and confidence given through transparency and alignment of regulation with key trading partners. It was suggested to the author by those involved in GM policy in Europe that there was opportunity for global collaboration on:

[69] Food Waste Index Report 2024. Think Eat Save: Tracking Progress to Halve Global Food Waste
[70] SDG Progress Report 2023
[71] Reducing food waste | Ministry for the Environment
[72] Expert reaction: what does lifting the 'ban' on genetic modification mean for predator free? - Predator Free NZ Trust

1. International agreement of scientific language and terms used in legislation and regulation, and
2. Development of an international portal to streamline the regulatory application process by country and avoid a high degree of duplication, saving both the regulator and the applicant time and cost.

However, both were deemed aspirational and unlikely to be implemented as terms used in different countries legislation were already different and parties who could contribute capital for portal development e.g. multinational seed companies, could be viewed as having a conflict of interest, even if they had no control over its operation.

At the time of writing, the NZ Gene Technology Bill was being drafted using the Australian Gene Technology Act as a reference. This will ensure continuity with a peer and trading nation and an example of regulation in action with Australia already regulating GM crops and field trials. The UK, now sitting outside the EU following Brexit, would also be a good reference for legislation and regulation as an independent trading nation.

7.2 Customer and Consumer Confidence

"UK retailers can see it [GM] working but are concerned about frightening their customers."
Dr. Janet Talling, Head of Genetic Technologies & Farm Tenancy, DEFRA, UK (interview)

Since GM technology was commercialised in the USA in 1996, The US Food & Drug Administration (FDA) has stated there has been no scientific evidence that GMOs pose a greater threat that non-GMO foods, with no link identified between GMO consumption and diseases such as cancer, allergies or digestive problems.[73] There has been some public concern about potential health impacts on the increased use of herbicides e.g. glyphosate on GMO-herbicide resistant crops in the USA but the American Cancer Society has stated there is no evidence to link GMO food intake with an increased or decreased risk of cancer.

Food Standards Australia and New Zealand (FSANZ) confirms that "to date, gene technology has not been shown to introduce any new or altered hazards into the food supply, therefore the potential for long term risks associated with GM foods is considered to be no different to that for conventional foods already in the food supply. As a consequence, FSANZ does not consider that long term studies are generally needed to ensure the safety of GM foods."[74]

On the face of it, multinationals and large retailers appear to be generally supportive of innovative technologies but are also highly responsive to market sentiment and any potential impact to their reputation and brand. Most are seeking reductions in the environmental footprint of their suppliers to reduce their Scope 3 emissions and are also promoting sustainability and ESG principles. This puts pressure on the food producer to adapt, often without incentive.

Retailers and producers have the complexity and perplexity of delivering products that appeal to consumer perception of what they want (e.g. reduction in emissions, less pesticide use) but then face being challenged on the safety of innovative tools designed to achieve this, despite having regulatory approval. This is a delicate balancing act, and there is a key role for

[73] GMO Crops and Humanitarian Reasons for Development
[74] Safety assessments of GM foods | Food Standards Australia New Zealand

multinationals and retailers in engaging with customers and consumers about the safe use of technology in food production.

For example, Nestlé states on their website[75]:

"We support the responsible use of any innovative, safe technology. We decide whether to use ingredients derived from GMOs at a local level, based on consumer expectations and local regulations. We believe 'GMO ingredients' have a potentially important role to play in increasing food production, to support sustainable agriculture and help feed a growing world population."

Any consumer push-back or back-lash is likely to reverberate through the value chain back to the exporter and farmer-producer, or to place the manufacturer of the 'product' in an explanatory role. The online backlash towards the rumen modifier Bovaer® trial by dairy company Arla in December 2024 is a recent example (note Bovaer® is not a gene edited product).

Bovaer® - Sustainability Initiative meets Social Media Perception

A recent example of an online backlash towards the application of innovative science to reduce agricultural emissions was towards Arla Foods, a Danish-Swedish company which owns the UK's biggest dairy cooperative. Arla announced a planned trial with some of UK's largest supermarkets, including Tesco, Morrisons and Aldi, to supply milk from cows treated with the rumen modifier Bovaer® which when added to feed could reduce methane emissions by between 30-45%.

Within days of posting on X, misinformation and general safety concerns saw photos and videos go viral of Arla milk being poured down the sink and toilet. This prompted Bovaer® manufacturer DSM-Firmenich to issue a detailed public statement addressing misconceptions and providing scientific facts to reassure the public.[76] With a social media storm erupting, New Zealand dairy cooperative Fonterra was prompted to issue a statement on social media platform X that Bovaer® was not used on any Fonterra farms and was not licensed for use in New Zealand.[77]

This gives some insight into the complexity of public expectations and acceptability around food safety and sustainability, e.g. push-back on reducing farm-related methane emissions using a product approved for use. The power of social media in public perception should not be underestimated. Regulation needs to be transparent and publicly available, and companies responsive, so consumers can be factually informed about the safety of food using new technologies.

[75] What is Nestlé's position on genetically modified organisms?
[76] statement-bovaer-january-2025.pdf
[77] Fonterra caught up in misinformation around use of feed additive Bovaer | RNZ News

Consumer freedom of choice about GM is provided through mandatory labelling as a regulatory requirement, though this may vary by country. Meat and dairy products that have been produced through the consumption of GM livestock feed (as is currently the case in the EU) do not have labelling requirements.

Health concerns around the safety of GM food consumption by consumers relies on trust and confidence in science and the regulatory system through a robust and transparent assessment process, rigorous monitoring process and information sharing with the public.

7.3 Environmental Impacts

Concerns around the potential environmental impact of gene technology include:

- 'Gene flow' or the introduction of new genetic material into a population, for example by pollen or seed dispersal, is a potential risk in cultivated gene edited plants. This introduces GM traits into potentially susceptible populations with uncontrollable and/or socially unacceptable or market prohibitive outcomes. Strict regulatory requirements of field trial conditions and buffer zones are designed to prevent this.

- Successful co-existence of GM and non-GM is a risk for organic and non-GM producers and requires strict regulatory, monitoring and management controls. The risk of gene flow or contamination in the supply chain would be catastrophic for organic and non-GM producers.

- Increased use of herbicides in GM-herbicide resistant or tolerant crops and potential to select for herbicide resistance in exposed non-target species

- Impact on biodiversity of a monoculture GM environment and/or non-specific toxicity to insects

7.4 Unintended Consequences

Unintended consequences of GMOs for human health or the environment are the unknown or unforeseen that cause harm. Examples would be toxicity to human health, novel proteins or molecules produced by GMOs causing allergies in humans, biodiversity loss through harm to non-target species and habitat destruction, accelerating the selection of pesticide resistant pests or disease, increased herbicide use, increased herbicide tolerance of weeds, disruption of soil or water ecosystems.

This begs the question if an unintended consequence was to occur, what happens next (both publicly and privately) and who is liable? These are questions the regulatory system needs to be able to answer.

7.5 Loss of Social Licence

Navigating the adoption of gene editing must be an inclusive and transparent process so that public trust and confidence is not compromised. This places responsibility on all parts of the agricultural value chain to provide opportunities for engagement and the requirement for responsible and representative regulatory oversight and communication with the public.

Chapter 8: Navigating Change

8.1 Responsible Governance

The concept of responsible innovation to guide governance in genetic technologies was introduced to the author by Phil Macnaghten, a social scientist at the Knowledge, Technology and Innovation Group at Wageningen University in the Netherlands during an interview.

Governance of gene-editing technology will require a shift from institutional governance to responsible governance, where policy makers and regulators need to operate a transparent process and address the wider ethical and societal implications, in addition to a safety and risk assessment framework.

The definition of responsible innovation in science policy has been defined as "**taking care of the future through collective stewardship of science and innovation in the present**"[78]. Collective stewardship is the anti-thesis of authoritarian or expert top-down policymaking of the past. In developing governance framework, Macnaghten and Habets[79] derived four pillars or dimensions to raise awareness, prompt discussion and respond to questions relating to the broader aspects of science and technology.

Termed the AIRR framework, the pillars are characterised below:

A – Anticipation	• To ask "what if?" questions, to consider contingency, what is known, what is likely, what are possible and plausible impacts. • Encourages discussion and consideration beyond a simple determination of risk to systematic, wider socio-economic and ethical-cultural considerations. • An example would be to challenge what may be perceived as over-optimistic promises and the impact of this being realised.
I – Inclusion	• Engage in early and two-way deliberation with a wide range of stakeholders and the public on the visions, impacts and broader socio-economic questions associated with particular research and innovation initiatives.[80] • Forms of inclusion would be multiple, ranging from small-group public dialogue (focus groups, conferences, deliberative mapping, public meetings) to multi-stakeholder formal partnerships, lay members on scientific advisory committees, user-centred design involvement. • Acknowledgement that public participation does not equate to legitimization.

[78] Stilgoe, J., Owen, R., & Macnaghten, P. (2013). Developing a framework of responsible innovation. *Research Policy*, *42*(9), 1568-1580.
[79] Macnaghten P, Habets MGJL. Breaking the impasse: Towards a forward-looking governance framework for gene editing with plants. *Plants, People, Planet*. 2020;2:353-365. https://doi.org/10.1002/ppp3.10107
[80] Wilsdon, J., & Willis, R. (2004). *See-through-science: Why public engagement needs to move upstream*. London: Demos.

R – Reflexivity	• Being aware of how individual and organisational assumptions, beliefs and experiences influence the research and governance processes. • Can help identify biases and establish rigour in research and governance decisions. • An example would be to widen the science governance ecosystem and include social scientists and lay people to bring different perspectives and questions.
R – Responsiveness	• Requires research managers and science policy organizations to develop capacities to focus questioning on the three dimensions listed above and to change shape or direction in response to them. • An example would be being responsive to the wider national and international political context shaping science policy initiatives.

The AIRR framework, or similar, could be incorporated into government, regulatory and research leadership to ensure a balanced and socially robust approach. The New Zealand government has been a public-facing proponent of gene editing and drafting of legislation has been relatively swift, with release of the draft on 20 December 2024 and closure of submissions on 17 February 2025. Consultation and engagement of the agricultural and horticultural sectors with their members has been compromised by the very short timeline for submissions. This is not consistent with the AIRR framework principles of inclusivity, reflexivity and responsiveness. Government would be better to give industry organisations and representations, including Māori and the public, sufficient time to constructively engage.

Macnaghten and Habets[81] article "Breaking the impasse: Towards a forward-looking governance framework for gene editing with plants" lays down a challenge. **"Rather than interpreting public distrust as an expression of ignorance towards relevant facts, this literature emphasizes the need for institutional reflexivity arising from the possibility of competing framings, including those that are driven by lay concerns and perspectives. How to embed reflexivity into scientific and science policy culture and practice remains a formidable challenge."**

While government will need to continue leading and engaging throughout the period of establishing the regulatory body, key primary sector stakeholders should have a leadership role in establishing framework that is fit for purpose.

8.1 Engagement

"It's the middle ground, the 60-70% of the population that want to understand. They may be unsure, they want to be informed. Answer their questions."

"When people are told about a solution, they won't like it because they don't understand the problem. If you force a solution, they won't want it."

Ewen Mullins, Principal Research Officer, Head of Crop Science Department, Teagasc, Ireland

[81] Breaking the impasse: Towards a forward-looking governance framework for gene editing with plants - Macnaghten - 2020 - PLANTS, PEOPLE, PLANET - Wiley Online Library

The author met with Ewen Mullins, Principal Research Officer, Head of Crop Science Department at Teagasc, Oak Park, Co. Carlow, Ireland, to discuss public engagement around gene editing and genetic modification. An example shared was part of an EU funded project assessing the impact of GM potatoes on agro-ecosytems[82]. Because the study was the first field evaluation of GM potatoes in Ireland and only the second GMO field licence authorized by the Irish Environmental Protection Agency, it understandably generated significant media and stakeholder interest – breeding a GM potato resistant to a late blight that devastated the same country in the potato famine of the 1840's. Over 5,000 participants were engaged at public and stakeholder events over 4 years of the project, ranging from open days, public meetings, conferences, workshops and smaller community groups.

Lessons Learnt from an Irish field of GMO potatoes
The project designed a communication engagement strategy around three core actions:

1. **Accessibility** - all requests for information and participation would be granted where logistically possible, irrespective of potential or perceived organiser bias.

2. **Transparency** – explanation of objectives and purpose of the research was delivered in an objective and humble manner

3. **Engagement** – a commitment to building trust through empathy and respect, listening and acknowledging all concerns and respect for opinion, countering ideologies with scientific fact delivered in non-scientific language.

Key learnings identified from the project were:

1. In hindsight, gaining **input and guidance from social scientists** prior to commencing public engagement would have been useful.

2. **Face-to-face** forums presented the single most important opportunity for engagement.

3. **Contextualisation** using imagery of something people could relate to was crucial in the opening engagement and for framing discussions.

4. **Factually present the advantages and disadvantages** of each system in an unbiased manner, from the context of both the farmer and the consumer.

5. **Clarifying the principles of risk** in terms of people's everyday lives to give context to hazard and exposure.

6. **Empowering people to come to their own conclusions** based on sound, scientifically based reasoning explained in a non-scientific format.

7. **Admitting uncertainty** is acceptable and helps build empathy and credibility.

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[82] *Journal of Experimental Botany*, Vol. 70, No. 15 pp. 3699–3703, 2019
doi:10.1093/jxb/erz196 Advance Access Publication 27 April, 2019
This paper is available online free of all access charges (see https://academic.oup.com/jxb/pages/openaccess for further details)

These themes are consistent with research reviewing historical communication around GMO by Arujanan[83] who described the need to 'unlearn and relearn' how to communicate with the public about gene editing. He described key areas for successful engagement as:

1. **Good science needs good communication**, not propaganda.
2. **Starting from a place of shared values**, not the point of contention.
3. **Ask questions first**, provide information second.
4. **Story-tell the science** so it is relatable.
5. **Use social-centric messaging**.

The themes here and in the Irish example describe a **dialogue and participatory communication approach**, not an expert or linear transmission of knowledge, the latter with the aim of giving people the 'right' information so they can take a positive view rather than having an open and transparent conversation so people can form their own view. Asking questions clarifies what concerns and claims need to be addressed in a relatable way, rather than espousing the benefits of the technology. Examples of shared values may be societal values of nature positive farming and improved environmental outcomes.

These key themes and insights should be used to guide policymakers, regulators and others engaging with the public to design for effective engagement as New Zealand navigates a future with gene editing.

8.2 Courageous Conversations

8.2.1 Brand New Zealand

New Zealand's national brand was valued at US$248 billion in 2022 by Brand Finance Nation[84]. Brand strength was calculated based on investment in the national brand (25% weighting), public perception (50% weighting), and performance (25% weighting).

Many primary export brands successfully leverage New Zealand's picturesque landscapes, temperate climate and progressive farming systems for customer and consumer marketing. A good example is the "Taste Pure Nature" campaign by Beef & Lamb New Zealand, which doubles down on the concept of natural landscapes and grass-fed beef and lamb[85]. Another is Fonterra's marketed grass-fed standard requires cows to be 80% grass-fed on a dry matter basis and spend a minimum of 90% of non-milking time grazing outdoors. It also clearly states that all feed for cows is from plants that are not genetically modified.[86] By comparison, Ireland's Bord Bia grass-fed standard is a minimum of 240 days on pasture for dairy and 220 days for beef, with no GM feed claims. Although no GM cultivation occurs in Ireland, the EU annually imports around 30 million tonnes of soya bean from the USA and South America for livestock feed of which 90-95% is GM.

[83] ISAAA. 2021. Breaking Barriers with Breeding: A Primer on New Breeding Innovations for Food security. ISAAA Brief No. 56, pp.56 ISAAA: Ithaca, NY.
[84] New Zealand brand comes out strong in global rankings post Covid-19
[85] The story behind the Taste Pure Nature campaign - Our Land & Water - Toitū te Whenua, Toiora te Wai
[86] Grass Fed Goodness

Any trade or marketing advantage to leveraging a GE-Free New Zealand status may be short-lived as global legislation moves towards a future utilising gene technology. Reviews undertaken have concluded that it is highly unlikely that introduction of GM pasture into New Zealand would create perception issues in the global marketplace.[87] However, there must be successful co-existence so organic and GE-free producers can continue to farm as they wish.

A New Zealand Institute of Economic Research (NZIER) report commissioned in 2024 by Organic Aotearoa NZ valued the market perception of GE-free New Zealand products at a 24 percent premium over basic world prices.[88] This was extrapolated based on primary sector export revenue and calculated as a loss of $10.6 billion of food and fibre export annually. It would have been useful for the report to compare in-market pricing for the same food products produced by countries that are not GE-free e.g. USA, Brazil, Australia, versus New Zealand, to get a better understanding of the premium ascribed to a GE-free status.

Ultimately, it will be for New Zealand government trade officials and exporters to socialise the threshold for where the use of GE could be problematic for market access and customer or consumer acceptance and ensure that regulatory assessment reflects this. A cautious approach would be prudent. Alongside this, it is vitally important that regulation and assurance protects the status and GE-free product claims of the organic and GE-free communities.

8.2.2 Understanding Concerns

"How the farmer or the company makes their money is important to society…at the expense of what?"
John van der Oost, Wageningen University & Research, interview
(renowned for his pioneering work on the CRISPR-Cas technology)

There is growing awareness that public sentiment towards gene editing and modification is not a binary debate, as simple as a 'for' or 'against' stance, but more related to an understanding and judgement on why and how it is used and what the social and environmental impact is likely to be.

In discussion at Wageningen University about understanding societal concerns, the author was directed to research papers examining this in relation to new or emerging technologies.

The first was research into public dialogues by Macnaghten and Chilvers[89] on emerging science and technology sponsored by the UK Government "Sciencewise" initiative. This identified five **broad thematic concerns** that structured public responses and gave key insights into factors that could inform regulatory framework and public engagement.

[87] Knight JG. 2011. New Zealand's 'clean green' image: will GM plants damage it? ISBN 978-1-877156-45-8. p. 68.
[88] NZIER. 2024. Potential costs of regulatory changes for gene technology: economic assessments of an MBIE proposal. A report to Organics Aotearoa New Zealand. [NZIER OANZ Potential costs of regulatory changes.pdf - Google Drive]
[89] Macnaghten, P., & Chilvers, J. (2014). The future of science governance: Publics, policies, practices. Environment & Planning C: Government and Policy, 32, 530–548.

These were concerns about:

- The **purposes** of emerging technology
- The **trustworthiness** of those involved
- Whether people feel a sense of **inclusion and agency**
- The **speed and direction of innovation**
- **Equity**

Understandably, public concerns were related to the intent of the technology rather than just the technological process. Questions were raised about the potential for corporate control of global food systems and associated distribution of wealth and power, creating monocultures over ecosystems and marginalising the small grower through accessibility barriers. The pace and nature of change understandably raised concern and would be heightened if there was a lack of inclusion and opportunity for knowledge empowerment. Fair distribution of social benefit was more important than the direct benefit of the technology itself.

The researchers noted such findings differed markedly from dominant approaches to risk communication and risk perception research, which have tended to presume that public acceptability to emerging technology depends on how people weigh up risks and benefits or assume that people are either 'pro' or 'anti' a particular technology.

They concluded that all emerging technologies are perceived to involve a level of risk and uncertainty, and that perceived 'benefits' may turn out to not be beneficial at all. Public responses to novel technologies are thus rarely expressed in simple distributional terms, of maximizing the 'benefits' of technology while minimizing its 'harms'. Rather, they suggested the narratives deployed in engaging the public with novel developments should speak to the moral meanings of the technology, its purposes, significance and possible potential for moral or social transgression.

"Concerns are driven by the narratives that people can draw upon. They are trying to make sense of something."
Phil Macnaghten, Social Scientist at the Knowledge, Technology and Innovation Group, Wageningen University (interview)

A project by Macnaghten et al[90] into **cultural narratives of concern** where people were unfamiliar with emerging technologies and the social issues they posed provides interesting insights. They identified five key themes that were likely to be elicited in public responses in such situations:

[90] Phil Macnaghten, Sarah R. Davies & Matthew Kearnes (2019) Understanding Public Responses to Emerging Technologies: A Narrative Approach, Journal of Environmental Policy & Planning, 21:5, 504-518, DOI: 10.1080/1523908X.2015.1053110

Narrative of Concern	Related Social Issue
Be Careful What You Wish For	May lead to unforeseen disaster and catastrophe.
Pandora's Box	Once it's "out", there's no going back.
Messing with Nature	Nature is sacred and sets moral and ethical boundaries that human beings should not transgress.
Kept in the Dark	People feel alienated or disenfranchised from the technology and R&D innovation process. While they feel compelled to trust 'expert systems' responsible for development and governance of emerging technologies, they feel deeply powerless over the conduct of these systems.
The Rich get Richer	The potential of emerging technologies to engender further injustice and inequality, both globally and locally, resulting in big business and the already powerful benefiting while the poor or excluded are further marginalised (a concentration of power and wealth).

Another study exploring concerns about gene editing of livestock in the Netherlands[91] identified similar themes of pushing moral and ethical boundaries, unintended consequences, inequity and the importance of governance:

Narrative of Concern	Related Social Issue
Technological Fix	Attempting to respond to social problems by technical means gives rise to new problems.
Market Rules	The potential and likelihood of technology to increase inequality locally and globally.
In Pursuit of Perfection	Not foreseeing consequences in the pursuit of perfection, or the ambition of producing 'better' animals.
Finding the Golden Mean	Exercising moderation and control to avoid overextension or excess, including technical capability.
Governance Through Care	A need for a deliberative, independent and composed group of experts to foresee consequences.

[91] Middelveld S, Macnaghten P, Meijboom, F. (2022). Imagined futures for livestock gene editing: Public engagement in the Netherlands. Public Understanding of Science. 1-16.

These key themes are useful as they can be used to inform framing of considerations and communications in addressing areas of general concern, at both a regulatory level and sector farmer-grower level. It also highlights the need for regulation to be holistic, encompassing environmental, social and ethical considerations, as well as safety and risk management. Transparency of governance is vital, with the inclusion of independent experts but also non-technical governors who can challenge science from a cultural and social conscience perspective. The latter is a key role for social scientists, Māori and governors outside the primary sector to play in the New Zealand regulatory space.

8.2.3 Lifting the Lid on Food Production

In the quest to address questions around purpose and 'technological fix' in a transparent way, how food is produced is likely to warrant further explanation. With urbanisation, urban population growth and less direct connection with farming, there is an increasing knowledge gap between the consumer and farming practices involved in food production. This is not intentional, but in considering the use of gene technologies against the status quo, more detail about the status quo and reason for change is required.

Referring to the earlier Irish example of the genetically modified potato trial and public discussion, Mullins outlined the aggressive EU agricultural sustainability targets, including its Farm to Fork Strategy targeting a 50% reduction in pesticide use by 2030 from the 2018 baseline. Mullins explained that gene editing for pest resistance could be a tool to assist in achieving that goal. On average, more than 10 spray applications were required for late blight protection, versus one in the GM trial potatoes. The obvious perspective from this conversation was "I didn't know potatoes received so many sprays". This instigated further dialogue around conditions for potato blight and management options for control including conventional, organic and GM spray approaches. It highlighted the dependency on chemistry in food production, and the need to look for other solutions, of which one was GM.

"A policy to reduce chemistry use will ultimately drive innovation. Dependency on chemistry in Europe has taken the focus off breeding for crop traits other than yield for the past 20 years."

Ewen Mullins, Principal Research Officer, Head of Crop Science Department, Teagasc, Ireland

8.2.4 Managing Expectations

The Chief Scientist at the Department for Environment, Food and Rural Affairs (DEFRA) estimates that it would take at least five years for a product to go from research trials to market.[92]

Despite some gene editing applications 'inside the lab' being considered field-trial or market 'ready', gaining regulatory approval, conducting field trials and scaling up for commercial release will take time, in some cases many years.

While some of the potential applications for NZ may be considered transformative e.g. accelerated breeding programmes, time to production (permanent horticulture) or having sufficient planted area to have significant impact (pastoral) at a systems level needs to be clearly communicated. Developing a potential sector adoption strategy and likely timeline under consultation with farmers and growers would be a useful early engagement platform. This would enable sharing of what it is the gene editing pipeline for each sector, the value

[92] Gene-edited crops may be 5 years away from sale in the UK | New Scientist

proposition at a farmer-grower level, sector level and national level is, broadly how far from being commercially available each is likely to be, as well as what alternatives or complementary approaches are available.

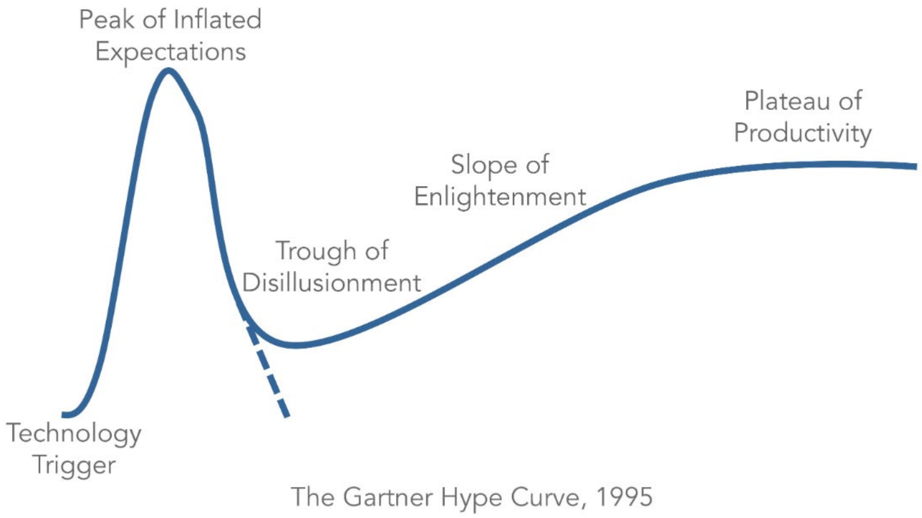

Figure 16. The Gartner Hype Curve

The Gartner Hype Curve[93] describes five key phases of a technology's life cycle and could be useful to predict expectations and responses if applied to gene editing technology. If the 'trigger' is assumed to be the CRISPR technology 'breakthrough', this is followed by a rapid peak where the possibilities create inflated expectations. After an initial flurry of investment and progress, interest may wane, and further progress appears slow or non-existent. This can create a sense of disillusionment in the technology and its perceived benefits. This could be during the field trial or early adoption phase. When benefits start to crystallise and become more widely understood, investment and adoption (e.g. farmer-grower uptake) gain momentum. Communicating the principles of the Gartner Hype Curve to farmer-grower end-users of gene editing would be valuable during the sector strategy consultation phase to help manage expectations.

8.3 Building Science Capability

Regulatory oversight and independent monitoring of gene editing performance outcomes will require scientific capability, capacity and investment. In January 2025, the New Zealand government announced reform of its science, innovation and technology (SIT) system to clarify priorities, lift economic outcomes and harness advanced technology for a more prosperous future.[94] A Prime Minister's Science Innovation and Technology Advisory Council will be established to provide strategic direction and oversight of the system. Other announcements related to these reforms included:

- The establishment of a new agency Invest New Zealand
- Refocusing New Zealand Trade and Enterprise (NZTE)

[93] Linden-HypeCycle-2003.pdf
[94] Refocusing the science, innovation and technology system | Ministry of Business, Innovation & Employment

- Disestablishing Callaghan Innovation and redistributing its most important functions to other parts of the system
- Establishing four future-focused Public Research Organisations (including a merger of all primary sector-focused CRIs)
- Developing a national policy to better manage intellectual property. At face value, while creating uncertainty, these changes should be beneficial to gene technology research, investment and commercialisation.

At face value, while creating uncertainty, these changes should be beneficial to gene technology research, investment and commercialisation. A challenge will be to build the capability of scientists that can transcend the legislative and regulatory environment, but also across sectors, to end-user farmers and growers, and the public. Many scientists are scientists for science's sake and fronting public forums may be unappealing or a distraction from research. Primary sector organisations will need to play a key role at the science-engagement interface.

A significant finding of this project has been the vital role that social scientists play at the science-engagement interface of new and emerging technologies. How social scientists can be integrated into the process, following recent restructure of the NZ$75 million Marsden Fund, the nation's sole funding source for fundamental science[95], should be a task for the newly formed Prime Minister's Science, Innovation and Technology Advisory Council.

[95] Amid cuts to basic research, New Zealand scraps all support for social sciences | Science | AAAS

Chapter 9: Conclusion

At the face of it, genetic modification was an achievement for science but a public relations disaster when it was commercialised in USA maize crops in the 1990's, driven by a lack of transparency in the regulatory process that did little to address public concerns around intent, safety and equity of the new technology. This created a foundation of mistrust by the public towards policy makers, multinational companies and some farming practices in relation to genetic modification. Addressing missteps of the past to ensure a more transparent and inclusive approach is vital in the modern era of gene technologies.

Recent scientific advances have developed new gene editing techniques, such as CRISPR, that can edit genes more precisely, faster and safely than before. This has ushered in the anticipation of a 'bio-revolution' in global agriculture, with applications wider than crop productivity to those that help address complex global challenges of food security, climate change and environmental impact. Legislation and regulation in many countries, including China, Australia, Japan, the European Union and the United Kingdom, have been revised to reflect these advances in gene editing and some may classify small changes that don't introduce foreign DNA as non-notifiable or unregulated.

As an independent export nation, market access and continuing to be a preferred and trusted partner is vital to the future success of the New Zealand primary sector. Being a 'fast follower' in changing gene technology legislation is exactly where New Zealand needs to be, delicately balancing the opportunities of science with retaining the trust of trading partners and consumers, in delivering a product of integrity. Communication and collaboration with our main trading partners and agricultural trading peers will be vital to ensure regulatory alignment and continued market access.

In the New Zealand agricultural context, gene editing has the potential to be transformational in certain parts of the value chain, such as scientific research, the biotech sector and plant breeding. The opportunity to breed plants with traits such as drought tolerance, reduced emissions and nitrogen losses, disease resistance and improved animal performance would be complementary to New Zealand's traditional plant breeding programmes. Change may be incremental in other segments of the value chain, and it is important that outcomes are socialised so that expectations of the government, primary sector and public are realistic.

New Zealand research indicates gene editing is not something farmers or the public know a lot about but are cautiously receptive to its potential. Consultation and engagement will be critical components of obtaining social licence for its application. Discussion needs to progress beyond a binary 'for' or 'against' debate to an inclusive conversation, with opportunity for engagement and gaining knowledge so that individuals can form their own opinion. Science capability and capacity is needed to fulfil this role and project findings indicate input from social scientists can add value to the engagement process.

Chapter 10: Recommendations

New Zealand's approach to gene editing should be cautious but also building on the innovation that has advanced the primary sector to where it is today. Gene editing should leverage the fundamentals of what the primary sector does well, which is growing pasture, crops and livestock, and where it could add value with minimal risk to trade, production systems and the environment. Commercial application must also respect the farming communities that choose to remain GE-free, e.g. organic, and ensure co-existence is successful.

It is recommended that ESG (Environmental and Social Governance) principles be applied to regulation within a holistic framework in New Zealand. This would ensure that economic, societal and environmental impacts are considered in addition to the standard assessment of safety and risk. This expanded method would necessitate case-by-case evaluations, which would be more demanding for both regulators and applicants. However, it would ensure a more comprehensive and balanced assessment, enhancing public, sector and trade confidence. The regulator also needs to be informed of the impact on market access and trade from qualitative and quantitative insights of government, trade and farming perspectives.

Changing legislation and regulation is a catalyst for leadership of a societal conversation about shared values as food producers and as a nation, shaping the future of how we produce food. A coordinated scientific and primary sector leadership approach to engagement is important with the focus on answering questions and presenting using relatable examples, being the 'honest broker' rather than the 'expert'. The principles of anticipation, inclusivity, reflexivity and responsiveness should be followed. Involvement and input from the different production sectors, Māori, farmers and growers and the general public will be important.

Development of a production sector gene editing strategy in consultation with farmers and growers would be a useful engagement platform. This would enable questions to be asked and the sharing of trade insights, the gene editing pipeline for each production sector, the value proposition and risk considerations, broad commercialisation timelines, and what alternatives or complementary approaches are available.

It is also important that outcomes and timelines from gene editing are socialised so that expectations of the government, primary sector and public are realistic. Primary sector and government research should play an important role in independent monitoring and reporting of performance outcomes. The use of social scientists in the public engagement process should be leveraged as overseas experiences indicate this adds value and independence to the process.