MINISTRY OF BUSINESS,
INNOVATION & EMPLOYMENT
HĪKINA WHAKATUTUKI

13 February 2025

Ref: DOIA-REQ-0008002-Claire Bleakley

Claire Bleakley
Email: claire@gefree.org.nz

Tēnā koe Claire

Thank you for your email of 8 January 2025 to the Ministry of Business, Innovation and Employment (MBIE) requesting, under the Official Information Act 1982 (the Act), the following information:

> *Please could you provide all documents you considered relating to the Gene Technology Bill –*
> *1. a. on published peer reviewed research that show safety to the environment and human health of Gene Editing trials?*
> *b. Documents on how the GTB regime should enable the greater use of safe gene technologies that researchers are not already conducting?*
> *c. How will exempt new gene technology products be verified as proportionate to the risks that each application poses?*
>
> *2. All the documents you considered relating to*
> *a. New Zealand missing out on economic opportunities and development of new technologies and the income it would generate.*
> *b. What crops was New Zealand missing out on that are more resistant to disease, resistant to climate change and have enhanced nutritional content?*
>
> *3. The Technology Committee members who wrote the GTB are all going to financially benefit from the introduction of this piece of legislation.*
> *a. Are these going to be the same people on the Technology Committee who will be advising the Regulator?*
>
> *4. There are many hundreds of laboratory applications approved under HSNO*
> *a. Please provide all documents that MBIE considered in the development of the Gene Technology Bill that relate to the performance and outcome of the approved twenty field tests of GM plants, animals, and microorganisms.*
> *b. What has been their commercial worth?*
>
> *5. All research needs to have raw data to show the outcomes of any experimental process.*
> *a. Please provide the grant amounts that MBIE has provided to the biotechnology sector for GM developments?*

b. Were the compliance costs factored into the MBIE Foundation grants?
c. If not why not?

I am writing to respond in part to your request and to advise you that MBIE will provide a further response but needs to extend the time available to answer your request fully. MBIE's further response will be sent to you no later than 13 March 2025.

The reason for the extension to respond fully is that your request necessitates both a search through a large quantity of information and consultations to make a decision on the request. Meeting the original time limit would unreasonably interfere with our operations and the consultations required are such that a proper response to the request cannot reasonably be made within the original time limit.

Please note that the summer break period also affects the time for responding to your request. The Act excludes days from 25 December 2024 to 15 January 2025 (inclusive) and Waitangi Day from the definition of working days and therefore the timeframe within which we must make a decision on requests.

If you wish to discuss any aspect of your request or this response, or if you require any further assistance, please contact OIA@mbie.govt.nz.

You have the right to seek an investigation and review by the Ombudsman of our decision to extend the time limit and our decisions (below) concerning parts of your request. Information about how to make a complaint is available at www.ombudsman.parliament.nz or freephone 0800 802 602.

Please see MBIE's response to your request below.

Partial response to questions 1 and 2

The majority of documents we considered are referenced in MBIE's Regulatory Impact Statement which can be located at the following link: https://www.mbie.govt.nz/dmsdocument/29936-regulatory-impact-statement-reform-of-gene-technology-regulation-pdf. In addition, MBIE's disclosure statement on the Gene Technology Bill lists key inquiry, review and evaluation reports that have informed, or are relevant to, the policy to be given effect by the Bill and which we considered in developing the policy (see particularly the response to question 2.1). The disclosure statement can be found here: https://disclosure.legislation.govt.nz/assets/disclosures/bill_government_2024_110.

Additionally, we considered the following publicly available documents:

- Ebah E.E., Yange I.A., Ohie I.R., and Inya O.J. (2022). Application of genetically modified organisms in waste management – a review. *Stamford Journal of Microbiology*, Vol. 12, Issue 1, p. 15-20. https://doi.org/10.3329/sjm.v12i1.63338
- Lester, P.J., Bulgarella, M., Baty, J.W. *et al.* (2020). The potential for a CRISPR gene drive to eradicate or suppress globally invasive social wasps. *Sci Rep* **10**, 12398. https://doi.org/10.1038/s41598-020-69259-6

- Dearden, P. K., Gemmell, N. J., Mercier, O. R., Lester, P. J., Scott, M. J., Newcomb, R. D., Penman, D. R. (2017). The potential for the use of gene drives for pest control in New Zealand: a perspective. *Journal of the Royal Society of New Zealand*, *48*(4), 225–244. https://doi.org/10.1080/03036758.2017.1385030

- Business and Economic Research Limited (BERL). (2003). Report to Ministry for the Environment and the Treasury on Economic Risks and Opportunities from the Release of Genetically Modified Organisms in New Zealand. https://environment.govt.nz/publications/economic-risks-and-opportunities-from-the-release-of-genetically-modified-organisms-in-new-zealand/

- Office of the Minister of Finance and Office of the Minister for the Environment. (2004). Government Response to the Royal Commission on Genetic Modification: Economic Analysis Results and HSNO Act Implications. https://www.treasury.govt.nz/sites/default/files/2007-09/pol03-77.pdf

- Knight, J.G.. (2016). GM crops and damage to country image: much ado about nothing? *Acta Horticulturae*. 23-32. DOI: 10.17660/ActaHortic.2016.1124.4

- Harris Consulting. (2009). Assessing the Economic Impact of Cisgenic Technologies in Ryegrass. Report prepared for Pastoral Genomics Ltd. Harris Consulting, Dairy NZ, Annette Litherland, Butcher Partners, Infometrics. [Attached as Annex 1 as we were unable to locate the URL.]

Concerning question 1c, this will be a matter for secondary legislation, in order to operationalise the regime that the Bill will establish. However, we have considered the following publication by the Australian Office of the Gene Technology Regulator, which outlines their approach to conducting risk assessment, as part of our development of the Bill: https://www.ogtr.gov.au/resources/publications/risk-analysis-framework-2013

Additionally in respect of question 2, attached as Annex 2 is a short paper about HME ryegrass prepared in 2023 for the Minister of the Environment which we obtained from the Ministry from the Environment in April 2024. The paper summarises the results of research conducted to date, which includes potential climate benefits and increased energy content.

Response to question 3

The Bill provides that the Minister responsible for the Gene Technology Act will appoint members to the Technical Advisory Committee that will advise the Regulator. Members must be knowledgeable in a relevant area of science. No proposals for membership have been made and, until the Act is passed, the Minister does not have the power to make any such appointments.

Decision regarding question 4

MBIE is refusing question 4a under section 18(e) of the Act (for the reason that the document alleged to contain the information requested does not exist) as MBIE did not consider such documents.

MBIE is refusing question 4b under section 18(g) of the Act as the information requested is not held by the department and I have no grounds for believing that the information is either—

(i) held by another department (for itself and for a departmental agency hosted by it or an interdepartmental executive board serviced by it) or interdepartmental venture or Minister of the Crown or organisation, or by a local authority; or

(ii) connected more closely with the functions of another department (for itself and for a departmental agency hosted by it or an interdepartmental executive board serviced by it) or interdepartmental venture or Minister of the Crown or organisation or of a local authority.

Response and decision regarding question 5

In response to question 5a, research projects which have received grants from MBIE are published on the MBIE website: Who got funded | Ministry of Business, Innovation & Employment.

This data is updated monthly and it includes titles and public statements about each project title, the amount of funding provided and the recipient. The data is not specific to the biotech sector but can be searched for keywords. If you would like a more specific set of information, you may wish to consider refining what you would like information about using Australian and New Zealand Standard Research Classification (ANZSRC) codes. Information about the codes and how to access a list of them can be found here: https://www.mbie.govt.nz/science-and-technology/science-and-innovation/research-and-data/anzsrc.

In response to questions 5b and 5c, we do not request a detailed breakdown of costs, including compliance costs, from applicants. While we would expect any compliance costs involved in delivering a research programme would be included in the funding application, we cannot say with any certainty whether these specific costs were covered by our contracts for research. MBIE is therefore refusing your requests in 5b and 5c under section under 18(e) of the Act, as the document alleged to contain the information requested does not exist.

Nāku noa, nā

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Assessing the Economic Impact of Cisgenic Technologies in Ryegrass

Report prepared for Pastoral Genomics Ltd

Harris Consulting
DairyNZ
Annette Litherland
Butcher Partners
Infometrics

FINAL

December 2009

Acknowledgements

The authors wish to acknowledge the assistance of Grant Edwards, David Stephens, Zac Hanley, Mike Dunbier, and other people who assisted with data, input and comments on the draft. All errors and omissions remain our responsibility.

Disclaimer

The information collected and presented in this report and any accompanying documents by the consultant and supplied to Pastoral Genomics is accurate to the best of the knowledge and belief of the consultant and subconsultants. While the consultant and subconsultants have exercised all reasonable skill and care in the preparation of information in this report, neither the consultant/subconsultants nor Pastoral Genomics accept any liability in contract, tort or otherwise for any loss, damage, injury or expense, whether direct, indirect or consequential, arising out of the provision of information in this report.

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1 Executive Summary

1. The Pastoral Genomics (PG) group is a farmer levy funded research consortium with aim of forage improvement through biotechnology. As part of its programme PG are developing cisgenic technology ryegrass varieties. Cisgenics utilises genes that have been identified as having useful traits in other related species, and which are present in the ryegrass or clover genome but not expressed or expressed in different ways. The existing genome is manipulated so that the useful trait is expressed in a more useful way within the cultivar, but new genetic material is not introduced into the plant.

2. The consortium has a number of potential ryegrass cultivars that have been or are being generated through use of cisgenic technology. The cultivars being investigated will be nearing the stage of requiring field trials over the next few years. As part of their application to ERMANZ for approval of field trials of these varieties, Pastoral Genomics has commissioned this report on the potential economic impact of the release of new cisgenic cultivars in New Zealand farm production and its flow on impacts in the economy.

3. Because no actual field trial data is available on cisgenic trait performance, four ryegrass cultivars were modelled for this exercise in an approach that aims to represent a realistic potential outcome. These four traits were represented by:

   - Increased biomass (MBG) –increasing the radiation conversion efficiency 20%.
   - Drought tolerance (DT) –an additional 4 weeks of growth during a dry period.
   - Nitrogen efficiency and Water soluble carbohydrates (NE) were jointly represented by decreasing the loss of N from urine of grazing animals and by decreasing the amount of nitrogen applied by 50%.
   - Combined trait (MBGDT) all of the three traits represented together.

4. The modelling of pasture growth show that the MBG trait produces significantly more dry matter than the baseline, but that the monthly production curve is very similar to the baseline pasture production. In contrast the DT traits have an altered production curve with relatively more summer production. A summary of the pasture production from each variety is shown in Table 1 below.

Table 1: Summary table showing the effect of the cisgenic traits on annual growth (kg DM/ha/year)

Region	Baseline	MBG	DT	MBGDT
Northland	16,335	20,256	17808	23035
Waikato	17,598	22,834	18,582	24,730
Taranaki	18,095	22,548	18,624	24,951
Canterbury	17,027	20,583	17,960	22,898
Southland	15,396	19,167	15,694	19,940

5. The pasture models were used as inputs to farm production models - the Dairy Whole Farm Model (WFM) (dairy), the FarmMax model (sheep and beef), and direct conversion of stocking rate changes (deer).

6. For individual farms that operate under a 10 yearly pasture renewal programme, the size of the impact on farm profit from the new cultivars is significant. The dairy operations would experience increases that range from 20 – 30% up to a doubling of profit in Northland with the MBGDT trait. The sheep and beef farms on a full pasture renewal programme would experience increases in operating profit ranging from close to 0% in the more extensive properties up to 22% in Northland for the combined trait. In most intensive properties where there is a significant area available for regrassing, a full regrassing programme of the modelled cultivar would result in an increase in operating profit are in the order of 8% - 12% for the MBGDT trait.

7. The 6 dairy models, 13 sheep and beef models and two deer models were aggregated up to the national level using statistical data on milk production (dairy), numbers of farms by farm type (sheep and beef) and numbers of livestock (deer). These were adjusted for attenuation of new pastures, existing rates of regrassing and potential adoption rates.

8. The aggregated national on farm impact, with existing rates of pasture renewal and different rates of adoption of the technology, were used to represent the likely scope of on farm changes as a result of the technology. For the dairy industry the new cultivars will produce a national benefit at full take up for the dairy industry of between $14 million per annum (drought resistance only, low adoption) and $270 million per annum (all characteristics, high adoption).

9. The sheep and beef industries show a relatively small impact for the drought tolerance trait, but a larger impact of approximately $30 million per annum for the combined biomass and drought tolerance trait. The aggregated sheep and beef models generally show a smaller increase in operating profit than do the dairy models because of less area regrassed, and the low profitability of the years modelled. For the deer industry the gains are in the order of an increase in $3 million per annum for the MBGDT trait at 50% adoption, which reflects the smaller size of the industry.

10. A cashflow analysis was used to assess the future stream of costs and benefits associated with the cisgenic cultivars. This included the costs of introduction of cisgenic technologies (including the ongoing research), the application process, the testing process, conditions imposed by ERMANZ, and the breeding programme. The results in Table 19 show that the cultivars all demonstrate a positive net present value and the net benefit from the cisgenics programme, assuming that at least one cultivar is successful, would range from $0 to $600 million (excluding externalities).

Table 2: NPV (8%) of cultivars for different adoption rates ($million)

Scenario	Adoption rate		
	0.2	0.5	0.8
Drought tolerance	$31	$105	$178
More Biomass	$129	$349	$570
Nitrogen efficiency/Water soluble carbohydrates	($1)	$25	$51
All traits	$141	$379	$618

11. This results suggest that even with a 10% reduction in prices, and moderate levels of adoption, the technology returns a net positive value. The probability of success for one of the production traits (MBG, DT or MBGDT) would need to be in the order of 5% - 20% for the technology to demonstrate a net positive return under the factors considered here.

12. A national input output (I/O) analysis was used to estimate the flow on impacts through the economy from the cultivars. Using this approach we estimate that the cultivars add between $75 million and $1.5 billion in GDP, and between $25 million and $0.5 billion in household income, depending on the cultivar and adoption rate. Employment impacts are up to 8,000 additional full time equivalents (FTEs)1, and even at low uptake for the DT trait there is close to 500 additional jobs in the economy.

13. A second approach to estimating the flow on impacts in the economy utilised a Computable General Equilibrium (CGE) modelling approach which takes a longer term steady state view of the economy. This model was run with using same level of gains achieved in the MBGDT scenario (including 80% adoption) in three different scenarios which varied depending on whether the gains were achieved here or overseas (or both)[2]:

- Scenario 1: Productivity gains achieved ***in NZ but not overseas***
- Scenario 2: Productivity gains achieved ***overseas but not in NZ***
- Scenario 3: Productivity gains in ***both overseas and in NZ***.

14. For Scenario 1 where the technology is adopted only in NZ, GDP increases by $446 million, exports increase by $340 million per annum, RGNDI by $160 million, and there is a small increase in wage rates and a decrease in terms of trade. However where the productivity gains are achieved overseas but not in NZ, there is a fall in GDP of $491 million, a decrease in exports of $248 million, a fall in RGDNI of $765 million, and a 0.4% fall in real wage rates. The difference between these two scenarios is in the order of $900 million in both GDP and RGDNI.

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[1] Note that one of the problems with the IO modelling is the lack of constraints and price impacts, and at the higher levels of impact there are likely to be some feedback mechanisms, such as labour availability and costs, which change the nature of the flow on impacts in the economy. This is explored further in the CGE modelling.

[2] The nature of the CGE model and level of aggregation mean that the scenarios with a smaller impact fell below the margins of error for the model

15. When we use the CGE model to assess the situation where the productivity increase is achieved both in NZ and overseas (Scenario 3), we see a fall in GDP and RGDNI of $22 million and $300 million respectively, and effectively no change in exports. This implies that NZ is able to hold its share of the world market for agricultural products, but at the expense of lower prices and a larger fall in the exchange rate. NZ remains better off under this scenario than in the scenario where the rest of the world achieves productivity gains but NZ does not.

16. The results show a potentially significant impact on the pastoral sector and the economy as a whole from the introduction of cisgenic cultivars. While this analysis does not take into account any externalities, it does show that:

    - The introduction of cultivars similar in characteristics to those modelled here would represent a net positive gain to the pastoral sector and the economy as a whole (before externalities), regardless of the modelling approach taken.

    - The size of the positive impact can be explained by the relatively low cost of the technology, the ready pathway to adoption through the existing seed supply network, and the low marginal cost for farmers of using the technology (since it can be incorporated with the existing regrassing programme).

    - The size of the benefit is constrained by key factors such as adoption, the attenuation of new cultivars in a pasture situation, and the rate of regrassing. Changes to any of these will have significant impact on the final result.

    - Rates of regrassing in particular will have a major impact on the final outcomes. If the rate of regrassing were to increase to 10% (so that all paddocks were regrassed on a 10 year rotation), the national impacts of the cultivars would more than double. This outcome is potentially possible if the cultivars were shown to have a major impact on production systems, which would encourage greater rates of regrassing.

    - There are some environmental impacts associated with the cisgenic cultivars. In the case of the N efficient/WSC cultivar there is some potential for a small reduction in nitrate losses, although the extent of this has not been calculated. With the other cultivars there is likely to be an increase in both nitrate losses and greenhouse gas emissions associated with the increased intensity of production. In the case of the higher adoption and more productive cultivars, these increases and associated environmental externalities could be significant.

    - The comparative CGE modelling shows that there are significant differences in economic impacts between the situation where there are agricultural sector productivity gains in New Zealand but not overseas, and where there are productivity gains overseas but not in New Zealand. When we know already the magnitude of uptake for some GE crop internationally is 70% - 90%, the implications of precluding access to cisgenic or other productivity increasing technologies is potentially significant in terms of the national economy.

17. Each of the analyses used in this report is partial in the sense that it considers only the impact of the technologies on the adopters of the technology and the subsequent flow on impacts through the economy. There is no consideration of externalities which may arise from the introduction of the technology which are understood to have been dealt with by the applicants elsewhere. The key externalities to consider in this regard are likely to be:

    - Trade in products which have no cisgenic technologies in their production chain
    - Organic production systems
    - Tourism
    - Animal welfare considerations from reduced feed variability
    - Reduced demand for water abstraction for irrigation
    - Water quality impacts (positive and negative)
    - Public perception.

2 Background

The Pastoral Genomics group is a farmer levy funded research consortium with aim of forage improvement through biotechnology. Their focus is on gene markers for conventional breeding, and cisgenic technologies for development of new cultivars. Cisgenic technology differs from transgenic technologies in that only the species' own genome is used – no genes from other species are introduced. Typically the technology utilises genes that have been identified as having useful traits in other related species, and which are present in the ryegrass or clover genome but not expressed or expressed in different ways. The approach is then to manipulate the existing genome so that it is expressed in a more useful way within the cultivar,

The consortium has a number of potential ryegrass cultivars that have been or are being generated through use of cisgenic technology. The cultivars being investigated will be nearing the stage of requiring field trials over the next few years. Currently these field trials are likely to require a full application to Environmental Risk Management Authority (ERMANZ) under the Hazardous Substances and New Organisms (HSNO) Act for conditional release of a GE organism. As part of this application Pastoral Genomics has commissioned a report on the potential economic impact of the release of new cisgenic cultivars in New Zealand. This report focuses only on the farm production impacts of the potential new cultivars, addressing the farms systems and profitability, and their flow on impacts in the economy. It does not address any potential externalities that may arise and as such is a partial rather than full CBA and impact analysis.

3 Method

3.1 Pasture modelling

The likely impact of new ryegrass cultivars is in effect impossible to determine, since the new cultivars have not in any meaningful way been tested, and in some cases have not even been developed. The development of potential performance of the new cultivars was therefore undertaken on a "what if" basis. While they are intended to be a realistic representation of how a new cultivar could perform, they should not be considered to represent the actual performance of a new ryegrass cultivar.

Pastoral Genomics has four main objectives with its cisgenic breeding programme. These are:

- Increased biomass
- Drought tolerance
- Nitrogen use efficiency
- Water soluble carbohydrates

The cultivars were modelled by DairyNZ using the modified McCall pasture model (McCall and Bishop-Hurley (2003)) with a simple cutting regime in four ways:

- Increased biomass (MBG) – this trait has been simulated by increasing the radiation conversion efficiency in the model by 20%. It was assumed that no extra water or nutrients were required to meet this increased growth potential.

- Drought tolerance (DT) – the project team used an additional 4 weeks of growth during a dry period as a realistic interpretation of a potential drought tolerant cultivar. This was simulated by increasing the soil water holding capacity (SWHC) by the equivalent of four weeks of summer potential evapotranspiration (119, 124, 111, 113 and 91.3 mm for Northland, Waikato, Taranaki, Canterbury and Southland, respectively). This was only one way to reproduce the effect of a drought tolerance trait within the framework of the models, and was not intended to be a mechanistic representation of the trait.

- Nitrogen efficiency and Water soluble carbohydrates (NE) were jointly modelled by decreasing the loss of N from urine of grazing animals and by decreasing the amount of nitrogen applied by 50%. No production increases were associated with this combined trait because:
    - The increased biomass trait is already effectively representing a nitrogen efficient plant because it is increasing biomass without any additional N inputs.
    - Advice received was that there is insufficient evidence that the WSC trait will lead to increased production, but there were potentially some gains in terms of reduced N losses from urine. These were assessed qualitatively.

- Combined trait (MBGDT) – a cultivar that incorporates the increased radiation efficiency, increased SWHC and reduced losses of N from urine using the same simulation approaches as for the individual traits.

The pasture models were used in the farm modelling in the following ways:

<u>Dairy</u> – the pasture models were incorporated directly into the production model, with the cutting regime being replaced by a grazing regime according to the farm system requirements. The farm systems pasture module as a result has lower pasture growth overall than the idealised modelling above.

<u>Sheep and Beef</u> – the baseline pasture growth curves from the MAF Farm Monitoring models were adjusted by the percentage change from the pasture models, using the closest suitable location. Thus for example the Waikato sheep and beef models August new cultivar production was increased by the same percentage changes as the Waikato pasture model August new cultivar production over the baseline. These adjustments are shown in Table 34, Table 35 and Table 36.

<u>Deer</u> – pasture was not modelled directly in the deer models, but the additional DM production from the equivalent sheep and beef property was used as the basis for conversion into deer outputs (see below).

3.2 Farm modelling

Three different approaches were used to simulate the impacts of the increased DM production from the new cultivars on the farm system. These approaches were dictated by availability of models, resources, and availability of data.

Dairy – the Dairy Whole Farm Model (WFM) is a proprietary model of DairyNZ that incorporates modules for climate, pasture production, grazing, animal production and financial outputs. The model is described in (McCall, 2003) and the baseline parameters are outlined in the report in Annex 1. The dairy modelling was undertaken initially for the 2006 season. These results were then used to select the stocking rates under the new cultivars on the basis that the ratio of the LIC data for the baseline to the estimated optimum for the baseline was the same as the selected stocking rate to the optimum stocking rate for the new cultivar (Equation 1). In doing this we were estimating how the average farmer would operate under the new cultivar, rather than an optimal farmer.

Equation 1: Calculation of stocking rate used for new cultivars

$$\mathrm{SR\_Trait(i)} = \mathrm{SR\_Baseline(LIC)} / \mathrm{SR\_Baseline(opt)} * \mathrm{SR\_Trait(i, opt)}$$

Where:

SR: stocking rate
opt: optimum stocking rates from the previous runs
i = i^{th} trait (MBG, DT or MBG+DT)

Table 3: Stocking rates used in Dairy WFM

Model	Baseline (based on LIC) cows/ha	MBG cows/ha	DT cows/ha	MBG + DT cows/ha
Northland	2.3	3.0	2.9	3.7
Waikato	2.9	3.9	3.1	3.9
Taranaki	2.9	3.2	3.0	3.3
Canterbury	3.2	3.9	3.2	4.1
Southland	2.8	3.7	2.8	3.7

Using the selected stocking rate, the dairy model was rerun for all available climate data for the applicable region. Because the dairy WFM is data demanding, particularly in the climate area, the set of data varied by region according to the data that was able to be supplied. The range of years modelled was from 7 – 30 years.

Sheep and Beef – the FarmMax model was used to estimate changes to sheep and beef farms resulting from the introduction of the new cultivar. Farmax ((http://www.farmax.co.nz) uses Stockpol (Marshall et al., 1991)[3] for the underlying biological programming. Information and case studies can be sourced from the Farmax website and a full description is available in a Meat

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[3] Marshall, P.R., McCall, D.G. and Johns, K.L., 1991. Stockpol: a decision support model for livestock farms. Proceedings of the New Zealand Grassland Association. 53, 137-140.

and Wool NZ report (Litherland et al., 2005)[4]. Farmax defines a farm in component subfiles which define stock (numbers and performance), land (area, pasture growth rates and land use) and costs and product prices. Once defined, scenarios are tested for biological feasibility by calculating if there is enough pasture cover on the farm at all times to meet animal requirements for target performance levels. Policies for biologically unfeasible farms can be automatically modified (increase or reduce stock numbers, feed more supplements, put on nitrogen etc) if necessary. Farmax generates detailed physical and financial reports.

In this analysis base files were used to recreate the financial and production performance of the 2006/07 MAF monitor farms for different sheep and beef farm types. The new pasture growth curves for regrassed areas of the farm were added to the base files, and the modify option was then used to adjust stock numbers. Then additional supplements were made to capture the full benefit of the genetically modified pastures when feed surplus were greatest and these supplements were fed to offset time periods when low pasture cover was most limiting. Stock numbers were then modified in an iterative fashion using the modify option of Farmax to make the farm feasible.

Deer – because of poor geographic coverage of the deer models a direct conversion of stocking rate changes to deer outputs was undertaken. This involved the:

- Estimating the average additional stock units on NI and SI intensive sheep and beef models.
- Estimating output per su for deer properties on a SI/NI basis.
- Estimating additional expenses on a per ha and per su basis for NI and SI models.
- Creating a weighted average deer model based on livestock numbers in NI and SI.

3.3 Land use aggregation

The 6 dairy models and 13 sheep and beef models and two deer models were aggregated up to the national level.

In the case of the dairy models, the model results were broken down into a per ha estimate of production, revenue, expenses and net surplus. The closest matching model types were assigned to each of the dairy regions as shown in Table 4, and then scaled so that the total production from the models equalled the total production from each set of regions to which the model type applied, using the average of the 2006 – 2008 production seasons. Each new cultivar model was then multiplied by the same scaling factors and the regions aggregated to give total production at a national level.

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[4] Litherland A.J, Snow V., Dynes, R., 2005. Decision Support Software and Computer Models to Assist in Feed Allocation and Utilisation in the New Zealand Pastoral Sheep and Beef Industries. A report for Meat and Wool New Zealand.

Table 4: Assignment of dairy regions to model

Dairy region	**Regional MS production (average 2006 - 2008)**	**Regional Effective ha (average 2006 - 2008)**	**WFM Model type used**
Northland	74,839,503	121,180	Northland
Central Auckland	33,242,862	48,367	Waikato
South Auckland	338,983,425	364,272	Waikato
Bay of Plenty	59,946,418	66,452	Waikato
Central Plateau	66,379,293	78,644	Waikato
Western Uplands	8,345,615	11,802	Waikato
East Coast	1,311,809	1,898	Waikato
Hawkes Bay	11,006,984	12,479	Waikato
Taranaki	149,917,181	170,032	Taranaki
Wellington	60,351,324	68,806	Taranaki
Wairarapa	50,080,464	58,077	Taranaki
North Island	852,133,470	667,841	
Nelson/Marlborough	26,884,390	30,619	Canterbury
West Coast	42,232,524	59,057	Southland
North Canterbury	134,485,744	109,895	Canterbury
South Canterbury	44,216,782	37,170	Canterbury
Otago	60,415,106	57,221	Southland
Southland	123,623,604	120,175	Southland
South Island	426,535,806	145,671	
New Zealand	***1,256,648,418***	***1,416,147***	
Dairy WFM Model type		**Effective ha**	
Northland		121,180	
Waikato		583,914	
Taranaki		296,915	
Canterbury		177,683	
Southland		236,453	
Total		***1,416,147***	

In the case of sheep and beef models, each model type was multiplied by the number of farms for that model type. The number of farms assigned to each model was based on MAF's estimates which are used in the generation of the MAF national model. MAF's figures were checked against StatisticsNZ estimates of area in grassland, and were found to be within 4% of this figure (excluding South Island merino model).

The deer model estimates were weighted by the number of livestock in NI and SI, and the weighted average per ha gain was multiplied by the number of ha of deer farming (both livestock and area from StatisticsNZ 2007 census of agriculture).

The number of farms in the sheep and beef models is shown in Table 5 below.

Table 5: Farm numbers and land area for sheep, beef and deer models, (MAF 2008, Statistics NZ 2007)

Model Farms	Number of Farms Represented	Area
Canterbury/Marlborough Hill Country	420	586,740
Canterbury/Marlborough Breeding and Finishing	1,630	594,950
Hawkes Bay/Wairarapa	1,165	726,960
Central North Island Hill Country	2,210	1,403,350
Gisborne Hill Country	605	496,705
Lower North Island East	845	293,215
Lower North Island West	420	87,360
Northland	975	306,150
Otago Dry Hill 400	400	800,000
South Island Merino	220	
Southland/South Otago Intensive	1,680	325,920
Southland/South Otago Hill Country	720	520,560
Waikato/Bay of Plenty Intensive	1,050	315,000
Deer Farms		154,000
	12,340	**6,610,910**

The estimates for sheep, beef and deer show an 8% variance from the Statistics NZ estimates for grassland in those land uses. These differences are likely to be explained by the presence of tussock grassland in a number of the farm types (Gisborne, South Island Hill country, Otago Dry Hill, and Southland/South Otago Hill). However to ensure the benefits are not overestimated, the differences in model estimates with and without the new cultivars are assigned to the area regrassed, and then multiplied only by the number of farms – so the estimates slightly under-represent the actual by about 8%. The model estimates of area regrassed are discussed below, together with the total area regrassed nationally.

3.4 Estimation of production benefit

3.4.1 Rates of pasture renewal

Rates of pasture renewal are generally lower than are considered by some commentators to be optimal (e.g. see Stevens et al 2007[5]). However pasture renewal creates difficulties for managers in terms of managing feed supply whilst a portion of the farm is out of production. Furthermore, pasture renewal tends to create additional feed in the spring months when there is currently a surplus on most farms, but does not markedly increase feed during winter months. To take advantage of the additional spring/summer feed requires a higher stocking rate, for which other means must be found to carry stock through the winter. For example Stevens et al (2007)

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[5] Stevens, D et al 2007. “Benefit Analysis: Literature Review and Modelling Outcomes” Report prepared for the NZ Pasture Renewal Charitable Trust. Unpublished AgResearch Client report. Available from http://www.pasturerenewal.org.nz/article/36.html

achieve this by incorporating a winter feed crop in the pasture renewal rotation, thus allowing for the increase in winter carrying capacity[6].

The farm modelling was undertaken with existing rates of pasture renewal estimated from the current expenditure on pasture renewal and on model parameters provided by MAF and DairyNZ.

Dairy - Using the $35/ha expenditure on pasture renewal derived from Dairybase and a $600/ha cost of pasture renewal, the dairy operations renew approximately 5.8% of their pasture annually on a 10 year rotation This figure equates reasonably well with the 3 - 4% rate of pasture renewal estimated by the Pasture Renewal Trust nationally[7]. In reality the rate will be higher for some operations and lower for others, and for very high rates of renewal there will be an effect on the attenuation factor discussed below. However as we have no way of correcting for this factor the average has been used and as long as the actual prevalence of properties regrassing more frequently than 10 yearly is low, the impacts on the final results will not be significant.

Sheep, Beef and deer property estimates of regrassing are between 0.1% and 5.8% for different model types based on regrassing expenditure in the MAF models. While these figures appear low, it should be seen in the context of a smaller proportion of the farm that is available for regrassing through full resowing programmes. Large parts of many sheep and beef farms are not accessible to tractor, and cannot be considered for a full pasture renewal programme which typically involves a feed crop. While country not accessible to tractors can be oversown successfully, the impact of this is uncertain where a very high performing, and potentially high maintenance, cultivar is involved. For this reason only resowing undertaken through drilling has been considered in this analysis.

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[6] This problem is particularly acute for sheep and beef farmers, for whom the option of grazing off during winter is less economically attractive. For this analysis it was considered that incorporating a feed crop into the rotation would confound the benefits from the new cultivar with that of the feed crop. In order to accommodate the additional stock the surplus pasture was cut turned into hay or silage, then fed out in the winter months to maintain the desired stocking rate. For dairy operations feed was bought in as required to cover any periods of deficit.

[7] http://www.pasturerenewal.org.nz/article/2.html - a higher rate than the national average would be expected on more intensive dairy systems.

Table 6: Estimates of area regrassed by model type

	Area of model farm	Estimate of area potentially regrassable under 10 year pasture renewal	Area estimated as regrassed annually under current regrassing rates
Canterbury Marlborough dry hill country	1397	419.1	14
Canterbury Marlborough finishing and breeding	378	207.9	9.6
Central North Island Hill Country	635	127	9
Eastern Lower North Island Intensive	347	277.6	18
Gisborne Hill Country	821	246.3	5
Hawkes Bay Wairarapa Hill Country	624	187.2	7.1
Northland sheep and beef	326	228.2	2.3
Otago Dry Hill Country	2000	300	2.6
South Island High Country Merino	10508	1050.8	36
Southland and Otago Hill Country	723	289.2	11
Southland Otago Intensive	194	155.2	10.5
Waikato Bay of Plenty Intensive	250	200	4.8
Western Lower North Island	208	145.6	12

3.4.2 Attenuation

In general new pastures do not maintain their full productivity gain in perpetuity. The newly sown species can die out from drought, overgrazing, pugging, and increases in weeds and pests. As there will tend to be a seed bank in the soil of earlier pasture species, over time the productivity of the pasture will tend back to the level it was prior to resowing. While there are various estimates of the rate at which new pastures attenuate, there seems to be general acceptance (Stevens et al 2007 *ibid*) that the pasture will attenuate through to year 10 where no benefit is seen over the original pasture. Their assumptions for rates of attenuation are shown in Table 7

Table 7: Assumed rates of attenuation of pasture post sowing (Source Stevens et al 2007)

Year post sowing	**Proportion of gain from new pasture retained**
0	100%
1	84%
2	68%
3	52%
4	36%
5	20%
6[8]	16%
7	12%
8	8%
9	4%
10	0%
Mean gain 10 years post sowing	**40%**

This estimate of attenuation was used to scale the results to reflect the actual change resulting from the adoption of new pastures. For pastures that are renewed more frequently than 10 yearly, the 40% will underestimate the gain from the new pasture. However because rates of regrassing tend to be below even that required for a 10 year renewal, it is likely that the occurrence of renewal more frequently than 10 yearly is relatively rare.

3.4.3 Adoption

The new cultivars as modelled show significant gains over existing cultivars, and as such their adoption should be favoured by farmers. However historically adoption of new technologies has not always been as high as might have been expected. In the case of ryegrass cultivars, this can arise through

- cost of seed for new cultivars
- doubts about efficacy and likely benefits
- problems with establishment
- doubts about persistence

It is difficult to determine what rate of adoption there will be for a new variety. There are examples of very high uptake of technologies in the plant breeding industry. The endophyte AR1, which has all the benefits and none of the side effects of the wild endophyte, was used in 70%[9] of seed sold in New Zealand (prior to the release of the new AR37 endophyte). GE technologies overseas have achieved very high rates of adoption. For example it is estimated that 70%[10] of all soybean grown contains the Roundup Ready trait developed by Monsanto, and in some countries (Argentina for example) over 90% of the crop is GE[11].

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[8] There appears to be a calculation error in the Stevens 2007 report whereby they assume a 5% reduction annually to 0% at year 10, where this requires a 4% reduction annually to achieve 0% at year 10. The 4% figure has been adopted for this report, but does not have a material impact on the results.

[9] http://www.stuff.co.nz/national/farming/6160

[10] http://www.isaaa.org/resources/publications/briefs/39/executivesummary/default.html, Also Brookes & Barfoot "GM crops- global socio economic and environmental impacts 1996-2006"

[11] Srinivasa, K., Kruse, J., and Kalaitzandonakes, N. 2000. "Global Economic Impacts of Roundup Ready Soybeans" Chapter 19, Genetics and Genomics of Soybean. Gary Stanley ed. Springer, NY.

The rates of adoption in New Zealand of any new cisgenic cultivars can only be speculative, and to counter this a wide range of adoption rates have been used. The results are tested at 20%, 50% and 80% adoption rates. We believe that the 80% adoption rate, while high, is possible of the technology has significant benefits and is appropriate at the upper end of sensitivity testing. It partly reflects the fact that the Pastoral Genomics consortium intends to make the technology available to all breeders, so new traits will be able to be incorporated in a number of different germplasm lines increasing the reach of the technology. For the drought tolerance trait we have assumed nil adoption in regions where there is minimal gain from the technology, which correlates to the Taranaki and Southland pasture production models (summer moist).

3.4.4 Genetic Progress without GM cultivars

Historic rates of progress in ryegrass breeding have been estimated at between 0.25 and 0.73% p.a (Woodfield 1999)[12] and at 0.4% (Easton *et al.* 2002)[13]. In the absence of development of the cisgenic cultivars progress will continue to be made through traditional breeding or through alternatives such as the Marker Assisted Selection (MAS) programme[14]. The key question to consider is what difference there will be in the rate of progress made with and without GM, including the cisgenics programme. There are two considerations here:

- *If cisgenics are introduced would genetic progress continue to be made at the historic rate or more slowly after the introduction of the cisgenic cultivars?* Because plant breeders use the best germplasm available from which to select and improve, in the event of a successful introduction, they would be most likely to use the cisgenic cultivar as the germplasm from which to improve. Therefore unless the cisgenic gene is considered likely to have “taken up” all the potential genetic progress in the species, we would expect continued progress even after the introduction of a cisgenic cultivar. While there is no information about the degree to which ryegrass is approaching its biophysical limitations, experience from other species such as maize and wheat show that continued improvement is possible for a long period following a major breakthrough (hybridisation in the case of maize and dwarf varieties in the case of wheat).

- *If cisgenics are not introduced (either for technical reasons or because of a lack of approval), would the resources from the cisgenics programme be diverted to a programme, such as MAS, that resulted in increased rate of progress above historic rates of progress?* Because we have no a priori knowledge of how the MAS programme or other plant breeding stacks up against the full range of other investments that the industry could make (either in forage or in other areas), there is no reason to consider that the absence of a cisgenics programme would speed the rate of progress likely to be made

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[12] Woodfield, D.R. 1999. Genetic improvements in New Zealand forage cultivars. *Proceedings of the New Zealand Grassland Association 61*: 3-7

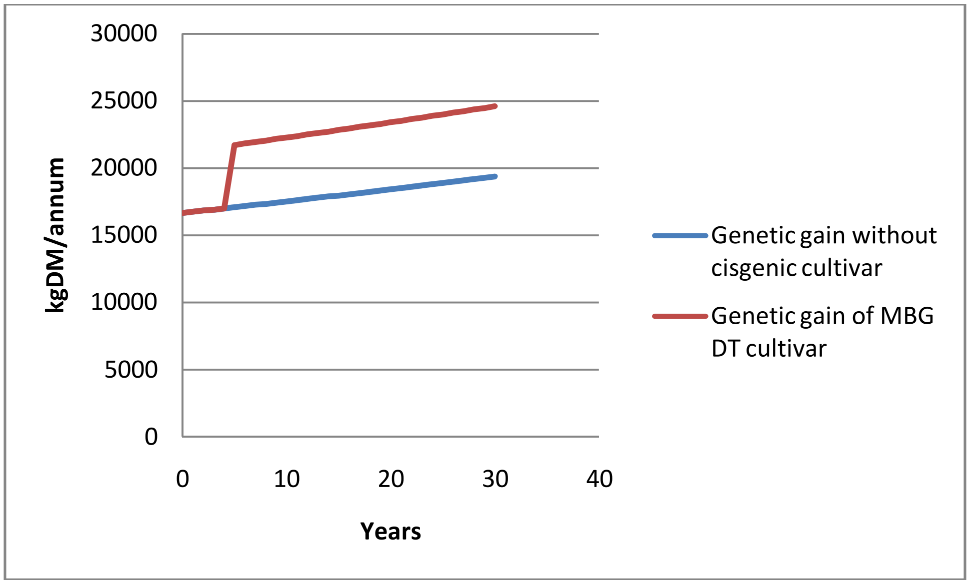
[13] Easton, H.S.; Amyes, J.M.; Cameron, N.E.; Green, R.B.; Kerr, G.A.; Norris, M.G.; Stewart, A.V. 2002. Pasture plant breeding in New Zealand: where to from here? *Proceedings of the New Zealand Grassland Association 64*: 173-179.

[14] This technology involves the identification of marker genes associated with desirable traits.

under the MAS programme or any other plant breeding programme. Even if the resources were diverted, the difference to rates of progress is likely to be small as the cisgenics programme is not a large part of the overall resources in the forage research area.

For these reasons we do not consider it necessary to make any allowances in the calculations for differences in rates of genetic progress between the “with cisgenic” and “without cisgenic” scenarios, and we have chosen to represent the with and without scenarios as shown in Figure 1.

Figure 1: Differences in rates of genetic gain with and without cisgenics (0.5%/annum rate of gain)



3.4.5 Summary of calculation

The total annual on farm impacts for each cultivar were calculated in the following manner:

Equation 2: Estimating annual benefit from new cultivar

$$\sum_{Regions} \Big\{\Big[\Big(\Big(\Big\langle \frac{Model\ new}{ha} - \frac{Model\ baseline}{ha}\Big\rangle * regrassing\ (0.1\ to\ 0.58) * attenuation\ (0.4) * adoption\Big) + \frac{Model\ baseline}{ha}\Big] * Area\ scalar\Big\}$$

3.4.6 Financial adjustments

There were a number of additional adjustments that were made to the financial results:

Income prices – income price indexes in the farming sector tend to be volatile, varying with international trading conditions and the exchange rate. For this reason the base year prices have been adjusted to the average of the 2006 – 2008 years prices[15].

Farm expenses – the 2006 base year costs have been adjusted to June 2008 using StatisticsNZ data. While data is available up until March 2009, the June 2008 figure was thought to be a better match for the equivalent price series that has been used. For deer farms the weighted average of the 2006 – 2008 years was used.

Share prices – the milk price figures used are inclusive of the value added component of the Fonterra payout. To reflect the difference in capital invested in the businesses for the higher production the average share vale for 2006 – 2009 was used ($5.62/share), multiplied by the discount rate to approximate the cost of capital.

Livestock changes – the differences in livestock numbers was multiplied by available livestock value information (2006 – 2007 for dairy, MAF model per su estimates for sheep, beef and deer) and the discount rate of 8% used to approximate the cost of capital associated with increasing stock numbers.

Wages of Management – the degree of intensification in dairy models was considered likely to be associated with increased wages of management. This increase was calculated on a per cow basis and multiplied by the number of additional cows/ha. For sheep, beef and deer the scale and changes to the farm system were considered likely to be encompassed within the existing scope of the operation, and no changes to wages of management were included.

Table 8: Price assumptions used in modeling

Item	**Price Used**
Milk Solids ($/kgMS)	$5.49
Livestock ($/cow)	$1,293
Fonterra share cost ($/share)	$5.64
Sheep	$3.70
Bulls	$3.13
Prime Beef	$3.47
Wool ($/kg greasy Crossbred)	$2.55
Wages of Management (dairy)	$142/cow

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[15] Source MAF, SONZAF 2008.

3.5 Costs of Cisgenic introduction

The introduction of cisgenic technologies will have cost implications for the Pastoral Genomics consortium and for plant breeders. While there are possibly impacts on farmers such as higher prices to farmers for cisgenic seeds, we have treated these as transfers between producer surpluses rather than welfare effects, and they are not included in the analysis[16]. From a welfare point of view the primary influence of seed price is likely to be adoption rates, which are covered elsewhere.

The major areas of cost identified in getting the cisgenic cultivar to market include the ongoing research, the application process, the testing process, conditions imposed by ERMANZ, and the breeding programme.

3.5.1 Ongoing research

The research programme for cisgenics is funded through the Pastoral Genomics consortium. The funding for this consortium includes marker assisted selection and cisgenics in approximately equal proportions, and comprises $2.881 million per annum from 2010 to 2014 (inclusive). There is no commitment to ongoing funding beyond that period. This funding is anticipated to bring three new cultivars (biomass, high sugar grasses, drought tolerance) to the point of release to breeders, and the fourth cultivar (nitrogen efficiency) to the testing stage. Total cost for the Pastoral Genomics research programme are shown in Table 9, with approximately 50% of these attributed to the cisgenics programme, and the remainder to the Marker Assisted Selection programme.

Table 9: Research costs by organisation in Pastoral Genomics ($ million)

Year	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
FRST	$2.834	$3.437	$3.437	$3.437	$3.437	$3.437
Agritech Clove Ltd (MWNZ)	$0.635	$0.826	$0.826	$0.826	$0.826	$0.826
Vialactia	$0.635	$0.826	$0.826	$0.826	$0.826	$0.826
Insight Genomics	$0.854	$1.110	$1.110	$1.110	$1.110	$1.110
AgResearch ltd	$0.058	$0.750	$0.750	$0.750	$0.750	$0.750
Deer Research PG	$0.034	$0.440	$0.440	$0.440	$0.440	$0.440
Total	$5.050	$7.389	$7.389	$7.389	$7.389	$7.389
Total for ryegrass cisgenics	**$2.525**	**$3.695**	**$3.695**	**$3.695**	**$3.695**	**$3.695**

3.5.2 Application process

The costs for a single cultivar to go through the application process are difficult to estimate, and not necessarily relevant to the ERMANZ decision (since they will be sunk costs at the time of the decision). Nevertheless because the initial decision will be precedent setting for the subsequent traits and because the impact of those subsequent traits has been assessed in this

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[16] Effectively the ability for the plant breeder to charge higher prices for seed as a result of better performance increases the profit of the plant breeder and decreases the profit of the farmer. However there is no overall welfare change to society from this transaction. However real increased costs, such as development and monitoring costs, have been included.

report, the costs of subsequent applications need to be subtracted from the overall benefits of allowing the release of cisgenic technologies. The application costs are estimated at the upper end of the ERMANZ range at $50,000. Other costs such as legal representation and expert witnesses have been estimated based on a case study of the relicensing hearing for 1080[17].

In the hearing for the relicensing of 1080, AHB and DOC experienced costs of approximately $470,000. This included:

- an externally contracted project manager,
- external consultants for preparation of some major elements of the reassessment application particularly information on the substance, hazard classification, default controls and analysis of risks, costs and benefits
- preparation and publication of public consultation documents and analysis of submissions (to the applicants)
- final preparation of the reassessment application document
- contracted assistance in evaluation of the submissions to ERMA, preparing formal or technical responses to some issues raised in submissions, preparation for hearings and attendance at hearings

In addition to these costs there were significant costs for staff time – estimated by AHB at close to $300,000. For the purposes of this exercise we have included $150,000 in staff time across organisations associated with Pastoral Genomics to cover the cost of the application process.

ERMA charged $160,000 to AHB/DOC for the 1080 hearing process, but it is understood that a proportion of the costs were absorbed by ERMA in recognition of the public interest in the process. The ERMA process for 1080 involved hearings at various regional centres, which increased costs significantly, and it is considered likely that an application for GE release would have similar level of interest and therefore cost. In addition to the ERMA costs there would be an additional cost to the submitters and general public, but this is not able to be quantified here.

The total cost of the initial application process is estimated here at $780,000, but the true cost of the application process will be somewhat in excess of that amount. Of this $670,000 is a cost to Pastoral Genomics and associated entities, and the remainder a cost to ERMA.

3.5.3 Proof of concept trialling

The trialling phase of the programme to proof of concept is expected to require four years in total. This would cover the cost of ensuring that the cultivar was capable of performing in a sward context in an open environment. The initial two years for the first cultivar are being undertaken overseas in Florida, at a cost of $US 240,000 over two years. This would then be extended to a larger scale trialling in a single location under more realistic conditions. If this trialling were undertaken initially in NZ, the expected cost would be $250,000 per annum including regulatory management costs (monitoring, separation crops etc). If it were undertaken

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[17] While the situations are not exactly analogous, it is expected that the first release of a genetically modified organism will be of a similar scale of complexity

overseas the cost would be in the order of $240,000 US over two years but there would also be an additional delay of a year. The choice of which approach were taken would depend on the nature of the conditions attached to the approval.

3.5.4 Breeder trialling

Once the cultivar is at a proof of concept stage, it would be released to breeders for incorporation in their breeding and evaluation programme. This would involve multiple sites and larger scale trials. However the marginal costs of this trailing would be limited to any regulatory requirements, since the trialling itself would be part of the normal cultivar evaluation programme in each breeding unit (effectively the cisgenic cultivar is just one among a number of cultivars being trialled). We have estimated a $50,000 per year cost for monitoring this part of the programme.

3.5.5 Release phase

Once the cultivar has been approved for release for sale, there may still be conditions associated with its release. For the purposes of this exercise we have allowed an additional $20,000 per annum to record location and sales of the cisgenic cultivar, and for any other regulatory requirements which may be incurred for ten years following wider release.

3.5.6 Reapplications

Each stage of the development programme beyond the initial approval for conditional release will require a reapplication to ERMANZ for a change of conditions associated with the cultivar. In the first instance this would involve approval of release over a wider geographical area, and in the second instance a release for sale. While these applications are likely to be considerably less onerous than the initial approval, costs will still be incurred. At each reapplication a further $50,000 has been allowed, $20,000 for the ERMANZ process and a further $30,000 for legal and ancillary costs.

4 RESULTS

The results of six different analyses are presented in this section. These are:

- The potential changes in pasture growth that arise from the new cultivars.
- The potential impacts on individual farms that operate under a 10 yearly pasture renewal programme, in effect representing the size of the potential productivity gain from the new technology.
- The aggregated national on farm impact, which uses existing rates of pasture renewal and different rates of adoption of the technology. This represents the likely scope of on farm changes as a result of the technology.
- A cashflow analysis, which uses constant prices to assess the Net Present Value (NPV) of the introduction of the new cultivars after taking into account development costs, rates of adoption and other costs to implementation. This analysis tells us whether there is a net benefit from the introduction of the new technology (excluding externalities) at constant prices. This analysis does not take into account any changes in prices or flow on impacts throughout the economy.
- A national input output analysis, which assesses the changes in the economy as a result of the changes in the farming sector. This is an annual model run at full implementation of the cultivar types using constant prices, and does not consider any feedback effects from other parts of the economy on the outcomes.
- A national computable general equilibrium analysis, which takes the changes in productivity changes implied by the farm modelling, and considers the flow on impacts throughout the economy, feedback effects from the increased activity, and impacts on prices as a result of the change in productivity.

Each of these analyses is partial in the sense that it considers only the impact of the technologies on the adopters of the technology and the subsequent flow on impacts through the economy. There is no consideration of externalities which may arise from the introduction of the technology. The key externalities to consider in this regard are likely to be:

- Trade in products which have no cisgenic technologies in their production chain
- Organic production systems
- Tourism
- Animal welfare considerations from reduced feed variability
- Reduced demand for water abstraction for irrigation
- Water quality impacts (positive and negative)
- Public perception.

These externalities are dealt with elsewhere by the applicants, and have not formed part of this analysis.

Because of the scope of the data generated in the modelling exercises, the following section presents only a summary of the results. Greater detail of the results is provided in the appendices.

4.1 Pasture Growth

The average monthly pasture growth rates for the production traits (MBG, DT and MBGDT) are shown in the appendices for each region in Table 25 to Table 31 and summarised in Table 10 below. They show that the MBG and MBG DT traits produce significantly more dry matter than the baseline. For the MBG trait the monthly production curve is very similar to the baseline pasture production. In contrast the cultivars which include the DT traits increase summer production significantly. The DT cultivar has a reduced production through the winter, which is thought to result from decay in material built up through late summer. It may be that this is an artefact of the modelling process rather than an underlying biophysical process, which would result in an underestimate of the impacts of the drought tolerant cultivar.

Table 10: Summary table showing the effect of the cisgenic traits on annual growth (kg DM/ha/year) (average 2000-2007)(December-April average kgDM/ha/day in brackets)

Region	Baseline	MBG	DT	MBGDT
Northland	16,335±1498 (41±6%)	20,256±794 (41±4%)	17808±1295 (45±5%)	23035±1542 (46±5%)
Waikato	17,598±1608 (48±5%)	22,834±940 (49±3%)	18,582±1539 (51±5%)	24,730±510 (53±1%)
Taranaki	18,095±939 (52±5%)	22,548±1058 (54±2%)	18,624±760 (53±5%)	24,951±382 (50±6%)
Canterbury	17,027±990 (53±2%)	20,583±1251 (50±2%)	17,960±542 (55±2%)	22,898±593 (55±1%)
Southland	15,396±660 (57±3%)	19,167±782 (56±2%)	15,694±583 (58±3%)	19,940±691 (58±3%)

4.2 Individual Farm Outcomes

4.2.1 Dairy

As noted above the pasture growth models were incorporated into the dairy WFM and integrated with the grazing regime. The full production system models were run for the available climate years, and then averaged to produce an expected annual gain for each cultivar in each region. The results from the WFM modelling are shown in Table 11 below.

Table 11: Dairy per ha model results after pasture attenuation, 10 yearly pasture renewal (profit after overheads and other fixed expenses) ($/ha/annum)

		Northland (/ha /annum)	Waikato (/ha /annum)	Taranaki (/ha /annum)	Canterbury (/ha /annum)	Southland (/ha /annum)
Baseline	**Milk Solids**	632	1,106	1,115	1,304	1,093
	Revenue	$2,685	$4,670	$4,728	$5,470	$4,578
	Farm Working Exp	$1,755	$2,540	$2,911	$3,686	$2,823
	Operating Profit	$259	$1,771	$1,070	$940	$907
MBG	**Milk Solids**	709	1,253	1,176	1,414	1,227
	Revenue	$3,010	$5,280	$4,982	$5,930	$5,124
	Farm Working Expenses	$1,868	$2,732	$2,955	$3,818	$3,066
	Operating Profit	$408	$1,988	$1,282	$1,187	$1,068
DT	**Milk Solids**	702	1,135	1,126	1,307	1,096
	Revenue	$2,979	$4,798	$4,772	$5,483	$4,590
	Farm Working Expenses	$1,843	$2,561	$2,942	$3,598	$2,819
	Operating Profit	$391	$1,866	$1,072	$1,057	$931
MBG DT	**Milk Solids**	785	1,262	1,189	1,455	1,233
	Revenue	$3,330	$5,332	$5,039	$6,099	$5,148
	Farm Working Expenses	$1,955	$2,706	$2,981	$3,895	$3,068
	Operating Profit	$557	$2,135	$1,296	$1,254	$1,097

Table 11 shows that individual properties will achieve significant productivity gains as a result of adoption of cisgenic cultivars should they perform as modelled. In Northland in particular the operating profit more than doubles with the MBGDT cultivar, and other regions experience increases in profit of 20% - 30% in that scenario. Associated with this increase in production is reduction in variability associated with the DT trait highlighted in the previous section on pasture production. This level of gain is very significant at the individual farm level, and is achieved with a technology that provides production increases at a very low incremental cost in both cash outlay, system terms, and in management terms.

4.2.2 Individual Sheep and Beef Farm Impacts

The sheep and beef have been modelled using FarmMax as discussed above. The farms were modelled with existing pasture renewal rates and with 10 yearly renewal of all suitable pastures. The existing pasture renewal rate modelling was used to in estimating national impact parameters, and the 10 yearly renewal was used to estimate potential productivity gains on individual farms. The potential productivity gains are shown in Table 38 in the appendices, and summarised as potential changes in Table 12 below. The results show that for the individual farmers on intensive properties and 10 yearly pasture renewal, the gains from the MBGDT cultivar would be in the order of 10% to 20% in revenue and 6% - 15% increases in operating profit. In the drier parts of the country the gains from the drought tolerance cultivar are in the order of 5% - 6% increases in revenue and profit. This level of change represents a significant gain at the individual farm level.

Table 12: Change in Revenue and Operating profit (before interest, tax, depreciation) for individual farms renewing pastures every 10 years (% change from baseline with 10 yearly pasture renewal of the new cultivar, after attenuation).

Model	Item	MBG	DT	MBGDT
Otago intensive	**Revenue**	10%	1%	11%
	Operating profit	7%	1%	7%
Otago Southland Hill	**Revenue**	5%	0%	5%
	Operating profit	3%	0%	4%
Hawkes Bay Wairarapa Hill	**Revenue**	5%	3%	7%
	Operating profit	3%	2%	5%
South Island Merino	**Revenue**	9%	1%	10%
	Operating profit	8%	0%	8%
Canterbury Marlborough Finishing Breeding	**Revenue**	8%	4%	10%
	Operating profit	7%	3%	8%
Canterbury Marlborough Hill	**Revenue**	5%	1%	2%
	Operating profit	2%	1%	6%
Central NI	**Revenue**	3%	0%	5%
	Operating profit	2%	0%	4%
Gisborne	**Revenue**	4%	1%	5%
	Operating profit	3%	1%	4%
Northland	**Revenue**	7%	6%	22%
	Operating profit	6%	5%	17%
Waikato BOP Intensive	**Revenue**	8%	2%	13%
	Operating profit	8%	2%	12%
West NI	**Revenue**	8%	1%	12%
	Operating profit	7%	1%	11%
East NI	**Revenue**	9%	6%	14%
	Operating profit	8%	5%	12%
Otago Dry Hill	**Revenue**	7%	3%	6%
	Operating profit	5%	2%	3%

4.3 National Aggregated on Farm Impact

4.3.1 National Dairy On Farm Impacts

The results for individual farms were scaled to reflect pasture attenuation, adoption and areas regrassed and aggregated up to national level in Table 13 and Table 14.

Table 13: Dairy benefits aggregated up to national level, after accounting for attenuation and regrassing. 50% adoption ($ million per annum)

	Existing	MBG	DT	MBGDT	N efficiency/WSC
Milk Solids	1,281	1,344	1,293	1,356	1,281
Revenue	$6,809	$7,136	$6,876	$7,203	$6,809
Farm Working Exp	$3,407	$3,510	$3,412	$3,505	$3,399
Operating Profit	$1,977	$2,015	$1,989	$2,030	$1,985

Table 14: Net annual impact to dairy industry at three adoption rates after accounting for attenuation and regrassing rates (operating profit after interest but before tax and depreciation, $million/annum)

Adoption	MBG	DT	MBGDT	N efficiency/WSC
20%	$50	$14	$67	$3
50%	$124	$36	$167	$7
80%	$198	$57	$267	$12

The results show that after accounting for adoption, regrassing and attenuation, the new cultivars will produce a national benefit at full take up for the dairy industry of between $14 million per annum (drought resistance only, low adoption) and $270 million per annum (all characteristics, high adoption).

4.3.2 National Sheep and Beef Impacts

For aggregation at the national level we have used existing rates of pasture renewal, and these results are shown in Table 15, and Table 16 below. Table 38 in the appendices gives the detail of stocking rate, revenue and profit for each model type prior to attenuation and adoption.

Table 15: Aggregated revenue, expenses and operating surplus for sheep and beef farm after scaling, attenuation and adoption, existing rates of pasture renewal ($million per annum, 50% adoption)

Item	Existing	MBG	DT	MBGDT	N efficiency/WSC
Revenue	$3,207	$3,268	$3,231	$3,280	$3,207
Farm Working Exp	$2,313	$2,351	$2,333	$2,357	$2,306
Operating surplus after int. before tax, depn.	$402	$414	$402	$419	$408

Table 16: Net Benefit results for sheep and beef models, national ($ million per annum)

Adoption rate	MBG	DT	MBGDT	N efficiency/WSC
20%	$5.1	$0.1	$7.0	$2.6
50%	$12.7	$0.2	$17.5	$6.4
80%	$20.2	$0.3	$28.1	$10.3

These results show a relatively small impact for the drought tolerance trait, but a larger impact of approximately $30 million per annum for the combined biomass and drought tolerance trait. The aggregated sheep and beef models generally show a smaller increase in operating profit than do the dairy models. This arises because:

- On average a relatively small part of sheep and beef farms is regrassed each year, meaning that overall less than 20% of the area in sheep and beef pastures is in new cultivars.

- The low profitability of sheep and beef farming in the years modelled means that it has been difficult to utilise all the feed grown. Typically the most feed constrained time of year is winter for these properties, and none of the varieties grow significantly more feed in the winter. This has meant that in order to carry a higher stocking rate pasture has had to be cut for hay and silage and fed out at times of feed deficit. The economics of doing so in periods of low return has limited the extent to which the stocking rate has been able to be increased. This problem could have been partially overcome by growing more feed crops, but the economics of the new cultivars would have become confused with the economics of growing feed crops.

- The modelling is undertaken on a single "average" year. The benefits of traits such as drought tolerance in reducing variability will not be fully demonstrated in this approach.

- The response to the new cultivar has been achieved through increasing stocking rate. It may have been that alternate strategies around growing lambs to a larger size, or use of trading stock, may have increased profitability by a greater amount. This is particularly true for scenarios such as the drought tolerance trait, where reduced variability can change management systems. However when undertaking modelling on a large scale such as this, it is important to ensure that the results are able to be consistently achieved across all properties[18], and for this reason a simple response to the increase in pasture was chosen.

The models do show significant increases in stocking rate and profit, particularly for the more intensive properties where gains of 10% - 15% are observed. The drought tolerance traits show lower gains although still significant in the drier parts of the country, and these results partly reflect the fact that the sheep and beef modelling uses only average pasture production and is unable to replicate the variability to which the drought tolerance trait responds.

4.3.3 National Deer Impacts

The deer impacts were modelled off the changes in stocking rate for intensive sheep and beef properties. As with the Sheep and beef properties, the responses to drought tolerance is muted, but there are more significant gains with the combined biomass/drought tolerance trait. As the deer industry is relatively small, the contribution to the overall impact is relatively minor.

Table 17: Annual revenue, expenses and operating profit for deer farms, 50% adoption ($million/annum)

Item	Existing	MBG	DT	MBGDT	N efficiency/WSC
Revenue	$153.07	$157.75	$154.97	$158.39	$153.07
Farm Working Expenses	$101.55	$102.88	$101.87	$103.13	$101.33
Net Surplus after interest but before depreciation, tax, Wages of Management	$31.05	$33.78	$32.38	$34.09	$31.27

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[18] For example it is unlikely to be possible for all properties to increase the proportion of trading stock, because of constraints in availability. Similarly holding onto stock for longer would decrease the availability of trading stock on other farms, which would in turn change the overall economics of the sheep and beef system.

Table 18: Change in annual operating profit, deer farms ($million/annum)

Adoption	MBG	DT	MBGDT
20%	$1.1	$0.5	$1.2
50%	$2.7	$1.3	$3.0
80%	$4.4	$2.1	$4.9

4.4 Cashflow analysis

The cashflow analysis assesses the future stream of costs and benefits associated with the cisgenic cultivars. It is undertaken in real $ (no incorporation of inflation), and as discussed previously assumes that in all other respects the situation with and without the technology are constant. The cashflow analysis considers each of the technologies separately. In this regard it is conservative, since it is likely that, if successful, different parties may adopt different cultivars to reflect the demands of their particular circumstances which would increase the overall benefit. Thus for example a summer dry property may choose only the drought tolerant variety, while a property in an area with restrictions on nitrogen discharges (such as Taupo or Rotorua lakes catchments) may choose only the N efficient/water soluble carbohydrate technology for the potential reduction in nitrogen losses.

Table 19: NPV (8%) of cultivars for different adoption rates ($million)

	Adoption rate		
Scenario	**0.2**	**0.5**	**0.8**
Drought tolerance	$31	$105	$178
More Biomass	$129	$349	$570
Nitrogen efficiency/Water soluble carbohydrates	($1)	$25	$51
All traits	$141	$379	$618

The Net Present Value summary of the cashflows at different adoption rates in shown in Table 19, and the full cashflow for the 50% adoption rate is shown in the appendices as Annex: Detailed tables of results
Table 39.

The tables show that the cultivars all demonstrate a positive net present value, with the exception of the N efficiency/WSC cultivar which is negative in the terms quantified here at low adoption rates (without taking into account the water quality benefits associated with a reduction in nitrate losses). The net benefit from the cisgenics programme, assuming that at least one cultivar is successful, would range from $0 to $600 million increase in welfare to the community.

Dairy represents the majority of this benefit - on average 86% of the returns from the cisgenic programme come from dairy properties. This is because of the higher profitability of the dairy sector and the higher rates of regrassing. As a result the conclusions are sensitive to prices, particularly in the dairy sector. A sensitivity analysis with prices plus and minus 10% is shown in Table 20 below.

Table 20: NPV (8%) of cultivars for different prices at 50% adoption ($million – uses only positive values by industry[19])

	Price		
Scenario	**-10%**	**Main assumption**	**+10%**
Drought tolerance	$87	$105	$130
More Biomass	$259	$349	$439
Nitrogen efficiency/Water soluble carbohydrates	$25	$25	$25
All traits	$295	$379	$463

This analysis shows that even with a 10% reduction in prices, and moderate levels of adoption, the technology returns a net positive value. The probability of success for one of the production traits (MBG, DT or MBGDT) would need to be in the order of 5% - 20% for the technology to demonstrate a net positive return under the factors considered here. As an IRR the technology demonstrates a return of between 12% (WSC/NE) and 26% (MBG) assuming 100% chance of success.

4.5 Changes in Environmental Impacts - nitrate losses

The cashflow modelling demonstrates a potential net benefit from the cisgenic cultivars. However there will also be some environmental externalities that are associated with the increase in production. In relative terms we can expect that the intensification of farming that is associated with higher producing properties will result in a greater loss of nitrates, phosphates and microbes to waterways, and an increase in greenhouse gas emissions.

The N efficient/WSC cultivar has some potential to mitigate the impacts of intensification. While no specific modelling has been undertaken on this area, there is some evidence to suggest that if the ratio of water soluble carbohydrates to crude protein (WSC:CP ratio) in this cultivar are increased sufficiently (above a ratio of 0.9), there could be some reduction in the concentration of N in the urine of animals[20]. Studies have also shown a nearly linear relationship between the concentration of N in urine and the losses of N from urine patches[21]. We conclude based on this information that an increase in WSC has the potential to reduce nitrate leaching from pastures if sufficiently high WSC:N ratios are achieved.

Any reductions in nitrate losses will have both an environmental and an economic impact, since nitrate losses are currently (Taupo and Rotorua Lakes) or are likely to be a significant constraint

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[19] For example at -10% it is uneconomic for sheep and beef farmers to adopt the new cultivars under the FarmMax assumptions used, so the result is significantly negative for this industry. As the likely outcome is nil adoption for this industry rather than accept a loss, a zero value has been included in the totals.

[20] Edwards et al 2007. "High Sugar ryegrasses for livestock systems in New Zealand". Proceedings of the NZ Grasslands Association, 69: 161 - 171

[21] Cameron, K.C. and Hong, J.D. 2007 "Nitrate leaching losses and pasture yields as affected by different rates of animal urine nitrogen returns and application of a nitrification inhibitor – a lysimeter study" Nutrient Cycling Agroecosystems 79: 281 - 290

on increasing production. The level of benefit associated a reduction in nitrate losses from the N efficient/WSC cultivar has not been calculated.

Similarly however the increase in production associated with the MBG, DT and MBGDT cultivars will have an environmental impact – both from increased nitrate losses and greenhouse gas losses. These nitrate losses are likely to increase at a more than linear rate with increasing production, since both the urine concentration and rate of deposition will increase. The level of increase and costs of that increase have not been calculated in this study.

Greenhouse gas production is likely to increase at a fairly linear rate with the increase in production from these pastoral animals since the increased production is a result of increased feed eaten, which by and large is the cause of methane emissions from ruminants. The CGE modelling discussed below has calculated the increase in greenhouse gas emissions directly, which increase by 1.1% compared with an increase in output of 0.7 – 1.7%. This has a direct cost to the economy from the need to purchase offset credits.

4.6 National Input/Output (I/O) analysis

The I/O analysis is a modelling approach that defines the relationships between different sectors, and thereby is able to estimate the flow on impacts through the economy from a change in one sector or industry.

The national outcomes report the annual change on farm and in the national economy as a result of the increase in irrigation. The national annual outcomes are divided into those produced on farm, and the total impacts which are those that occur throughout the community as a result of increase in the on farm production. The impacts are given as:

> **Output -** Output is the value of sales by a business. In the case of wholesale and retail trade, it is the total value of turnover (and not simply gross margins)[22].
>
> **Value-Added -** Value-added includes household income (wages and salaries and self-employed income), and returns to capital (including interest, depreciation and profits). It also includes all direct and indirect taxes.
>
> **Employment -**Employment is work done by employees and self-employed persons, and is measured in Full-Time-Equivalent jobs (FTEs). Where work is seasonal, the conversion to FTEs is based on 12 months' work per year. So a seasonal worker working full time for six months per year is 0.5 FTEs, and a part time seasonal worker working ten hours per week for six months is 0.125 FTEs.
>
> **Household Income -** Household income is the gross income of households. It includes the income of self-employed persons. There is sometimes considerable uncertainty as to the proportion of business income which goes to households and this is particularly the case for farms, where tax accounts are more likely to show various forms of income and

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[22] Care has to be taken in combining retail sales figures with employment per $m of output from input - output tables. In these tables, output is generally defined as gross margin. By contrast, business statistics figures usually give employment per $m of turnover.

drawings which are tax effective as opposed to a realistic assessment of the actual flows of funds during the year.

The detailed outputs from the IO model are shown in Table 40 in the appendices, and summarised in Table 21. The national modelling shows that using the IO model assessment the cisgenic cultivars add between $75 million and $1.5 billion in GDP, and between $25 million and $0.5 billion in household income, depending on the cultivar and adoption rate. Employment impacts are up to 8000 additional full time equivalents (FTEs)[23], and even at low uptake for the DT trait there is close to 500 additional jobs in the economy.

Because of the way the IO model works, it does not allow feedback effects from other parts ofthe economy, and therefore probably overstates the impacts of the technology. It is useful to think of the IO results as a linear short run outcome from the introduction as opposed to the long run equilibrium position. .

Table 21: National economic impacts of cisgenic cultivars, IO analysis (per annum)

		MBG	**DT**	**MBGDT**
20% Adoption	**Total value added (GDP, $million/annum)**	$315	$75	$378
	Total employment	1,806	468	2,023
	Total household income($million/annum)	$100	$25	$114
50% Adoption	**Total value added (GDP, $million/annum)**	$788	$187	$945
	Total employment	4,515	1,171	5,057
	Total household income($million/annum)	$250	$63	$285
80% Adoption	**Total value added (GDP, $million/annum)**	$1,261	$299	$1,512
	Total employment	7,224	1,873	8,091
	Total household income($million/annum)	$400	$100	$456

4.7 Computable General Equilibrium (CGE) modelling

The CGE modelling follows a process that involves the development of a baseline scenario which represents a Business as Usual (BAU) picture of the economy without any changes to agricultural productivity[24]. The model is then ‘shocked’ with the changes to agricultural productivity and composition of inputs derived from the farm modelling. In all scenarios the following are held constant at the outcomes from the baseline scenario:

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[23] Note that one of the problems with the IO modelling is the lack of constraints and price impacts, and at the higher levels of impact there are likely to be some feedback mechanisms, such as labour availability and costs, which change the nature of the flow on impacts in the economy. This is explored further in the CGE modelling.

[24] The BAU is not necessarily the most likely forecast of what the economy might look like. It will inevitably be wrong. Rather it is intended to be a plausible projection of the economy that can constitute a frame of reference against which other scenarios may be compared.

- Total employment is held constant, with wage rates being the equilibrating mechanism[25].
- The rate of return on capital (plant, equipment, buildings etc) is held constant, with capital stock being the factor that varies. For example, lower rates of return to capital will result in less investment and thus a smaller capital stock.
- The balance of payments is a fixed proportion of nominal GDP, with the real exchange rate varying. This means that any adverse shocks are not met simply by borrowing more from offshore, which is not sustainable in the long term.
- The fiscal surplus is held constant at the baseline level, with personal income tax rates varying to ensure that this level is maintained.
- Carbon charges are held constant at $25/tonne of CO^2 equivalent[26].

In contrast the IO modelling above holds wage rates constant and allow employment to increase, and makes no assumptions about return on capital and capital stock, balance of payments or fiscal surplus and tax rates. This means that the CGE model is closed model, whereas the IO model remains open for these and a number of other factors.

Because of the level of aggregation at which the CGE model operates, it was necessary to maximise the size of the shock to which the economy was subjected. For the purposes of the CGE modelling therefore the adoption rate was set at 80% and only the MBGDT scenario was considered. The CGE model reports a number of measures of economic welfare, including GDP, Real Gross National Disposable Income (RGNDI), imports and exports, private consumption, terms of trade and wage rates. The baseline scenario projects RGDNI to rise from around $165 billion in 2009 to around $231 billion by 2020. In per capita terms, this is an increase from around $38,500 to $48,900.

The model was run with the MBGDT scenario including 80% adoption. The nature of the CGE model and level of aggregation mean that the scenarios with a smaller impact fell below the margins of error for the model. The model was run for three different scenarios of uptake of cisgenic technologies:

- Shock 1: Productivity gains achieved in NZ but not overseas
- Shock 2: Productivity gains achieved overseas but not in NZ
- Shock 3: Productivity gains in both overseas and in NZ.

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[25] While employment may be more variable than wage rates in the short run, in the medium term the nature of the labour market and employment law in New Zealand mean that how the economy adjusts to a higher agricultural productivity is more likely to affect wage rates than employment.

[26] Alternative charges of $100/tonne were run on the model, but these did not make a major difference (<5%) to the final outcomes.

For each scenario the rate of productivity increase was assumed to be the same as the productivity gains modelled for the NZ situation. The changes in world prices in the scenario with productivity change overseas but not in NZ was modelled using the Lincoln Trade and Environment Model, which is able to better model changes in overseas productivity than the New Zealand CGE model. The weighted average changes in world prices estimated by LTEM are:

- Dairy -7.5%
- Meat -3.2%
- Wool -3.7%

Changes for the Shock 3 scenario with productivity gains both NZ and overseas were estimated by combining the price impacts from the Shock 1 and Shock 2 scenarios.

Table 22: CGE model outcomes Shock 1 - MBGDT productivity increase in NZ but not overseas ($ million per annum)

	Baseline	**MBGDT at 80% adoption**		
	$m[27]	**$m**	**Change**	**% change**
Macroeconomy				
Private Consumption	$136,998	$137,130	$132	0.10%
Exports	$73,057	$73,397	$340	0.47%
Imports	$78,971	$79,023	$52	0.07%
GDP	$233,730	$234,176	$446	0.19%
RGNDI	$231,784	$231,944	$160	0.07%
Real wage rate (index)	1.4206	1.4207	0.0001	0.01%
Terms of trade (index)	1.0881	1.0841	-0.004	-0.37%
				-0.15%
CO$_2$e emissions (Mt)	82804	83315	511	0.62%
of which CH$_4$ & N$_2$O	40544	41002	458	1.13%
Agricultural Output				
Dairy	$7,354	$7,475	$121	1.65%
Sheep & Beef	$7,809	$7,864	$56	0.71%
Other farming (incl deer)	$1,506	$1,523	$17	1.15%
Agricultural Prices (index)				
Dairy	1.134	1.094	-0.041	-3.60%
Sheep & Beef	1.141	1.123	-0.018	-1.53%
Other farming (incl deer)	1.094	1.075	-0.019	-1.73%

Table 22 shows that under the assumptions used in this modelling approach where the technology is adopted only in NZ, GDP increases by $446 million, exports increase by $340 million per annum, RGNDI of $160 million, and there is a small increase in wage rates and a decrease in terms of trade. However where the productivity gains are achieved overseas but not in NZ as shown in Table 23, there is a fall in GDP of $491 million, a decrease in exports of $248 million, a fall in RGDNI of $765 million, and a 0.4% fall in real wage rates. The difference between these two scenarios is in the order of $900 million in both GDP and RGDNI.

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[27] All figures in 2005/06 dollars

Table 23: CGE model outcomes, Shock 2 - MBGDT productivity increase overseas but not in NZ ($ million per annum)

-	Baseline	Productivity increase overseas but not NZ - -		
-	$m[1]	$m	Change	% change
Macroeconomy	-	-	-	-
Private Consumption	$136,998	$136,395	-$603	-0.44%
Exports	$73,057	$72,809	-$248	-0.34%
Imports	$78,971	$78,402	-$569	-0.72%
GDP	$233,730	$233,239	-$491	-0.21%
RGNDI	$231,784	$231,019	-$765	-0.33%
Real wage rate (index)	1.4206	1.4146	-0.01	-0.42%
Terms of trade (index)	1.0881	1.0836	0.00	-0.41%
				-0.48%
CO2e emissions (Mt)	82804	$81,496	-$1,308	-1.58%
of which CH4 & N2O	40544	$39,397	-$1,147	-2.83%
Agricultural Output				
Dairy	$7,354	$7,019	-$335	-4.55%
Sheep & Beef	$7,809	$7,690	-$119	-1.53%
Other farming (incl deer)	$1,506	$1,490	-$16	-1.04%
Agricultural Prices (index)				
Dairy	1.134	1.13	-0.0041	-0.36%
Sheep & Beef	1.141	1.14	-0.0041	-0.36%
Other farming (incl deer)	1.094	1.09	-0.0040	-0.37%

When we model the situation where this level of productivity increase is achieved both in NZ and overseas, we see a fall in GDP and RGDNI of $22 million and $300 million respectively, and effectively no change in exports. This implies that NZ is able to hold its share of the world market for agricultural products, but at the expense of lower prices and a larger fall in the exchange rate. NZ remains better off under this scenario than in the scenario where the rest of the world achieves productivity gains but NZ does not.

Table 24: CGE model outcomes, Shock 2 - MBGDT productivity increase both in NZ and overseas ($ million per annum)

	Baseline	Productivity increases in NZ and Overseas		
	$m[1]	$m	Change	% change
Macroeconomy				
Private Consumption	$136,998	$136,763	-$235	-0.17%
Exports	$73,057	$73,103	$46	0.07%
Imports	$78,971	$78,713	-$258	-0.33%
GDP	$233,730	$233,708	-$22	-0.01%
RGNDI	$231,784	$231,482	-$302	-0.13%
Real wage rate (index)	1.4206	1.42	0.00	-0.21%
Terms of trade (index)	1.0881	1.08	0.00	-0.39%
				-0.32%
CO_2e emissions (Mt)	82804	$82,405	-$399	-0.48%
of which CH_4 & N_2O	40544	$40,199	-$345	-0.85%
Agricultural Output				
Dairy	$7,354	$7,247	-$107	-1.45%
Sheep & Beef	$7,809	$7,777	-$32	-0.41%
Other farming (incl deer)	$1,506	$1,507	$1	0.06%
Agricultural Prices (index)				
Dairy	1.134	1.11	-0.023	-1.98%
Sheep & Beef	1.141	1.13	-0.011	-0.95%
Other farming (incl deer)	1.094	1.08	-0.012	-1.05%

The major lessons from the CGE model are:

- Generalised increases in productivity in the primary sector will tend to result in lower GDP and RGDNI than would be the case without those gains. This arises because for commodity products where we are price takers, the benefits of the increases in productivity are captured by the consumer rather than the producer. This is a consistent lesson from both history, and other approaches to modelling productivity increase[28].
- The modelling also shows that if New Zealand is able to capture productivity increases that other countries are not able to access then we can increase measures of economic wellbeing
- However if other countries increase their productivity in a manner that we are not able to match, then measures of economic wellbeing in New Zealand will fall regardless.

The differences in economic impact between the situation where NZ captures productivity gains that the rest of the world does not, and the situation where the rest of the world has productivity gains but we do not, are significant being in the order of $1 billion in GDP. Because of flow on impacts into competition for resources, changes in the exchange rates and impacts on wage rates these impacts are spread across the economy and not restricted to the agricultural sector.

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[28] See for example BERL 2003. “Economic Risks and Opportunities from the release of Genetically modified organisms in NZ.” Report prepared for the Ministry for the Environment and Treasury. April 2003.

4.8 Comparing model approaches

The majority of the difference when comparing the cashflow and IO analysis with the CGE modelling can be attributed to:

- Change in prices – the CGE model assumes that the increase in production in New Zealand depresses agricultural product prices – by up to 3.6% in the case of dairy. Because the price change impacts on the whole industry, the change in overall revenue is much less than is predicted by the other model approaches.

- Constraints on the system, such as the fixed employment pool. While the increase in wage rates contributes to GDP and RGDNI, competition for labour constrains the ability of industries to grow, and any sectors that do grow do so at the expense of other sectors.

- The inclusion of carbon prices, which result in a constraint on agricultural production that is not present in the other model approaches. The carbon price also represents a transfer outside the country, which partly explains why RGDNI in is proportionately much less than the change in GDP.

5 Discussion

The results show a potentially significant impact on the pastoral sector and the economy as a whole from the introduction of cisgenic cultivars. While this analysis does not take into account any externalities, it does show that:

- The introduction of cultivars similar in characteristic to those modelled here would represent a net positive gain to the pastoral sector and the economy as a whole (before externalities), regardless of the modelling approach taken.

- The size of the positive impact can be explained by the relatively low cost of the technology, the ready pathway to adoption through the existing seed supply network, and the low marginal cost for farmers of using the technology (since it can be incorporated within the existing regrassing programme).

- The size of the benefit is constrained by key factors such as adoption, the attenuation of new cultivars in a pasture situation, and the rate of regrassing. Changes to any of these will have significant impact on the final result.

- Rates of regrassing in particular will have a major impact on the final outcomes. If the rate of regrassing were to increase to 10% (so that all paddocks were regrassed on a 10 year rotation), the national impacts of the cultivars would more than double. This outcome is potentially possible if the cultivars were shown to have a major impact on production systems, which would encourage greater rates of regrassing.

- There are some environmental impacts associated with the cisgenic cultivars. In the case of the N efficient/WSC cultivar there is some potential for a small reduction in nitrate losses, although the extent of this has not been calculated. With the other cultivars there is likely to be an increase in both nitrate losses and greenhouse gas emissions associated with the increased intensity of production. In the case of the higher adoption and more productive cultivars, these increases and associated environmental externalities could be significant.

- The modelling approaches all produce different results. It is likely that the assumptions used for each approach are right and wrong to varying degrees. The cashflow analysis shows a NPV of between $-1 million and $600 million, depending on the cultivar and adoption rate. This demonstrates a likely positive welfare change from the introduction of the cisgenic cultivars and that the probability of success of any one cultivar does not have to be high for the overall outcome to be positive. The IO modelling and CGE modelling suggests annual impacts on national GDP in the order of $0.4 billion to $1.8 billion in the highest adoption scenario. However the CGE modelling suggests that there are price and employment constraints that will limit the degree to which the benefits are able to be captured in New Zealand. The degree to which the various closure assumptions in the CGE model are exhibited in real life cannot be determined, and it is likely that the true answer regarding the impact on the wider national economy will lie somewhere between the extremes of the CGE and IO models. In either case the annual impact is likely to be significant and ongoing.

- The comparative CGE modelling shows that there are significant differences in economic impacts between the situation where there are agricultural sector productivity gains in New Zealand but not overseas, and where there are productivity gains overseas but not in New Zealand. The differences are in the order of $1 billion in GDP, for a relatively conservative and one off productivity gain. When we know already the magnitude of uptake for some GE crop internationally is 70% - 90%, and when the EU is predicting a significant increase in the number of GE commercially available events from the current 30 to approximately 120 in 2015[29], the implications of precluding access to cisgenic or other productivity enhancing technologies is potentially significant in terms of the national economy.

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[29] Stein, A.J. and Rodriguez-Cerezo, E. 2009. "The global pipeline of new GM crops. Implications of asynchronous approval for international trade" JRC Scientific and Technical Reports, EUR 23486 EN – 2009. European Commission.

6 Annex: Terms and definitions[30]

CGE – Computable General Equilibrium Model
A class of economic models that use actual economic data to estimate how an economy might react to changes in policy, technology or other external factors

Cisgenics
A method of plant breeding that involves the manipulation of the existing genome without introducing foreign genetic material.

Dairy WFM (Whole Farm Model)
A proprietary model of DairyNZ that incorporates modules for climate, pasture production, grazing, animal production and financial outputs.

DT – Drought Tolerance trait

FarmMax
A farm model used for estimating the impact of changes to elements of pastoral farming systems.

Gross Domestic Product (GDP)
The total market value of goods and services produced in New Zealand after deducting the cost of goods and services utilised in the process of production, but before deducting allowances for the consumption of fixed capital.

Input/Output Modelling
This is a type of modelling analysis that establishes the input and output structure (type and origin) of the industries in question (in this case, farming industries).

MBG –More Biomass Growth

MBGDT – combined more biomass and drought tolerance

NPV – Net Present Value
This refers to a method for calculating the total present value (PV) of a time series of cash flows. It is a standard method for using the time value of money to appraise long-term projects. Used for capital budgeting, and widely throughout economics, it measures the excess or shortfall of cash flows, in present value terms, once financing charges are met

Real Gross National Disposable Income (RGDNI)
The total income of New Zealand residents from all sources available for final consumption or savings. In the 1993 SNA this is, more correctly, renamed Net National Disposable Income.

Terms of Trade
The relative prices of a country's exports to imports.

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[30] See www.wikipedia.com for many of these definitions

7 Annex: Pasture modelling assumptions

The More Biomass Growth (MBG) trait is a combination of Greater photosynthetic, water and nutrient use efficiency sufficient to increase pasture yield without additional inputs of irrigation or fertiliser above maintenance requirements. Current knowledge suggests that MBG would require both increased yield potential and resource use efficiency. It is known, for example, that that increasing yield by increased fertiliser use increases water use. The effect was assumed to be not limited by temperature or incident radiation level. Increased biomass growth (MBG_{20}): simulated by increasing the radiation conversion efficiency in the model by 20%. It was assumed that no extra water or nutrients were required to meet this increased growth potential.

The Drought tolerance (DT) trait was represented by increasing the soil water holding capacity by the equivalent of four weeks of summer potential evapotranspiration (119, 124, 111, 113 and 91.3 mm for Northland, Waikato, Taranaki, Canterbury and Southland, respectively). This was only a way to reproduce the effect, at a farm system level, of a pasture that is able to keep growing for 4 weeks longer into a dry period. It was not intended to be a mechanistic representation of the trait, so it does not mean that the plant will actually extract that much more water from the soil. In effect the drought tolerance trait is represented as an ability to extract more water from the soil profile.

The implementation of both traits (MBG and DT) in the model assumed no effects of improved grass performance on clover.

The traits were represented in a simplistic and arguably optimistic manner, while the systems modelling approach considered many system-level implications the caveats outlined above suggest that other effects rippling through the system could offset some of the gains shown here.

The combined MBG_{20} and DT traits were represented by combining the two sets of assumptions in the pasture model.

The initial runs were undertaken for the years 2000-2007 for the 5 regions simulating a simple cutting regime to estimate monthly average growth and variability. The results were used as input for the representation of the traits in the sheep and beef models and parameterise the Dairy WFM.

The NIWA climatological stations used for the simulations were located at:

- Northland: Dargaville
- Waikato: Ruakura
- Taranaki: Stratford
- Canterbury: Lincoln University
- Southland: Gore

Table 25: NORTHLAND Effect of the cisgenic traits on daily growth (kg DM/ha/day) (average 2000-2007).

Month	Baseline	MBG = 20%	DT	MBG_{20} plus DT
1	48.0	63.2	73.9	101.7
2	44.3	57.6	60.9	93.0
3	34.5	45.6	52.0	77.1
4	35.2	45.2	47.1	62.1
5	31.6	41.4	30.4	39.5
6	26.2	34.7	24.0	30.9
7	28.5	36.8	24.7	32.5
8	41.6	51.4	36.4	45.6
9	55.0	68.3	50.1	62.7
10	60.2	75.5	60.3	76.6
11	70.3	88.3	73.4	93.0
12	61.3	77.8	77.9	99.2

Table 26: WAIKATO Effect of the cisgenic traits on daily growth (kg DM/ha/day) (average 2000-2007).

Month	Baseline	MBG = 20%	DT	MBG_{20} plus DT
1	67.4	86.4	73.9	101.8
2	50.0	64.1	60.9	93.0
3	44.8	57.9	52.0	77.1
4	45.4	57.2	47.1	62.1
5	30.0	39.1	30.4	39.4
6	23.5	30.7	24.0	30.9
7	24.8	32.1	24.7	32.5
8	36.1	45.1	36.4	45.6
9	50.0	61.9	50.1	62.7
10	60.7	75.9	60.3	76.6
11	72.6	90.7	73.4	93.0
12	72.9	91.7	77.9	99.3

Table 27: TARANAKI Effect of the cisgenic traits on daily growth (kg DM/ha/day) (average 2000-2007)

Month	Baseline	MBG = 20%	DT	MBG_{20} plus DT
1	81.1	101.3	83.6	102.4
2	65.5	82.4	72.2	90.8
3	51.5	65.9	56.1	76.5
4	44.4	55.6	44.9	62.9
5	28.6	37.3	28.2	40.5
6	20.0	26.5	20.2	31.2
7	22.2	28.4	21.9	32.4
8	32.4	40.3	32.8	46.6
9	45.1	55.6	44.7	62.8
10	54.2	67.6	54.4	76.7
11	71.4	88.3	72.5	94.8
12	78.7	97.8	80.8	102.9

Table 28: EAST COAST NI DRYLAND Effect of the cisgenic traits on daily growth (kg DM/ha/day) (average 2000-2007)

Month	Baseline	MBG = 20%	DT	MBG_{20} plus DT
1	38	47	52.4	64.8
2	40.2	48.2	50.8	61.3
3	32.8	41.1	41.4	50.9
4	33	43	38.8	49.7
5	31.2	41	31.6	41.4
6	27.6	35.1	26.7	34.2
7	31.1	38.3	29.9	37.1
8	43.5	53.1	42.2	51.6
9	56.1	68.6	54.4	66.7
10	75.5	91.9	73.7	90.2
11	70.7	86.4	75.6	92.9
12	56.2	68.8	65	79.3

Table 29: CANTERBURY IRRIGATED Effect of the cisgenic traits on daily growth (kg DM/ha/day) (average 2000-2007)

Month	Baseline	MBG = 20%	DT	MBG_{20} plus DT
1	67.2	85.0	75.4	97.0
2	63.6	80.2	72.6	92.0
3	50.4	59.5	55.7	71.3
4	38.6	44.0	40.9	51.9
5	24.4	31.0	24.9	33.0
6	16.9	21.6	17.6	23.1
7	17.3	22.3	17.5	23.2
8	26.7	33.4	26.6	34.4
9	44.9	55.1	44.5	55.6
10	59.2	73.2	58.2	74.0
11	74.3	91.9	75.4	94.6
12	76.9	95.5	82.1	103.8

Table 30: CANTERBURY DRYLAND: Effect of the cisgenic traits on daily growth (kg DM/ha/day) (average 2000-2007)

Month	Baseline	MBG = 20%	DT	MBG_{20} plus DT
1	34.6	43.0	37.5	47.7
2	31.9	37.7	37.0	45.2
3	25.5	30.1	30.2	37.2
4	23.6	29.3	24.6	32.5
5	17.1	24.5	16.7	25.4
6	20.4	25.7	19.9	26.0
7	24.8	29.8	24.1	29.7
8	32.8	39.7	31.7	39.5
9	40.0	48.3	38.3	47.5
10	63.9	75.9	60.8	74.5
11	66.3	81.4	64.2	78.7
12	46.9	56.8	47.9	58.7

Table 31: SOUTHLAND: Effect of the cisgenic traits on daily growth (kg DM/ha/day) (average 2000-2007).

Month	Baseline	MBG = 20%	DT	MBG_{20} plus DT
1	72.5	90.7	76.8	97.6
2	65.6	81.5	68.2	85.7
3	48.3	60.9	48.9	62.6
4	31.5	40.2	31.6	40.7
5	20.6	26.6	20.3	26.8
6	13.8	18.1	13.7	18.3
7	14.6	18.5	14.5	18.8
8	20.9	26.4	20.8	26.8
9	37.4	46.5	37.4	47.1
10	50.2	62.4	50.2	63.5
11	60.3	75.1	60.5	76.4
12	72.5	90.2	74.8	94.0

8 Annex: Dairy WFM assumptions

8.1 Process

To compare these traits, the climate and prices for season 2006-07 were used for the Whole Farm Model simulations; the following sequence was followed for each site:

- Set up baseline farms in the WFM imitating average farms from DairyBase for each region (season 2006-07). Farms were chosen with no more than 10% of the diets as imported feed.
- Run the baseline farm over a range of stocking rates.
- Run the model over a range of stocking rates for a farm with trait MBG_{20} grass
- Run the model over a range of stocking rates for a farm with trait DT grass
- Run the model over a range of stocking rates for a farm with trait MBG_{20}+DT grass
- Compare the responses in terms of production and economics.

The comparisons were done between the baseline and the steady state situation of farms already fully covered with the new cultivars.

8.2 Economic inputs

Prices for the season 2006-07 were used in the simulation, with milk payout of $4.14.These were subsequently adjusted to the 2006 – 2008 average No costs were assumed to change as a direct consequence of the traits, except in the case of irrigation cost in Canterbury. In that case, the DT trait allowed a reduction in the amount of irrigation water required, so the cost was reduced proportionally. Notice, however, that those costs presented on a per-cow basis changed with stocking rate; therefore the total costs of the farm did increase with stocking rate.
Support blocks for dry stock were simulated in Canterbury (on pastures) and Southland (kale in winter), block size varied proportionally as stocking rate on the milking platform increased. Replacements were bought in all scenarios (i.e. no young stock was raised on the farm; grazing costs refer only to cows wintered off).

The economic analysis was steady state and does not consider transitional costs/risks or issues that are known to be important in adoption.

Table 32: Economic input data used for the simulations, season 2006-07. Subsequently adjusted to 2006 - 2008 average.

Per cow costs ($/cow) (i.e. total cost alter with stocking rate)	**Cost**	**Supplements (driven by feed flow)**	**Cost**
Wages	152	Grass silage ($/t)	223.5
Unpaid Labour	142	Maize silage ($/t)	269.8
Farm Dairy	18	Grazing-off ($/cow/week)	19.6
Electricity	28		
Animal health	59		
Breeding and herd improvement	37		
Costs per ha ($/ha) (i.e. total cost is fixed)		**Overheads ($/ha) (i.e. total cost is fixed)**	
Weed and pest control	31	Administration	95
Regrassing ($/ha)[1]	35	Insurance	36
Vehicle fuel	158	ACC	32
Repair and maintenance	249	Rates	69
Freight expenses	47		
Fertilization and irrigation costs		**Adjustments**	
Urea ($/t) –N amount changed with the site, but not with SR	580	Except depreciation, all calculations depend on simulation results and are affected by stocking rate.	
Potash Super ($/t) - Driven by outputs[2], alter with stocking rate	356		
Fertilizer spreading ($/ha). Changed with the site, but not with SR	8		
Irrigation ($/ha)[3] Only for Canterbury, fixed	319		

[1] Becomes $55/ha with brassica crop on proportion of the farm.

[2] Maintenance fertilizer: 0.8 kg Potash Super / kg MS.

[3] Includes electricity, repairs and maintenance.

8.3 Farm Systems

The baseline farms are described in Table 33, along with simulation results for season 2006-07. Notice that, to calibrate the model to the observed data, the pasture model parameters were modified from the defaults used in the preliminary runs. Therefore the simulated pasture yields in Table 33 differed from those from the preliminary runs. The utilization regimes were also different, e.g. cutting to 1500 kg DM when reaching 3000 kg DM of pasture cover in the preliminary runs (optimum for pasture growth) was replaced by realistic grazing regimes at farm level.

Environmental issues associated with farm intensification associated with increased pasture growth were not considered.

Table 33: Description of the baseline farms inputs and simulation outputs for season 2006-07 (simulated with WFM).

Characteristic	Northland	Waikato	Taranaki	Canterbury	Southland
Inputs					
Stocking rate (cow/ha)	2.22	3.38	2.74	3.47	2.89
Breed	Jersey	Crossbred	Crossbred	Friesian	Friesian
Initial average live weight (kg)	435±58	483±71	483±72	481±80	475±69
Milking frequency	Twice a day	Twice a day	Twice a day	Twice a day	Twice a day
Grazing-off	1/Jun – 20/Jun	none	15/Jun-calving	1/Jun – calving	1/Jun – calving
Support block (% of total area farmed)	no	no	no	yes	yes
Initial farm cover (kg DM/ha)	2000	1700	1700	Platform: 1700 /Support: 1950	Platform: 1700 /Support: 1950
N fertilizer (kg/ha)	100	230	200	Platform: 200 /Support: 200	Platform: 100 /Support: 117
Initial grass silage stack (kg DM/cow)	102	612	612	204	979
Other supplements initial stack (t DM/cow)	-	282	327	361	110
Irrigation	no	no	no	Platform	no
Model outputs (WFM)					
Start calving	15/Jul	14/Jul	6/Aug	1/Aug	3/Aug
Pasture yield (kg DM/ha)	11464	16266	14302	Platform: 14901 /Support: 12978[311]	Platform: 12302 /Support: 14551
Days in milk (cows over 100 days)	277	271	272	260	260

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[31] It does not include crops

9 Annex: Assumptions for sheep and beef farm modelling[32]

- This analysis used Farmax files based on the 2006/07 MAF Farm monitor farms whereby the economic outputs were recreated from the supplied and assumed performance data
- Three genetic improvements in pasture growth were included in the analysis, an increase in biomass (+BM), an increase in drought tolerance (+DT) or both combined (+BMDT)
- The genetic improvement in pasture growth occurred without any increase in water, N or fertiliser requirements
- Genetic improvement in pasture growth was calculated using percentage changes generated from the pasture growth model (see Table 34, Table 35 and Table 36) and these were applied only to areas of the farm that could be regrassed
- Two varying proportions of the farm undergoing regrassing were evaluated. Namely an existing regrassed area and an assumed potentially possible area that could be regrassed using cultivation or oversowing (Table 2). It was assumed that these levels of regressing were in equilibrium and not in a building up phase.
- The existing area of regrassed pasture for each farm type was assumed to be the current area of crop (assumed from MAF reports costs of cropping) multiplied by 10 years (assumed rate of renewal). The potential area of the farms were assumed and the area actually regrassed each year was this area divided by 10 and when subtracted from the current area regrassed each year gave the additional area requiring regrassing each year to achieve potential level of regrassed pastures (Table 2)
- It was assumed that the regrassed area had higher pasture growth rates due to better contour than the non regrassed area (Table 3). On the base farm the overall farm annual DM production was fixed under both existing and potential pasture renewal programmes. On the intensive farms with 80% potentially regrassable pastures the pasture growth rates were assumed to be the same on both regrassed and non regrassed areas of the farm.
- Currently farmers regrass following crops (wheat, oats, pasja etc) and this crop area remained the same in all analysis and genetically improved grass was sown after cropping.
- Because we didn't want to confound the analysis with the benefits associated with growing a crop the additional regrassing required to achieve potential areas of regrassed pastured was achieved via direct drilling grass to grass via a 2 month fallow period.
- All regrassing costs were assumed to be $600 per ha.
- It was assumed that there would be no greater weed and pest problems
- It is assumed that there was no change in quality of pasture and therefore animal performance remained the same
- Additional feed generated by genetic improvement in forage was used to run additional animals at the same performance level using Farmax's modify animal numbers option

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[32] References: Litherland A.J, Snow V., Dynes, R., 2005. Decision Support Software and Computer Models to Assist in Feed Allocation and Utilisation in the New Zealand Pastoral Sheep and Beef Industries. A report for Meat and Wool New Zealand.
Marshall, P.R., McCall, D.G. and Johns, K.L., 1991. Stockpol: a decision support model for livestock farms. Proceedings of the New Zealand Grassland Association. 53, 137-140.

- Where the new genetic forage generates a surplus in feed supply and this could be economically captured through making additional supplements (hay or silage) these were made at the optimum time to address feed surpluses and were then fed out in winter or early spring to further support higher stock numbers
- As such some of the economic benefits of the genetically improved pasture are due to an improvement in utilisation of feed.
- The average carcass price for sheep is assumed to be \$4.70/kg CW, bulls \$3.50 and prime steers (\$3.60/kgCW). This was subsequently adjusted to the average for the price series from 2006 – 2008.

Table 34: Proportionate adjustment to base pasture growth for different months for pasture genetically modified for improved biomass (+BM), drought tolerance (+DT) or in combination (+BMDT) for various sheep and beef farm types.

Month	Southland Otago Intensive			Southland and Otago Hill Country			South Island High Country Merino			Otago Dry Hill Country		
	MBG	DT	MBGDT	MBG	DT	MBGDT	MBG	DT	MBGDT	MBG	DT	MBGDT
July	0.274	-0.008	0.287	0.274	-0.008	0.287	0.274	-0.008	0.287	0.274	-0.008	0.287
Aug	0.277	-0.003	0.282	0.277	-0.003	0.282	0.277	-0.003	0.282	0.277	-0.003	0.282
Sep	0.248	-0.001	0.258	0.248	-0.001	0.258	0.248	-0.001	0.258	0.248	-0.001	0.258
Oct	0.252	0.001	0.266	0.252	0.001	0.266	0.252	0.001	0.266	0.252	0.001	0.266
Nov	0.255	0.003	0.266	0.255	0.003	0.266	0.255	0.003	0.266	0.255	0.003	0.266
Dec	0.250	0.031	0.296	0.250	0.031	0.296	0.250	0.031	0.296	0.250	0.031	0.296
Jan	0.259	0.059	0.345	0.259	0.059	0.345	0.259	0.059	0.345	0.259	0.059	0.345
Feb	0.251	0.040	0.307	0.251	0.040	0.307	0.251	0.040	0.307	0.251	0.040	0.307
Mar	0.272	0.012	0.296	0.272	0.012	0.296	0.272	0.012	0.296	0.272	0.012	0.296
Apr	0.286	0.002	0.291	0.286	0.002	0.291	0.286	0.002	0.291	0.286	0.002	0.291
May	0.308	-0.011	0.301	0.308	-0.011	0.301	0.308	-0.011	0.301	0.308	-0.011	0.301
Jun	0.315	-0.002	0.331	0.315	-0.002	0.331	0.315	-0.002	0.331	0.315	-0.002	0.331

Table 35: Proportionate adjustment to base pasture growth for different months for pasture genetically modified for improved biomass (+BM), drought tolerance (+DT) or in combination (+BMDT) for various sheep and beef farm types.

Month	Canterbury Marlborough dry hill country			Hawkes Bay Wairarapa Finishing and Breeding			Eastern North Island			Gisborne Hill Country		
	MBG	DT	MBGDT	MBG	DT	MBGDT	MBG	DT	MBGDT	MBG	DT	MBGDT
July	0.302	0.014	0.341	0.232	-0.039	0.193	0.232	-0.039	0.193	0.232	-0.039	0.193
Aug	0.268	-0.001	0.292	0.221	-0.030	0.186	0.221	-0.030	0.186	0.221	-0.030	0.186
Sep	0.239	-0.010	0.237	0.223	-0.030	0.189	0.223	-0.030	0.189	0.223	-0.030	0.189
Oct	0.249	-0.016	0.251	0.217	-0.024	0.195	0.217	-0.024	0.195	0.217	-0.024	0.195
Nov	0.252	0.015	0.272	0.222	0.069	0.314	0.222	0.069	0.314	0.222	0.069	0.314
Dec	0.257	0.068	0.350	0.224	0.157	0.411	0.224	0.157	0.411	0.224	0.157	0.411
Jan	0.280	0.122	0.444	0.237	0.379	0.705	0.237	0.379	0.705	0.237	0.379	0.705
Feb	0.269	0.141	0.445	0.199	0.264	0.525	0.199	0.264	0.525	0.199	0.264	0.525
Mar	0.282	0.106	0.415	0.253	0.262	0.552	0.253	0.262	0.552	0.253	0.262	0.552
Apr	0.252	0.058	0.343	0.303	0.176	0.506	0.303	0.176	0.506	0.303	0.176	0.506
May	0.294	0.021	0.352	0.314	0.013	0.327	0.314	0.013	0.327	0.314	0.013	0.327
Jun	0.313	0.040	0.367	0.272	-0.033	0.239	0.272	-0.033	0.239	0.272	-0.033	0.239

Table 36: Proportionate adjustment to base pasture growth for different months for pasture genetically modified for improved biomass (+BM), drought tolerance (+DT) or in combination (+BMDT) for various sheep and beef farm types.

Month	Central North Island Hill Country			Western North Island Hill Country			Waikato Bay of Plenty Intensive			Northland		
	+BM	+DT	+DTBM	+BM	+DT	+DTBM	+BM	+DT	+DTBM	+BM	+DT	+DTBM
July	0.288	-0.013	0.459	0.288	-0.013	0.459	0.303	-0.005	0.311	0.305	-0.134	0.140
Aug	0.251	0.012	0.441	0.251	0.012	0.441	0.256	0.007	0.262	0.244	-0.125	0.096
Sep	0.245	-0.011	0.391	0.245	-0.011	0.391	0.248	0.002	0.254	0.247	-0.089	0.140
Oct	0.253	0.004	0.416	0.253	0.004	0.416	0.259	-0.007	0.262	0.263	0.002	0.273
Nov	0.245	0.016	0.327	0.245	0.016	0.327	0.257	0.010	0.280	0.265	0.043	0.323
Dec	0.248	0.026	0.308	0.248	0.026	0.308	0.266	0.069	0.361	0.279	0.271	0.619
Jan	0.259	0.031	0.263	0.259	0.031	0.263	0.289	0.096	0.509	0.330	0.540	1.121
Feb	0.266	0.102	0.387	0.266	0.102	0.387	0.290	0.219	0.861	0.307	0.376	1.101
Mar	0.286	0.089	0.485	0.286	0.089	0.485	0.307	0.161	0.721	0.335	0.505	1.232
Apr	0.261	0.012	0.416	0.261	0.012	0.416	0.269	0.037	0.369	0.292	0.337	0.764
May	0.315	-0.012	0.416	0.315	-0.012	0.416	0.318	0.013	0.317	0.322	-0.040	0.248
Jun	0.333	0.007	0.558	0.333	0.007	0.558	0.320	0.022	0.315	0.336	-0.084	0.178

Table 37: Annual dry matter production for various types of sheep and beef farms on base farm as whole farm average and on non regrassed areas of the farm assuming potential or current areas undergoing regrassing.

Sheep and beef farm types	Annual dry matter production (kgDM/ha)						
	Overall Base farm	Non regrassed area		Regrassed area			
		Potential	Current	Base	+BM	+DT	+BMDT
Canterbury Marlborough dry hill country	3440	2100	3100	6500	8180	6730	8550
Canterbury Marlborough finishing and breeding	8150	8150	8150	8150	10290	8470	10780
Central North Island Hill Country	7090	6485	6690	9500	11964	9700	13060
Eastern Lower North Island Intensive	8450	8450	8450	8450	10450	9350	11560
Gisborne Hill Country	6190	5200	6040	8500	10500	9280	11480
Hawkes Bay Wairarapa Hill Country	6590	5800	6350	8430	10420	9080	11240
Northland sheep and beef	8140	4970	8040	9500	12220	10815	14340
Otago Dry Hill Country	3132	2540	2910	6500	8170	6605	8360
South Island High Country Merino	1177	585	990	6500	8170	6680	8450
Southland and Otago Hill Country	6610	5380	6280	8460	10650	8605	10910
Southland Otago Intensive	12710	12710	12710	12706	16010	12900	16400
Waikato Bay of Plenty Intensive	8150	8150	8150	8150	10500	8550	11420
Western Lower North Island	8200	5150	6470	9500	12000	9710	13100

Table 38: Sheep and Beef per model outcomes – properties regrassing at 10 yearly interval ($/ha/annum)

Model	**Item**	**Base**	**More Biomass**	**Drought Tolerance**	**Drought tolerance and biomass**
Otago intensive	**Area**	194	194	194	194
	su/ha	17.6	19.2	17.7	19.4
	Revenue ($/ha/annum)	$1,230	$1,353	$1,246	$1,364
	Working expenses ($/ha/annum)	$198	$252	$204	$255
	Operating profit ($/ha/annum)	$1,033	$1,101	$1,042	$1,109
Otago Southland Hill	**Area**	723	723	723	723
	su/ha	9.6	10.1	9.6	10.1
	Revenue ($/ha/annum)	$642	$673	$643	$675
	Working expenses ($/ha/annum)	$119	$132	$121	$133
	Operating profit ($/ha/annum)	$523	$541	$522	$542
Hawkes Bay Wairarapa Hill	**Area**	623.8	623.8	623.8	623.8
	su/ha	10.0	10.4	10.3	10.7
	Revenue ($/ha/annum)	$553	$578	$569	$593
	Working expenses ($/ha/annum)	$143	$155	$152	$161
	Operating profit ($/ha/annum)	$410	$423	$417	$431
South Island Merino	**Area**	10507	10507	10507	10507
	su/ha	0.9	1.0	0.9	1.0
	Revenue ($/ha/annum)	$53	$58	$54	$59
	Working expenses ($/ha/annum)	$19	$21	$19	$22
	Operating profit ($/ha/annum)	$34	$37	$34	$37
Canterbury Marlborough Finishing Breeding	**Area**	378	378	378	378
	su/ha	11.7	12.7	12.1	12.8
	Revenue ($/ha/annum)	$744	$806	$771	$817
	Working expenses ($/ha/annum)	$111	$129	$117	$133
	Operating profit ($/ha/annum)	$633	$676	$655	$684
Canterbury Marlborough Hill	**Area**	1397	1397	1397	1397
	su/ha	4.2	4.5	4.2	4.3
	Revenue ($/ha/annum)	$212	$224	$215	$217
	Working expenses ($/ha/annum)	$46	$53	$47	$40
	Operating profit ($/ha/annum)	$166	$171	$168	$177
Central NI	**Area**	635	635	635	635
	su/ha	10.0	10.3	10.0	10.4
	Revenue ($/ha/annum)	$538	$554	$540	$562
	Working expenses ($/ha/annum)	$72	$77	$72	$80
	Operating profit ($/ha/annum)	$466	$477	$467	$483
Gisborne	**Area**	821	821	821	821
	su/ha	9.0	9.3	9.1	9.4
	Revenue ($/ha/annum)	$491	$508	$497	$515
	Working expenses ($/ha/annum)	$46	$51	$47	$53
	Operating profit ($/ha/annum)	$445	$457	$450	$462
Northland	**Area**	326	326	326	326
	su/ha	10.9	11.7	11.6	13.2
	Revenue ($/ha/annum)	$729	$778	$770	$890
	Working expenses ($/ha/annum)	$71	$83	$82	$123
	Operating profit ($/ha/annum)	$658	$695	$688	$767
Waikato BOP Int	**Area**	250	250	250	250
	su/ha	12.0	13.1	12.3	13.7
	Revenue ($/ha/annum)	$978	$1,061	$999	$1,101
	Working expenses ($/ha/annum)	$140	$158	$144	$163

Model	**Item**	**Base**	**More Biomass**	**Drought Tolerance**	**Drought tolerance and biomass**
	Operating profit ($/ha/annum)	$839	$904	$855	$938
West NI	**Area**	208	208	208	208
	su/ha	12.1	13.2	12.2	13.6
	Revenue ($/ha/annum)	$916	$993	$923	$1,029
	Working expenses ($/ha/annum)	$113	$132	$115	$141
	Operating profit ($/ha/annum)	$803	$861	$808	$888
East NI	**Area**	347	347	347	347
	su/ha	12.2	13.4	12.9	14.0
	Revenue ($/ha/annum)	$826	$903	$874	$944
	Working expenses ($/ha/annum)	$132	$154	$146	$166
	Operating profit ($/ha/annum)	$693	$749	$727	$778
Otago Dry Hill	**Area**	2000	2000	2000	2000
	su/ha	3.5	3.7	3.6	3.7
	Revenue ($/ha/annum)	$232	$248	$240	$245
	Working expenses ($/ha/annum)	$41	$47	$44	$47
	Operating profit ($/ha/annum)	$192	$201	$195	$198

10 Annex: Detailed tables of results

Table 39: Cashflow summary for 50% adoption

Adoption rate	50%																				
Attenuation	40%																				
Lag time for bulk up (years)	5																				
Adoption phase in (linear)	10																				
			Year																		
		NPV	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027 onward**
Costs																					
Research	FRST		$2.834	$3.437	$3.437	$3.437	$3.437	$3.437													
	Agritech Clover Ltd (MWNZ)		$0.635	$0.826	$0.826	$0.826	$0.826	$0.826													
	Vialactia		$0.635	$0.826	$0.826	$0.826	$0.826	$0.826													
	InSight Genomics		$0.854	$1.110	$1.110	$1.110	$1.110	$1.110													
	AgResearch Ltd		$0.058	$0.750	$0.750	$0.750	$0.750	$0.750													
	DeerResearch PG		$0.034	$0.440	$0.440	$0.440	$0.440	$0.440													
	Total		$5.050	$7.389	$7.389	$7.389	$7.389	$7.389													
	Total for ryegrass cisgenics	**$16.00**	$2.525	$3.695	$3.695	$3.695	$3.695	$3.695													
Proof of concept trialing	Overseas (Florida, then Australia or Chile)	**$0.59**	0.18	0.18	0.18	0.18															
	New Zealand	**$0.45**			0.25	0.25															
Cultivar testing (monitoring)		**$0.17**					0.05	0.05	0.05	0.05											
Monitoring bulking up and release		**$0.13**									0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	
			Initial application cultivar 1		Application cultivar 2	Application cultivar 3	Application for wider release cultivar 1	Application cultivar 4	Application for wider release cultivar 2	Application for wider release cultivar 3		Application for wider release cultivar 4									
Application process	Pastoral Genomics	**$0.89**	0.67		0.05	0.05	0.05	0.05	0.05	0.05		0.05	0.05								
	ERMA	**$0.10**	0.11																		
Net Costs		**$18.32**	**$3.48**	**$3.87**	**$4.17**	**$4.17**	**$3.79**	**$3.79**	**$0.10**	**$0.10**	**$0.02**	**$0.07**	**$0.07**	**$0.02**	**$0.02**	**$0.02**	**$0.02**	**$0.02**	**$0.02**	**$0.02**	**$0.00**

Returns

			Year																									
		NPV	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
Cultivar 1: Drought tolerance only																													
	Maximum annual		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	100%	100%	100%	100%	100%	100%	100%
Dairy	$29.97	**$117.77**	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$3.00	$5.99	$8.99	$11.99	$14.99	$17.98	$20.98	$23.98	$26.97	$29.97	$29.97	$29.97	$29.97	$29.97	$29.97	$29.97	$29.97
Sheep and Beef	-$0.23	**($0.88)**	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	-$0.02	-$0.05	-$0.07	-$0.09	-$0.11	-$0.14	-$0.16	-$0.18	-$0.20	-$0.23	-$0.23	-$0.23	-$0.23	-$0.23	-$0.23	-$0.23	-$0.23
Deer	$1.33	**$5.22**	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.13	$0.27	$0.40	$0.53	$0.66	$0.80	$0.93	$1.06	$1.19	$1.33	$1.33	$1.33	$1.33	$1.33	$1.33	$1.33	$1.33
Total	**$31.07**	**$122.10**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$3.11**	**$6.21**	**$9.32**	**$12.43**	**$15.54**	**$18.64**	**$21.75**	**$24.86**	**$27.97**	**$31.07**	**$31.07**	**$31.07**	**$31.07**	**$31.07**	**$31.07**	**$31.07**	**$31.07**
Cultivar 2: MBG Only																													
	Maximum annual		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	100%	100%	100%	100%	100%
Dairy	$94.97	**$316.32**	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$9.50	$18.99	$28.49	$37.99	$47.48	$56.98	$66.48	$75.98	$85.47	$94.97	$94.97	$94.97	$94.97	$94.97	$94.97
Sheep and Beef	$12.66	**$42.15**	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$1.27	$2.53	$3.80	$5.06	$6.33	$7.59	$8.86	$10.12	$11.39	$12.66	$12.66	$12.66	$12.66	$12.66	$12.66
Deer	$2.73	**$9.10**	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.27	$0.55	$0.82	$1.09	$1.37	$1.64	$1.91	$2.18	$2.46	$2.73	$2.73	$2.73	$2.73	$2.73	$2.73
Total	**$110.36**	**$367.57**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$11.04**	**$22.07**	**$33.11**	**$44.14**	**$55.18**	**$66.21**	**$77.25**	**$88.28**	**$99.32**	**$110.36**	**$110.36**	**$110.36**	**$110.36**	**$110.36**	**$110.36**
Cultivar 2: N efficiency/Water soluble carbohydrates																													
	Maximum annual		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	100%	100%	100%	100%
Dairy	$7.46	**$22.85**	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.75	$1.49	$2.24	$2.98	$3.73	$4.47	$5.22	$5.96	$6.71	$7.46	$7.46	$7.46	$7.46	$7.46
Sheep and Beef	$6.41	**$19.64**	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.64	$1.28	$1.92	$2.56	$3.20	$3.85	$4.49	$5.13	$5.77	$6.41	$6.41	$6.41	$6.41	$6.41
Deer	$0.22	**$0.69**	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.02	$0.04	$0.07	$0.09	$0.11	$0.13	$0.16	$0.18	$0.20	$0.22	$0.22	$0.22	$0.22	$0.22
Total	**$14.09**	**$43.17**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$1.41**	**$2.82**	**$4.23**	**$5.64**	**$7.04**	**$8.45**	**$9.86**	**$11.27**	**$12.68**	**$14.09**	**$14.09**	**$14.09**	**$14.09**	**$14.09**
Cultivar 4: All traits																													
	Maximum annual	**NPV**	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	100%	100%
Dairy	$132.96	**$344.25**	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$13.30	$26.59	$39.89	$53.18	$66.48	$79.78	$93.07	$106.37	$119.66	$132.96	$132.96	$132.96
Sheep and Beef	$17.55	**$45.43**	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$1.75	$3.51	$5.26	$7.02	$8.77	$10.53	$12.28	$14.04	$15.79	$17.55	$17.55	$17.55
Deer	$3.04	**$7.86**	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.30	$0.61	$0.91	$1.22	$1.52	$1.82	$2.13	$2.43	$2.73	$3.04	$3.04	$3.04
Total	**$153.54**	**$397.54**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$15.35**	**$30.71**	**$46.06**	**$61.42**	**$76.77**	**$92.13**	**$107.48**	**$122.83**	**$138.19**	**$153.54**	**$153.54**	**$153.54**
Net benefits - costs																													
			Year																										
		NPV	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
Cultivar	**Drought tolerance**	**$103.77**	($3.48)	($3.87)	($4.17)	($4.17)	($3.79)	($3.79)	($0.10)	($0.10)	($0.02)	($0.07)	$3.04	$6.19	$9.30	$12.41	$15.52	$18.62	$21.73	$24.84	$27.97	$31.07	$31.07	$31.07	$31.07	$31.07	$31.07	$31.07	$31.07
	More Biomass	**$349.25**	($3.48)	($3.87)	($4.17)	($4.17)	($3.79)	($3.79)	($0.10)	($0.10)	($0.02)	($0.07)	($0.07)	($0.02)	$11.02	$22.05	$33.09	$44.12	$55.16	$66.19	$77.25	$88.28	$99.32	$110.36	$110.36	$110.36	$110.36	$110.36	$110.36
	Nitrogen efficiency/ Water soluble carbohydrates	**$24.85**	($3.48)	($3.87)	($4.17)	($4.17)	($3.79)	($3.79)	($0.10)	($0.10)	($0.02)	($0.07)	($0.07)	($0.02)	($0.02)	$1.39	$2.80	$4.21	$5.62	$7.02	$8.45	$9.86	$11.27	$12.68	$14.09	$14.09	$14.09	$14.09	$14.09
	All traits	**$379.22**	($3.48)	($3.87)	($4.17)	($4.17)	($3.79)	($3.79)	($0.10)	($0.10)	($0.02)	($0.07)	($0.07)	($0.02)	($0.02)	($0.02)	($0.02)	$15.33	$30.69	$46.04	$61.42	$76.77	$92.13	$107.48	$122.83	$138.19	$153.54	$153.54	$153.54

Table 40: Detailed IO models outcomes, ($ million per annum, FTEs)

20% Adoption		**MBG compared to Base**					**DT compared to Base**					**MBGDT compared to Base**			
		Output ($million/ annum)	***Employment (FTE)***	***Value added ($million/ annum)***	***Gross Household Income ($million/annum)***		***Output ($million/ annum)***	***Employment (FTE)***	***Value added ($million/annum)***	***Gross Household Income ($million/annum)***		***Output ($million/ annum)***	***Employment (FTE)***	***Value added ($million/ annum)***	***Gross Household Income ($million/annum)***
Direct	Dairy	$82	205	$63	$13		$17	37	$17	$2		$99	238	$82	$15
	Sheep & Beef	$24	57	$11	$2		$10	22	$2	$1		$29	67	$14	$2
	Deer	$2	15	$1	$0		$1	10	$1	$0		$2	15	$2	$0
	Combined	$108	278	$75	$15		$27	69	$20	$3		$130	320	$97	$18
Total	Dairy	$485	1,179	$262	$71		$96	172	$53	$12		$576	1,288	$315	$79
	Sheep & Beef	$132	583	$49	$28		$58	275	$20	$13		$157	686	$59	$33
	Deer	$8	44	$4	$2		$3	21	$2	$1		$10	48	$4	$2
	Combined	$625	1,806	$315	$100		$157	468	$75	$25		$743	2,023	$378	$114
50% Adoption		**MBG compared to Base**					**DT compared to Base**					**MBGDT compared to Base**			
		Output ($million/annum)	***Employment (FTE)***	***Value added ($million/ annum)***	***Gross Household Income ($million/annum)***		***Output ($million/ annum)***	***Employment (FTE)***	***Value added($million/annum)***	***Gross Household Income ($million/annum)***		***Output ($million/ annum)***	***Employment (FTE)***	***Value added ($million/ annum)***	***Gross Household Income ($million/annum)***
Direct	Dairy	$204	513	$157	$33		$42	92	$41	$6		$246	595	$204	$38
	Sheep & Beef	$61	144	$27	$5		$24	56	$6	$2		$73	168	$35	$6
	Deer	$5	37	$4	$1		$2	25	$2	$1		$5	38	$4	$1
	Combined	$270	694	$188	$39		$68	172	$49	$8		$325	801	$243	$45
Total	Dairy	$1,211	2,947	$655	$176		$240	431	$133	$29		$1,441	3,221	$786	$199
	Sheep & Beef	$330	1,458	$123	$69		$144	687	$50	$32		$393	1,715	$148	$81
	Deer	$21	110	$9	$5		$8	53	$4	$2		$24	121	$10	$5
	Combined	$1,562	4,515	$788	$250		$392	1,171	$187	$63		$1,857	5,057	$945	$285
80% Adoption		**MBG compared to Base**					**DT compared to Base**					**MBGDT compared to Base**			
		Output ($million/an	***Employment (FTE)***	***Value added($mi***	***Gross Household***		***Output ($million/***	***Employment (FTE)***	***Value added($milli***	***Gross Household***		***Output ($million/***	***Employment (FTE)***	***Value added($m***	***Gross Household***

		num)		***llion/annum)***	***Income ($million/annum)***		***annum)***		***on/annum)***	***Income ($million/annum)***		***annum)***		***illion/annum)***	***Income ($million/annum)***
Direct	Dairy	$327	821	$250	$52		$67	147	$66	$9		$394	951	$327	$61
	Sheep & Beef	$98	230	$44	$8		$38	89	$9	$3		$117	269	$56	$9
	Deer	$8	60	$6	$2		$3	39	$3	$1		$9	61	$7	$2
	Combined	$432	1,111	$300	$62		$108	276	$78	$14		$520	1,281	$389	$71
Total	Dairy	$1,938	4,714	$1,049	$282		$385	689	$213	$46		$2,305	5,154	$1,258	$318
	Sheep & Beef	$528	2,333	$198	$110		$230	1,099	$80	$51		$629	2,744	$237	$130
	Deer	$33	176	$15	$7		$13	85	$6	$3		$38	193	$17	$8
	Combined	$2,500	7,224	$1,261	$400		$628	1,873	$299	$100		$2,972	8,091	$1,512	$456

HME Ryegrass

AgResearch

Briefing prepared 24 October 2023.

Results show an increase in lipids of approximately 50%, which can potentially deliver:
- 10-15% decrease in methane production;
- 6% reduction in waste nitrogen in urine that will subsequently reduce nitrogen leaching into waterways;
- 10% reduction in emissions of the greenhouse gas nitrous oxide.

Animal nutrition trials are scheduled to take place in late-2024 and will provide a more definitive dataset. Potential year of first New Zealand field trial: 2029. Potential year of commercialisation: 2031/32.

Summary

High Metabolisable Energy (HME) Ryegrass is being developed as a future option for grazing pastoral farmers in New Zealand and in temperate climates internationally, to help reduce environmental impacts of grazing ruminants while increasing farm efficiency and productivity. HME Ryegrass contains novel genetic modifications that have generated elevated leaf lipids and enhanced photosynthesis efficiencies in ryegrass leaves, thus delivering greater energy in each mouthful eaten by livestock. Under some ideal-type conditions the HME Ryegrass has increased dry matter production when compared to the null controls. The HME plants have a shift in carbon storage from carbohydrate to lipids and altered nitrogen-use efficiency. In a 2019 field trial in the US we demonstrated that the increase in energy content translated from ideal growth conditions in the containment glasshouse to conditions in the field. Using *in vitro* assays we have also demonstrated that both fresh and ensiled HME Ryegrass reduces methane emissions. Altered nitrogen-use efficiency in HME Ryegrass suggested benefits in how the plants respond to different forms of nitrogen. We have recently shown substantial reductions (10%) in nitrous oxide emissions from mesocosms in controlled environment chambers and hypothesise that this is due to a direct influence on microorganisms in the root rhizosphere. Through various mechanisms HME Ryegrass has the potential to contribute to a reduction in on-farm GHG emissions of up to 24% - a 20 year carbon saving (methane and nitrous oxide) of 20,507 kt CO_2e (NZ$6 Billion).

HME description

HME transgenics have co-expression of diacylglycerol acyl-transferase (DGAT) and sesame cysteine-oleosin in photosynthetic tissues, a gene combination designed to increase lipid content. HME Ryegrass has increased levels of lipids stored in the green tissues of the plant in micro organelles (Winichayakul *et al.,* 2013; Roberts *et al.,* 2010, 2011; Beechy-Gradwell *et al.,* 2020a, 2022). These organelles are stable within the leaf and remain during the ensiling process (Winichayakul *et al.,* 2020). The allocation of different forms of carbon (sugars and fat) in different tissue is altered, leading to reduced negative feedback of photosynthesis (Beechy-Gradwell *et al.,* 2020a; Cooney *et al.,* 2020). This results in an increase in the fixation of atmospheric CO_2, and consequential increase in the amount of energy stored within the plant. Increased plant growth rates are affected by competition for light in densely packed sward conditions, and also plant nutrition, especially nitrogen, therefore once the leaf density becomes high enough growth rates are expected to be similar to non-HME plants.

Agrobacterium-derived HME Ryegrass we have shown that we can increase foliar fatty acids by 18-75% compared to non-transgenic controls (Cooney *et al.,* 2000).

Recent changes to the programme

The programme team recently applied to Australia's Office of the Gene Technology Regulator (OGTR) for permission to conduct further field trials in Australia. Through the course of the application process with

OGTR, it emerged that additional detailed analysis would be required on a specific issue for the application to proceed and be successful. The issue relates to the possibility that the sesame oleosin was possibly an allergen, and could be released in the pollen of the ryegrass. While AgResearch's initial analyses demonstrated that sesame cysteine oleosin is not expressed in the pollen of HME Ryegrass, a more rigorous standard of testing is required by OGTR. Given the timeframe and complexity associated with this more detailed analysis, the team reached the view that the best course at this point is to withdraw the application to the OGTR. This has delayed the programme by 2–4 years while the sesame oleosin is substituted for an alternative oleosin.

Translation from lab to field

Field trials in the USA in 2019 provided strong evidence that the increases in fatty acids, gross energy and plant growth measured in a PC2 containment facility translated into the field (Beechy-Gradwell *et al.,* 2020b). The trial used first generation Gene Gun-derived hemizygous HME Ryegrass at an intermediate T_2 generation of the breeding. Under controlled growth conditions the HME Ryegrass progeny had 34% higher leaf fatty acids compared to the null controls. In mini-sward field trials this delivered a 0.5 kj/gDW increase in herbage gross energy content compared to null controls. In the field trial in the USA HME Ryegrass swards exhibited 15-24% higher mid-season herbage fatty acid content than null control swards, and 25-34% higher end-of-season herbage fatty acid content. This coincided with a 0.3-0.5% kj/gDW higher end-of-season gross energy. Herbage growth rates were generally similar for HME and null control swards.

Reduction of methane emissions from ruminants

We performed *in vitro* fermentation experiments on both fresh and ensiled HME Ryegrass and demonstrated a greater percentage of valuable unsaturated fatty acids compared to the control ryegrass, a significant reduction in butyrate and a 10-15% decrease in the methane proportion of the total gas production (Winichayakul *et al.,* 2020). The scale of reduction in methane is consistent with the meta-analysis published in 2011 by Grainger and Beauchemin.

The Winichayakul *et al.* (2020) study demonstrated that the level of leaf lipid influenced the methane proportion of gas released (10-15%). A key conclusion of the study was that the effect of HME Ryegrass on fermentation may not be simply due to the higher lipid content, but to several factors possibly acting in concert, including other compositional differences in HME Ryegrass.

Intake also affects methane emissions from ruminants and in the Cosgrove *et al.,* (2004) study the ram lambs supplemented with the highest level of plant oil consumed 16% less feed. This needs to be identified experimentally and it is another potential source of methane reduction.

Comprehensive animal nutrition trials in metabolism crates or Green Feed machines are needed to determine if the methane reductions identified in the Winichayakul *et al.* (2020) study translate into whole ruminant animals. Feeding trials with ram lambs to measure methane emissions and nitrogen partitioning is planned for late-2024.

Nitrogen use efficiency and reduction of nitrous oxide emissions

Nutrition models (FarmaxDairy™) suggest that the improved animal nutrition (energy:protein ratio) may lead to a reduction in urine-nitrogen by 6-7%, primarily resulting in a reduction in nitrous oxide emissions and a reduction in nitrogen leaching into waterways. The scale of this potential benefit will be assessed in a ram lamb nutrition trial in late-2024, and will also help to refine modelling on this area. Further nutrition trials in cattle will be required to confirm these potential benefits.

Glasshouse studies have also shown a decrease in nitrous oxide emissions that cannot be directly associated with urine-nitrogen. The mechanism is yet to be determined and a separate research project focusing on denitrifying bacteria in the soil microbiome has been initiated to explore this effect.

Other

Evidence supporting the target of increasing plant lipids came from a supplementary feeding trial (Cosgrove *et al.,* 2004) that simulated the proposed HME Ryegrass and showed that lambs had a 33% higher feed conversion-efficiency compared to control lambs, resulting in a 16% reduction in feed intake for the same liveweight gain. The study indicated that a total fatty acid level of 7-8% of the dry weight (DW) would be ideal for this productivity benefit. Further support from another trial in New Zealand by Pinares-Patiño *et al.* (2016) showed that supplementation by oil applied as a spray directly onto the pasture reduced methane emissions by ~19% (from 20.9 to 17.2 g methane/kg DMI). Outputs from biophysical modelling using FarmaxDairy indicated that milk solids production would increase 12-17%. The outputs from FarmaxDairy were used to inform Overseer™ which was used to calculate nitrogen load on pasture (6% - 7% decrease) and subsequent reduction in nitrous oxide emissions (17%). Evidence for further potential for environmental benefits come from nutrition studies that indicate the level of dietary lipid influences methane emissions from ruminants (Grainger and Beauchemin 2011). The INFORM™ model was used to carry out biophysical modelling on a scenario sheep and beef farm to calculate the financial benefit. This was similar to that assessed for a dairy farm and indicated that HME Ryegrass may increase farm revenues by up to $500 per ha. Utilising current re-grassing rates to assess adoption then increased on-farm livestock productivity for domestic and export markets (*e.g.,* milk, meat and wool) would generate additional revenue of ~NZ$14 Billion over 20 years.

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HME Ryegrass

AgResearch

Briefing prepared 24 October 2023.

There are a number of approaches being taken to reduce methane emissions from ruminants including vaccines, feed supplements, inhibitors and animal breeding. It is anticipated that each of these solutions will contribute to reductions but no single approach on its own will make the reductions needed to meet New Zealand's GHG Inventory reduction goals.

Perennial ryegrass and white clover form the backbone of the New Zealand pastoral feedbase, representing the most widely sown, cost-effective sources of energy for livestock enterprises across the country. For New Zealand to maintain current and meet future production requirements and at the same time achieve reduced methane production per livestock unit, livestock producers need forage species with increased energy density and reduced emission profiles.

The application of genetic technologies was utilised to achieve an increase in plant fat in perennial ryegrass (High Metabolisable Energy - HME), and can possibly generate environmental, production and economic benefits. For grazing livestock the HME Ryegrass technology has the potential to reduce ruminant methane emissions by approximately 10%, provide approximately 10% more energy, and lowering the concentration of nitrogen in the urine – reducing nitrogen leaching into waterways and decreasing nitrous oxide emissions from the soil. The 10% increase in gross energy is also expected to provide farmers with improved flexibility to manage pastures to reduce environmental impacts without impacting profitability.

In a recent (2022) farm productivity study carried out on a Whanganui sheep and beef farm comparing livestock productivity of current perennial ryegrass and with HME Perennial Ryegrass the results demonstrated that the total incremental 'farm-gate' financial benefit (*i.e.*, value) for HME Ryegrass was estimated at $305 per hectare compared to animals grazing current perennial ryegrass.

Based on the potential to increase the available energy in HME Ryegrass by an additional 1.0 MJ ME/kg DM the following table demonstrates the potential 'Incremental Farm-gate value' generated from the projected increase in milk production (+9.7%).

New Zealand Dairy Region	Incremental Milk Production[1]	Incremental Milk Solids	Incremental MS Value	Incremental MS Value
	L/cow/yr	kg/cow/yr	$cow/yr	$/ha/yr
Northland / Waikato / Bay of Plenty	372	35	$234	$614
East Coast - Gisborne / Hawkes Bay	383	33	$223	$599
Taranaki / Manawatu	432	39	$261	$712
Marl / Cant / West Coast / Nelson	443	39	$259	$768
Otago / Southland	482	40	$270	$775
Average	*422*	*37*	*$249*	*$692*

Based on 2019/2020 dairy industry data and assuming all New Zealand dairy pastures were converted to HME Ryegrass there is the potential to generate more than an additional 400M L of milk per year, with an incremental Farm Gate value >$220M[2].

A key element of the research programme is to generate the data required for an Application to the Environmental Protection Authority (EPA) seeking Approval to Field Trials in Containment. This includes

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[1] Input data based on NZ Dairy Statistics 2019/2020).

[2] Assumes 10 years to achieve full adoption from year of initial release.

conducting sheep feeding trials in New Zealand and field trials in Australia. Due to the current requirements for obtaining Approvals for field trails in New Zealand, field trials planned for Australia will be critical for advancing the HME Ryegrass technology – generating to support an EPA Application and commercialisation processes in New Zealand.