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Can We Farm Without Glyphosate?

By Hamish Marr

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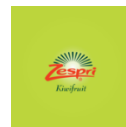
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ph: 021 1396 881.

Scholar Contact Details

Name: Hamish Marr

Phone: 027 532 9556

Email: marrsroad@gmail.com

In submitting this report, the Scholar has agreed to Nuffield New Zealand publishing this material in its edited form.

Nuffield New Zealand

PO Box 85084

Lincoln 7647

admin@ruralleaders.co.nz

+64 27 431 7575

Executive Summary

In 1974 a product was developed that would revolutionise agriculture. It would go on to be the most used chemical spray in global agriculture largely due to its low toxicity, negligible soil residue and zero plant back period. That product was glyphosate and was sold under the trade name Roundup. It was the product of intensification, of specialisation and globalisation.

There has been much dialogue in the last few years regarding glyphosate and claimed negative impacts on the environment and human health. This dialogue is in part due to its association with genetically modified plants and also as it is the world's most widely used agrichemical. The classification of glyphosate as a probable human carcinogen by the International Agency for Research on Cancer has led to calls for a reduction in use and led to a ban in some European Countries.

The aim of this study was to establish, from a farmer's point of view, what the issues are around glyphosate use, how it is regulated in New Zealand and what farmers in New Zealand could learn from others if a ban or de-registration were to become a reality.

Science is conflicted over glyphosate and its use. However there appears to be no definitive answer or evidence that glyphosate is detrimental to human health or the environment. In contrast there is much correlation between these two factors and a robust conclusion is difficult to draw.

Farmers overseas are successful in reducing their reliance and applications on glyphosate by adopting a more holistic approach to their agronomic management. In cases such as the seed industry in Denmark, the loss of glyphosate would see a shift in farming policy and a move of the industry off shore.

I found no real need for alarm in New Zealand as our current inputs of glyphosate are relatively low and are confined to 6% of our land area. It is important that we retain the option of this product and we as farmers need to be mindful of its use and avoid applications such as pre-harvest weed control.

In isolation farmers can certainly do without glyphosate but at an industry level and global level the loss of this tool would mean a loss of yield, an increase in alternative chemistry, an increase in carbon emissions, higher costs to the farmer and an increase in the price of food.

Central to this issue is a social problem that stems from fear of the unknown, due to a lack of understanding on the part of the consumer but also the farmer. The linear nature of the current value chain means feedback to either end is virtually impossible. This is the biggest challenge of all.

As a result of my observations and reflections I can recommend the following actions for industry.

1. Avoid pre-harvest weed control on cereal crops and pasture.
2. Discuss openly the future of agriculture including GMO
3. Establish a communication loop in the value chain between the consumer and the farmer
4. Model Glyphosate's contribution to the economy in New Zealand

Acknowledgements

From the outset, I wish to acknowledge that to have been awarded a Nuffield Scholarship is an honour unrivalled in agriculture. The year has been a real privilege and I have relished every moment of it. I have 'carried the flag' with an immense amount of pride and hope I can live up to the expectations that come with such an honour.

I wish to start by thanking the Rural Leadership Trust, Chairman Andrew Watters and those people involved that have given me the opportunity. To Anne Hindson, Lisa Rogers, Hamish Gow, Patrick Aldwell and Corene Walker, you are the people that prepared us so well for our year and continue to work hard on our behalf. It has been a pleasure for me to get to know you all throughout and I am grateful for your support.

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To Craige MacKenzie, thank you for all your support throughout the process and for making the year what it was. A familiar face when you are a long way from home is always a good thing and I enjoyed our travels together.

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1. Introduction

The idea for my studies throughout last year came from an interview I heard on the radio between journalist Kathryn Ryan, and Prof Jacqueline Rowarth on Radio New Zealand whilst I was sowing a paddock of wheat. Prof Rowarth was being interviewed in her capacity as the chief scientist for the New Zealand Environmental Protection Agency (EPA) on the safety and registration of glyphosate (Roundup). As an arable farmer, seed producer and user of glyphosate, I was listening with interest and frustration as regardless of the scientific answer to any question, the reporter was not satisfied with a) the answer and b) the position of the EPA to, what was then and is still, a very contentious issue within food production globally.

My frustration began in disbelief that an educated person is not prepared to respect or listen to what science and an expert in their field is telling them. It then changed over a 3-4 hour period realising that, ultimately this journalist is a cross section of the people that we are producing food for and that we should probably listen to what they are saying or at least asking.

As a farmer listening to this interview it was frustrating that what farmers and agriculture at large think is best and safe practice, is being perceived as the opposite in a lot of cases and in my case it seemed at the time without any foundation. In the case of glyphosate, it is widely known of its very low toxicity, almost zero soil residue and absolute versatility as a broad spectrum, systemic herbicide. To modify how we use or even suggest a deregistration of this product would have immediate detrimental impact on my current operation and intensive agriculture globally.

Intensive agriculture is very much a multi layered system of events that must occur in the correct sequence and at the correct time. To change one of these 'events' (i.e. a new cultivation technique, stubble burning or remove a chemical) always has a consequence to the rest of the system. The consequence may be short term and/or long term. For example, stubble burning appears to be very environmentally harmful, however the practice is very good at efficiently removing the residue and seeds of previous crops,

reduces cultivation, destroys unwanted pathogens and diseases and halts the life cycle of slugs and other insects such as aphids.

Glyphosate in my farming operation is no different to anyone else's in that it allows for quick and clean transition between crops. The practical reality is that there is virtually no regrowth from the previous crop or pasture that then go on to become weeds in the next that then requires alternative management or selective chemistry to eliminate. Glyphosate is to agriculture what a duster is to a blackboard. A very simple product that allows for clean fields and fast turnaround.

We have all read and heard about lawsuits in the United States, about how glyphosate and Monsanto's GMO crops have ruined agriculture globally, that France and Germany will ban glyphosate in 2022 and the EU will likely follow suit. Whilst drilling my wheat paddock that April morning, all I could think of was the effect on farming a loss of glyphosate would have; no more seed production, no more double cropping, more cultivation, more fuel, more work, production of more commodity products and most of all an absolute loss of efficiency and gains made over the last 46 years.

As a result of that morning in a tractor, I wanted to know the answer to a number of questions:

1. What is the actual problem with glyphosate... especially when agriculture generally, including me, is so quick to defend its use?
2. Is glyphosate under threat of deregistration in New Zealand?
3. How are farmers in other countries tackling this issue?
4. What are the possible impacts of deregistration in New Zealand?

The aim of this report is to give some clarity to farmers and industry personnel on my take as a farmer and glyphosate user on these issues. It is no way a scientific paper nor literature review. The commentary provided is the result of my thoughts following a year spent looking for an answer to a very wicked problem.

2. Background

This report is based on 22 weeks of overseas travel and are my thoughts, observations and reflections of that journey. I have endeavoured to travel with an open mind and free from bias towards New Zealand. What I have seen in agriculture is a real dichotomy from incredible innovation to absolute desperation in developing rural Indonesia. To really understand the situation for a lot of places and people you have to understand history and the politics that dictate the normal of every person's situation.

If I had to sum up my year in one sentence it would be a year spent looking at agriculture, listening to people on both sides of the debate and trying to find a mechanism to bridge the gap between.

One of the most important aspects of my Nuffield travel year has been to look at agriculture at a global level and how different things are in different countries. Politics and history have had, and are having, huge impacts on the way agriculture operates around the world.

The year consisted of six weeks in the USA, seven weeks travelling as a group to Singapore, Japan, Indonesia, France, Canada and the USA again, a further eight weeks was spent in UK, France, Italy, Germany, Ireland, Denmark, Netherlands and Sweden.

I visited all the major chemical companies including Monsanto in Missouri - ground zero for glyphosate. The biggest realisation in the US is the scale of agriculture. No matter what the industry is in the Mid-West, if it is successful it will be huge. I wanted to look at GMO, organics, regenerative agriculture, cover cropping, and conventional farming systems.

I have looked at big agriculture and little agriculture; a 35,000 acre tomato, cherry and almond farm in California to a tiny greenhouse in Japan that sells mangoes for \$300 each, and everything in between. I have well and truly had my eyes opened and enjoyed every minute of it.

As well as looking at agriculture I felt it was important to talk to people everywhere about such things as:

- What they eat and why?
- How do they make their shopping decisions?
- What their impressions of farmers and farming actually is?
- What is organic?
- What is agriculture doing well?
- What can agriculture improve on?
- What is GMO?
- Is climate change real?

The answers I got from these questions when asked all around the world were so varied and, almost always, so removed from what actually goes on.

Out of all of these chance interviews I conducted, there was a huge realisation that somehow farming has got lost in its own explanation about what goes on. How have people got so confused in what is actually quite simple or have we given up trying to explain?

As farmers we tell people we grow wheat for flour, barley for beer, cows for milk etc but we don't tell them that the cows need drenching or that they get mastitis. If we forget the fungicide on the malting barley and the grain deteriorates, the brewers don't want the malt. These are the realities that society are oblivious too because we have shied away from explaining it.

Farmers everywhere face many of the same problems and have the same goals. They are all trying to produce a plant or animal to sell, and have to contend with issues with soil, rainfall, weeds, diseases, pests, nutrition, labour and price. These factors are all considerations for farmers everywhere and farmers develop their own systems to combat each in their own way.

When you consider an ever increasing population and an increasing urbanised population the role of the farmer is more and more important. It is therefore vital that farmers and agriculture listen to what the public are saying but also that the public respect what agriculture gives them even if it's not directly produced for them.

3. What is Glyphosate?

Glyphosate is a broad spectrum, non-selective herbicide. It was first commercialised in the United States by St Louis, Missouri based Monsanto under the tradename Roundup in 1974. Today there are over 50 registered variations of the original chemical in New Zealand and it is the most widely used agricultural chemical globally. Having started out life as a potential industrial cleaner, it was discovered to have herbicidal qualities. The mode of action works simply by blocking protein synthesis through what is known as the shikimate pathway and the production of plant specific amino acids. When translocated thoroughly the lack of protein effectively starve the entire plant. These plant specific amino acids are not found in animals and more importantly mammals or humans.

Science tells us that if consumed in food, glyphosate passes harmlessly through the human body and is expelled in urine rapidly after ingestion. In terms of toxicity it is classified by its LD50 number, which means the lethal dose that kills half the test animals when given to them in doses per unit of body mass. The higher the number, the safer the product. For test rats, caffeine has an LD50 of 192 mg/kg liveweight, table salt has an LD50 3000 mg/kg liveweight and glyphosate has an LD50 of 5600 mg/kg liveweight. A reasonable conclusion to draw is in line with the Swiss physician Paracelsus, who in the 1500s claimed that *“Solely the dose dictates that a thing is not a poison.”*

Globally glyphosate is the most widely applied agrichemical with usage steadily increasing per year. From 1974 until 2014, a total of 8.6 billion kg of glyphosate active ingredient was applied with 90% of this amount applied to agricultural land.

The advent of GMO crops (see section) and particularly Roundup Ready types in 1996 saw consumption increase by a factor of five and a factor of 15 by 2014 (Beckie et al, 2019).

Period	Use (Million kg)
1974	3.2
1975–1984	130.5
1985–1994	387.3
1995–2004	1909
2005–2014	6133
Total	8563

Table 1. Glyphosate active ingredient use globally, 1974-2014, (Beckie, Flower, & Ashworth, 2020)

Glyphosate has been labelled the chemical of the century due to its main attributes, low toxicity to animals and humans, low soil residual and zero plant back period.

3. How is Glyphosate Used?

Glyphosate is labelled in New Zealand for use before planting forestry and broad-acre crops, pasture renovation, pre-harvest weed control in cereals, vineyards, orchards and market gardens, turf and recreation areas, drains and waterways and in domestic gardening. Attributes include its broad spectrum of target plants including most grasses, annual and perennial weeds. With little or no soil residue there are no restrictions labelled for plant back periods for any crops. This made its applications for pre planting and post emergence weed control very popular. This attribute was also a key factor in the adoption of minimum tillage (min-till) and zero tillage (no-till or direct seeding) in areas such as the Mid-West of the United States, South America and Australia. These two seeding techniques largely halted what was a rapid decline in soil quality following years of intense cultivation. No-Till farming rapidly increased crop yields in marginal environments through soil moisture conservation and more timely sowing.

I saw a lot of examples of this in Iowa, Nebraska, Missouri and Illinois. In Corning, Iowa, Ray Gaesser was very concerned about soil quality and had started cover cropping all of his 4,500 acres every year with cereal rye. In the spring he No-Till seeded into the standing rye, following an application of Roundup the day before.



Figure 1. Sowing soybeans into standing rye cover crops

Globally glyphosate is widely used for pre harvest weed control in cereals, brassicas (mainly oil seed rape) and some legumes (peas and soy beans). It is also labelled for conservation tillage with no grazing withholding period.

Prior to 1974 the only broad spectrum herbicide was a fire and/or a cultivator and many variations of. In New Zealand the establishing of a new crop or pasture could take as many as ten cultivation passes, not to create the subsequent seed bed but to kill the weeds present. Particularly challenging to farmers here and overseas are the perennials such as common couch, *Elymus repens*. These cultivations often spanned months to enable livestock and weather breakdown and also to allow strikes of weeds to occur before replanting. In real terms it means one crop per year and to replace or replant a pasture could take a year of working.

With glyphosate everything changed and systems changed. In New Zealand, where the country is dominated by pasture, and in a lot of cases permanent pasture on hill country, the impact of farm system change was not as large as other countries. However, in some areas of New Zealand, a transformation took place. All of a sudden multiple crops per year could be grown, yields increased and growers could operate more specialised systems without integrating livestock. In New Zealand glyphosate has been the tool for managing weed seed banks efficiently through pre sowing application. It is the

tool of strategy and management and is the number one go to when transitioning between crops.

While studying at Lincoln University, Dr Warwick Scott would refer to glyphosate as “Sunshine in a can”. This label was in reference to the effect that this one product had on managing weeds and it had substituted the cultivator, weather and time.

Glyphosate is entrenched in everyday farming and its use is considered best practice when establishing any new crop or pasture in a “conventional” scenario. Table 2. shows examples of where farmers use glyphosate in pasture renewal. Arable farmers generally follow the columns labelled ‘Cultivation’ or ‘Spray-drill’.

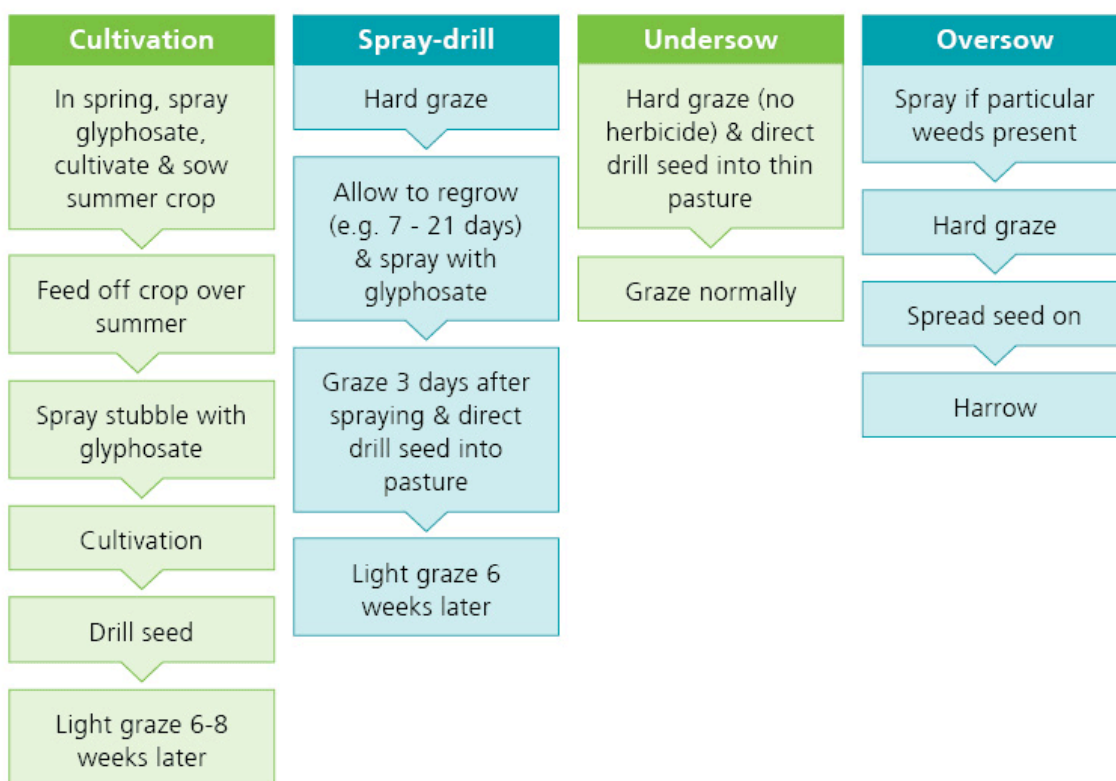


Table 2. Pasture renewal methods. Source: Dairy NZ <https://www.dairynz.co.nz/feed/pasture-renewal/sowing/pasture-renewal-methods/>

3a. Value to New Zealand

The actual amount of glyphosate applied in New Zealand is difficult to determine for commercial reasons. Companies approached for market statistics were reluctant to divulge their IP and there are no import or applications statistics kept by government or even the industry bodies unlike other countries. Table 3 shows glyphosate usage per farming type and is at best an assumption with information gained from Beef and Lamb, Hort NZ, and NZ Wood.

	Agricultural Area (000 Ha)	Hectares sprayed with glyphosate per year(00Ha)	% of total land area
Sheep and Beef Farming	9,382	322	3.43%
Dairying	2,415	161	6.67%
Cropping	284	227	79.93%
Horticulture	121	90	74.38%
Forestry	1,700	50	2.94%
Total	12327	850	6.8%

Table 3. Potential Glyphosate usage in New Zealand

Statistics on the wider agrichemical industry generally in New Zealand are difficult to find also. It is estimated by the Ministry for the Environment that the retail value of Agrichemicals is around \$200 million. However, a report completed for Agcarm (Agricultural Chemical and Animal Remedy Manufacturers Association) NZ by the New Zealand Institute of Economic Research shows that crop protection products (agrachemicals) are worth between \$7.5 and \$11.4 billion to the New Zealand economy. This translates to a return on investment of around 4000%. The same report found that many industries would face severe losses without them. Horticulture, including kiwifruit could faces losses of up to 75%.

The lack of strong market intelligence for individual products makes impact calculations difficult. However, Mark Ross, CEO of Agcarm, believes glyphosate to make up around 10% of the herbicide market by sales value and that herbicides contribute 46% of total sales. Extrapolating this further it could be assumed that glyphosate contributes 4.6% of the \$7.5 to \$11.4 billion that

agrichemicals contribute to the NZ economy. It is, therefore, in monetary terms worth \$300 to \$520 million to New Zealand agriculture.

One product changed farming forever, creating very nimble and efficient systems capable of producing high quality through low contamination of foreign plants and seeds, high yielding produce from limited competition that was safe for the environment and safe for the consumer (both animal and human). A win/win for everyone.

4. Agrichemical Regulation in New Zealand

In New Zealand the industry is regulated by the Ministry for Primary Industries (MPI) under the ACVM (Agricultural Compounds and Veterinary Medicines) Act and the Environment Protection Agency (EPA) under the HSNO (Hazardous Substances and New Organisms) Act.

Both of these departments are governed by their acts and all based on the scientific information available at the time of registration and also renewal. The EPA is a government department but is independent of government oversight with no Minister above with any authority. The main reason being that decisions made must be based on science, risk vs benefit rather than the politics of the day. The EPA's role is to regulate substances and their permitted use. In the case of agrichemicals this is the active ingredients. MPI's role is within risks to the public and residues within food. It also sets withholding periods and MRL (Maximum Residue Limits) within the framework of the food act.

MPI sets MRL's with three clear factors in the calculation:

1. Good Agricultural Practice (GAP). Products must be able to be used at dosages suitable for the job they were intended.
2. Residue data is analysed to find the point where residues are at their lowest but the compound is still achieving effect.
3. Average Daily Intake (ADI).

If the ADI is less than or equal to the Health Based Guidance Value as set by the EPA based on international science, the MRL is then set and the withholding period as a result.

New Zealand Food Safety tested for glyphosate residues in pea and wheat crops in the 2015/2016 survey. No glyphosate residues were detected in 60 pea samples. Glyphosate residues were detected in 26 out of 60 wheat samples. Twenty of these samples contained glyphosate above the MRL of 0.1 mg/kg. The results were assessed and indicated no food safety concern. At the highest level detected (5.9 mg/kg), the average adult would have to consume 14kg of wheat-based products every day for their lifetime to reach the World Health Organization Acceptable Daily Intake for glyphosate. (<https://www.mpi.govt.nz/food-safety/food-safety-for-consumers/whats-in->

our-food-2/chemicals-and-food/agricultural-compounds-and-residues/glyphosate/#pea)

In the case of glyphosate, both MPI and the EPA view glyphosate as being low risk to human health based on Good Agricultural Practice and Average Daily Intake. The issue of deregistration, as is the case in Europe, is not likely in New Zealand unless new scientific findings dictate a change in risk profile or monitored food residues change. As such we are not likely to lose glyphosate in the foreseeable future.

The retail end of the New Zealand agrichemical industry is regulated very differently from other parts of the world. The United States, Canada, EU and the UK are very strict on chemical usage on crops and monitor this very closely but with subtle differences. Both the EU and UK require all chemical purchases to have a formal agronomist's recommendation and any product applied must be labelled for the particular crop and rates followed. The monitoring and audits of these rules is incorporated into the subsidy payments farmers receive. In North America they operate slightly different, no recommendation is required but adherence to product labelling is strictly enforced by state and federal agencies through standard audits.

Due to the relatively small size of NZ's agrichemical market, 0.26% of the world market and the cost of registering individual products, MPI allows off label chemical use. Growers and applicators are instead required to prove their competency by obtaining an approved handler's certifications such as 'Growsafe'. Anything used off label does not have a registered MRL or withholding period and is therefore an absolute risk to end use. There is therefore no standard of GAP recognised and, as a result, no scientific basis for safe usage. The use of any chemical off label is viewed by MPI as a privilege and the practise is monitored for food safety. MPI do randomly test all crops and these tests are becoming more thorough

A critical realisation for farmers is that withholding period compliance doesn't mean no residue, it simply means the residual is less than the maximum permitted based on daily intake.

5. What is the Problem with Glyphosate?

No matter what side of opinion, people generally have one about glyphosate. As farmers we are constantly told of its enduring safety and low toxicity for all parts of the environment. In stark contrast there is the dialogue around long term exposure and what that could lead to, especially as we are now 46 years on from commercial release and the relative trials that led to the label claims that are still in place today.

5a. Safety In Question

Since the mid- 1990s, and particularly in the last ten years, glyphosate has received a lot of bad press. This is almost always completely contrary to what was claimed originally regarding its key attributes, human safety and residues. In 2015 the World Health Organisation's (WHO) International Agency for Cancer Research (IARC) labelled glyphosate 'probably carcinogenic' (World Health Organization, 2015) and in the same category as red meat and very hot beverages. This classification came at a time when there was already a strong opposition to the increased use of glyphosate and a growing realisation from the general public that farmers actually spray crops.

In 2016, the European Chemicals Agency (ECHA) Committee for Risk Assessment stated that *"on the available scientific evidence, there were no grounds to classify the controversial herbicide, glyphosate, as a carcinogen, as a mutagen or as toxic for reproduction"*. (ECHA, 2016)

In 2018 and 2019 juries in California found Monsanto responsible for the cancer and Non Hodgkin Lymphoma of two different parties. The damages awarded to each have been the hundreds of millions of dollars. Environmental groups and a lot of individuals clearly see glyphosate as responsible for much of the world's health problems as a result of these lawsuits.

5b. GMO

To many people glyphosate and/or Monsanto is the emblem for a growing number of people who object to the effect that large multinational companies such as Monsanto (now Bayer), Syngenta, Dow Agro Sciences and Du Pont (now Corteva) have had on global agriculture and their domination within the

food system globally. The roots of the scepticism, objection and opposition, in my opinion, are largely born in the US as a result of Genetic Engineering and the lack of understanding to both the complexity of it but the simplicity of the goal and the benefit to the consumer.

Genetic Engineering (GE), Genetically Modified Organism (GMO) and Genetic Modification (GM) are all terms thrown around that are subtly different but are used in general terms to describe the same thing.

The first genetically-modified crop was corn in the US, modified to contain the bacteria, *Bacillus thuringiensis* (Bt). This naturally occurring soil bacteria produces proteins called *cry* that are toxic to caterpillars and beetles. Bt toxins cause little or no harm to non-target organisms including beneficial insects, spiders, wildlife and people. For these reasons, organic farmers have been using Bt sprays and other formulations as their primary insect control mechanism for fifty years. (Ronald & Adamchak, 2018)

The introduction of Bt to corn, cotton and potatoes has seen a reduction of insecticide use by around 85%.

In 1996 Monsanto commercialised 'Roundup Ready' corn. Again, with genetic modification, plant breeders were able to modify the DNA sequence of the corn genome at the point of susceptibility to glyphosate. The result being a corn plant that was tolerant to glyphosate and a real game changer. This trait was soon modified in soybeans, cotton, canola, sugar beets and alfalfa.

There are three very key factors to consider at this point. From a farmers point of view, they could seriously limit and simplify the amount of active ingredient applied per year, the types of chemistry used, lower their costs of production and produce a more consistent crop year in year out with less wastage. For Monsanto they had a differentiated seed product that had benefits for the farmer and as such would be in very high demand. The most important factor of all was that the consumer would be availed with food that was virtually chemical free. As close to organic as possible without being and all thanks to a chemical that everyone said was safe to drink. Where once growers were spraying crops numerous times per year with organophosphate insecticides, now there were none. Where crops were sprayed with herbicides such as atrazine and the phenoxy family, they were now only exposed to the harmless glyphosate, again a win/win for everyone.

Unfortunately the last point was not well managed. What should have been a good news story has instead become one of the greatest marketing mistakes in agriculture. Both to the consumer and the grower.

Also of note is that prior to 2000 the USDA, who are responsible for regulating agriculture, made no mention of GMO. In 2000 it was decided that GMO crops were not permitted in organic agriculture.

In 2000 the USDA, who are responsible for regulating agriculture, decided that GMO crops were not permitted in organic agriculture. The marketing machine within the food system pounced on this fact. Retailers and environmentalists very cleverly used the fact that the USDA had classified it outside of both 'conventional' and 'organic' agriculture and that it is potentially bad for humans. Every supermarket has shelves full of food labelling saying "GMO Free" or nothing. Naturally a product with 'nothing' on the label compared to "GMO Free" must contain GMO and therefore can be priced accordingly. In the United States nearly all food, both whole and processed contains labelling of this kind, even though there are only nine registered GMO crops.

The European Union's decision to not allow GMO registration is based on their regulation 1829/2003 and requests that: *for food and feed products derived from GE organisms, it is "adequately and sufficiently demonstrated" and "must not: have adverse effects on human health, animal health or the environment"*. This includes ensuring that the respective products: Regulation 1829/2003 requests that, for food and feed products derived from GE organisms, it is *"adequately and sufficiently demonstrated" and "must not: have adverse effects on human health, animal health or the environment"*. This includes ensuring that the respective products: *"...should only be authorised for placing on the Community market after a scientific evaluation of the highest possible standard ..."*.

The hysteria that has come from anti GMO and the EU decision then started looking at farming and actually what happens on farm.

5c. Glyphosate – The scapegoat

The mid-20th century saw what we all know as the green revolution. The combination of improved crop and livestock breeding, new synthetic fertilisers and pesticides, machinery and irrigation led to a sharp increase in food

production worldwide. As a result world food production more than tripled in the last 50 years. Nitrogen fertiliser usage increased sevenfold, irrigated land area doubled and there is now 50% more food for each person compared to 1961 despite considerable population growth.

As time has passed, the general population has become more and more removed from the realities of agriculture. This removal has led to a lack of understanding of how things are done on farm. A lack of understanding naturally causes people to question how things are done and want to return to the point where they feel comfortable and understand a particular process.

Glyphosate has become the poster child for the anti 'conventional farming' movement led by groups such as PAN (Pesticide Action Network) and Greenpeace who are opposed to GMO, pesticides and fertilisers. To many, glyphosate is the symbol of what farming has become and is blamed for insect death, loss of habitat, and the health and wellbeing of people in general.

There are bodies of work everywhere regarding glyphosate and its impacts of human health, animals, insects and the environment at large. A lot of the work comes from within the health sector. An example is some work done by Samsel et al who found correlations between glyphosate use on a variety of crops including, wheat, corn, soy and health problems such as celiac, gluten intolerance, diabetes and even death rate in the United States.

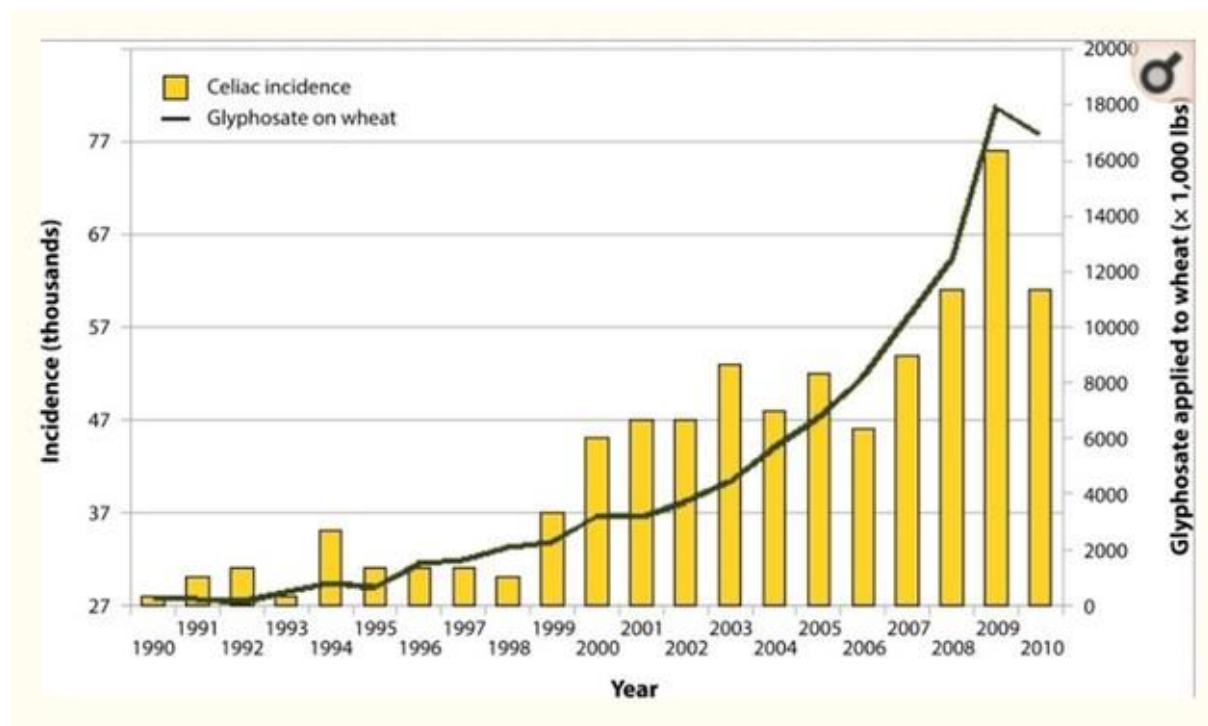


Table 4. Correlation between increase in celiac disease (gluten intolerance) and increase in use of the herbicide glyphosate (Roundup ®) on genetically modified grain (Samsel & Seneff, 2013)

A simple google search with the keywords “Roundup or Glyphosate” has 285,000,000 hits and 6,150,000 hits respectively. A sample of the negative impacts of glyphosate use is shown in figure 2. from the website www.ecologycenter.org/factsheets/so-whats-the-problem-with-roundup/

They say: *"It's Safer than Mowing"; "Biodegradable"; "Environmentally Friendly"*

SOME IMPORTANT FACTS YOU SHOULD KNOW

- Glyphosate, the active ingredient in Roundup, is the third most commonly-reported cause of pesticide illness among agricultural workers in California.
- Glyphosate is the most commonly reported cause of pesticide illness among landscape maintenance workers in California.
- The surfactant ingredient in Roundup is more acutely toxic than glyphosate itself and the combination of the two is yet more toxic.
- Glyphosate is suspected of causing genetic damage.
- Glyphosate is acutely toxic to fish and birds and can kill beneficial insects and soil organisms that maintain ecological balance.
- Laboratory studies have identified adverse effects of glyphosate-containing products in all standard categories of toxicological testing.
- Glyphosate residues in soil can persist over a year.
- Glyphosate residues has been found in strawberries, wild blueberries and raspberries, lettuce, carrots and barley.
- Glyphosate has been measured 1,300 – 2,600 feet away from its application site.
- This year Monsanto, manufacturer of Roundup, agreed with the New York Attorney General's office to discontinue their use of the terms "biodegradable" and "environmentally friendly" in ads promoting glyphosate-based products, including Roundup.

Effective and Safe Alternatives Exist!

For more information, contact the Ecology Center.

Sources:

Cox, Caroline. 1995. *Glyphosate, Pt. 1: Toxicology*

Journal of Pesticide Reform Vol.15, No.3:14 -20

Cox, Caroline. 1995. *Glyphosate, Pt. 2: Human Exposure and Ecological Effects*

Journal of Pesticide Reform Vol.15, No.4:14-19

Moses, Marion. 1995. *Designer Poisons*

Figure 2. Example of a negative impact from glyphosate website

Many city councils (in New Zealand and internationally) and government departments have legislated that glyphosate is not to be used for health and safety reasons.

The problem regarding glyphosate in my opinion and the issues surrounding it, is the real lack of an absolute answer one way or another. You cannot dispute the science and the advice, if used correctly there is no risk to human health. However, you cannot ignore the vast amount of literature stating the direct opposite. A lot of work seems to be correlations rather than results of trial work and is very ambiguous as a result.

5d. The Dilemma

Agriculture and farming are at a real crossroads, a Dilemma that is almost impossible to solve. Wherever you look there is information and people talking of everything that is wrong with the way our food is produced and yet there are huge swaths of literature and people claiming the opposite. The problem that agriculture must tackle and it must do so head on, is deciding what is right.

To ascertain what is right or wrong is no easy task. The whole dilemma over glyphosate use is merely opinion on both sides of the debate with people searching for science to back up their opinion.

One theory that is widely discussed socially is that food in developed countries is too plentiful and undervalued socially. It is not seen as a necessity as in other parts of the world. The unconscious assumption of unlimited food availability allows people the ability to view the production of that food with scepticism.

We are told as farmers that consumers are questioning more and more where their food comes from and how it is made. The reality, from 22 weeks of asking every random person overseas 'what they think of when buying groceries?', is a long way removed from that statement. GMO was often quoted but very rarely, glyphosate or spraying of crops. Is therefore the noise we hear about the risk to human health, just noise from groups of people?

Generally people purchase food on price and familiarity. There is an ever-increasing class of shopper buying from markets such as whole foods and they make a lot of noise; however, they only represent 2% of the market.

5e. Case Study: The right of choice

While travelling through Missouri in May, 2019 I was staying in St Joseph for a few days. At breakfast I had a conversation with a nurse, Gale from Nebraska who is also a rancher in South Dakota. Her knowledge of farming and also health were fascinating. Both her husband and herself suffered from gut problems, bloating and joint pain and have looked into why they both encountered the issue around the same time. Through trial and error and looking for an alternative grain source, they have discovered grains self-imported from the Middle East, has virtually eliminated their health problems. Their gut problems and joint pain are largely gone. Gail's conclusions from one farmer to another was that no-one is breaking any laws or doing anything wrong. But the food industry takes away people's right to choose what it is they are eating through making a more informed choice. Gail used the example that GMO's have enabled very tight cropping rotations, corn-soy-corn. This naturally has removed the diversity of plants from within cropping systems. It has also meant a shortening of the time period between like chemicals and glyphosate is now everywhere in American broad acre agriculture, multiple times per year. Farmers shouldn't be held responsible for this as they have been doing the right thing with what was told was a very safe product with the backing of science and government. Her testimony is in no way a scientific trial, her blame of GMO and glyphosate not an actual correlation but her own conclusions and emotion particular were very raw.

The conversation with Gail has caused a lot of reflection and really puts into perspective one part of a farmer's dilemma. Who actually is a farmer's customer and where do the boundaries start and stop?

In commercial broad acre agriculture, the customer of the farmer is the meat works, the flour mill, feed mill, the seed merchant, the dairy co-op. It is not the end user. The food value chain is very linear as shown in figure 3. The retail consumer is at least four steps removed from the farmer and there is no mechanism available for information flow between the two apart from

purchasing decisions. To the same degree the farmer produces a product that complies with the requirements of their customer.

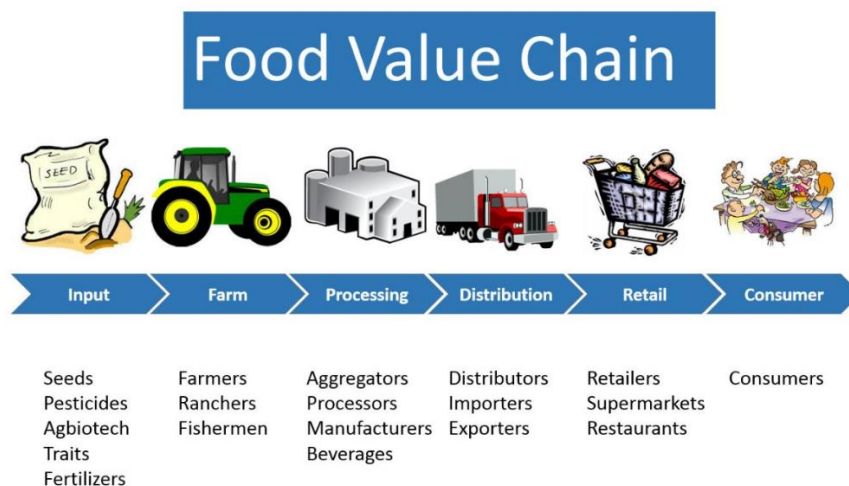


Figure 3. The food Value chain, www.rozendale.org

What and who is right or wrong in this issue comes down to the individuals in and how informed they are. The dilemma farmers face is very real and is clearly demonstrated in Figure 4 below. The Author is invited to speak on a panel discussion labelled ‘Pesticides – Good or Evil’



Figure 4. Invitation to What's Your Poison

Three scientists with differing opinions and a farmer who is essentially caught in the middle of the argument because ultimately this a social question answered by science and the ultimate decision is down to individual farmers.

6. Farming without Glyphosate

I always come back to the memory of a visit to an organic vegetable farm outside of New Zealand (location not divulged). The farm was producing carrots, parsnips, broccoli, cauliflowers and other green vegetables. When I asked what the biggest problem was, I was told “weeds”, namely docks and couch. With all sorts of mechanical technology, gangs of people hand weeding, even sheep and cattle, these are the two plants that cause the biggest headaches. The problem has got to the point that vegetables and crops can't be grown in some places on that farm and it is a problem getting worse every year.

The only solution for this grower has been to go back to 'conventional' methods and spray. Is that success? Is that the sustainability that people want to believe? How widespread is this practice? Does it mean that 'organics' and 'conventional' farming are just labels used for marketing? The hardest thing I found when looking at these different systems was not focussing on the problems but actually looking for the solutions. I was very grateful for the honesty of this grower.

The first question to ask is “Is it as simple as stopping using glyphosate?” The answer to that question is clearly no, it is not that simple. What would we base the decision on? Do we look to science?

If you ask an agricultural scientist, generally they will say we can't live without it but work is certainly underway to reduce the reliance on it. Richard Hill, a weed scientist with Rothamsted Research in the UK, says that farmers could not do without glyphosate. The efficiency of min till and zero till would simply break down. The ability for a farmer to manage their crops is severely diminished. An example used by Richard Hill was the recent removal of neonicotinoid insecticides from EU countries. This decision was based on good intention to restore biodiversity and insect populations, including honey bees. The downstream effect is some places can no longer grow oil seed rape due to the insect 'flea beetle' ravaging their crops. Richard also makes a very important distinction in management theory. Where glyphosate has been considered the blackboard duster, the mechanism for cleaning the last crop and preparing for the next. The future must be thought of as managing weed

seeds strategically without an absolute reliance on one product. Just as farmers vary their cultivation methods depending on the crops, glyphosate must be seen in the same vein and seen as one option among many.

Brad Hanson, a weed scientist at the University of California, Davis, says “farming without glyphosate will be very tough, our farming systems now days are so intensive that chemistry has replaced both animals and machines”. Hanson also makes the point, “There are now two generations of farmers who don’t know any different”.

There are several points here, firstly chemical weed control and chemicals in general are now firmly ingrained in the psyche of many people within agriculture simply as a result of time and the efficiency gains associated with them. Farming practices as a result of this have changed and so too has farmer’s perception of normal. A farmer in 1974 would think glyphosate was revolutionary and could instantly see the benefits. If it were not under threat as is currently, a farmer in 2019 would probably not mention it as important. The absolute threat to agriculture from this, is collectively we will have forgotten about life before Roundup and how things were done at that time.

There are of course a lot of farmers who operate and have operated for years without chemicals and do so successfully. Dr Kerry M Clarke, a soil scientist from the University of Missouri, Columbia, has been working on organic farming strategies and believes that organic farming certainly has a place. However, she goes on to say that chemicals generally provide security to production. This is a key thought when thinking about scale within agriculture and feeding a large population. It is important to consider this metric when thinking about production levels. Prior to the green revolution of the 1950s food production came from an available land per capita of 0.43ha compared to today, 0.23ha per capita available. In 2100 it is estimated that area to be reduced to 0.16ha per capita.

In a study for the European Parliament, (EPRS, 2019) found that Plant Protection Products (PPP), including biopesticides, increased yields between 19% and 42% in wheat, rice, maize, potato and soy bean. Without PPP food security, food quality and food safety will reduce. These factors will negatively impact on food security and farmers income and therefore the banning of PPP is unrealistic and unacceptable especially given population projections of 11 billion people by 2100.

There has been much work done on the effects of farming without glyphosate and the consequences of such a move. The Andersons Centre in the UK found that a failure to renew the licence for glyphosate would have a significantly negative impact on farmers. Yields for the current combinable crop mix could generally decline by 10%. (Figure 5.)

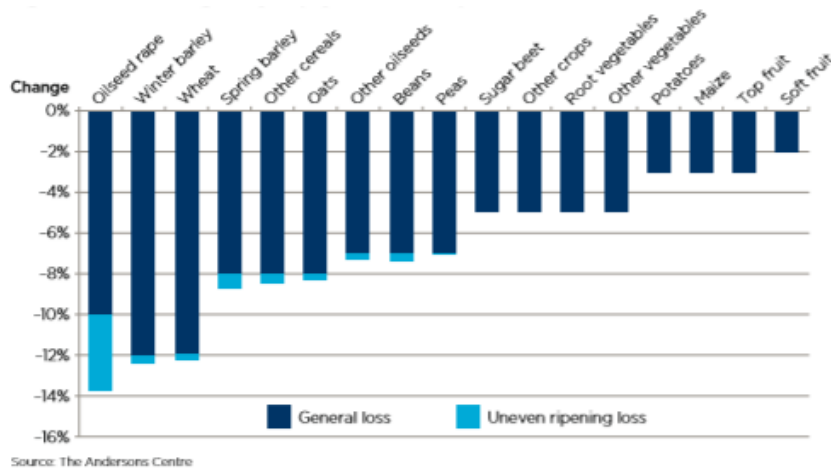


Figure 5. Changes in crop yield by crop and cause (Economics, 2017)

Lack of production would need to be made up from imported product. The UK economy stands to lose close to a billion dollars as a result. Cultivations would increase by at least two extra passes. In short yields would decrease, costs would increase, and output per unit of input would decrease. Carbon emissions per unit of saleable product would also increase as a result.

Richard King of the Anderson Centre, Melton Mowbray, hypothesises that glyphosate has taken farmers down a cul-de-sac and that it will be very difficult to move out of it. The main reason being that the current generation of farmers are oblivious to the methodology of old that will be required if deregistration does occur.

The effects of farming without glyphosate at a global level are summed up by UK economist Graham Brookes *“There would be an annual loss of global farm income gains of \$6.76 billion and lower levels of global soybean, corn and canola production equal to 18.6 million tonnes, 3.1 million tonnes and 1.44 million tonnes respectively. There would be an annual environmental loss associated with a net increase in the use of herbicides of 8.2 million kg of herbicide active ingredient (+1.7%). Also, there would be additional carbon emissions arising from increased fuel usage and decreased soil carbon sequestration, equal to the equivalent of adding 11.77 million cars on the roads. World prices of all grains, oilseeds and sugar are expected to rise, especially soybeans (+5.4%) and rapeseed (+2%). Land*

use changes will arise, with an additional cropping area of 762,000 ha, of which 53% derives from new land brought into cropping agriculture, including 167,000 ha of deforestation. These land use changes are likely to induce the generation of an additional 234,000 million kg of carbon” (Brookes, Taheripour, & Tyner, 2017)

6a. What are Farmers doing?

If agriculture faces a future without Glyphosate, more integrated systems will be required, systems that embrace the whole of farming businesses. Integration of different crop species, animals, beneficial insects, rainfall distribution, and a more thorough understanding of a farm’s biological framework. These things will be huge challenges for growers who only know chemical agriculture.

6b. Case Study: Beeswax Dyson Farming



Purpose – A long term commitment to sustainable farming

Vision – At Beeswax Dyson Farming we have a simple, clear approach which we are determined to implement. We try to learn from the past to ensure that our core assets, such as soils, are protected and improved. We aim to look forward to ensure that the decisions we make today impact positively on future production and value.

Beeswax Dyson Farming is a large UK farming operation owned by the Dyson family, known globally for their vacuum cleaners and hand driers. The farming operation covers approximately 14,500 hectares in five different locations, mainly in Lincolnshire, with a geographical spread of 250 miles.

The operation is mainly arable with ten crops harvested over eleven months of the year: wheat, barley, oil seed rape, maize, potatoes, onions, potatoes, carrots, oats, hybrid rye and hybrid barley. The farm also operates two anaerobic digesters, 1 x 3 mw and 1 x 2 mw which between them produce enough electricity to power over ten thousand homes.

As well as providing electricity, the digesters provide hot water for heating all the farm buildings. The key output from the digestion process is the two kinds of slurry. James Thompson likens an anaerobic digester to a 2 megawatt, concrete dairy cow, *“If you want the best out of it you must feed it the same thing, at the same time, every day.”* Of the 110,000 tonnes of silage that goes in, the same amount is returned in either dry slurry (Figure 6) with 0 nitrogen and high in P & K or wet slurry that is high in N and low in P & K.



Figure 6. Dry slurry form anaerobic digester

The family have clear goals to be commercially successful and innovative. They want to create industry best practice through using innovative technology to do things right and better for the produce, for the environment, for the customer and for the future.

The farm is managed with one eye on public image and therefore environmental stewardship is a key focus. The Dyson family desire to eliminate glyphosate and synthetic nitrogen fertiliser completely. James Thompson, overall manager of farming operations, is working towards this point and the business has made big strides in the last few years in doing so.

The first decision/trial was to stop pre-harvest weed control with glyphosate in cereals. This policy has been successful for three years with all grain precleaned, dried and graded at harvest time. The second decision was weed control pre-sowing. The company decided to trial sheep, with instant success. Today the farm employs four shepherds and buys in trading sheep (store lambs). In most instances where sometimes up to five applications of glyphosate was applied pre-sowing, it is now down to one or zero thanks to rotational grazing of sheep.

Farm managers identify key areas of weed pressure and graze accordingly. There are no permanent fences or water so it is all done with portable troughs and electric fencing.

The crop rotations have been completely changed and lengthened but the actual crop sown decision comes down to a very simple management decision. All fields on the farms are given a simple visual weed burden score from 1-3. A score of 1 means no weed pressure, any crop can be sown; a score of 2 means some selectivity on crop choice and selective chemistry; a score of 3 means no autumn or winter crops may be sown. Instead the field is planted in pasture for two years with digester slurry and sheep grazing.

In the past where blackgrass *Alopecurus myosuroides* has been difficult to control, it is not so much of an issue following a pasture phase. By lengthening the rotation and adding short term pasture the continued exposure to like chemistry is reduced and is an example of another tool in the tool box.

Beeswax have also found a novel way of dealing with flea beetle in brassica crops following the removal of neonicotinoids. It has been discovered that the beetles are deterred by the smell of digester slurry and that flea beetles are always more of a problem the closer a susceptible crop is planted to one from the following year. The combination of smell and a vigorous crop as a result of the slurry and distance from potential infestation has dramatically reduced attacks in rape crops.

Innovation at Beeswax comes from knowledge and a willingness to try anything. Results to date show that diversity within a cropping rotation and flexibility to change within that rotation allow management more options. To visually assess individual fields for weed score incorporates a real holistic approach into very modern cropping techniques. In traditional British cropping systems, fields would be locked into very simple three crop rotations with no flexibility. Weed management would come down a selection of sprays.

The company has a strong emphasis on capturing information and measuring performance of everything. Lessons can only be learnt if accurate measurements are taken and it is the key to traceability. Knowing what works and what doesn't ensures progress is made.

A key take home from Dyson Beeswax is the importance of diversification and circular economics. The two anaerobic digestors mean there is zero biological wastage on this farm. A lot of what is produced is converted into heat and electricity and the biproduct redistributed as fertiliser. The ability to use the digestors as a legitimate sale point give flexibility in new management techniques that are not available to other farmers.

To me this operation was a real eye opener of what is possible within farming if you are willing to try and think outside of normal. The business is a real credit to farm manager James Thompson. It was a privilege for me to spend the time looking at the operation and getting a feeling for the managerial processes involved in the success of the business. The operation is unlike anything else I have visited and is the benchmark for where we are going as an industry.

One solution available to farmers in the UK that is very similar to the approach taken at Beeswax Dyson Farming, is via LEAF (Linking Environment and Farming), a charity organisation based in Warwickshire. They have developed an Integrated Farm Management (IFM) model that looks at the whole farm system and considers all the components within the farm system when making management decisions, such as crop selection.

LEAF was set up originally by a group of farmers who wished to farm in a more environmentally sustainable way than was normal practice at the time. They also wanted consumers to be aware of their IFM programme and initiated the Leaf Mark certification that allows to identify that the products they are buying

have been through the LEAF audit process and is grown according to the IFM framework as explained in figure 7 below.

Integrated Farm Management

Integrated Farm Management (IFM) is a site-specific farm business approach that uses the best of modern technology and traditional methods. Attention to detail is key; appropriate and efficient use of inputs, smarter approaches to business planning and the adoption of innovations and new technologies, all contribute to increasing productivity whilst protecting valuable resources.

IFM is made up of nine sections, which together address the entire farm business. Each of the nine sections is interrelated and an understanding of how they work together is essential for the effective implementation of IFM.



Figure 7. Integrated Farm Management Framework
(<https://leafuk.org/farming/integrated-farm-management>)

Integrated Weed Management (IWM) is a term discussed by many including the major agrichemical companies and similarly to IFM, is something that farmers are going to have to embrace.

The big players in the agrichemical space, Syngenta, Bayer, BASF and Corteva have no replacement for glyphosate. Company people I spoke with all said similar things. The company that develops a broad spectrum biological herbicide will own the game. The reality from these large companies however is they have no real appetite for biologicals, they are seen as outside of repeatable science and as such come with no guarantee. Instead they see themselves as players in schemes such as Integrated Pest Management (IPM) and IWM where chemicals are seen as a valid tool but only one of a number of other management methods e.g. monitoring for pest numbers before spraying rather than spraying for insurance. These large companies see the future more in smart technology than traditional chemistry and as such warn the industry of such a future.

6c. Case Study:

The Danish Seed Industry

New Zealand and Denmark are both large players in the international herbage seed market. I wanted to look at the industry in Denmark to understand how it operates in comparison to New Zealand but also how they are adapting to the regulatory environment

One thing that surprised me immediately was how many organic farmers there are and that the number is increasing. If it is happening in Denmark, should we be expecting it in New Zealand? To not look at organic is to not understand Denmark's natural progression.

Denmark is a member of the European Union, and therefore Danish farmers benefit from the EU Common Agricultural Policy (CAP). This policy consists of two main parts: Pillar 1 which provides direct payments to the farmers, and pillar 2 which is the rural development policy.

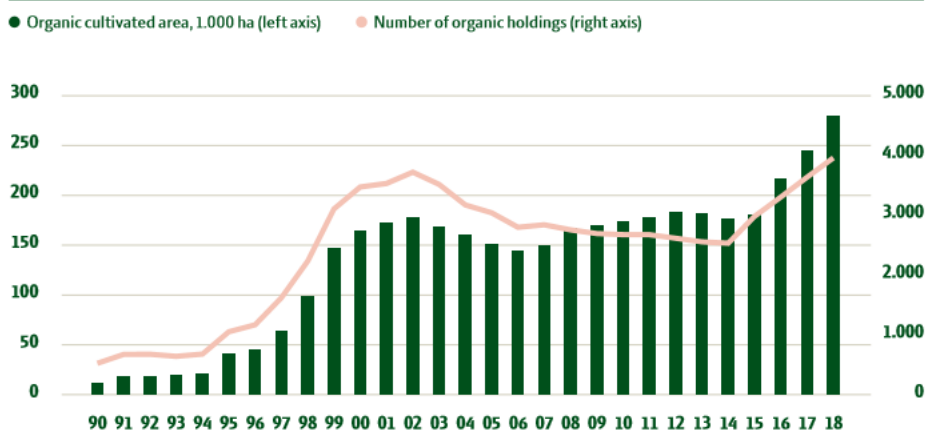
The direct payments aim to supplement the farmers income and at the same time support a competitive and sustainable production of agricultural products and food. Farmers must meet the high European standards of environmental protection, animal welfare, plant and animal health as well as food safety in order to obtain the subsidies.

The rural development policy supports actions such as modernising production facilities, as well as agri-environmental measures and organic farming.

The pillar 1. policy contains an ever-decreasing list of agrichemicals that are available to be used within the EU. The Danish government can further regulate chemicals on the pillar 1. list but they cannot authorise chemistry not already approved by the EU. Glyphosate is on this list and is due for review in 2022.

Denmark also has an ever increasing number of organic farmers with around 12% of farmland or 280,000 ha currently under organic control and this figure is increasing.

Organically cultivated area and holdings, 1990-2018



Note: Change in calculation method from 2005
 Source: Ministry of Environment and Food of Denmark

The Danish seed industry produces around 125,000 tonnes of seed annually and is responsible for around 50% of the seed sales by volume within the EU.

In anticipation of losing glyphosate in the near future, many growers and seed companies are trialling herbage seed production without any glyphosate. Currently red and white clover, red fescue, perennial ryegrass and cocksfoot are grown successfully. There are trade-offs however. The first trade-off is yield/quality. A conclusion given was that expect half the yield and pay twice the price as a rule. Conventional yields of red fescue are expected around 1300 kg/ha vs 800 kg/ha for glyphosate free. Secondly, volunteers from previous crops are a real issue under a no glyphosate scenario both in existing crops and also in the fallow period between. Figure 8. shows volunteer ryegrass in a cultivated field near Ringsted, Zealand. In a glyphosate free scenario, as in this case, these volunteers will be cultivated multiple to ensure they don't survive as contaminants in following seed crops. To further complicate this issue the

government strictly enforce a rule regarding ground coverage over winter. The mechanism for doing this is via a reduction in CAP payment if not adhered with. Farmers have found this frustrating without glyphosate in the past due to an increased time taken to adequately manage volunteers and comply with ground cover regulations.



Figure 8. Volunteer ryegrass following a cereal crop

A key feature of Danish seed production is the amount of companion cropping that is normal practice. White clover and Kentucky Bluegrass are established under spring barley. (Figure 9.) The barley is harvested in year one, white clover seed is then harvested in year two and then the Kentucky Bluegrass is harvested in years three and four. This practice avoids annual sowing and it also reduces soil disturbance which avoids weed strikes. The pillar 1. chemical list has made weed control very difficult and this is one strategy that is proving successful.



Figure 9. Companion crop of Kentucky Bluegrass and White Clover following Barley Harvest

Another strategy Danish farmers use is around weed seed management. It has been discovered that grass seeds will remain viable on the soil surface for only a short time, they will either germinate or die. Growers remove all residue from the previous cropping operation and maintain very short crops throughout the autumn and winter to stimulate seed mortality through sunlight (Figure 10)



Figure 10. Kentucky Bluegrass mown for weed seed management

Arable farmers are beginning to adopt smart technology as a means to weed crops. The combination of GPS and smart camera technology is being used in hoeing machinery that can interrow and interplant crops. GPS technology is now available that can plant row crops in two dimensional patterns and record where individual plants are for individual weeding.



Figure 11. Garford robotic tractor mounted inter row cultivator

Machinery such as the Garford robotic tractor mounted inter row cultivator can be configured in a variety of ways and are now widely used in Europe. When you combine this with seed planting equipment that will plot with GPS where individual plants are located, the future of mechanised weeding is bright.

The mood of the seed industry generally in Denmark, is that production of many seed crops will move from to Eastern Europe or other parts of the world where the regulations are less severe, and this is for both organic and conventionally grown crops. Plans are afoot for this and grass seed crops are being grown in Romania already.

Production of seed in Denmark will cease in its current form if the EU decide to deregister glyphosate in 2022. Farmers and company officials predict that this will be the case. The exit of seed production will leave farmers with two options, producing commodity cereal crops and/or animal farming. I predict that the regulations will soften in time, but there will be collateral damage along the way in the form of a value added product.

What I saw in Denmark was an industry under siege from environmental constraints. Farmers expect that organics will be forced upon them in the future as their chemical management options diminish. The seed industry, like

New Zealand, is relatively small in terms of importance to the country's economy and to a large degree is collateral damage in a much bigger movement.

Growers in Denmark are making good progress and are innovating with machinery and management. An important observation is the commercial reality that farming with restrictions are having and that the flow on effects need to be considered. A key difference to New Zealand is the effect of subsidisation. Farmers are profitable because they are paid to be and as such incentivised to make the changes that the wider population require of them.

Environmental constraints are a reality for every farmer and the farmers I spoke with found the practicalities quite restrictive at times. Issues such as volunteer weed control coupled with ground cover restrictions are one example. However, when you consider the value chain, Denmark is farming to the constraints as set down by their consumers and every member of the chain must comply.

7. New Zealand without Glyphosate

The first thing to consider is how different New Zealand agriculture is to almost anywhere else. We are unique in the world with grazing animals and the way in which we integrate them into other farming systems, arable, horticulture and viticulture. Our arable systems generally include livestock and by default we already cover crop for animal feed. The important history in this is that a lot of our arable farming systems have evolved out of mixed farming operations. The same is true in the UK, however the integration between the two are not as common as in New Zealand today.

The arable and horticulture industry are the two sectors that will feel the loss of glyphosate the most. As shown in table 3. They are the two sectors with the heaviest potential use per hectare. They are also the two that continuously grow and harvest annual crops.

Farming without glyphosate will mean for those current growers, a complete mind shift in how they operate. This was true of life after 1974, farmers completely changed their mindset and this will be no different in a world without. In the case of Beeswax Dyson, the paddock situation on the day dictates the cropping decision. Currently normal practice in NZ is generally paddocks are scheduled sometimes years ahead for particular crops at particular times and the management fits around this. The opposite will be the reality and the crop will fit around the management.

Reflecting on the Denmark case, the small seed industry is under serious threat and that would almost certainly be the case here. New Zealand is fortunate that we still have alternative chemistry. Diquat and Paraquat are both available as an alternative broad spectrum herbicide but both are undesirable as a replacement. More selective chemistry would also be used. All of these alternatives come at a cost in terms of environmental stability, desirability and, as mentioned earlier, residues and plant back restrictions. There will be a greater reliance on pre-emergence, soil active chemical controls such as the triazines.

New Zealand is seen internationally as a very safe place to produce and multiply seed. Our secure governance and regulatory structure, coupled with complimentary soils, climate and abundance of irrigation water, makes New Zealand a first choice production country for many and indeed for our own established companies. The trade of these seeds is all based around purity.

Purity is a measure of contamination of a seed line by other species. The world regulations that govern the seed trade are very strict on this purity and in most cases the purity can dictate the price. The value of the grain and seed industry in New Zealand is around \$1 billion with \$239 million of that coming from the export seed trade. (NZGSTA)

The loss of the seed industry to New Zealand arable is the loss of the arable industries differentiation with the rest of the world, the loss of the industry's ability to add value to its product. The alternative is commodity grains, horticulture and pastoral agriculture. Commodity grains in New Zealand have historically been almost cost neutral to produce due to transport constraints to markets and imported product from Australia is a more viable option for many end users particularly in the North Island.

Farming without glyphosate will absolutely see an increase in livestock numbers and particularly in Canterbury, where the majority of arable farming occurs and, in many cases, it will mean wholesale changes to more intensive livestock as the only viable alternative, more cows, more sheep, and more methane. In my opinion we will see as predicted by both Brookes and The Anderson Centre, increases in cultivation which will lead to an increased use of fuel and a reduction in productivity through time spent with multiple cultivation. There will be losses in productivity due to an unwillingness to renovate pasture. This flows through to reduced pasture performance, animal performance and also reduced seed sales domestically.

There is technology being developed that can plant, spray, weed, and harvest an individual plant to within a centimetre with repeatability. There are machines that can plant seed into standing crops to accurate depths at speed and at scale. There is technology coming that can identify the plant species and then with pin point accuracy spray the particular weed with the appropriate product and avoid the planted crop. These types of technologies will only improve. The uptake of this type of technology has the potential to seriously reduce the amount of glyphosate used particularly in pre-harvest weed control and virtually remove the risk of residues in food.

I believe we will see farmer led innovation in this area and there is no doubt that the future crop mix will not be as it is today.

Reflecting on what I have seen around the world and even what is happening in New Zealand, there are options and they mainly revolve around more

holistic types of management. In the central valley of California, I visited an organic vegetable grower who found that drip irrigation had reduced his weed problem to almost nothing. Simply the soil surface was so dry that weeds would not germinate. Transplanted tomatoes were able to capture the drip water below the germinating zone. (Figure 12.)



Figure 12, Weed free organic tomatoes growing above drip line irrigation

In France, popcorn producing company Natais have initiated corn planting into standing faba beans. (Figure 13) The beans are planted in the autumn on top of a ridge. In the following spring corn is planted into the standing beans between the rows. The Beans are pushed over and provide ground cover that restricts weed growth and also provides nitrogen for the subsequent corn crop. An active living root also helps increase soil carbon. This is considered standard practice for Natais growers and they are paid an incentive for doing so.



Figure 13. Sowing corn into standing faba beans.

New Zealand as a country is well positioned for an environment post glyphosate and will adapt if necessary. The trade-offs for the country is a vastly different arable and horticulture industry, with a movement away from

one value added industry towards more of what the population are saying we don't want, namely animals and more fossil fuel.

8. Conclusions

A year's worth of travel, observations, questions and thoughts are difficult to sum up succinctly. I set out to try and understand the issue as it was broken down between Prof Jacqueline Rowarth and Kathryn Ryan that morning listening to their interview. My opinion on this is they are both correct in their view. A frustration for me in all of this trying to decide where farming should position itself within this conflict.

An important consideration that farmers must respect is that glyphosate residues are found in food. Science around these residues is well known and governed accordingly in New Zealand. Currently there is no suggestion that glyphosate will be deregulated here but we do need to be mindful of the growing opposition to its use. The opposition maybe around correlations at this stage but what if those correlations turn out to be true? As farmers we owe it to consumers and the future generations to constantly improve our best management practices. We must consider the end point of produce and realise that best is not always just about complying with the regulations.

In my opinion western countries have become so reliant on glyphosate and it is used so much that to stop using it would devastate world supplies of agricultural commodities and it would do so overnight. In the case of North America alone, how do you go about changing such a vast farming system without upsetting the balance of food production in some way?

The maths has been done, as a global industry, without glyphosate we will require more land and produce less from it, consume more fuel and risk global food security. The challenge of feeding an ever growing population requires efficiency and could see a change in crop mix in the future.

I have seen examples of what can be done without glyphosate but conclude that it is too important strategically to say we can do without it. One immediate thought is we need to do more to reduce our dependence on this product. Incorporating as many other methods of husbandry as we can, in a similar vein to both Beeswax Dyson and LEAF's IFM strategies. We are incredibly fortunate in New Zealand that our farming systems are already integrated with diversity of crops and animals and are already a long way down this road.

A key distinction when comparing international practices is New Zealand's free market economy and how that influences the outcomes of many key decisions. Farmers in Europe and the UK operate within a government subsidised environment. As is the case in Denmark, many believe they will eventually be forced into organics, the key difference is they will be subsidised in doing so.

Glyphosate has been labelled the 'chemical of the century' and could remain if we treat its use as a specialist tool rather than a duster on a blackboard. For industries such as the international seed trade, it is the backstop that allows the industry to add value. In direct contrast there is real value to be added in marketing feed crops as glyphosate free.

At the very core of this topic is a social issue that doesn't revolve around one chemical product. It is one symptom within a movement of people with a voice who not only question the origins of their food but make value suggestions about alternative supplies. Too often these suggestions are made in isolation without any consideration of the unintended consequence of that action. It seems the communication between the two groups only flows one way which is understandable. How can the voice of normal be heard when an alternative is always more appealing? Agriculture must do its absolute best to ensure its voice is heard and that it actually engages with population. We must also make every effort to listen, not to the noise but to what is the underlying message. The mechanism for this will be a challenge, it is the biggest challenge farmers face.

In 1974 Monsanto developed a product that would revolutionise agriculture and food production. With claimed zero soil residue, low toxicity and a very broad weed spectrum, it would become the most widely used agricultural chemical product on the planet. It would be responsible for the development of very efficient farming systems and viewed by many as the most important agricultural development in history.

Today there are a growing number of people who question the overuse of this product and lay the blame for a number of health and environmental issues on it. As an agricultural industry we cannot deny the conflict that exists and need to think of this tool as just one of a number and not necessarily number 1.

I do not want to see an end to this incredible product that is so important to sustainable agriculture. I would prefer to see more strategic use and long term availability.

9. Recommendations

1. No preharvest weed control applications

Glyphosate residues are finding their way into food. The logical entry point is pre harvest weed control in cereal crops and through applications to hay/silage pre mowing or grazing. We must as an industry recognise the importance of this issue. We owe it our consumers to continually improve best management practices including stopping glyphosate use at these two points. This is only a very small issue in New Zealand but one we must be mindful of at all times. The risk of losing glyphosate in New Zealand is low but could be looked at if residues are found above the MRL's or the science changes. The importance of glyphosate strategically and its continued availability is threatened by inaction. Peak industry bodies could help foster this recommendation.

2. Discuss openly the future of agriculture including GMO

Agriculture needs to address the tough questions for our farming future in an open and honest way. Not just glyphosate, but GMO, CRISPR-cas9 and other technologies. As a trading nation, our image is everything and we must be very conscious that any changes we make could affect our tradability. There is a real dilemma around GMO in that it could potentially reduce chemical input and increase production in marginal areas, yet we potentially taint our image in adopting the technology. GMO discussions in the past have been derailed by activism and politics. There are real benefits for farming, the environment and the consumer. Exactly how these questions could be discussed would be a challenge and would need careful consideration

3. Communicate with the public.

A lot of what I heard and have reflected on is the result of a lack of understanding from consumers. We must as an industry endeavour where possible to explain to the public about agriculture, about farming, the complexities of modern farming systems and international trade. The linear

nature of the value chain means there is no fee back loop and we must address this problem. The mechanism for doing so is endless with social media as one example.

4. Model glyphosate use within the New Zealand economy.

A frustration in preparing this report was a lack of specific New Zealand data. Without critical numbers modelling of a New Zealand scenario could not be done accurately and any conclusions were made on overseas work or my own assumptions. While appreciating the commercial realities of the situation, it is an important discussion that maybe an independent economic institute could investigate.

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11. Scholar Biography

I am 42 year old arable farmer, married to Melanie and we have three daughters aged between 9 and 4. Along with my brother and his wife and our parents, we operate a 500 hectare mixed arable and stock property, above Methven. Our farm, Longfield, has been in my family since the 1870's. We take great pride in maintaining it for the future generations and respect those family members who have done the same on our behalf.

We grow a range of different crops and specialise in grass seed production and processing. Our operation involves crops, sheep and replacement dairy stock and they complement one another well.

Prior to farming I gained an agricultural commerce degree from Lincoln University in 2001 and spent four years as a field officer for Ravensdown Fertiliser following. In 2005 Melanie and I spent a year traveling overseas before coming home to pursue a career in farming.

Outside of the farm I am active in four industry organisations and enjoy challenge that these roles present and respect the positions I am in on behalf of others.

To have been awarded a Nuffield Scholarship is similar to being selected as an All Black in status and I am very proud to have had the honour bestowed on me.