New Technologies in Arable Farming

Michael Tayler 2012 Nuffield scholar

A report for the New Zealand Nuffield Farming Scholarship Trust

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Executive Summary

Agricultures importance in the world is growing**.** In 1988 New Zealand agriculture was infamously described by David Lange, the then leader of the Labour party as “a sunset industry”. He believed New Zealand’s reliance on agriculture was diminishing and the country should now be focusing on manufacturing and tourism. 25 years on agriculture is as important to New Zealand’s economy as ever. Today agriculture is seen as an industry of the future with the outlook for farming never as bright.

Every day there are more people on our planet than the day before. Demographers tell us that the planet is gaining around 160,000 extra people every day. With global starvation already higher than it has ever been, especially in the developing world, pressure on agriculture to lift production and fill this food shortage will continue to increase.

Where will this additional food come from?

There will be small gains made from better food distribution, improving transport networks and by minimising the enormous wastage from paddock to plate but the greatest increases in available food must come from increasing production on farm.

Farmers’ ability to keep lifting yields at the same rate using conventional farming methods is diminishing, so any further gains will involve the capacity to adapt and adopt new technologies. These new technologies, whether they are precision agriculture, genetically modifying crops or something else entirely, will certainly play a part in achieving the additional production that is needed.

New Zealand is a country that can benefit from this increased global demand for food. With an economy that is more reliant on agricultural production than most, increasing agricultural exports would have direct benefits to the wealth of our country. New Zealand has many natural advantages, from its fertile soils and temperate climate, to its established production systems and recognised quality assurance programs, creating huge opportunities for agriculture throughout the country. As an already high yield producer, New Zealand’s gains will come from looking at fresh ways to improve production and adopting new technologies rather than any modest variations to our existing farming systems.

Two of these technologies, Genetic Modification (GM) of crops and Precision Agriculture are both likely to play a big part in New Zealand’s agricultural future.

Due to rapid advances in equipment, software and expertise, the Precision Agriculture industry will continue to progress and evolve helped by a greater uptake from farmers. The ever increasing environmental pressure now on farming means the ability to accurately apply, record and map any inputs will become more important than ever. The real benefits of precision agriculture are still ahead of us.

While the advantages of precision agriculture are generally understood and accepted, the benefits of the genetic modification of crops are less so. Critics of GM food products insist that they are unsafe, untested, unregulated and unnecessary. But the facts are starting to show otherwise. We are starting to consistently see many benefits including new varieties of crops like wheat or maize with resistance to different pests and diseases. This in turn is leading to lower pesticide use and higher yields. It is often quoted that in North America there has been over two trillion servings of food that contain GM ingredients without any cases of documented harm. Is this enough? How long will it take before the science is seen to be proven?

Currently New Zealand is practically free of any Genetic Modification due to the very strict regulations around release. But for GM to be a useful tool for the future, research has to start now. This research is critical to New Zealand's future.

Globally public attitudes towards GM may be softening but the New Zealand consumer still might not be quite ready for GM technology. New Zealand farmers will be commercially growing genetically modified plants one day, but not yet. While there is growing interest from producers and consumers, there still needs to be more information on the benefits and risks so the purchaser is able to make an informed decision.

Education is the key, moving people away from the extremes to more middle ground. There is also a need to respect the views of people who take a contrary view and respect people's right to choose.

But Genetic Modification is a powerful tool if used well which may bring many benefits to future generations. Can New Zealand agriculture afford to turn its back on this?

At the very least this is a debate worth having.

Acknowledgements

To be awarded a Nuffield scholarship has been one of the most rewarding experiences of my life. To allow me to take part in the Nuffield programme there are many people who have given me support and encouragement, without which I could not have completed it.

Firstly thank you to Stuart Wright (Nuffield International Chair) for 'sowing the seed', Julian Raine (Nuffield New Zealand Chair) and all the trustees of the Nuffield New Zealand Farming Trust for creating what has really been the opportunity of a lifetime.
To Richard Green (Director of Nuffield New Zealand) and Barbie Barton (Secretariat Nuffield New Zealand), thank you both for your guidance and support.

Obviously this all would not have been possible without the on-going sponsorship of our Nuffield partners; Agmardt, Dairy NZ, Beef + Lamb NZ and Farmers Mutual Group, who continue to proudly invest in New Zealand agriculture.
Also our supporting sponsors Foundation for Arable Research, Mackenzie Charitable Trust and Landcorp; to all of you I am extremely grateful.

In addition thank you very much to Nuffield Australia, especially their CEO Jim Geltch, for allowing me the opportunity to join the Global Focus Programme. This seven week trip was the highlight in a year of highlights. The organisation and itinerary were fantastic and I feel lucky to have travelled with such a special group. Brenda, Ewan, Jemma, Linda, Mark, Robin, Sandra, Shane and Stu, thanks for your laughter, your company and for making our trip the extraordinary trip it was.

Before setting off on my Nuffield adventure many individuals assisted me with arranging contacts and sharing their knowledge. Thank you to Nick Pyke at FAR, Nick Brookes and Murray Kelly from PGG-Wrightson, Greg Carr from Winslow Ltd, Phil Rolston from AgResearch and Bill Angus, U.K. wheat breeder.

To all the wonderful people who housed, fed and entertained me right around the world, your hospitality really was appreciated, especially Henry and Mary Wilson for providing me with an English home away from home once again.

Thank you to all my fellow participants on the 2012 Worshipful Company of Farmers Advanced Management course. I value your friendship and could not have asked for a better group and hope to be able to return all the hospitality one day. There were so

many more wonderful people I have met around the world that have helped me in so many ways, to you all thank you.
Thank you also to Sandra Taylor for spending the time to proofread this report .Your help was really appreciated.

I would like to also thank my friends and family for their unwavering support and encouragement. My parents, Peter and Jo Tayler, and special mention to my brother Nick for the exceptional job he did covering for me in my absences over the year.

The Nuffield scholarship has been such a unique experience and one that I will be forever grateful for. It has challenged me, changed me and provided me with some wonderful new friendships and networks that will always be valued.

Finally, I give a special thank you to my wife Sally and three boys Sam, Will, and Henry. For the sacrifices that you all have made this year and your encouragement and unconditional support, I will always be incredibly grateful.

Preface

It is said timing is everything, and although I didn't know it at that stage, when I came home to South Canterbury to farm fulltime in 1994 I was lucky with my timing.
New Zealand agriculture had just shaken off the painful legacy of the previous decade of high interest rates, the removal of subsides and some tough droughts.

Over the following 19 years of my farming career we have seen farming as an industry in New Zealand stabilise and grow. With unprecedented year-on-year increases in land value, farmers have been able to leverage against this new equity in their businesses, borrowing large amounts of money to invest in new ideas and technologies.

This "low hanging fruit" has seen huge advances in many areas of New Zealand agriculture. With increased and smarter use of fertilisers, better plant breeding programmes and more recently precision agriculture, we have seen crop yields lift substantially over this period.

But….where to from here?

Ironically the day of my Nuffield interview was the day the world population officially reached seven billion people. Against this background of a rising population and a slowing of yield growth, I was interested to see what the new technologies may look like and how New Zealand might position itself to capitalise on the increasing global demand for food.

Over the last nine months I have travelled extensively, looking at global agriculture and wondering where these next gains in food production will come from. Two areas that seemed to come up again and again were Genetic Modification and Precision Agriculture.

There may be other ways to increase food production but for the purposes of this report I will focus on the two areas where I see the most potential.

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Introduction

"Of history, one thing is certain: Civilisation as we know it could not have evolved, nor can it survive, without an adequate food supply. Likewise, the civilisation that our children, grandchildren and future generations come to know will not evolve without accelerating the pace of investment and innovation in agriculture production." Mr. Norman Borlaug, a professor at Texas A&M University who won the 1970 Nobel Peace Prize for his contributions to the world food supply.

Never before in our history, has there been such demand on agriculture and pressure on our natural resources. As the world population continues to grow at an alarming rate the burden on our resources to provide for this increase intensifies. With very little new land coming into production and continued urban sprawl of cities and towns, the pressure on existing land is rising.

Globally we need more food. To satisfy this demand, agricultural nations around the world must produce more. In this report I am going to be looking at how this can be done, the background to the food shortage and what part, if any, New Zealand agriculture and specifically arable farmers can play. Will current conventional cropping practises be sufficient or do we need to find new ways to lift yields?

Around the world cereal yield growth is slowing. Between 1961 and 1990, yields were increasing by 2.5% per year. But over the decade 1990-2010, this annual increase almost halved to 1.3% with the Food and Agriculture Organization of the United Nations (FAO) predicting a further drop to only 0.7% cereal growth yearly until 2050.[1]

From these trends and predictions it is evident that innovation is required. This could come from advances in science; through genetic modification, allowing us to breed plants that are tailored to grow and flourish in many diverse environments.
On-going advances in precision agriculture will be important also. As the precision agriculture industry matures and the technology evolves, it will give farmers the ability to plant seeds, apply inputs and measure results more accurately than ever before. This improved precision will not only lift yields but also provide financial and environmental benefits.

Food is a basic human right.

According to the United Nations:

- food insecurity threatens more than 1 billion people worldwide [2]
- nine million people die every year from malnutrition[3]
- hunger claims the lives of 12 children every minute[4]

Simply if world agriculture cannot adapt and advance then starvation will increase.

New Zealand is a country that can benefit from this global imbalance of food. Through a commodity-based economy that relies on agriculture more than almost any other developed country in the world, the prospects for New Zealand are greater than most. With the strong economic growth of the developing world forecast to continue, particularly Asia, it presents an exciting and huge opportunity for agriculture in New Zealand.

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[1] Jelle Bruinsma, "The resource outlook to 2050: by how much do land, water and crop yields need to increase by 2050?",FAO, 2009.
[2] Food and Agriculture Organization of the United Nations. 2009. "More people than ever are victims of hunger." www.fao.org/fileadmin/user_upload/newsroom/docs/Press%20release%20june-en.pdf
[3] Borlaug, N. 2009. "Farmers Can Feed the World." Wall Street Journal. Accessed 3/01/13. http://online.wsj.com/article
[4] World Food Programme. "Winning the War on Hunger." Accessed 3/01/13. http://one.wfp.org/policies/introduction/other/documents/guide_winning_hunger/ENG/home.html

CHAPTER 2

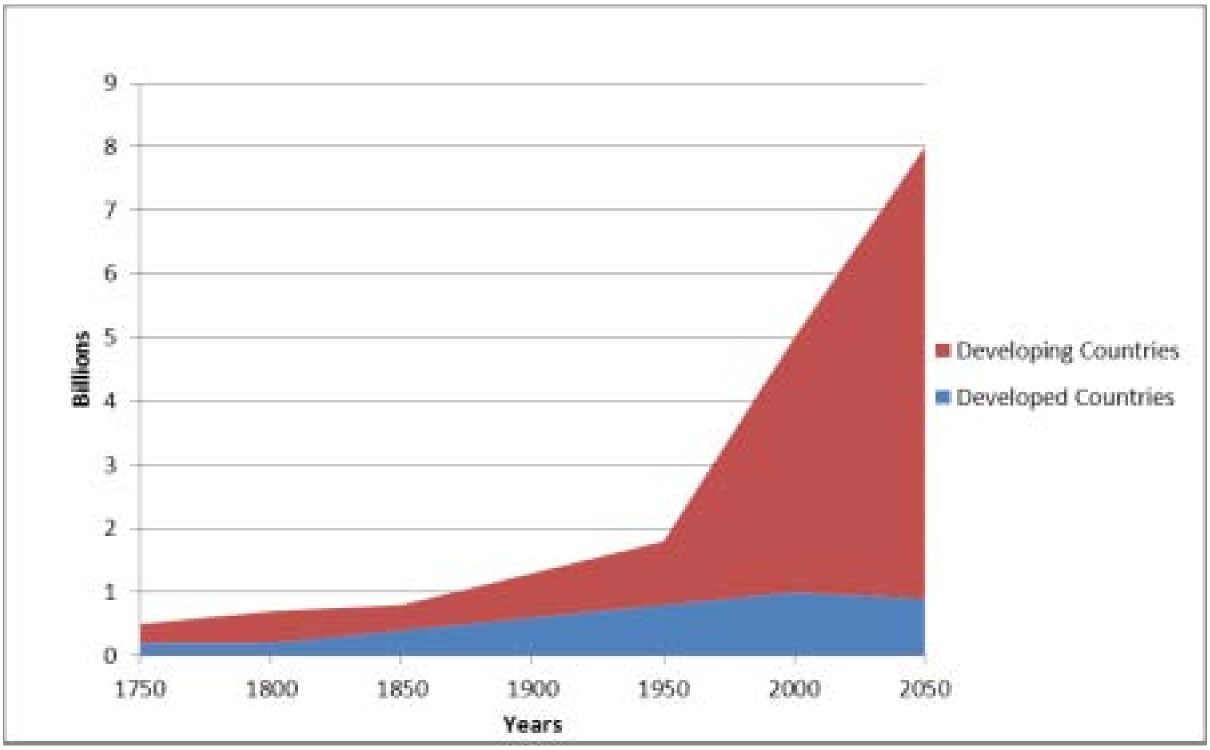
Background

Throughout history man has had the ability to feed himself. With the exception of periodic events such as drought, political instability or agronomic failures, the planet's plentiful resources have meant the human population has been able to nourish itself. What is different today and what are the reasons behind this perfect food storm?

Population

The simple answer is the world's population is increasing at such a rate that increases in the production of food are not keeping up. After many centuries of steady growth, the world population accelerated after the Second World War, with the last 25 years seeing over two billion more people added to our planet. Because of this the global food table is becoming ever more crowded.

Figure 1 : Change in World Population, 1750 - 2050



Source: United Nations (2001)

Interestingly nearly all of this increase has come from the developing nations (Figure1). As recently as 2005-2010, the developing world contributed almost three quarters of global growth. Between 2011 and 2100 the populations of high-fertility countries, which includes most of sub-Saharan Africa, are projected to triple, rising from 1.2 billion to 4.2 billion.[5]

This rapid rate of growth will slow (Figure 2) due to a anticipated population decrease in some developed countries such as Germany, Italy, Spain and Japan but the world population is still predicted to rise to around 9.3 billion by 2050.

Figure 2: Rate of change of World Population

Population		
Years Passed	**Year**	**Billion**
-	1800	1
127	1927	2
33	1960	3
14	1974	4
13	1987	5
12	1999	6
12	2012	7
14	2025*	8
18	2043*	9
40	2083*	10

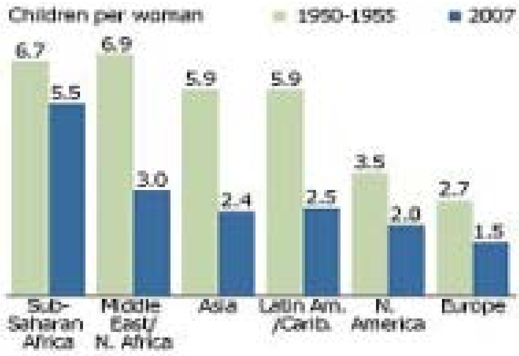
* United Nations Population Fund estimate

Why the recent growth?

There are two significant reasons for this spike in population growth, decreasing mortality rates and longer life expectancy. From the second half of the 19th century, death rates (especially in the developing nations) have been steadily reducing due mainly due to the advances in modern medicine.

[5] Source: United Nations (2007)

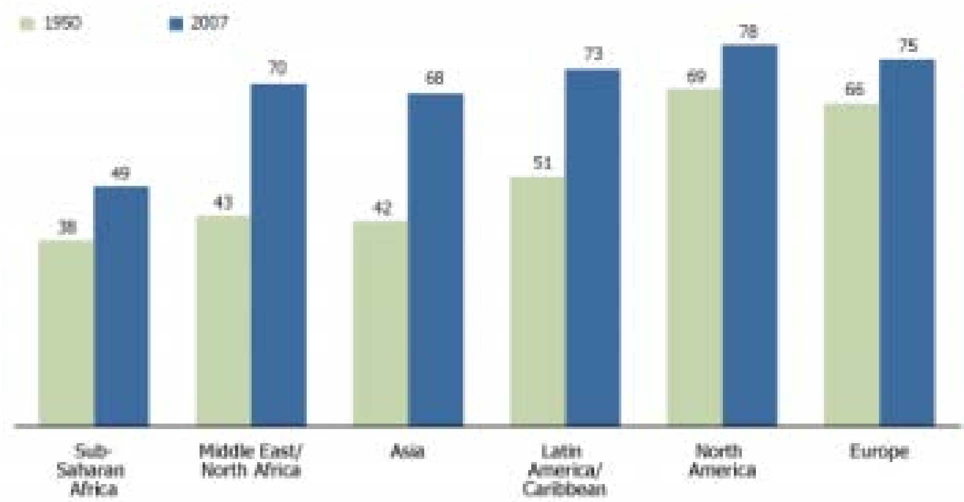
Figure 3: Fertility rates 1950-2007



Source: United Nations, *World Population Prospects: The 2006 Revision* (2007); and Carl Haub, *2007 World Population Data Sheet.*

These advances in medicine mean babies born today are now surviving longer [6] even though fertility rates (figure 3)across the globe are declining. When this higher survival rate is combined with a longer life expectancy we see populations rise. This is particularly so in the developing world, where the average life expectancy at birth from 1950 to 2007 has risen from 41 to 66 years. Even developed countries, while not as great, have shown lifts in life expectancy. Over the same period from 1950 to 2007, the average life expectancy at birth for men rose from 64 years to 73 years while life expectancy for women rose from 69 to 80 years.

Figure 4: Life Expectancy Has Increased Most in Less Developed Regions Since 1950.



Source: United Nations, *World Population Prospects: The 2006 Revision* (2007); and Carl Haub, *2007 World Population Data Sheet*.

[6] A dramatic decline in fertility rates during the 20th century coincided with decreased child mortality, access to family planning, economic development, increases in girls' and women's education, and urbanization.

So not only do we have more people on the planet than ever before but they are also living longer than ever before. There are some who believe, due to the exponential advances in modern medicine, that the first person to live to two hundred years old has been born already.

Income

Rising wages are another factor contributing to demand on food globally. As incomes increase, diets are changing to greater calorie consumption and higher protein diets, especially in the developing world. A study by the OECD suggests that China alone could see 75% of its population reach middle class status by 2030.[7]

Land

"They are not making any more land" - a common expression heard from buyers when purchasing farms around the world.

The availability of arable land around the world influences production. With increasing competition for land from urban expansion, industrial growth, biofuels and the mining industry do we have enough land to sustain this growth?

Globally agriculture uses around 4.9 billion hectares (37%) of the world's total land area. Another 4.1 billion hectares (31%) of the remaining land is in forestry with a further 3.6 billion hectares (27%) regarded as desert or unsuitable for sustainable agriculture. The remaining 5% of global land area is taken up by cities and towns.

Of this agricultural land, arable farming takes up around one third. This is only predicted to grow by 0.1% per annum, [8] which is a significant slowdown from the 0.5% annual growth seen in arable land over the past 40 years. [9]

Water

As with land, do we have enough water?

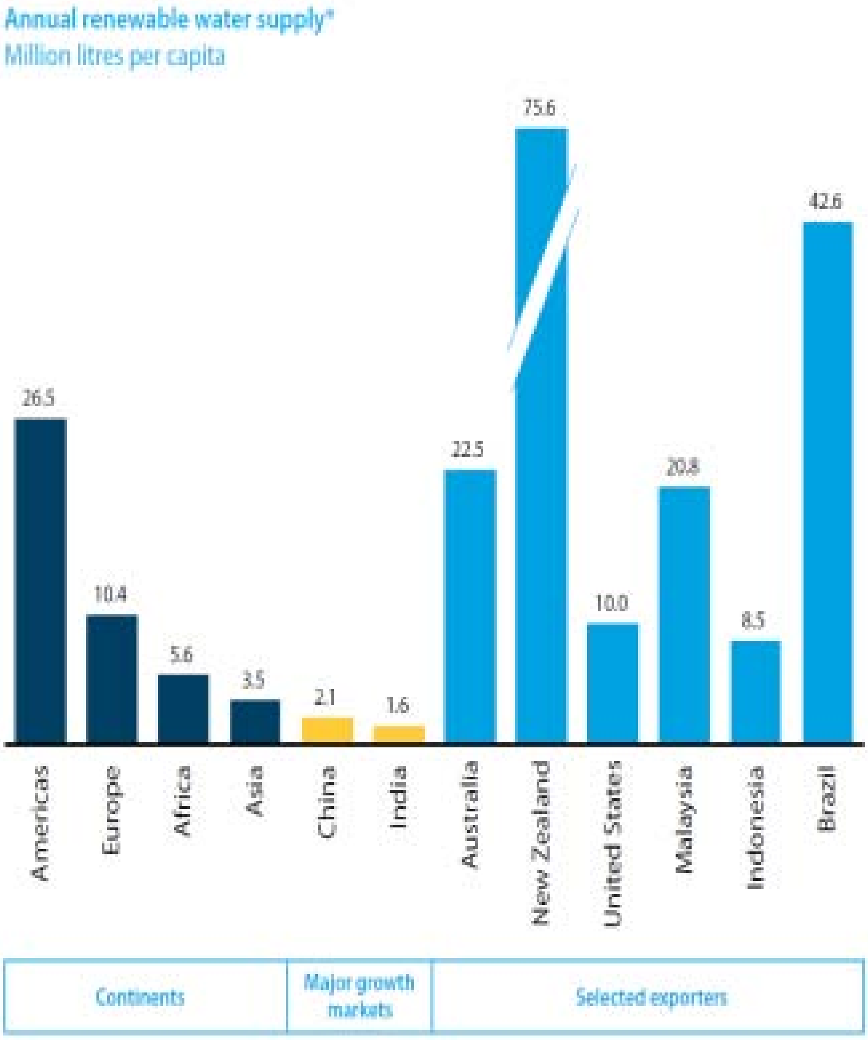
Seemingly no. One estimate suggests that between 15% and 35% of water used for agriculture is unsustainable. [10]Accordingly numerous farmers around the world say that

[7] " The Emerging Middle Class in Developing Countries", Working paper No. 285, OECD Development Centre, January 2010
[8] The Food and Agriculture Organization of the United Nations
[9] "World Agriculture Towards 2030/2050: 2012 Revision", FAO, 2012.

water availability is one of the major concerns they face going forward. With aquifers drying up and well levels dropping; water availability is reaching critical levels. Agriculture already uses almost 70% of all water withdrawals and will only face more competition from domestic and industrial uses as poorer countries develop and progress. Infrastructure like running water and flushing toilets will become more common-place increasing demand on already overstretched water resources.

Countries like China, India and the US already have huge areas where water use is outstripping supply.[11] For example, studies have identified more than 160 areas in China suffering from the over-exploitation of ground water for urban use.[12]

Figure 5: Water resources by region and country - 2009



** Fresh water from surface and underground sources, including rainfall.* Source: FAO.

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[10] "Ecosystems and Human Well-being: Synthesis", Millennium Ecosystem Assessment, 2005.
[11] "Unsustainable water use threatens agriculture, business and populations in China, India, Pakistan, South Africa and USA – global study", Maplecroft, 10 May 2012.
[12] "Ensuring the Safety of Urban Water Supply, Facilitating the Frugal and Appropriate Consumption of Urban Water", Ministry of Construction, People's Republic of China, August 22, 2006.

As figure 5 shows, excluding New Zealand and Brazil, there is a severe shortage of available fresh water around the world especially in Asia where emerging nations like China and India face serious challenges.

So what effect does this have on agriculture?

This global water shortage added to restrictions on new arable land, and an increasing population, means agriculture has to continue to develop new ways to increase yields and production. In recent years the desire for agricultural products has seen demand begin to outstrip supply causing volatility in global food prices. This is in contrast to the 20th century where commodity surpluses were common. This new demand will provide vast opportunities for countries who are net exporters of produce.

CHAPTER 3

New Zealand Agriculture

When looking around the world at countries that might benefit from this increased global trade and demand for food, New Zealand would be near the top of the list. As a young and fertile land with rich soils and a temperate climate New Zealand is ideally suited to producing high quality safe food products.

New Zealand relies greatly on its ability to grow, process and successfully export its produce to every part of the world. Over the last decade New Zealand has been growing its agricultural exports by 9% per annum, primarily on the back of its hugely successful dairy industry. Unlike many other developed countries, agriculture is one of the main drivers of New Zealand's economy, with the primary sector in 2011 providing over half of all New Zealand's exports with earnings of NZ$ 27.1Billion.[13]

Figure 6: The Canterbury plains – New Zealand

[13] Statistics New Zealand, 2012

As a politically stable agricultural producer with a reliable legal system and strong property rights, New Zealand has many advantages over its international competitors. Its efficient and competitive primary production systems combined with abundant water and a favourable temperate climate enables New Zealand to produce more per hectare than almost anywhere else in the world.

Combined with an ability to produce food, New Zealand has developed an international standing for its food quality and safety standards. Its reputation for having strict on-farm quality assurance requirements right through to its rigorous food safety regulations mean it is well placed to take advantage of any new trading opportunities that may present themselves. As the world's largest dairy exporter and one of the biggest sheep meat exporters, trading is a real strength of New Zealand and it is seen in the world of trade as a reliable exporter of food.

As populations continue to rise, particularly in Asia, pressure will come on each countries own resources. This may cause them to focus away from exports and more towards securing food for their own people, presenting further opportunities for export-reliant countries like New Zealand.

Two growing export markets with huge potential for New Zealand are China and India. These two countries have more than one third of the world's population but less than a fifth of the world's arable land and less than a tenth of the world's renewable water[14] , creating an increasing reliance on imports.

New Zealand's free-trade agreement with China (the first developed country to negotiate one), secured in 2008 provides New Zealand with an advantage over its competitors by allowing greater access to this ever expanding market. In the period 1990 – 1993, the value of China's agricultural imports was 82% of its agricultural exports but by 2006-2009 that figure had increased to 191%, making China now a major global net importer of agricultural products.

Currently India is New Zealand's seventh largest export market and while the country is still a net agricultural exporter, its volume of imports are growing, having nearly doubled as a percentage of exports, from the period 1990 -1993 to 2006 – 2009.[15] India is predicted to be the third largest economy in the world by 2025, consequently its importance to New Zealand as a trading partner cannot be underestimated. [16]

Like many agricultural countries around the world New Zealand still has challenges to overcome. Shortage of labour on farms is one of the problems farmers are facing today. With an ageing population and many young people moving to the cities, farmers are looking overseas for seasonal or permanent staff to countries like the Philippine's and the Pacific Islands. This is particularly so in the dairy industry.

[14] ANZ Insight report, issue 3, October 2012
[15] The Statistics Division of the FAO (FAOSTAT), 2012.
[16] New Zealand started negotiating a free trade agreement with India in 2010 and hopes to have agreement by 2015.

Increasing environmental and regulatory pressure is also seen by some as a constraint to future growth and may be putting New Zealand agricultures competitiveness at risk. Farmers “right to farm” is seen as being eroded by layers of bureaucracy causing inefficiency and frustration to those on the land.

An unpredictable and volatile currency is another concern and makes an export dependant country like New Zealand susceptible. With agricultural debt already at high levels, (NZ$48.3 billion)[17] the ability of farmers to raise capital to fund growth and allow succession is also limited. Foreign investment and equity partnerships may be a way to overcome this.

Other factors such as an increased focus on research and development, the closure of the significant gap between the top farmers and the rest, improving regulations around water and investing in new technologies and best practices are all critical to future growth in New Zealand.

Overall New Zealand agriculture is fortunate; if these issues can be addressed then it is well positioned to capture the rewards available in agriculture today. A greater uptake of the two technologies covered in this report, Genetic Modification and Precision Agriculture may help New Zealand increase arable production to meet the demands of a growing world market.

[17] Reserve Bank June 2012

CHAPTER 4

Genetic Modification (Engineering)

Genetic engineering (also called genetic modification) is the direct manipulation of an organism's genome using biotechnology. New DNA may be inserted in the host genome by first isolating and copying the genetic material of interest. - Wikipedia

Background

The term *Genetic Engineering* was first used by Jack Williamson, the American Science fiction writer, in his book *Dragons Island* back in 1951.Although it was not until the early 1970s that the direct manipulation of DNA by humans actually started to occur. Starting with the first genetically modified mouse to the successful production of genetically engineered high quality human insulin, Genetic Modification was here to stay.

Today, 40 years later, there are many areas where GM technology is used including medicine, industrial biotechnology and of course agriculture. It is arguably in the field of agriculture, in particular commodity foods, where GM has been the most controversial and for the purpose of this report will be the area of focus.

What is Genetic Modification of plants?

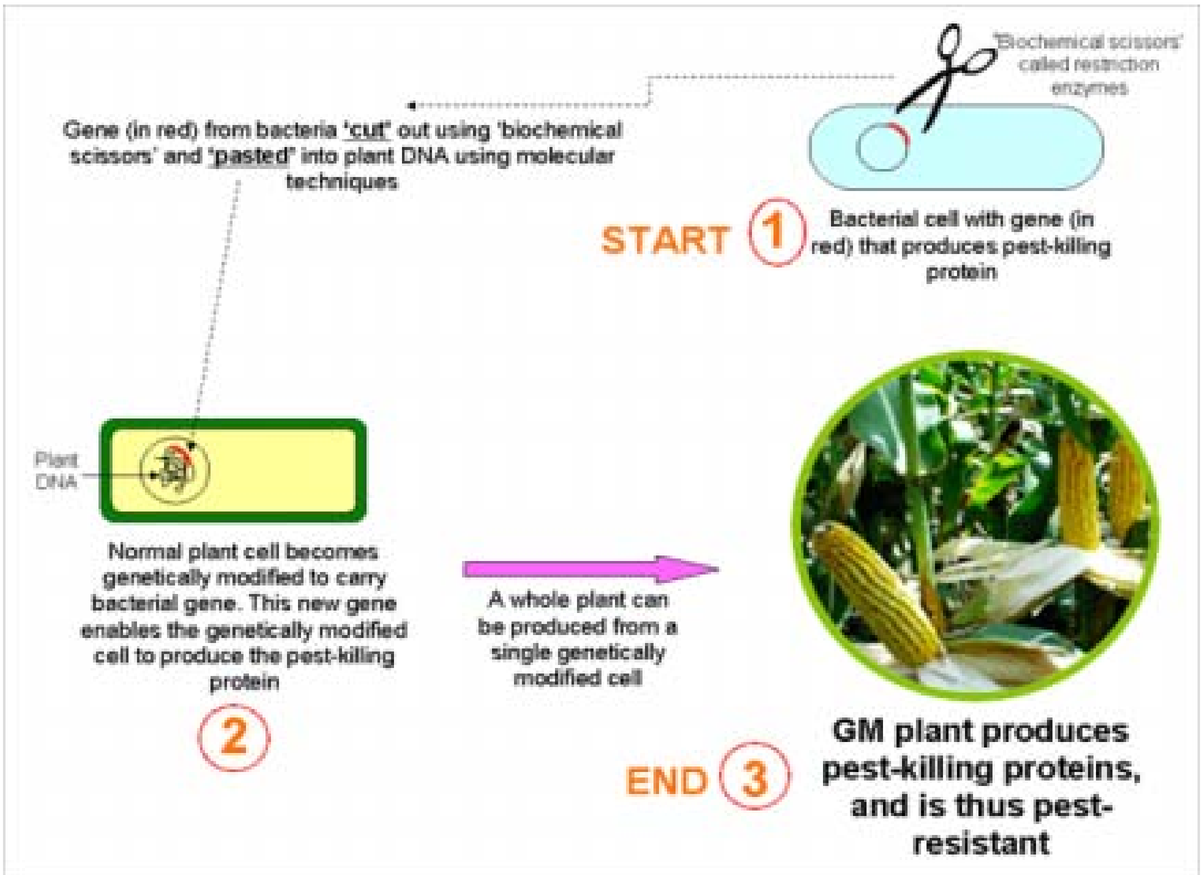
Genetic Modification is a process carried out outside of the cells that manipulates an organisms DNA by adding, removing or changing the DNA. Changes are made directly to the plant's genome.[18] By putting a new piece of DNA into a cell, researchers can then produce any number of desired traits. To start with scientists need to find and isolate the gene[19] to be inserted, this can take years of research to find and then identify its beneficial functions.[20]

[18] A genome is the complete set of genetic material of an organism
[19] A gene is the basic physical and functional unit of heredity. Genes are made up of DNA,
[20] The gene that provides resistance to the glyphosate herbicide was found, after seven years searching, in the outflow pipe of a Monsanto roundup manufacturing facility.

This new genetic material can then be either inserted into the host organism at a specific site or more usually randomly within the host organism. When introduced this gene needs to be combined with other genetic elements to enable it to be more effective. At any stage in the process the presence of the desired gene can be tested for, such as in small seedlings in a greenhouse tray. From this a breeder can then quickly evaluate the plants that are produced and select those that best express the desired trait.

The next step is for the organism to be regrown from that single cell. In plants this is accomplished through the use of tissue culture. If successful, an adult plant will contain the new gene in every cell.

Figure 7: How a pest-susceptible plant can be genetically modified to carry a bacterial gene which makes it pest-resistant



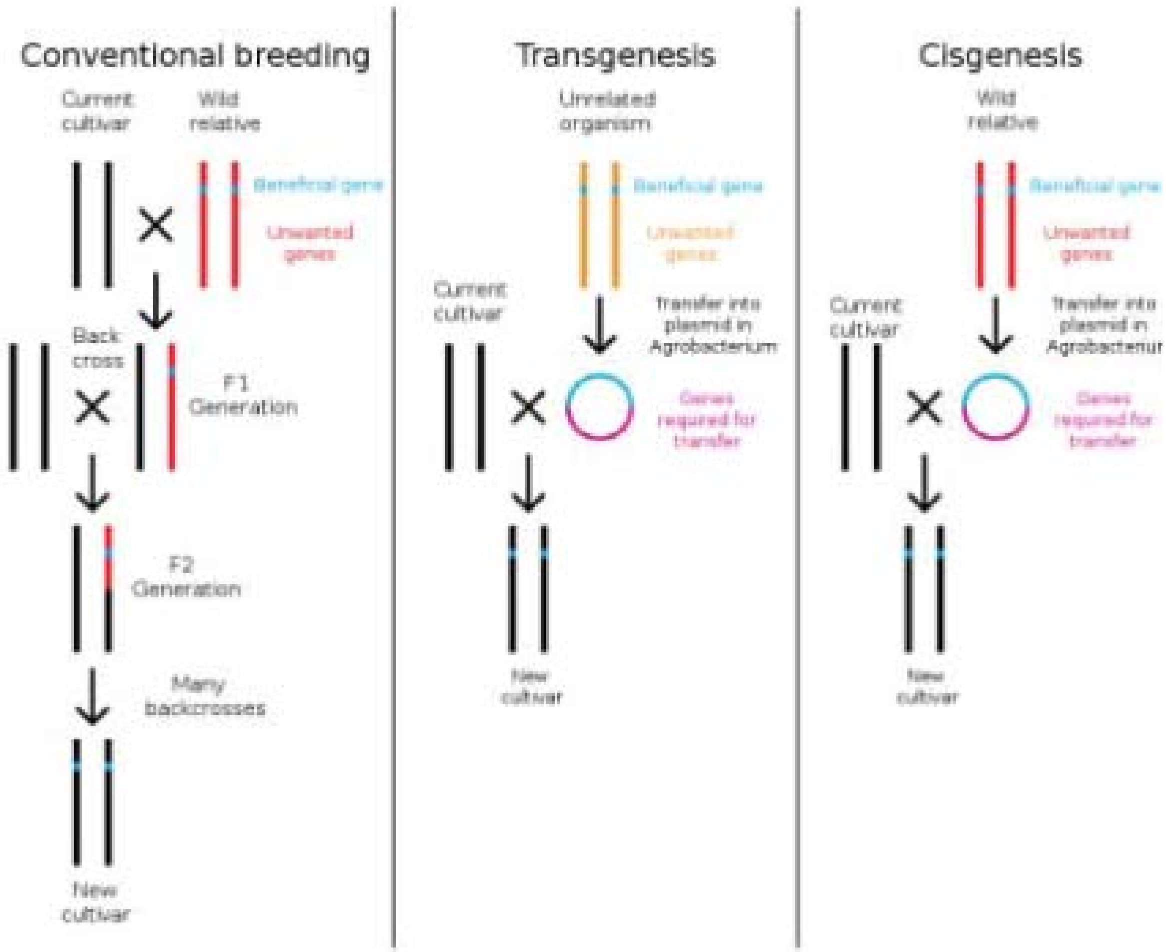
Source: www.gmac.gov.sg

Essentially there are two different categories within Genetic Modification, **transgenic** and **cisgenic**.

When genetic material from the **same species** or a species that can naturally breed with the host is used the resulting organism is called **cisgenic**. Cisgenic plants contain genes that have been isolated either directly from the host species or from sexually compatible species.

If genetic material from **another species** is added to the host, the resulting organism is called **transgenic**. Some genetically modified plants are developed by the introduction of a gene originating from distant, sexually incompatible species into the host genome.

Figure 8: Comparison of conventional plant breeding with transgenic and cisgenic genetic modification.



Genetic Modification is also used to remove genetic material from a target organism or sometimes as a quicker way of selecting and breeding for existing natural variation and traits already in some crops and plants. The process may be quicker than conventional breeding but producing new varieties of crops through Genetic Modification on average still takes around 10 years.

What are the differences between Genetic Modification and conventional breeding?

Both conventional breeding and genetic modification are methods used for intentional manipulation of an organism's heritable traits.

Take corn for example. To make an originally susceptible corn variety resistant to drought, conventional breeders can cross the susceptible corn variety with its resistant wild cousin. Offspring exhibiting drought-resistance (i.e. the desired quality) are then selected and crossed with its resistant parent (backcrossing). The offspring are subjected to several more generations of backcrossing and selection before a new variety of corn exhibiting drought-resistance can be achieved.

As conventional breeding involves the transfer of many thousands of genes randomly, the outcomes are often difficult to predict and it typically takes many years before an organism with the desired characteristics can be produced. Conventional breeding is also dependent on genetic compatibility of donor and recipient organisms. Breeders may not be able to cross distantly-related species, or the resultant offspring may not be viable.

Genetic Modification, on the other hand, is a more precise method. It involves the identification, isolation, and introduction of specific genes from donor to recipient organisms. Genetic Modification also permits the transfer of genes between totally different organisms, for example from a turnip to a cereal grain. [21]

Agriculture – why use G.M?

The reasons for growing GM crops are continually evolving but over the relatively short history of GM there have been five main desirable traits targeted in crops. Those traits are;

- herbicide resistance
- insect protection
- virus resistance
- enhanced nutrition
- tolerance of environmental pressures.

These were all developed to assist farmers in the management of their crops and more importantly, potentially increase crop yields.
Food production must increase and upgrading transport networks, improving resource allocation and reducing the huge food chain wastage between paddock to plate will all play a part. But the major burden will ultimately fall on the shoulders of agriculture and GM will play a part in that.

[21] Reproduced from GMAC Singapore. www.gmac.gov.sg/Index

The reduction in the use of pesticides is a major environmental benefit of GM. In 2006 the UK consultancy firm PG Economics, carried out a study showing that globally pesticide spraying was reduced by 286,000 tons because of GM, decreasing the environmental impact of herbicides and pesticides by 15%.[22]

Crops with the ability to resist insects, as shown below in figure 9, have less pests feeding on these plants resulting in farmers not having to spray as many insecticides.[23,24]

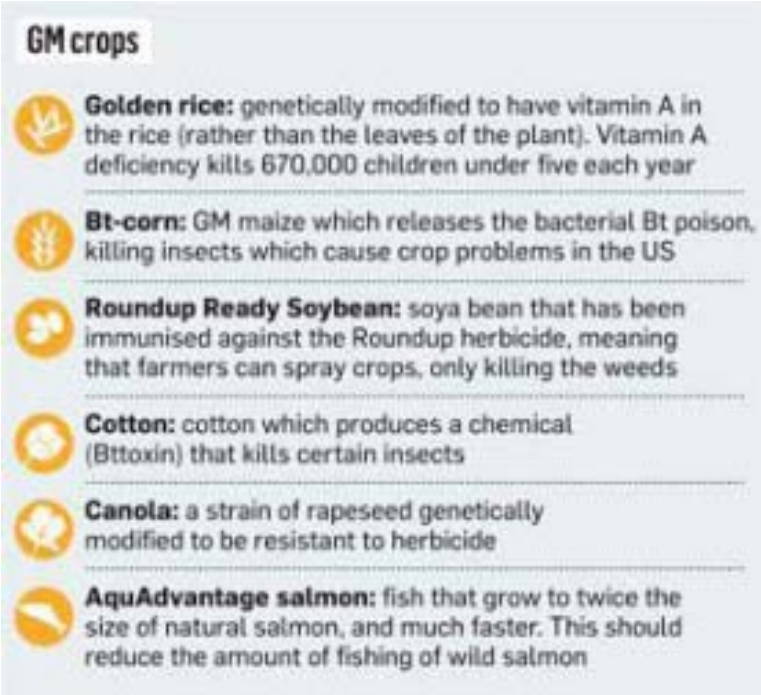
Figure 9: Bt-toxins present in peanut leaves (left image) protect it from extensive damage caused by European corn borer larvae (right image).

Eight years ago reports predicted farmers globally need to double food production by 2050. If it is accepted that genetically modifying crops can increase yields then food security may be the biggest reason of all to adopt this technology.

[22] Brookes, Graham & Barfoot, Peter (2008) Global Impact of Biotech Crops: Socio-Economic and Environmental Effects, 1996-2006 AgBioForum, Volume 11, Number 1, Article 3
[23] Roh JY, Choi JY, Li MS, Jin BR, Je YH (April 2007). "Bacillus thuringiensis as a specific, safe, and effective tool for insect pest control". J. Microbiol. Biotechnol.
[24] Marvier M, McCreedy C, Regetz J, Kareiva P (June 2007). "A meta-analysis of effects of Bt cotton and maize on nontarget invertebrates". Science 316 (5830): 1475–7. doi:10.1126/science.1139208.

Insect resistant (shown below) and herbicide tolerant crops are the most common GM crops grown today.

Figure 10: Some GM crops grown today



Source: The Sunday Times – U.K.

More recently a report, The Future of Food and Farming, proposed that the global demand for food could rise by 70% by 2050, with others predicting a doubling of food will be required. While these numbers may be seen as being extreme, there is no doubt that the world is going to need more available food to feed the anticipated rise in our population. Trying to produce more food without increasing the land area by conventional farming alone will not meet this target. Genetic modification is not the full answer but it can be a part of the solution.

Since the very first field trials in France and the USA in 1986, plants have been engineered or modified. While some feel that the process of genetically modifying plants is playing with nature others believe that it is just an extension of natural plant propagation. But while the debate continues, the area of GM crops grown is increasing all the time. With big areas of GM crops grown in North and South America, others like India, China, Pakistan and South Africa also have significant areas.

Figure 11: Where genetically modified crops are grown

In 2010 there were 148 million hectares of GM crops grown in 29 different countries.[25] [26]

The Risks

For all the current and future benefits of producing genetically modified crops and genetically modified food there are always going to be risks and these can't and shouldn't be ignored.

There are many opponents and advocacy groups such as Greenpeace and Friends of the Earth that have serious concerns about the risks of GM produced food and at times these concerns have led to protests and the destruction of GM trials around the world. Without doubt the biggest concern is the safety of genetically modified food. How safe is it really? What are the human health implications of consuming GM food and what toxic or allergic reactions could occur?

[25] International Service for the Acquisition of Agri-biotech Applications.

[26] With 67 million hectares the US is by far the biggest producer of GM crops, followed by Brazil and Argentina. With many European countries currently having restrictions on growing GM crops, any future increase in area will most likely come from developing countries such as India.

Food Safety

The overall responsibility for the safety, regulation and risk assessment of GM foods lies individually within each country, normally through independent regulators. This individual approach creates differing standards across different countries.

In each country regulators compare the GM food with a similar conventional food, looking at the molecular, toxicological and nutritional aspects of that food. They examine all genetically modified food, its protein products, and any intended changes that those proteins make to the food.[27]

In New Zealand this assessment is carried out on a case-by-case basis by Food Standards Australia New Zealand (FSANZ). From there, before it can be sold, it also has to be approved by the Australia New Zealand Foods Standards Council (ANZFSC), a council which includes both the Health Ministers of Australia and New Zealand. This is a rigorous assessment with regulators taking a far more cautious approach than seen in some other countries, when assessing the safety of GM food. In some developing countries, their national regulations around GM are not well established and need more work from all the stakeholders.

One of the arguments of groups opposing GM foods is that these regulatory authorities are not totally independent and are too close to companies. They allege cases of corruption and bribery by certain companies seeking support for their products.

Overall there have been many studies done on the safety of GM food, some more rigorous than others but the wide-ranging scientific agreement is that GM food poses no greater threat than conventional food.[28,29,30,31,32]

In 2010, a report by the European Commission Directorate-General for Research and Innovation GMOs stated that ***"The main conclusion to be drawn from the efforts of more than 130 research projects, covering a period of more than 25 years of research, and involving more than 500 independent research groups, is that biotechnology, and***

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[27] Regulators also check to see whether the food derived from a GMO is "substantially equivalent" to its non-GM-derived counterpart, which provides a way to detect any negative non-intended consequences of the genetic engineering. If the newly incorporated protein is not similar to that of other proteins found in food or if anomalies arise in the substantial equivalence comparison, further toxicological testing is required. Source: Winter, CK and Gallegos, LK. 2006. University of California Agricultural and Natural Resource Service. ANR Publication 8180. Safety of Genetically Engineered Food

[28] World Health Organization 20 questions on genetically modified foods

[29] Dr. Christopher Preston AgBioWorld 2011. Peer Reviewed Publications on the Safety of GM Foods

[30] Safety of Genetically Engineered Foods: Approaches to Assessing Unintended Health Effects. National Academies Press.

[31] 4 Winter CK and Gallegos LK. (2006) Safety of Genetically Engineered Food. University of California Agriculture and Natural Resources Communications Publication 8180.

[32] Pamela Ronald (2011) Genetically Engineered Crops—What, How and Why

in particular Genetically Modified Organisms, are not per se more risky than conventional plant breeding technologies.” [33]

There are many more organisations from the American Association for the Advancement of Science, to the Royal Society of Medicine who all have indicated that there have been no reports of any adverse health effects from GM food on the human population. There have been some individual studies published in journals suggesting negative impacts from eating G.M. food but overall no reports of ill-effects have been proven in the human population from GM food.

Other concerns

A lot of reports over the years have linked GM foods to allergies. Studies show that the transfer of an allergen from one food to another through Genetic Modification is possible and has happened, for example, with Brazil nuts and soybeans. In both cases the companies developing them have withdrawn these products before they reached the marketplace. Conversely genetic modification also has the ability to reduce the risk of food allergies by removing allergens from foods

Other concerns include the possibility of genes transferring to different plants, and the effect on beneficial organisms and biodiversity[34]. It is possible for this transferring of genes between plants to happen, but cross-contamination can also occur in conventional crops. With developed co-existence regulations in many countries to avoid cross contamination, this risk with GM crops is largely considered to be very low and it can be argued is actually lower than in conventional plants due to extra precautions taken.

Also corporate control of the food supply through intellectual property rights and contaminating non GM food lines are issues that cause concern. While some just simply feel that GM meddles too much with nature

While on balance it seems GM foods are safe, it is imperative that future testing continues to improve and develop with a need to further differentiate between cisgenic and transgenic GM foods.

[33] Organisation for Economic Co-operation and Development. Report of the Task Force for the Safety of Novel Foods and Feeds 17 May 2000 page 4, paragraph 4.

[34] A study on the effects of using Bt cotton in six northern provinces of China from 1990 to 2010 concluded that Bt cotton halved the use of pesticides and doubled the level of ladybirds, lacewings and spiders, with the environmental benefits extended to neighbouring crops of maize, peanuts and soybeans.

Genetic Modification - Case Study

A wheat plant without insecticides

Can we travel a full circle and once again grow crops without applying insecticides?[35]

In the US during the 1850s, records show there were no agricultural insecticides used on any crops. During this time though crop losses were substantial with reports of over 50% lost each year due to insects in the field, and during storage. It was common at that time for fields to be abandoned completely with crops such as onions, succumbing to the onion maggot and potato crops being wiped out by the Colorado potato beetle. [36]
Change was needed.

Figure 17: Spraying insecticides on wheat

To combat this problem arsenic based products were applied in small areas and by 1875 all the potatoes in the American Midwest were being sprayed.
Since the introduction of synthetic chemical insecticides in the 1940s, global agriculture has become more dependent on insecticides than ever. A three year study by the Crop Protection Research Institute in the US estimates farmers in the states of California, Washington, Florida and Georgia (mainly fruit and vegetable producers) would lose more than $1 billion of income annually without insecticides. [37]

[35] Insecticides are substances used for killing insects?
[36] The pest first began eating potato foliage in 1859. The beetle fed its way across the country and eventually reached the Atlantic Ocean. As a result, potato production in the country dropped by a third and prices for the diet staple quadrupled
[37] www.croplifefoundation.org

The study also claims that without insecticides 31 of the 50 crops surveyed would see yields drop 40%, or more and seven of the crops would experience yield losses of over 70%.[37]

Over many years in Florida farmers tried to grow sweet corn but were unsuccessful because of the pressure from insects. With modern insecticides that has now changed and today the state of Florida is the biggest producer of fresh sweet corn in the US.

For over 20 years researchers at Rothamsted Research in Hertfordshire, England have been trying to reverse this dependence. At Rothamsted the scientists have found a gene originating from a peppermint plant which when bred into wheat enables the plant to produce high amounts of the alarm pheromone, E-alpha Farnesene. The pheromone is given off naturally in aphids when they are under attack signalling for the other aphids to keep away. This alarm pheromone also attracts the natural predators of aphids such as ladybirds and parasitic wasps increasing the sometimes limited natural protection given. The study is also looking at the changes in behaviour of other insect populations.

Today they have a field trial of GM wheat, which has been genetically modified to repel aphids from the crop.

What is the problem with aphids?

Three of the main causes of disease found in wheat are fungi, bacteria and viruses. These viruses are transmitted by aphids.

Figure 18: Aphid infestation on wheat

Viruses such as Barley Yellow Dwarf virus restrict the transport mechanisms of the plant effectively reducing the supply of moisture and nutrients from the roots. These viruses cannot survive outside the plant except when an insect such as an aphid transmits it. So without aphids the spread of these viruses would be virtually eliminated. Work on this project started in 1985 and after positive results in the laboratory the testing was moved out to field conditions.

[37] www.croplifefoundation.org

Figure 19: A GM aphid resistant wheat trial Rothamsted, UK

Getting high levels of the alarm pheromone into the plant was difficult. The decision to use genetic modification as a way to breed the gene into the plant was made after other ways of providing the plant with high levels of the alarm pheromone were tried but were not effective. If successful this trial will show that by breeding these aphid resistant varieties of wheat, farmers in the future may be able to cut out the use of insecticides completely. This would result in not only financial savings but environmental ones as well.

Why wheat? Globally wheat is the second most important staple food crop after rice so the potential benefits are considerable. Wheat plants can be infected by a virus at any time during their growing season but they are most vulnerable as young plants up to growth stage 30. If this technology is successful in wheat then it also could be replicated in other plants such as potatoes with similar benefits.

CHAPTER 5

Public Attitudes to GM

"Opposition to GMs was perhaps understandable a decade ago, but today it is a mistake. The science is clear that genetic modification in food crops is nothing to be scared of, and in fact can help address numerous environmental challenges, such as the need to raise yields whilst using less water, pesticides and fertiliser." -Mark Lynas, an environmentalist and author who ripped up GM crops in the 1990s and later became a supporter of the technology.

There will always be many vocal environmental and other advocacy groups that are strongly opposed to any form of GM food and would like a total ban on any commercialisation of genetically modified products. That view has to be respected.

But there are also signs currently that consumer attitudes to GM foods are slowly changing. There seems to be a gradual acceptance (sometimes reluctantly) that GM foods will eventually become a part of our everyday diet in the future. Surprisingly, even in parts of Europe there seems to more openness to the potential of GM.

This is backed-up by a 2009 review of European consumer polls which show that resistance to Genetically Modified organisms in Europe has been steadily declining. The review shows around half of European consumers accepted gene technology, especially when it could show a link between benefits for consumers and the environment and GM products. Significantly for exporters to Europe, it also showed that most purchasers did not actively avoid GM products while shopping.[38]

Author, journalist and prominent environmentalist, Mark Lynas (see appendix C) is one who has changed his views. Lynas, who helped establish the anti-GM movement back in the mid 1990's, says now that his original opposition to GM crops had "been misguided and lacked any scientific basis".

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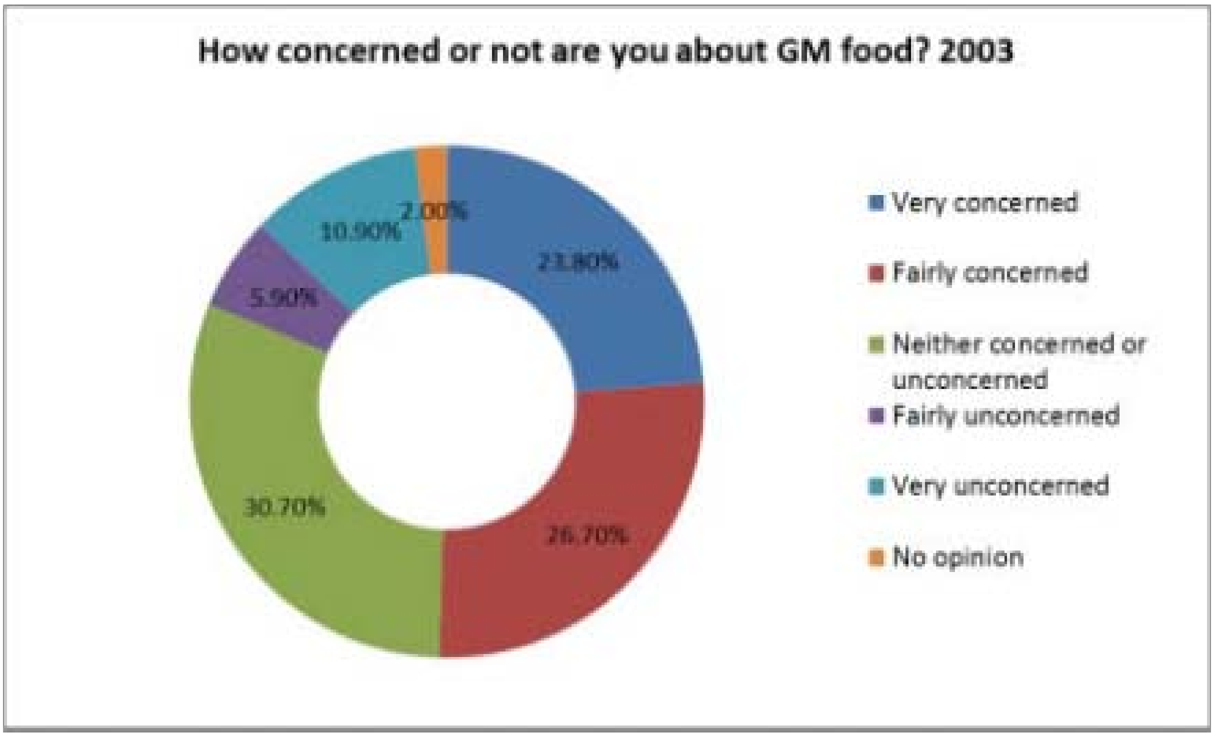
[38] "Opposition decreasing or acceptance increasing?: An overview of European consumer polls on attitudes to GMOs". GMO Compass. 16 April 2009. http://www.gmo-compass.org/eng/news/stories/415.an_

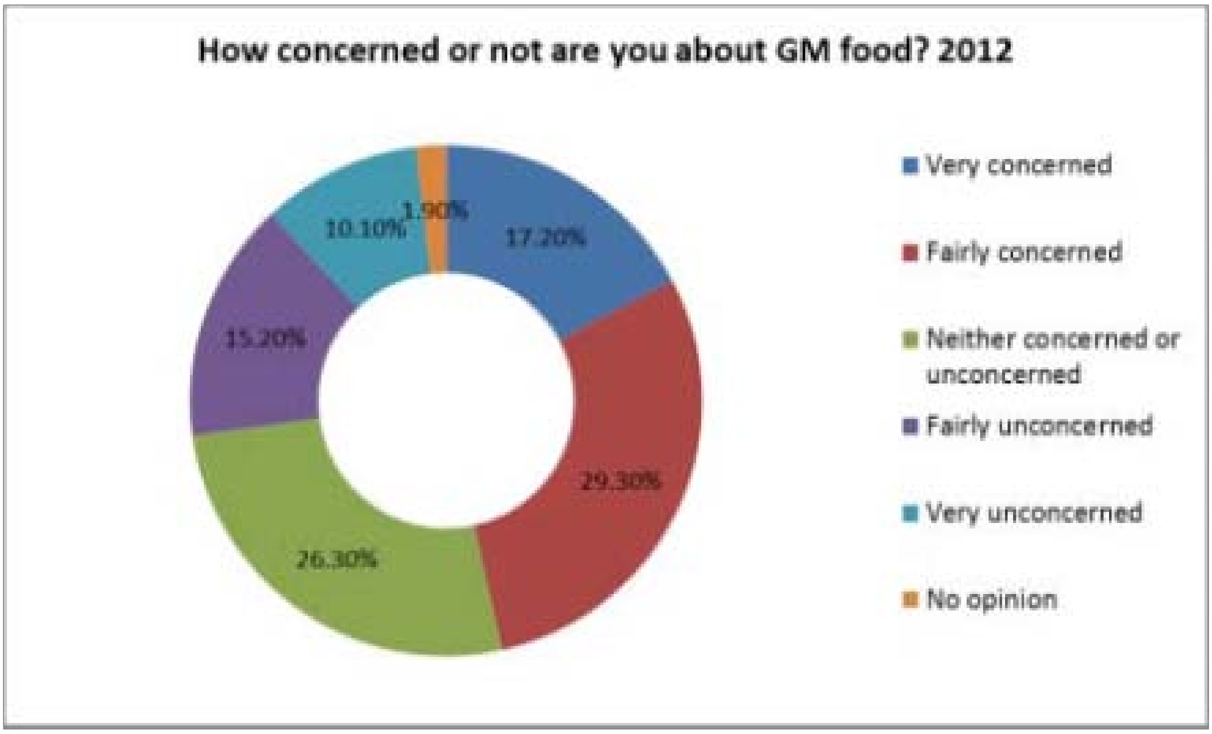
In the US a review of survey results on GM foods between 2001 and 2006 by the Pew Initiative on Food and Biotechnology showed that American consumers "do not support banning new uses of the technology, but rather seek an active role from regulators to ensure that new products are safe".[39] The review also showed that the knowledge of GM amongst US consumers over this period was low. Interestingly a 2010 Deloitte survey shows there is a huge gender difference with 16% of woman very concerned about GM food compared to 10% of men.

A recent survey commissioned by the British Science Association shows, that since 2003 the number of people now unconcerned about GM food has risen by 9%. While there is still a significant group who are concerned, this group also has shown a small decrease of 4% since 2003. This survey identifies not only a slight shift in public concerns but also finds a large group who are undecided illustrating a real need for more evidence on any benefits or risks of GM foods.

Figure 12: Change in consumer opinion on GM food 2003-2012



[39] The Pew Initiative On Food And Biotechnology, 16 November 2006. Review Of Public Opinion Research



Populus survey, commissioned by the British Science Association

The debate around Genetic Modification has always been and will always be emotive but particularly so in the area of food. Although today's consumers are more informed than they have even been, driven by a desire to understand what is in their food and understand any risks, there still seems to be an unawareness of the science behind GM.

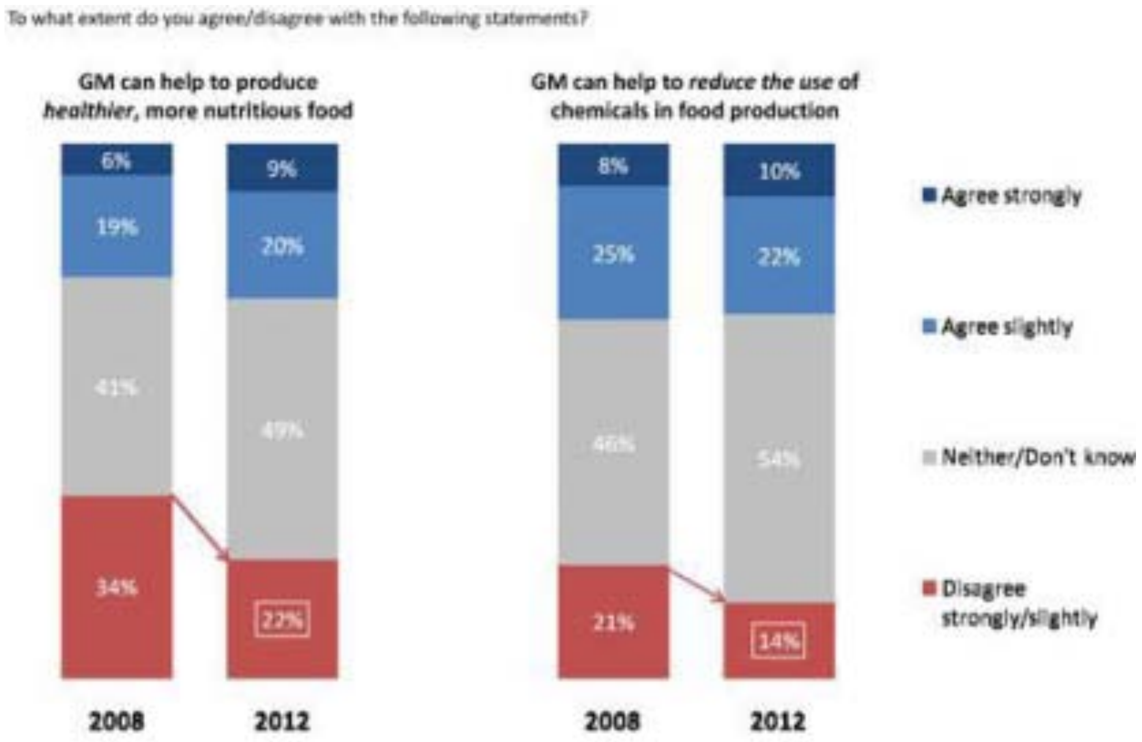
After a lot of publicity consumers do seem to have a general understanding of the effects of fats and carbohydrates (including sugars) in their food but not so with GM. It is an area that is not always easy to comprehend but as the public start to understand the science behind it and consumers become better informed then their choices around GM may change too.

When forming opinions on genetically modified foods consumers have many factors that can influence them. Supermarkets can have a big effect through leaflets, promotions, advertising and labeling. This can mean that some purchasing decisions are made for the consumer by the supermarket. Coverage in the press has another big influence with environmental groups and food pressure groups making a big contribution to this medium. Finally, to lesser degree, governmental information has an influence.

Perceptions of Genetically Modified food

Are perceptions changing? Recently the company IGD, an international retail expert, looked at shoppers' attitude to a range of potential benefits of GM food. This survey replicated earlier in 2008 shows since then consumers views have softened slightly with more open to the possibility of GM foods providing certain benefits, particularly in relation to health and reducing chemicals in food production. Again there are still a large proportion of consumers who don't know.

Figure 13: Shopper beliefs about GM and food health



Source: IGD ShopperVista, base: all main shoppers ('12), all adults ('08), boxes denote significant decrease over time.

Labeling

One large issue in GM has been the debate around the labeling of food. Across the world each country has weighed up the pros and cons of labeling and based their decisions on their findings. Whether it should be voluntary, be compulsory or if they need any labeling at all. In some countries like New Zealand, Australia and the European Union labeling of GM foods is mandatory while in many others like the U.S. it is not [40]. A 2007 study on the effect of labeling laws found that once labeling came into effect, few products sold actually contained genetically modified materials.

[40] The U.S. Food and Drug Administration currently requires labelling of GE foods if the food has a significantly different nutritional property; if a new food includes an allergen that consumers would not expect to be present or if a food contains a toxicant beyond acceptable limits.

The view of consumers is pretty clear. Many different organisations over the years have carried out labeling surveys and all have found an overwhelming support for labeling of GM foods (see figure 14).

Figure 14: Labeling of GM surveys, 2001 – 2011

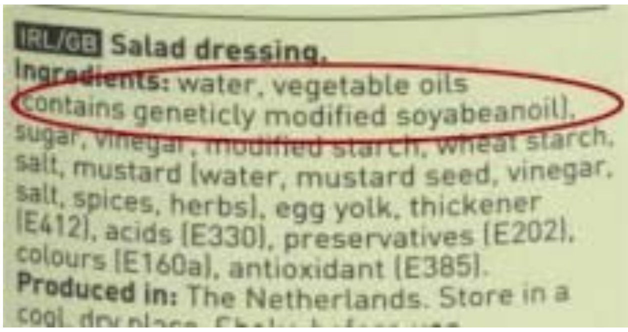
Surveying Organization	% of people in favor of GMO labeling	Year of survey
MSNBC	96%	2011
Reuters / NPR	95%	2010
Washington Post	95%	2010
Consumer Reports	95%	2008
ABC News	93%	2001

Consumers who considered themselves better informed about biotechnology were less concerned about the labeling of GM foods; however most of the people surveyed said they were not willing to pay a premium for such labeling.

One of the arguments used by advocates of no labeling is the cost. To allow the factual labeling of these products there needs to be either a rigorous testing procedure or full monitoring of all the food chain. This can be done either by testing the content for the presence of foreign DNA or protein[41] or by the detailed verification of recorded seed source, field location, harvest, transport and storage of the crop.

Some estimate the cost of this labeling to be a few dollars per person while others say the costs could be as high as 10% of a consumer's food bill.[42] So if the consumer is not willing to pay for the cost of labeling then who does?

Figure 15: GM labelling



[41] Thresholds as low as 0.01% (the approximate limit of detection) have been recommended (Hansen, 2001).
[42] Gruere and Rao, 2007

There are other issues when deciding to label or not. For example what percent of a GM ingredient does it take before a product is classed as genetically modified?
In New Zealand, if any ingredient of a product exceeds 1% GM content, then the product needs labeling. This one percent threshold is relatively common but there are many variations to this, Europe has a threshold of 0.9% while Japan has a 5% limit.

Figure 16: GM labelling

What about food like eggs and dairy products from animals that have been fed GM crops, do they need labeling? The science would say 'no' as there are no cases of DNA or protein from inserted genes having been found in these products.

Dr. Pat. Byrne, a professor and extension agronomy specialist from Colorado State University posted a website listing the pros and cons of labeling GM food.[43] The list is reproduced here

Pro-labeling Arguments

- Consumers have a right to know what's in their food, especially concerning products for which health and environmental concerns have been raised (Raab and Grobe, 2003)
- Mandatory labeling will allow consumers to identify and steer clear of food products that cause them problems
- Surveys indicate that a majority of Americans support mandatory labeling. (However, such surveys often do not specify the effect on food prices)
- At least 21 countries and the European Union have established some form of mandatory labeling (Gruere and Rao, 2007; Phillips and McNeill, 2000)
- For religious or ethical reasons, many Americans want to avoid eating animal products, including animal DNA

[43] P. Bryne, Colorado State University Extension agronomy specialist and professor, soil and crop sciences. 4/02. Reviewed 9/2010. Updated Friday, 3 August 2012 Labelling of Genetically Engineered Food

Anti-labeling Arguments

- Labels on GM food imply a warning about health effects, whereas no significant differences between GM and conventional foods have been detected. If a nutritional or allergenic difference were found in a GM food, current FDA regulations require a label to that effect
- Labeling of GM foods to fulfill the desires of some consumers would impose a cost on all consumers. Experience with mandatory labeling in the European Union, Japan, and New Zealand has not resulted in consumer choice. Rather, retailers have eliminated GM products from their shelves due to perceived consumer aversion to GM products (Carter and Gruere, 2003)
- Consumers who want to buy non-GM food already have an option: to purchase certified organic foods, which by definition cannot be produced with GM ingredients
- The food system infrastructure (storage, processing, and transportation facilities) in this country could not currently accommodate the need for segregation of GM and non-GM products
- Consumers who want to avoid animal products need not worry about GM food. No GM products currently on the market or under review contain animal genes. (However, there is no guarantee that this will not happen in the future)

CHAPTER 6

GM in New Zealand

"It would be unwise to turn our back on the potential advantages on offer, but we should proceed carefully, minimising and managing risks". Conclusion from the New Zealand Royal commission on Genetic Modification - July 2001.

Biotechnology has been critical to New Zealand's success for over 100 years and is likely to become even more important through the 21st century.

In May 2000 the New Zealand government set up a Royal Commission on Genetic Modification to look at all the issues around GM and make recommendations.[44] This report, released in July 2001, showed that while many New Zealanders were comfortable with Genetic Modification used in medicine there was still a strong opposition to other uses particularity in crops and food. This general distrust of GM in New Zealand at this time probably reflected the view shared in other parts of the world, which is that the science is still yet to be proven.

Two outcomes of this report were the formation of a recognised biotechnology strategy to keep up with all new developments in the future and a Bioethics Council to address any ethical and cultural issues. In 2001, to allow these strategies to be implemented, a two year restriction on any new GM applications was applied. It allowed time for research into the potential benefits of genetic modification for New Zealand and ways of more effectively managing any potential risks. The restricted period expired in October 2003.

Regulatory Environment

New Zealand has extremely rigorous laws concerning GM. Our processes and regulations are some of the most robust in the developed world. These laws are governed by the Hazardous Substances and New Organisms Act 1996 (HSNO Act). From this act the Environmental Risk Management Authority (ERMA) was established, now the Environmental Protection Authority (EPA), to assess and decide on applications to

[44] www.mfe.govt.nz/publications/organisms/royal-commission-gm

introduce hazardous substances or new organisms into New Zealand. This includes genetic modification of plants, animals and other living things. [45]

Currently there are no genetically modified crops grown in New Zealand or genetically modified vegetables, meat or fresh fruit sold.

To import or release a genetically modified organism in New Zealand you first need to get the approval of the Environmental Protection Authority (EPA). This government organisation is an independent body which regulates on a case-by-case basis, the introduction of new organisms.

Firstly an application has to be lodged with supporting information on the effects of this new organism. From there the application has to be publically notified, with a submissions and a hearing process to follow. EPA will then accept (potentially with conditions) or decline the application then make that decision public. This decision can be appealed.

Before any GM food is sold in New Zealand, it must also pass the safety assessment of Food Standards Australia New Zealand (FSANZ). FSANZ are responsible for the pre-market safety of GM foods, they assess all areas, including labelling. No food can be sold in New Zealand without passing this safety assessment.

The diagram below shows the steps in the process for releasing GM organisms in New Zealand.

[45] www.mfe.govt.nz/laws/hsno

Figure 19: Steps in the process for releasing GM organisms into the environment

Application lodged with EPA.

The applicant must provide EPA with all the information about all the effects the organism will have.

↓

EPA notifies the public that it has received the application and calls for submissions.

↓

EPA receives public submissions on the application and conducts hearings.

↓

EPA considers all information and makes a decision to approve (with or without conditions) or decline the application.

↓

EPA publicly notifies its position.

↓

EPA's decision can be appealed to the High Court on points of law, as can the procedure EPA followed to come to its decision.

↓

If the application proceeds, conditions are monitored, enforced and amended as necessary.

The Future

New Zealand has a choice; it can stay effectively GM free or cautiously embrace the new technology.

As a GM free country, New Zealand could position itself as a “pure” niche producer, targeting high end export markets who are opposed to genetic modification of any sort. This possibly would be a viable strategy in the short term but as public attitudes globally continue to shift the premiums for this niche market may shrink or disappear, leaving NZ at a competitive disadvantage. As our export driven competitors became more competitive we would become more dependent on these premiums from this produce to remain economic.

Alternatively New Zealand could treat GM like any other new technologies. Keep an open view, invest in the necessary research and development and proceed carefully with regulations and constraints that are scientifically sound but not restrictive. Promote a better awareness of its risks and advantages so consumers are better informed. New Zealand would need to be aware of its markets, both domestic and international, testing consumer opinions.

The structures allowing the coexistence of different primary production systems to operate commercially would have to be reviewed and improved. Organic, conventional and GM farmers should all be able to continue to operate together, with goodwill and the help of tools such as the Seed Crop Isolation Distance System (SCID) system. This web based voluntary system developed to help vegetable seed crop production by minimising the cross pollination risk when flowering, could be adapted to include GM crops. The system database would record placement of crops and site information annually.

There is no doubt that sometime in the future genetically modified crops will be grown commercially in New Zealand. As the risks are better understood and managed and the awareness of GM benefits grows, the opposition to it will decline.

Scientists and researchers have been using Genetic Modification for over 20 years. 12 years on from the Royal commission is it time New Zealand had another look?

CHAPTER 7

Precision Agriculture

"We live in a society exquisitely dependent on science and technology, in which hardly anyone knows anything about science and technology."
Dr. Carl E. Sagan was an American astronomer, astrophysicist, cosmologist and author.

Precision Agriculture is a system that allows the fine-tuning of crop management. It means farmers can record and analyse information about the variability of soil and crop conditions in small precise areas within a field. Using Precision Agriculture, small areas of a crop can be managed with different levels of input depending on the requirements and yield potential of the crop in that specific area. This allows farmers to apply only what is really necessary in each small area, not only creating a potential reduction in chemical and fertiliser use, but also giving financial and environment benefits.

In the past, Precision Agriculture was seen by many as being too complicated and too costly. The setting up and operating of complex systems that were very expensive was not appealing to a lot of farmers. Today this is changing with more and more farmers looking for ways to increase their production and their profits through the uptake of this technology.

New Zealand has always had a reputation as an early adopter of new technology demonstrated in the 1980s with the rapid uptake of the Eftpos electronic payment system. Its agriculture sector is no different, from the first use of refrigeration for meat exports through to the many examples of new software programmes we see today.

With the cost of farm inputs rising, the need to be able to precisely and efficiently plant and sustain crops is more important than ever. As this technology becomes cheaper, it is likely there will be more interest and an increase in the uptake of Precision Agriculture among farmers.

Precision Agriculture covers a broad range of technologies but has four main areas;

- Global Positioning System (GPS) – a referencing device capable of identifying sites within a field

- Geographic Information Systems (GIS) – maps of these sites can be generated and analysed using simple browsers or complex models
- Variable rate technology for implementing ideal models
- Remote sensing for data collection

Global Positioning System

Developed by the US Department of Defence, Global Positioning System (GPS) is a worldwide navigational and positioning system. Initially the acronym GPS referred only to the US Department of Defence's Global Navigation Satellite System (GNSS) also known as NAVSTAR. Today GPS is used as a generic term to describe all the global positioning systems including the Russian GLONASS and the European Galileo systems.

The Department of Defence sanctioned the NAVSTAR GPS program in December 1973 and the first GPS satellite was launched in 1978. Initially it was designed for the US military to improve their strategic and tactical ability before it was authorised for civilian use in 1983. Around the same time developers started building and testing ground receivers in vehicles on land, sea and air.

Today Global Positioning Systems allow precise real-time grid-reference information for military and civilian users worldwide. The accuracy of GPS means users, including the police and emergency services, can now determine the location of an object in any weather, anywhere on earth down to centimetre precision, depending on the receiver and the signal processing.

Since its inception in the early 1990s Global Positioning System (GPS) would now be one of the most widely used and most recognised technologies. As the systems have become more reliable, accurate and easy to use the uptake over the last few years has grown exponentially. From satellite navigation systems used in cars, trucks and planes to Google maps to running applications for smartphones we are now surrounded by applications where GPS is used.

How does this system work?

Basically there are three parts that make up GPS,

- the satellites that orbit around the earth
- the control stations on the ground

- the GPS receivers we see in cars, trucks and tractors today

The system works by using a constellation of satellites all programmed to transmit signals at the same time down to land-based control stations and receivers.

The control stations monitor the orbit of each satellite, constantly recording the satellites exact position in real time. This enables the GPS receivers to use these as reference points to help determine their exact position. There are five control stations, including the master GPS control station, evenly spaced around the world that controls the GPS satellites. The master GPS control station has overall control of the remote monitoring and is situated at Scheiver Air Force base in Colorado, US.

The other four Monitor Stations are unmanned stations located in Hawaii and Kwajalein in the Pacific Ocean; Diego Garcia in the Indian Ocean and Ascension Island in the Atlantic Ocean. They predict and correct the orbits of the satellites, correcting the clocks and transmitting data back up to the satellites tracking up to 11 satellites twice a day. The GPS control station on Kwajalein Atoll in the Republic of the Marshall Islands, due north of New Zealand is the closest.

Figure 21: Location of GPS master control and monitor stations

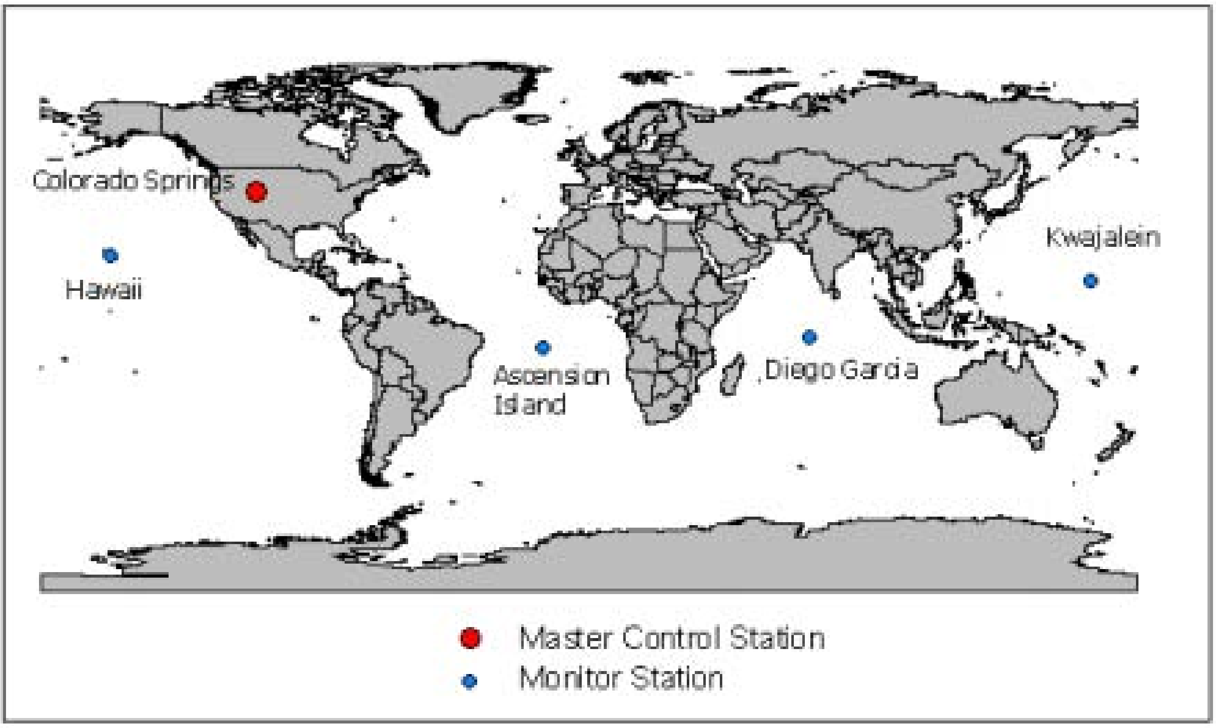


Figure 22: NAVSTAR Global Positioning System Satellite

Source: US Department of Defence

These solar powered satellites, which are around five meters wide (including the extended solar panels) and weigh about 900kgs, only last around 10 years. So they are constantly being manufactured and launched into orbit replacing older ones.

The satellites, which are at an altitude of around 20,000kms, orbit the earth about every twelve hours at over 11,000 km/hr. sending constant radio signals down to the receivers. The satellites are evenly spaced at around 60 degrees apart in orbital planes which allow the operator on the ground to always have between five and eight satellites available from any place on earth.

Every individual satellite sends a radio signal down to the receiver, transmitted at the same instant as the other satellites in the constellation. This signal travels by line of sight so can pass through clouds, plastic or glass but not trees, buildings or mountains. This signal contains information about each satellite's identification and position but more importantly the time it takes to get from the satellite to the receiver. This time, generally between 65 and 85 milliseconds, determines the distance between a GPS satellite and a GPS receiver. Radio waves travel at the speed of light (300,000 km per second), so by knowing the time taken for the signal to travel from the satellite to the receiver it allows the receiver to automatically calculate the distance. Both the satellites and the receivers have very accurate synchronised clocks to enable the time between when the signal was sent and when it was received to be measured. (See appendix D)

Differential GPS (DGPS)

The accuracy of GPS averages around 15 meters. This “inaccuracy” can be caused by the deflection of the satellites signals when they enter the atmosphere or by errors purposely built into the GPS receivers clocks signals by the GPS systems operator (Department of Defence). With the help of a correctional method called Differential GPS (DGPS), where signals are sent to DGPS receivers which then correct the position errors, it is possible to improve the accuracy of GPS determined positions.

Some progressive farmers are now beginning to use GPS for recording observations, such as weed growth, unusual plant stress, and growth conditions. These can then be mapped with a programme using geographic information systems.

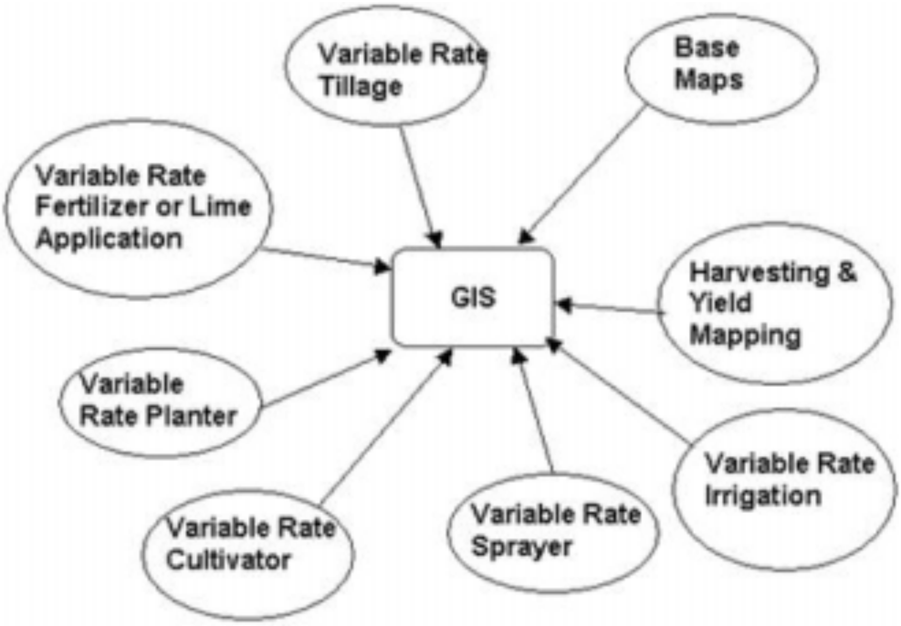
Geographic Information Systems (GIS)

As crops are harvested or inputs are applied the data from these operations are measured and stored on the farm equipment. Yield monitors are measuring devices installed on harvesting equipment.

Yield data from the monitor is recorded and stored at regular intervals along with positional data received from the GPS unit. GIS software takes the yield data and produces yield maps.

Once mapped the limiting factors are identified and action can be taken to overcome or minimise these problems

Figure 23: GIS overview



Variable rate technology (VRT)

Variable Rate Technology (VRT) gives growers the ability to overcome vast variability within a field. Traditionally farmers would treat the entire field the same when applying inputs such as seed, fertiliser and chemicals. This "blanket approach to application means some areas will get higher levels of inputs than needed while some would get lower.

A way of controlling this variability within the field is VRT. It allows the grower to apply crop inputs only where they are needed. It can mean reducing seeding rates on lighter soils or increasing fertiliser on areas with higher yield potential. For farmers with variable rate irrigation it allows for minimising water on areas that pond or applying more water on light ridges.

Variable rate technology combines three main parts; a GPS receiver, a computer controller and GIS mapping software.

The computer controller adjusts the equipment application rate of the crop input applied. The computer controller is integrated with the GIS database, which contains the flow rate instructions for the application equipment. A GPS receiver is linked to the computer. The computer controller uses the location coordinates from the GPS unit to find the equipment location on the map provided by the GIS unit. The computer controller reads the instructions from the GIS system and varies the rate of the crop input being applied as the equipment crosses the field. The computer controller will record the actual rates applied at each location in the field and store the information in the GIS system, thus maintaining precise field maps of materials applied.[46]

Remote sensing

Remote sensing data and images provide farmers with the ability to monitor the health and condition of crops. Multispectral remote sensing can detect reflected light that is not visible to the naked eye. The chlorophyll in the plant leaf reflects green light while absorbing most of the blue and red lightwaves emitted from the sun. Stressed plants reflect various wavelengths of light that are different from healthy plants. Healthy plants reflect more infrared energy from the spongy mesophyll plant-leaf tissue than stressed plants. By being able to detect areas of plant stress before it becomes visible, farmers will have additional time to analyse the problem area and apply a treatment. [46]

Figure 24: Yara N- Sensor *ALS* mounted on a tractor's canopy.

The Yara N – Sensor in figure 24 records light reflection of crops, calculates fertilisation recommendations and then varies the amount of fertiliser to be spread. This data can then be recorded and added to a GIS database.

[46] Reproduced from -Remote Sensing in Precision Agriculture: An Educational Primer, by Randall J. Covey, Ames Remote

7.1 Precision Agriculture - Case Study

In agriculture today it is becoming increasingly important to know and be able to measure what is happening below the ground. Having an understanding of soil and its properties is essential if farmers are going to continue to increase their production. Soil variation is one of the most significant factors affecting crop yields with nutrient budgeting and soil testing being commonly used to overcome this variation. The importance of soil mapping is illustrated by the high correlation of soil maps with yield making them a significant tool when applying crop inputs.

Having the capability to accurately map soil variability has been challenging farmers for many years. Numerous studies show the current practise of manually testing only 1- 2 samples per hectare, to be inaccurate due to the high variations between those samples across the whole field.

But to take the 20-40 samples needed per hectare to get the desired accuracy has always been too time consuming and costly…..until now.

Veris 3150 MSP3

A Kansas based agricultural company, Veris technologies, has developed the world's first on the go real-time soil sampler. This device has a collection of soil sensors that allows it measure soil organic matter (OM), soil pH and the electrical conductivity of the soil, simultaneously. In 1997 Veris technologies developed the Veris 3100, a machine that could measure soil electrical conductivity on-the-go. Since then they have produced many more models culminating in the company building a Mobile Sensor Platform (MSP) that allows for extra sensors to be added including sensor models to record pH and organic matter.

How does the system operate?

The Veris 3150 MSP3 measures three different properties - pH, organic matter and electrical conductivity of the soil.

Figure 25: Veris 3150 MSP3

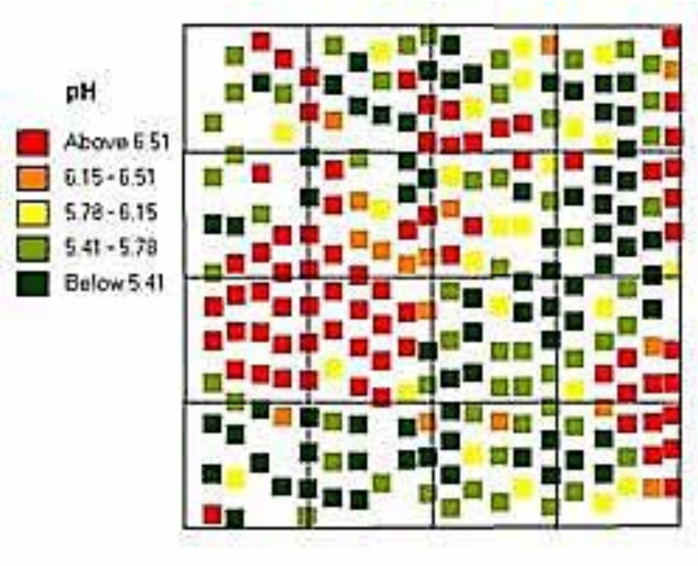
Soil pH

Soil pH is a measurement used to determine the acidity or alkalinity of different soils. It affects the nutrient availability and consequent growth of a crop.

To measure soil pH, firstly two discs clear away any crop residue followed by a firming wheel which compacts the loose soil. Then a hydraulic cylinder lowers a cutting sampler shoe into the ground, creating a soil core which flows into a sampling trough. The hydraulic cylinder then raises the trough with the soil core against two pH electrodes. After a few seconds the shoe is lowered again to collect more soil. As it does this, the new soil coming in moves the previous soil sample out the back of the shoe trough then covering disks close over the track. During each cycle the cutting shoe is cleaned by a scraper and the pH electrodes are washed with two 150 psi nozzles. Water used to wash the soil off the electrodes is held in a 380 litre tank mounted on the platform. The sampling process is controlled with an external electronic control module and the pH data is recorded on a Veris recording instrument.

With soil pH varying hugely across small areas this allows for more tests to be taken per hectare increasing the accuracy.

Figure 26: pH variations across a field



Source: Veris Technologies Field Trials 2002-2004

Soil Organic matter

Organic Matter (OM) is an important indicator of the health of the soil. Soils high in organic matter generally have better soil structure increasing its nutrient and water-holding capacity and ability to make nitrogen more available to the plant. Also soils high in OM tend to increase the action of herbicides.

Figure 27: Veris optical sensor

The Veris 3150 MSP3 works by using a dual-wavelength optical sensor that is attached to a coulter and dragged through the soil at a constant depth of around 50mm. The depth is important as a variation in moisture on the surface can affect the readings.

This sensor measures soil reflectance (soils high in OM are darker and absorb more light) through a special Sapphire window on the bottom of the sensor. Readings are measured once every second and then matched back to their GPS location to produce the map.

Soil Electrical conductivity

The next soil property to be measured by this machine is soil electrical conductivity (Soil EC). Soil EC measures how much electrical current the soil conducts which can tell us the texture of a soil. As the machine is pulled along, one pair of coulter- electrodes injects a known voltage into the soil while the other coulter-electrodes record the drop in that voltage. Sandy and silty soils conduct less current than smaller clay particles.

From the Soil EC we can tell the texture of the soil which is important when growing crops. A soil with good texture has better water-holding capacity, drainage and nutrient and nitrogen-use efficiency; all important factors when maximising crop yields. As average field sizes and farm sizes continue to increase the time it takes to grid sample soils in such a concentrated way becomes inefficient. The main advantage of the Veris 3150 MSP3 is the speed at which it is possible to map your fields. Depending on field conditions and what functions are being used farmers are able to map at over 20 hectares per hour.

Figure 28: Hectares mapped per hour at different widths

	Transect Width-m			
Speed (km/hr.)	**15**	**18**	**21**	**24**
7	8	10	11	13
10	12	15	17	19
13	16	19	23	26

Accuracy

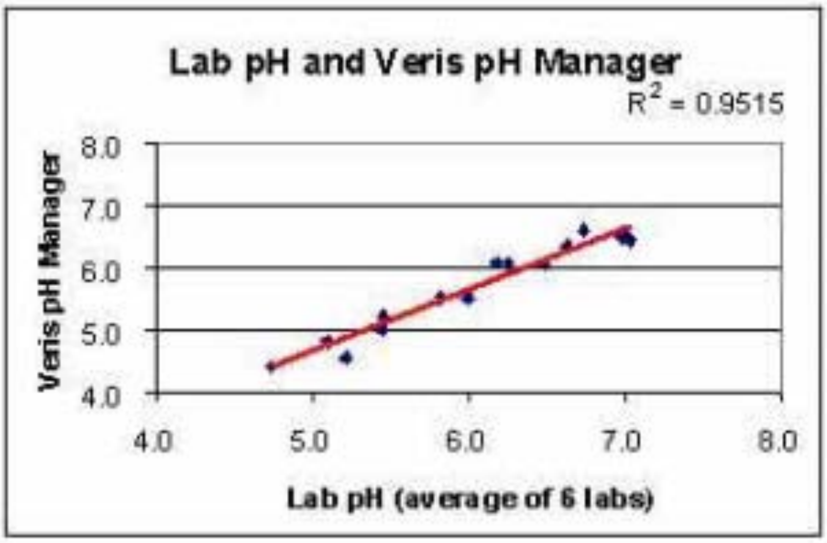
One of the most common questions farmers ask is "Is it accurate?"

With any type of technology, reliability and accuracy are crucial when using them. If an operator cannot have confidence in the results they are getting then that information is basically valueless. So how accurate is the Veris 3150MSP3 when on-the-go mapping compared with traditional methods?

During a pH trial, field samples taken manually and analysed at a lab were compared with results from the Veris on-the-go-mapping. These showed a high level of accuracy between the two systems (figure 29).

Lab samples overall did show greater accuracy at the particular spot where the sample was taken. But due to the large distances and huge variability often seen between the samples the map ends up with significant errors. These errors can be reduced by taking more samples, but this can be time consuming and costly. The Veris on-the-go mapping system allows increased sample density over a short timeframe.

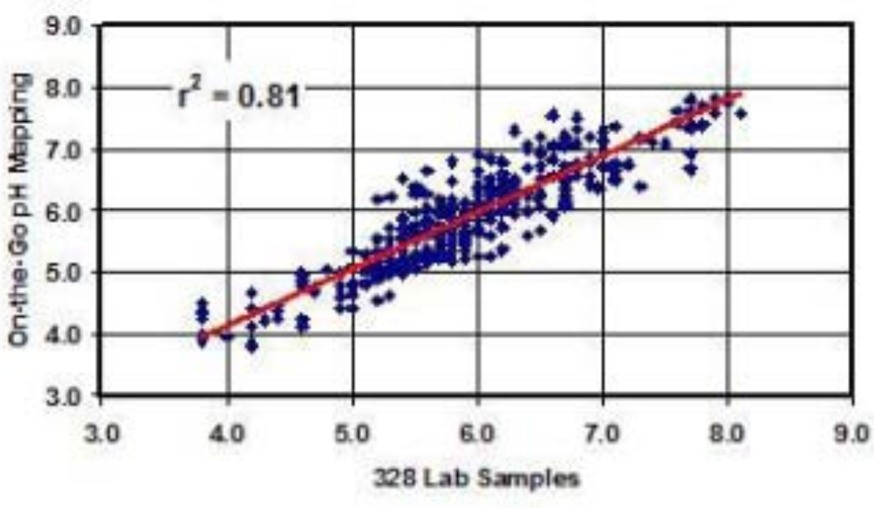
Figure 29: Correlation between Veris and Lab pH tests



Source: Veris Technologies Field Trials 2002-2004

In more extensive field trials taken from 15 fields over 4 states in the US there was still a high correlation between the two systems. In these trials the soil sample was taken within 6 metres of the sensor point.

Figure 30: 328 further samples between Veris and Lab pH tests



Source: Veris Technologies Field Trials 2002-2004

As the importance of understanding soil properties grows, so does the need to be able to sustainably manage inputs and comply with environmental regulatory bodies, demand for technology like the Veris range of on-the-go soil samples will increase.

While admittedly this technology has more room to develop and increase its accuracy it does show the future capability of Precision Agriculture, where it is heading and the exciting potential it has.

CHAPTER 8

Conclusions and Recommendations

When looking at global agriculture over the last year, many things have emerged. Labour shortages, water shortages and lack of capital are common throughout the world. Environmentally farmland is ever more under pressure as the world is demanding additional food to feed itself. The world's population is increasing at such a rate that rises in the production of food are not keeping up. Ultimately existing levels of production and conventional farming practises are not going to be enough to fill this food imbalance and pressure will come on farmers to produce more.

This will create market opportunities and agricultural industries able to respond quickly to these will significantly improve profitability. This is particularly so for major exporters in the developed world, many of whom are facing increasing cost-based competition from counterparts in the developing world.

Overall New Zealand is fortunate. As a strong agricultural exporter, it is well placed to benefit from these growing opportunities. With good soils, plentiful water and good infrastructure, New Zealand can capitalise on this growing demand, particularly from Asia. Through its efficient and competitive primary production systems, New Zealand has many advantages over its international competitors.

But this alone will not be enough. To lift production, further innovation is required by investing in and adopting new technologies. Greater emphasis needs to be placed on technology transfer from universities and researchers to commercial agribusiness industry.

Genetic Modification

There is no doubt that sometime in the future genetically modified crops will be grown commercially in New Zealand. As the risks are better understood and managed and the awareness of the benefits of GM develops, consumers will come to understand that GM food is as safe as conventional food. GM is not the answer to food shortages but it can be a part of the answer. But if GM is going to be a useful tool for the future, research has to start now. More money (including public funding) will need to be spent on research and development and also on improving testing procedures and protocols that can identify and manage risk.

There is still a real lack of understanding around GM and there needs to be more education so the consumer can make an informed decision.

We must also recognise that there is still a lot of opposition to GM and we should respect people's rights to choose. The consumer will ultimately choose what they wish to eat and therefore influence what is produced and farmers will decide what they grow based on market acceptance and production costs.

New Zealand has a choice; it can stay effectively GM free or cautiously embrace the new technology.

As a GM free country, New Zealand could position itself as a "pure" niche producer, targeting high end export markets. This could be a viable strategy in the short term but as public attitudes globally continue to shift the premiums for this niche market may shrink or disappear, leaving New Zealand at a competitive disadvantage.

Alternatively New Zealand could treat GM like any other new technology. With an open view, invest in the necessary research and proceed carefully with regulations and constraints that are scientifically sound but not restrictive. New Zealand should also be aware of its markets, both domestic and international, understanding consumer preferences and opinions.

New Zealand may not be quite ready for GM but at the very least it is time New Zealand had another look.

Precision Agriculture

In the future Precision Agriculture will move away from simply measuring crop data to telling us the reasons for any soil and crop variability. It will become valuable as tool to meet new environmental regulations, helping farmers to meet the required standards. How fast Precision Agriculture is adopted will depend upon it meeting the needs of the end user, the farmer. As more agricultural information technology companies enter the marketplace the cost of equipment associated with Precision Agriculture will come down appealing to a broader market.

Precision Agriculture is a young industry with its real benefits still ahead of it. Uptake will continue to increase as the technology improves. With satellites in the future having better spatial and spectral resolutions and the delivery time of remote sensing data to the customer improving, the value of Precision Agriculture to the farmer will only increase.

Appendices

Appendix A

As well as the gene to be inserted most constructs contain a promoter and terminator region as well as a selectable marker gene. The promoter region initiates transcription of the gene and can be used to control the location and level of gene expression, while the terminator region ends transcription. The selectable marker, which in most cases confers antibiotic resistance to the organism it is expressed in, is needed to determine which cells are transformed with the new gene. The constructs are made using recombinant DNA techniques, such as restriction digests, ligations and molecular cloning. [47]

Appendix B

In the early 1990s, Pioneer Hi-Bred attempted to improve the nutrition content of soybeans intended for animal feed by adding a gene from the Brazil nut. Their studies showed that the modified strain produced immune reactions in people with Brazil nut allergies and Pioneer Hi-Bred discontinued further development.[49][50] In 2005, a pest-resistant field pea developed by the Australian Commonwealth Scientific and Industrial Research Organisation for use as a pasture crop was shown to cause an allergic reaction in mice. Work on this variety was immediately halted.[48]

Appendix C Article reproduced from the U.K. Sunday Star Times

Turncoat hails GM food a world savior

AN ENVIRONMENTALIST who helped launch the campaign against genetically modified food has been subjected to a tide of personal attacks after renouncing his former beliefs and insisting that the world needs GM food to avoid famine. In a speech to the Oxford Farming Conference, Mark Lynas said his original opposition to GM crops had been misguided and lacked any scientific basis.

His outspoken comments have sparked furious attacks, including allegations that he had been "paid off" by GM companies, that his views were equivalent to "saying rapists should have freedom to rape" and that he was a "pocket-lining hypocrite".

[47] Wikipedia
[48] Wikipedia

In his speech, Lynas said: "I apologise for having spent several years ripping up GM crops. I am also sorry that I helped to start the anti-GM movement back in the mid-1990s, and that I thereby assisted in demonising an important technological option which can be used to benefit the environment.

"As an environmentalist . . . I could not have chosen a more counterproductive path. I now regret it completely."

Lynas attributes his about-face to studying the science behind GM food and discovering there was no evidence of it ever causing harm. He told the conference: "The GM debate is over. It is finished. We no longer need to discuss whether or not it is safe — over a decade and a half with three trillion GM meals eaten there has never been a single substantiated case of harm. You are more likely to get hit by an asteroid than to get hurt by GM food."

Mark Lynas says protesters against GM are 'anti-science'

Lynas, who confessed that in 2008 he was "still penning screeds in The Guardian attacking the science of GM — even though I had done no academic research on the topic, and had a pretty limited personal understanding", said the anti-GM protest was "explicitly an anti-science movement".

He said: "We employed a lot of imagery about scientists in their labs cackling demonically as they tinkered with the very building blocks of life. Hence the Frankenstein food tag . . . What we didn't realise at the time was that the real Frankenstein's monster was not GM technology, but our reaction against it."

The speech, in which Lynas emphasises the need for GM food in order to meet the demands of the growing world population, has been downloaded 250,000 times

and translated into five languages. A video of his presentation has been watched by 25,000 people.

Some have voiced virulent opposition to Lynas's views. Vandana Shiva, the Indian campaigner described by The Guardian as one of "the top 100 women in the world", tweeted: "saying farmers should be free to grow GMOs [genetically modified organisms] which can contaminate organic farms is like saying rapists should have freedom to rape".

More than 500 people have posted comments on Lynas's website, including some accusing him of being "a fraud" and in the pay of GM companies.

"People make these allegations and obviously they are false," Lynas said this weekend. "Since they don't have any evidence to back them up, they just make stuff up. I have a special mail box now where I put the hate mail. I delete most of it from the website, but bear in mind that the response has been 95% supportive."

The government wants the process by which the European Union approves proposals for GM crops to be speeded up. Owen Paterson, the environment secretary, told the Oxford conference: "We are talking with the EU on this, but I think the rules are holding back our farmers . . . The whole process is going grindingly slowly."

So far, the EU has approved just two GM crops, maize and a potato, to be licensed for cultivation but not for human consumption.

In his speech, Lynas complained: "In the EU, the system is at a standstill, and many GM crops have been waiting a decade or more for approval but are permanently held up by the twisted domestic politics of anti-biotech countries like France and Austria.

"Around the whole world the regulatory delay has increased to more than 5.5 years now, from 3.7 years back in 2002. The bureaucratic burden is getting worse." 49

Appendix D

In order to do this, the satellites and the receivers use very accurate clocks which are synchronised so that they generate the same code at exactly the same time. The code received from the satellite can be compared with the code generated by the receiver. By comparing the codes, the time difference between when the satellite generated the code and when the receiver generated the code can be determined. This interval is the travel time of the code. Multiplying this travel time, in seconds, by 300,000 kilometres per second gives the distance from the receiver position to the satellite in miles.

[49] www.thesundaytimes.co.uk/sto/news/uk_news/Environment/article1193508.ece

List of Figures