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What are the barriers to the adoption of new technologies and innovation by the New Zealand Farmer?

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Executive Summary

Market signals and regulation necessitates sustainably produced products that meet the expectations of the conscious consumer and society. These will require improved ways of doing what has been done before and in some cases a transformative change. This report identifies barriers facing New Zealand farmers towards innovating and taking on new technologies.

Most of New Zealand farms are small to medium enterprises. How able they are to innovate and take on new technology will determine their ability to remain profitable and keep ahead of their competitors.

The research methodology comprised of a literature review and 21 semi-structured interviews to identify key themes from the literature and farmers, agribusiness, science and political views. This allowed the author to gain a better understanding of the context that is affecting farmers directly and indirectly.

New Zealand primary production is now driven by producing more, with less input and less impact. The paradigm shift from efficient production to sustainable production is being driven top down by free trade agreement requirements and legislative change in New Zealand. Innovation and new technologies will be part of the solution.

This report finds that the New Zealand farmer is looking to innovate on farm and take on new technologies if they can demonstrate an advantage, match personal values held, are easy to use, can be tested and show results. However, resistance may still be present due to fear and the rate of change being experienced by the farming community. A financial return is critical for the farming enterprise and the need for knowledge is increasing.

Recommendations for primary industry are that farmers must:

1. Be viewed as individuals each with their own viewpoints, systems and requirements.
2. Engage at the local and regional level to create 'Innovation ecosystems' as ideas come from multiple groups working together; farmers with farmers including rural professionals and scientists.
3. Be prepared for disruption and be the support that is needed.
4. Learn from failures; use them, share negativities as it will build better resilience.
5. Have realistic expectations regarding change, innovation takes time.

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Introduction

Technology has changed farming processes throughout New Zealand's history. Horses provided the 'horsepower' on New Zealand farms prior to the introduction of machinery in the early 1900s. By the 1950s horses had been replaced by tractors that didn't tire or need feeding, which also freed up land for food production once dedicated to growing oats to feed horses. The tractor of today still has four wheels, a steering wheel, a driver (for now) and is used to provide the 'horsepower' carrying out the heavy work on farm.

A temperature-controlled cab, suspension, and precision technology that quantifies how much fertiliser is applied, accurately records it for farm records and prevents overlap have made the task easier for those involved. Innovations have made tasks more comfortable, streamlined data capture and allowed for mitigating negative impact on the environment.

New Zealand's primary industries export revenues for food and fibre products was worth $48 billion (MPI. 2021) to the New Zealand economy, equating to 11% of gross domestic product (GDP), in 2021. Thirteen percent of New Zealand's workforce is employed in primary industries. Farmers and growers are the individual businesses that have direct contact with the land. The decisions they make will impact how commodity food and fibre products are produced.

Subsidy reform in the 1980s was a transformational time for New Zealand's farmers which made them react to market signals and the farm into a commercially viable enterprise. At the time of writing this report, thirty-eight years has passed. Food and Fibre export revenue is forecast to be worth $50.7 billion in 2022. The word 'transformation' is being heard again from rural leaders, agribusiness and politicians however it means different things to different groups.

What does this mean to the farmer? Market signals and regulation necessitates sustainably produced products that meet the expectations of the conscious consumer and society. These will require improved ways of doing what has been done before and in some cases a transformative change. Innovation and new technologies will be part of the solution. Are there barriers facing farmers towards innovating and taking on new technologies? By defining the barriers, opportunities should become more apparent.

Aim and Objectives

This report aims to create a greater understanding for the farmer of the barriers to the adoption of new technologies and innovations in the New Zealand farming context.

This will be done by investigating:

- Where ideas come from
- How innovations diffuse through a population
- Factors that increase the adoption of innovation
- Resistance to change
- Productivity growth in the sector
- Barriers identified by farmers

Method

The methodology used in this report comprised a literature review and semi-structured interviews; allowing the author to explore themes in greater depth. A literature review was carried out to provide context about where ideas come from, to define innovation, how innovations diffuse through a population, why there may be resistance to change and what changes may be happening at a national level. Semi-structured interviews gave the author subjective information from different viewpoints.

A literature review was carried out to combine information from a variety of sources: peer-reviewed papers, government publications, Crown Research Institute reports, news articles, websites and farmer's viewpoints from industry journals.

Interviews were designed to be semi-structured to allow the conversation to flow in an organic way. Interviews were conducted across four different community groupings: farmers, agribusiness, science community and political. This aim was to garner information from diverse voices; farmers themselves and those that have been involved with the farmer (end user) in new technologies and innovation whether it be creation, deployment or use. A total of 21 individuals were interviewed: six farmers from a mixture of operations; arable, dairy (cow and sheep), sheep and beef, seven individuals from the agribusiness community (some being part of the farming community themselves), seven individuals from the scientific community and one political voice. Viewpoints from each group that were interviewed are identified as Farmer A to F, Agribusiness A to G, Science A to G and Political A as there was only one political voice. This was done to ensure the confidentiality of those interviewed.

Limitations of this study from the qualitative nature of data allows for conclusions but does not represent all individuals in a sector.

Technological change: Invention, Innovation, and diffusion

The concept of 'creative destruction' is from Josef Schumpeter (1942). Modern theory of technological change in the field of economics can be traced back to his theories (Dosi, G. 2010). The 'perennial gale of creative destruction' describes the effects of innovation in a free market, capitalist economy. New ways of doing things are created which then destroy the old way. New businesses come into being and replace the old. Modern examples are the Blockbuster video franchise replaced by the online streaming platform Netflix and online shopping platforms that replaced the physical shopping experience on the high street to the couch. Robotic fruit picking that reduces labour requirements could be a reality in the future of New Zealand's horticulture sector (Harris, 2021).

Schumpeter identified three stages in the process of technological change; invention, innovation and diffusion. The New Zealand productivity commission noted these three stages of technological change (Figure 1) in their report 'Technological change and the future of work' (NZPC, 2020). Invention is the creation of a new product or process followed by innovation which proves the usability of a new idea or product and creates a pathway to market. Diffusion is the uptake and adoption of said technology by the end user (Dosi, G. 2010).

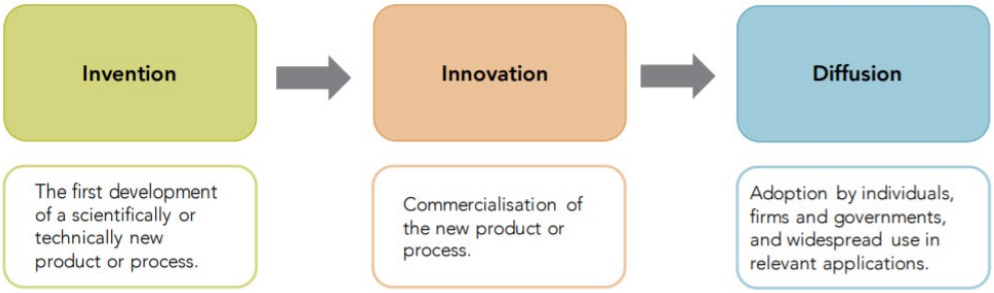

Figure 1: Three stages of technological change (NZPC, 2020)

However, inventions do not always become innovations (Jaffe, 2000). An invention can be protected or not; by patents or plant variety rights (PVR) which give the inventor intellectual property rights (Caradus, 2021), but it is not an innovation unless it is commercialised and available on the market.

Agricultural innovation in New Zealand can be found at Fieldays, the largest southern hemisphere agricultural event located in Hamilton. The New Zealand National Fieldays Society (2021) have the pillars of innovation, education and globalisation. Fieldays Innovation Awards give inventors the opportunity to showcase their creations to a national and global audience. The winner of the 'Protoype' award in 2021 was SpringArm, designed by Waikato dairy farmer Ric Awburn. Developing a ball-cock arm for water troughs that springs back rather than breaks has saved him time on farm

during summer that he used to spend checking for breakages and leaks. The product has moved from invention to innovation as it is available to purchase.

Innovation is new ideas, processes and products that change the way we do things (Ridley, 2011). However, innovation is not a destination, it is a cumulation of ideas that change and add to an existing idea that was made up from ideas before it (Robinson, 2009). Innovations create value or can simplify operating practices which increases adoption; new and meaningful versus novel and useless, as in the example of SpringArm.

The lack of innovation, not invention, has been highlighted as a frustration for New Zealand and Irish agritech startups (Rennie, 2022) who recently discussed this at a NZ-Ireland agritech summit. There are numerous solutions already available for problems however research continues to reinvent but poorly execute commercialisation.

How do innovations diffuse through a population?

An influential theory that attempts to explain how new ideas are taken up in a population is the 'Diffusion of Innovations' theory (DOI) described by Everett Rogers (1962) (Figure 2). It separates a population into five groupings: innovators, early adopters, early majority, late majority and laggards (Rogers, 1995). Rogers quantified what percentage of a population each segment made up: innovators 2.5%, early adopters 13.5%, early majority 34%, late majority 34% and laggards 16%. As a new idea moves through a population, becoming more mainstream, it will have passed through these groups. Each grouping has its own characteristics and propensity for taking up innovations.

Innovators are the first group to adopt an innovation. They are less risk averse, social, have financial liquidity, tend to be younger, are closely connected to scientific sources and other innovators. Early adopters are the second group to take up an innovation and are on the lookout for new ideas. They are socially well connected, have financial resources, are well educated, respected as leaders and share their successes with others. The early majority need more proof regarding the advantages of an innovation before they will commit and are watching the early adopters. Simplicity, efficiency, less risk and proven benefits are important for this group. The late majority are the fourth group to adopt an innovation. They aren't as well connected to peers and have lower financial resources. The last group to take on new ideas are laggards. They tend to be older, less socially connected, highly risk averse and focus on traditions.

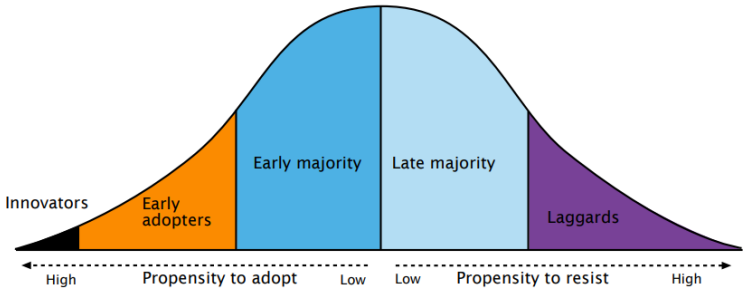

Figure 2: Diffusion of Innovation Model (Robinson, 2009)

Case Study - The Iowa Hybrid Seed Corn Study

Diffusion is the spreading of something more widely, just as the light diffuses forward when a torch is put on in the dark, ideas move through a population. A well-known diffusion study that Rogers mentions is the Iowa hybrid seed corn study. The basic framework for the diffusion model was provided by this study (Rogers, 2004). It is worth noting as it is the foundational work to a much-cited theory regarding the way innovations move through a farming population.

Hybrid maize had been developed in the 1920s in America and brought with it many advantages over the older varieties. Yields were increased by up to twenty percent, stalks were sturdier standing up to harvesting by machines and plants were hardier and better able to deal with droughts. Yet researchers, Ryan & Gross (1943), thought there was slow uptake of the new technology. They found that it took thirteen years for the technology to diffuse through the two communities that they studied. There was 10% adoption after five years, 40% adoption over the next three years and a small number of non-adopters 13 years after the new seed had been released. Traditionally, farmers in the study had harvested the best-looking ears of corn from their own plantings that would be used to plant the subsequent years crop. The new hybrid required the farmer to buy new seed every year. Education, age, farm size, income and tendency for travel outside of their district were correlated with the time of technology adoption, which gave rise to the labels: innovators, early adopters, early majority, late majority and laggards.

Case Study – Pregnancy scanning technology

Pregnancy scanning technology was introduced in New Zealand almost 30 years ago in the sheep industry. Sheep are scanned between 60 and 90 days of pregnancy, allowing the farmer to identify whether the ewe is in lamb, and with a single or multiple pregnancy. A pioneer of the technology, Richard Chantler, toured Australia and New Zealand as part of a Nuffield Farming Scholarship in the 1980s (MacNicol.K, 2011). He is thought to be one of the first in the world to scan sheep as a commercial enterprise. He had bought a Romney mob from Wye College in Kent, in the United Kingdom where he was working as a shepherd. This mob was the result of breeding trials set up by

the New Zealand Romney Development Group working towards genetic improvement. Richard intended to offer scanning services across New Zealand in the 1980s, but subsidy reforms had reduced farm incomes. New Zealand sheep farmers were too financially constrained to take on another cost.

A decade later, Brett Burgess started up his own commercial scanning enterprise in New Zealand, he had been trained while on his overseas experience (OE) by Richard Chantler. A local discussion group heard of the technology and contracted Brett to scan 50,000 ewes.

Pregnancy scanning technology was initially used to scan for ewes that were not in lamb, that could then be sold early to reduce winter feed costs. It provided the opportunity to quantify the number of pregnancies, single, twins or triplets. Foetal aging and the nutritional requirements of the ewe could be matched with feed supply allocation to increase lambing success. Table 1 is adapted from a paper detailing StockScan Ltd's, a commercial company, business timeline by the late 1990s (Farmer, 1999). The number of ewes scanned increased from 50,000 to 960,000 in 6 years. The number of ewes scanned for multiple births increased from 20% to 100% over the same time period.

Year	**1992**	**1993**	**1994**	**1998**
No. of sheep scanned	50,000	100,000	300,000	960,000
% scanned for twins	20	70	90	100
% scanned for triplets			3	10
Employees	1	1	3	11

Table 1: StockScan Ltd business timeline, adapted (Farmer, 1999)

Breeding numbers of ewes have steadily decreased from the 1990s to 2020s (40.4 million to 16.6 million) and lambing percentages have increased from 100% to 132% (Moot & Davison, 2021). One main reason for the increase is attributed to better quality and quantity of forage on offer.

Scanning provides an interesting study of diffusion. The innovator shared information through their network, early adopters trained in the technology and farmers took advantage of the data to make decisions and optimise their systems. It shows the importance of human connections, social networks which are the pathway of knowledge distribution. As the innovation was adopted more widely, its use changed. Scanning's initial purpose was to reduce stock that weren't useful for breeding and reduce winter costs. It diffused through users to identify non-performing stock and allow for ewes with multiple pregnancies to be fed appropriately which increased productivity, therefore efficiency.

What factors increase the uptake of innovation?

There are five factors that increase the uptake of innovation: relative advantage, compatibility with existing values, simplicity and ease of use, trialability and observable results (Robinson, 2009). Everett Rogers found that 49 to 87 percent of the variation in the uptake of new products was dependant on these five factors (Rogers, 2003).

Relative advantage

Relative advantage is how much better the new innovation is over the old. This is measured by the value that users perceive. It can be financial, more productive, more efficient, time saving, enhances an individuals' prestige or added convenience (Robinson, 2009). Dairy NZ surveyed farmers in 2019-2020 carrying out milking three times in 2 days (3-in-2) to identify what they perceived as the benefits over milking twice a day (Edwards et al, 2020). Key reasons were identified: attract staff and keep them through better and flexible working hours, better overall cow health, more family time and improved wellbeing.

Compatibility with existing values

In the Iowa hybrid seed corn study, farmers traditionally used corn ears from their own crop to plant next years' crop. They were not dependant on others and had carried out this practice for some time. Using the new hybrid seed required dependence on others and a financial outlay changing the traditional way of doing things.

Simplicity and ease of use – Precision Ag technology example

An innovation that is easy to use and is simple, will be adopted more readily. Complex farm software can be too challenging for individuals and therefore don't persevere with it '*too complicated for some people'* (Farmer B).

Data and technology interoperability have been identified as a barrier to the uptake of digital technology (Turner et al, 2020). The software technology options from different organisations often have different data standards making data sharing across platforms very difficult. Software that can be used on one tractor can't be used on another, increasing farm complexity.

Farmers identified that technology had to be flexible and move across different hardware from the primary device to the mobile phone '*interface for mobile connectivity'* (Farmer B), in order for real time information flow and not having to wait to get back to the office.

Trialability

An innovation that can be trialled and tested by the user is more likely to be adopted. If it is a large change or a commitment that can't be changed it is less likely to be adopted (Caradus, 2013). Income from 'carbon credit farming' has met with resistance from some as they are not sure if the markets are secure for the future and the perceived degradation of 'high productive land' being lost.

Large and ambitious investment such as in infrastructure or farm system software that did not save resource as promised had lasting effects '*took a couple of years to get out of the hole'* (Farmer E) which had to be paid regardless of income '*paying it whether the pay-out is $6 or $8'* (Farmer E).

Observable results

Seeing is believing. Whether that be forage species that perform better in dry environments, less weed burden due to herbicide use, an increase in milk solids, better lambing percentages: that which can be seen visually or using data will increase the uptake of an innovation.

Resistance to Change

The very nature of trying new things is to change the status quo and what is currently being done. By changing from the old to the new or status quo to the different there must be a phase of learning and with this brings apprehension. The old adage of 'the only constant is change' is true as the world around an individual is always in a state of flux whether it be in small (incremental) or large (transformational) ways. The sociopsychological bases of learning anxiety are made up of several fears: fear of temporary incompetence, fear of punishment for incompetence, fear of loss of personal identity and fear of loss of group membership (Schein, 2004). These are discussed in more detail below.

Fear of temporary incompetence

Not yet having mastered a task is due to the uncertainty of how to carry it out therefore is the unknown. The unknown is unsafe as it has ambiguity and unclear definitions. Maslow's hierarchy of needs is a psychological model that explains the universal needs of people (Figure 3). If uncertainty is the unknown and the unknown is unsafe, according to Maslow's model the safety needs of security are lacking.

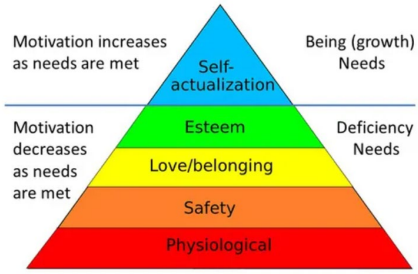

Figure 3: Maslow's Hierarchy of Needs (Simply Psychology, 2020)

Previous failures experienced by farmers impacted their ability to take on the next new technology '*challenge would be to get it over the line'* (Farmer A).

Fear of punishment for temporary incompetence

The punishment experienced, from a farming perspective, could be a negative financial impact to business income due to a reduction in productivity, directly effecting profitability. The security of income could be affected which again results in safety needs not being met. By making a mistake the penalty may be time, '*one years' mistake needs five years to get back to where you were'* (Farmer F) and resistance to being able to try new things again.

Fear of loss of personal identity

Personal identity is based on previous experiences up to that point and the past will influence the future decisions made. The ladder of inference, Figure 4, is a mental model that was developed by Chris Argyris, an organisational psychologist, in the 1970s. This model indicates that beliefs affect conclusions made. All people have different experiences, and therefore link their individual experiences through their life to their decision making for the future. If change does not adhere to personal values, which are complex, there will be resistance.

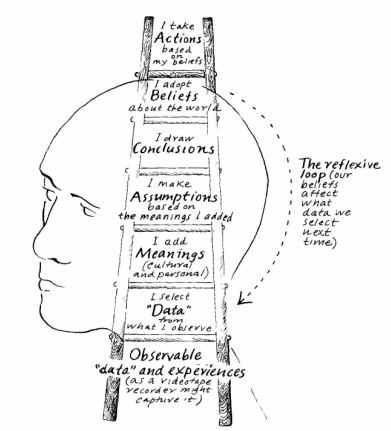

Figure 4: Ladder of Inference (Senge, 1994)

Family and lifestyle were a high priority for those interviewed. Wanting to hand on the farm to family and improve it for future generations was a strong driver. Pride was felt for the land and all were planning for the future. The business was also home therefore a huge emotional tie. Running a business, being their own boss and having the autonomy to plan their day was important '*pick and choose what you do'* (Farmer C).

Fear of loss of group membership

Being part of a group creates belonging which is the commonality of thought. If the new way of doing things is contrary to the groups' belief, there is risk to the individuals who follow it as they may be ostracised. People have a need for belonging, as shown on Maslow's hierarchy, and the threat of no longer having it may result in resisting new ways of doing things.

The Pathway to change

Incremental change allows for small changes to improve efficiency thereby improving productivity. A farmer has gained knowledge on their system through trial and error by making small step changes and tweaks to the current system. When the system reaches a plateau, a transformational change may be required. Figure 5 illustrates how a transformational change occurs when implementing a new technology. In this case the adoption of lucerne grazing in New Zealand.

The plateau is a flat line of performance indicating that the system is no longer improving, which necessitates change. The farmer adopts the change and sows lucerne on the farm. At this initial stage there is a risk of reverting back to the previous system due to disruption, errors will be made and negativities experienced. This is the dip where learnings are made and the risk of giving up and going back to the original system is greatest. The 'dip' is the point where support is needed from a network of knowledge be it from science, agribusiness or further education. More support increases the likelihood of success, reduces disruption as problems can be dealt with and reduces the time to optimisation.

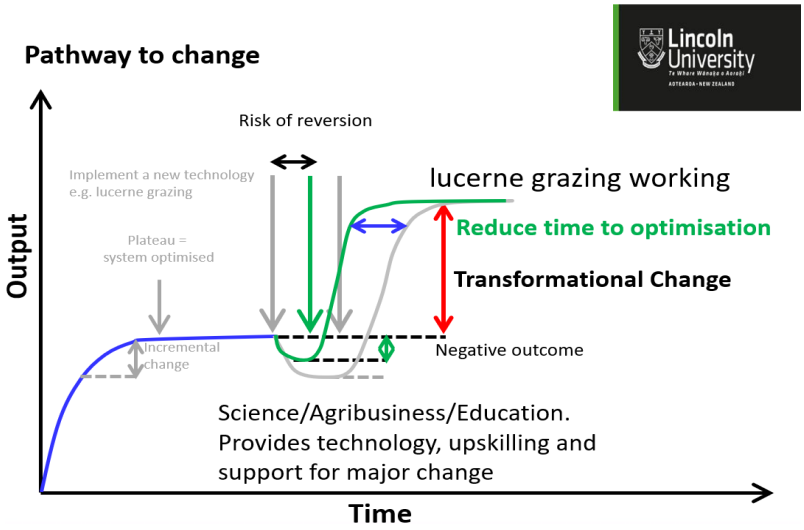

Figure 5: Pathway to Change (Moot, 2021)

The New Zealand Research, Science, and Innovation System

The research, science and innovation (RSI) system is beginning a journey of change as signalled in the governments green paper, Te Ara Paerangi Future Pathways (MBIE. 2021a). The last major reforms were in 1992 with the disestablishment of the Department of Scientific and Industrial Research (DSIR) and the Ministry of Agriculture (MAF), resulting in the formation of the current Crown Research Institutes (CRIs). The change from publicly funded research to 'user pays' created a completely different lens for science and remains a contentious point for those who had experienced the reforms. The reforms were described by one interviewee as '*complete public good, moved to complete commercial good*'.

Te Ara Paerangi Future Pathways future for the Research, Science and Innovation System cabinet paper, released on 28th October 2021, underscores the wide-spread issues in the RSI system (MBIE. 2021b). Fragmentation is present, institutions are unclear on their roles, the competition for funding is intense and there is a lack of integration between different parts of the RSI sector. The system is not focusing adequately on specialised, distinctive knowledge areas that would develop and grow world-leading firms.

New Zealand is underfunding research and development, 1.5% GDP, which is lower than other small advanced economies (SAEs) (MBIE, 2021b). Research in New Zealand is funded by government and business, 45% and 55% respectively. R&D tax credits were introduced recently to increase private sector investment.

Primary Industry have been innovating

Productivity is an economic measure of growth that is used to compare a country's competitiveness with others. It measures how well resources are being used. Labour productivity, capital deepening and multifactor productivity are the quantifiable metrics. Labour productivity is the ability to produce goods and services. Capital deepening measures the amount of better capital per worker over time; workers having access to more or better equipment in their daily lives. Multifactor (MFP) productivity is a measure of overall efficiency and how all inputs combine to produce outputs. It can be used to reflect growth that is due to technological change, method improvement and gains in knowledge (NZPC, 2021b).

New Zealand Primary industries had the highest productivity growth over the past 40 years when compared with goods producing and service industries (Figure 6). Primary industry have adopted technologies and looked for efficiencies since subsidy reform in the 1980s.

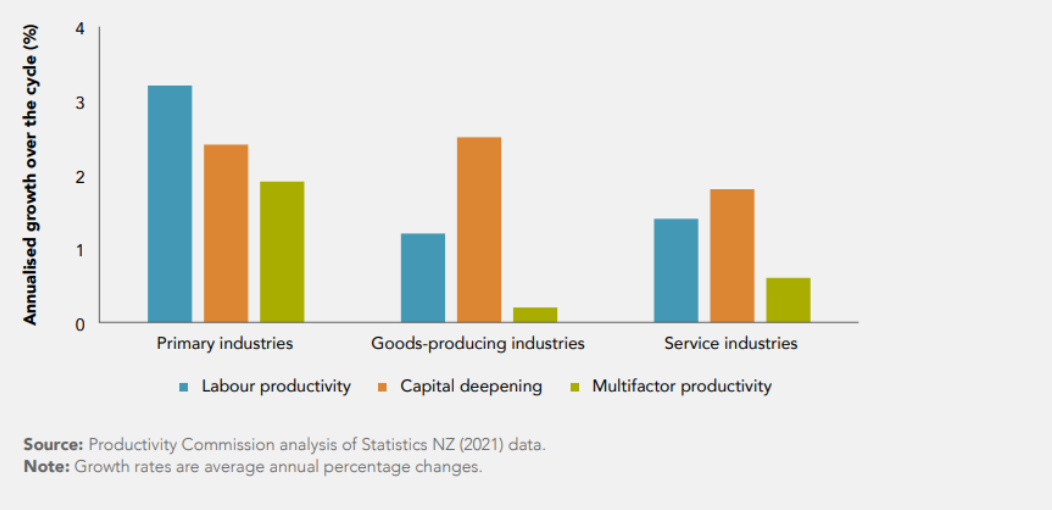

Figure 6: Primary Industry Productivity between 1978 and 2020 (NZPC, 2021b)

Innovation ecosystems

The NZPC released 'New Zealand firms: Reaching for the frontier' in April 2021 (NZPC, 2021a). Other small advanced nations (SAEs) that successfully export goods and services and command a value have more frontier firms than New Zealand. Value over volume is extracted through goods and services that are distinctive and novel instead of commodity products. The NZPC define frontier firms as 'the most productive firms in the economy within their industry'. Frontier firms impact others within their industry, non-frontier firms, as technologies and innovation taken up as early adopters will then diffuse. New Zealand's remoteness results in diffusion being predominantly from frontier firms within the country unlike other SAEs that benefited from frontier firms out with their country.

Frontier firms are at the centre of 'innovation ecosystems'. The innovation ecosystem comprises of a network of many parties; researchers, science, firms, government agencies and more. Their success is acquired through scale, more resource and ability to maintain networks.

The farming business

New Zealand is a nation made up of small to medium enterprises (SMEs). SMEs are defined as businesses with fewer than 20 employees. A large proportion of farms are SMEs; 93% of sheep and beef farms are owner operated (Beef + Lamb New Zealand, 2021). Over the 2019/2020 season the dairy workforce comprised of 11,092 people, 56% of those being owner-operators (DairyNZ, 2020).

New Zealand farmers are at risk of the commodity markets, as was seen in the early 1990s. Low commodity prices drove efficiencies and increased productivity growth. By early 2022, global prices

for New Zealand's commodities have been rising but so too has inflation and interest rates. Fonterra lifted their forecast Farmgate Milk Price from $8.90 to $9.50 up to $9.30 to $9.90 per kg of milk solid. Representing $14 billion to the economy from the mid-range payment. But input costs have also increased; electricity costs rose by 21% and stock grazing costs increased by 36.9% (Fonterra, 2022).

Smaller firms are less able to keep up with technological change as they have less resources; less financial liquidity, less labour and less infrastructure. Energy and resources are concentrated on operation, what to do today and tomorrow, rather than exploring different ways of doing things. The OECD have found that smaller firms are lagging behind in the digital transformation (OECD, 2021).

Regulatory change

In the global perspective, the European Union is one of the largest trading entities, with which New Zealand is currently in trade negotiations. The European green deal will require those in the European Union (EU) to farm in a way that is 'fairer, greener and more animal friendly' (NZFAT. 2021) This will also be expected of imported products, 'non-compliant' imports may be restricted.

New Zealand secured a free trade agreement with the United Kingdom in February 2022, estimated to boost New Zealand's GDP between $700 million to $1 billion (Beehive, 2022). This is the first bilateral agreement that will include a specific article regarding climate change.

In New Zealand, over the past two years, regulatory policy changes have come thick and fast: The National Policy Statement for Freshwater Management, National Environmental Standards for Freshwater and Biodiversity Strategy 2020. The Resource Management Act (RMA) is about to go through a redesign and split into three different pieces of legislation: Natural and Built Environments Act (NBA), Strategic Planning Act (SPA) and the Climate Change Act (CAA). Touted as one of the 'biggest regulatory shakeups in the environment space in New Zealand's history' (Morton,J. 2021) would suggest this is not going to be an easy or quick endeavour.

At the farmer level there will be enforced changes: stock exclusion regulations, changes to winter grazing practices regarding sowing dates and slope of land, restrictions on intensive winter grazing, restrictions of changes of land use, caps on amount of synthetic fertiliser use, managing critical source areas and animal welfare requirements. (Grant. 2021)

'The Howl of a Protest', organised by Groundswell NZ, in July 2021 was a show of frustration by farmers. Reported at the time as 'a rally against Government regulations' (NZ Herald, 2021) the

legislative changes were felt as an accusation by farmers; of being polluters and not caring about the environment around them, their farms, their homes and therefore their legacy.

Paradigm shift

Thomas Kuhn (1962), physicist and philosopher, theorised that science works in its own paradigm, a framework that provides models and accepted norms. Until that is, the paradigm shifts. A revolutionary idea comes along that shifts the way of thinking. Charles Darwin's 'Theory of Evolution' (1859) was revolutionary and changed the accepted world view that of Creationism to Evolution; that humans evolved and had common ancestry to apes. The discovery of DNA, genetically inherited information, revolutionised science resulting in research to combat genetic diseases.

The concept of paradigm shift can also be viewed in general terms; normality is challenged by the different. If the different proves to be better and is accepted it will replace the current framework which shifts the paradigm.

New Zealand is unique in that farmers don't rely on agricultural subsidies like many countries in the World. A few of the biggest subsidisers are China, USA, Japan and the EU. Subsidies were present in New Zealand through the 1970s into 1980s. They were introduced due to high oil costs, commodity price collapse and Britain's entry into the European Economic Community (EEC) reducing income. Subsidies were removed in the 1980s. They had caused a number of problems: a surplus of product that couldn't be sold (sheepmeat), had kept the market from diversifying and developing different products and had encouraged maladaptive practices such as developing land that didn't make economic sense (NZIER. 2006).

The removal of these subsidies in 1984 was a transformational time for the sector. As with any transformation there was disruption, impacting Individuals and rural communities. New Zealand's agricultural production forty years on is driven by the market (MPI. 2017).

Subsidies encouraged a productionist model through the 1970s until subsidy reform (Pomeroy, 2015). Farmers were encouraged to boost production whether the market was there or not: more is better. Reforms in 1984 removed that income, efficiency became the driver for those who continued to farm (fertiliser use and sheep numbers decreased): more with less input. Drivers of todays' production are to continue to produce product efficiently but also sustainably: more with less input and less impact. A shifting paradigm of more, to more with less input, to more with less input and less impact is now expected of the farmer (Figure 7).

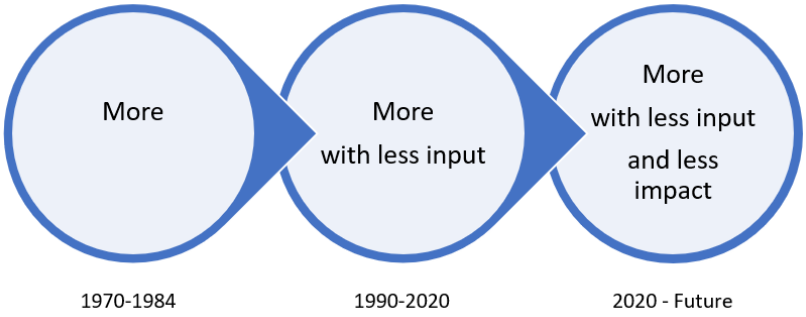

Figure 7: Paradigm shift – New Zealand Primary Production, adapted (Pomeroy 2015)

Productivity is still a key metric for some farmers that are working on increasing profitability. The environmental impact of farming is part of the decision-making process '*environmental aspect of farming is at the forefront of my mind*' (Farmer A) and '*good farmers are doing it already*' (Farmer E). Continuing to farm by meeting environmental standards is accepted but the cost of compliance weighed on the mind. There are uncertainties concerning compliance requirements and whether they will be beneficial to the environment '*if compliance measures aren't adding to the environment, it's a step for nothing. We're just jumping through hoops'* (Farmer E).

Findings and Discussion

The main themes from interviews that impacted the ability of farmers to take on new technologies and innovation were financial, knowledge gaps and rate of change.

Financial

Rogers (1995) DOI identified that financial liquidity was one factor used to correlate the terms innovator through to the laggard; innovators and early adopters are said to have more financial resources. However, up to sixty percent of a population make up the early and late majority that have less financial resources therefore are risk averse. Proof is needed before new products and processes are adopted.

Farmers

Farmers interviewed want to have economically viable businesses and one of their drivers is to reduce debt. Debt wasn't seen as purely negative as it pushed for change to ensure a good return, *'no debt, no worries'* (Farmer C). Total farm debt in New Zealand was reported to have increased 270% in 20 years, to $62.8 billion in 2019 (Walls, 2019), two thirds of that sitting in the dairy sector. Many farming businesses are dealing with debt, '*money is holding us back'* (Farmer C) and '*pressure is financial'* (Farmer A). Although debt is seen to be slowing the uptake of new technologies the

future was looking positive, *'Rome wasn't built in a day'* (Farmer A) and '*5-10 years to get it where you want*' (Farmer A).

New technologies that could have a positive impact on farm by reducing labour hours on certain tasks may be priced too high for the size of the farming operation; if they do not replace a full labour unit and are an additional cost they will not be adopted '*can't afford to pay everything'* (Farmer E). The lack of scale (Rogers defined this as farm size) and shorter growing seasons (lower productivity than other regions) will negatively impact the viability of some technologies. The cost of technologies that can identify problems in infrastructure using sensors, which pinpoints the location of the problem rather than having to find it were not of consequence '*the cost with it is irrelevant as at least one person could spend half a day getting it going again. The opportunity cost is animals without water*' (Farmer B). Lower costs combined with a relative advantage will increase adoption.

Agribusiness

Those in agribusiness stated that many farming businesses are dealing with low profits. '*Farmers are under pressure, a lack of finance and are cautious about investment*' (Agribusiness E) but farms are not homogenous, they are not all the same. Farm development is different for each farm '*huge variance of farm development across the catchment'* (Agribusiness C) therefore if all farms were assessed at a set point in time they would be at different stages of growth.

Agribusiness acknowledge that technologies and innovation that do not show an advantage will not be taken up *'real benefit and clear return'* (Agribusiness E) and *'must add value'* (Agribusiness G). If there is no change to what the farmer is currently doing the technology will fail to be adopted *'failures have been when there's no monetary benefit for the farmer above what he's doing'* (Agribusiness F).

Science

Those working in science talked of the financial risk facing farming SMEs due to their conservative nature '*risk of failure when operating under small margins*' (Science A), are '*financially less able to make transformative change*' (Science B) wary of risking their family home. Although others felt that those working in science did not think of the business side of farming, '*scientist not taking bottom line into account'* (Science F) and '*not funded to look at the rest of the equation, economic component is often overlooked, it's not production per animal but production per hectare*' (Science E).

Older farmers who have reduced debt are seen to be less open to change '*older farmers are risk averse'* (Science B), although this changes if help is free. Rogers (1995) DOI identified that the older the farmer is the less they are open to change.

Financial constraints also affect the science community who are working on projects for farmers, '*science is underfunded*' (Science C), '*good research is expensive especially on perennial species that have to be tested in different regions*' (Science G). This would suggest that a lack of funding and the expense of carrying out high quality trials in extension are at odds.

Political

The political lens perceived that farming SMEs are innovating and trying to run profitable businesses but they are asset rich and cash poor '*the business model is problematic*' (Political A). Diversification has increased over the last decade, accelerating in the past five years as farmers look to increase their income from a variety of sources *'can't rely on wool, lamb or beef cheque'* (Political A). The availability not affordability of new technologies and innovation, such as genetic engineering, could lead to New Zealand being less competitive with off-shore trading partners.

<u>Knowledge gaps</u>

The lack of knowledge can be a barrier to the uptake of new technologies and innovation. The remedy is to increase knowledge; to learn about the new product or process as it is a change of what is currently being done. The fear of not knowing what to do and being penalised for getting it wrong are powerful barriers. If the new process or product does not fit with current values or does not match the group values that a farmer belongs to there will also be resistance. Education and access to social networks is highlighted by Rogers (1995) DOI. The more education and better connected one is the more open to innovation.

Farmers

Farmers are looking for better ways to do things on farm and are open to change '*constantly changing how we do things'* (Farmer E) and '*looking at what we've got around us, has to create an opportunity*' (Farmer B). They aren't creating the technologies themselves '*not creating the product, fitting it into your* system' (Farmer B) but are motivated to find out more information '*do research yourself*' (Farmer A). Most importantly, they are trying different ways of doing things. Assessing their own farming environments and looking for solutions to the problems.

Farmer opinions of knowledge being sourced directly from science are mixed, some felt that science was '*off the radar*' (Farmer A) and '*science has a long way to come, we're due for the next big thing*'

(Farmer E). Others felt that they know where to look having made connections through their own education backgrounds. The need for education was seen as essential for the current and future farmer '*knowledge requirement is a lot greater now*' (Farmer B).

Links to agribusiness were commonly positive as information was shared freely behind the farm gate '*there's a lot to tap into. Farmers and suppliers are easy compared with past the farm gate*' (Farmer B). Farmers trying to create businesses past the farm gate found knowledge came at a price, through consultants, with no guarantee of the quality of information.

Farmers reach out to catchment groups to increase networks, wanting to connect with community and upskill themselves as well as others. Those attending catchment groups acknowledge that there has to be a social element *'group with no social culture, we don't think it will last long'* (Farmer C). Not all attend catchment groups regularly due to *'groups tend to be same old, same old'* (Farmer E) but do if there are new innovations of interest. Sharing data in catchment groups is regarded as strengthening communities, as it helps everyone's mental health in those poorer performing years, reducing the feeling of isolation '*openly share their failings, a lot of positivity comes from that*' (Farmer D).

Information available through levy bodies is regarded differently by farmers interviewed. If information is hard to find and is not specific there is a lack of engagement '*it's too broad, too unspecific and farmer engagement is low because it's too general*' (Farmer C). However, the same levy group that had low famer engagement was praised for involvement at catchment level with farmers.

The lack of knowledge at the local council level was highlighted as a barrier when trying to get resource consents for infrastructure on farm '*The local council have their systems and have trouble dealing with anything out of the norm*' (Farmer D) and '*those enforcing the policies don't know what is required*' (Farmer C).

Agribusiness

A lack of technical support for those who are considered early adopters is seen as a barrier for those on farm '*when taken out of their comfort zone, there isn't a lot of technical support'* (Agribusiness A). Farmers need support from sources who understand the whole system, '*need big picture people, multi-disciplinary teams'* (Agribusiness B) to act as translators to tell the farming community what they need to know '*farmers need to feel in control'* (Agribusiness C). Focus farms that have a lot of technical support from multi-disciplinary teams have been seen to have successful outcomes. However, as the system is adopted further afield by farmers with less or no technical support the

process can break down '*Others looking over the fence and not doing what they should at the right time and then trying to catch up could cost more'* (Agribusiness F).

Farmers are credited with innovating on farm which is then validated by science and industry. Farmers need to be part of focus groups to ensure products are fit for purpose '*develop products with the customer'* (Agribusiness E). The successes are shared readily but negativities are not '*fear of sharing realism, the negativities are not shared'* (Agribusiness A).

Science

Farmers are seen to be working hard in the background looking for advice in a format that they can access on their own terms *'quiet achievers who don't attend field days and want non-judgemental, private and positive information'* (Science B). Applied science through on farm trials is crucial '*applied science is needed as it's end user relevant'* (Science B) as a farmer is familiar with their farm and their farming system. Yet, some believe that those carrying out research are not looking at the 'big picture' on farm, *'too much of research is being done by those who are narrow, fewer people are thinking in systems'* (Science E).

The majority of those working in science want to use their skills to help others '*most scientists want to produce products for the end user and do good in the world'* (science C) and *'integrity is all a scientist has'* (Science B). Yet there are knowledge gaps affecting the science community's ability to do that '*a lot of scientists didn't think about end users'* (Science D) and '*science links to end user are tenuous'* (Science F). The commercial component of the current RSI system in New Zealand is seen to be tying up resources that used to link with the end user '*in the days of DSIR, scientists had access to end users and it wasn't clogged up with business development'* (Science C). The nature of academia was seen as a barrier to innovation due to a lack of collaboration *'academia Is based on individual performance, the system encourages individual success*' (Science A).

Political

Farmers are being disadvantaged due to not knowing about products that could help them '*they don't know how to tap into commercially available products that will help them'* (Political A). The younger generation of farmers have less knowledge, higher debt and young families that add to their everyday pressures '*farmers in their 60s and 70s have seen it before and know the cycle'*. It is important to pay attention to those who are older and have experience as they have many years of knowledge gained over farming cycles. The potential laggards should not be dismissed as they may have advice having previously tried products and processes.

<u>Rate of Change</u>

The resilience of farming systems is the ability to maintain integrity and identity following shocks; natural or caused by humans (Pomeroy, 2015). Resilience can be affected by a combination of pressures: economic, ecological and societal (Meuwissen, 2019). Those who were interviewed for this project, across the groups, talked of the regulatory rate of change experienced by farmers; interviews were completed at the end of 2021. Viewpoints across the groups are compiled together.

Regulatory changes have been expected by most farmers who have been following international trends '*it's been on the cards'* (Farmer B) but there are those who are frustrated by the legislative change '*comes at you from nowhere*' (Farmer E).

Frustration is due to the rate of change '*waves in the ocean'* (Farmer C) taking up energy that could be used to look at new ways of doing things '*mind is full of regulatory rate of change never mind looking at new ways of doing things'* (Farmer E). The farming community are wary of increasing spending '*why would you invest when there is so much change going on'* (Agribusiness C).

Technology options are not keeping up with the rate of change in legislation *'legislation is moving faster than technology*' (Farmer B) *and 'Legislation has been too fast and regional councils can't cope'* (Agribusiness C). The need to fill out submissions weighs heavily on some, the younger generation of farmers worry for older less engaged farmers '*young, tech savvy but still not all over it*' (Farmer C).

Conclusions and recommendations

Primary industries have been adopting technology and innovating, increasing productivity growth over the last 40 years. Individual farmers are evaluating their systems and finding ways to optimise their processes. The assumption that the farmer is stuck in their ways and not open to new things is not backed up by the evidence.

However, a farmer is an individual characterised by such things as point of view and history of experiences. Thought processes and decision making will be made from a complex algorithm of personal values, previous experiences (good and bad) in a reflexive loop. Treating farmers as a sector, as an average, rather than individuals will miss the mark for most. Assessing the needs and expectations at an industry level is to talk of the many but miss the one.

Farmers deal with external forces every day; farms are biological systems and weather patterns change every year. The farming community have been dealing with the same volatile, uncertain, complex and ambiguous (VUCA) world as the rest of society. They are professionals at dealing with change, weather is a prime example, but the effects of a global pandemic, the pace of regulatory

change and the unknown costs associated with environmental compliance in the new paradigm of the primary sector is leading to uncertainty.

Most New Zealand farms are small to medium enterprises, businesses that do not have slack in the system as they are running as efficiently as possible with what they have. It takes time and energy to research new options. Social networks are important and having more of them across different disciplines increases knowledge; knowledge creates opportunity. New Zealand farmers have diverse businesses across diverse regions. Therefore, there is not a one size fits all solution. One farmer joining many farmers in a region, interacting with science and rural professionals will bring together intricate knowledge held by different groups.

The adoption of new technologies will depend on whether they present an advantage, match personal values that are held, are easy to use, can be tested and show results. Disruption follows change while problems are dealt with. The saying 'you don't know what you don't know' is relevant but having help to persevere with change, especially transformational change, is vital. Change is only possible if one has security and help along the way.

My recommendations for primary industry are that farmers must:

1. Be viewed as individuals each with their own viewpoints, systems and requirements.
2. Engage at the local and regional level and create innovation ecosystems. Ideas come from multiple groups working together; farmers with farmers including rural professionals and scientists.
3. Be prepared for disruption, be the support that is needed.
4. Learn from failures; use them, share negativities as it will build better resilience.
5. Have realistic expectations regarding change. Innovation takes time.

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Appendix

Interview questions for each group:

Farmers:

1. Have you identified new ways of doing things on your farm?
2. What would stop you from pursuing them?
3. Where do you go to get information?

Agribusiness and science community:

1. What do you see the links are between science and industry/agribusiness?
2. What do you see the links are between your sector and the farmer?
3. What barriers have you come across in your career when deploying innovation?

Political:

1. What do you see is driving the farmers in your constituency?
2. What do you think the barriers are to farmers regarding innovation and technologies?
3. How is regulation affecting the farmer?

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