KELLOGG
RURAL LEADERSHIP
PROGRAMME

Virtual Fencing

Leading the Digital Transformation of New Zealand Pastoral Farming

Kellogg Rural Leadership Programme

Course 38 2018

Greg Shepherd

I wish to thank the Kellogg Programme Investing Partners for their continued support:

'Don't aspire to make a living, aspire to make a difference'

- *Denzel Washington*

EXECUTIVE SUMMARY

The first settlers were recognised for establishing farms and runs by breaking in land, building boundary fences, establishing key farm infrastructure, processing facilities and forging development of new distribution channels. Pastoral farming[1] rapidly became the mainstay of the New Zealand economy, creating the fabric of rural communities, provincial towns and provided the opportunity for urban citizens to flourish. The last 20 - 30 years has witnessed exponential change globally in land use, ownership, labour supply, technology and urbanisation. As the resulting global expansion puts pressure on natural resources measures of value, priorities and political points of view, the need for change is being realised and vocalised.

In this research there is an exploration of digital transformation forming the convergence of the physical and biological world, with the digital and virtual world in the context of pastoral farming and virtual fencing. Readers will be familiarised with the establishment and use of fences, the associated legislation, a foundation of livestock and pasture management and the art of livestock grazing to formulate the basis of fencing today. This holistic view provides the backdrop to understand the opportunity virtual fencing has for digitally transforming existing farming practices and assessment against industry priorities and political policies driven by voters, consumers and shareholders.

The research provides the following broad conclusions:

1) The uses of fences on pastoral farms are proven through history and fundamentally aren't expected to change despite the introduction of virtual fencing technology.
2) Other than pest or wild animal control virtual fencing has the potential to be a foundation technology and catalyst for digital transformation of New Zealand pastoral farming.
3) Virtual fencing will resolve or enable the resolution of many of the items represented in the contextual overview by Hon. Damien O'Connor, the Grassroots Roundtable, the industry priorities and political policies.
4) Most importantly, to achieve digital transformation and therefore large-scale change will require strong leadership from the pastoral industry, technology innovation and regulatory changes from government to shift from the status quo.

The following smooth the way for adoption and to capitalise on the opportunities presented for virtual fencing:

1) Monitor New Zealand trials of virtual fencing technologies.
2) Review research relating to environmental exclusion zones and perform detailed cost benefit analysis.
3) Appoint industry lead working group/s to drive legislation reviews and changes.
4) Investment in digital transformation strategies for pastoral farming.

Disruption of New Zealand pastoral farming will be determined by voters and the industry stakeholders as masters of New Zealand's destiny on the supply side or by international business and consumers on the demand side to reach new value. Leaders need to inspire pastoral farming beyond the status quo in order to capitalise on Fourth Industrial Revolution technologies, like virtual fencing, to improve national productivity and move the value web into the global frontier position across food and fibre production, processing and products.

[1] **Pastoral farming** is a form of agriculture aimed at producing livestock, rather than growing crops. Examples include dairy farming, raising beef cattle, and raising sheep for wool (Wikipedia, 2018).

ACKNOWLEDGEMENTS

Again, to the sponsors for your leadership and your ongoing support of the Kellogg Rural Leadership Programme.

To the Kellogg Rural Leaders Programme and the masterful hands of Anne Hindson, Patrick Aldwell, Dr Scott Champion, Lisa Rogers and all the speakers for course 38, thank you for keeping us on task and providing an incredible environment to learn and develop leadership skills.

To Dr David Stevens, Graeme Mulligan, Paul McGill, Mark MacLeod-Smith for providing your insights relating to virtual fencing technologies.

To my Spark colleagues who provided leadership and the opportunity to implement challenging projects and for your support while on the Kellogg Rural Leaders Programme. Thanks to Patrick Verryt, David Walker, Tony Sinclair (Farmlands), Dave Scullin (Ballance), Tim Lloyd (Ballance), Dr Mark Bojesen-Trepka (NIWA) and Geoff Latimer (NIWA) for getting me back on farm to bring Internet of Things to agriculture.

To my parents (David and Elizabeth), grandparents (Mortimer and Eileen Shepherd, Frank and Janet Hore) and extended family, collectively you have instilled in me a passion for farming and a will to achieve.

Finally, to my wife Jo and our new born Florence, thank you for inspiration and undivided support, you both rock!

FOREWORD

In 1991 I was seeking a project to use technology and innovation in agriculture, it led to the creation of a digital map of the family farm. The base layer was produced showing farm boundaries and internal fences on top of the original farm image. Paddock features such as troughs and gates were added and the ability to add paddock records including names, areas, fertiliser history, stock grazing and pasture types. That snapshot in time of is now mainstream technology and fundamental to choosing the subject of the report.

My career has evolved from professional services to financial services and most recently telecommunications spanning a range of process re-engineering, digital transformation and Internet of Things projects.

The internet and the associated technologies of The Third Industrial Revolution paved the path for digital transformations. Now the Fourth Industrial Revolution technologies is initiating the diffusion of digital value beyond gadgets. Artificial Intelligence, Augmented Reality, Virtual Reality, Internet of Things, Blockchain and Robotics will allow the convergence of the physical and biological world, with the digital and virtual world predicted to significantly alter how our world operates (World Economic Forum, 2018), (Morris, 2018).

Observations of New Zealand companies undergoing digital transformations, show a desire to use technology to compete in the rapidly changing dynamics of domestic and global markets. Improving customer experiences, automation of value chain processes or revolutionising business models to deliver new products and services faster and more sustainably (Rossman, 2016) (Westerman et al, 2014), to meet consumers' ever-increasing demands is key to economic survival and maintaining shareholder investment.

For pastoral farming the industrial revolution technologies provided the catalyst for machines to reduce labour and scale activities across value chains and industrialise agriculture leading to commoditisation of primary products. Today there are several industries disrupted by digital technology including, finance, insurance, retail, telecommunications, utilities, transport, logistics and tourism (Westerman et al, 2014). Arguably digital technology hasn't disrupted the agricultural value chain … yet, leaving New Zealand with the most value to gain or most potential to lose.

Globally a rapid investment shift is occurring into arguably the world's first industry and certainly from a prolife perspective most valuable industry (Agritech NZ, 2018). Organising the use of the earth's finite resources to feed the exponential expansion of population, certainly won't happen on its own.

Nationally the reallocation of capital and resources into pastoral farming technologies, such as virtual fencing, will provide substantial gains in output and terms of trade by smoothing the path of products to international markets. In measures captured in the World Economic Forum's Global Competitiveness Index it has the potential to shift New Zealand to a global frontier position across social, environmental and sustainability measures while enhancing existing market positions to maintain an economic edge against international competition.

CONTENTS

Executive Summary I

Acknowledgements II

Foreword III

Contextual Introduction 6

- Measuring Value in Today's World 6
- Measuring Progress 7
- Levers for Progression 8
  - Labour Productivity 8
  - Terms of trade 8
- Opportunities 10

About the Research 11

- Purpose 11
- Structure of this report 11
- Aims and Objectives 12
- Method 12

Literature Review 14

- Virtual Fencing 14
  - Virtual Fencing Definition 14
  - Virtual Fence Components 14
  - Commercial Entities 14
  - Discussion 15
- Key Farm Management Practices 15
  - Property Ownership & Responsibility 15
  - Livestock Management 21
  - Pasture Management and Grazing 28
  - Financial Management 32
- Digital Transformation 33
  - Customer Experience 35
  - Operational Processes 35
  - Business Models 35

Building Leadership Capabilities 36
Discussion 36
Shortcomings 38
Conclusions 38
Recommendations 40
References 41
Appendix 51
Search Topics 51
Research Sources 52

CONTEXTUAL INTRODUCTION

Historically peasant farming allowed subsistence living, providing food for one's family and a means to trade (or barter) for other goods and services. Farming formed the genesis of the industrial revolution and the rise of the agricultural related industries, by forming more efficient production, harvesting and processing of products ready for market. While it resulted in the commoditisation of agricultural goods to supply urban residents across villages, towns, and cities, in the specific case of New Zealand's, it enabled exports to other countries. The distinctly unique position has been achieved through the link to the British Colony as a key market and *'the number 8 mentality'*[2], combining ingenuity and resourcefulness, to afford New Zealander's a position of respectable incomes and standards of living.

A lot has changed and in many respects a lot hasn't, however maintaining New Zealand's standard of living is front of mind and a hotly debated topic covering national values, economics, health and wellbeing, social and environment to form the fabric of society and our political status. It is proving equally important to balance the policy framework that impacts pastoral farming and the needs of pastoral farmers to encourage succession and new labour into the industry.

The Fourth Industrial Revolution (World Economic Forum, 2018) we find ourselves in today formed from the origins of internet, mobile phone, social media, supported by gradual democratisation of navigation systems, battery and solar energy within a very short 20 – 25 years and is part of 'The Big Shift' (Morris, 2018).

This section provides context of how as a country we measure value, progress and the levers and opportunities to adjust improve those values whether financial or otherwise.

Measuring Value in Today's World

The measure of success for people, society and nations is a combination of many factors covering values, beliefs, income, standard of living, but may also include ambitions and legacies that people may wish to leave.

The democratic capitalist mantra prescribes 'increasing income provides, improved material living standards, including education, employment opportunities, health' and therefore lifestyle, thus promoting income as the key measure of success.

Using this approach New Zealand is benchmarked against other OECD countries by comparing key indicators like income (real GNI per capita), output (GDP

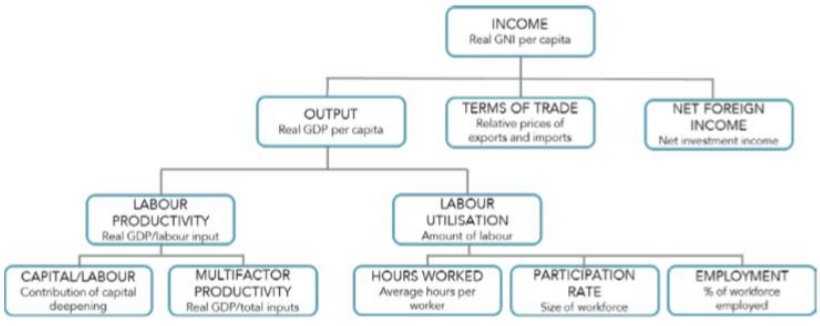

Figure 1 - Components of real GNI per capita
Source: (Conway and Meehan, 2013) *modified from New Zealand Treasury (2008)*

[2] **Number 8 wire** - was the preferred wire gauge for sheep fencing, so remote farms often had rolls of it on hand, and the wire would often be used inventively to solve mechanical or structural problems.[1] Accordingly, the term "number 8 wire" came to represent the ingenuity and resourcefulness of New Zealanders,[2][3] and the phrase "a number 8 wire mentality" evolved to denote an ability to create or repair machinery using whatever scrap materials are available on hand.[4] (Wikipedia, 2018)

per capita) and terms of trade calculated by which New Zealand treasury using the following components (Conway and Meehan, 2013). Income is one measure, however progressive improvement is expected across multiple aspects including but not exclusively, environmental and conservation, social and mental wellbeing, crime, tourism and customer perceptions, our identity and even the balance of equality across contrasting sections of society such as urban and regional communities. These factors form social policies, demonstrated within the New Zealand government's agenda (NZ Labour Party,2, 2017).

The World Economic Forum's, Global Competitiveness Index measures the distance to the competitive frontier, to determine national competitiveness defined as the set of institutions, policies and factors that determine the level of productivity (Schwab, 2018).

The index's 12 pillars used to measure human capital, innovation, resilience and agility, as drivers and features of economic success in the Fourth Industrial Revolution, align with a worldwide consensus for a holistic model of economic progress that promotes higher living standards for all, respects planetary boundaries, and does not disadvantage future generations.

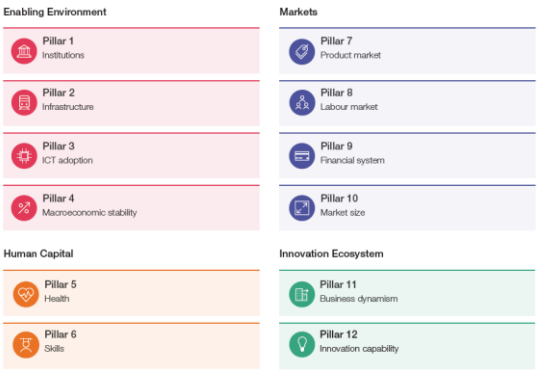

Figure 2 - Global Competitive Index 4.0 2018
Source: The Global Competitive Report 2018

Changes are occurring globally influenced by perceptions, expectations and values of international consumers, tax payers, voters and shareholders. The changes are challenging New Zealand to evolve to maintain or improve its global ranking, reflected by the ongoing effort to have robust trade agreements to create alignment with other nations. In a rapidly changing world that is drawing heavily on the global resources, the World Economic Forums Global Competitiveness Index uses more comprehensive measures, providing balance across political policies.

Measuring Progress

History demonstrates that humans are naturally inclined to innovate, adopting technology and change to evolve and progress, which in turn continually shifts expectations, demand and value. In New Zealand, significant focus is applied to improving output or terms of trade to increase overall GNI and providing progress. However, the recent changes in global sentiment and the coalition government are challenging the status quo and therefor the measure of progress.

New Zealand regularly reports on output (GDP per capita) as the economic measure of output, showing consistent improvement since 2008 (Figure.NZ, 2018). Labour productivity (GDP per hour worked) remains low against our OECD peers (OECD, 2018), despite 50% growth contribution to gross national income per capita (Conway and Meehan, 2013). Technology has a substantial role improving the labour productivity measure. Labour utilisation, the other lever to improve output, is physically constrained and expected to be further restricted by the ageing population (Conway and Meehan, 2013).

These dynamics mean labour productivity is a focus of economic related policies, and labour utilisation becomes a focus of employee rights for social development policies, which creates a perceived paradox for voters and therefore short-term contention to exploit political gain.

Levers for Progression

LABOUR PRODUCTIVITY

Labour productivity measures exemplify doing more for less, however aggregated data doesn't provide a means to identify levers to improve this measure.

A recent study by the productivity hub provides insights, refer to figure 3, concluding the diffusion of technology from global frontier firms to the domestic frontier firms closes the gap between the domestic and global frontiers. Diffusion of technology between top domestic performers to poor performers improves labour productivity (i.e. producing more for less), as aggregate productivity growth moves closer to the global frontier (Allan, 2018).

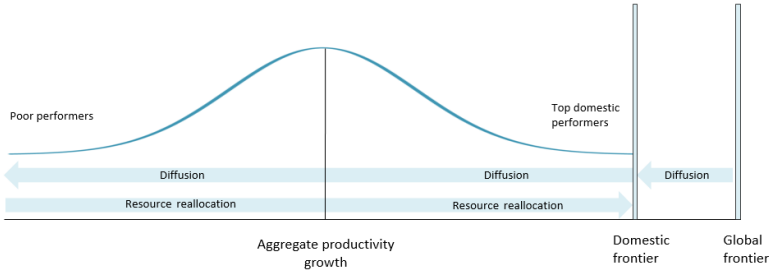

Figure 3 - A stylised model of firm productivity
Source: Conway (2016) based on OECD (2015)

Conversely the reallocation of resource from poor to top performers allows employee productivity progression and top performing firms progression by expansion, with poor performers becoming uncompetitive and unviable (Allan, 2018).

The value of firm level data can't be underestimated to identify opportunities to adopt technology and improve labour productivity. In New Zealand the Longitudinal Business Database (LDB) is the data research resource, linking firm level data from Statistics NZ, NGO's and government agencies (Statistics NZ, 2018), to develop government policies and influence shifts in labour productivity and GNI.

TERMS OF TRADE

Terms of trade is another component to improve GNI, measuring the relative prices of imports verses exports, with merchandise exports (predominately food and fibre commodities) showing a positive trajectory in the last few years (Statistics NZ, 2018). It is widely accepted New Zealand pastoral farming, as commodity producers, need to add value to support farm gate and terms of trade growth.

In 2015 Silver Fern Farm shareholders decided, with an 82.22% majority vote in favour of a 50/50 partnership with Shanghai Maling Aquarius Group instead of a proposed merger with Alliance Group (Silver Fern Farms, 2015). The partnership was completed (Silver Fern Farms, 2016), providing Silver Fern Farms the platform to build their Plate to Pasture value add strategy.

> *As part of our Plate to Pasture strategy, we are focussed on successfully building branded, differentiated products and then linking these consumer programmes directly with livestock supply programmes – creating that market-based linkage from consumer to farmer. - Dean Hamilton (Chief Executive).*
>
> *Source:* (Silver Fern Farms, 2017)

Fonterra was recently publicly criticized in the media for its first financial loss and questioned on its ability to deliver on the value-add strategy of the previous leadership (Hickey, 2018). A social media article (Craner, 2018) captures the paradox Fonterra shareholders and leadership face to establish best way to compete with other multi-national branded products.

> *… farmers who rightly want the maximum return for their milk, so they can invest in their own farm infrastructure. On the other side we have Fonterra wanting to pay the least for its milk raw product, so it can make a greater margin on its products and invest in more value-adding infrastructure ... – St John Craner (Kellogg Alumni)*
> *Source: LinkedIn* (Craner, 2018)

Like output, terms of trade are susceptible to dramatic shifts from outside influences, including supply and demand shifts, exchange rate fluctuations or geopolitical events. The 12 pillars represented in the World Economic Forum's Global Competitiveness Index and the change in sentiment from consumers, indicates value alignment will move to environmentally sustainable food production processes. The challenge will be efficiently educating and providing evidence to consumers to attract the added value.

Opportunities

What opportunities are there in New Zealand pastoral farming to influence the measures of progress?

Political parties, voters (and consumers) debated the following key policies in the last election:

1) **Water** was high on the election agenda. Labour as the majority holder of seats in the coalition government, contends land use and farming practices, have contributed to degradation of water and river ecology (NZ Labour Party,1, 2017). The policy's twelve-point plan includes:

   … compliance with nutrient budgets, monitoring of land use, fencing within 5 years of all intensively stocked land near waterways, and setbacks for riparian planting to filter and absorb silt and nutrients to counter the degradation concerns … (NZ Labour Party,1, 2017).

2) **Jobs and Innovation** another Labour policy aims to achieve digital equality by 2020, expedite access to world class broadband and telecommunications, establish a Chief Technology Officer to support a national technology roadmap and update legislation (including the Telecommunications Act) to give certainty to digitisation for industry, businesses and consumers (NZ Labour Party,3, 2017).
3) **Climate Change** and the environment are also on the agenda with the emissions trading scheme (ETS) and intention to explore the potential of different land-use choices, biological processes and production systems for both reducing emissions and being profitable (NZ Labour Party,4, 2017).

The World Economic Forum's Global Competitiveness Index[3] and Labour's Policy statements, signal changes for agriculture, captured succinctly in the KPMG Agribusiness Agenda 2018 foreword:

> *… Consumers are increasingly buying products to align with their values and we must make the most of our natural advantages such as pasture-fed livestock, environmental sustainability and good animal welfare – and now more than ever is time to tell our story - Hon. Damien O'Connor*
> *Source: KPMG Agribusiness Agenda 2018*

With a counter position following many public debates about the industry, is represented by:

> *People outside of farming do not realise that your whole life is consumed by farming – day in, day out. After six years … I am not certain I want a farm now. With the low returns, environmental issues, weather and biosecurity risks, long hours, animal health and welfare challenges, why would you do it? - Comment from Grassroots Roundtable*
> *Source: KPMG Agribusiness Agenda 2018*

The KPMG Agribusiness Agenda 2018 ranks priorities as shown in Figure 4 as a result of annual research conducted in consultation with 60 industry leaders.

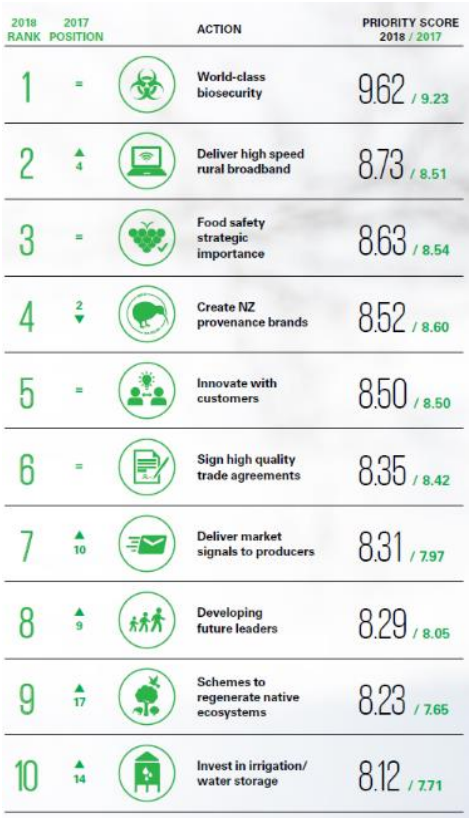

Figure 4 - 2018 Top Ten Priorities
Source: KPMG Agri-business Agenda 2018

[3] Refer to Measuring Value in Today's World.

ABOUT THE RESEARCH

The information presented in the preceding sections provides a valuable basis and relevant context for the research. The components of GNI, such as labour productivity and terms of trade and measures represented in the World Economic Forum's, Global Competitiveness Index influence how pastoral farming should leverage innovation and digital technology and form purpose, structure of the report, aims and objectives, method of research.

Purpose

The following literature review is an investigation of the touch points associated with implementing virtual fencing technology into pastoral farming. It is intended to provide a theoretical qualification of whether virtual fencing could act as a foundation technology and therefore catalyst for scaled technology adoption, by addressing the priorities, challenges and opportunities for pastoral farming in New Zealand and improve labour productivity and terms of trade.

The primary purpose of the research and subsequent findings in the report relating to the above can be summarised by asking the following question:

> *Is virtual fencing a foundation technology for digital transformation of New Zealand pastoral farming?*

An initial hypothesis assumed that suitable specific literature wouldn't be available to easily establish an answer, was confirmed, so instead of altering the question it was decided exposing the intersect between science, technology, pastoral farming practices, legislation and digital transformation was more valuable.

Therefore, this report is expected to, demystify some terminology, the technology, flush out constraints or risks, and show the complexity requiring collective collaboration and joint leadership between public and private sector for diffusion of innovation to resolve publicly aired frustrations, which have turned into political debates.

Structure of this report

The report is structured to provide readers with a contextual introduction of the country's economic measures, measure progress and success at a national level. Highlighting key opportunities for the agricultural industry to support the economic measures and the sustainable improvement of production volumes and delivery of higher valued products to international consumers.

The report then captures the purpose of the research and the overarching aims and objectives including the relevance of investigation of virtual fencing.

The method section describes the approach taken to gather relevant information and the parameters used to refine the collection process. It also describes the process for analysing and presenting the results of key themes researched. The literature review contains specific evaluations relevant to each section.

The conclusion section provides an answer to the purpose question and follows with recommendations to provide the next steps.

Aims and Objectives

This report aims to use virtual fencing as one example to discuss the convergence of the physical and biological world, with the digital and virtual world, a key aspect of digital transformations and The Fourth Industrial Revolution. Although there may appear to be significant challenges ahead for the industry and New Zealand, I hope to demonstrate that what may be ideology to some, the greater good to others is achievable once the parts of the puzzle are understood. Using Simon Sinek's[4] mantra; I seek to demonstrate collective collaboration at a macro level to empower pastoral farming and agree a position to inspire the world with *Why*, that will lead to adapting practices using digital strategies to explain the *How*, so New Zealand can advance production and distribution of the *What*.

On a personal level through reigniting ties and a selfless passion for New Zealand's primary industries, I aim to align the themes and learnings of the Kellogg Rural Leadership Programme to develop a career in leadership within the agricultural industry. The research is seen as an opportunity of re-familiarising with the science of pastoral farming and extending my knowledge of the associated legislation and policies to gain a view of how digital technology could easily benefit or disrupt New Zealand pastoral farmers. Virtual Fencing is an appropriate example of a digital technology to apply within the framework of the report.

Method

Conference proceedings at industry events assert collaboration is required to resolve challenges or exploit opportunities, as they cross boundaries of a broad spectrum of disciplines (Agritech NZ, 2018) (MobileTech, 2016-2018) (PAANZ, 2017).

It was determined input from several specific disciplines including agricultural science, history, technology, policy, law, economics and farm management would provide the necessary information.

Given the breadth of disciplines to be considered, it was deemed most efficient to perform literature reviews using thematic analysis from a variety of publicly available sources covering the specific subject disciplines that virtual fencing and digital transformation cross. This approach is to provide an objective conclusion a farmer or industry stakeholder could use in a commercial context.

Literature that included surveys, opinions or quotes relating to virtual fencing that is publicly available would provide subjective balance although none was readily found. It was decided that forming an appropriate questionnaire and specific interviews in relation to virtual fencing technology and then targeting suitable audiences wouldn't fulfil the purpose of the report, evidenced by the following:

a) Producers need education on the technology first (Anderson J. , 2015).
b) Producer research has been done in relation diffusion of innovation (Rogers, 2003), adoption and characterisation of innovativeness for dairy farmers (Anderson J. , 2015) and sheep and beef farmers (Bruce, 2018), with neither investigating digital transformation.

[4] **Simon Sinek** mantra refers to his bestselling book Start with Why (Sinek, 2009).

c) Conversations with those with substantial knowledge are predominately in the commercial domain conducting early stage trials and building their commercial models, which this report isn't intended to expose (Agersons, 2018), (Halter, 2018) (Vence, 2018).
d) Independent international research (Safaryan, 2014) shows technology implementation failures can result in the better innovation failing, reinforced by (Taylor, 2013), stating the 'implementation space is where value is created' and 'perfectly good innovation can fail' in relation to the implementation and customer engagement during the journey. Therefore, identifying and calling out broader structural challenges for digital transformation of pastoral farming was deemed critical.

It was quickly identified that the legislation governing the subjects was substantial and therefore Act's and only legislative instruments that were referenced within an Act if relevant were referenced to ring fence the scope of the research.

In the absence of available research covering the entirety of the question, the method as described intends to provide objective conclusions for the themes established and the overall conclusion, using critical, reflective and creative thinking, to form conclusions and recommendations.

The literature reviewed for virtual fencing was predominately across livestock and technology science, using prototypes for research trials. The trials have accelerated development of early stage commercialisation

LITERATURE REVIEW

Virtual Fencing

This section covers the virtual fencing to provide macro level understanding of what it is, the functions that it currently performs, and the organisations involved in bringing it to market.

VIRTUAL FENCING DEFINITION

An early accepted patent describing virtual fencing is titled an 'animal control system using global positioning and instrumental animal conditioning' (Anderson & Hale, 1999).

A CSIRO representative who developed the technology in Australia with Agersons titles another patent application 'A control device and method is taught for controlling an animal's location' (Lee et al, 2009). Additionally, CSIRO's website (CSIRO, 2018) answering the question 'What is virtual fencing?', states:

> *Virtual fencing is an animal-friendly fencing system that enables livestock to be confined or moved without using fixed fences. CSIRO's patented virtual fencing technology uses coordinates, wireless technologies and sensors to control the location of livestock without the need for an actual fence.*
> *Source: CSIRO website*

VIRTUAL FENCE COMPONENTS

The respective patents (Anderson & Hale, 1999) and (Lee et al, 2009) detailed specific features and methods. They both include a 'control device' with various sensors, connected to a 'wireless network', a 'cloud application' provides the user interface access through a 'internet enabled device' to remotely communicate with the control device via the wireless network.

Virtual fencing is primarily supported by Internet of Things and Artificial Intelligence technologies. In general components includes a 'control device' (with various 'sensors' and a 'method'), which is connected to a 'wireless network', with functionality managed through a 'cloud application' allowing an operator to interface with the control device with an 'internet enabled device'. The operator interacts with the cloud application to exercise defined functions within the method to influence animal movement and containment parameters and allow animal behavioural activities to trigger alerts.

COMMERCIAL ENTITIES

Virtual fencing technology is currently under commercial development. Each of the following companies are progressing trials and having a strong relationship with New Zealand:

I. Agersens - (Agersons, 2018)
II. Halter - (Halter, 2018)
III. Vence - (Vence, 2018)

The following videos provide a pitch or demonstration of each of the products:

I. Agersens – https://youtu.be/cA1Lh5fH718 (Agersons, 2018)
II. Halter - https://youtu.be/ueSXvIcNpJs (Halter, 2018)
III. Vence - https://youtu.be/S3PhBJNdEwU (The Pearse Lyons Accelerator, 2018)

The analysis below represents the publicly promoted functions of each commercial organisations virtual fencing solution.

Table 1: Comparative analysis of functions for virtual fencing technology.

Function	Implied Benefits	Agersens	Halter	Vence
Containment	Reduce fencing costs	✓	✓	✓
Shift Stock	Reduce production cost	✓	✓	✓
Drafting	Reduce production cost	✓	✓	✓
Break-feeding	Reduce production cost	✓	✓	✓
Tracking	Reduce production cost	✓	✓	✓
Heat Detection	Reduce production cost	✓	✓	✓
Lameness	Reduce production cost	✓	✓	✓
Calving	Reduce production cost	✓	✓	✓

Sources: Based on interpretation of publicly available information from Halter 2018, Agersens 2018 and Vence 2018 websites.

DISCUSSION

1) Commercial trials are expected to validate the technology, in the meantime understanding the value of each of the functions across pastoral farming given the value of livestock and land is expected to give a significant contribution to GNI through economic and environmental value. New Internet of Things network technologies such as LoRaWAN™, Cat M1 (Spark NZ, 2018) and NBIoT (Vodafone, 2017) will provide for more long range low powered IoT devices such as those used for virtual fencing. This is positive for pastoral farming, but an internet connection (mobile or broadband) is still required for the farmer to interface with the cloud application and for backhaul of the device data.
2) Network connectivity and coverage for pastoral farms is constantly discussed, relating to broadband and mobile services provided by Spark (Spark NZ, 2018), Vodafone (Vodafone, 2018), and 2 Degrees (2 Degrees, 2018), with Wireless Internet Service Providers (WISP's) offering alternative services (WISPA NZ, 2018). Telecommunication regulations are administered by Ministry of Business, Innovation and Employment (MBIE, 2018).
3) In low population areas such as remote pastoral farming the telecommunication industry is faced with a paradox for infrastructure investment measured by subscriber metrics to present economic, market competition regulations, future economics and technologies. In the meantime, diffusion of innovation is stifled for remote pastoral farming businesses, with the lack of connectivity to multimillion-dollar businesses like not having Eftpos in an Auckland Queen Street dairy. However, despite the priority of high-speed rural broadband (Proudfoot et al, 2018), there is only one submission from Venture Southland (Commerce Commission, 2018) representing primary sector concerns for the 'Study of mobile telecommunications market in New Zealand' (Commerce Commission, 2018) as part of the governments jobs and innovation policy (NZ Labour Party,3, 2017).

Key Farm Management Practices

The following section captures key farm management practices related to fencing framed from history, science and legislation to establish the functional fit of virtual fencing in New Zealand pastoral farming.

PROPERTY OWNERSHIP & RESPONSIBILITY

Does the existing legislation relating to property ownership and responsibility in respect to land and fencing have implications for the imminent commercialisation of virtual fencing technology?

Land - tenure, ownership and responsibility

Land tenure and security of title has been a subject of conflict since New Zealand was first settled by Europeans (Phillips, 2015). The Land Registration Act 1841 was introduced, 'FOR the purpose of rendering titles to real property more secure and facilitating the transfer of the same', as captured in the preamble (New Zealand Government, 1841). It was to regulate land tenure and registration, however the 1865 Native Lands Act, dismantled the collective tenure of Maori land by awarding no more than 10 individual grantees as absolute owners, resulting in grievances as recently as this year (New Zealand Government, 2018).

The Land Transfer Act 1870 introduced the land transfer registration system (Torrens), which became compulsory on the introduction of the Land Transfer (Compulsory Registration of Titles) Act of 1924, with New Zealand recognised for pioneering compulsory registration of titles, taking until the 1950's to complete the transition (Te Ara - the Encyclopedia of New Zealand, 1966).

The subjects of land tenure, rights, registration and therefore security over land are legislated by Land Act 1948 (LINZ,4, 2017), Crown Pastoral Land Act (LINZ,6, 2017) for many high country pastoral farming runs. The Land Transfer Act 2017 (New Zealand Government, 2017), to manage registrations and titles, the Cadastral Survey Act 2002 (LINZ,3, 2016) providing for cadastral surveys of land and the associated specific rules relating to surveying title[5] boundaries and occupation[6] boundaries (LINZ,1, 2017).

Fences

What are fences used for? What types of physical fencing is virtual fencing competing with? What is the associated legislation?

History

The ditch and bank fence was established in the British Isles and used by Captain Cook in Tahiti (Cook, 1769), to secure the fort for observing the transit of Venus. It was a popular low-cost fence with first settlers leading into the 1840's, using local resources and able to be relatively quickly established (Peden, Farm Fencing, 2008).

Other early fencing techniques recorded (Peden, Farm Fencing, 2008), included recycled rock, stone walls, post and rail (totora posts) and live fences / hedges of gorse or broom popular given their vigorous growth. Boundary keepers were used for extensive open pastures, effectively forming a dynamic barrier.

The Fencing Act 1847 paved the path for resolving neighbour disputes to share costs of erection, maintenance and repair of boundary fences, encouraging provincial ordinances for the fencing of land boundaries (New Zealand Government, 1847).

> *The word " fence," in this Ordinance, shall be construed and mean a fence between land in the occupation of a person and the land adjoining; the word "land," shall be construed and mean any land in the Province of Canterbury not being waste lands of the Crown.*

[5] **Title boundaries** means the boundaries of the land shown—(a) on the record of title or Crown grant; or (b) on the latest survey plan approved under the Cadastral Survey Act 2002 or any corresponding previous Act.

[6] **Occupation boundary** means any of the following that limits or defines the land occupied by the applicant: (a) a fence, wall, hedge, building, ditch, or other artificial thing: (b) a natural feature of land

Source: NZLII website (New Zealand Legal Information Institute, 1863)

Wire fencing technology progressed from hard to tension annealed iron wire in the 1850's, to steel more suitable wire in the 1860's (Peden, Wire fencing, 2008). In 1860 Fred A Weld a respected pioneer farmer highlights a change in practice in 'Hints to intending sheep-farmers' (Weld, 1860), providing evidence of the shift from 'grazing natural pasture or wild runs' to 'cultivated grasses and enclosed paddocks'.

The 1860's gold rush provided a pool of under-utilised labour combined with the technology change and run holders funding contractors by sharing the proceeds from cultivated roots, cereals and pasture, resulted in extensive fencing (Evans, 1969). By 1878, 77% of New Zealand's fenced area (82% in the South Island) was enclosed with wire (Peden, Wire fencing, 2008).

The British Board of Trade made the British Standard Wire Gauge a legal standard in 1884 (Wikipedia, 2018), with No. 8 (0.160 inches or 8 gauge) wire chosen as most suitable for containing livestock. Barbed wire (also known as American Wire) was evidenced in 1879 (Peden, Wire fencing, 2008), however cattle rubbing on barbs is renowned for damaging hides.

The introduction of rabbits in the 1850's and 60's, creating plague proportions in the years that followed and as recently as the 1980's in Central Otago, with several rabbit fences erected on district and private boundaries to contain and prevent their spread in the 1880's (Peden, Rabbit Fences, 2008).

In 1930's Bill Gallagher developed an electric fence for livestock (Gallagher Group Ltd (NZ), 2018), which was battery powered, due to it being illegal to run off mains power (Bridges & Downs, 2014). It wasn't until after World War II production expanded with the legislation changing in 1961 allowing energisers to connect to the mains power, with Doug Phillips developing a low-impedance electric fence extending their range to tens of kilometres in 1962 (Bridges & Downs, 2014).

Today permanent electric fence systems (Lincoln University, 2011, pp. I-14 to I-20), provide an effective means to control stock, with dairy farms commonly using 2 wire permanent electric internal fences, while other livestock operations commonly use electric outriggers to deter livestock from rubbing and damaging permanent fences whether on the boundary or internal. Temporary electric fence systems are used for management practices such as strip grazing, with recent innovations such as TechnoGrazing (Wier, 2001), provided a means to move electric fences much faster.

Electric fence energisers are legislated under the Electricity (Safety) Regulations 2010 (Ministry of Business, Innovation, and Employment, 2016), with Gallagher now a leading global provider of electric fence competes with Tru-Test, a manufacture of several other brands recently purchased by Datamars (Datamars, 2018), having previously been a takeover target of Gallagher and prior to reducing their major shareholding (Vaughan, 2013).

Sir Tim Wallis a pioneer of live capture of feral deer in the 1960's (Peat, 2005), led to Cyclone creating the first deer netting (1.9m) in 1967, proving effective for the domestication of deer, which was legalised in 1969 (Drew, 2008) (Country Calendar, 1987).

Legislation

The current legislation, Fencing Act 1978 Schedule 2 (Ministry of Justice, 2017) provides 'specimen types of fence' (refer to the **Error! Reference source not found.**) for both urban and rural land, only refers to

physical fence types, including definitions for **adequate fence, fence** and **repair** (refer to the **Error! Reference source not found.**) under interpretations. There is no definition for an electric fence despite its extensive use and being mentioned under the interpretation of repair, stating 'keeping an electric fence in working order'. Section 3 of the Act (Ministry of Justice, 2017) stipulates:

> *… the act doesn't apply to roads, land forming part of a national park under The National Parks Act* (New Zealand Government, 1980)*, Te Urewera land* (New Zealand Government, 2014) *… some land and structures under the New Zealand Railways Corporations Restructuring Act* (New Zealand Government, 1990) *… marginal land as captured in the Conservation Act* (New Zealand Government, 1987) *… esplanade reserves defined in the Resource Management Act* (New Zealand Government, 1991) *...*
> *Source: Fencing Act 1978, No 50*

This implies that securing or fencing a farm boundary next to a road, national park, railway line, marginal land or esplanade reserves is the responsibility of the farmer (land owner or occupier). Typically, each owner on a shared boundary is responsible for an equal share of material and labour costs for the erection and maintenance of fences.

The Wildlife Act 1953, section 42 Fencing of Land (Department of Conservation, 1953), and Reserves Act 1977 section 43 fencing and maintenance of reserves allow for the erection of fences.

The Reserves Act (DOC,1, 2017) provides for the Minister to take steps for 'fencing and maintenance of any reserve vested in the Crown', going on to state the 'occupier of the adjoining land is liable for half the costs' provided the fence is 'within the meaning of the Fencing Act 1978'. The Reserves Act includes protected private land, which requires the land to be 'sufficiently fenced or otherwise protected from damage by stock'.

These Acts form the overarching legislation specific to erecting fences with district and regional councils implementing permits and bylaws specifically for roads within their geographical jurisdiction.

Animals

Determining and identifying property owners is important enabling farmers to identify and classify their livestock[7] and provide clarity of responsibility in respect of trespass, impoundment and tort law. Therefore, how are the owners determined? How does animal identification occur? Can virtual fencing control device work within the existing legal framework?

The Animal Welfare Act 1999 (MPI,7, 2018), specifies several types of animals without mentioning livestock. It goes further to define owner in relation to an animal including parent or guardian of a person under the age of 16 years (MPI,7, 2018):

Earmarks are commonly used on young stock for livestock identification and ownership (Lincoln University, 2011, pp. O-22), with ear tags most common on stud and breeding livestock for classifying age and ownership. The introduction of Radio Frequency Identification (RFID) ear tags has allowed electronic animal identification for tracing livestock and supporting food provenance and security. The National

[7] **Livestock** means animals kept as part of an agricultural operation, whether for commercial purposes or for private use … under NAIT legislation (MPI,9, 2018)

Animal Identification and Tracing Act 2012 (MPI,9, 2018), defines livestock, NAIT animal[8], transition animal and unidentified animal, along with animal identifier and animal identification device and also defines a PICA (person in charge of NAIT animal) and PICA delegates.

Only NAIT animals are currently covered under the NAIT legislation, however tracking and tracing of livestock is critical from a biosecurity, food security and safety perspective, extending further with trespass, impoundment and tort law also applicable.

During early settlement fences protected owner's property by keeping stock out rather than in (Peden, 2008), with the Cattle Trespass Act 1842 passed to enforce those owners (or responsible) for the animal, held accountable for damage to another's property (New Zealand Government, 1842).

The Trespass Act 1980 (Ministry of Justice, 2013), supersedes early Cattle Trespass Acts, defines domestic animals referencing the Animals Act 1967 (believed to be UK common law) and specific goats and deer that are kept in a respective-proof fence.

The Impoundment Act 1955 (Department of Internal Affairs, 2017), defines occupier, owner, stock (including horse, cattle, deer, ass, mule, sheep, pig, or goat) and fence (adequate fence within the meaning of Fencing Act 1978).

Tort is a unique area of law relating to trespass to property, confidential information, negligence and defamation. Tort[9], originates from the Latin word *Tortum*, meaning 'something twisted', and in New Zealand is typically aligned to British common law[10], and defined as (Collins English Dictionary, 2018):

> ***tort*** *(in British) - noun*
> *a civil wrong arising from an act or failure to act, independently of any contract, for which an action for personal injury or property damages may be brought*
> *Source: Collins English Dictionary*

There is a common law relationship for animal trespass with the Animals Act 1971 ss 2–6 (UK) in Britain, *Highways (Liability for Straying Animals) Act 1983 s 3 (WA)* and case law *'Searle v Wallbank rule', which was abolished in New Zealand under* The Animals Law Reform Act 1989[11] (Ministry of Justice, 1996), with the conditions.

Discussion

History provides evidence that tenure, boundary rights and land title disputes are far reaching, with fencing use and legislation regularly needing to evolve, through intensification, change of land use, pest

[8] **Nait Animal** covered under Schedule 1 - **Cattle** - All members of the subfamily Bovinae (including bison and buffalo that are farmed or kept in captivity). **Deer** - All members of the family Cervidae that are farmed or kept in captivity (MPI,9, 2018).

[9] **The law of tort** is the general law, out of which the parties can, if they wish, contract; and ... the same assumption of responsibility may, and frequently does, occur in a contractual context. Approached as a matter of principle, therefore, it is right to attribute to that assumption of responsibility, together with its concomitant reliance, a tortious liability, and then to inquire whether or not that liability is excluded by the contract because the latter is inconsistent with it. (*Henderson v Merrett Syndicates Ltd* [1995] 2 AC 145 (HL), per Lord Goff of Chieveley, 193) (New Zealand Law Commission, 2018).

[10] **Common-law 1** the law developed by the common law courts as being common to all the Crown's subjects, as distinct from equity. **2** a general name for Anglo-American case-based systems, as opposed to civilian code-based systems.
enactments (W.J. Stewart, 2006).

[11] **Law Reform** – Legislated under the Law Reform Act 1936 as 'an Act to effect reforms in the law relating to' Part 1—'Survival of causes of action after death … Part 3—Charges on insurance moneys payable as indemnity for liability to pay damages or compensation … Part 5—Liability of tortfeasors. Part 6—Liability of employers to their servants for injuries caused by the negligence of fellow servants.' (Ministry of Justice, 1996).

control, but possibly most significant from innovation and technology adoption. The following discussion points provide a means to develop critical thinking to support recommendations and conclusions relating to the commercialisation of virtual fencing.

1) **Land**
    (a) It will become increasingly more important to have clarity of where virtual fencing sits given the historical reasons for having clear legislation relating to property boundaries and therefore tenure and land security.
    (b) Regardless whether virtual fencing is accepted on boundaries, cadastral survey data would provide a means to rapidly create property boundaries as a base layer and presumably reduce a farmer's setup cost and time. This said consideration is required to ensure physical fences, title boundaries, cadastral survey data and the required GPS co-ordinates for virtual fences are aligned. This data could also be valuable tool for issuing containment and movement control areas notices, in accordance with the Biosecurity Act (discussed later).
2) **Fences**
    (a) History provides an understanding of how and why fences are important and therefore the need for legislation. Fencing contractors should be the most familiar with existing legal framework relating to erecting new physical boundary fences. However, given existing physical fences are likely to be several years old, which combined with an intergenerational handover of farms, may mean many farmers are not fully conversant with the current Fencing legislation. The introduction of new technology provides an opportunity to clearly capture whether virtual technology is accepted, including a review of the definitions of fence, repair and adequate fence and public communications.
    (b) Virtual fences are dynamic and can be easily moved, and not being visible raises many questions for their use on boundaries, and possibly laneways given increased stock pressure, however it does make sense for some internal fences depending on the type of livestock being farmed and adopted management practices.

    NOTE: Analysis of existing boundary and internal fencing types, states of repair, costs and maintenance are beyond scope for this report.
3) **Animals**
    (a) Virtual fencing could support animal ownership and identification; however, responsibility would still require determining, especially where animals grazing on another person's property could be managed by a third party and complicated when virtual fencing and infrastructure is provided as a service, meaning contracts between the various parties need to clearly articulate responsibilities.
    (b) Tort legislation has been adjusted through the Animals Law Reform Act 1989 and the Rule in Searle v Wallbank abolished, balancing responsibilities for all parties in a court challenge and allowing interpretation in the instance stock are on a road / highway. However, the locality / regional policy variations, creates a challenge for public / tourists not appreciating regional practices. Personal observations would suggest that farmers are complying with regional bylaws (Hurunui District Council, 2014) for livestock movements on roads or installing underpasses to limit road accidents involving livestock movements. Recent accidents

between motorists and livestock include a Whanganui farmer prosecuted with $273,000 in damages claimed by the trucking operators (Hutching, 2018), with two others in Canterbury (Quinlivan, 2018) and Taranaki (Jessy Edwards et al, 2016), both involving cows at night causing severe damage to the vehicle and fortunately no casualties. The potential liability and cost of an accident is high. If farmers had a means to be alerted that stock were outside a containment zone it would allow early intervention.

(c) The terminology across the different legislation shows some disparity between definitions for: animal, livestock, NAIT animal, domestic animal and stock, which could be more cleanly represented in the Animal Welfare Act and Trespass Act, by creating a hierarchical group for animal / livestock terminology that is adopted across all legislation. In addition, the Trespass Act references the Animal Act 1969, which is presumed to be common law from the UK, which if so, is superseded by the Animal Act 1971.

4) The following captures challenges for land owners who wish to use virtual fencing on boundaries:
    1. In the eyes of the law how are virtual fences defined in the scope of the Fencing Act 1978, is it a fence, adequate fence or under the determination of repair? This question applies to these example scenarios:
        a) A shared boundary with another farmer, where both are responsible for the boundary fencing as per Fencing Act 1978, if either or both parties don't wish to rely on a physical fence, whether to be newly erected or maintained.
        b) Boundaries on a road, national park, Te Urewera land, railway, marginal strip or esplanade reserve or, water course, river, lake or next to the reserves.
        c) Following extensive damage from an event such as the earthquakes, floods, fires, where fence repair becomes critical for livestock containment and to reduce the concern of Trespass and Impoundment Acts or endangering public on a public road.
    2. In the instance that virtual fencing is accepted as an adequate boundary fence, then:
        a) Sharing of cadastral survey data would support defining legal boundaries but, may create confusion / disputes where fences aren't on legal boundaries.
        b) Digital products, such as virtual fences, are often run as a service i.e. a lease rather than an outright purchase, which party is liable when there is a failure and the fence doesn't contain stock?
        c) Can it be used as a primary or secondary layer of security, enclosure?
            i. during a Biosecurity outbreak
            ii. as a temporary fence when a physical fence is being repaired or replaced
    3. There are standards for wire grades and electric fence energisers. It is expected that standards will be required for virtual fencing control devices to ensure farmers purchase a service that aligns to animal welfare and electrical safety.

LIVESTOCK MANAGEMENT

Livestock management and husbandry on pastoral farms is captured in this section, to examine the use of virtual fencing livestock.

Animal Identification and Tracking

Virtual fencing control devices, attached or worn allows individual animal identification and tracking, however can they complement or replace the NAIT ear tag? What other value does animal identification provide the industry?

> ***NAIT device*** *means an animal identification device manufactured or supplied in accordance with standards issued under section 14 or regulations made under this Act.*
> *Source:* (MPI,9, 2018).

Section 50 'Identification systems' of the Biosecurity Act 1993 (MPI,2, 2018) provides the Director-General to approve systems for the purposes of 'identification of organism and their product and associated premise'. Recommended best practices within for sheep, beef, dairy include branding (hot and freeze), marking and tagging, with care required due to soft tissue tears when tagging and marking animals. Compulsory use of ear tags is required for cattle and deer, within the bounds of The National Animal Identification and Tracing Act 2012 (2018) established to control provide compulsory tracing of individual NAIT animals from birth to death or export, to provide movement records, biosecurity management, risks associated to food, disease and transmission of disease to humans, which supports animal productivity, market assurance and trading requirements.

The NAIT legislation governs any 'NAIT system', 'NAIT device', approved through respective registration processes. 'NAIT Animal' and 'PICA' are required to be identified and registered in accordance with the Act. All NAIT devices are required to undergo an approval process including a physical assessment and performance assessment measured through a 3 year trial, with provisional approval annual volumes allowed in market of 250,000 (after yr1) and 500,000 (after yr2) until approval is granted (OSPRI, 2012). 'Core data' and 'no-core data' can be accessed and shared provided they are not an international organisation with no registered office in New Zealand.

The act provides specific sections for 'Purposes of holding core data', and within a 'NAIT System' with the subsequent sections relating to 'Non-core data held by agreement', 'Rules on holding and accessing data' and the 'Method of making' and 'Handling of' applications for the 'Determinations of administrator' and/or 'panel' relating to the 'method … conditions on, access' to data.
The National Animal Identification and Tracing (Fees and Forms) Regulations 2012 (MPI,4, 2013), provides forms for '…the application for approval of an identification system…' and '…application for accreditation…' for an information provider' or 'an entity dealing with NAIT animals' and therefore allowing 'a PICA employed by the entity, to qualify for any exemptions … under' covered by National Animal Identification and Tracing (Obligations and Exemptions) Regulations 2012 (MPI,11, 2018)

In addition, the Animal Products Act 1999 (MPI,1, 2018) and Animal Products Regulations 2000 (MPI,12, 2018) legislates for the;

> *'… identification, differentiation, and security systems and device …'* in respect to the *'… use and security…'*, *'… security of manufacturing process… '* and *'…approval… '* of any *'system or device…'*, associated to *'… identification, differentiation, or security of animal material, animal products, premises or other places, or other matters or things …'*, with the *'Object of Act … to …minimise and manage risks to human or animal health … from the production and processing of animal material and products … ; and … facilitate the entry of animal material and products into overseas markets…'*

Source: (MPI,10, 2018).

Section 165B stating, 'The Director-General may arrange … use of an automated electronic system to do the actions described in … this Act or another enactment …' (MPI,10, 2018).

Animal Containment and Movement Control

Virtual fencing research trials has used devices worn or attached to an animal using treatments of a combination of cues (audio, tactile and visual stimuli) and / or consequence (electrical stimulation), to restrict and stimulate animal movements. Is this legal for commercial use in New Zealand? How can virtual fencing be used to support animal containment relating to biosecurity, animal welfare and for livestock security?

Domesticated livestock are familiar with the use of audio, tactile and visual (physical) stimuli to contain within a perimeter or to move them. In early years, boundary keepers, drovers and shepherd's on horseback whistling at dogs was common prior to the expansion of What are fences used for? What types of physical fencing is virtual fencing competing with? What is the associated legislation?

, and in Weld's 'Hints to intending sheep-farmers'.

> *The general management of sheep on wild runs in New Zealand approaches nearest to that pursued in the hill districts of Great Britain and is very different from that of New South Wales. In New Zealand, the golden rule is to harass the flock as little as possible. Accustom them as much as you can to respect certain boundaries; but within those limits do not needlessly disturb them. The result of this system is superior condition, and less liability to disease, whilst it also enables you to lessen the expense of herding by enlarging the numbers of a flock. - Fred A Weld*
> *Source:* (Weld, 1860).

Today physical fencing of boundaries and internal paddocks now provides the most common means for animal containment, with temporary fences used for strip grazing. Labour cost and time to perform stock movements has reduced through adoption of technology from fencing and laneways, to the introduction of motor-vehicles (especially motorbikes) and helicopters. Recent changes in Health and Safety legislation and continual innovation has seen an increase of side by sides and now adoption of drone technology (Norman, 2016). On sheep and beef properties today, animal movement still uses huntaway and heading dogs, with horses used mainly on steep hill and high country. Deer farmers limit the use of dogs and loud audio stimuli to avoid stress and excitement to maintain balanced temperaments when shifting deer (Lincoln University, 2011, pp. A-136). Dairy cows become familiar with the routine of walking to and from the dairy shed, but typically still require someone to open and shut the gates and keep the herd moving.

Reasons for moving animals has a significant relationship with animal welfare legislation, requiring owners or persons in charge of animals to attend properly to the welfare of animals, under Section 4 covering physical, health and behavioural needs including 'food', 'water', 'shelter', 'display normal patterns of behaviour' and alleviating any 'illness', 'injury' or 'unnecessary pain or distress' (MPI,7, 2018).

Using virtual fencing to move (or contain) animals is expected to be captured within the definition of manipulation which is extensive including 'interfering with the normal physiological, behavioural, or anatomical integrity of the animal by deliberately', with procedures able to declared not manipulation by the National Animal Welfare Advisory Committee and the National Animal Ethics Advisory Committee for the purposes of the Animal Welfare Act (MPI,7, 2018). Research, testing and teaching in accordance with Section 5, provides further definition relating to the manipulation of animals, with 1 b stating any work

that – involves the manipulation of any animal; or c) any teaching that involves the manipulation of any animal; what is deemed manipulation, and subsection 3 providing exclusions.

The closest existing physical fence to a virtual fence is the electric fences commonly used for strip grazing (temporary) and hotwires to keep livestock from rubbing fences (permanent) (Lincoln University, 2011, pp. I-14 to I-20). Electric fences control units defined as energisers are manufactured and governed by the specification standards in the Electricity (Safety) Regulations 2010 (Ministry of Business, Innovation, and Employment, 2016).

Animal movement and control using virtual fencing have undergone different training, tests and trials using virtual fencing prototypes internationally. Those trials for sheep using feed and social attractants, haven't been conclusive in replacing conventional fences to provide absolute control (Jouven M., 2012), while trials with cattle have proved successful (Lee et al C. , 2009), showing cattle identify an audio conditional cue to learn the relative proximity of their boundary and avoid the consequence or electric stimuli. Further to this virtual fencing provides the containment of livestock without the need to build physical fences (Anderson D. , 2007) and providing dynamic digital control of paddock perimeters.

Biosecurity and Disease Control

If a key benefit of virtual fencing is to contain animals within, or exclude from an enclosed area can it be adopted for biosecurity and disease control?

Biosecurity is the top priority for all primary sectors (O'Connor, 2018), while containment a key to biosecurity measures, is used to restrict the spread or control of biosecurity outbreaks or threats.

The Biosecurity Act 1993 (MPI,2, 2018) doesn't specify containment although does talk about 'controlled area'[12], however section 2 provides interpretation for the words 'quarantine'[13] and 'quarantine areas'[14], with Section 122 'Power to give direction … 3) an inspector or authorised person may direct the owner or person in charge … with a pathway management plan[15].

Section 130 'Declaration of restricted place … allows an inspector or authorised person to issue notices to … declare … a restricted place'.

Section 131 'Declaration of controlled area … to enable the institution of movement and other controls … by public notice to the extent and subject to the conditions specified in the notice'.

The recent Mycoplasma Bovis outbreak, exercised sections 122 and 130 of the Biosecurity Act, and is currently testing the pastoral industries' tools and management processes to contain and eradicate the outbreak (MPI,13, 2018). MPI's protection and response website for Mycoplasma Bovis (MPI,6, 2018), also provides the appropriate information under *Advice about Mycoplasma Bovis for all farmers* (MPI,5, 2018). It informs farmers to inspect boundary fences regularly and repair as needed, advising stray stock

[12] **controlled area** means an area for the time being declared under subsection (2) of section 131 to be an area that is controlled for the purposes of that section.

[13] **quarantine** means confinement of organisms or organic material that may be harbouring pests or unwanted organisms

[14] **quarantine area** means a place so designated under section 41

[15] **pathway management plan** means a plan to which the following apply **(a)** it is for the prevention or management of the spread of harmful organisms:

and wild/feral animals may spread or introduce diseases from or to your farm. Information about managing Mycoplasma Bovis provided by DairyNZ (DairyNZ, 2018) and New Zealand Beef and Lamb (BLNZ,2, 2018) is similar,

> *… to maintain your fences and gates to secure your boundaries. Have one main entrance to your property…Create 2m buffer zones along all fence lines to prevent cattle contact, including roadways and lanes. Where there is a need to graze multiple herds in one paddock, create a semi-permanent double fence using rows of warratahs 2m apart, and graze cattle away from each other. Use the feed in buffer zones before or after cattle are on both sides of the fence.*
> *Source:* (BLNZ,2, 2018)

The 'rules on holding and accessing data' between the NAIT database and the biosecurity and Animal Products database allowing processes between the organisations to be streamlined (MPI,9, 2018).

The Hazardous Substances and New Organisms Act 1996 (Ministry for the Environment, 1996), caters for restricting an organism or substance to a secure location or facility to prevent escape; in respect of genetically modified organisms, field testing and large-scale fermentation. It goes on to state a 'containment facility' caters for 'new and genetically modified organisms', and it is implied a 'containment structure' is for the purposes of 'genetically modified organisms'.

However, under part 2 'Matters to be addressed by containment controls for new organisms excluding genetically modified organisms' it does provide for 'controls provided by an approval of requirements', meaning it could apply an order to use a virtual fence as a requirement.

Animal Health and Welfare Management

Can the virtual fencing be used for the management of animal health and welfare?

The Codes of Welfare for 'Sheep and Beef Cattle' and 'Dairy Cattle' (MPI,3, 2018), provides farm management guidelines for minimum standards for animal welfare.

The existing Commercial Entities control devices functions indicate the algorithms are combining geo-spatial data with sensor data to capture temperature, heart rate, acceleration, tilt angle and which is then matched with behavioural observations to create the AI algorithms to monitor animal behaviours and health such as lameness, heat cycle and calving. As the base software is implemented it will be iteratively improved to perform new functions.

Providing other data sources including current weather conditions and forecasts, water locations, areas of shelter, flood zones, river levels, pasture covers could support stock movements into more desirable areas of grazing, helping manage some items in the Code of Welfare.

Combining the control device data with climate, soil conditions etc will provide a means to trigger stock movements under certain weather conditions towards shelter, lower altitudes, closer to water, away from sodden ground, or flood zones etc.

Combining the control device data with pasture monitoring data could allow automation of animal movements based on available pasture cover.

In addition, herd behaviours are different to individual behaviours meaning interaction between animals could allow hierarchies, bullying and stampedes to be identified allowing for livestock to be measures to direct animals away from hazards such as smother zones or maintain a level of separation between animals to reduce bullying.

Livestock Security, Predator and Pest Control

Securing livestock has been mentioned in previous sections, how might predator and pest control be represented by virtual fencing?

During early settlement when large runs requiring extensive fencing boundary keepers and droving were common practice as part of stock trading and grazing management (Peden, 2008). In New Zealand security of livestock is best known in the Mackenzie Country, named following the capture, sentencing and release (by pardon) of James Mackenzie (Marr, 1990) for sheep rustling in 1855. News articles confirm the practice is still occurring (Hartley, 2016), with Federated Farmers stating it could be costing $120m per year (Eleven, 2014), impacting on sheep, cattle and dairy farmers (Galuszka, 2017). The 'Sentencing (Livestock Rustling) Amendment Bill is now before the Primary Production Select Committee' (Ohara, 2018).

Earlier erected rabbit fencing still provides a means to control rabbits, with pest control plans in the Mackenzie basin (TVNZ, 2018) intended to limit the spread of native bird predators including mustelids[16], which were initially introduced to control rabbits. The extent of this type of fencing is evidence at Zealandia (2018) wildlife reserve with breaches still proving possible (Radio New Zealand, 2018).

Discussion

1) **Animal Identification**
    a) The recent amendments to the National Animal Identification and Tracing Act and associated Regulations (MPI,14, 2018), including 'Every PICA must declare every animal movement to the NAIT organisation', means they are more comprehensive for cattle and deer movements NAIT process, especially in the wake of the Mycoplasma Bovis outbreak.
    b) The changes to link identification and automation into the Animal Products Act supports identification of NAIT animals and subsequent products through the supply chain to consumers, is a positive move to support food provenance and security, and therefore the necessary information to support the added value stories.
    c) It appears there is little benefit for Commercial Entities to apply for NAIT Device approval unless they are ear tags, as the NAIT Device approval process refers to 'RFID ear tags'. It is expected that the Control Device is to remain on the animal until the point of live export or slaughter at which point, they are to be discarded and unable to be repurposed.
2) **Animal Containment and Movement Control**
    a) Virtual fencing control device isn't outlawed, however there is no indication it is "controlled" meaning no specific regulation or electronic standards apply to the control device. Good animal

[16] **Mustelid** – from the family Mustelidae in New Zealand includes Ferret, Stoat and Weasel (Waikato Regional Council, 2018).

welfare practice would suggest the 'control device' and therefore 'method' should go through the National Animal Ethics Advisory Committee process to alleviate any public concerns, given the electrical stimuli triggered as a 'consequence'. This would support determining animal welfare regulations and standards for virtual fencing devices equivalent to those defined for cattle prodders and electric energiser (Ministry of Business, Innovation, and Employment, 2016). This will ensure the functionality of the control device caters for when animals are intentionally or unintentionally moved outside containment zones or into exclusion zones as a result of herd behaviours such as a stampede or disturbance such as rustling.

3) **Biosecurity and Disease Control**
   a) There is provision for approval of 'containment facilities' meeting certain standards, however there was no reference found associated to 'containment structure', this implies that depending on the classification of the hazardous substance or new organism, virtual fences may not be classed as either a containment structure or facility, if livestock are a vector for the organism's spread (think Mycoplasma Bovis). However there appears to be suitable provisions under the Biosecurity Act to establish 'controlled areas' and 'pathways management plans', which could consider virtual fencing.
   b) Animal identification is not consistent for all animals requiring targeted messaging to ensure compliance with the specifics of NAIT law. Other than cattle and deer livestock identification under the NAIT legislation, there is no other compulsory identification practice found. Further to this the NAIT Amendment Bill intends to support greater controls to enforce recording of NAIT animal movements, with the National Radio Station discussion querying whether sheep should be included as a NAIT animal (Radio New Zealand, 2018), with the impact of a foot and mouth outbreak deemed greater than the Mycoplasma Bovis outbreak. That said it not just for the industry to resolve, and something that flows into food provenance and safety. Recently 'New Zealand Food Safety' released intentions to strengthen standards for food in particular relating to 'recalls and improve risk-based plans and programmes' (MPI,8, 2018), which follows the 'Whey Protein Concentrate Contamination Incident' this does create an opportunity to thoroughly investigate the opportunities of end to end supply chain tracking and tracing including from farm, which will require suitable technology to facilitate the requirements.

4) **Animal Health and Welfare Management**
   a. As animal behaviour data capture increases, it will allow automation of animal movement to protect livestock from intense heat, floods, snow etc, and may support prediction model for earthquakes or improved management of nutrient distribution relating to stock camps. This demonstrates using behavioural monitoring could provide customised animal management and previously unachievable increases in animal care, well beyond the lameness, heat detection and calving promoted by the commercial enterprises.

5) **Livestock Security, Predator and Pest Control**
   a. Combining virtual fence spatial data, device geo-location data and the animal behaviour data using AI allows real-time detection of animal safety (predator or poacher) or escape (rustler or perimeter breach) and therefore earlier intervention by the owner or those responsible and therefore authorities. This uses the early principles of movement and location (Anderson D. , 2007) and is also evidenced by recent cases referenced under containment.

PASTURE MANAGEMENT AND GRAZING

This section highlights the pasture management and grazing as critical skills farm management practices to convert pasture into primary products for export efficient growing and conversion of pasture into a primary product such food or fibre, how can virtual fencing play a role in this key practice?

Carrying Capacity

What are the benefits of using virtual fencing for managing carrying capacity?

Stock units (Lincoln University, 2011) is the common measure used to determine livestock carrying capacity of pastoral land. Using head count, stock unit index and effective areas allows statistical benchmarking within stock types, across different farm uses, and between different land types (BLNZ,1, 2018).

Crown pastoral lease stock limitations and rents (LINZ,6, 2017) are calculated using rules to determine either base and / or current carrying capacity measures. Carrying capacity, stock numbers and stocking rates are key measures, indexes, benchmark for determine land productivity, sustainability, valuation, financial and taxation calculations and therefore a measure of farm management practices. The information is sourced by Beef and Lamb (BLNZ,1, 2018), Dairy NZ and Statistic's New Zealand, for production, economic reporting and to frame policies relating to pastoral industries.

Pasture Production

What are the benefits of using virtual fencing for pasture production?

Pasture production, which is the source of most of the nutrients consumed by livestock, so it is imperative for farmers understand the science of pasture production to perform feed planning (Korte et al C. , 1987), and therefore carrying capacity. Pasture production (kg DM/ha) is the result of multiple factors including: solar radiation, soil temperature, soil moisture, soil fertility, pests and disease, pasture species and livestock grazing impact the sward dynamics (Korte et al C. J., 1987). Livestock selectively defoliate young green leaves, which have the highest growth rates, meaning a sward is left in a less productive state (Korte et al C. J., 1987). Livestock damage pasture through treading and cause soil compaction or pugging from too higher stocking rates, with defecating and urinating provide nutrients for pasture production, nutrients distribution such as nutrient rich stock camps (Korte et al C. J., 1987). Energy provided by pasture is measured in megajoules (MJ) of metabolizable energy (ME) per kg DM/ha, or M/D and is a measure of pasture quality. The M / D varies due to the chemical composition, plant maturity, seasonal changes affecting the pastures digestibility, with the amount of pasture left after grazing affecting the pastures digestibility for the next grazing (Waghorn et al, 1987).

Innovative new technologies such as Farmote (Barton, 2018) and LIC's Space^{TM} (LIC, 2018) provide a means to calculate pasture production (DM) digitally at scale in a paddock or across a farm.

Pasture Grazing

What are the benefits of using virtual fencing for pasture grazing?

Differences in animal production results occur from variances in pasture composition, digestion and metabolism of absorbed nutrients (Waghorn & Barry, 1987). The metabolizable energy (ME) requirements of livestock change with the requirements of livestock during periods of maintenance,

reproduction or production of primary products such as milk, meat and fibre (wool) (K.G. Geenty et al, 1987). The process of energy conversion relates to pasture intake, digestion, nutrient absorption and nutrient utilisation of livestock (K.G. Geenty et al, 1987).

Various trials have shown that grazing behaviour (bite rate, bite intake & therefore grazing fatigue), animal effects (mouth size, breading index, physiological requirements, technique), site selection (plant species, maturity of material, contamination, micro-topography, shelter, fence lines, shade and water sources) and pasture characteristics (height and breaking strength) all contribute to overall pasture intake (D.P. Poppi et al, 1987). However, the most important non-nutritional factors impacting pasture intake are pasture structure, pre-grazing pasture mass, pasture allowance and post grazing pasture mass (D.P. Poppi et al, 1987). Trials on sheep, have shown these factors have a direct relation to maximum daily intake, however the models were not conclusive to determine time spent grazing a paddock or grazing pressure to achieve a target average daily intake based on pre-grazing mass (D.G. McCall et al, 1986).

Feed Planning

What are the benefits of using virtual fencing for feed planning?

Feed planning allows farmers to gain foresight into demand and supply for a feed profile (used for long term policy decisions such as lambing date, time of weaning), feed budget (used for medium term economic decisions to manage a feed surplus or overcome a feed deficit) associated to feed surpluses to determine economic d) or grazing (used for short term decisions relating to rotation lengths) plans.

Grazing plans are calculated using either a residual method or allowance method to establish number of days, and the typical rotation of paddocks being determined from highest pasture mass to lowest pasture mass (K.E. Milligan et al, 1987), to maximise pasture production during the rotation. The methods of allocating livestock to pasture is done by either; 1) allocating stock classes to a paddocks or area of the farm; 2) pro-rated based on relative numbers or stock units in each class; or most preferably 3) based on feed requirements to achieve levels of production (K. E. Milligan et al, 1987).

Given grazing management is not linear, for an animal class, season, paddocks and therefore a farm in order to improve efficient use of pasture. There is a desire globally to introduce practical data driven methods to improve grazing management (Laca, 2009), with greater emphasis on livestock feed requirements and environment objectives to traditional, pasture management, production objectives.

Irrigation in general is used as a management tool to balance seasonal and daily variations of soil moisture (and temperature), while variable rate irrigation is providing precision allocation of water, improving the efficiency of water use and minimising environmental impacts from over watering (Anderson J. , 2015).

Weed Management

What are the benefits of using virtual fencing for weed management?

Rotation grazing research identified paddocks that weren't grazed during the critical period of reproduction of an invasive weed will tend to become weedy, whereas those paddocks grazed when the weed is susceptible to defoliation will tend to be less weedy (DiTomaso et al. 2008).

Siting fences

How will virtual fences change where fences are sited?

Given that many expansive pastoral farm fences were erected many decades ago it is important to understand the methods used to site those fences, including geographical and environmental characteristics including topography, soil types, to establish whether a site was susceptible to snow or rainfall causing avalanches, slips, floods or in a path of a controlled fire (Hughes, 1962).

This knowledge would be combined stock knowledge to avoid smothers, proper grazing of pastures or challenges in herding and moving stock past or through physical obstacles such as bluffs or creeks. Siting a fence poorly was costly and created productivity inefficiencies (Hughes, 1962).

Fencing Configurations

Settlers originally fenced farms to secure property boundaries, create holding paddocks for stock management and to protect crops, including vegetables (Weld, 1860). Subdivision of internal paddocks around physical characteristics of paddocks (aspect, contour, soil types, pasture species), forms the basis for paddock configuration.

Laneways provided a more efficient means to move stock between paddocks or between different parts of a farm. A model of configuration (branched or ring) laneways on square or hexagon shaped farms provided 25-37% variation in associated fencing costs (Scott, 2006), with consideration required that the dimension of laneways impacted on their use, access way (50m width), subject to overgrazing and trampling (100 metre width) or a paddock (200 metre).

Sustainability and Environmental Management

What are the benefits of virtual fencing for sustainability and environmental management?

A significant aspect to pastoral farming is ensuring they are sustainable and attending to environmental management of natural resources, including water quality and use, nutrient management, waste management, CO_2 and climate change to protect the environment and associated recreational areas including native flora and fauna ecosystems. This has imposed the use of environment plans (Canterbury Water, 2018) and reporting for resource consents, which 'supports farmers to improve nutrient use on farms, delivering better environmental outcomes and more value for farms' (Overseer, 2018).

The Conservation Act (DOC,2, 2017) defines marginal strips relating to 'a strip of land 20 metres wide extending along … the landward margin of … any foreshore … normal level of any lake … or river or any stream'. With the Soil Conservation and River Controls Act 1941 (Ministry for the Environment, 2017) catering for 'areas of land … protected and offences declared in relation to soil conservation reserves for animal trespass upon such land … or damage to watercourses … or a defence against water'.

The dairy industry has been subjected to increased pressure to improve farming practices to manage impacts both on farm and the surrounding environment, such as downstream evidenced through the implementation of the Dairy Industry water accord (DairyNZ, 2017) and environment plans across pastoral farming (BLNZ,4, 2018). Trials performed to see if the troughs placed near streams would deter stock from entering were unsuccessful (Bagshaw et al, 2007). Other trials confirming the distribution of

nutrients by animals is a common problem on dairy farms and intensive sheep and beef properties with nutrient leaching (Betteridge et al, 2010).

Discussion

1) **Carrying Capacity**
    a. The combination of virtual fence geo-spatial data of land areas, with the geo-location data of individual livestock (measured when grazing), could provide behavioural grazing patterns for zones, based on physical characteristics, within a paddock. This could be used to build baseline datasets of carrying capacity and grazing behaviours. Carrying capacity information could also be used to support more regular reporting of national statistics.
2) **Pasture production**
    a. The science indicates it is possible to have significant variations in pasture production across different zones within a paddock based on the physical characteristics and grazing practices. Therefore, new IoT (i.e. Farmote) or satellite technology (Space™), enabling real-time dry-matter measurements combined with real-time virtual fencing of livestock will aid grazing management and optimise pasture production. This is expected to occur by limiting pasture damage and pugging through trampling, reduce repeated grazing of young leaves and minimise nutrient transfer to stock camps. This reduction in pasture waste has the potential to improve production and may reduce input requirements such as fertiliser.
3) **Pasture Grazing**
    a. The key factors impacting animal intake could be much better understood by understanding grazing behaviour within existing physical paddocks. A key aspect of animal production today is that the industry is working with averages and not able to measure individual intake against production. Mapping number of grazing passes based on the tilt of the head will provide a means to qualify who are good converters of pasture into production figures. This could be provided using technology within virtual fencing control devices and geospatial data of animals to better understand the choice livestock make of when, where and what to graze based on physical characteristics of paddocks and the pasture. This information could be matched to physical characteristics of a paddock and the pasture compositions within the paddock with along with geo-spatial datasets for topography, soil type, paddock shape, water supply to establish livestock within a herd that resist climbing, are more selective grazers of pastures, having different water requirements as examples. Combining this information with individual production outputs may support advances in animal genetics as well as breeding and selection programs.
4) **Feed Planning**
    a. The science of pasture allocation includes juggling land areas, pre and post grazing covers relating to pasture production (feed supply) with livestock feed requirements (feed demand) throughout the season. The art of pasture allocation is balancing the science with other future variables (e.g. climate, input costs and product prices) to optimise production and profitability. Using live datasets of DM / ha such as provided by Farmote and Space™, automated real-time datasets for pasture growth parameters such as climate, current dry matter cover, soil temperature, UV light, humidity will provide the ability to use AI and continuously improve and refine pasture production models, budgets and plans for feed supply. Dataset captured from

virtual fencing control devices of animal behaviours combined with livestock requirement models using AI could allow refinement of production models, budgets and plans for feed demand.

5) **Weed Management**
    a. As virtual fencing provides a means to electronically contain livestock, containment areas can be created with much greater precision cost effectively. This is likely to allow a more cost-effective way to manage weed populations, especially on hill and high-country properties. There are many weeds such as hieracium, barley grass, gorse and broom that can be managed through grazing (Ag Research, 2018).
6) **Siting Fences and configuration**
    a) Siting of virtual fencing still cater for physical characteristics of grazing areas but reduce the need to bulldoze fence lines. Subdivision of larger paddocks or management of different grazing zones based on paddock shape, slopes, pasture swards, aspects, etc will be easy to implement and adjust. Allowing management of stocking rates improved pasture production and grazing patterns, which is expected to add significant value for extensive pastoral farms.
    b) Dairy farms currently using physical fences for rotational grazing and daily stock movements will still benefit from virtual fencing, given the daily routine of stock movements.
7) **Sustainability and Environmental Management**
    a) The carry capacity within a zone could support observations of impacts such as soil erosion and pugging based on soil type, topography, rainfall and soil moisture measurements improving knowledge on how and when land is grazed.
    b) The largest environmental management opportunity relates to streams and rivers, as proposed in Labour's policy papers. Using physical fences has already required a significant amount of capital investment not to mention ongoing maintenance costs and environment impacts where bulldozing fence lines is required. Investing to expedite virtual fencing technology and core communications infrastructure based on the benefits would appear to provide a more robust use of capital than the investment in physical fences alone.

FINANCIAL MANAGEMENT

What should be considered for accounting for virtual fencing setup?

Virtual Fencing Setup

IMPORTANT: The below shouldn't be interpreted as financial advice, please talk to your accountant in the first instance.

Valuations of improvements and the accounting for operational and capital expenditure on a farm is an important driver for technology adoption, therefore the definition of each element including labour and materials to introduce or maintain may have significant implications for virtual fences and digital technologies adoption on farm in general.

Fences are deemed as improvements for the purposes of tenure and valuations (LINZ,4, 2017), pastoral leases (LINZ,6, 2017) and rates (LINZ,2, 1998). Depreciable property (IRD,5, 2007) includes fences under depreciable land improvement (IRD,7, 2007), applicable for deductions of expenditure relating to income tax calculations for land transfers between companies within the same group (IRD,2, 2007),

enhancements to land (IRD,3, 2007), expenditure by a lessor or sublessor (IRD,4, 2007), and in terms farm labour or contracted services scheduled payments in relation to PAYE (IRD,1).

Discussion

1) In the digital world, the virtual fence components are completely different and may consist of network infrastructure, devices and software, with components potential purchased outright, leased or purchased as a service depending on the providers business model. The business model to provide virtual fencing will impact the way that depreciation is calculated, meaning there is no one answer as it depends on the business model options provided by the service provider, farmers choice and accounting practice adopted.
2) In addition, calculating income tax doesn't provide specific consideration for virtual fences and it is beyond the scope of this project to determine accounting for a farmer. However, if the commercial trials prove successful early indications suggest that there will be a material reduction of capital costs associated with capital fencing and operational costs associated to materials and labour (including repairs and maintenance, animal health, stock management and depreciation expenses). The changes for an individual farm will be associated with the ownership structure and contribution for each component which will depend on an individual farm's location, layout, size, topography and other physical characteristics for the availability and scale required for the wireless network infrastructure, as well as the number of control devices required, and business model offered by the provider. Most importantly internet availability is required to interface with the cloud application on a device (mobile phone, computer) to enabler the technology.

Digital Transformation

This section covers digital transformation and what factors allow an organisation or industry to successfully perform digital transformation, providing discussion for using virtual fencing in the digital transformation of pastoral farming.

What is digital transformation? What does it take to enable digital transformation? What are the technologies? How does virtual fencing technology allow digital transformation of the pastoral industry?

Digitalization of products and services is a fast-moving, global megatrend that is fundamentally changing existing value chains across industries and public sectors. The manifestations of ongoing digital transformation are various, and there are many terms used in literature to refer to the phenomenon, e.g. Mobile Apps, Big Data, Machine-to-Machine, Internet of Things, Industrial Internet, and Industry 4.0 (Prof. Jari Collin, 2015).

> Scholar Saul Berman (2012) reviewed digital transformation in regard to its effects on business models, encouraging leaders to focus on two complementary activities: using digital technology for greater customer collaboration and interaction, and the reshaping of current customer value propositions in order to transform the whole operating model (Berman, 2012).
> *Source: Leadership in the digital age* (Khan, 2016)

English economic historian Arnold Toynbee popularised the industrial revolution through lectures to describe Britain's economic development between 1760 and 1840 (Encyclopaedia Britannica, 2018). This has been further refined to show the transition between 4 different revolutions.

Graph depicting four industrial revolutions, in progress from the 18th century to the 21st
Source: (Encyclopaedia Britannica, 2018)

The Fourth Industrial Revolution technologies, such as artificial intelligence, genome editing, virtual and augmented reality, robotics, social media, Internet of Things, drones, blockchain and 3-D printing, are rapidly changing the way humans create, exchange, and distribute value, driven largely by the convergence of digital, biological, and physical innovations (Schwab, 2018).

The World Economic Forum (2018) website provides a brilliant diagrammatic view and states:

> *The Fourth Industrial Revolution represents a fundamental change in the way we live, work, and relate to one another. It is a new chapter in human development, enabled by technology advances that are commensurate with those of the first, second and third industrial revolutions, and which are merging the physical, digital, and biological worlds in ways that create both promise and peril. The speed, breadth, and depth of this revolution is forcing us to rethink how countries should develop, how organizations create value, and even what it means to be human; it is an opportunity to help everyone, including leaders, policy-makers and people from all income groups and nations, to harness technologies in order to create an inclusive, human-centred future.*
> *Source: World Economic Forum 2018*

Further to this a global study of digital business found that maturing digital businesses are focused on integrating digital technologies, such as social, mobile, analytics and cloud, in the service of transforming how their businesses work, while less mature digital businesses are focused on solving discrete business problems with individual digital technologies, identifying that digital transformation is about strategy not technology (Gerald C. Kane, 2015).

Langdon Morris captures the dynamics of our changing world calling out 83 shifts (much broader than just technology) occurring simultaneously, which on their convergence will form *The Big Shift* or when the world moves from the existing operating model of one that is more for me, to a new one that is better for everyone (Morris, 2018).

Regardless of the nuances of the above, digital transformation requires organisations to build digital and leadership capabilities (Westerman et al, 2014). It requires identification of what changes will improve customer experience, improve operational processes or allow a whole new business model to be adopted (Westerman et al, 2014).

Regardless of how we define the global changes many have gone from linear to exponential (Morris, 2018), so while looking at history provides us with insight it doesn't consider the rate of change that society including consumers, voters and shareholders are experiencing and demanding from our economies and resources.

CUSTOMER EXPERIENCE

Does virtual fencing enable or significantly improve a customer experience?

Social media has provided the means international consumers, voters and shareholders become more informed of food production practices and share their views and values relating to origin, farming practices and procedures to influence international trade to define customer experience.

Today the challenge of producing sustainable products, looking after animals, ecology and our natural resources for national values is achieved through effective engagement across multiple channels and is influencing customer experience.

Creating a compelling customer experience is at the heart of digital transformation, with digital masters using continual improvement to design experiences based on what customers want, delivering through new channels to improve engagement and using data analytics to mesh the physical world with the digital world (Westerman et al, 2014).

OPERATIONAL PROCESSES

Does virtual fencing enable or significantly improve on existing operational processes?

In order to transform operational processes, the bottlenecks and process inefficiencies need to be identified and changed through adoption of strong digital technology platforms, followed by breaking the three traditionally operational paradoxes of the non-digital world (Westerman et al, 2014):

1) Standardizing <-> Empowering
2) Controlling <-> Innovating
3) Orchestrating <-> Unleashing.

Technology that delivered an IF This, Then That experience has been at the forefront of Amazon's thinking (Rossman, 2016). In agriculture, irrigating when the soil is dry and not irrigating when the soil is saturated, has been adopted through variable rate irrigation (Anderson J. , 2015).

Rossman (2016) talks of Bezos original name for Amazon as relentless.com based on a motivation of continuous improvement, by measuring processes, tracking and monitoring items with sensors with a feed-back loop, referred to as the Amazon Flywheel. The idea being Amazon's order selection and fulfilment processes and open market place, feed revenue back to improve the infrastructure and speed up the processes.

> *Measurement is the first step that leads to control and eventually to improvement. If you can't measure something, you can't understand it. If you can't understand it, you can't control it. If you can't control it, you can't improve it - H. James Harrington*
> *Source: The Amazon Way on IoT* (Rossman, 2016)

Pastoral farming's value web needs to provide consumers' confidence the processes and practices to produce primary products are environmentally sustainable and that animal and employee's welfare within the process is of accepted standard (Proudfoot et al, 2018).

BUSINESS MODELS

Does virtual fencing enable or significantly improve existing or change the business model?

The other way that digital transformation is implemented it through whole new business model, with plenty of examples including the Apples iTunes, Uber, Airbnb, Amazon, Facebook, Google and even My Food Bag, Mighty Ape or Xero to name a few.

Each of the above have established how to fundamentally change the way the customer is engaged using digital technology to transform or disrupt their own or another industry. They have replaced existing products and services with new version or changed the value proposition using rapid experimentation and iterative innovation to develop and enhance the business models (Westerman et al, 2014).

BUILDING LEADERSHIP CAPABILITIES

Digital transformation doesn't happen on its own, it requires a shared understanding between IT and the business to create trust and a seamless partnership. Investment in skills and capabilities is required to meet the speed of a digital economy and may require changes to the organisational structure and a clean structured digital platform. It is then important to continually improve of IT-Business relationship, digital skills and the digital platform (Westerman et al, 2014). Research by Khan (2016) discusses the transformational, value-based and authentic leadership characteristic and style changes with digital transformation showing leaders and therefore stakeholders change through digital transformations.

DISCUSSION

Digital transformation provides business, industry or in New Zealand's case (given its dominance in pastoral farming), a country to re-invent or disrupt itself. Can virtual fencing be the catalyst for pastoral farming?

The two highest value items on a pastoral farm are land and livestock excluding investments in primary processes considered separate to on farm operations. To improve utilisation and performance of land and livestock requires regular (daily or weekly) metrics, something that the dairy industry can easily implement given the daily milking routine, with the sheep and beef herds more capable of doing as connectivity issues are resolved.

1) Virtual fencing provides the opportunity to understand animal behaviour, health, welfare, security and manage pasture allocation which fundamentally enables measurement of pasture conversion to a primary product from an individual animal. This is enabling measurement and therefore iterative improvements for pasture and animal management and a paradigm shift to existing operational processes. When technology to automated pasture production measurements is combined with animal behaviour, containment and movement, it will provide substantial opportunity to change operational processes to iteratively improve pasture utilisation and livestock performance.
2) Virtual fencing technology is expected to drastically reduce the cost of larger capital fencing, and operation expenditure in labour, repairs and maintenance, animal health and management costs. This provides a fundamental change to investment in operational processes, staff experiences and business models by allowing capital and labour reallocation elsewhere on farm or in the value web.
3) Customer experiences will improve as data evidencing animal behaviour, welfare along with environmental measurements will allow continuously improve of farm management practices improve environmental impacts and public, consumer and voter perceptions of pastoral farming.

4) Given virtual fencing technology are expected to provide cost and time savings on farm it is expected investment in core infrastructure creating a Flywheel effect for the industry (Rossman, 2016). This will support investment and adoption to accelerate of other technologies requiring network connectivity such as robots, autonomous vehicles and drones. Connectivity will allow universal use of blockchain to complete decentralisation of the value chain to a value web recording all animal related activities and transactions building greater trust with trading partners (Schwass, 2018) (Morris, 2018, p. p. 48 & 77) (Proudfoot et al, 2018).
5) Digital transformation (and therefore virtual fencing technology by way of example) requires strong leadership to engage the value web and either enable or deliver digital capabilities. The recent additions of AgriTech NZ and IoT Alliance to NZTech umbrella provides a means to empower industry and technology sectors to collaborate more (NZTech, 2018). The role of the Chief Technology Officer (NZ Labour Party,3, 2017) or equivalent position/s will strengthen government engagement with technology experts and policy makers to accelerate regulation adjustments for future technologies.

SHORTCOMINGS

The decision to restrict the legislative literature to Acts means there will be shortcomings, especially with the legal system making equitable judgements and determinations from all legislative instruments including: case law, regulations, codes, regional and district legislation or plans by way of examples.

The subject became very expansive, showing the importance of fencing for pastoral farming. Investigations of the commercial solutions would have provided further value, however requesting and sharing commercial trial information was deemed commercially sensitive for the start-ups involved.

Research relating to virtual fencing pricing and infrastructure requirements to establish costs and financial and environmental benefits between virtual fencing and traditional fencing, would help farmers to make decisions. This is expected to be done by commercial enterprises as part of product pricing.

CONCLUSIONS

1) The uses of fences on pastoral farms are proven through history and fundamentally aren't expected to change despite the introduction of virtual fencing technology:
    a) Livestock containment and security (Boundary fences)
    b) Animal welfare and health (internal fencing for separating livestock classes or groups)
    c) Livestock movement (Laneways)
    d) Pest control (Rabbit and predator fences)
    e) Environment management (exclusion zone fencing)
    f) Pasture production, allocation and planning (paddock size and stocking rate / grazing management)
    g) Weed management (fence siting and animal)
    h) Reduce labour (boundary keepers, drovers)
2) Virtual fencing is a foundation technology for digital transformation of New Zealand pastoral farming for the following reasons:
    a) Livestock numbers are sufficiently large enough to provide scale for establishing the technology in New Zealand for dairy (6.53m), beef (3.62m), and potential deer (0.84m) and sheep (27.5m), as the technology improves (Statistics NZ, 2017)
    b) New Zealand pastoral farming is looking for a cheaper option to physical fencing environmental exclusion zones
    c) Virtual fencing provides additional benefits over and above traditional uses of fencing including:
        i. Livestock identification, behaviour and welfare information
        ii. Scalable real-time livestock location and electronic biosecurity management
        iii. Fencing delicate or extensive environmental zones (e.g. steep hillsides or marginal strips)
        iv. Likely to be substantially cheaper than permanent or temporary fencing
        v. Reduces operational labour costs associated to shifting livestock
        vi. Alert farmers of containment zone breaches
        vii. biosecurity management
        viii. Automate animal movements, and if integrated with pasture production measurements the potential for more accurate pasture allocation and pasture intake and conversion

ix. Automate data capture of provenance, health, welfare and if integrated with pasture types potential to market diet qualities

d) Additionally, it is expected to provide extra value to farmers and providing opportunity to and a positive impact on labour productivity and terms of trade figures. This will support further investment in core telecommunications and network infrastructure into areas of New Zealand that have substantially more livestock than people.

e) The data capture and connectivity will open the way for much broader adoption of other technologies that would struggle to scale otherwise including blockchain, AI, robotics, autonomous vehicles and drones.

3) The priorities represented in the contextual overview with what appear as opposing perspectives by Hon. Damien O'Connor

> *… Consumers are increasingly buying products to align with their values and we must make the most of our natural advantages such as pasture-fed livestock, environmental sustainability and good animal welfare – and now more than ever is time to tell our story - Hon. Damien O'Connor*
> *Source: KPMG Agribusiness Agenda 2018*

and the Grassroots Roundtable may be resolvable using virtual fencing:

> *People outside of farming do not realise that your whole life is consumed by farming – day in, day out. After six years … I am not certain I want a farm now. With the low returns, environmental issues, weather and biosecurity risks, long hours, animal health and welfare challenges, why would you do it? - Comment from Grassroots Roundtable*
> *Source: KPMG Agribusiness Agenda 2018*

Virtual fencing is expected to contribute to Labour's policies for water, jobs and innovation, and climate change and facilitate key industry priorities[17] including; world class biosecurity (1) driving economic and environmental value to support delivery of high-speed broadband (2), enabling datasets to be enriched with live data which will help firm level analysis. Leveraging new datasets will allow advances in food safety (3), provenance (4) and innovation with customers (5), to support higher quality trade agreements (6). Fourth Industrial Revolution technology adoption will provide opportunities for millennials leadership development (8) and enable communities to develop schemes to regenerate native ecosystems (9).

4) Most importantly, to achieve digital transformation on farm and therefore large-scale change will require strong leadership to focus on core infrastructure from the pastoral industry, technology innovation, regulatory bodies to shift from the status quo.

[17] Refer to Opportunities

RECOMMENDATIONS

The following recommendations are to support further resolution of the priorities represented in the Agri-business Agenda and remove barriers that will prevent rapid scaling of virtual fencing technology throughout New Zealand pastoral farming:

1) **Monitor existing NZ trials** - to confirm costs, use ability, scalability and integration of solution.
2) **Review research relating to environmental exclusion zones** - using physical fences or virtual fences with consideration to trial results, capital and operational costs, core infrastructure, financial and environmental benefits, farm classes, animal types and the diffusion of innovation.
3) **Appoint industry working group/s to drive legislation reviews and changes associated with**:
    a. **Fences** – Including fencing, land, cadastral survey, reserve, conservation, trespass, impoundment and other related legislation, regulations or codes relating to fence, adequate fence and repair clearly represent both physical and virtual fences. Review policies relating to defining digital / virtual biosecurity 'controlled areas' using Cadastral Survey Datasets and sharing through LandOnline (or similar) with third parties to provide digital geo-mapping.
    b. **Virtual fencing devices** - Review NAIT device standards and electrical safety regulations for animal welfare and animal ethics in respect of control devices and standards for sharing data from non-legislated NAIT devices relating to biosecurity.
    c. **Core infrastructure** – Review Telecommunications regulations to promote greater balance of capital investment towards connectivity for business growth over consumer, especially now scalable solutions are becoming more accessible for rural New Zealand.
    d. **Reporting requirements** – To frame legislated reporting requirements (including production and biosecurity reporting) and firm level datasets to identify to support technology innovation and diffusion to level virtual fencing technology. This will provide greater context for discussions relating to the inclusion of non-NAIT animals such as sheep into NAIT.
    e. **Animals** – Review animal, welfare, products, wildlife, biosecurity, trespass, impoundment, NAIT, fencing, reserve and other related legislation, regulations or codes to ensure alignment of animal / livestock related definitions.
4) **Invest in digital transformation strategies for pastoral farming including:**
    a. Develop automation and digital strategy and identify key technology pillars to fulfil outcomes for pastoral farmers aligned to consumer demands and measures of value.
    b. Develop flywheel models to promote reinvestment to optimise productivity for core products and services while establishing and growing supporting services.
    c. Develop investment, partnership and development roadmaps to prioritise delivery.
    d. Design trials and commercial pilots to scale diffusion of solutions for pastoral farming using Fourth Industrial Revolution Technologies.
    e. Develop communication plans to educate pastoral farming stakeholders the advantages and leverage existing models of on farm demonstrations to promote and showcase the benefits.
    f. Promote data standards to support system integration.
    g. Create an open private and public funding model for agriculture technology investment to promote a vested interest for all stakeholders and increase collective collaboration for diffusion of innovation.

REFERENCES

2 Degrees. (2018). *Coverage Maps*. Retrieved October 5, 2018, from 2 Degrees: https://www.2degreesmobile.co.nz/coverage/

Ag Research. (2018, November 8). *Weed*. (A. Research, Editor) Retrieved November 8, 2018, from AgPest: http://agpest.co.nz/pest-directory/#weeds

Agersens. (2016, November 3). *Agersons - Gallagher Invests*. Retrieved October 2, 2018, from Agersens: https://www.agersens.com/gallagher-invests/

Agersons. (2018, January 21). Agersons. Retrieved October 15, 2018, from https://www.youtube.com/watch?v=cA1Lh5fH718

Agersons. (2018, October 2). *Agersons*. Retrieved October 2, 2018, from www.agersens.com

Agritech NZ. (2018). *Agritech New Zealand Launch.* Auckland: EventBrite. Retrieved October 24, 2018 , from https://www.eventbrite.co.nz/e/the-2018-agritech-new-zealand-showcase-auckland-tickets-50248278955?utm_source=eb_email&utm_medium=email&utm_campaign=reminder_attendees_48hour_email&utm_term=eventname#

Allan, C. (2018). *Getting Under the hood - insights from recent firm level.* Productivity Hub. Retrieved from https://productivity.govt.nz/sites/default/files/Getting%20under%20the%20hood_Insights%20from%20recent%20firm-level%20productivity%20research%20in%20New%20Zealand.pdf

Anderson, D. (2007, January 17). Virtual fencing – past, present and future. *The Rangeland Journal*(29), 65–78. doi:https://doi.org/10.1071/RJ06036

Anderson, D. M., & Hale, C. S. (1999, July 14).

Anderson, J. (2015). *THE IMPACT OF MACHINE TO MACHINE COMMUNICATION ON THE DAIRY INDUSTRY IN NEW ZEALAND.* Kellogg Rural Leadership Programme. Retrieved August 28, 2018, from https://ruralleaders.co.nz/the-current-and-future-impact-of-machine-to-machine-technology-on-the-dairy-industry-in-new-zealand/

Bagshaw et al, C. S. (2007, May 9). The influence of season and of providing a water trough on stream use by beef cattle grazing hill-country in New Zealand. *Applied Animal Behaviour Science*(109), 155–166.

Barker, G. (Ed.). (1987). Country Calendar. Retrieved November 11, 2018, from https://www.nzonscreen.com/title/country-calendar-tim-wallis-1987

Barton, R. (Ed.). (2018). *Farmote*. Retrieved May 30, 2017, from Farmote: https://farmote.com/

Betteridge et al, K. a. (2010). Urine distribution and grazing behaviour of female sheep and cattle grazing a steep New Zealand hill pastur. *Animal Production Science*(50), 624–62. doi:DOI: 10.1071/AN09201

BLNZ,1. (2018). *Beef and Lamb Statistics.* Retrieved October 14, 2018, from https://beeflambnz.com/data-tools: https://beeflambnz.com/data-tools

BLNZ,2. (2018). *M. bovis - information for graziers.* Retrieved October 8, 2018, from https://beeflambnz.com/knowledge-hub/PDF/mp-bovis-—-information-graziers

BLNZ,3. (2018). *Beef and Lamb NZ.* Retrieved October 12, 2018, from NZ Farm Facts Compendium 2018: https://beeflambnz.com/sites/default/files/data/files/nz-farm-facts-compendium-2018.pdf

BLNZ,4. (2018). *Environment Plans*. Retrieved September 8, 2018, from Beef and Lamb NZ: https://beeflambnz.com/compliance/environment/environment-plans

BLNZ,5. (2018, June 30). *Stock Number Survey.* Retrieved October 18, 2018, from beeflambnz.com: https://beeflambnz.com/sites/default/files/news-docs/Stock-Number-Survey-30-June-2018.pdf

Bridges, J., & Downs, D. (2014). The Electric Fence. In J. B. Downs, *No. 8 Rewired* (pp. 234-235). Penguin Books. Retrieved November 8, 2018

Bruce, H. (2018, June). *technology-use-by-sheep-and-beef-farmers-hannah-bruce/.* Retrieved October 20, 2018, from Rural Leaders: https://ruralleaders.co.nz/technology-use-by-sheep-and-beef-farmers-hannah-bruce/

Canterbury Water. (2018). *Farm Environment Plans*. Retrieved September 24, 2018, from Canterbury Water: https://www.canterburywater.farm/fep/

Collins English Dictionary. (2018). *Tort.* HarperCollins Publishers. Retrieved October 15, 2018, from Collins English Dictionary: https://www.collinsdictionary.com/dictionary/english/tort

Commerce Commission. (2018, August 31). *Mobile market study - Documents*. Retrieved September 14, 2018, from Commerce Commission: https://comcom.govt.nz/regulated-industries/telecommunications/projects/mobile-market-study?target=timeline#projecttab

Commerce Commission. (2018, November 2). *Mobile market study - Submissions on issues paper due*. Retrieved November 12, 2018, from Commerce Commission: https://comcom.govt.nz/regulated-industries/telecommunications/projects/mobile-market-study?target=documents&root=94224

Conway and Meehan, P. a. (2013, September). Productivity by the numbers: The New Zealand experience. Retrieved October 3, 2018, from https://www.productivity.govt.nz/sites/default/files/NZPC-Conway-Meehan-Productivity-by-the-Numbers_0.pdf

Cook, J. (1769, May 1). Cook's Journal. Retrieved September 20, 2018, from http://southseas.nla.gov.au/journals/cook/17690501.html

Copeland et al. (2018, September 6). The Role of NGO's interest groups and lobbyists.

Craner, S. J. (2018, September 13). Why Fonterra will continue to fail . Retrieved September 13, 2018, from https://www.linkedin.com/pulse/why-fonterra-continue-fail-st-john-craner

CSIRO. (2018, October 22). *Virtual-fencing*. Retrieved October 23, 2018, from CSIRO: https://www.csiro.au/en/Research/AF/Areas/Animal-Science/Animal-Health-Welfare/Virtual-fencing

D.G. McCall et al, R. J. (1986). The Interdependence of animal intake, pre and post grazing pasture mass and stocking denisty. *Proceedings of the New Zealand Grassland Association*(47), 255-261. Retrieved October 15, 2018, from https://www.grassland.org.nz/publications/nzgrassland_publication_1156.pdf

D.P. Poppi et al, T. H. (1987). Intake of pastures by grazing ruminants - Non-nutritional factors influence intake. In A. Nicol (Ed.), *Livestock Feeding on Pasture* (pp. 55-64). New Zealand Society of Animal Production. Retrieved October 12, 2018

DairyNZ. (2017, May 15). *Sustainable dairying water accord*. Retrieved September 8, 2018, from DairyNZ: https://www.dairynz.co.nz/environment/in-your-region/sustainable-dairying-water-accord/

DairyNZ. (2018). *Biosecurity WOF A4 brochure.* Retrieved October 8, 2018, from DairyNZ: https://www.dairynz.co.nz/media/5788853/biosecurity-wof-a4-brochure.pdf

Datamars. (2018, September 28). *Datamars Announces Tru-Test Acquisition Completion*. Retrieved October 22, 2018, from https://group.tru-test.com/: https://livestock.tru-test.com/sites/default/files/Datamars_Annouces_Tru-Test_Acquisition.pdf

Department of Conservation. (1953). *Wildlife Act.* Retrieved October 1, 2018, from http://www.legislation.govt.nz/act/public/1953/0031/latest/DLM277826.html

Department of Internal Affairs. (2017). *Impoundment Act 1955.* Retrieved October 5, 2018, from New Zealand Legislation: http://www.legislation.govt.nz/act/public/1955/0108/latest/DLM293864.html?search=sw_096be8ed807a4f9f_impound_25_se&p=1

DOC,1. (2017). *Reserves Act 1977.* New Zealand Legislation. Retrieved October 2, 2018, from http://www.legislation.govt.nz/act/public/1977/0066/latest/DLM444305.html?search=sw_096be8ed815599dd_sufficiently_25_se&p=1#DLM444910

DOC,2. (2017, December 16). *Conservation Act*. Retrieved October 5, 2018, from New Zealand Legislation: http://www.legislation.govt.nz/act/public/1987/0065/latest/DLM103610.html

Drew, K. (2008, November 24). *Deer and deer farming*. (K. Drew, Editor) Retrieved October 24, 2018, from An Encyclopedia of New Zealand: https://teara.govt.nz/en/deer-and-deer-farming/page-4

Eleven, B. (2014, April 27). *Stock rustling costing up to $120m a year*. Retrieved October 5, 2018, from Stuff: http://www.stuff.co.nz/business/farming/agribusiness/9982588/Stock-rustling-costing-up-to-120m-a-year

Encyclopaedia Britannica. (2018). *Industrial Revolution.* (E. Britannica, Ed.) Retrieved October 18, 2018, from Encyclopædia Britannica: https://www.britannica.com/topic/The-Fourth-Industrial-Revolution-2119734/media/2119734/229695

Encyclopaedia Britannica. (2018). *Industrial Revolution*. (T. E. Britannica, Editor) Retrieved October 18, 2018, from Britannica.com: https://www.britannica.com/event/Industrial-Revolution

Evans, B. L. (1969). *A history of agricultural production and marketing in New Zealand.* Keeling & Mundy. Retrieved October 4, 2018

Figure.NZ. (2018). Gross Domestic Product per capita in New Zealand. Figure.NZ. Retrieved October 3, 2018, from https://figure.nz/chart/HHcKjWNLqTP3FBMh-Ns4vph9iktmN6fsT

Gallagher Group Ltd (NZ). (2018). *The Gallagher Story*. Retrieved September 2018, from Gallagher Group Ltd (NZ).

Galuszka, J. (2017, June 19). *MP expects cattle rustling bill to get support from all parts of Parliament*. Retrieved October 5, 2018, from Stuff: https://www.stuff.co.nz/business/farming/93683342/mp-expects-cattle-rustling-bill-to-get-support-from-all-parts-of-parliament

Gerald C. Kane, D. P. (2015). *Strategy, not Technology, Drives Digital Transformation.* MIT Sloan Management Review and Deloitte University Press. Retrieved October 18, 2018, from https://sloanreview.mit.edu/projects/strategy-drives-digital-transformation/

Governor General of New Zealand. (1842). *Cattle Trespass Act.* Retrieved September 3, 2018, from http://www.nzlii.org/nz/legis/hist_act/cta18425v1842n16305

Halter. (2018, June 13). Halter. Retrieved from https://youtu.be/ueSXvIcNpJs

Halter. (2018). *Halter*. Retrieved October 2, 2018, from www.halter.co.nz

Hartley, S. (2016, December 14). *Theft of stock alleged*. (ODT, Editor) Retrieved October 5, 2018, from ODT: https://www.odt.co.nz/business/farming/theft-stock-alleged

Hickey, B. (2018, September 18). Is it time to carve up Fonterra and sell it? *Newsroom*. Newsroom. Retrieved September 18, 2018, from https://www.newsroom.co.nz/2018/09/17/241094/is-it-time-to-carve-up-fonterra-and-sell-it

Hughes, J. G. (1962). High Country Fences. *TUSSOCK GRASSLANDS AND MOUNTAIN LANDS INSTITUTE*(Special Publication No.1), 1 - 2.

Hurunui District Council. (2014, February 12). *Livestock Movement Bylaw.* (H. D. Council, Ed.) Retrieved November 12, 2018, from Hurunui District Council: http://www.hurunui.govt.nz/assets/Documents/Bylaws/2014/Livestock-Movement-Bylaw-2014.pdf

Hutching, G. (2018, November 2). *Court orders farmers to pay $273,000 after truck collides with cattle.* Retrieved November 8, 2018, from Stuff: https://www.stuff.co.nz/business/farming/108292771/Court-fines-farmers-273-000-after-truck-collides-with-cattle

IRD,1. (2007). *Income Tax Act 2007.* New Zealand Legislation. Retrieved October 9, 2018, from http://www.legislation.govt.nz/act/public/2007/0097/latest/DLM1523257.html?search=sw_096be8ed817a95a7_%22DO+1%22_25_se&p=1&sr=13

IRD,2. (2007). *Income Tax Act.* New Zealand Legislation. Retrieved October 9, 2018, from http://www.legislation.govt.nz/act/public/2007/0097/latest/DLM1513913.html?search=sw_096be8ed817a95a7_%22Subpart+DO%22_25_se&p=1&sr=2

IRD,3. (2007). *Income Tax Act.* New Zealand Legislation. Retrieved October 8, 2018, from http://www.legislation.govt.nz/act/public/2007/0097/latest/DLM1513915.html?search=sw_096be8ed817a95a7_%22DO+4%22_25_se&p=1#DLM1513915

IRD,4. (2007). *Income Tax.* New Zealand Legislation. Retrieved October 8, 2018, from http://www.legislation.govt.nz/act/public/2007/0097/latest/DLM1513963.html?search=sw_096be8ed817a95a7_%22DO+1%22_25_se&p=1&sr=4

IRD,5. (2007). *Income Tax Act.* New Zealand Legislation. Retrieved October 9, 2018, from http://www.legislation.govt.nz/act/public/2007/0097/latest/DLM1514512.html?search=sw_096be8ed817a95a7_%22tangible+property%22_25_se&p=1#DLM1514512

IRD,6. (2007). *Income Tax Act.* Retrieved October 9, 2018, from http://www.legislation.govt.nz/act/public/2007/0097/latest/DLM1523348.html?search=sw_096be8ed817a95a7_%22intangible+property+%22_25_se&p=1#DLM1523348

IRD,7. (2007). *Income Tax Act.* New Zealand Legislation. Retrieved October 9, 2018, from http://www.legislation.govt.nz/act/public/2007/0097/latest/DLM1523346.html?search=sw_096be8ed817a95a7_%22DO+4%22_25_se&p=1#DLM1523346

Jessy Edwards et al, a. J. (2016, April 12). *Campervan ripped to pieces after hitting cattle in Taranaki.* Retrieved November 8, 2018, from Stuff: Campervan ripped to pieces after hitting cattle in Taranaki

Jouven M., L. H. (2012). Can virtual fences be used to control grazing sheep? *The Rangeland Journal*(34), 111-123. doi:https://doi.org/10.1071/RJ11044

K. E. Milligan et al, I. B. (1987). Feed Planning on Pasture - Allocation of grazing areas. In A. M. Nicol (Ed.), *Livestock grazing on pasture* (p. 82). New Zealand Society of Animal Production. Retrieved October 12, 2018

K.E. Milligan et al, I. B. (1987). Feed Planning on Pasture - Feed Profiles, budgets and grazing plans. In A. M. Nicol (Ed.), *Livestock feeding on pasture* (pp. 78-81). New Zealand Society of Animal Production. Retrieved October 15, 2018

K.G. Geenty et al. (1987). The Energy Requirements of grazing Sheep and Cattle. In A. M. Nicol (Ed.), *Live Stock Feeding on Pasture.* New Zealand Society of Animal Production.

Khan, S. (2016). *Leadership in the digital age – A study on the effects of digitalisation on top management leadership.* Stockholm Business School.

Korte et al, C. (1987). Pasture Production. In *Livestock Feeding on Pasture* (p. 7). Retrieved October 11, 2018

Korte et al, C. J. (1987). Sward Dynamics. In C. J. Korte et al, & A. Nicol (Ed.), *Livestock Feeding on Pasture* (pp. 15-19). New Zealand Society of Animal Production.

Laca, E. A. (2009, September). New Approaches and Tools for Grazing Management. *Rangeland Ecology & Management, 62*(5), 407-417. Retrieved October 15, 2018

Lee et al. (2009, July 24). Retrieved October 19, 2018, from https://patents.google.com/patent/US20120111286A1/en?q=virtual&q=fencing&q=halter&oq=virtual+fencing+halter

Lee et al, C. (2009, April 10). Associated Learning by cattle to enable effective and ethical virtual fences. *Applied Animal Behaviour Science*(119), 15-22. doi:10.1016/j.applanim.2009.03.010

LIC. (2018). *LIC Products and Services - SpaceTM*. Retrieved October 15, 2018, from https:/LIC.com: https://www.lic.co.nz/products-and-services/space/

Lincoln University. (2011). *Farm Technical Manual.* Christchurch. Retrieved October 9, 2018

LINZ,1. (2017). *Rules for Cadastral Survey 2010*. (L. I. Zealand, Editor) Retrieved October 9, 2018, from New Zealand Legislation: http://www.legislation.govt.nz/regulation/public/2010/0492/latest/DLM7127676.html?search=ts_act%40bill%40regulation%40deemedreg_Rules+for+Cadastral+Survey+2010_resel_25_a&p=1#DLM6960436

LINZ,2. (1998). *Rating Valuations Act 1998*. (Land Information New Zealand, Editor) Retrieved October 9, 2018, from New Zealand Legislation: http://www.legislation.govt.nz/act/public/1998/0069/latest/DLM427297.html?search=sw_096be8ed814f71b4_rating+value_25_se&p=1#DLM427296

LINZ,3. (2016). *Cadastral Survey Act 2002*. (Land Information New Zealand, Editor) Retrieved October 5, 2018, from New Zealand Legislation: http://www.legislation.govt.nz/act/public/2002/0012/latest/DLM141995.html?search=sw_096be8ed8179a5b6_%22survey+act%22_25_se&p=1

LINZ,4. (2017). *Land Act 1948*. (Land Information New Zealand, Editor) Retrieved October 5, 2018, from New Zealand Legislation: http://www.legislation.govt.nz/act/public/1948/0064/latest/resultsin.aspx?search=sw_096be8ed8150edb2_torren_25_se&p=1

LINZ,5. (2012). *Crown Pastoral Land (Rent for Pastoral Leases) Amendment Act 2012*. (Land Information New Zealand, Editor) Retrieved October 5, 2018, from New Zealand Legislation: http://www.legislation.govt.nz/act/public/2012/0036/latest/DLM3404640.html

LINZ,6. (2017). *Crown Pastoral Land Act 1988*. (Land Information New Zealand, Editor) Retrieved October 5, 2018, from New Zealand Legislation: http://www.legislation.govt.nz/act/public/1998/0065/latest/DLM426894.html?search=qs_act%40bill%40regulation%40deemedreg_pastoral_resel_25_h&p=1#DLM426987

Marr, C. (1990). *'Mackenzie, James', Dictionary of New Zealand Biography.* Te Ara - the Encyclopedia of New Zealand. Retrieved October 10, 2018, from https://teara.govt.nz/en/biographies/1m30/mackenzie-james

MBIE. (2018). *Regulating the telecommunications sector*. Retrieved September 14, 2018, from Ministry of Business Innovation and Employment: https://www.mbie.govt.nz/info-services/sectors-industries/technology-communications/communications/regulating-the-telecommunications-sector/?searchterm=telecommunications%2A

Ministry for Culture and Heritage. (2016, March 17). *A history of New Zealand 1769-1914*. (Ministry for Culture and Heritage) Retrieved September 30, 2018, from https://nzhistory.govt.nz: https://nzhistory.govt.nz/culture/history-of-new-zealand-1769-1914

Ministry for Culture and Heritage. (2018, October 13). *Declaration of Independence*. (M. f. Heritage, Editor) Retrieved October 20, 2018, from New Zealand History: https://nzhistory.govt.nz/culture/declaration-of-independence-taming-the-frontier

Ministry for the Environment. (1996). *Hazardous Substances and New Organisms Act.* Retrieved October 5, 2018, from http://www.legislation.govt.nz/act/public/1996/0030/latest/DLM381222.html?search=sw_096be8ed8178275a_control_25_se&p=1#DLM384404

Ministry for the Environment. (2017, March 1). *Soil Conservation and Rivers Control Act 1941*. Retrieved October 5, 2018, from New Zealand Legislation: http://www.legislation.govt.nz/act/public/1941/0012/latest/DLM230365.html?search=sw_096be8ed815135e9_Soil+Conservation+and+River+Controls+_25_se&p=1

Ministry of Business, Innovation, and Employment. (2016). *Electricity (Safety) Regulations 2010*, SR 2010/36. (I. a. Ministry of Business, Editor) Retrieved October 13, 2018, from New Zealand Legislation: http://www.legislation.govt.nz/regulation/public/2010/0036/latest/DLM5878644.html?search=sw_096be8ed817e616b_energiser_25_se&p=1&sr=0

Ministry of Justice. (1996). *Animal Law Reform Act 1989.* Retrieved October 20, 2018, from New Zealand Legislation: http://www.legislation.govt.nz/act/public/1989/0097/latest/DLM191756.html?search=ad_act%40bill%40regulation%40deemedreg_Highways+(liability+for+straying+animals)_____25_ac%40bc%40rc%40dc%40apub%40aloc%40apri%40apro%40aimp%40bgov%40bloc%40bpri%40bmem%40rpu

Ministry of Justice. (2013). *The Trespass Act 1980.* (M. o. Justice, Ed.) Retrieved October 5, 2018, from New Zealand Legislation: http://www.nzlii.org/nz/legis/hist_act/ta19801980n65157/ta19801980n65157.html

Ministry of Justice. (2017). *Fencing Act 1978* (1978 No 50 ed.). Retrieved October 5, 2018, from http://www.legislation.govt.nz/act/public/1978/0050/latest/DLM21813.html?search=sw_096be8ed8156ed99_Resource+Management_25_se&p=1

MobileTech. (2016-2018). *MobileTech.* CONNEX: Event Innovators. Retrieved from MobileTech: https://mobiletech.events

Morris, L. (2018). Blockchain Disruption. In L. Morris, *The Big Shift.*

Morris, L. (2018). Commoditization Shift - From Wealth to Commodity. In L. Morris, *The Big Shift* (pp. 42-43). Retrieved September 20, 2018

Morris, L. (2018). Digitization Shift - From Industrial to Digital. In L. Morris, *The Big Shift* (pp. 78-79). Retrieved September 25, 2018

Morris, L. (2018). *The Big Shift.* FutureLab Press. Retrieved October 18, 2018

Morris, L. (2018). Urban Shift - From County to City. In L. Morris, *The Big Shift* (pp. 32-33). Retrieved September 26, 2018

MPI,1. (2018, October 1). *Animal Products Act 1999.* Retrieved October 25, 2018, from New Zealand Legislation: http://www.legislation.govt.nz/act/public/1999/0093/latest/DLM33502.html?search=sw_096be8ed817de3f5_animal+products_25_se&p=1

MPI,10. (2018, October 1). *Animal Products Act 1999*. Retrieved October 15, 2018, from New Zealand Legislation: http://www.legislation.govt.nz/act/public/1999/0093/latest/DLM33502.html?search=sw_096be8ed817c1c06_nait+device_25_se&p=1#LMS19580

MPI,11. (2018, August 23). *National Animal Identification and Tracing (Obligations and Exemptions) Regulations 2012.* Retrieved October 22, 2018, from New Zealand Legislation: http://www.legislation.govt.nz/regulation/public/2012/0116/latest/DLM4479801.html?search=sw_096be8ed817b7c32_nait_25_se&p=1

MPI,12. (2018, September 10). *Animal Products Regulations 2000.* Retrieved October 24, 2018, from New Zealand Legislation: http://www.legislation.govt.nz/regulation/public/2000/0207/latest/DLM9546.html?search=qs_act%40bill%40regulation%40deemedreg_animal+products_resel_25_h&p=1&sr=1

MPI,13. (2018). *legal-notices-for-mycoplasma-bovis*. Retrieved November 2, 2018, from https://www.biosecurity.govt.nz/protection-and-response/mycoplasma-bovis/what-is-mpi-doing/legal-notices-for-mycoplasma-bovis/

MPI,14. (2018, August 22). *National Animal Identification and Tracing Amendment Act 2018*. Retrieved September 28, 2018, from New Zealand Legislation: http://www.legislation.govt.nz/act/public/2018/0026/latest/LMS72270.html?search=qs_act%40bill%40regulation%40deemedreg_nait_resel_25_h&p=1

MPI,2. (2018, October 1). *Biosecurity Act 1993.* (Ministry for Primary Industries, Ed.) Retrieved Octobre 20, 2018, from New Zealand Legislation: http://www.legislation.govt.nz/act/public/1993/0095/latest/DLM314623.html

MPI,3. (2018). *Codes of Welfare*. Retrieved October 23, 2018, from Ministry of Primary Industries: https://www.mpi.govt.nz/protection-and-response/animal-welfare/codes-of-welfare#codes

MPI,4. (2013, January 10). *National Animal Identification and Tracing (Fees and Forms) Regulations 2012.* Retrieved October 20, 2018, from New Zealand Legislation: http://www.legislation.govt.nz/regulation/public/2012/0114/latest/resultsin.aspx?search=sw_096be8ed809ef2d2_nait_25_se&p=1&pss=qs_act%40bill%40regulation%40deemedreg_nait_resel_25_h&psp=1

MPI,5. (2018). *Advice about Mycoplasma bovis for all farmers.* Retrieved October 8, 2018, from https://www.biosecurity.govt.nz/protection-and-response/mycoplasma-bovis/advice-on-mycoplasma-bovis/advice-about-mycoplasma-bovis-for-farmers/

MPI,6. (2018). *Mycoplasma Bovis (Protection and Response).* Retrieved October 8, 2018, from https://www.biosecurity.govt.nz/protection-and-response/mycoplasma-bovis/

MPI,7. (2018). *Animal Welfare Act.* Legislation New Zealand. Retrieved October 8, 2018, from http://www.legislation.govt.nz/act/public/1999/0142/latest/DLM49664.html#DLM50484

MPI,8. (2018, Oct 25). *New regulations proposed to strengthen food recalls and manage risks*. Retrieved October 27, 2018, from Ministry of Primary Industries: https://www.mpi.govt.nz/news-and-resources/media-releases/new-regulations-proposed-to-strengthen-food-recalls-and-manage-risks/

MPI,9. (2018, August 23). *National Animal Identification and Tracing Act 2012*. (M. f. Industries, Editor) Retrieved October 12, 2018, from New Zealand Legislation: http://www.legislation.govt.nz/act/public/2012/0002/latest/DLM3430220.html?search=ad_act%40bill%40regulation%40deemedreg__animal+identification____25_ac%40bc%40rc%40dc%40apub%40aloc%40apri%40apro%40aimp%40bgov%40bloc%40bpri%40bmem%40rpub%40rimp_ac%40bc%40

New Zealand Government. (1841). *The Land Registration Act 1841.* Retrieved September 2018, from New Zealand Legal Information Institute: http://www.nzlii.org/nz/legis/hist_act/lra18415v1841n9311/

New Zealand Government. (1842). *Cattle Trespass Act.* Retrieved September 3, 2018, from http://www.nzlii.org/nz/legis/hist_act/cta18425v1842n16305

New Zealand Government. (1847). *Fencing Act 1847.* Retrieved September 29, 2018, from New Zealand Legislation Information Institute: http://www.nzlii.org/nz/legis/hist_act/fa184711v1847n8192/

New Zealand Government. (1980). *National Parks Act.* Retrieved October 5, 2018, from http://www.legislation.govt.nz/act/public/1980/0066/latest/DLM36963.html?search=sw_096be8ed8156ed99_Resource+Management_25_se&p=1

New Zealand Government. (1987). *Conservation Act* (Vol. 65). Retrieved October 1, 2018, from http://www.legislation.govt.nz/act/public/1987/0065/latest/DLM103610.html?search=sw_096be8ed8156ed99_Resource+Management_25_se&p=1

New Zealand Government. (1990). *New Zealand Railways Corporation Restructuring Act.* Retrieved October 5, 2018

New Zealand Government. (1991). *Resource Management Act* (Vol. 69). Retrieved Octber 1, 2018, from http://www.legislation.govt.nz/act/public/1991/0069/latest/DLM230265.html?search=sw_096be8ed8156ed99_Resource+Management_25_se&p=1

New Zealand Government. (2014). *Te Urewera Act.* Retrieved October 1, 2018, from http://www.legislation.govt.nz/act/public/2014/0051/latest/DLM6183601.html?search=ts_act%40bill%40regulation%40deemedreg_Te+Urewera_resel_25_a&p=1

New Zealand Government. (2016, March 17). *A history of New Zealand 1769-1914*. (Ministry for Culture and Heritage) Retrieved September 30, 2018, from https://nzhistory.govt.nz: https://nzhistory.govt.nz/culture/history-of-new-zealand-1769-1914

New Zealand Government. (2017). *Land Transfer Act 2017* (2017 No 30 ed.). New Zealand Government. Retrieved October 5, 2018, from http://www.legislation.govt.nz/act/public/2017/0030/latest/DLM6731038.html?search=sw_096be8ed8179acc1_land+act_25_se&p=1&sr=4

New Zealand Government. (2018). Heretaunga Tamatea Claims Settlement Act 2018. New Zealand Legislation. Retrieved from http://www.legislation.govt.nz/act/public/2018/0014/latest/DLM7317618.html?search=sw_096be8ed81794ef8_Heretaunga+Tamatea+Claims+Settlement+Act+2018_25_se&p=1#DLM7317628

New Zealand Law Commission. (2018). *4 The Law of torts*. Retrieved October 23, 2018, from New Zealand Legal Information Institute: http://www.nzlii.org/nz/other/nzlc/report/R50/R50-4.html

New Zealand Legal Information Institute. (1863). *Canterbury Provincial Ordinances.* Retrieved September 29, 2018, from New Zealand Legal Information Institute: http://www.nzlii.org/cgi-bin/sinodisp/nz/legis/can_ord/fo1863125/fo1863125.html?query=canterbury%20fencing%20ordinance%2018

Norman, E. (2016, July 28). *Drones at work on farms*. (T. Country, Editor) Retrieved October 31, 2018, from The Country: https://www.nzherald.co.nz/the-country/news/article.cfm?c_id=16&objectid=11682887

NZ Labour Party,1. (2017). *Water Policy.* (A. Kirton, Ed.) Retrieved October 22, 2018, from Labour Party Policy: https://d3n8a8pro7vhmx.cloudfront.net/nzlabour/pages/8414/attachments/original/1504825077/Water_Policy.pdf?1504825077

NZ Labour Party,2. (2017). *NZ Labour Party Policy.* (D. Lacy, Ed.) Retrieved Octobre 22, 2018, from NZ Labour Party: https://www.labour.org.nz/policy

NZ Labour Party,3. (2017). *Information & Communications Technology.* Retrieved October 2018, from Labour: https://d3n8a8pro7vhmx.cloudfront.net/nzlabour/pages/4112/attachments/original/1504908762/ICT_Policy.pdf?1504908762

NZ Labour Party,4. (2017). *Climate Change Policy.* Retrieved October 2018, from Labour: https://d3n8a8pro7vhmx.cloudfront.net/nzlabour/pages/8493/attachments/original/1504847668/Climate_Change_Manifesto.pdf?1504847668

NZTech. (2018, September 29). Retrieved from NZTech: https://nztech.org.nz/

O'Connor, D. (2018). *KPMG Agribusiness Agenda 2018.* KPMG. Retrieved October 4, 2018

OECD. (2018). GDP per hour worked (indicator). . doi:doi: 10.1787/1439e590-en (Accessed on 03 October 2018)

Ohara, Y. (2018, March 28). *Get tough on rustlers: Fed Farmers*. (Y. Ohara, Editor) Retrieved October 16, 2018, from Otago Daily Times: https://www.odt.co.nz/rural-life/rural-life-other/get-tough-rustlers-fed-farmers

OSPRI. (2012, November). *NAIT-RFID-approval-process.* Retrieved October 3, 2018, from NAIT: http://www.nait.co.nz/assets/RFID-approval/NAIT-RFID-approval-process.pdf

Overseer. (2018). *Overseer*. Retrieved September 8, 2018, from https://www.overseer.org.nz/: https://www.overseer.org.nz/

PAANZ. (2017). Hamilton: https://precisionagriculture.org.nz/events/pa17-the-international-tri-conference-for-precision-agriculture-in-2017/.

Peat, N. (2005). *Hurricane Tim: the story of Sir Tim Wallis.* Longacre Press. Retrieved September 10, 2018

Peden, R. (2008, November 24). *Farm Fencing*. (R. Peden, Editor, & T. A.-t. Zealand, Producer) Retrieved September 25, 2018, from An Encyclopedia of New Zealand: https://teara.govt.nz/en/farm-fencing/page-2

Peden, R. (2008, November 24). *Rabbit Fences*. Retrieved from An Encyclopedia of New Zealand: https://teara.govt.nz/en/rabbits/page-4

Peden, R. (2008, November 24). *Wire fencing*. (R. Peden, Editor) Retrieved October 2, 2018, from An Encyclopedia of New Zealand: https://teara.govt.nz/en/farm-fencing/page-5

Phillips, J. (2015, August 1). *history-of-immigration*. Retrieved September 20, 2018, from Te Ara - the Encyclopedia of New Zealand: https://teara.govt.nz/en/history-of-immigration/page-3

Prof. Jari Collin. (2015). *IT Leadership.* Aalto University . Helsinki 2015: SCIENCE + TECHNOLOGY 7/2015 . Retrieved October 30, 2018, from https://aaltodoc.aalto.fi/bitstream/handle/123456789/16540/isbn9789526062433.pdf?sequence=1&isAllowed=y

Proudfoot et al, I. (2018). *KPMG Agribusiness Agenda 2018.* KPMG. Retrieved October 4, 2018

Quinlivan, M. (2018, May 28). *Cows killed as herd hits State Highway 1 in South Canterbury.* Retrieved November 8, 2018, from Stuff: https://www.stuff.co.nz/timaru-herald/news/104262075/cows-killed-as-herd-hits-state-highway-1-in-south-canterbury?rm=m

Radio New Zealand. (2018, October 31). Midday Rural News. Retrieved from https://www.radionz.co.nz/audio/player?audio_id=2018669140

Radio New Zealand. (2018, October 2). *New Zealand Environment: Zealandia breach: 'Even one introduced predator is one too many'*. Retrieved October 4, 2018, from Radio New Zealand: https://www.radionz.co.nz/news/national/367777/zealandia-breach-even-one-introduced-predator-is-one-too-many

Rogers, E. N. (2003). *Diffusion of Innovations* (5th ed.). New York: Free Press. Retrieved October 23, 2018

Rossman, J. (2016). *The Amazon IoT Way.* Clyde Hill Publishing.

Safaryan, R. (2014). *The failures of IT projects. Factors and early prediction.* Christchurch. Retrieved October 23, 20018, from http://raf.nz/publ/the_failures.pdf

Schmalensee, R. L. (1988). *Industrial Economics: An Overview.* Massachusetts Institute of Technology, Sloan School of Management. Retrieved October 18, 2018, from https://dspace.mit.edu/bitstream/handle/1721.1/48172/%EE%80%80industrial%EE%80%81econom00schm.pdf?sequence=1

Schwab, K. (Ed.). (2018). *https://www.weforum.org/reports/the-global-competitveness-report-2018.* Retrieved October 22, 2018, from World Economic Forum: http://www3.weforum.org/docs/GCR2018/05FullReport/TheGlobalCompetitivenessReport2018.pdf

Schwab, K. (2018, May 25). *The Fourth Industrial Revolution*. (Encyclopædia Britannica, inc.) Retrieved October 18, 2018, from Encyclopædia Britannica : https://www.britannica.com/topic/The-Fourth-Industrial-Revolution-2119734

Schwass, M. (2018, August). *https://ruralleaders.co.nz/the-potential-of-blockchain-monica-schwass/.* Retrieved October 20, 2018, from https://ruralleaders.co.nz: https://www.dropbox.com/s/ca2sx3vt4z9c8qj/Final%20-%20The%20Potential%20of%20Blockchain%20-%20Monica%20Schwass%20.pdf?dl=0

Scott, D. (2006). Consideration of paddock shape and access in subdivision fencing. *Proceedings of the New Zealand Grassland Association, 68*, 321–323. Retrieved October 15, 2018, from https://www.grassland.org.nz/publications/nzgrassland_publication_399.pdf

Silver Fern Farms. (2015, October 16). *Shareholders Strongly Support Shanghai Maling Partnership Proposal*. Retrieved September 24, 2018, from Silver Fern Farms: http://www.silverfernfarms.com/our-company/latest-news/shareholders-strongly-support-shanghai-maling-partnership-proposal/

Silver Fern Farms. (2016, December 06). *Completion of investment by Shanghai Maling*. (Silver Fern Farms) Retrieved September 24, 2018, from Silver Fern Farms: http://www.silverfernfarms.com/our-company/latest-news/completion-of-investment-by-shanghai-maling/

Silver Fern Farms. (2017, September 11). *Value-Add Supply Milestone Achieved*. Retrieved September 24, 2018, from Silver Fern Farms: http://www.silverfernfarms.com/us/our-company/latest-news/value-add-supply-milestone-achieved/

Sinek, S. (2009). *Start with why.* Penguin. Retrieved September 2, 2018

Spark NZ. (2018). *LoRaWAN Coverage*. Retrieved October 28, 2018, from http://www.sparkdigital.co.nz/solutions/iot/loracoverage/

Spark NZ. (2018). *Spark 4G - Our Spark Network*. Retrieved October 5, 2018, from Spark: https://www.spark.co.nz/4g/

Statistics NZ. (2017, June). *Agricultural Production Statistics June 2017.* Statistics NZ. Retrieved October 20, 2018, from stats.govt.nz: https://www.stats.govt.nz/information-releases/agricultural-production-statistics-june-2017-final

Statistics NZ. (2018). LBD. Retrieved October 3, 2018, from https://www.stats.govt.nz/integrated-data/longitudinal-business-database/

Statistics NZ. (2018, June 30). Overseas-trade-indexes-prices-and-volumes-june-2018-quarter-provisional. Retrieved October 3, 2018, from https://www.stats.govt.nz/information-releases/overseas-trade-indexes-prices-and-volumes-june-2018-quarter-provisional

Taylor, G. (2013, June). Managing change: the key to unlocking the value of innovation on farm. *Primary Industry Management, 17*(2). Retrieved October 13, 2018, from https://www.nzipim.co.nz/Folder?Action=View%20File&Folder_id=120&File=PIM%20June%202013%20low_res.pdf

Te Ara - the Encyclopedia of New Zealand. (1966). *The Torrens System*. (A. H. McLintock, Editor) Retrieved October 12, 2018, from An Encyclopaedia of New Zealand: https://teara.govt.nz/en/1966/property-law-of-real/page-2

The Pearse Lyons Accelerator. (2018, October 3). 3/10/2018 · Virtual Fencing for Cattle ... World Rivers in Hindi | Top 10 Rivers of the World | Famous Rivers of the World - Duration: 4:53. *Vence Pitch - The Pearse Lyons Accelerator - YouTube*. Retrieved October 28, 2018, from https://www.youtube.com/watch?v=S3PhBJNdEwU

TVNZ. (2018, November 2). govt-announces-massive-20-year-project-protect-species-in-vast-south-island-area. *One News*. TVNZ. Retrieved November 2, 2018, from https://www.tvnz.co.nz/one-news/new-zealand/govt-announces-massive-20-year-project-protect-species-in-vast-south-island-area?auto=5856650259001

Vaughan, G. (2013, February 11). *Tru-Test's biggest shareholder and rival Gallagher Group says 'no' to renounceable rights issue launched to help fund Tru-Test's 'transformational' acquisition*. Retrieved November 11, 2018, from https://www.interest.co.nz/rural-news/63045/tru-tests-biggest-shareholder-and-rival-gallagher-group-says-no-renounceable-rights

Vence. (2018, October 2). *About*. Retrieved October 12, 2018, from Vence: http://vence.io/about/

Victoria University of Wellington. (2018). *The Farmer in New Zealand.* Retrieved October 4, 2018, from Victoria University of Wellington: http://nzetc.victoria.ac.nz/tm/scholarly/tei-AllFarm-t1-body-d2.html

Vitalis, V. (2018, September 4). International Trading Environment.

Vodafone. (2017, July 3). *Vodafone IoT*. Retrieved from Vodafone : https://news.vodafone.co.nz/article/vodafone-readies-mobile-network-internet-things-future

Vodafone. (2018). Retrieved October 5, 2018, from https://www.vodafone.co.nz/network/coverage/

W.J. Stewart. (2006). *Legal Dictionary - Common law*. (W. Stewart, Editor, & Collins Dictionary of Law) Retrieved October 23, 2018, from The Free Dictionary: https://legal-dictionary.thefreedictionary.com/Common+Law

Waghorn et al, G. C. (1987). Pasture Chemical Composition, Maturity and Digestibility. In A. Nicol (Ed.), *Livestock Feeding on Pasture* (p. 28). Society of Animal Production.

Waghorn, G., & Barry, T. (1987). Pasture as a Nutrient Source. In A. Nicol (Ed.), *Livestock Grazing on Pasture* (pp. 21-36). New Zealand Society of Animal Production. Retrieved October 8, 2018

Waikato Regional Council. (2018). *Mustelids*. Retrieved November 2, 2018, from Waikato Regional Council: https://www.waikatoregion.govt.nz/services/regional-services/plant-and-animal-pests/animal-pests/mustelids/

Weld, F. A. (1860). *Hints to intending sheep-farmers.* Retrieved September 17, 2018, from http://www.enzb.auckland.ac.nz/document/?wid=3855&page=1&action=null

Westerman et al, D. B. (2014). *Leading Digital;.* Retrieved September 15, 2018, from www.leadingdigitalbook.com

Wier, J. C. (2001). TechnoGrazing a new grazing concept. *Proceedings of the New Zealand Grassland Association 6*, 33-36. Retrieved October 27, 2018, from https://www.grassland.org.nz/publications/nzgrassland_publication_260.pdf

Wikipedia. (2018, August 28). *Number 8 wire*. Retrieved October 10, 2018, from Wikipedia: https://en.wikipedia.org/wiki/Number_8_wire

Wikipedia. (2018, September 22). Parallax. Wikipedia. Retrieved September 24, 2018, from https://en.wikipedia.org/wiki/Parallax#cite_note-oed-2

Wikipedia. (2018, October 18). *Pastoral Farming*. Retrieved October 20, 2018, from Wikipedia: https://en.wikipedia.org/wiki/Pastoral_farming

Wikipedia. (2018, August 28). *Standard wire gauge and Number 8 wire*. Retrieved September 12, 2018, from Wikipedia: https://en.wikipedia.org/wiki/Standard_wire_gauge

WISPA NZ. (2018). *Find Local WISP*. Retrieved October 5, 2018, from WISPA NZ: https://www.wispa.nz/wispa-nz-members/

World Economic Forum. (2018). *The Fourth Industrial Revolution*. (W. E. Forum, Editor) Retrieved October 18, 2018, from World Economic Forum: https://toplink.weforum.org/knowledge/insight/a1Gb0000001RIhBEAW/explore/summary

Zealandia. (2018). *A World First Sanctuary*. Retrieved September 25, 2018, from Visit Zealandia: https://www.visitzealandia.com/About/History/A-World-First-Sanctuary

APPENDIX

Search Topics

The below provides how key search subjects were formulated and resulting in themes, which have been ordered to create flow to systematically layer information for readers to understand prior to the conclusions and recommendations.

Context searches

1) *Standard of living*
2) *Productivity measures*
3) *Challenges New Zealand Agriculture*
4) *Opportunities New Zealand Agriculture*

The searches for the literature review were structured by separating the key components of the question.

> *Is **Virtual Fencing** a foundation technology and catalyst for **digital transformation** of **New Zealand pastoral farming**?*

Interlocking the components created further search criteria:

1) *Fencing New Zealand pastoral farming*
2) *Foundation digital transformation*
3) *Foundation pastoral farming*
4) *Catalysts digital transformation*
5) *Virtual fencing digital transformation*

The searches provided a means to establish themes:

- **Standards of living and productivity** – GNI, GDP and productivity measures, to understand international benchmarking, government policy and drivers for change and digital transformation as part of the introduction to provide context for the research subject.
- **Challenges and opportunities in NZ the agricultural** – relative to pastoral farming, to establish the cross over with virtual fencing benefits as part of the introduction to provide context for the research subject.
- **Virtual Fencing Technology** – patents, scientific research, components, commercial operators and their solutions expected benefits. The information is expected to provide a means to conduct comparative analysis with traditional physical fencing and key farm management practices relating to property ownership & responsibility, livestock, pasture and grazing management, sustainability, environmental and financial management.
- **History of pastoral farming** – land settlement and how pastoral farming was established to understand; the types and role of fences adopted, core farming management practices, early influencing legislation.

- **Ownership and responsibility for land and animals** – including legislation relating to land and improvements, rights and responsibilities, boundary fencing responsibilities, animal ownership and responsibilities.
- **Livestock Management** - including animal identification practices and legislation; animal related legislation, animal movement control, animal containment control, biosecurity and disease, animal health, animal behaviour and welfare, livestock security, predator and pest control, related legislation, animal science
- **Pasture Management and Grazing** – carrying capacity, pasture production, pasture grazing, feed planning, weed management and fencing
- **Sustainability and environmental management** – nutrient management, soil degradation and erosion, water utilisation and river management
- **Financial management** – financial legislation relating to fencing and animals
- **Digital transformation** – including technologies, influencing factors, capabilities and leadership, technology adoption, The Fourth Industrial Revolution, Industrial Revolution

Research Sources

As information was gathered broader resources were identified to provide more evidence with some of the resources listed below:

Search Engines / Wikis:

- Google scholar
- Google
- Bing
- Te Ara
- NZ history websites
- Wikipedia
- NZ Legal Information Institute
- New Zealand Legislation

Scientific Literature:

- Science publications
- Agricultural publications
- Agricultural research
- Scientific journals
- Scientific research papers
- Animal science literature Pasture science literature leadership literature

Media Websites

- New Zealand Herald
- Stuff

Books:

- Amazon Way on IoT
- The Big Shift
- Leading Digital
- Farm Technical Manual 2011
- Start with Why
- Live Stock Feeding on Pasture
- How to improve critical thinking & Reflective skills

Corporate Websites:

- Fonterra
- Silver Fern Farms
- Alliance
- Spark
- Vodafone
- Halter
- Agersens
- AgResearch
- Pamu
- Gallagher
- CapGemini

Statistical Searches:

- Statistics New Zealand
- World Economic Forum
- Figure
- Beef and Lamb

Other Websites

- Beef and Lamb
- DairyNZ
- Labour Party
- Rural Leaders
- Research at Lincoln
- CSIRO

Events Attendence

- Halter - Akd
- AgriTech – Akl
- National Fieldays ‘10 – ‘18
- MobileTech ‘15-‘18
- PAANZ


KELLOGG
RURAL LEADERSHIP
PROGRAMME