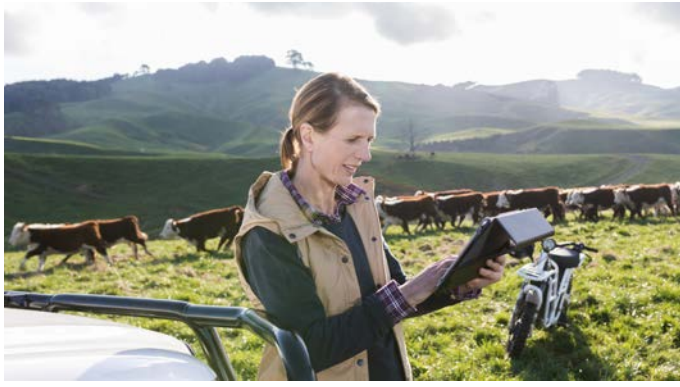
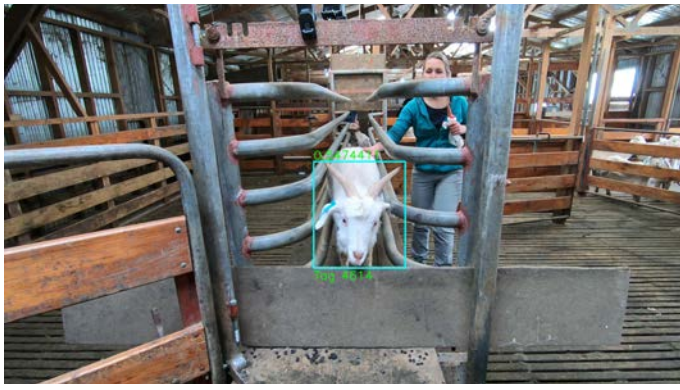
Artificial Intelligence for Agriculture in New Zealand

Ahuwhenua i te Atamai Iahiko





forum NEW ZEALAND
Te Kāhui Atamai Iahiko o Aotearoa

Agriculture Sector Partner

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Other AI Forum of New Zealand Research Reports:

ARTIFICIAL INTELLIGENCE
Shaping a Future New Zealand
(May 2018)

This report examines the New Zealand and international AI industry landscapes, investigating AI's potential impacts on New Zealand's economy and society. The report identifies key AI opportunities, in the public, private and education sectors, that New Zealand can invest in now to actively shape the effects on our collective future.

TOWARDS OUR INTELLIGENT FUTURE
An AI Roadmap for New Zealand

TE ARA MŌ TĀTOU ATAMAI O ĀPŌPŌ
Te huarahi atamai iahiko ō Aotearoa
(September 2019)

This report identifies that New Zealand urgently needs to increase its focus on the core foundations needed to operate in an AI enabled future – particularly investment, skills and talent, research, trusted data, ethics and regulation. The report also shows how AI enabled solutions can be used to improve New Zealand's wellbeing, productivity and sustainability.

Download our reports at
https://aiforum.org.nz/our-work/publications/

About the AI Forum of New Zealand

THE ARTIFICIAL INTELLIGENCE FORUM OF NEW ZEALAND IS A NON-GOVERNMENT ASSOCIATION WITH A MISSION TO HARNESS THE POTENTIAL OF ARTIFICIAL INTELLIGENCE (AI) TO HELP BRING ABOUT A PROSPEROUS AND INCLUSIVE FUTURE NEW ZEALAND.

The rapid development of AI technologies presents major opportunities and challenges for our country: from creating world leading AI businesses, nurturing a pool of talented AI engineers and applying AI technologies to our agriculture, government, manufacturing and service industries to holding a meaningful national debate on the broader implications for society, New Zealand needs to actively engage with AI now in order to secure our future prosperity.

The Forum brings together citizens, business, academia and the government to connect, promote and advance the AI ecosystem to help ensure a prosperous New Zealand.

About AsureQuality

HELPING AOTEAROA SHAPE A BETTER FOOD WORLD.

As a leading provider of food assurance services to the primary production and food manufacturing sectors for over 100 years, AsureQuality is part of New Zealand's global reputation for safe, quality food production and transparent assurance systems. AsureQuality's services help customers to achieve access to their chosen markets, gain competitive advantage and protect their products, brands and reputation.

AsureQuality provides a range of services to producers, processors, wholesalers, retailers and regulators across the food supply chain including dairy, food, meat, poultry and seafood, horticulture and wine, arable, forestry and biosecurity.

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Please download a free digital copy of the e-report from the AI Forum website, **www.aiforum.org.nz**

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TOWARDS OUR INTELLIGENT FUTURE
TE HUARAHI ATAMAI IAHIKO Ō AOTEAROA

The AI Forum of New Zealand would like to extend our sincere gratitude for the generosity of all the Programme Partners and Supporters who have made this report possible.

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Foreword

AsureQuality

KIA ORA KOUTOU, NEW ZEALAND'S PREMIUM POSITION IN THE GLOBAL FOOD VALUE CHAIN IS AT STAKE.

In this constantly changing world, each of us have the opportunity to embrace the rapidly advancing science, technology and digital capabilities and forge ahead to secure New Zealand's place in this brave new world.

It's important to note that cyber-physical systems and the Internet of Things (IoT) are only mechanistic tools. The magic happens when a these advances converge and the rate of change accelerates. These synergies bring different and previously unforeseen ways of solving or leaping over problems. Game-changing innovation. Fiction becomes fact.

As a nation and individuals, we must keep imagining and asking "What if....?"

While our understanding of what we mean by AI is evolving, what hasn't changed is the innate power of data for driving insight, understanding and competitive advantage. With the accelerating rate and scale at which we can produce this data, it is only through using emerging AI capabilities to collect, collate, curate and crunch these datasets that we can stay ahead of our competition and meet societies' challenges head on.

This challenge is very keenly felt in the agriculture and food space. As a country we need to leverage our know how in food production, whilst meeting the challenges of supplying food in an increasingly discriminating world. The good news is that we are starting to see the building blocks emerge.

We now see many applications of AI working hard across our agricultural landscape. For example, utilising the networks of sensors and machines on farms to help productivity, or find new chemicals to kill weeds. AI combined with machine vision is being used to harvest lettuce, identify animals and measure their behaviour, health or predict impending illness. AI is also enabling autonomous drones for precision herbicide and fertiliser applications.

On the food testing front, we are seeing the application of AI help develop new test methods and interpret complex test outputs faster, and machine vision used as an alternative test method in some applications.

Darren Wilson,
Chief Digital Officer
AsureQuality

AsureQuality

We are starting to see digital twins of farms and orchards emerge which simulate operating and business models to allow smarter, no-risk cause and effect modelling. AI is also being used to help predict which commodities or products are at risk of fraud using supply, demand and macroeconomic data sets, and to predict whether a new food product would succeed or fail in the market.

Because we can now more easily monitor and test supply chains, we can take an increasingly holistic approach to better assure supply, recognise trends, grab opportunities and mitigate risks to company brands and brand NZ.

AsureQuality is proud to support the AI Forum's efforts and to be the Forum's 2019 Research Programme Agriculture Sector Partner. In the end, how we progress in shaping New Zealand's place in the food world will depend on how boldly we go up to and step over the AI horizon. AI is the new 'number 8 wire' which will enable New Zealand to achieve a premium position in the global food value chain in the twenty first century.

Ngā mihi.

Executive Summary

"We should look to technology opportunities in sectors adjacent to the areas where we already excel – agriculture and horticultural production... are obvious examples."

– NEW ZEALAND GOVERNMENT MINISTER DAVID PARKER at the launch of the Government's Industry Strategy, July 2019[1]

Agriculture and horticulture play a dominant role in New Zealand's export economy – dairy products, meat, fruit, wine, fish and seafood make up around 40% of New Zealand's NZ$80 billion annual exports.[2] However the broadly-defined agriculture sector in New Zealand continues to face significant ongoing challenges including climate change, low productivity growth, labour shortages, increasing regulation and environmental sustainability.

Artificial intelligence (AI) is a new general-purpose technology. AI is transforming industries around the world by augmenting human labour, automating processes and providing intelligent analytics.

AI is a catch-all term for a range of automation technologies that most often use "machine learning" to make predictions using data. We include within our definition a range of computational techniques which can be applied to problems in agriculture including: **robotic process automation, computer vision, natural language processing, reinforcement learning** and generalised **deep learning**. For a fuller explanation of AI and machine learning, see our recent report *Towards Our Intelligent Future: An AI Roadmap For New Zealand*.

AI in agriculture is in its early days globally and very much in an embryonic stage in New Zealand. Markets such as the USA have the advantage of scale and corporate / venture investment to drive innovation and commercialisation in AI whereas the EU and UK have different advantages of significant government investment. New Zealand's access to investment capital for developing AI in Agriculture is still a significant constraint, despite significant recent inroads by the new Agritech New Zealand association.

AI presents opportunities across an incredible diverse range of use cases. These include yield optimisation, addressing labour shortages, meat alternative research, real time risk management along the supply chain, assurance of the quality of the food with traceability, providing food security through locating and isolating disease outbreaks in animals and plants, waste reduction within the supply chain, biosecurity, conversion efficiency on farm linked to animal health and sustainability, valuation and insurance. In addition, value add opportunities from reducing intermediaries in the supply chain are seen as key to allowing New Zealand to increase the overall worth of its exports.

Perhaps the greatest potential is to use AI to support "NZ Inc." value differentiation and brand strategies in both our perceived premium "niche play" markets and also with emerging food technologies as we compete for market access against other countries and producers, for example those from Ireland and South America.

While there is some AI activity in New Zealand in agriculture, it is disproportionately focused behind the farmgate. Technology costs money and a lack of understanding on how the technology could be of benefit are seen as limiting uptake in the farming sector. On-farm commercial activity appears to be focused on sensors, precision farm data with smarter alerts, robotics and decision support with the focus moving to predictive analytical ability. AI in horticulture appears to be further behind than in the agricultural sector with the primary focus on descriptive and some diagnostic computation analysis.

The conversation and activity in AI needs to lift from behind the farmgate to include the whole value chain. Although New Zealand's focus on farming anchors our provenance story, there is a tendency to look at food "from farm to fork" as opposed to using data and technology to look back down the supply chain from the consumer and drive thinking

from that direction. Application of AI in our supply chains to manage risk, provide transparency to consumers and maximise outputs through effective utilisation of inputs have the highest potential provide value adding opportunities for New Zealand.

Startups are developing products with marginal points of differentiation in an attempt to take a slice of a small pie. This has led to competitive pressures where startups are failing fast, farmers are losing confidence and trust in new companies and not investing time and money into new technology.

Agricultural AI Startups also face several other challenges. This includes the need to globalise to create a sustainable growing business model combined with needing access to venture and enterprise capital to grow.

While AI is certainly recognised as a future tool to drive productivity for New Zealand, it is also seen to have the potential for sustainability gains and an improved environmental footprint, however, there appears to be a general disconnect between expectations and reality when it comes to the time and cost to invest in this technology. This also goes hand in hand with an appetite for risk.

A proprietary data ownership mentality appears to be driving siloed behaviour across the New Zealand agriculture sector and limiting the added value benefit of sharing data to create meaningful data sets. Changing this mindset may require Government, Corporate and CRI collaboration.

Collaboration on AI will require interoperating platforms, wider trust networks and means for returning value from the beneficiary to the data provider need to be considered. Work is needed to continue development of agricultural data standards and establish structures for data sharing such as data trusts.

There are conflicting views on whether our CRIs are set up to support AI in Agriculture as effectively as they could be. One view is that they are investing in the risky future and so are risk proofing organisations, the other view is that because of their funding model they are not set up to deliver on the fast paced nature of Agritech, including AI. While CRI research can generate prototypes, the timescale to further develop, have meaningful datasets for validation and commercialise, does not always line up with the short term, 12 to 18 months, return on investment, that present industry demands. In addition, industry sees this space as fast paced which can cause changing priorities.

AI for Agriculture needs to compete with more data-rich sectors for talent. As noted in the AI Forum's recent report *Towards Our Intelligent Future*, our local education and training system is struggling to address the current shortages of machine learning specialists, software developers, data scientists and software architects. There also needs to be capability development with a view to industry application. Agriculture needs to compete for talent with other sectors which already hold more data – including financial services, health, transport and government services.

It is widely acknowledged that there is a skill gap in the Agritech space and companies do not have time to wait for NZ to develop a deep pool of skilled talent on its own. Immigration is likely to continue to be a major source to rapidly import the skills needed across the continuum to meet our growing demand.

Furthermore, educating farmers and other roles within the food supply chain on the benefits of data and AI applied to that data is also key to ensuring that they are ready when the technology is commercially viable.

Call to Action...

- Accelerate efforts to increase adoption of Agricultural Data Standards and establishment of data sharing structures such as Data Trusts
- Increase investment in New Zealand AI startups focused on understanding and modeling the whole food value chain, not just food production
- Increase understanding of AI for farmers and other agriculture sector workers, while at the same time ensuring that a talent pool of AI technologists are developed with understanding of agriculture
- Identify opportunities to apply AI to New Zealand's environmental and sustainability goals for agriculture.

Who is This Report For?

The aim of this report is to explain how the agriculture sector can utilise AI, the global state of play, and what research, innovation and commercialisation is occurring right now in New Zealand. We outline what is possible, the scale of the impact, and how New Zealand might move forward. Agriculture sector stakeholders: farmers, technologists, regulators and decision makers can use the content to increase their awareness of AI in agriculture and guide thinking around AI and its benefits for the wider global food value chain.

After reading this agriculture sector report we hope that interested parties will have a better understanding of how AI can enhance productivity and commercial outcomes in the food supply chain, where to begin, and what obstacles may be faced. We also hope that consumers and the general public will use this report to understand how AI can be used to provide more sustainable, environmental agricultural practices.

A Note on Methodology

This research report covers the outputs from interviews across the New Zealand agriculture landscape, web searches, conference proceedings and literature reviews.

The broad term “agriculture” has been defined as land-based agriculture including arable, beef, dairy and sheep. We also use the contractions **agritech** to refer to agricultural technology generally and **agrifood** to refer to the broader agriculture – food supply chain.

Key Highlights

AI in agriculture is in its early days globally and very much in an **embryonic stage in New Zealand.** Activity in AI needs to **lift from behind the farmgate to include the whole value chain.**

AGRICULTURAL AI USE CASES ARE INCREDIBLY DIVERSE: YIELD OPTIMISATION, **ADDRESSING LABOUR SHORTAGES**, MEAT ALTERNATIVE RESEARCH, **REAL TIME RISK MANAGEMENT ALONG THE SUPPLY CHAIN**, ASSURANCE OF THE QUALITY OF THE FOOD WITH TRACEABILITY, **PROVIDING FOOD SECURITY THROUGH LOCATING AND ISOLATING DISEASE OUTBREAKS IN ANIMALS AND PLANTS**, WASTE REDUCTION WITHIN THE SUPPLY CHAIN, **BIOSECURITY**, CONVERSION EFFICIENCY ON FARM LINKED TO ANIMAL HEALTH AND SUSTAINABILITY, **VALUATION AND INSURANCE**.

Agricultural professionals will be **key to the implementation of AI.**

A vision for AI is that it can help farm-based food supply chains reduce wastage through helping retailers sell food before it goes bad, **forecast and predict sales** to more efficiently **connect supply to demand** when ordering food.

WORK IS NEEDED IN NEW ZEALAND TO CONTINUE DEVELOPMENT OF AGRICULTURAL DATA STANDARDS AND ESTABLISH STRUCTURES FOR DATA SHARING SUCH AS DATA TRUSTS.

The EU plans to **digitise over two million farms** across Europe.

AI FOR AGRICULTURE NEEDS TO COMPETE WITH MORE DATA-RICH SECTORS FOR TALENT.

AI IN AGRICULTURE IS PREDICTED TO UNLOCK AN ESTIMATED GLOBAL ECONOMIC OPPORTUNITY OF UP TO US$486 BILLION PER YEAR OF ADDED VALUE.

Agricultural Crown Research Institutes may need to change in order to deliver on the fast paced nature of Agritech, including AI.

AI decision-making, research and innovation in New Zealand agriculture needs to be guided by **Mātauranga Māori** and help unlock the potential of **Māori knowledge, people and resources** for the benefit of New Zealand.

WITHOUT ACCURATE UNDERLYING DATA SETS THE PRECISION CAPABILITY OF AI IS LIMITED.

Section 1: Current State of AI in Agriculture

"Agriculture in the 21st century faces multiple challenges: it has to produce more food and fibre to feed a growing population with a smaller rural labour force... contribute to overall development in the many agriculture-dependent developing countries, adopt more efficient and sustainable production methods and adapt to climate change."[3]

– FOOD AND AGRICULTURE ORGANISATION (FAO) OF THE UNITED NATIONS

AI in Agriculture – A Global Overview

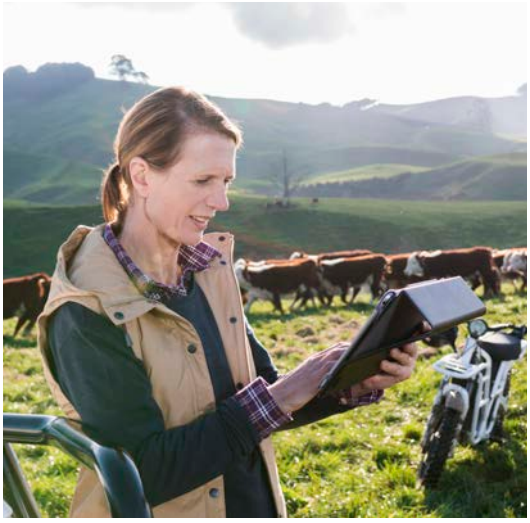
INTRODUCTION

Agricultural production, while only accounting for 3% of global gross-domestic product (GDP),[4] is crucial to the world's economy and society. Agricultural development is one of the most powerful tools to end extreme poverty, boost prosperity and feed a projected 9.7 billion people by 2050. Agriculture remains central to the lives of many people around the world – in 2012, an estimated 1.3 billion people (19 percent of the world's population) were directly engaged in farming.[5]

Agriculture uses 11 percent of the world's land area, is a significant consumer of freshwater resources and a major contributor to greenhouse gas emissions. These factors are driving a focus on how new technology including AI can enable the development of new business models resulting in food systems which are more productive, sustainable, efficient, inclusive, transparent and resilient.[6]

Farmers' yields are nearly always well below potential (water-limited) yields, regardless of whether conditions are irrigated or rainfed. In the most productive agricultural systems on earth, farmers produce around 80 to 85 percent of the theoretical maximum. These persistent yield gaps are due to a combination of yield-defining (varieties, seed quality and growing season), limiting and reducing factors. They also hold promise; they mean that production can be significantly increased on existing agricultural areas, in many cases without irrigation.[7]

The major factors driving the growth of the global agritech market include: growing demand for agricultural production owing to the increasing



population and a global aspiration to feed up to ten billion people in 2050, rising adoption of information management systems, new advanced technologies for improving crop productivity by implementing deep learning techniques, and growing initiatives by governments supporting the adoption of modern agricultural techniques.

There is no clear consensus on the current value of AI in Agriculture or what it will grow to, with ranges from US$240 to 520 million in 2017 through to US$790 to 2,628 million by 2025. However what is evident is that people are expecting a step change in value from the application of AI in agriculture. In 2017 the United States market accounted for about 43 percent of the global consumption of AI, while Europe was at about 23 percent.[8]

McKinsey[9] conducted a study of more than 400 use cases covering 19 industries and nine business functions. Using the 2016 global economy as the baseline, they estimated that applying AI and other analytics in agriculture, could provide potential annual value of up to US$486.3 billion. If successful, the whole industry would be accountable and transparent to itself and to consumers, who buy agricultural products and, ultimately, affect production practices and subsequent regulatory policy.[10]

CURRENT STATE

There are myriad views on where AI can be used in agriculture.

IBM[11] believe that AI can benefit agriculture through:

1. Helping IoT achieve its maximum potential
2. Image recognition and insight
3. Skills and workforce
4. Determining the best options to maximise return on crops
5. Chatbots for farmers

To deliver on the above requires predictive analytics, supply chain efficiencies along with animal, crop and soil monitoring.

Some of the major applications of AI in agriculture include robotics, crop and soil management and monitoring, automated irrigation, AI guided drones and predictive analytics. Research published in 2018,[12] showed crop monitoring was the largest solution type with AI guided drones expected to overtake as the fastest growing solution.

In addition, large scale technology companies are increasingly stepping into the agriculture space to provide scalable solutions such as IBM with weather, analytics and cloud-based computing infrastructure and Microsoft with its FarmBeats solution.

In 2019 Deloitte Consulting LLP released a paper[13] that categorises company development towards achieving full utilisation of AI into three stages:

1. Assisted intelligence where large-scale data programs, the cloud and science based approaches allow data-driven business decisions.
2. Augmented intelligence where machine learning capability is layered onto information management systems to augment human analytics.
3. Autonomous intelligence where processes are digitised and automated to a degree allowing machines, bots, and systems to directly act upon intelligence derived from them.

Smith[14] plotted a view on how AI enabled capabilities used in agriculture could progress over the next decade (see Figure 1). If the definitions from Deloitte are overlaid on the figure below it is clear to see that the focus in agriculture has been at the front end in collecting data to enable data-driven business decisions via drones, remote sensors, satellites and smart farm equipment providing real-time data for farmers to make decisions driving towards increased efficiencies.

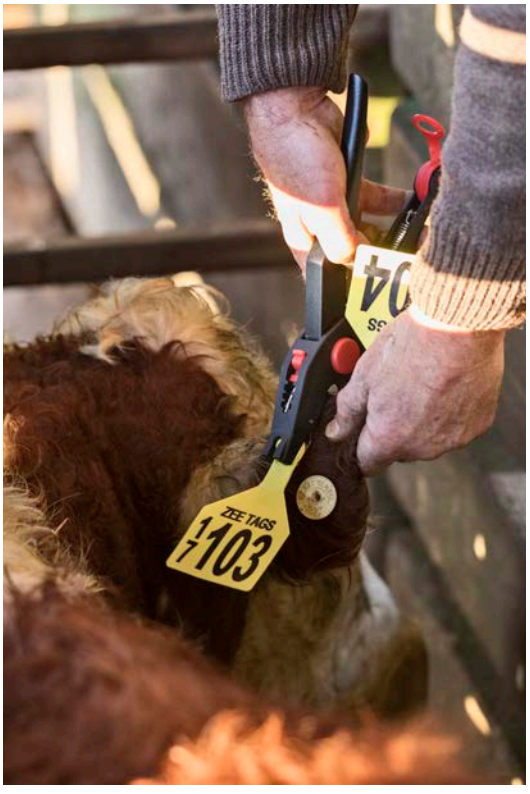
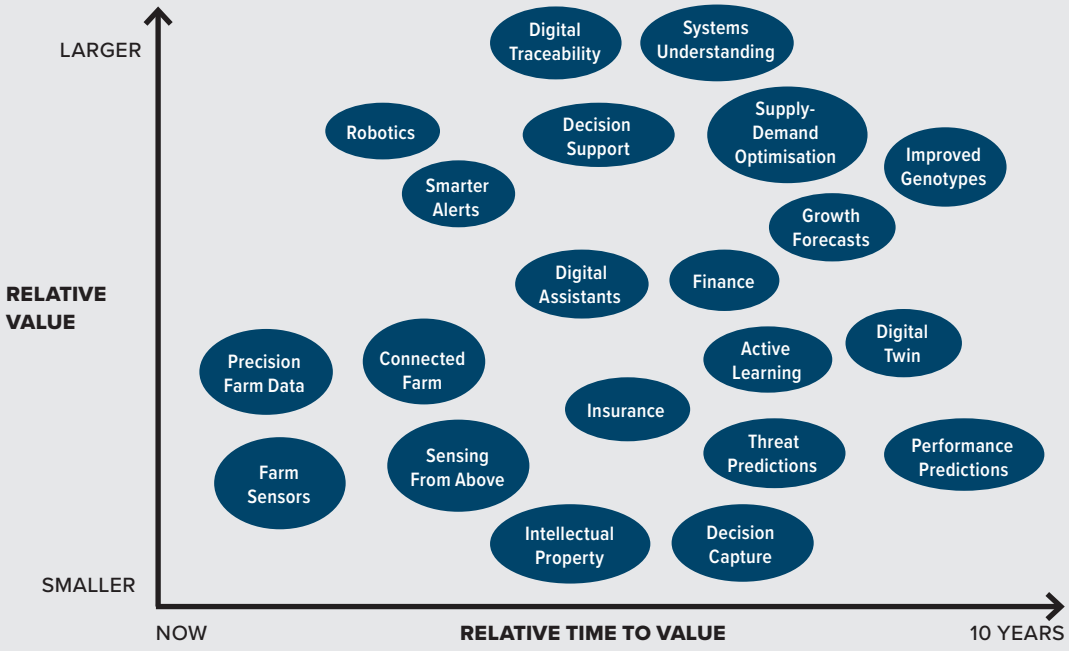


FIGURE 1: Value vs. Time to Value for AI-enabled Capabilities in Agriculture



SOURCE: Adapted from M Smith, Microsoft

CROP MONITORING

Software for crop monitoring promises to leverage the predictive power of AI to tell farmers and agricultural suppliers exactly how much fertilizer to lay down, exactly how many seeds to plant per acre, exactly which varieties and fields give you the highest probability of a positive ROI on a fungicide application – and make these fields more profitable than ever before. In addition it is looking to provide a scalable and consistent solution

In-field sensors and technologies like drones are increasingly available. This trend has led to innovators providing analytics across the data and generating insights to enhance farm management systems. Ultimately, this results in better farm business management tools.

REAL-TIME DATA ANALYSIS

The combination of the IoT and AI technologies, such as machine learning, computer vision, and predictive analytics, further allow farmers to analyze real-time data of weather conditions, temperature, soil moisture, plant health, and crop prices in the market.

DIGITAL TWINS

Startups and large corporates, such as IBM and John Deere, with an eye to the future, are now focusing on how to move to an augmented intelligence space with the creation of "digital twins". Digital twins are virtual models of a process, product or service and allow for analysis and performance predictions, heading off problems before they occur.

SUSTAINABILITY

The European agrifood scene is leading the charge for sustainability in many ways. The Europeans have already started to make a general mindshift to close the gap between agriculture and the rest of society to see what can be done to improve the impact of food production on the environment. Twenty five European countries signed a declaration of cooperation on the 9th April 2019.[15] The declaration recognised the potential of digital technologies such as AI to help tackle the social, climate and environmental challenges facing the EU's agrifood sector and rural areas.

Another example of sustainability in practice is demonstrated by Truterra,[16] launched by Land O'Lakes Sustain to drive on-farm conservation solutions at scale. The Truterra Insights engine allows farmers, agricultural suppliers, food companies and consumers to measure sustainability progress and trends in real time at the sub-field level. It brings together the proven value of stewardship practices with agronomic expertise and agricultural suppliers to provide farmers with field-customised insights for their business and natural resources.

CIRCULAR AGRICULTURE

Wageningen University, based in the Netherlands, believes that the circular agrifood system[17] is a way to create an efficient system for food product.

The existing linear agricultural system in the Netherlands is based on individual supply chains (linear) dedicated to producing as much food as possible at minimal environmental cost. The Dutch

FIGURE 2: The Role of Animals in a Circular Agrifood System

In 2050, the global populations will have risen to 9.5 billion people. In a circular food system we can use the current available agricultural land to provide the growing world population with food, without causing any extra burden to the earth. An essential part of this system is in establishing smart connections between plant-based and animal products, in order to create an integral agrofood system. **www.wur.eu/circularfood**

CROPS
Only 30% of the crops are suitable for human consumption. We can use the other parts and **residual flows** from agriculture and the food industry to produce **animal feed**.

CATTLE
Cattle and sheep can consume grass and herbs in pastures that are unsuitable for growing food, such as the peat **grasslands** in the Netherlands.

LAND
Manure from the animals contributes to a fertile healthy soil and **improves crop yields**.

MANURE
Manure is also a valuable source of organic material that **replenishes the soil** and completes the circular agrofood system.

SOURCE: Adapted from Wageningen University Research

system is praised all over the world for its outstanding efficiency. But new studies have shown that biomass within this linear food system is not being used as optimally as it could, for example, grains that could be used to feed people are being fed to animals instead.

Circular agriculture is based on the principle of optimising the use of all biomass. The waste streams of one supply chain can be the raw materials for another. In this scenario, animals would be fed from our food waste. Achieving this kind of circular agriculture system will require smart integration between plant-based and animal-based supply chains.

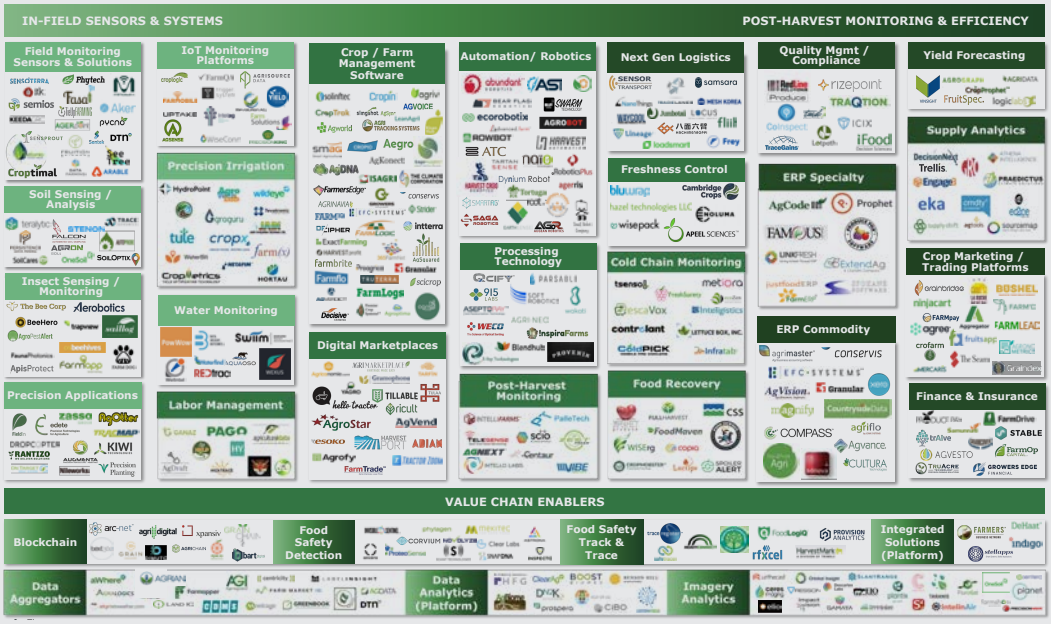
McKinsey and Company believe that scaling up AI's deep learning technology with a circular-economy vision could revolutionize the way food is grown, designed, purchased, and enjoyed. AI is predicted to unlock an estimated economic opportunity of up to US $127 billion per year by reducing food wastage.[18]

To enable a move from a linear economy to a circular economy will require companies to collaborate, in an unprecedented way, across the ecosystem when it comes to data generation, collection, curation and sharing.

STARTUPS INTO POST-HARVEST MONITORING AND VALUE CHAIN ENABLERS

An Agritech landscape[19] published in June 2019 and seen below shows startups innovating on the farm and also the growing focus on post-harvest monitoring and efficiency along with value chain enablers. It was noted that a growing number of ag technologies are allowing the connection between farm, farmgate and post harvest to connect to create fuller value chains with greater connectivity between farming and end food products.

FIGURE 3: Agritech Landscape 2019



SOURCE: Seana Day, Better Food Ventures (Copyright, reproduced by permission)

FOOD TRACEABILITY AND SAFETY

Food traceability and safety also provide opportunities for AI – possibly in conjunction with distributed ledger technology ("Blockchain"). Food safety affects the entire agriculture and nutrition supply chain, from the use of chemicals on farms to the challenge of food waste at the retail and consumer level. Globalisation has increased incidents of contamination and led to more foodborne illness, food safety scandals and health scares among consumers.[20] AI enables remote monitoring of conditions to ensure safety and improved quality of the final agricultural produce.

Increased adoption of both AI and digital ledger technology will strengthen food safety infrastructure, leading to less contamination and fewer mass recalls.

SUPPLY CHAIN CONNECTIVITY

Smith (2018)[21] looked at where AI could add value to agriculture and determined that the areas most likely to transform agriculture included supply/demand optimisation, crop pricing, insurance, and overall health of the farming system including soil health and biosecurity. AI will provide the capability needed to recommend adjustments in what is produced (e.g. planted, slaughtered) and to what criteria (e.g. carcass weights, milk composition), so as to best meet demand and minimise wastage.

A vision for AI is that it can help farm-based food supply chains reduce wastage through helping retailers sell food before it goes bad, forecast and predict sales to more efficiently connect supply to demand when ordering food.

Consumers are increasingly demanding safe and healthy food, with traceable provenance, and exhibit a growing awareness on environmental impact. This will drive increased demand for sustainable, ethical, low carbon production and processing techniques requiring the entire supply chain to innovate to keep pace with consumer demand.[22]

McKinsey[23] predict that AI in agricultural supply chain management and manufacturing will reach US$396.3 billion value. In the figures below[24] the overall supply chain management has been categorised based on the potential value delivered through either traditional AI and analytics (traditional machine learning eg, clustering and statistical techniques eg, basic regression) or "Advanced AI" (deep learning neural networks eg, convolutional neural networks).

McKinsey also predict that the value derived from the agricultural supply chain through sales and demand forecasting will have a value of US$211.6 billion driven off traditional AI and analytics which is nearly twice the value predicted from yield, energy and throughput with a combined value of US$113.6 billion. In addition they have workforce productivity and efficiency gains at US$866.3 million and requiring advanced AI.

PwC economic modelling[25] shows there is a clear relationship between AI uptake and productivity. Initial GDP gains will come from productivity improvements via automation and augmentation of work, however long term gains will come from increased product personalisation and quality driving increased consumer demand.

Operational excellence, supply chain orchestration and transparency are becoming an increasingly important focus for AI in agriculture which should lead to step changes in our supply chain.

Some key areas where AI will enable a change are:[26]

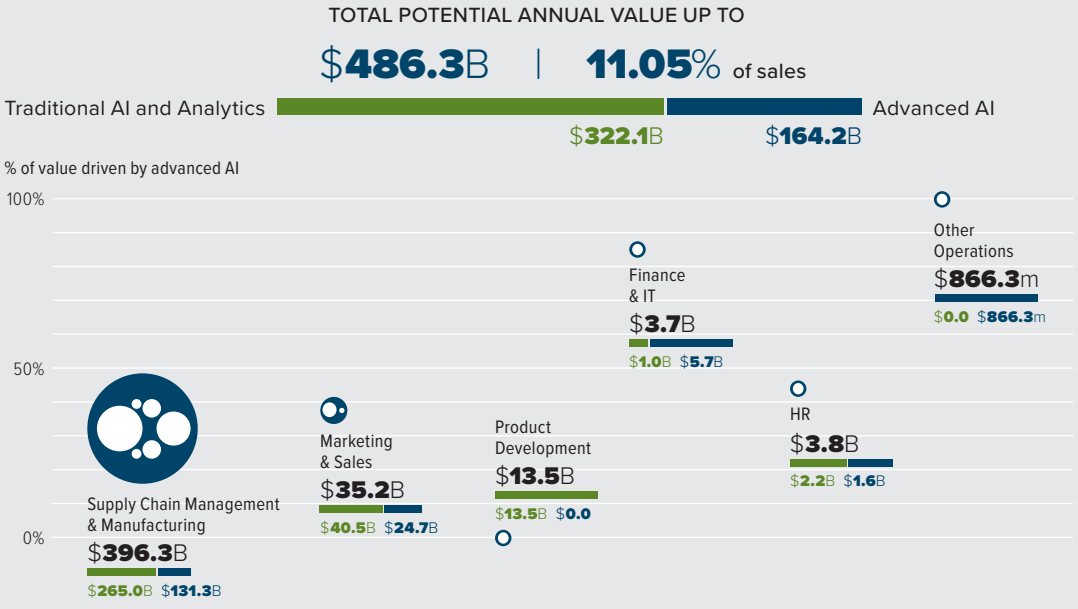
Streamlining Processes

Data sets can be leveraged by AI-enabled bots to conduct basic conversations and discussions with suppliers, to send actions to suppliers about governance and compliance materials, to place purchasing requests or to field and respond to internal questions about procurement functionalities. Bots can even carry out filing and documentation of invoices and payments in the supply chain, again streamlining traditional processes.

Supply Chain Planning

Machine learning (ML) will come into its own, too, in a couple of key areas of logistics. Supply chain planning can be enhanced using ML, since it helps with forecasting inventory, demand and supply, and can drive a much more agile supply chain and optimize decision making. Intelligent algorithms and machine-to-machine analysis of big data sets can give greater granularity and accuracy in forecasting than humans can currently achieve.

FIGURE 4: Total Potential Annual Value for AI in Agriculture



SOURCE: Adapted from McKinsey Analysis, 2019

AI optimisation leading to enhanced shipping reduces lead times and transport expenses, it makes logistics companies more environmentally friendly, it reduces labour costs and ultimately gives competitive advantage.

Warehouse Management

Warehouse management can also benefit from AI and good warehouse management can inform supply chain planning, too. Successful warehouse management can be built on a forecasting engine that leverages machine learning, making a continuous process that uses algorithms and data streams to create predictive power.

AI potentially (with distributed ledger technology) will enable logistic companies to make decisions faster, leading to higher customer satisfaction and a more efficient, productive supply chain.

Research Investment

Significant investments are being made to help provide the research to meet the aspirations of the agrifood sector.

GLOBAL PUBLIC SECTOR INVESTMENT

SmartAgriHubs is a €20 million European Union project which brings together a consortium of well over 164 partners in the European agrifood sector. The project aims to realise the digitisation of European agriculture by fostering an agricultural innovation ecosystem dedicated to excellence, sustainability and success. Moreover, this network of Digital Innovation Hubs consists of 2000 Competence Centers and 28 Flagship Innovation Experiments where ideas and prototypes are developed and introduced into the market.

For the livestock sector, the focus is on the ability to track and identify cattle at any given time in order to create a more efficient and sustainable sector.

For the arable sector, the focus is on optimising machinery, increasing transparency in the crop value chain, helping make decisions on irrigation and other inputs, and measuring ground water and weather conditions, in order to create an efficient and sustainable arable farming sector.

SmartAgriHubs aims to deliver 80 new digital solutions to the market, raise €30M additional funding from public, regional, national and private sources, and plans to help digitise over two million farms across Europe. End-users will be trained and informed throughout the lifespan of SmartAgriHubs (2018-2022).[27]

The Australian Government has invested more than AUD$150 million into an innovation hub under its Cooperative Research Centres programme called **Food Agility**.[28] Food Agility has the mission of working with partners across agrifood businesses, tech companies, researchers and government to develop creative digital solutions for maximum industry impact. Projects include Yarrabilba circular food economy, predicting harvest timing and yield in intensive cropping, on-farm experimentation, and valuing the environment in viticulture.

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) conducts federally funded scientific research. The Australian Government formed CSIRO Data61[29] in 2016 from the integration of CSIRO's Digital Productivity flagship and the National ICT Australia Ltd (NICTA). They are creating an innovation ecosystem and building a global applied R&D network of partners in government, industry and academia called the **D61+ Network**. With over 1,100 staff, including 415 PhD students they are Australia's leading digital research powerhouse.

Globally, a number of institutes are established with a focus on autonomous systems. These include **Lincoln Centre for Autonomous Systems in the UK** which is leading the new GBP £6.9 million EPSRC Centre for Doctoral Training in AgriFood Robotics and are co-leads of a GBP £6.3 million award from the UK Government's Expanding Excellence in England (E3) Fund. The idea is to create Lincoln Agri-Robotics, a global centre of excellence for agricultural robotics. Announced in June 2019, Lincoln Agri-Robotics will be the UK's first global centre in agri-robotics research. Lincoln's Deputy Vice Chancellor for Research and Innovation, Professor Andrew Hunter said the new funding would enable the research and development to be conducted to enable robotics to transform the food and farming industries in the coming years.[30]

The UK has also invested GBP £90 million into four agritech centres of agricultural innovation:[31]

1. **Crop and Soil Health & Protection (CHAP)**, fundamentally changing how soil and crop threats are managed with few interventions, lower environmental impact and improved productivity.
2. **Centre for Innovation Excellence in Livestock (CIEL)**, which looks at animal productivity, welfare and health to position the UK livestock sector as world-leaders in sustainability.
3. **Engineering & Precision Technologies (Agri-EP)**, is accelerating the adoption of new technologies.
4. **Data Science, Analytics and Modelling (Agrimetrics)**, to drive solutions for the sourcing and connecting of data in the agrifood sector to deliver food sustainably.

GLOBAL PRIVATE SECTOR INVESTMENT

Companies are also either acquiring the technology and research they need to future proof them or investing heavily. Examples include:

- John Deere acquired Blue River Technology in 2017, seen as a leader in applying machine learning to agriculture to a plant level.[32]
- BASF acquired ZedX to combine modelling expertise with their knowledge of chemistry to benefit growers and agriculture.[33]
- Monsanto (now part of Bayer) invested in Atomwise to help the agritech company find a quicker and more cost-effective way to bring the use of deep neural networks for new crop protection products to the market.[34]
- Alibaba applied the same technology they have used to optimise urban transportation and run e-commerce platforms more smoothly

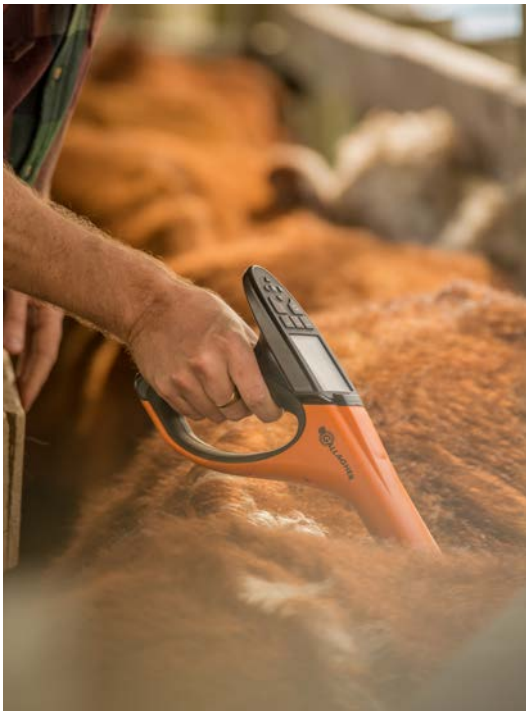
to agriculture. Alibaba Cloud are looking to provide efficient and technically advanced farm management approaches.[35]

CHALLENGES FOR AI ADOPTION

There are some intrinsic issues to be overcome for the adoption of AI in agriculture to be scalable, these include the high cost of cutting-edge AI technology and gathering precise field data.

Much of the data currently being fed into precision systems could prove to be very useful pieces of the "information pie". However, without real, ground-truthed, geo-referenced points in the field, it is extremely difficult to correlate actions to results and impossible to replicate with any sort of consistency.[36]

The old saying of "you can't manage what you can't measure" also applies to AI. Without accurate underlying data sets the precision capability of AI is limited.



DATA MANAGEMENT CHALLENGES

Farming data business Farmobile co-founder and CEO, Jason Tatge, outlined the problems they have addressed over five years and the issues they face as providers of a platform that ingests, standardises, views and shares data:[37]

1. **Data from a mixed fleet**

   The focus was on enabling farmers to collect and compare all of their data, in one place, regardless of the make or model of machine used.

2. **Real-time, accessible data in one place**

   Farmobile's research indicated that farmers were not implementing a digital strategy on their farm as there was no clear way to make use of it — other than passing it on to an agronomist or seed dealer for interpretation. Data had no real value to farmers in their day-to-day operations.

3. **Creating a standard data format**

   Perhaps the biggest challenge when it comes to data in agriculture has been the lack of a standardised format. How are farmers and agronomists supposed to make sense of what's happening on their fields when each machine and make essentially has its own data language? How do you compare apples to oranges?

4. **An industry driven by total amount of fertiliser applied.**

   Farmobile sees an opportunity to align incentive structures based on outcomes rather than the total amount of fertiliser applied. In addition they believe that this will lead to sharing of practices to ensure that the right amount of fertiliser is applied at the right time leading to optimised, efficient and effective outcomes.

In addition there is a lack of understanding among end users about AI in agriculture. In a recent study, more than 60% of the small and medium businesses (SMBs) surveyed said that serious AI implementation is not on the radar for their business process due to budget constraints and lack of skilled workforce.[38]

A review on big data in smart farming[39] highlights that governance including data ownership, privacy and security, as well as business models, are key issues to be addressed in unlocking the potential of AI in agricultural systems.

Companies need to ensure that the AI systems they use produce correct, precise and reliable results. To do so algorithms need to be free from bias and systematic errors deriving, for example, from an unfair sampling of a population, or from an estimation process that does not give accurate results.[40]

In addition there needs to be clearer communication about the uncertainty in outputs of predictive models so that the decision-maker can understand the limitations.

Concern is evident around ensuring that farmers do not feel that they are detrimentally affected or even exploited through the use of data and AI.[41]

Some public institutions are actively influencing big data applications in farming through their advocacy on open data and data-driven innovation or their emphasis on governance issues concerning data ownership and privacy. These organisations include, the Agricultural Data Coalition, Open Ag Data Alliance (OADA) and AgGateway.

Connectivity is an important element in the Agritech revolution and the speed of connectivity is becoming increasingly important to resolve in rural areas. In 2019, New Zealand telecommunications company Spark completed a nationwide rollout of its Internet of Things (IoT) cellular (Cat-M1) network. The network covers 98 per cent of New Zealand's population. Spark also operates a low power LoraWan network which enables significant increased battery life for connected IoT devices.[42] 5G technology could bring reliable, high bandwidth speeds to areas that typically lack coverage, and in turn, enable new precision agriculture capabilities on farm equipment leveraging real-time connectivity. John Deere see the possibility to have farm equipment that is able to communicate with other machines on the field by streaming data from vehicle to cloud and back down to machine operators in the shortest time possible.[43]

The challenge for a company like John Deere is convincing network operators and regulators that there's value in spectrum that provides broadband in rural areas. John Deere isn't the only company advocating for gains in rural connectivity.

Microsoft is pushing the "white spaces" spectrum with the US Federal Communications Commission, suggesting that the unused bandwidth spectrum between TV channels could enable wireless signals to travel over hills and through buildings and trees.[44] While 5G is being used in pockets of pilot studies around the world, the first near-nationwide coverage is not expected in countries such as China, Japan or the United States until 2023, according to industry analysts.[45] 5G coverage in New Zealand is just beginning to be rolled out in 2019.

SMART FARMING: OPEN VS. CLOSED?

The future of smart farming may unfold in two extreme scenarios (Wolfert et al, 2017):[46]

1. Closed, proprietary systems in which the farmer is part of a highly integrated food supply chain, or
2. Open, collaborative systems in which the farmer and every other stakeholder in the supply chain network is flexible in choosing business partners for the technology as well as for the food production side.

AI in Agriculture – New Zealand

INTRODUCTION

Opening the inaugural Primary Industries New Zealand Summit on July 1, 2019, Prime Minister Jacinda Ardern told participants that the challenge for everyone in the sector was to work smarter for a better New Zealand.

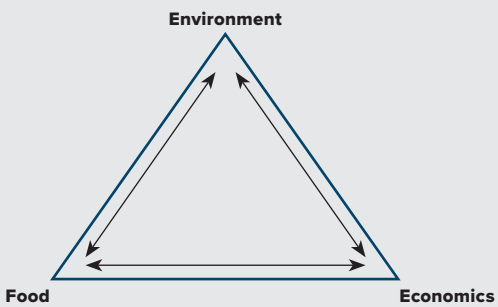
On July 2 the Government announced a shake up to New Zealand's $1.5 billion agritech sector with acting Economic Development Minister David Parker releasing 'From the Knowledge Wave to the Digital Age: Growing Innovative Industries in New Zealand', a report charting the challenges and opportunities the economy is

responding to. Parker said "Sustainably boosting productivity – creating more from our resources while staying within environmental limits – is key to raise the living standards of all New Zealanders".[47]

The draft strategy for the agritech sector,[48] published in July 2019, outlines that agritech is important to agriculture and the wider economy, as a significant amount of our manufacturing and services are dependent on the success of the primary sector. With a goal of land management that is more efficient, has better environmental outcomes, including improved water quality and reduced methane, nitrous oxide and CO2 emissions plus delivering, higher-quality produce, the draft strategy makes it clear that agritech is a key enabler for the productivity and sustainability improvements in our primary sector.

Interactions between suppliers (and their farm systems) and consumers are changing and becoming more complex and demanding than previously. For instance, changes in consumer tastes and preferences around ethics and/or consumption of meat products can spur trends in technology. Similarly, advances in technology (e.g. better measurement of environmental impacts or animal welfare) can drive changes in consumer tastes and preferences. The entire supply and value chain in food production is becoming increasingly interrelated and important as seen in Figure 5.[49]

FIGURE 5: Food Production Relationships Diagram



MBIE have funded a 2-year programme "New Zealand Bioeconomy in the Digital Age",[50] led by AgResearch, which aims to "harness the power of digital technologies to enable the transformation of New Zealand food systems to meet the challenges the world faces by diversifying land use, creating new ways of doing business and new ways of adding value to the products we produce."

BASELINING NEW ZEALAND AGRITECH

Crown Research Institute AgResearch are conducting a survey to get a baseline on the current use of digital technologies by players in New Zealand agrifood supply chains – including input providers, such as fertiliser, seed and agritech companies, farmers and growers, through to processors and retailers. They are not only interested in what digital technologies are being used and where they are used in their business (e.g. financial management, logistics, customer relationships, etc.), but also how the use of digital technologies is changing the way these players do business (e.g. are the technologies supporting more efficient production processes, greater service oriented business, etc.).

A final aspect of the survey is to see if uptake of digital technologies by businesses along the supply chain is related to the degree of trust among partners in the supply chain – overseas experience suggests a lack of trust among supply chain partners is a barrier to digital technology uptake, particularly by farmers and growers.[51]

CURRENT STATE

Early Days

Productivity growth generally is stagnant or declining globally, and many of the gains anticipated by technology have not yet materialised. It could be

that the new digital economy may still be in the 'installation phase' rather than the 'deployment phase' which is causing delay between the recognition of a technology's potential and its measurable effects.[52]

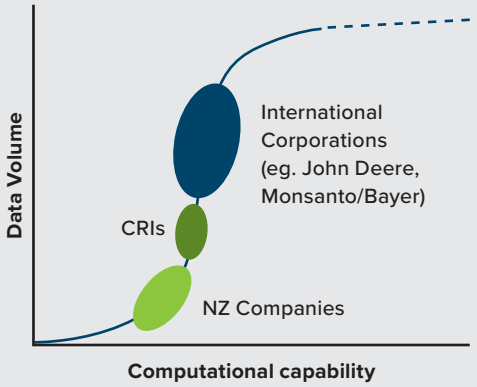
This sentiment came through strongly in conversations with those interviewed as part of this research, where it is seen as early days for AI in agriculture in New Zealand.

The focus of AI for agriculture appears to be behind the farmgate with very few examples of application in the supply chain to add value. One explanation for this could be that farm sensors have become cheaper and combined with an increase in computation power this "precision farming" space is opening up.

Overall there is a lot of activity in the farm sensor and precision farm data area with smarter alerts, robotics and decision support with the focus moving to predictive analytics capability. AI in horticulture appears to be further behind than in the pastoral agricultural sector with the primary focus on descriptive and some diagnostic computation analysis.

New Zealand's complexity in terms of typography, climate, microclimates, scale and farming practices open up the opportunity to be adaptive and gives the potential to gain early momentum in developing and implementing technologies that countries such as the USA with their large cropping areas are unlikely to focus on.

FIGURE 6: New Zealand Agricultural Data and Computational Capability (indicative)



When it comes to the availability of large data sets to build models on it was acknowledged that New Zealand lags behind other countries. If international corporations, CRIs and New Zealand companies were plotted on a maturity curve (as above) mapping data set scale with respect to data and computational capability it was speculated that NZ companies would be lagging CRIs who would be behind their international competitors due primarily to the size of the data sets available.

Disproportionately Focused Behind the Farmgate

New Zealand has activity in the AI in agriculture space but it is disproportionately focused behind the farmgate. From those interviewed as part of this research, a consensus emerged that the conversation and activity in AI needs to lift from behind the farmgate to include the whole value chain. Application of AI in our supply chains to manage risk, provide transparency to the consumers and maximise outputs through effective utilisation of inputs will provide value adding opportunities for New Zealand.

New Zealand's agritech startups are still developing products for behind the farmgate, with marginal points of differentiation and narrow use cases, in an attempt to take a small slice of a small pie, which has

led to competitive pressures. Anecdotally, domestic startups are failing fast and farmers are losing confidence and trust in new companies with respect to investing time and money into the new technology.

There was recognition that the "farm to fork" provenance supply chain has huge amounts of data that are not currently able to be mined for insights. With complete supply chain data there are opportunities to deliver traceability from farm to consumer and the ability to provide the consumer with information on what has happened to the apple including how many times it was sprayed, how old it is and transport history to name a few. More complete supply chain data also enables whole new classes of AI-enabled predictive and optimisation use cases.

Conversely, it is also remarked that the entire "farm to fork" conceptualisation should be reversed, instead starting with the end consumer – providing a market demand centric rather than supply centric viewpoint.

Investment is the rate limiting step for AI development, with many prototypes not being validated or commercialised owing to the time and cost involved. The lack of "connected capital" has been identified as a problem for NZ Agritech (and the tech sector generally). While there have been some exemplar deals in recent years in New Zealand, the reality is that the capital gap between seed and venture remains a meaningful roadblock.[53]

Section 2: Early Adoption Opportunities

"How do we start to create those moments of empowerment where we can take young, talented people and give them a place where they can actually experiment and create new technologies?"

– STEVE SAUNDERS, FOUNDER, PLUS GROUP

Early Adoption Opportunities for New Zealand

Areas considered likely to benefit, if not transform, through the utilisation of AI in agriculture include yield optimisation, addressing labour shortages, meat alternative research, real time risk management along the supply chain, assurance of the quality of food with traceability, providing food security through locating and isolating disease outbreaks in animals and plants, waste reduction within the supply chain, biosecurity, conversion efficiency on farm linked to animal health, and sustainability, valuation and insurance.

CONVERSION EFFICIENCY

Benefit will be realised as we move along the continuum of assisted intelligence to augmented intelligence[54] which allows farmers to move to decision making capability based on their data. AI could be considered as an "assistive technology" in that it can screen large or complex inputs and help the farmer either to focus on the important elements or guide them in their actions.

Examples in this space include monitoring animal health and movements. Companies such as Allflex are already achieving significant results. SenseHub™ can be used as either a collar or ear tag to monitor the animals fertility and health status to maximise profitability and reduce management costs.[55] In addition the LIC SPACE™ service[56] applies satellite data to pasture management practices.

LABOUR

Labour shortages in agriculture are a problem and accessibility, availability and cost are issues facing the agriculture sector. Pain points being felt in New Zealand will create a need to adopt AI as we drive towards productivity gains.

PHOTO: Halter AI-enabled herd management solution. (Image Copyright Halter, reproduced by permission).

AI can be applied in numerous ways from robotics and autonomous systems through to automating practices on the farm. Examples in New Zealand include robotic milking sheds and, in horticulture, fruit picking robots (see RoboticsPlus case study).[57] Halter is a New Zealand AI-powered technology which allows "fenceless farming", enabling farmers to automatically move the herd from the paddock to the shed, draft lame cows, and set up a break fence without even leaving the house.[58]

ENVIRONMENTAL FOOTPRINT

Environmental footprint improvements could also be made from AI through the optimisation of fertiliser, sprays, pesticides and water utilisation. There is a view that to obtain the data and investment required to realise these environmental goals a catchment view may need to be taken. This also lifts investment from farm level to a wider aggregate economic level.

BIOSECURITY

AI provides the opportunity for early detection of disease outbreaks in either animals or plants and predictive models for isolation leading to increased food security and reduced economic losses to farmers. AI in biosecurity at our borders provides a similar benefit and enables people to focus on the high risk areas and leave low risk to technology.

YIELD GAP

Globally there is a lot of focus going on the yield gap and how to feed 10 billion people by 2050 in a sustainable way. The same focus and opportunity of yield optimisation and effective land management exists in New Zealand with examples such as DataCol,[59] Precisionfarming, FarmIQ,[60] GPSIt,[61] Farmax,[62] Greentechrobotics[63] and Regen,[64] to name a few, providing solutions ranging across irrigation, water and effluent management, providing customised maps and GIS for land management, farm management platforms, and tools providing efficiencies and optimisation gains for vegetable growers.

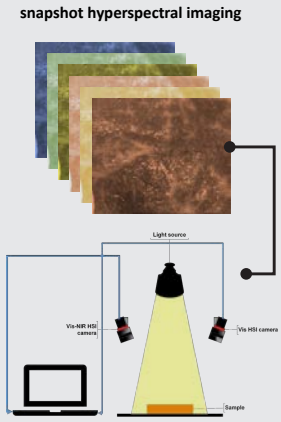
SUPPLY CHAIN

Optimisation

Waste reduction within the supply chain (or supply chain optimisation) is highly relevant to New Zealand. Map of Ag has positioned itself as a pioneer in this

AI BEING USED TO ANALYSE SNAPSHOT HYPERSPECTRAL IMAGING FOR MEAT QUALITY INSPECTION

PHOTO: AsureQuality, Copyright, Used by permission).



ACKNOWLEDGEMENT: Yash Dixit, Marlon M. Reis, AgResearch

space by enabling businesses within the agriculture industry and food chain to maximise the impact of planning and decision-making.[65] PrecisionAI[66] partners with clients to develop bespoke solutions that use image analysis and computer intelligence to solve agricultural challenges along the supply chain.

The wider agriculture ecosystem could benefit by looking at areas where efficiencies through the application of AI could be gained. One example is fertiliser transport where AI could be used to smooth the traffic load on the roads. This could also be applied to all heavy duty vehicles servicing the rural sector.

In addition fourth party logistics (4Pl) provides the opportunity to have point to point fleet rationalisation with the potential to reduce empty stock truck movements on our roads.

Collaboration across sectors would be the key to delivering these integrated efficiencies.

Supply Chain Real-time Risk Management

Supply Chain Risk Management (SCRM) encompasses a wide variety of strategies aiming to identify, assess, mitigate and monitor unexpected events or conditions which might have an impact, mostly adverse, on any part of a supply chain.[67]

The supply chain has large data sources which lend themselves to the application of AI, providing the potential to assist companies in identifying risks that are either becoming harder to identify in an effective and timely manner, or are manifesting themselves in unfamiliar ways.[68]

Traceability

Consumers are demanding more than a statement about purity and that the product is from New Zealand, they want assurance about the provenance and traceability of their product. AI applied across the supply chain can support improved consumer confidence in the brand and the product, which creates added value.

MEAT ALTERNATIVES

When looking at alternate futures of agriculture, an area considered likely to benefit, if not transform, through the utilisation of AI was meat alternative research. This area is heating up as highlighted by the investment of Fonterra in the biotech startup Motif Ingredients[69] in February 2019. Internationally companies such as NotCo are applying machine learning to identify plant-based alternative ingredients to animal products including meat, milk and eggs.[70] New Zealand has some research in the meat alternative area underway, but the research does not yet appear to be AI assisted.

Impact to Agricultural Professionals

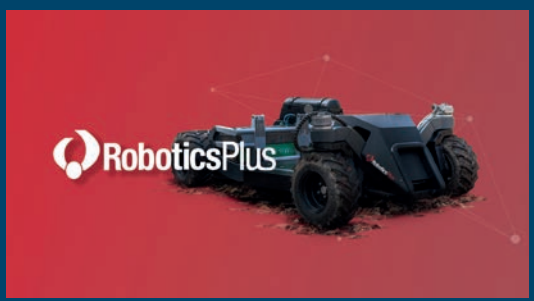
As previously noted, AI and robotics promise to help address many of the labour shortages in the New Zealand agriculture sector, together with removing "dull, dirty and dangerous" tasks from workers' daily roles and making human work more interesting, less arduous and considerably safer.

Agricultural professionals will be key to the implementation of AI, however the challenge will be adapting to the new technology and whether professionals can position themselves in a value add or strategic manner to the industry. At the end of the day agricultural managers will require accurate, real time critical information and agricultural experts and professionals will need to be able to translate the insights generated by AI along the continuum from AI experts to key agricultural managers.

CASE STUDY

ROBOTICS PLUS:
Machine Learning and Robots to Solve Real World Agricultural Problems

Tauranga-based Robotics Plus has a vision of "robotics to feed the world by powering up productivity in food and fibre value chains".[70a] The company has been focused from the outset on solving the growing challenges in horticulture including labour shortages, sustainability and yield security. The innovative business, which is part of the Plus Group of companies, has a number of technology products that use a combination of robotics and AI to solve real world agricultural problems. Its products include Āporo, a robotic apple packer which was launched in 2018. The Āporo, which is already in use in New Zealand and the United States markets, packs up to 120 apples per minute into trays.[70b] Another product is a log scaling machine that photographs and measures logs which are set for export. The product was developed with log exporter ISO Limited to increase worker safety and speed up the transport chain. The process of measuring logs was previously done by manual processes. "The machine is essentially a camera bar that takes dozens of photographs of the logs and can measure the outside edge," Robotics Plus chief executive Matt Glenn told Stuff.co.nz. "Artificial intelligence was developed so the camera can depict the outside edge of a log and make calculations to its volume."[70c] The company has other inventions in the works, including an autonomous vehicle that can drive around an orchard by itself. Functional units, like kiwifruit picking arms or pollination systems can be put on top of the vehicle.[70d] Robotics Plus was the anchor partner on the Multipurpose Orchard Robotics project, in collaboration with Plant and Food Research, University of Auckland, University of Waikato and 8 industry partners. The four-year project began in 2015 with over $10 million in funding and had 21 engineers and scientists working on the project with the aim of automating the harvesting and pollination of kiwifruit and apples. The company was named Callaghan Innovation Hi-Tech Kamupene Māori o te Tau – Māori Company of the Year.[70e] The company has also attracted major investment, with Yamaha Motor injecting US$10 million into the company.[70f] What the future holds Matt Glenn reflected that "building the future" isn't just about investment, it also involves partnering with the right people who can provide the ability to scale. Focus has gone into increasing capability, with the team building from 15 to 50 in just 12 months, identifying manufacturing parties to enable scale as the demand for their products increases and building opportunities for their products. The Āporo robotic apple packer has now been sold into France, UK and the USA with a total of 24 packers in use. Uptake on the log scaling machine is underway with orders placed by ISO limited (an international port logistics company) with a number of units already installed into New Zealand. Expansion plans are in place into international markets. Robotics Plus has continued to focus on the design of unmanned ground vehicles and their applications with a view that they have a large global market segment for medium sized vehicles. When asked on the role of AI, Matt's response was that AI is vital in all the systems that Robotics Plus build, including navigation and safety systems within autonomous systems, creating exciting opportunities.



RoboticsPlus

Learn more at www.roboticsplus.co.nz

CASE STUDY

IRIS DATA SCIENCE:
SheepNN™ - Using neural networks for animal identification

Dunedin-based AI and machine learning company Iris Data Science has developed the world's first sheep facial recognition software – which has the potential to eliminate the need for costly electronic identification or ear tagging. The project received a $40,000 grant from New Zealand's innovation agency Callaghan Innovation that will help take the AI technology to commercial prototype by the end of 2019.

"The goal is to develop a cost-effective and revolutionary sheep re-identification system for farmers using images captured by a camera rig," says Iris Data Science co-founder Greg Peyroux.

"Sheep face images are collected and fed into a machine learning model, which learns to identify sheep by finding recognisable features."

Mr Peyroux says the company has already collected thousands of images and hours of high-resolution video footage from farms to create a deep learning identification pipeline.

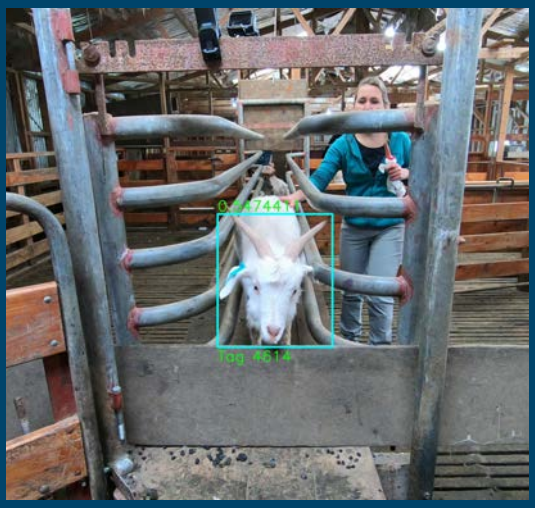
As more farmers move towards management technologies such as digital scales and automatic drafting gates, a reliable low-cost method of identification is essential. This machine vision solution is likely to become increasingly affordable as edge processing AI cameras go down in price.

Company co-founder Benoit Auvray says the main challenges to overcome are that images of sheep are complicated by changing head pose, background and lighting conditions.

Future applications for the technology include tracking animal locations to prevent rustling, monitoring animal behaviour, estimating weight, diseases, welfare, or other characteristics, or estimating parentage without the need to observe lambing or do DNA parentage testing.

The Iris Data Science team has also recently begun collecting data and developing similar facial recognition technology for other stock including cattle and goats.

The solution also has environmental and animal welfare benefits, reducing the use of plastic tags and animal manipulations.



iris DATA SCIENCE

Learn more at www.irisdata.co.nz

Section 3: Accelerating AI Adoption in Agriculture

"Artificial intelligence and 'the internet of farm things' will also allow farmers to trial changes designed to enhance production while lowering the costs (including environmental) of doing so."

– SAPERE, REPORT TO MBIE, CURRENT LAND BASED FARMING SYSTEMS RESEARCH AND FUTURE CHALLENGES, 31 OCTOBER 2018

How to get from Current State to an AI Enabled Future

MĀTAURANGA MĀORI

AI decision-making, research and development in New Zealand agriculture needs to be guided by Mātauranga Māori. AI innovation should be used to help unlock the potential of Māori knowledge, people and resources for the benefit of New Zealand. As noted in *Towards Our Intelligent Future*, Te Ao Māori – the Māori world view - should be incorporated into the practice and development of AI, including indigenous approaches to data sovereignty and the environment. For example, ensuring that AI technology considers rāhui practices which focus on protecting the environment for sustained long-term usage.

MAINTAIN AN EYE ON ETHICS AND GOVERNANCE

There is no doubt that with big agricultural data comes risks and challenges. Given the expected adoption of AI in the agriculture sector, there is the risk that the governance systems required to mitigate the potential risks of its deployment are overlooked. Data science teams should have structured controls and testing around their development process, which are overseen consistently by the business in which they operate. Because AI tools are often continuously learning, control and testing procedures should be dynamic and constant.[71] This includes:

1. Bias detection and correction.
2. Risk assessment and impact analysis of each AI tool, and approval by management.
3. Involvement of an ethics team to ensure that the AI systems in place are in line with the organisation's – and wider society's – values.
4. Involvement of legal and compliance teams to ensure compliance with data protection and privacy regulations.
5. Robust cybersecurity and controls, including access control.

The publication, 'Ethics and Liability – Mistakes by Machines',[72] by Russell McVeagh highlights that changes in the law are inevitable as concerns about the ethical use of AI and attribution of legal liability come to a head. Early-adopters should keep this in mind when implementing new AI technology as it will be important to ensure that unwanted liability does not attach in unexpected ways and that implementations err on the right side of the ethical debate so that the technology does not later become prohibited, or require a costly re-engineering effort to comply. Interested readers should also turn to our *Towards Our Intelligent Future* report, where we discuss data and AI ethics in more general terms.

CREATE LARGE TRUSTED DATA SETS

A proprietary data ownership mentality is driving siloed behaviour across the agriculture sector and limiting the added value benefit of sharing data. Changing this mindset will require Government, private sector and CRI collaboration.[73] Earlier research identified that a pan-industry strategy is needed for New Zealand and requires central coordination of a strategy.[74]

If large data sets are to be created through sharing then consideration needs to be given to the models under which the data will be shared. For example could NZ catalyse collaboration for data science and AI within this supply chain context, meeting governance, ownership, liability, anonymity and value protection needs?

Collaboration between sectors and groups will require interoperating platforms, wider trust networks, and

means for returning value from those that benefit from data use to those that provide data for use need to be considered. This in turn opens up the question on who owns the data and what is its value. Data trusts are one possible solution to this problem of coordination and access, and we discuss data trusts in the *Towards Our Intelligent Future* report.

ADVANCING NEW ZEALAND'S FARM DATA STANDARDS

A drive to improve interoperability will lead to a need to create defined standards for technology and data sharing. This is an area that the Netherlands and the USA (in the private sector) are starting to focus on.

The New Zealand Farm Data Standards,[75] which were developed to support efficient data exchange across the pastoral farming industry, are designed to be used during agritech product development and integration. If an organisation wants to be accredited under the New Zealand Farm Data Code of Practice[76] then it needs to ensure its systems adhere to these data standards. To date, widespread adoption of these standards has been limited – lack of data standardisation will effectively hold back effective adoption of AI.

Livestock identification company Allflex[77] believe that farming services, genetics and veterinary companies, particularly those serving the dairy and beef sectors, need access to data to improve and differentiate their services and reduce costs by working more productively and that the use of smart data will become increasingly important moving forward.

INVEST IN DATA INFRASTRUCTURE

Investment into infrastructure, and a move to the mindset of considering data as infrastructure, will be important to allow optimal use of data and widespread usage of AI technology in agriculture.[78] The practicalities of treating data as infrastructure are explored in more depth in the *Towards Our Intelligent Future* report.

STARTUP INVESTMENT

In addition to being in a competitive environment locally and globally, startups also face several other challenges. These challenges include the need to globalise to create a sustainable growing business model combined with needing access to venture and enterprise capital to fund growth. The shallowness of key capital markets in New Zealand and the inability of many firms to source expansion capital along a pathway from startup, to scale-up, to global competitor, has made it harder for some firms at the cutting edge of innovation to access capital. Earlier in 2019, the government announced an injection of $300 million into this space with a new venture capital investment fund with a view to plugging this gap.

New Zealand agritech AI startups face perennial challenges of scale – one solution may be that instead of implementing solutions farm by farm to implement solutions at catchment level to provide larger data sets and yet be of small enough scale that it would be suitable for investment.

INVEST IN RESEARCH TO MEET SHORT-TERM AND LONG-TERM NEEDS

MBIE commissioned a piece of work in 2018 to establish whether land-based farm systems research is fit for purpose in light of future challenges. The scope covered the types of production undertaken (e.g. dairy, sheep and beef, cropping) as well as the interactions along the entire food production value chain (i.e. on-farm and beyond the farmgate activities). The resulting report by Sapere[79] concluded that "the current capability of research organisations in land-based farm systems will need to be enhanced and augmented, with a change in focus from primarily production maximisation to production under constraints. Integration of existing scientific capability with other, so-called 'softer' scientific skills to look at the full value chain of food production will increase".

Issues the report identified included:

1. Risk aversion in terms of time and outcome of projects, with interviewees stating, 'There is a perception of a distrust of large programmes and how they are run. There are bigger consequences if a large investment goes wrong.' Furthermore, 'a challenge for projects is the political environment is challenging. Failure would be a big criticism.'

2. Industry led research is on immediate or current issues and typically have short payback periods of less than one year.
3. The current poor profitability meant there was not the money to pay to invest in game changing innovations.

In addition to the above there appears to be a general disconnect between expectations and reality when it comes to the time and cost to invest in this technology. This also goes hand in hand with an appetite for risk.

Government funded research grants such as the Endeavour Fund, which requires that the science stretch over 5 to 6 years, run the risk of being disconnected from practical application by today's businesses.

While research can generate prototypes the timescale to further develop, have meaningful sets of data for validation and commercialise, does not always line up with the short term, 12 to 18 months, return on investment, that industry demands. In addition, industry see this space as fast paced which can cause changing priorities. Contrast this with decade-long investment horizons for international technology venture capital firms and the challenges for New Zealand's agritech sector are stark.

The Government has made it clear that the Agritech sector per se was not as strongly represented in the investments made into research, resulting in a lessened amount of IP ready for commercialisation, an area they hope will be assisted by the recent changes to the R&D tax credit system.[80]

FARMER EDUCATION TO AID ADOPTION

Farmer education is also needed. The red meat profit partnership (RMPP) have been running an extension programme called RMPP Action Network.[81] The aim is to provide education capability and training to farmers by adopting a community approach to create a groundswell with tangible demonstrations and exemplars. It was suggested that a similar approach needs to be taken to assist adoption of AI in agriculture.

An overriding sentiment throughout the interviews we conducted was the need to communicate to the rural sector that AI is about reducing complexity, decreasing work-load to improve quality of life and time efficiencies. With the emphasis being placed on freeing up time versus replacing people.

Farmers (and also businesses) need to understand that they may not see an immediate benefit in their cash flow and that they are investing in future proofing but at a cost to today.

PARTNERSHIPS AND COLLABORATION

To be truly successful with AI in Agriculture, big data sets are needed which will require partnerships and collaboration across sectors. Such collaborations will ensure data can be shared to create value. Dialogue appears to be happening about partnering however perceived pre-competitive advantage is a hurdle that needs to be overcome. It was pointed out that the immaturity of AI in Agriculture is reflected in the complexity of sharing data.

Big companies internationally are moving fast and setting a target that New Zealand may struggle to catch if we start from scratch. An example of this is John Deere and Monsanto (now part of Bayer) who have been collecting data over the last three years and are believed to have multi-million acres recorded on yield maps, including data on harvest, planting, and spraying.

The implication of this is that collaboration on a national and international scale is becoming increasingly important for New Zealand agriculture to capitalise on the benefits of AI.

In addition the ability to collaborate within sectors, across adjacent industries, with universities and CRIs and with international researchers and companies will become increasingly important and will help to spread the technology risk with early research and development as well as prevent duplication of effort.

BUSINESS MODELS

Business models will need to be adaptable to allow for successful implementation in New Zealand owing to our limited scale and to gain adoption of the technology across the agriculture sector.

One example of this is Metris, who promote a service model whereby they sell the data not the hardware, this allows Metris to provide better continuity of data and build a more complete

FIGURE 7: Agricultural AI Skills Spectrum

dataset through well maintained and calibrated sensors. Effectively taking the onus off the farmer for buying and maintaining their own sensors.

Robotics Plus Limited are also looking at the potential of different business models, such as an operating lease or service model for their unmanned ground vehicles.

CAPABILITY DEVELOPMENT

In addition to addressing the current digital skill gaps, where there is a deficit of machine learning specialists, software developers, data analysts and software architects, there also needs to be capability development to support AI in agriculture with a ten year view.

While our education system is developing skilled AI experts there needs to be consideration on how to link solid AI technique with the interconnectivity and diversity of the agritech continuum to secure a future pipeline of talent.

An explanation of AI Expertise interconnectivity in the agriculture sector, as it relates to AI is captured below. One can imagine a continuum, which starts with the AI experts and ends with the agricultural professional where understanding and communication (not expertise) across the continuum is needed to fully unlock the benefit of AI.

Perhaps the greatest challenge for AI in Agriculture will be the need to compete for data science and machine learning talent with other sectors which already hold more data – including financial services, health, transport and government services.

POLICY CHANGES

It is widely acknowledged that there is a skill gap in the agritech space and companies do not have time to wait for New Zealand to develop talent entirely on its own. Immigration policy should be continually monitored to allow rapid importing of the skills across the continuum to meet expected growing demand.

Conclusion

As we explained the *Towards Our Intelligent Future* report, AI is a diverse set of general purpose technologies that is set to boost productivity and enhance product quality across many sectors. Agriculture is no exception and AI is an opportunity for the agriculture sector in New Zealand. However, a number of investments and changes to the way things are done will be needed.

More research is required to develop innovative products and processes and guide how AI is deployed in the sector. More cooperation will be needed so that data can be aggregated and the value of truly big data can be unlocked - a mindset of “data as infrastructure” is needed.

Also needed will be increased focus beyond the farmgate, because many of the most valuable use cases for AI in agriculture are across the value chain in planning, logistics and supply. Finally, attention should be paid to developing a pipeline of AI talent for agriculture in New Zealand as this is a highly pressured and competitive global market.

With the support of a coordinated overarching national AI strategy and a willingness to move quickly and boldly, New Zealand’s agriculture sector has clear opportunities to harvest the benefits of AI.

About MH4 Consulting Services

MH4 Consulting delivers future focus helping to develop people and organisations. MH4 provides tailored solutions across the wider agriculture and horticulture industry by offering a range of services including research, project management, reviews, programme and portfolio management to enable organisations to optimise operations and commercialise products.

Corrections Policy

We welcome feedback and are committed to correcting any errors in future editions. Please direct any comments on this report to our editorial team **research@aiforum.org.nz.**

Licence

Our thanks to those authors and organisations who have licensed their shareable content which has been adapted.

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