A Nuffield Farming Scholarships Trust Report

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Digital Dairy:
optimising the value of precision technology in the UK dairy industry

Dr Debbie McConnell

August 2017

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A
Nuffield (UK) Farming Scholarships Trust Report

Date of report: August 2017

"Leading positive change in agriculture. Inspiring passion and potential in people."

Title	Digital Dairy: optimising the value of precision technology in the UK dairy industry
Scholar	Dr Debbie McConnell
Sponsor	Thomas Henry Foundation
Objectives of Study Tour	• Understand how dairy farmers and the supporting industry are currently using data provided by precision technology and evaluate the skills base required • Understand how farmers are assessing technology investments and determining the perceived return on investment. • Identify new and emerging technologies of value to the UK dairy sector. • Explore the potential to collate data from precision technologies to improve our understanding, develop new technologies and facilitate new mechanisms for conducting research.
Countries Visited	Australia, France, Netherlands, New Zealand, USA
Messages	• There is significant scope to drive grassland utilisation on UK dairy farms but emerging technologies need to be validated. • Technology developments offer enormous potential to improve both technical efficiency and the image of farming within the UK dairy sector and should be embraced. • Technology adoption promotes better measurement but does not guarantee better management. • Current use of technology is being hindered by a data management and data interpretation skills gap both on-farm and in the supporting dairy industry. This needs to be addressed to capture the true value of technology. • Further integration of research and industry to identify key performance indicators for businesses using technologies, and tools for cost-benefit assessment are essential. • There must be a move from a technology-centric to a system-centric view of precision agriculture.

Executive Summary

Agriculture is changing. Developments in positioning systems, aerial technologies, and large scale data collection, with a promise of vast potential, are infiltrating into agricultural sectors. In this generation, technology development is expected to result in the greatest step-change we will see in the agricultural industry, causing fundamental shifts in our understanding and management of soils, plants and animals, and their interactions. Bringing knowledge from the experiences of those adopting digital techniques in other parts of the world, this study set out to explore how the potential value of technology on UK dairy farms can be maximised.

Globally, existing precision technologies are already offering a number of benefits to dairy farming - most notably the potential to drive more efficient use of inputs such as labour (through the use of robotics), feeding (through animal identification and precision concentrate allocation) and nutrients (via variable rate fertiliser application). Within the UK there is significant scope to encourage uptake of these technologies to drive an increase in pre-farm gate technical efficiency. In addition, emerging precision technologies from other grassland-based dairy production regions across the world - such as grass yield and quality mapping technologies, animal grazing behaviour sensors, and virtual fencing - require further investigation in UK climes. Additional value can be gleaned by integrating data capture from multiple sensors: although data integration remains a challenge, and industry-wide initiatives to do this require further road testing. Technological applications that operate throughout the food chain will be key in addressing future consumer demands for safe, high welfare, sustainably produced and traceable food.

However, investments in technology must be accompanied by a recognition of adequate return for the business. Purchasing and installing technology alone does not automatically guarantee improvements in either farm management or technical efficiency. Currently, three barriers hinder this value capture: adequate skills, recognition of the benefit of data and technology benchmarking.

There is a clear skills gap both on-farm and in the supporting industry driven by an absence of training in technology use, data management and data interpretation skills. Much greater commitment is needed to training and software support to realise the technology potential. The changing skill requirement on dairy farms also gives great opportunity, as yet unrealised, to make the industry attractive to a new generation of skilled personnel.

Failure to move from intuitive to data-driven decisions limits both technology uptake and technology benchmarking, leaving a paucity of evidence on the cost-benefit of these technologies. Investment requires clear vision of why the purchase is being made, and identification of appropriate performance targets in line with the overarching direction of the business. Technology users must understand how to influence and improve on these performance targets if successful technology integration in dairy farm businesses is to be achieved.

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1. Personal introduction


Figure 1: The author: Dr Debbie McConnell

Coming from a family farm in west Tyrone, Northern Ireland and having the typical hands-on, 'stand in a gap' farm kid experience growing up, I became really intrigued about livestock farming from a young age. Eager to know about the workings of biological systems, the question 'why?' was never far from my lips and I spent a good deal of time working with our home dairy, beef and (begrudgingly) sheep enterprises in a bid to learn as much as possible.

Following a geography degree at Durham University, I completed a PhD at the Agri-Food and Biosciences Institute (AFBI) in Northern Ireland, studying phosphorus management on dairy farms. Recognising the importance of 'sharing the science', I then took up a position at the Agriculture and Horticulture Development Board in their dairy research and development sector. That position gave me a fantastic insight into some of the key challenges facing the UK agricultural sector and it was at that stage that I first came across the Nuffield Farming Scholarship programme. Intrigued, I applied for a scholarship in 2016 and was extremely fortunate to receive the Thomas Henry Foundation award, an award designated for those connected to Northern Ireland agriculture.

I viewed my Nuffield Farming award as a unique opportunity to first and foremost learn about global agriculture: its scale, its diversity and, most importantly, its future. At c. 2500 dairy farms producing 2.2 billion litres of milk per year, NI is small fry in terms of milk output yet increasingly required to compete on a global scale, being heavily influenced by international markets, world politics and even far-off weather events. To succeed as an industry it is important to find a niche in this global marketplace, scrutinise current performance and play to any competitive advantages. Indeed, having this global outlook has never been more important for the NI or UK agricultural sectors given the uncertain future now faced post-Brexit.

For me, one of the most exciting developments currently playing out in agriculture is the infiltration of novel precision technologies from other industries into food production systems. Given the complex nature of any biological system, having the ability to collect and analyse large amounts of data will be fundamental to helping us understand and manage the dairy farm of the future. However, I recognise that the excitement brought by numbers, data and spreadsheets for me as a scientist is not necessarily shared by everyone. Hence I was intrigued to discover how farmers and industry were adapting to the ever increasing use of technologies which inevitably collect what is simply a series of nonsensical 1's and 0's. This interest was further fuelled as we went through the process of integrating new milking and animal monitoring technology onto the home farm, experiencing both the challenges and benefits of adapting to using technology. This spurred my chosen Nuffield Farming study subject of *Digital Dairy: optimising the value of precision technology in the UK dairy industry,* an area I have tried to address in detail in the following report.

I would like to thank my sponsor, the Thomas Henry Foundation, and the Nuffield Farming Scholarship Trust for enabling me to undertake what was truly a fascinating, once-in-a-lifetime experience.

2. Study background

"Complacency is expecting the world to change for us rather than changing to meet the world's needs." (David Basham, ADIC, 2016).

The digitalisation of agriculture is one small part of a worldwide technological revolution. New technologies feed into everyday life and the pace of change is greater than anything we previously experienced. Indeed, most smartphones now contain more computing power than was used to send Apollo to the moon in 1969 (*Kaku*, 2011).

Agtech will revolutionise our understanding of the soil, plant and animal interface

This technological development is facilitating the emergence of a continuously connected, data-sharing world. Between 2012 and 2020 a 700% increase in internet traffic is expected and last year the number of connected devices (smart devices which can talk to another device or a network) exceeded the global population (C*isco, 2017)*. By 2050, 6.6 connected devices will exist for every single person on the planet (*Cisco, 2017*; Figure 1).

Slowly, agriculture is beginning to embrace this change and the potential benefits that technology and data can bring to the farm are being explored. Indeed the emergence of 'agtech' is expected to result in the single greatest step-change in the agricultural industry in this generation, causing fundamental changes in both the understanding and management of soil, plants and animals.

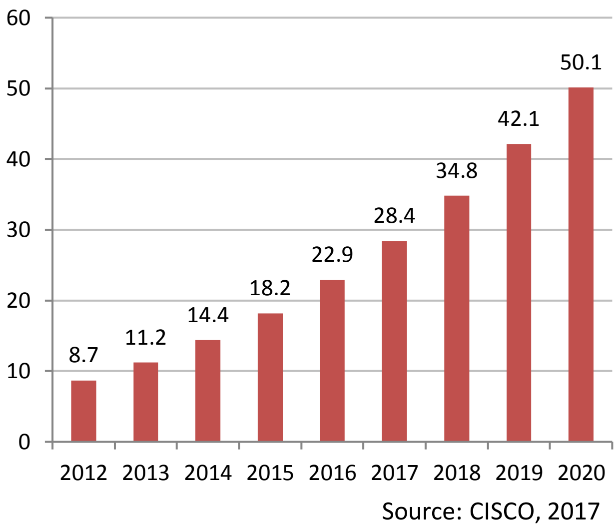


Figure 1: Number of connected devices worldwide from 2012 to 2020 (in billions)

Strong ambitions exist to bring the UK to the forefront of this agtech revolution, driving both product innovation and technology adoption on farm. In 2013, the UK Strategy for Agricultural Technology spearheaded by the UK government Department for Business, Innovation and Skills, outlined ambitions for the UK to:

"Become a world leader in agricultural technology, innovation and sustainability; exploits opportunities to develop and adopt new and existing technologies, products and services to increase productivity; and thereby contributes to global food security and international development."

These ambitions to use technology to drive productivity and sustainability in the UK agricultural sector call for a fresh look at current technical efficiency on UK dairy farms. The sector, which consists of

13 227 dairy farmers and 1.9 million cows producing 14 billion litres per annum, has retained a moderate level of competitiveness with neighbouring EU production regions in recent years; however, there is scope for improvement (*AHDB Dairy*, 2016).

Total factor productivity (TFP) of the UK dairy sector has remained static in the past decade whilst competing regions such as the Netherlands have grown by 1.3% per annum (*Kimura & Sauer,* 2015). This difference is evident across multiple productivity measures. Labour, land and capital productivity observed in both the Netherlands and Denmark are on average 163%, 136% and 135% of that evident in the UK dairy sector (*Figure 2*). Technology adoption is believed to be playing a key part in widening this gap. Within the UK, technical efficiency also varies widely between individual farms, as indicated by a 6.5 pence per litre difference in cost of production between the top and bottom 25% of benchmarked farms (*AHDB Dairy*, 2016).

Labour, land and capital productivity observed in both the Netherlands and Denmark are on average 163%, 136% and 135% of that evident in the UK dairy sector

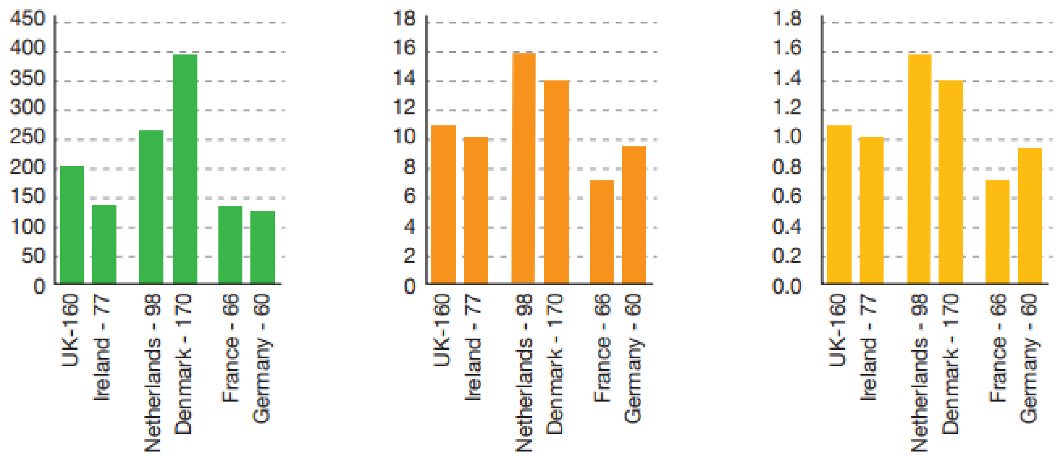


Figure 2: L-R Labour (kg ECM milk/hour), land ('000 kg ECM milk/ha) and capital (kg ECM milk/£ capital) productivity for the top milk producing regions in Europe (*Source: AHDB Dairy*, 2016).

Whilst global demand for dairy products is expected to double to 1043mt by 2050, immediate challenges of volatility in input and output prices, sustainability concerns and shortfalls in farm technical efficiency leave the industry poorly positioned to take advantage of this projected future growth (*FAO,* 2009).

2a. Study objectives

This study aimed to explore how to maximise the potential value of current and emerging precision technologies on UK dairy farms in order to improve technical efficiency and take advantage of future market opportunities. A number of objectives for the study were identified:

- Understand how dairy farmers and the supporting industry are currently using data provided by precision technology and evaluate the skills base.
- Understand how farmers are assessing technology investments and determining the perceived return on investment.
- Identify new and emerging technologies of value to the UK dairy sector.
- Explore the potential to collate data from precision technologies to improve our understanding, develop new technologies and facilitate new mechanisms for conducting research.

2b. Travel programme

In order to investigate this area of study, the regions visited across the world were those with well-developed ruminant livestock industries as these were often associated with the greatest level of technology development and adoption on-farm (*Table 1*). A range of different dairy production systems were sought (e.g. high input, housed production systems in the USA, intensive grazing farms in New Zealand) to reflect the wide variation in systems evident in the UK. Interviews and meetings were conducted with researchers, technology developers, industry, farmers and policy makers. Findings from travel to countries with less-developed dairy production sectors (India, Qatar and Turkey) as part of the Nuffield International Global Focus Programme were also used to formulate this report.

Table 1: Travel programme

June 2016	India, Qatar, Turkey
July 2016	USA - Iowa, Illinois, Indiana, Kentucky
September 2016	USA – New York, Vermont
November 2016	Australia
December 2016	New Zealand
June 2017	Netherlands, France

3. Exploring the potential: emerging technologies to support the UK dairy sector

Agriculture is the perfect host for precision technology. The sheer variability which can exist between animals, across landscapes/climatic regions, and throughout time, provides an overwhelming rationale for the development of devices which can monitor and interrogate large volumes of data to aid understanding and management of what is a complex environment.

In support of this challenge, investment in agricultural technology is growing at pace with an estimated $25 billion invested globally in 2015 (*Walker et al.,* 2016). Existing precision technologies have the potential to bring a number of benefits to livestock farms - most notably the potential to drive more efficient use of inputs such as labour (through the use of robotics), feeding (though animal identification and precision concentrate allocation) and nutrients (via variable rate fertiliser application).

the uptake of robotic milking technology has led to Denmark's dairy farm labour productivity (milk produced per hour of labour input) rising to double that of the UK

There is significant potential for the UK dairy sector to embrace this innovation. However, to date, technology uptake has been limited in the UK dairy industry and presents a lost opportunity to become more technically efficient. For example, the uptake of robotic milking technology has led to Denmark's dairy farm labour productivity (milk produced per hour of labour input) rising to double that of the UK where less than 10% of dairy cows are milked via robotic milking technology (*Holloway,* 2012).

Developing technologies that are suited to dairy production are extremely diverse and as such it is impossible to review all types of development in this report. Instead, the aim of this section is to provide a snapshot of those emerging technologies that have the greatest potential to impact on the UK dairy sector. They can be categorised into two key areas:

- Technologies to optimise the grazing environment; and
- Technologies to aid health monitoring.

3a. Optimising the grazing environment

With a competitive advantage of highly productive grassland, and significant scope to increase grassland utilisation, the UK is perfectly placed to drive further efficiencies in livestock production systems through better use of forage. Recent AFBI research has shown that improving grass production and grass utilisation by 1 tonne (DM) on dairy farms is worth £334 per hectare per annum (*Mayne and Bailey*, 2016). Enhancing meat and milk production from grassland will also buffer farmers against global fluctuations in purchased feedstuffs whilst addressing consumer ideals and expectations surrounding systems of food production.

Previously, restrictions on battery life and ability to withstand wet environments have limited technology development in the grassland space. This has left a marked gap; however new technologies are starting to emerge to measure both the grass plant and the grazing animal which have value within the UK.

3a.i. Measuring the grass plant

Regular measurement of grass yield and quality is an essential management tool in grassland systems and the first step to increase meat and milk production from pasture. However, with less than 10% of UK dairy farmers estimated to regularly measure grass yield, new systems of measurement which are labour efficient, have improved accuracy and are easy to use, are required.

Much development in this area is taking place in Australia and New Zealand and a number of techniques are being used. Some have focused on measuring the physical structure of the plant to determine grass yield. These include laser measurement of the height of individual leaves relative to the ground, and sonar measurement of the distance between the top of the grass plant and a fixed point e.g. the top of an ATV. Other developments in this area have centred on the use of visual imaging collected by drones and small aircraft to determine grass yield. Using differences in colour absorption and reflection by the grass sward in different parts of the light spectrum, indicators of grass yield and quality characteristics can be observed.

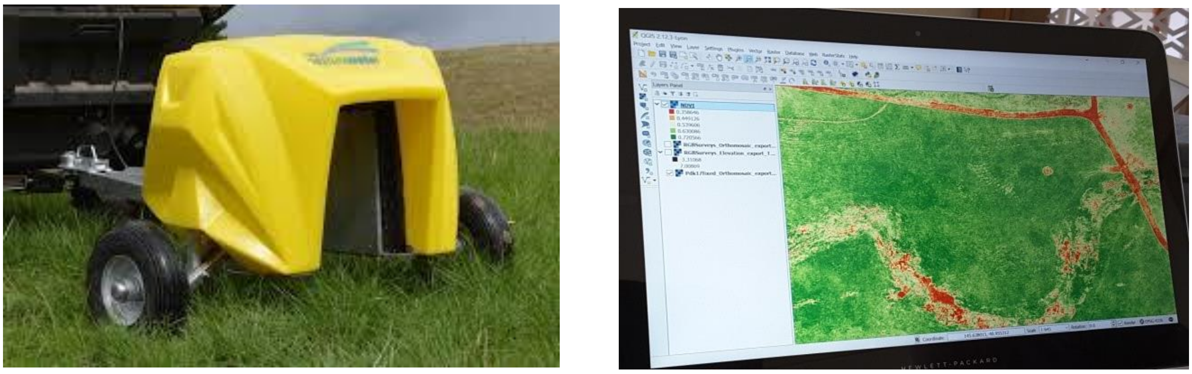


Figure 3: L-R: Pasture yield measurement being obtained from a series of lasers, NDVI Reflectance image taken from a drone for assessing pasture yield on a Tasmanian dairy farm

Case study: hyperspectral imaging of grass

Professor Ian Yule, Precision Technology specialist at Massey University, is exploring the potential of hyperspectral imaging using a sensor mounted to a small scale aircraft. Hyperspectral imaging collects data from a much wider part of the light spectrum than the technologies currently used. Ian’s team has been able to not only create maps for grass yield, but also measure grass quality characteristics such as metabolisable energy, crude protein and grass dry matter content.

Early results suggest exciting developments for grassland farmers and opens a range of applications for precision management of nutrient inputs to pasture and for cow nutrition. However, Professor Yule highlighted the need for on-going work in this area. *"For grass measurement there are still a lot of fundamental questions around visual imaging; for example, what's the difference between an image taken from the ground and one from the sky, what is the appropriate pixel size, what wavelengths do you need for imaging and how do we control for surrounding light level?. We have a lot more work to do before these technologies are ready to be used on farm."*

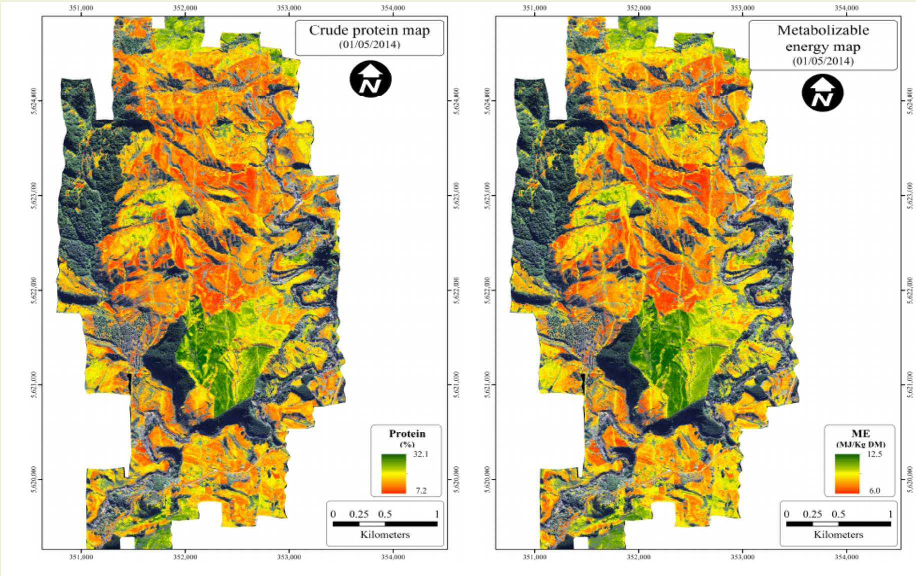


Figure 4: Hyperspectral imaging of grass quality across a New Zealand grassland farm

3a.ii. Understanding the grazing animal

With a focus on the animal, significant gains in technology are being made on two fronts: sensors to track animal location, and the adaption of housed technology to the grazing environment.

The use of sensors to track animal location is an extremely exciting development taking place in Australia. This technology provides preliminary data about animal grouping and grazing behaviour, and is now being used to determine within-field animal productivity. Researchers at University of New England, Australia, are integrating pasture availability data with animal location data to generate 'meat maps' indicating which areas of the paddock animals spend greater time actively grazing, and which demonstrate the most liveweight gain. This approach allows a change to an actual determination of the areas of the farm which produce the most milk or give the greatest heifer liveweight gains.

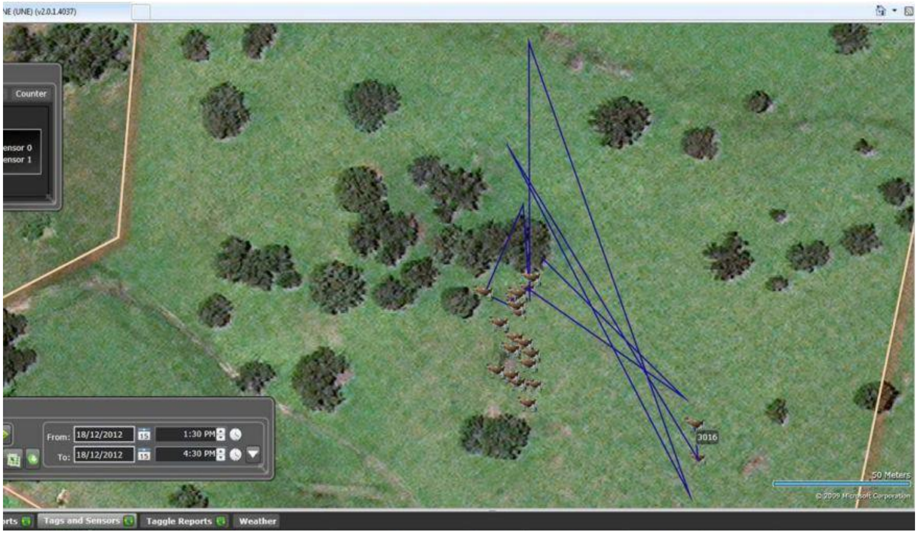


Figure 5: Animal location sensors providing movement patterns of beef steers at UNE SMART farm in Australia

Animal location technology also opens the door to virtual fencing. Virtual fencing uses a measure of animal position (achieved via GPS or triangulation) and a halter fitted with a negative stimulus to constrain animal movement to a set area - e.g. a sub section of a paddock - without the need for a physical fence. Researchers in Wageningen University in the Netherlands are considering how it can be used to segment the herd, giving certain animals preferential access to fresh pasture within the same field. Dr Pieter Hogewerf, dairy grassland scientist, comments:

"Our studies are on-going but so far we have been able to train cows quickly to use the virtual fencing collars and we have been able to run two different grazing mobs within the one paddock separated by the use of a virtual fence. The technology is showing great potential."

Alongside virtual fencing technology, researchers in both the Netherlands and Australia are exploring the use of technologies originally created in Europe and America for housed livestock in a grazing environment (e.g. pedometers to monitor lying time and activity, and rumination halters to understand eating behaviour). Dr Mark Trotter from Rockhampton University commented *"we talk about the 'internet of things' but for the grazing environment we've simply got no things."*

Figure 6: Animal fitted with rumination halter for grazing behaviour measurement in dairy grazing trials

Using these technologies, researchers are now beginning to monitor and analyse patterns of animal grazing behaviour and consider how this can be influenced to increase grass intake and improve performance from pasture. The development of both the grass and animal measurement technologies present the opportunity for a fundamental shift in the management of grazing animals, moving the focus from the herd level to the individual, allowing ultimate precision management in grass-based ruminant production system.

3a.iii. SMART Farm case-study: a connected landscape

An excellent example of the role research can play in creating useful technologies is highlighted in the University of New England's Sustainable Manageable Accessible Rural Technologies (SMART) farm initiative. David Lamb is Professor in Precision Agriculture and the key driver behind the Australian project.

"We're in the game of innovation here, not invention; our role is to help farmers reap the benefits of existing technology."

Following the roll out of a nationwide rural broadband network, David and his team established the SMART farm over 10 years ago. The SMART farm, which is supported by the federal government and industry is a test-bed for existing agricultural technologies. David highlighted *"a poor evaluation of a piece of technology is as good an outcome as any. It means the farmer is more informed when they go to purchase a piece of kit."*

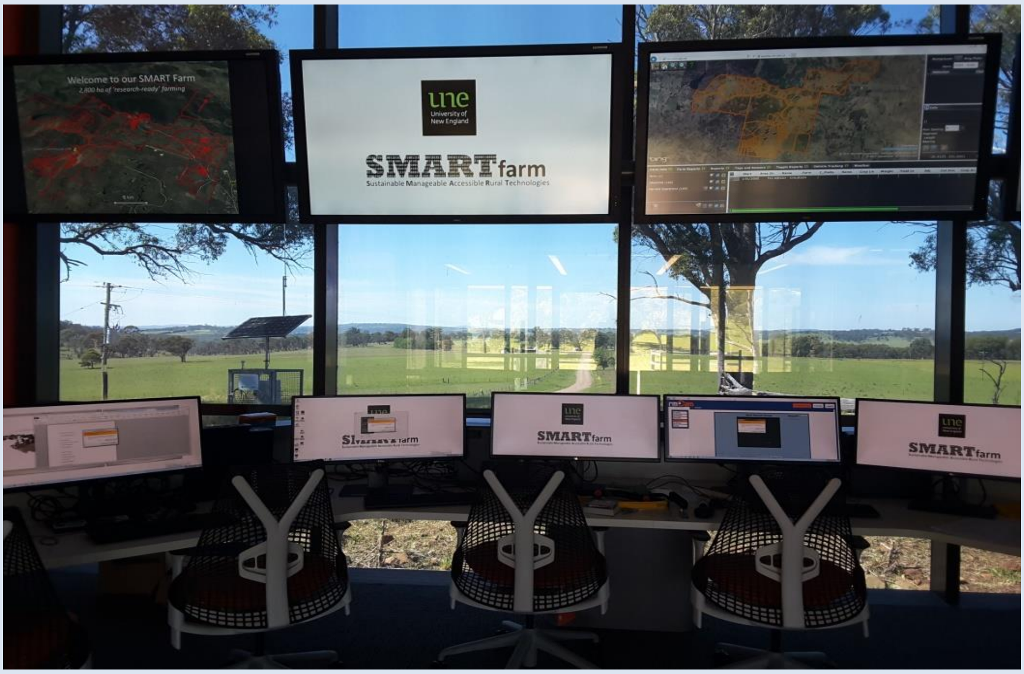


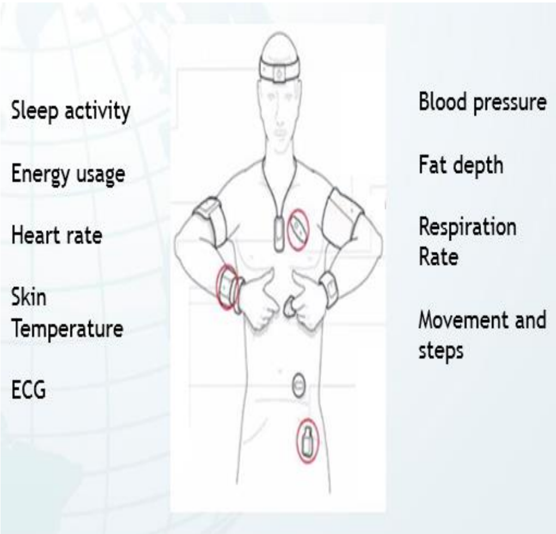
Figure 7: Data management centre at UNE's SMART farm hub. Live feeds of soil, plant and animal sensors can be viewed here and tools such as pasture growth forecasters used to help manage the grazing platform.

However the farm, which runs a commercial beef and sheep enterprise, also focuses heavily on creating a connected landscape, allowing real-time movement of data from sensors located throughout the farm's 2900ha platform.

A self-healing mesh network of soil sensors, weather stations, reflectance (NDVI) sensors and satellite images measuring pasture growth, all related through a 'store and forward' telemetry system, has allowed development of such tools, such as the use of a live drought-risk and pasture-growth map. The work of the farm is also supported by a network of 22 commercial farms and research centres located around Australia, trialling various precision technologies and farmer applications.

3b. Health monitoring systems

The role of the technology for monitoring animal health is set to increase. Building on the recent exponential growth in human health monitoring technologies which feed into personalised health plans, similar technology will allow us to focus on individual cow care providing precision monitoring of animal health. This is an increasingly important attribute with expanding herd sizes.



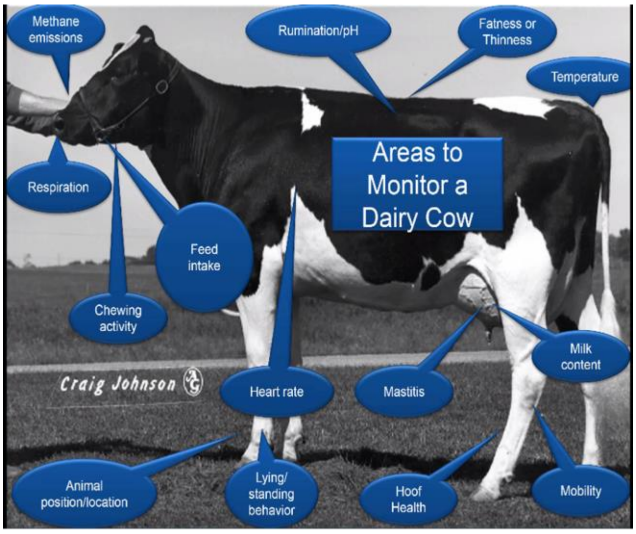


Figure 7: The concept of health monitoring and personal health management plans is easily adapted to the dairy sector (Source: *Bewley*, 2016).

Established technologies for monitoring lameness and animal rumination activity already exist. In recent years there has been a significant amount of movement in developing new sensors aimed at early detection of animal health problems. These include: boluses to monitor pH activity in the rumen to allow early detection of sub-acute ruminal acidosis; ear tags equipped with temperature sensors and location in the barn to identify changes in animal behaviour and temperature; mid-infrared spectroscopy of milk to identify metabolic disease, and imaging cameras for body condition scoring.

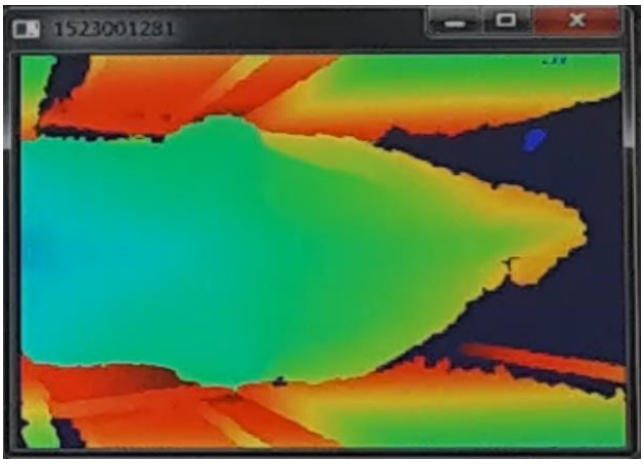


Figure 8: Image generated by a 3D camera to assess animal body condition on a New Zealand dairy farm. Each of the 340-cow herd was assessed up to twice a day. A computer programme tracked body condition change over time and identified animals with rapid body condition loss.

But, once early onset of a particular health condition is identified, there remains a question of what action to take? Treat too quickly and the opportunity for the animal to mount an immune response is taken away, weakening the long term health of the herd; treat later and the farmer runs the risk of having a longer recovery period for the animal. Hence these technologies must come with a better understanding of the variability in individual animal responses to health challenges, something that could be achieved through interrogation of big datasets and detailed animal monitoring.

Indeed, research has a key role to play in the technology adoption process, supplying three core functions which cannot be met by industry alone:

1. Providing a robust, evidence-based analysis of the capability of a new technology, shouldering the investment cost and minimising the risk of technology failure for the farmer.
2. Working with industry to develop appropriate key performance indicators (KPI) for new technologies. These should be system- and business-focused rather than technology-centric, encompassing both physical and financial factors of performance.
3. Integration of data from multiple, disparate sensors to glean additional benefit.

3c. Summary of chapter

Technology development presents exciting opportunity in both animal health and grassland management, but it is imperative that scientific understanding of these areas increases concurrently. Emerging sensors for manipulating the grass-animal interface warrant further investigation. Research has a key role in providing a robust, evidence-based analysis of the capability of a new technology, minimising risk to the farmer.

4. Digital dairying: who's adopting and why?

4a. Who's investing in technology: farmer snapshots

Throughout this study, dairy farmers from a range of countries and managing an array of different production systems who had invested in technology were interviewed. The following series of farm snapshots provides an insight into some of these farming businesses and the rationale for investment. The factors considered are: farm facts, the mission or focus of the farm, the technology employed and the reason for investing.

Business 1: Adam, Kentucky State, USA

Farm facts: Significant expansion since moving to a green-field site for 1300 cows in 2003. Now home to 2500 Holstein cows plus replacements managed on an all-year-round calving, housed system. Milking 3x day milking, producing 26 million litres/year.

Farm focus: Driving technical efficiency to be more competitive.

Technology employed: Heat detection, auto ID, cow management software, shedding gate

Reason for investing: Initially curious about technology and had difficulty accessing skilled labour. Now convinced of the value of data to drive efficiency within the dairy business.

"Data to me is almost as good as being out there with the cows.
With 20 lower skilled staff, although I'm not the one actually feeding the cow,
I am still making all the cow management decisions.
By having detailed data I can quickly see my least profitable cows."

Business 2: John, North Island, New Zealand

Farm facts: 300 Jersey-Friesian crossbred cows, milked via 4 robots, managed on a 3-way grazing system and grazed all year round. Producing 1.8 million litres per year, 90% from forage. Recently moved to 50:50 spring-autumn calving split to optimise robot and benefit from winter milk bonuses.
Farm focus: To produce milk in a stress-free environment for cow and man, and optimise the current production system, making the most from the 78ha effective grazing platform.
Technology employed: 4 x robotic milking machines
Reason for investing: Needed to replace existing parlour and was looking for a new challenge. Decided it was something he wanted to try in his lifetime.

"The local research institute set up an experimental robotic farm. Once that started testing robotics with three-way grazing, we looked to invest. We've managed to cut labour by a third; however, more importantly, job roles have changed giving us more time for tasks such as breeding"

Business 3: Duncan, Tasmania, Australia

Farm facts: 2 x 550 cow dairy farms. Jersey crossbred cows managed on a spring block calving system on a mix of dryland and irrigated pasture. Grazing all year round with 95% milk produced from pasture.
Farm focus: Driving productivity from grazed pasture and investigating the value of integrating technology in all aspects of the farm business.
Technology employed: C-Dax pasture meter, drones and visual imaging to measure grass yield.
Reason for investing: Duncan was always interested in technology. This equipment provided an opportunity to build on previous experience using mapping software.

"It started as a bit of a hobby but I was always interested in the potential of technologies for pasture management. I've spent a bit of time tweaking the technologies to suit my farm and give better results. I think there is certainly value in them but they do need to be more robust."

Business 4: Arjan, Aalten, Netherlands

Farm facts: 120 all year round calving Holstein cows plus 110 youngstock managed on a 65ha forage platform. Cows have access to pasture during summer months, availing of the grazing bonuses present in the Netherlands. Target production of 1.3 million litres per annum. Next generation currently working in industry but involved in farm business.
Farm focus: Maximising farm output per labour unit and driving overall production efficiency.
Technology employed: Two milking robots fitted in 2009 with inline milk sensing for oestrus detection.
Reason for investing: Old parlour needed replacing. Wanted greater flexibility in work pattern and with lower requirement for heavy labour.

"In 2009, the business succession plans were still uncertain and so we wanted to make our farm as labour efficient as possible, minimising manual labour. We also invested in additional sensors to help us better manage cow mastitis and fertility, which have been valuable."

From these case studies and other interviews conducted, a number of common themes were evident as to why people were investing in technology, and the particular person characteristics of those doing so (Table 2).

Table 2: Reasons given for investing in new technology during this study.

Rationale for investing	Characteristics
Curiosity	Younger
A desire to be ahead of the curve	Completed higher level education
Seeking a new challenge	Multiple business enterprises (well positioned to spread financial risk)
Limited resources especially labour	Had active knowledge exchange networks
Improved quality of life	

It was very apparent that those making the decision to invest fell very much within the 'early adopter' segment of the industry (Figure 9). Early adopters, which typically occupy 13.5% of any population, tend to:

- be driven by curiosity of the potential applications of a new technology,
- seek opportunities to gain a competitive advantage for their business,
- be more willing to accept an element of risk of technology failure and,
- be more accommodating to underdeveloped equipment.

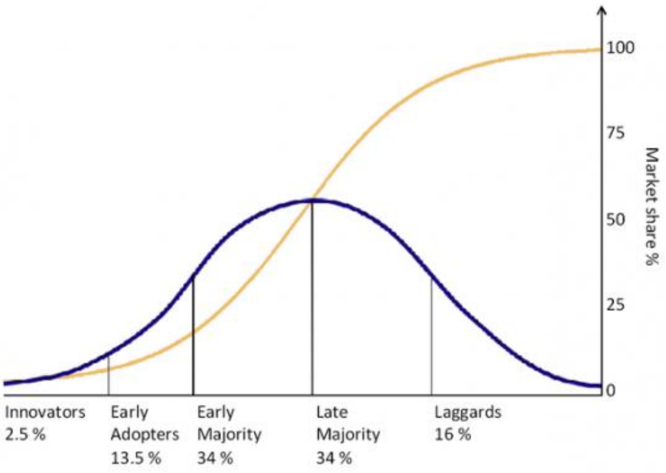


Figure 9: *Rogers* (1962) diffusion of innovation model for the spread of ideas and technology within a normal population (blue line). Rogers identified speed of adoption to be closely aligned with human characteristics and categorised individuals into groups accordingly. Understanding these groupings can assist in tailoring communication messages to improve adoption (yellow line).

Quite strikingly, none of the farmers interviewed as part of this study cited economic reasons for wishing to invest in precision technology, and this is indicative of the higher risk strategy which an early adopter is prepared to take.

4b. Barriers to technology adoption

As of yet few technologies have moved into the early majority phase of technology uptake which typically occupies 34% of the industry (*Rogers,* 1962). This is a widely recognised challenge in all industries and recent studies have begun to shed some light on this.

A study undertaken by DEFRA (2013) highlighted that 45% of farmers would be more inclined to use computers for their farm business should they have better computer skills, whilst the top two reasons for not engaging with technologies such as GPS were due to a lack of evidence on cost benefit and concerns over complicated systems (*Figure 10*).

Similarly, for US dairy farmers considering investing in wearable technologies for dairy cows e.g. cow identification collars and lameness monitors, evidence of cost benefit and lack of skills were amongst the top reasons for not investing, each accounting for over 30% of respondents (Bewl*ey and Russell,* 2010). As expected, age and education influence attitudes towards technology, with younger people and those with a higher level of education feeling less hindered by a lack of skill sets on-farm; however access to finance was more concerning.

This research mirrors many of the themes identified in this study found in Table 2.

Professor Jeffery Bewley, a specialist in precision dairy farming at the University of Kentucky, commented:

"from our experience of working with farmers, there is a lot of confusion about what are the best technologies to buy, and what impact they will have on farm. There is a need for independent research on the effectiveness of the technologies, and decision support tools are required to help farmers quantify potential economic return for investing in technology."

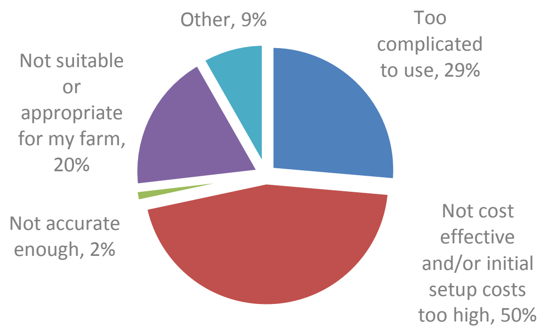


Figure 10: Reasons given for not using precision farming technniques (Source: *Defra* 2013)

4c. Summary of chapter

From speaking with the farmers visited on this Nuffield Farming study, curiosity and lifestyle changes were stronger drivers for technology adoption than economic rationale. Technology adoption in most areas was limited to the early adopter segment of the industry. A lack of independent information on the cost-benefit of new technologies and low confidence in on-farm skillsets suited to precision technology are the major barriers to technology adoption identified in the study.

5. Maximising the return from technology: addressing the skills gap

5a. Measure and manage?

Digital innovations through sensors and data capture, allow businesses to measure more. **More** variables in **more** locations are measured **more** frequently than was ever possible before. However, the most dangerous assumption that can be made as an industry that is investing in precision technology, is that simply by increasing the scale of measurement, the ability to manage activities will automatically improve.

Whilst the old adage '*you have to measure to manage*' still holds true, in reality it is naïve to assume that simply purchasing tools to measure and produce data will lead to management and technical efficiency improvements on-farm. This assumption is masking what is a growing disparity between the potential value and the actual on-farm value achieved from using precision technology and the data it generates. This "potential-actual" gap is being driven both by individual farmers' lack of previous interaction with technology, and an absence of skills in using data effectively for decision making. This is creating challenges for those both supplying and adopting technologies and will hinder future business progress. Harry Smit, Senior Analyst in Rabobank's Agricultural Inputs team commented:

"Farmers that can use technology well and who have the skillsets to become super users of the data will be the ones with the best opportunity to access finance and expand their business. Farms not making evidence-based decisions will undoubtedly find it harder to get access to credit, giving those that have the right skill, a competitive advantage."

The impact of this skills gap on the technology adoption process is neatly outlined by Dr Callum Eastwood, precision technology researcher at DairyNZ, New Zealand, who studied the adoption process of cow management software on Australian dairy farms. For Callum, the technology adoption process can be split into three phases each with different farmer actions: **early learning**, **consolidation** and **advanced learning** described in Figure 11.

3 – 6 months	→	**6 – 12 months**	→	**12 months +**
Early learning		**Consolidation**		**Advanced learning**
Completing basic data entry		Task repetition leading to knowledge consolidation		Combining different data to give more effective decision support
Creating simple groups		Growing data interpretation skills		System tailored to business specific need
Descriptive activity				Opportunity for true cost-benefit assessment

Figure 11: Technology adoption process and associated actions, adapted from Eastwood (2012)

In the study, whilst most farmers progressed through the early learning and consolidation phases outlined in Callum's model, few managed to make the transition into the advanced learning phase due to a lack of technology skills on farm *(Figure 12)*. However, those who did were able to tailor the data the system generated to produce farm-specific measures aligned with the business objectives of the farm, and ultimately take action on this information. Importantly, this transition placed those users in a position to assess the true-cost benefit of the system, a subject discussed further in the next chapter.

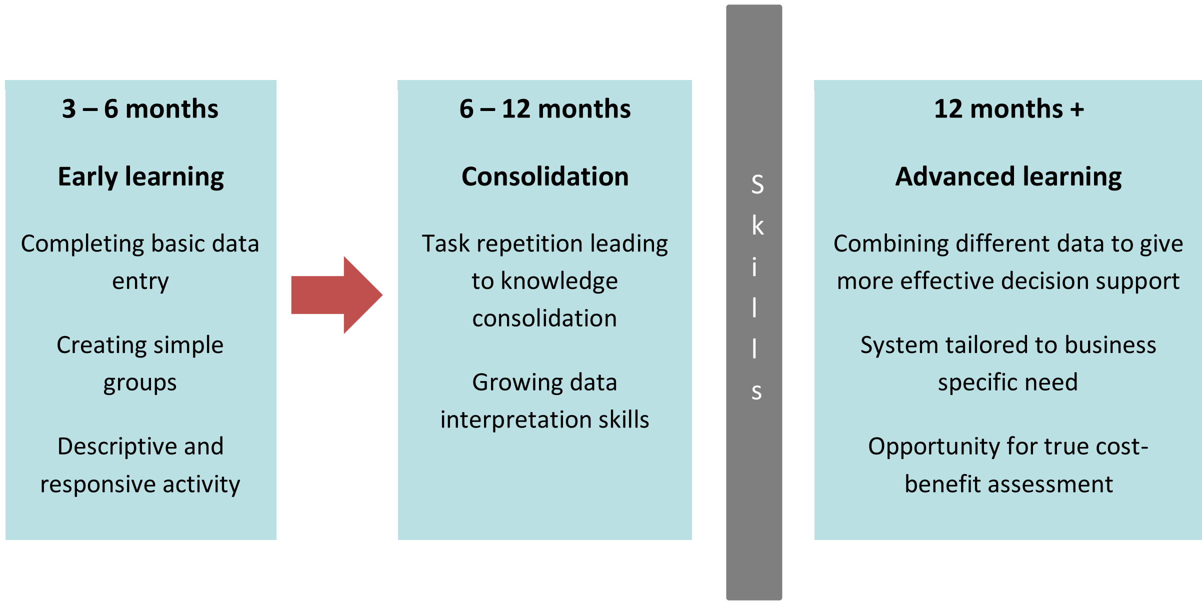


Figure 12: Technology adoption - a deficit of data skills hinders users moving from the consolidation phase to the advance learning phase. Adapted from *Eastwood* (2012)

5b. Bridging the skills gap: how do we achieve this?

Clearly it is imperative that the skills gap is addressed to maximise the return from technology. To achieve this, a number of areas require further focus, including:

- Building user confidence with digital devices
- Understanding current use of data on farm, and the data-action continuum
- Delivery of farmer specific training and
- Consideration of the changing farmer roles in the adoption process and development of a complementary skills base in the supporting industry.

5b.i. Building user confidence

Some attribute this skills gap simply to a lack of familiarity in using computers and digital devices. This certainly has merit given the trend for an aging farmer profile which is evident in most mature dairy industries around the globe. Kentucky dairy farmer Richard, who moved from 100% paper recording to install an oestrus detection system two years ago, and is in preparation for the installation of two robots, commented:

"It was a slow learning curve getting used to the data… it is hard to move away from the trusty pocketbook. My daughter has just started working with a robotic company and is much better at using software than I am. I am hoping that as she gets trained in the software she will show me how to use it."

Similarly Dr Sebastian Deroy from Institute de l'Elevage in Brittany, France noted:

"In this region, uptake of technology which uses a software package has been much slower than that without. There is a whole generation of farmers who are not comfortable with using software."

Whilst this is a significant challenge now, it is likely that interaction with digital interfaces will become less of a problem in coming years. This will be a result of more intuitive technology development, a higher degree of interaction with digital devices in everyday life and a new generation of farmers coming into agriculture who have grown up with technology.

Indeed, a sharp rise has been evident in the last decade in both computer ownership and use of computing in farm businesses. A survey of N.I. farms in 2001 identified 11% of farm households had a computer they used for the business, a figure now expected to be closer to 90% (*DAERA, 2002, DEFRA, 2013)*.

5b.ii. The data - action continuum

In addition to increasing awareness and interaction with digital devices, the true skill lies in becoming a 'super user' of the data, and making it a useful aid in the decision making process.

Figure 13: The data - action continuum. Data collected from precision technology needs to be translated into information and subsequently farmer knowledge to allow an action to be taken.

To achieve this, it is important to consider where we sit lie on the data – information – knowledge – action continuum (*Figure 13*). At present, most technologies afford the ability to collect **data** (a series of 1's and 0's) and convert this into **information** e.g. litres of milk produced per cow. But to then convert that into **knowledge** and subsequently an **action** (the point at which the technology has real value for the user) requires multiple data streams and reference points. This is something easily achievable in a human brain but difficult to replicate in technology.

At present some believe that technologies should be able to give them a clear actionable command as a result of the data collected, a task which is difficult to achieve. In reality, much of the decision making which takes place on farm is intuitive. Consequently, how do you rationalise a process which at times can appear emotive and is often based on gut-feeling with a software which can only operate on data-driven decisions?

Professor Kees Lokhorst, precision agriculture specialist at Wageningen University, has spent many years understanding the farmer-technology interface, examining how we design technology to move further along the Data – Action continuum.

> *"Yes, people in all industries often appear to make intuitive decisions but where do you think the foundations for this come from? In reality there is an initial evidence base for these, of past experiences, local knowledge and farmer attitudes. Ultimately it will be a balancing act, we must move technology to better replicate the intuitive, and the technology users must become more engaged with using data."*

Kees is now leading the 4d4f project, working with next generation agri-engineering students to try and better model the decision making process on farm. By taking students back, removing existing farm preconceptions and getting them to deconstruct the decision making process into a series of knowledge rules and reference values, they can then start to understand how to build technology which replicates a farmer's thought process.

5b.iii. Building the on-farm skills base

Whilst technology will continue to be more intuitive, to maximise use of technology, we also must address the other side of the coin – increasing data management and interpretation skills on-farm. For large technology investments both farmers and technology companies have underestimated the management and skills base change required.

But recently industry has been working to address this gap. Adrian Garner, Technical Specialist at DeLaval, New Zealand, outlined their robot academy initiative. "*We have been running an AMS academy for over two years, specifically designed to train farmers in using technology. A three-day training course, revolving around the herd management software, is standard for any new robotic farmer. Understanding how this works is fundamental to being able to manage the herd*." At this stage, Delaval will import any existing herd data onto the software prior to installation to allow users to begin to understand how to interact with and mine data relevant to their own farm. This provides farmers with useful experience before installation, easing the transition in management tasks. Competing AMS manufacturer Lely also undertakes a similar process, having weekly one-to-one webinars with the host farmer in the 10 weeks prior to installation. These webinars use a demo version of the farm's herd data so again the farmer can learn how to interrogate the reports and information the software system is producing.

But more needs to be done at an industry-wide scale. Simple rules on data management and data interpretation need to form part of our agricultural training. The fundamental principles of understanding what robust, reliable data looks like need to be highlighted, the value of good data entry and management needs to be emphasised, and, crucially, experience of using a data evidence base in the day to day management of an agricultural system needs to be an essential component of our teaching. If we fail to do this, we vastly reduce the value we can obtain from precision technology.

5b.iv. Who fills the skills gap?

We also need to ask who is the right person to fill the skills gap and in doing so recognise the growing opportunity for skill development in the supporting industry. We must recognise that technology can significantly change a farmer's day-to-day activity, potentially increasing time spent at a computer thus reducing cow contact time. Whilst this is agreeable to some, this change may be unacceptable to others. In time this opens up opportunities for the development of a service industry, offering data management services to the farmer.

AMS manufacturers Lely are working to address this gap. Steve Fried, Lely North America Sales Manager commented:

"For us, it's also important that those people supporting the farmer are equipped with the skills to use the data our equipment generates appropriately. We started running certified training courses on our farm management software for nutritionists, vets and consultants."

In addition to the 400 people that have been through these courses, Lely are also funding a Farm Management Software support team of nutritionist, vets and system specialists. The team operates a designated helpdesk for farmers with queries on their data, ensuring a 24-hour turnaround time for their queries. Currently one full time position will be able to support 60 robots and with significant investment in this support network, Lely North America foresee a growing demand for these services.

Many of those early adopters already invested in technology welcome this move. Marvin from Robo Holsteins in Illinois, which is home to 220 cows, milked on 4 robots comments:

"The more support we can get the better our management will be. Our previous nutritionist didn't want to engage with the software and so we have moved to someone who was already certified with Lely's training programme. Our vets currently aren't trained but we are hoping they will soon come on board."

Figure 14: The Beer family, Robo Holsteins

The change in the skill set required on-farm is also creating positive opportunities for those without a farming background to enter into agriculture. Rebecca Dornauf, from Gala Dairies robotic rotary farm in Tasmania, outlined their changing requirement, a sentiment echoed by many farmers who had invested in technology:

"We are now finding that the skills you would wish for on a conventional dairy farm are not necessarily what is needed here. Most important to us is having people who have good computer skills, are flexible and want to learn how to use the data tools. After that, dairy experience is useful but it is not top of the list."

With early adopters still dominating the digital dairy market, it is quite clear that the mental approach of the farmer has a key role in making the decision to invest. Hence it naturally follows that the type of farmer personality might feed into a successful technology adoption process.

5c. Technology adoption – the power of personality

During the course of this study, the resounding message from all aspects of the industry is that the single most important factor in successful adoption is not the technology's ability to work, or the technical know-how of the support staff, rather that the **farmer's attitude is king**. Many of the people encountered as part of this study pushed this message home. Associate Professor Kendra Kerrisk is an automatic milking systems (AMS) specialist at the University of Sydney and Project Leader of FutureDairy. FutureDairy is a research study investigating the role of automatic milking in the Australian dairy industry, and Kendra has been looking in detail at farmers investing in AMS technology:

*the single most important factor in successful adoption is not the technology's ability to work, or the technical know-how of the support staff, rather the **farmer's attitude is king***

*"The biggest difference between successful and unsuccessful robot performance on commercial farms here in Australia is undoubtedly **farmer personality**. Those that succeed are solution finders and take ownership of the technology. They have the approach: **I** bought this and **I** will make it work, not **you** sold me this now **you** need to make it work."*

For technology developers, flexibility and openness to new ways of working trump other more conventional factors such as farm layout or machine ability. Lely AMS specialist Coert van Lenteren commented:

"You can tell within a week of installation whether a farmer will be a good robot manager because of their ability to let go. They move from a cow pusher to a cow coach and motivator and that requires a very different management style."

Similarly, Jack Rodenburg from Canadian consultancy firm DairyLogix highlighted the large step change in management farmers often need to take when engaging with AMS:

"the degree of control a farmer has will reduce, they need to be able to step back, trust both the cow and the technology, and adapt their own actions to successfully manage this."

With the increasing role of the supporting technician for large technology investments, just having the right farmer personality is not sufficient to make technology a success. Kendra argues that those farmers who take ownership of their investment, then work harder to retain a good relationship with their dealer or service provider; but it is a two way street.

"In AMS the relationship between the farmers and the dealer or technician must be maintained at all cost. Dealers are an essential component of the system,

the farm simply cannot work without their buy in. However, it is a bit like a marriage: both sides need to have the right attitude and contribute equal effort."

With much of the market currently being occupied by early adopters, some of the challenges of adapting to technology use and working with dealers are partially overcome. This group has a tendency to be more open minded, have a willingness to compromise, and try to find solutions to retain the competitive advantage they believe the technology can offer. For technology companies these attributes also have offered some leeway in the development process, allowing immature technologies to be improved with on-farm use. However, this honeymoon period won't last forever and this poses the question: should we expect the farmer to change mindset to embrace technology, or does the technology company need to work harder to create a technology better suited to work with farmer' mindset?

5d. Case study: Robotic rotary

Rebecca and Nick Dornauf have experienced the ultimate dairy technology overhaul, but for them both, attitude is key to making their technology investment work. The couple play host to the world's first commercial robotic rotary parlour at Gala Dairy near Deloraine, Tasmania, a project they embarked on in 2010 after being approached by Delaval and their local dealer.

Acknowledging that in the past the family has been risk takers and has tried new ideas, they embarked on this project in part because of the challenge and curiosity of the unknown, and in part because they consider technology as being a great way of engaging a younger generation into farming. Nick commented:

"For me, stubbornness to make it work, patient people dedicated to the technology and a family that buy into the common goal have been key to this farm. Surrounding yourself with the right people is essential."

Using a previous drystock farm owned by the family, they built a 25 point, robotic rotary which is now home to 600 autumn and spring calving dairy cows, achieving 8000 litres per cow per year.

Starting with 200 heifers and a small herringbone parlour whilst the rotary platform was constructed, it has been a long learning process for both Nick and Rebecca and the technicians, with the technology also developing over time to meet the needs of a commercial farm. The farm now harvests on average over 13 000kg per day with an average of 2.2 visits per cow per day on voluntary access with cows walking up to 1km to the furthest paddock, impressive figures for any grazing robotic system.

LHS: World's first commercial 25 point robotic rotary in Tasmania. RHS: To operate a 4 way grazing system and VIP milking, a complex network of shedding gates are essential to ensure good cow traffic.

Whilst much has been written about this venture in recent years, the overwhelming impression the couple give is the sheer determination and passion they have to make this project work, at the same time retaining an open-minded, flexible attitude.

"*There have been some big highs and some very big lows but looking back we were incredibly stubborn, to the point that we wanted to make it work at any cost*", Nick comments.

5c. Summary of chapter

Personality is a key determinant in the success of technology on-farm. People who are flexible and take ownership of technology investments are more likely to succeed. As a result more emphasis should be placed on personal traits, leadership styles and social science by both technology developers and those in the supporting technology industry too.

Investing in technology brings greater access to data, but it does not automatically guarantee improvements in management or on-farm technical efficiency. Lack of data management and interpretation skills is a major barrier for farmers in realising the potential value of precision technology on-farm. Farmers must be willing to either invest in training both themselves and staff, or be prepared to buy in outside skills.

As an industry we have a duty to up-skill our workforce (on and off-farm) to be an able partner in using precision technology and understanding the data-to-action continuum. Consider it through another viewpoint: if you were a technology company would you want to invest in our sector?

6. Measuring, monitoring and benchmarking technology: are we realising its value?

6a. Barriers to benchmarking

One of the primary reasons given for not investing in technology is uncertainty in the potential cost benefit to the farm. In addition, technology can come at a significant financial outlay and it is common to have a long time-period before a positive return on investment may be evident. There is a constant stream of new technologies now available to the modern dairy producer, and some form of benchmarking is necessary to both inform potential technology purchases and assist current users hoping to maximise return on investment.

But does this happen in practice? Few farmers interviewed as part of this study were undertaking formal benchmarking of the technologies they purchased. There is also a lack of information available from research on the potential economic impact of technology adoption on dairy farms. Is there a rationale for this? From this study, multiple factors were found to contribute to a lack of benchmarking, including:

1. **Motivation behind the technology purchase -** Early adopters are typically less focused on economic gains and as a result it is likely that less focus is placed on monitoring the economic performance of the technology.

2. **Technology is often one part of a larger farm investment –** Large scale technology introduction in dairying often occurs concurrently with other investments such as new milking facilities. This is particularly evident on American farms, where the dairy milking parlour remains the main bottleneck to improvements in farm efficiency. Farms often use overhaul of a parlour as an opportunity to introduce robotic milking or detailed parlour software. However, this concurrent investment makes it difficult to attribute improvements in animal performance or system efficiency to the technology specifically.

Figure 15: Different milking technologies:
LHS: 25-year old triangular milking parlour in New York for 200 cows,
RHS: One of two 45 point side by side parlours in Nebraska servicing 4800 cows

3. **Limited pre-installation measurement –** Precision technologies afford us the ability to measure variables which previously were difficult or time consuming to determine. Consequently it is difficult to assess the impact of the technology on physical or economic performance if a baseline pre-installation measurement is not obtained.

6b. Before investing: can we quantify the potential benefit

Unfortunately limited decision tools are currently available for dairy farmers to assist them in projecting the potential return on investment from precision technology before they invest. The University of Kentucky precision dairy farming team developed a simulation model of a dairy farm to provide some guidance in the area of technology cost benefit assessment. The model projected impact over a 10 year period and included modelling expected impact of technology on physical herd performance and farm profitability. However due to the complex nature of the model, this remains purely a research function and has limited application to commercial farmers wishing to invest.

Projecting the future value of technology and the data it generates is also challenging. Given the fast pace of technology development, sensors which have the ability to connect to data hubs may have the potential to generate added value through data integration. In addition, the ability to measure new parameters through precision technology may have unforeseen benefits to the business, provided the user understands and utilises the information generated.

6c. Assessing existing investments - the importance of a KPI

Easier strides can be made in assessing the value of existing precision technologies through monitoring of physical parameters but this requires the identification of appropriate key performance indicators (KPIs). This however can be challenging with complex data technologies such as robotic milking generating a wide range of metrics. There is a clear need for independent research to identify the most important appropriate metrics to support good farm performance and formulate targets for these.

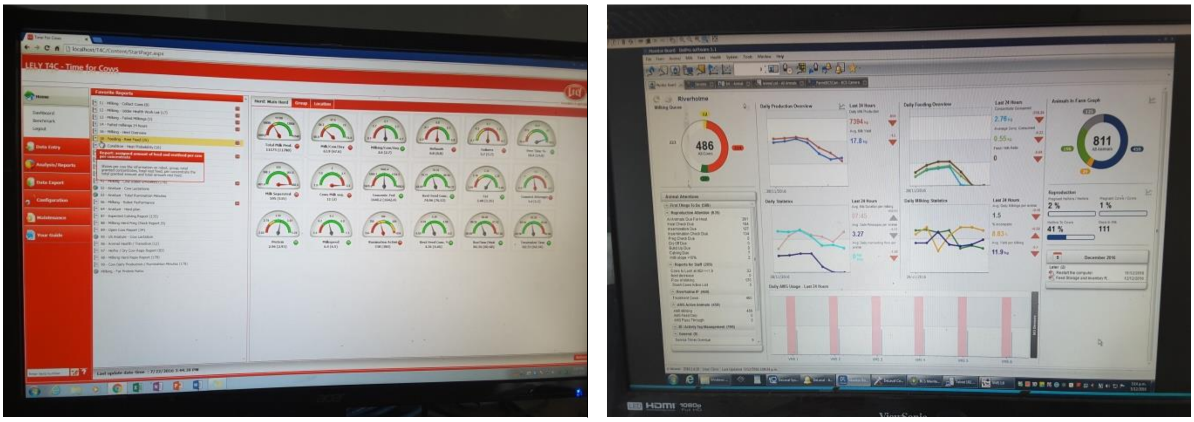


Figure 16: Technology can overwhelm us with data. Despite best efforts to simplify data presentation, identifying the correct metrics and KPIs is still challenging

For individual farms, benchmarking technology should start back at the pre-purchase stage and consider the reason for investment. Using this rationale it's worthwhile considering three aspects:

1. why performance is currently suboptimal, what are the drivers behind this,
2. if technology is the appropriate solution to fix this, and
3. what are the appropriate metrics to use to measure whether the technology has been successful (Figure 17).

Post-installation, continually reviewing actual performance against expected KPI targets is essential. Importantly users must be able to adjust management of the technology to achieve these KPIs.

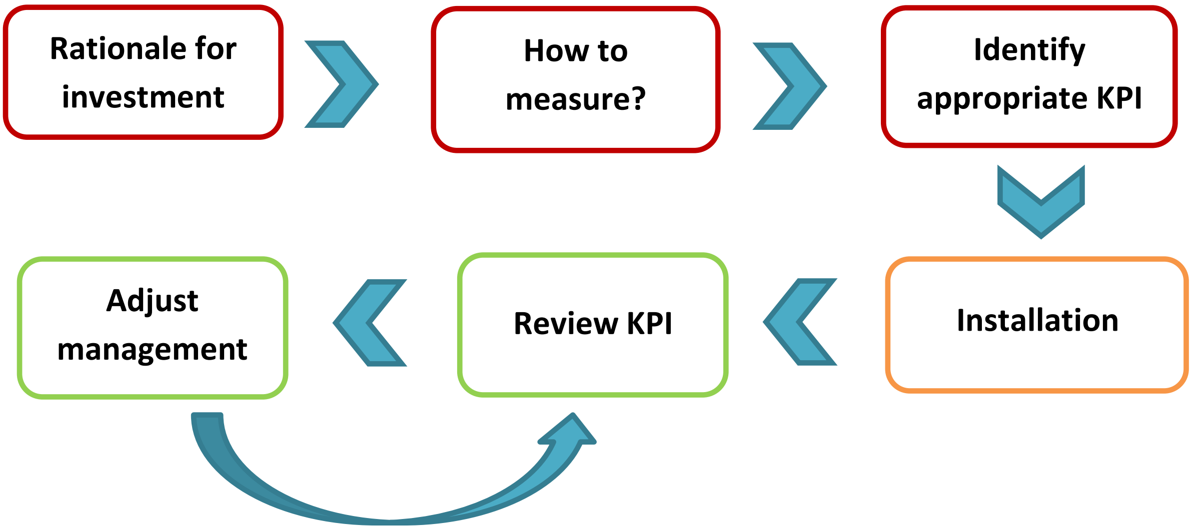


Figure 17: Schematic diagram showing the process of identifying metrics to ensure quantitative benefits are gained from introducing technology

Unfortunately, in reality, limited pre- or post-installation analysis of metrics is completed and so it is hard to ensure the value of the technology is maximised on farm. This is particularly true for large technology investment such as robotic milking where few guidelines exist as to how physical metrics relate to economic performance. To address this, there is a key role for research and industry here to investigate what metrics relate best to overall system profitability and define clear targets for these.

6c.i. Benchmarking against others

In the absence of clear KPIs related to profitability, services which allow farmers to benchmark themselves against others are highly valuable. One such recent developed is the Lely T4C cloud based programme which benchmarks farm physical parameters on robotic milking systems. The programme allows farmers to send and receive requests to share information covering a variety of performance metrics. This allows farmers to benchmark simple metrics such as visits per day or feed rate per litre with others from around the world. Users can form groups, create a virtual discussion board and are supported by an additional site for farm advisors and vets who can access their farm information.

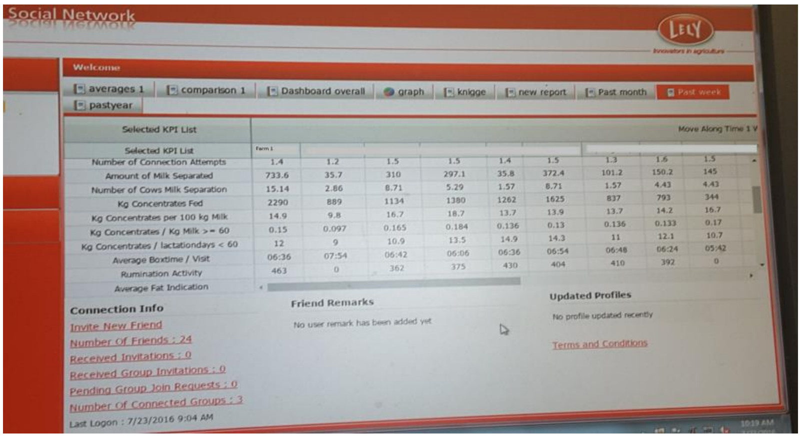


Figure 18: Lely's social network allowing farms to benchmark against others located anywhere else in the world. Each column represents a different farm. On this US farm the software was used to connect with farms in Canada and Europe.

The ability to assess farm and technology performance against others is something that is considered extremely valuable. Tasmanian dairy farmer, Nick, who farms in partnership with wife Rebecca and hosts the world's first robotic rotary parlour manufactured by DeLaval commented:

"Because robotic milking was so new to us (and our systems were slightly different to others), we actually felt quite alone and we didn't know if what we were doing was right or how we compared to other robot farms."

Following this the University of Sydney in partnership with the Australian Department of Primary Industries and supported by levy board Dairy Australia initiated a project to compare robot performance across initially Australia and now the world. Dr Nico Lyons, Project Leader explained:

"there was a real lack of industry data on the performance of robotic farms here in Australia, regardless of the colour of the machine. This made it difficult for farmers new to robotics to understand if their current performance was good or poor, and there was a real lack of data available for anyone considering buying this kit."

The project allows Nico and his team access to each of the farm's performance data each month, some of which he remotely collects and some of which is filled in by the farmer. The team then generates reports on robotic performance both for individual farms and across the four countries this project is now active in. This is helping build an independent evidence base on the impact of AMS on farm performance and identifies the key KPIs for successful robotic milking farms.

See chart on next page

Department of Primary Industries

International AMS KPI Project - Average farm information

July 2016

The First International Automatic Milking Systems' KPI Project provides the International Dairy Industry community with key information of what is achievable under commercial conditions. Information about milk production, AMS utilisation and farm demographics will help understand how these farms 'behave' over a 12 month period.

A total of 19 farms are being monitored: 12 from Australia, 2 from New Zealand, 4 from Ireland and 1 from Chile.

Table 1: Herd information

	ALL AMS Farms						
	Minimum	Average	Maximum	Australian AMS Farms	New Zealand AMS Farms	Irish AMS Farms	Chilean AMS Farm
Cows in milk (#)	62	143	286	165	77	98	220
Heifers (%)	3%	26%	52%	22%	38%	29%	36%
Animals that calved (#)	0	9	43	10	3	1	43
Farm stocking rate (milking cows/ha)	0.4	2.3	4.6	2.3	0.7	3.0	2.2
Robot stocking rate (milking cows/robot)	16	46	72	47	31	51	55
DIM (#)	99	174	269	181	149	172	156

Table 2: Daily milk production and quality

	ALL AMS Farms						
	Minimum	Average	Maximum	Australian AMS Farms	New Zealand AMS Farms	Irish AMS Farms	Chilean AMS Farm
Daily milk production (kg/day)	17	3,252	6,427	3,937	945	2,623	2,842
Fat (%)	3.6	4.1	5.3	4.0	4.7	4.0	5.28
Protein (%)	3.2	3.4	3.9	3.2	3.8	3.4	3.94
Somatic cell count (x 1000)	49	160	322	171	322	113	78

www.dpi.nsw.gov.au

Figure 19: The international AMS KPI project publishes monthly data from AMS farms across four countries in a bid to provide farmers with a better understanding of what can be achieved with robotic milking (Source: *DEPI, 2017*)

6c.ii. Valuing the 'soft' side

For many, the 'soft' benefits of technology such as improved cow welfare, labour requirements and changing job roles are key reasons for investing in technology; however, they are notoriously difficult to quantify.

At present there are limited techniques out there to capture this information and these variables will go unmeasured. Nonetheless they are important to recognise. In reality the true value of precision technologies will be heavily dependent on the value an individual farmer assigns to their own time, feeling of prestige etc. and on their ability to make the most of any savings in these areas. Dairy consultant Jack Rodenburg, DairyLogix, commented: *"quite often it is difficult to assign these soft benefits their true value. If time is money what do you do with the time that you save?"*

There is an opportunity to develop tools to support farmers to quantify the hidden benefits of technology, allowing them to construct farm-specific weightings for the harder-to-quantify variables.

6d. Case Study: Business vs Technology – importance of retaining the right focus

We must be careful when seeking to maximise returns from technology that this does not come at the expense of the main business objective. The nature of current technology adoption processes and an absence in identifying core KPIs is leading some farmers to focus on metrics supplied by outside personnel which are more directed at optimising the technology itself, consequently detracting from the overarching business objective.

A classic example of how technology objectives and business objectives can come into conflict lies in the transition from conventional to robotic milking. Alvin, dairy farmer from Wanaka in the South Island of New Zealand, runs four dairy farms: three conventional and one robotic farm. The latter is home to 6 robotic milking machines for 480 cows using 185 effective hectares of grassland. Each of the farms is grass-based and places a strong emphasis on achieving high grassland utilisation, with a minimum of 80% grazed grass retained in the diet throughout the lactation. However, achieving this target for Alvin means compromising robot performance.

"Many people use number of visits per day as a key metric for improving milk yield harvested per robot. Grazing farms here in NZ are achieving over 1.8 visits per cow per day and European farms over 2. Within our herd, we appear to have a sub-group of 70 cows which average only 1.2 – 1.3 milkings per day. Initially I thought this would be a problem."

Figure 20: Dairy cows moving through a series of selection gates to access a 185-hectare grazing platform in New Zealand.

However when Alvin investigated further, he identified these animals as late lactation animals with a lower concentrate allocation in the robot and hence less motivation to move back to the main yard for milking. Instead the cows remained in the paddock, continuing to graze and helping Alvin reach his target grass residual of 1500kg DM/ha.

"Although this group contribute to slightly lower robot performance,
they are ensuring high quality grass for the whole herd in the next rotation
by staying in paddocks longer and cleaning out swards.
For me, this group of cows are the most profitable animals on the farm."

6e. Summary of chapter and recommendations

Currently, limited quantitative assessment of the impact of technology on farm performance is conducted. Prior to purchasing technology, farmers need to have a clear vision as to why they are investing and the intended outcome of that investment. There is a role for research and industry to provide independent KPIs for technology that are linked to overall business profitability.

Many of the benefits of precision technology are 'soft benefits' and can be difficult to quantify. Better systems need to be put in place to recognise these. Prior to installation farmers need to identify key metrics that are of value to their business, to then monitor performance and determine the future impact and value of the technology for the farm business. Technology users need to understand how to influence the production systems that drive these performance measures in order to achieve successful technology integration into business decision-making.

Data platforms that allow physical indicator or financial benchmarking of farms against others are highly valuable and more should be developed. However the use of technology cannot be allowed to shift the overarching direction of the business, and the farm, rather than being "technology-centric", must retain a "business-centric" view.

7. Stronger together: the power (and challenges) of data integration

The data sharing and integration landscape remains challenging. Demands on data integration for industry development and 'the greater good' are often inconsistent with those demands placed on data for commercial product development. Fragmented approaches to sensor development has led to multiple and discrete storage of data either on-farm, online and/or on unconnected devices. The situation is further complicated by the absence of standards for both data formatting and data storage, creating numerous challenges when trying to bring datasets together. In addition, many questions remain unanswered about data access, data transformation and data ownership, topics that in themselves merit a full study.

Nonetheless it is important to continue to seek solutions to data integration. The true value of precision technology exists in bringing together the data that it generates in new ways to shift how agricultural systems are well managed. Professor Ian Yule from Massey University highlights:

"Precision technology is no longer about understanding the detail of one metric, the value is in bringing data together."

7a. Smart Dairy Farming Case Study – creating a digital highway for industry data

Countries with mature data-sharing platforms and a history of collaboration show the greatest potential to bring the concept of an integrated industry data platform to fruition. One such initiative currently being developed within the dairy sector is that of the Dutch Smart Dairy Farming project. The project, driven by a consortium of three cooperatives representing 90% of the dairy industry, FrieslandCampina, Agrifirm and CRV, aims to develop provide a platform or 'digital highway' to bring together farm-generated data.

The consortium capitalised on existing infrastructure for data sharing by purchasing EDI Circle, a company that operated a cloud-based data platform for sharing financial information between a number of industry bodies including the three consortium members. With the farmer ultimately in control, through giving consent as to who can use their data, the platform aims to receive and collate data from various sensors on Dutch dairy farms. This data will be available for purchase by technology start-up companies and software application providers to ensure novel software tools are developed for Dutch dairy farmers. According to Dr Ynte de Vries, project leader for FrieslandCampina, this is reflecting a significant shift in the precision dairy space:

"Up until now competition in the digital agriculture market was based on the size of the database you could draw from, not the quality of the algorithm generated. This reduces the quality of service the farmer receives from the software or technology package."

However with much greater activity in technology and software development, the conversation is now focused on service provision. FrieslandCampina board member Erwin Wunnekink commented:

"This is a service that is clearly required by the industry and needs to happen to allow our members to progress. Our role is to provide the initial investment to kick-start this development. However we are challenging this initiative to provide a rapid return on investment."

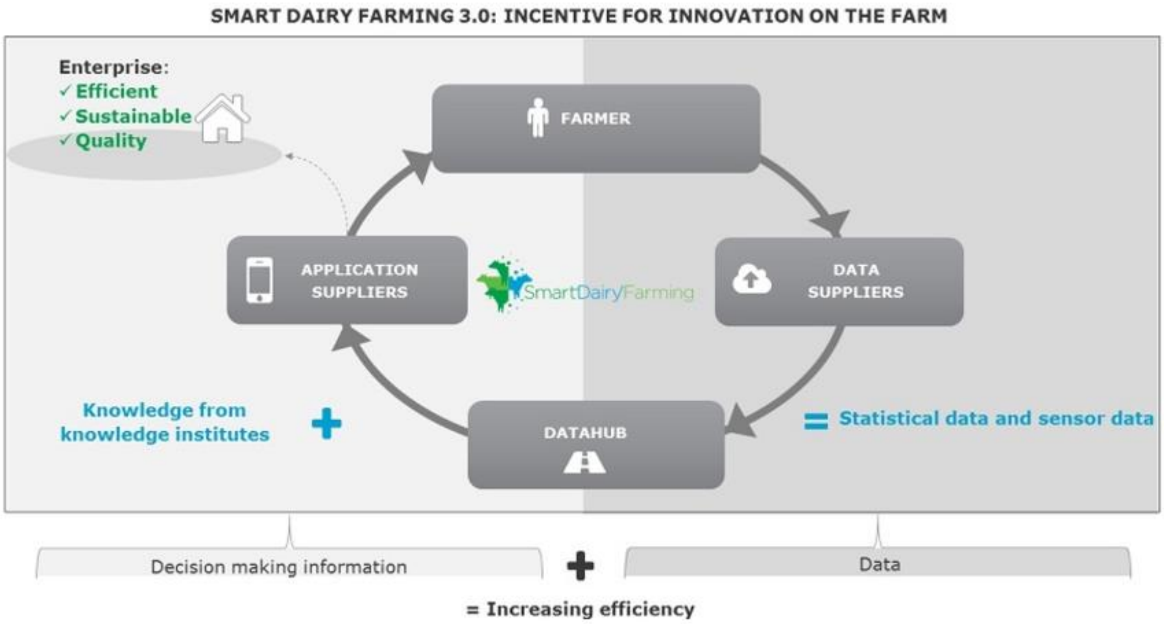


Figure 21: Strategic model of the Dutch SmartDairyFarming Initiative which aims to fast track technology use on farms by developing an industry wide data platform (Source: *Friesland-Campina,* 2017).

With limited other working examples to draw from, this is certainly a unique project and the success will be highly dependent on the development of suitable costing models and governance structure to allowing short-term payback and the buy-in of technology companies with well developed data collection platforms e.g. Lely's Farm Management Service network and Delaval's Dairy Data Warehouse initiative.

The project will also hinge on the willingness of farmers to provide access to data with no direct financial return, which in turns requires having a realistic estimate of what the data is worth, alongside the recognition of the potential value of new software solutions for the farmers themselves. As highlighted by Coert van Lenteren from Lely:

"individual farm datasets on their own are often noisy with limited value. This type of data for research and technology development only becomes useful when it is combined with 10, 20 or 100 other farms."

7b. Summary of chapter

Industry-wide data integration is challenging but has the potential to deliver significant value to both farmers and industry. Mechanisms to integrate data should be tested and experiences shared.

8. Digital dairy - building an innovative agricultural sector

"In my 37 years of farming, this has been the most rewarding, stimulating, interesting, challenging and demanding project I have taken on."
Alvin Reid, Canterbury dairy farmer, on building a remotely managed robotic dairy enterprise.

One of the most exciting prospects of the digitisation of our dairy industry is the potential to challenge perceptions of the agricultural sector here in the UK. Technology has a key role to play in three key areas: promotion of the industry as a viable career choice, supporting both large and small scale farmers to be competitive whilst maintaining high levels of individual animal care, and providing an evidence base for sustainable food production.

8a. Agriculture – a viable career choice?

The development of precision technologies in dairying is symbolic of the extent to which dairying has become a specialist industry, requiring a skilled workforce and expert knowledge. There is a key role for technology in showcasing the dairy industry as a progressive, high-tech and innovative industry to potential new entrants. As a result, this should encourage young, bright minds into a career in agriculture, either in primary production through the creation of a labour-efficient working environment, or by providing skilled job opportunities in the supporting technology and data industry.

Currently the opportunity to do this is being largely lost in the UK, but others have been more proactive. The importance of this task is being recognised in Australia through the University of New England's Smart Farm project which works with a consortium of seven 'Smart Farms', seven universities and 15 ag-tech companies. The SMART farm learning hub connects teachers and school students with researchers and new technology. The university has developed a range of learning modules covering herd management and farm mapping suitable for the classroom, allowing children and young adults to work with live data streams collected through the SMART farm's network of sensors.

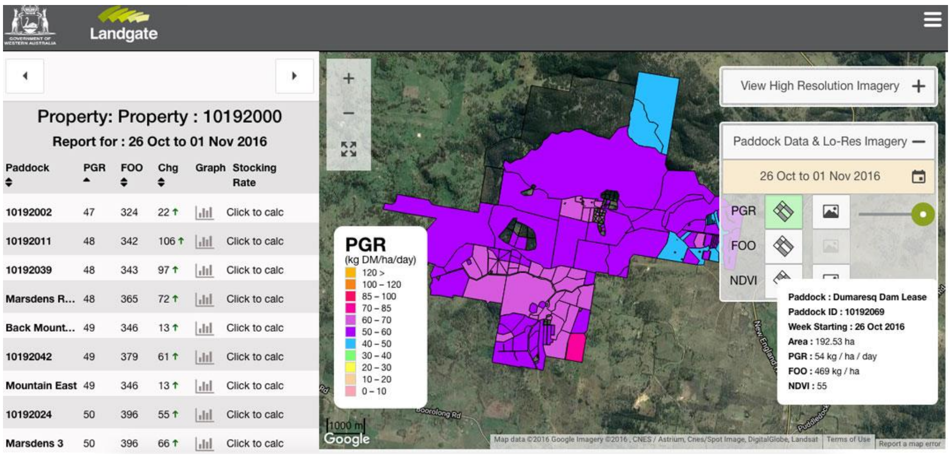


Figure 22: Students can get free access to a range of data such as pasture growth to use for school projects from the SMART farm Learning Hub.

8b. Big vs Small: technology for all

Although in general a trend for increasing herd sizes is evident across the UK dairy industry, the sector still retains a predominantly family farm structure, averaging 127 cows per farm (*AHDB Dairy,* 2016). Technology has a role to play in sustaining both large and small farms, but for different reasons. For the smaller farm, precision technology allows a unique opportunity to bring significant gains in technical efficiency through reduction in labour hours per cow and redirection of tasks to focus on individual animal management, and precision inputs of feed and fertiliser at a much smaller scale. Indeed in the UK, labour hours per cow fell from 40.9 to 32.0 between 2005 and 2013 (*Eurostat,* 2017). The introduction of precision technology allows gains to be made in technical efficiency and can offer potential savings in labour by reducing time consuming tasks.

In contrast, the main benefit of technology to the large farm (over 500 cows) is the ability to measure and manage animals individually. Through the use of animal sensors and the data they provide e.g. on lying time, step counts, and the use of rumination collars and feed-to-yield software, each animal has its own identity and can as a result receive individual management. This helps combat the current image of 'factory farming' - or the 'mega-dairy' - terminology which is often associated with mass scale production and connotations of poorer individual animal welfare. Indeed, for a number of technology companies, the greatest growth sector highlighted in the last few years is the 500+ cow farms, despite high initial investment costs.

8c. Role of technology in retaining our social licence

The image of our domestic agricultural production systems has never been more important as (at the time of writing) the industry enters into an uncertain environment of post-Brexit trade negotiations and development of a UK agricultural policy. Should the UK take a protectionist approach to domestic food production, even greater emphasis will be placed on supplying high quality, sustainably produced and traceable food.

With this in mind, technology will be required to play a key role in collecting information on farming practices and delivering assurance of these credentials. In the Netherlands, a country with increasing focus on environmental and welfare concerns (over 80% of farmers receive a payment bonus for grazing dairy cows at pasture), many farmers cited the importance of retaining a social licence to farm.

According to Harry Schmidt, Rabobank, transparency will be the major influence behind technology uptake on dairy farms. *"Organisations are now investing in how we can use drones or in-line milk monitoring to confirm if a cow is in fact out at pasture during the day."*

This sets a precedent for UK dairy farmers. Therefore the industry must be aware of the role that technology will have in delivering transparency in production systems through providing evidence of traceability and environmental and welfare credentials. However, delivering this benefit to the sector will require an upgrade in digital infrastructure and better uptake of technology, a potential opportunity for post-Brexit support mechanisms.

8d. Summary of chapter

Technology has a key role to play in promoting the UK dairy sector as a viable career choice by showcasing an innovative, dynamic industry. Technology can be used to connect students at colleges and universities to future careers in agriculture. Technology has a pivotal role too in supporting both large and small scale farmers, and could be used to create greater transparency and challenge negative perceptions of large dairy herds. Increasingly technology and data collection will be required to provide both an evidence base for sustainable food production and to deliver such production systems. Developing this approach now allows the UK dairy industry to gain a competitive advantage over other dairy production regions.

9. Discussion

From this study it is evident that the influence of new technologies and developments in digital infrastructure is set to increase markedly in the UK dairy sector. These technologies not only offer enormous potential to improve technical efficiency on farm, but also provide an excellent opportunity to boost the image of UK dairying, showcasing an innovative sector which produces sustainable, traceable and high quality food.

At present, technology uptake within the dairy sector is limited to early adopters. This is primarily due to, firstly, a lack of evidence of the financial benefits of technology introduction, and also influenced heavily by a lack of confidence in using technology on farm.

Undoubtedly agricultural sensor development will continue (pulled forward by advances in other industries), but in reality the rate of uptake of technology and its use on farm will be determined in part by changes in cultural attitudes, and recognition of the value of data to understand how the business is performing and in turn to drive improvements. Unless there is a move at the farm level towards more evidence-based approaches to decision making, it is difficult to grasp how the true value of technologies can ever be recognised. Furthermore the value currently being received from precision technologies on-farm is in many cases either sub-optimal or poorly quantified. This is due in part to a growing skills gap on-farm and in the supporting service sector. Whilst many technologies used on farm at present collect vast amounts of data, a lack of data management skills and support is limiting the progress of this through the data-information-knowledge-action continuum.

Unless there is a move at the farm level towards more evidence-based approaches to decision making, it is difficult to grasp how the true value of technologies can ever be recognised.

In addition, there is limited evidence on how some metrics produced by precision technologies relate to overarching farm profitability. This is particularly true with larger investments such as robotic milking. The lack of integration in terms of datasets and the quality of the associated management information that can be derived is limiting the degree of value capture from this technology, both for the industry as a whole and for individual farming businesses. The process of using technology to drive business benchmarking is currently challenging due to a lack of independent and validated information on the appropriate metrics and KPIs to employ when using these technologies.

Industry-wide data integration has been identified as the next significant step that must be taken to maximise the value derived from precision technologies. Although there are a number of challenges with this, the potential value to the whole food chain is significant given the likely future demands for transparency and traceable, sustainably produced food.

Finally, it is important to recognise that precision technology will mark a significant step change in dairying and present significant potential to build an industry with changing job and business structures and a requirement for skilled personnel which is attractive to new talent.

10. Conclusions

1. Early adopters still dominate the dairy technology market. To assist in uptake of technology more extensive research should be undertaken to understand patterns of adoptions and the rationale behind technology investment decisions. Current use of technology is being hindered by a skills gap both on-farm and in the supporting industry. The lack of basic data management and interpretation skills needs to be addressed if the true value of technology is to be recognised. Collaborative training mechanisms should be put in place both in education systems and for mature farmers to address this gap; however, end users must be prepared to engage. The industry also needs to improve:
    - User confidence with digital devices;
    - Understanding current use of data on farm, and the data – action continuum;
    - Delivery of farmer specific training; and
    - Consideration of the changing roles of farmers in the technology adoption process and the development of a complementary skills base in the supporting service industry.
2. Limited quantitative assessment is conducted on the impact of technology on farm performance, hindering the value received from technology. Mechanisms need to be put in place to:
    - Provide KPIs for technology that are linked to profitability;
    - Develop decision support tools for evaluating the impact of technology;
    - Ensure technology adoption is in line with the overarching aims of the farming business;
    - Encourage sharing of data from the use of technology to drive performance and financial benchmarking across farms; and
    - Assist farmers to manage the technologies post installation and derive maximum value from the data they provide.
3. The issues surrounding data integration should continue to be challenged and initiatives to develop industry-wide databases should be supported.
4. Technology presents a unique opportunity to improve the image of dairying in the UK. This opportunity should be exploited to its full potential and can be achieved through mechanisms to connecting young people to the industry via technology, and through using technology to create an evidence base around the industry's existing high welfare, and high sustainability credentials.

11. Recommendations

The recommendations from the study are:

- There is significant scope to drive grassland utilisation on UK dairy farms, but in order to capture value, emerging technologies need to be validated.
- Technology developments offers enormous potential to improve both technical efficiency and the image of farming within the UK dairy sector and as a result should be embraced.
- Technology adoption promotes better measurement but does not guarantee better management and the UK dairy sector needs to be mindful of this.
- Current use of technology is being hindered by a data management and data interpretation skills gap both on-farm and in the supporting dairy industry. The skills gap needs to be addressed to capture the true value of technology.
- Further integration of research and industry to identify key performance indicators for businesses using technologies, and tools for cost-benefit assessment, are essential.
- There must be a move from technology-centric to a system-centric view of precision agriculture.

12. Life after Nuffield

In October 2016, part way through my Nuffield experience, I joined the Agri-Food and Biosciences Institute in Northern Ireland as a principal researcher in grass-based dairy production systems. This role is allowing me to fully explore the potential of precision technologies to drive our understanding and management of the animal-grass interface, through the development of the AFBI Precision Grassland Platform.

This new initiative, a £1.2 million investment in agricultural research funded as part of the UK Centre for Innovation and Excellence in Livestock, aims to provide UK farmers with a cutting edge research platform to advance our knowledge of managing the grazing environment. The platform will use a combination of soil, plant and animal based sensors, as part of an integrated sensor and data network.

In the past few months we have started using some of these technologies to better understand the plant-animal interface, using rumination halters and lying time sensors to monitor cow behaviour in the grazing environment. This technology will form a core part of each new research project.

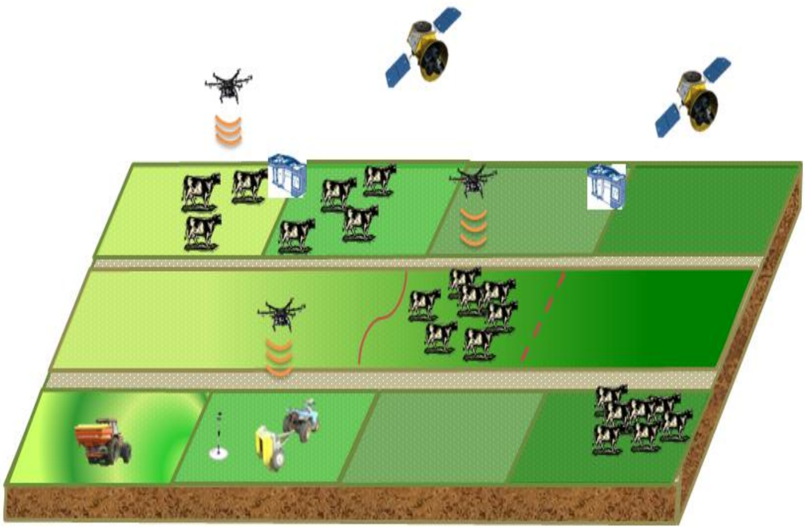


Figure 23: LHS: AFBI Precision Grassland Platform

Crucially this platform is also working with a network of commercial farms to understand and support technology uptake on dairy farms. A major priority for AFBI's Precision Grassland Platform is to develop efficient decision support systems that integrate data from various technology sources and as a result provide high level data summaries and easily understood action lists that both inform and simplify decision making at farm level. As part of this approach, we are working with technology providers and local farmers to ensure that maximum value is gained from investments made in these new technologies.

In the future I also hope to make a closer connection with this work and our next generation farmers by making our research platform more accessible to local agricultural students, integrating their learning with our new technology and digital infrastructure.

Debbie McConnell

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