Improving productivity for Australian pasture based dairy farming

A report for

By Aubrey Pellett

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Executive Summary

In the search for new technologies and management practices likely to improve productivity, several themes were considered. These included how technology enables greater labour efficiency, the growing and consumption of more feed per hectare, improving the feed conversion efficiency of the dairy herd, and what does the emerging concept of precision dairy mean?

The recent introduction of a robotic rotary milking system will significantly boost labour productivity. High system capacity will suit Australia's pasture based grazing systems allowing one supervisor to milk cows in a batch fashion. Adoption of this technology will require minimal farm or production system change, while providing physical relief and rich information at the cow level. Dairy-specific algorithms are being developed that enable generic robots to complete paddock related activities. Robotics tailored to the dairy farm environment will facilitate continued farm size expansion by providing a solution to dairy labour issues.

Ryegrass is likely to remain the base of the Australian dairy grazing system. The use of genomic technology has the ability to speed up development of new ryegrasses with improved yield and persistence. The provision of an industry cultivar selection tool in development by Dairy Australia will guide farmers' pasture selection decisions and provide feedback to breeders by incentivising genuine cultivar improvement. Inoculation of the best performing cultivars with novel and designer endophyte will boost both pasture and animal performance. The introduction of fodder beet as a high yielding crop would benefit from the development of Australian guidelines.

The development of precision dairy technology is in its infancy. Decisions based on real time cow and paddock information can increase yield, reduce costly inputs, improve animal

welfare, and enable farmers to focus on decision making rather than task completion. The ability to collate data from multiple sources improves the accuracy and reliability of decision support systems.

The capture and use of increasing quantities of information from the farm has the potential to change how the supply chain is integrated. Greater ability to predict input demand and milk supply will allow the farm to form value creating closer relationships and be more responsive to price signals.

There is variation in feed conversion efficiency between lactating cows. The opportunity to breed for improved feed conversion efficiency is now possible using genomic prediction. The recommended approach is as a part of a broad, future looking objective, recognizing that in the genomics era the speed of genetic gain is rapid. Using genomic information for individual herds will allow customized management best suited to a herd's predisposed genetic response.

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Foreword

As a first generation dairy farmer I made the choice to start farming together with my partner, Jacqui, in 2001. Our original motivation was to be self-employed, to be the prime decision makers and to create lasting wealth. In the sometimes elusive pursuit of annual profit I developed a recognition that a longer term focus on productivity was required. Even a well managed dairy farm business has a profit influenced largely by fluctuating international milk prices, rising input costs, and unpredictable climatic conditions. The desire to achieve solid profits prompted a scan of the horizon to identify what promise the future held.

I consider myself fortunate that my Nuffield scholarship has been sponsored by the Geoffrey Gardiner Dairy Foundation. They have offered me every assistance and I appreciate the informal discussions that helped guide my initial thinking. Conversations with some of the dairy industry's most experienced and talented people have greatly enhanced the Nuffield experience.

In recent years I have been a Director of both Gippsland's regional development program GippsDairy and the Bonlac Supply Company which represents the interests of the farmers who supply milk to Fonterra in Australia. Both these experiences are about benefiting farmers and have given me a broader understanding of the research, development and extension activities taking place in Australia. The combination of my own farm and these industry experiences framed the judgments I made on where to look and how any new technology would drive productivity in the Australian pasture based production system.

My Nuffield scholarship afforded me the opportunity to travel extensively in the second half of 2014. My first trip as a part of an international Nuffield group provided a global view of agricultural issues as we travelled through the Philippines, China, Canada, United States,

Netherlands, France, and Ireland. China provided the chance to see first hand the impact on food demand of increasing wealth, urbanization of a formerly rural population, and changing consumer tastes. There can be no doubt that China is in the middle of a transition from small scale tenant farmers to larger more mechanized farming businesses with the assistance of central government planning. It will be interesting to see how they resolve the issue of land ownership in the coming years as rural entrepreneurship is encouraged. A second trip to the Netherlands, Germany, Ireland, Sweden and the United Kingdom enabled me to understand how intensive systems and high labour costs promote development and uptake of automated milking systems. My final trip through New Zealand and the United States reinforced how a focus on pasture and the business of farming can deliver spectacular results. There were many inspirational visits and meetings along the way.

Producing more from less is the challenge we need to overcome in order to remain profitable and satisfy customers, while ensuring we pass on our natural resources in better shape to future generations. In undertaking this Nuffield Scholarship and producing this report I very much hope to paint a picture of what is possible in the future. If my own family farming business and wider dairy industry become more competitive and profitable in the future I will consider it to be a success.

Acknowledgments

My gratitude goes to Nuffield Australia for providing the opportunity and seeing potential in me. My sponsor, the Geoffrey Gardiner Dairy Foundation, has been more than willing to offer any assistance above and beyond the significant financial investment of a Nuffield sponsor. Special thanks go to Mike, Mary, Barry and Aaron; your guidance has been appreciated.

The scholars who joined me on the Global Focus Program made those six weeks of travel one of the highlights of my Nuffield experience. I am lucky to have shared the experience with Tania, Finola, Justine, Greg, Paul, Nigel, Nicky, and Steve.

To the many people around the world who kindly referred me to experts, organized meetings, visits, and hosted me, your willingness to assist a Nuffield scholar has surprised, delighted and humbled me.

I must acknowledge The Bonlac Supply Company Board for tolerating my absence and the financial contribution to the experience I had with the Global Dairy Farmers Irish study tour.

A sincere thank you is due to the team at home ensuring the farm hardly noticed I was away; in particular to Billy who stepped up to the challenge and taught me that the people around you will strive to do their best.

Of course I can never thank my own family enough for the willing sacrifices they inevitably had to make as I enjoyed the Nuffield experience. Thanks to my mother who was always available to help Jacqui and the children, I never had to worry. To Anneka and Jackson, I am confident that when you are older you will understand why Dad was away for what seemed

like endless weeks. But most of all, none of this would have been possible without the support of you, Jacqui. I always knew you would manage superbly in my absence and of course you did.

Abbreviations

VMS	Voluntary milking system
AMR	Automatic milking rotary
NSW	New South Wales
GPS	Global positioning system
CRC	Cooperative Research Centre
DNA	Deoxyribonucleic acid
GM	Genetically modified
DM	Dry matter
MJ	Megajoule
LDH	Lactate dehydrogenase
LIC	Livestock Improvement Corporation
FCE	Feed conversion efficiency
RFI	Residual feed intake
CIDR	Controlled internal drug release

Objectives

The objective of this report is to identify the new technologies, management practices and other factors that are likely to improve dairy farm productivity in the near future, specifically:

- What are the technologies that will be enablers of greater labour efficiency resulting in more milk solids or cows managed per operator?
- How can a farm produce more quantity and quality of 'home grown' feed?
- Is it possible and practical to improve the herd's efficiency of feed conversion?
- Does the growing ability to capture cow and farm data provide an opportunity to make better decisions leading to precision dairy optimization?

Gaining an insight into yet to be released new technologies has proved difficult given the commercial considerations of many innovations. The author experienced reluctance to reveal new research and development beyond what is already released to the market place. However, given the slow rate of adoption it is still possible to look at 'new' technology today and assess its usefulness in addressing productivity barriers in the future.

Chapter 1: Introduction

The Australian dairy industry is a significant contributor to economic activity and as Australia's third largest rural industry is estimated to be worth $13 billion. Approximately $4 billion of this is received at farm gate by 6,314 farms that directly employ 43,000 people. Total national milk production is 9.239 billion litres with 1.69 million cows producing on average 5,471 litres. The industry is a major exporter responsible for seven per cent of world dairy trade. Across Australia, the exportable surplus accounts for 38 per cent of total production (Dairy Australia, 2013/14).

Over time Australian dairy farm businesses have become larger. Since 1983 the average herd size of 90 cows has increased to an estimated 268 in 2014 (Dairy Australia, 2013/14). While business challenges and opportunities have necessitated this trend it has been supported by greater efficiencies resulting in more cows being managed per person, more feed being produced per hectare farmed and more milk produced per cow. The intention of this report is to identify what efficiency opportunities look promising for the future and to give some consideration of what is required for the Australian dairy industry to capture these opportunities.

There are ongoing and incremental improvements in plant and animal breeding that influence productivity growth at an individual farm level. However, this is often limited by factors not controlled by the farm business manager. For example, seasonal conditions influence pasture production and therefore milk solids output as well as the extent of supplementary feeding that reduces the efficiency of the relative input to output relationship. In addition, as farmers look to maximise profit in any given year by assessing the relative price of inputs and milk output, a temporary distortion of productivity gain can occur. This is especially so where prices are high and additional inputs may be used to deliver the most profit.

To ensure this report focuses on identifying real improvement, productivity has been considered as improvement in the ratio of inputs used to produce a quantity of output. Growth in productivity will therefore occur if either output is maintained while inputs are reduced, or output is increased with the same level of input. The main input and outputs that affect the dairy farming business are considered to be labour, farmed hectares, purchased supplementary feed and cows and milk solids produced. Focusing on these variables allows the effect on productivity to be understood and quantified.

Historical growth in productivity can be measured and presented as total factor productivity growth. Research by the Australian Bureau of Agricultural and Resource Economics and Sciences calculates that dairy total factor productivity growth averaged 1.6 per cent per year between 1978-79 and 2011-12 (Gray, 2014). A Victorian Department of Primary Industries report states Total Factor Productivity growth of 0.1 per cent per annum from 1988-90 to 2008-09 for Victorian dairy (Karanja, 2012). These results compare poorly with broader Australian agricultural productivity growth of 2.1 per cent per year from 1948-49 to 2011-12 (Gray, 2014). Despite large variation between individual farming businesses these results indicate limited improvement in productivity has occurred.

The challenge to create real efficiency improvement at farm level must address the building blocks of dairy farm productivity. These have been assessed in this report as themes around:

- Enabling greater labour efficiency.
- Boosting the quantity and quality of feed grown on a certain area of land.
- Increase milk production relative to what the cow consumes.
- Harness the power of farm data.

It is worth noting that there are two methods by which productivity growth could occur (Karanja, 2012):

- Technological Change - the adoption of new technology resulting in a more efficient dairy farm.
- Efficiency Change – better business management by adoption of existing best management practice.

Although not exclusively, this Nuffield report focuses on the potential for technological change. The importance of productivity is highlighted by this quote; *"Profitability is determined by two factors: productivity and the terms of trade, derived as a ratio of prices received to prices paid. As agricultural output and input prices are determined largely on global markets, farm managers have a negligible influence over their terms of trade. Therefore, it is only productivity that farm managers can improve through innovation in technologies and management systems (Nossal and Sheng 2010). Hence, while profitability is typically the objective of farm managers, they most commonly influence their profits through changes in productivity"* (Karanja, 2012).

Chapter 2: Improving labour productivity

One of the largest costs in the dairy farm budget is labour, both as the direct cash cost and the input cost of an owner operator. Therefore, any assessment of overall productivity must address the challenge of improving labour efficiency. On a dairy farm the obvious measurement of this efficiency is the number of cows per person employed. It is in this context that initiatives to improve labour productivity have been identified.

Increased labour efficiency has been supported by better milking shed design, larger farm machinery and more employed labour to support the family based owner operator. The mechanization of feeding and fodder conservation tasks with the more recent automation of milking practices, has facilitated the trend towards larger farms with higher stocking rates. Examples of this include a rotary dairy milking more than 300 cows per hour with one to two people and a combination round baler with wrapper allowing one person to operate the baling and wrapping activity simultaneously.

In the future, while the author expects the trend of increasing farm business size will continue, the automation of processes driven primarily by labour saving motivations will increasingly be supported by real time information that enables precise decisions. Empowering labour with both automation and decision support not only has the potential to increase productivity but will also:

- Attract labour with a different range of skill sets and interests.
- Improve lifestyle.
- Ensure consistent quality outcomes.

Automated milking systems

Most of the automated milking systems currently on the market originate in Europe where dairy farms predominately manage the feeding and milking of cows in a housed system. These robotic systems milk cows individually in a 'box' and have been adapted to work in our pastoral conditions using a voluntary cow traffic system. This is required to achieve the best utilization of the milking box asset.

Lely A4 milking robot

Lely offers a robotic milking solution where the cow chooses to enter a cubicle and a robot then completes the milking and dispenses concentrate if required. Within a grazing system the farmer will usually offer three pasture feed allocations per 24 hours that the cow accesses by way of a drafting gate on leaving the milking robot.

The number of cows the robot can milk depends on factors such as milking time, milk yield, voluntary cow flow, and farm layout. Lely estimates that the A4 robot system under optimum conditions could harvest 2.5 million kg milk per person per year. Their expectation is that the use of a robotic milking system with voluntary cow traffic would reduce labour requirements by half in ideal circumstances (Mourik, 2014).

The key to achieving these optimum conditions and high robot utilization is good voluntary cow traffic. Lely's experience leads them to believe good voluntary cow flow is driven by (Mourik, 2014):

- The feeding of concentrate based supplements at the robot.
- The strategic location of cow drinking water supply.
- The quality of grazed pasture affecting cow appetite.

Lely also introduced the author to the concept of both physical and mental relief for the staff when using a robotic milking system. This view was due to the disruptive change to the farming system when using voluntary cow traffic. The benefits of this go beyond just the automation of physical cup attachment. The aspect of mental relief was described as (Mourik, 2014):

- A reduced skill level for day to day farm activities being required; using a robotic system can compensate for lower skilled and cheaper labour.
- The requirement for highly skilled operators can be concentrated at farm manager level.
- Farm management would require less staff management time.

De Laval voluntary milking system (VMS)

De Laval offers a box milking robot system called the 'VMS'. The capacity of this system is quoted in optimum conditions as being able to harvest 3,000 kg milk per day (Sahlstrom, 2014). There has been a continual improvement in this milk harvest; for comparison the best result in the year 2000 was 1,800 kg milk per day (Sahlstrom, 2014).

In this report the application of robotic milking systems is viewed in relation to labour efficiency, however it is recognized that this is not the only consideration in a farmers purchase decision. De Laval quotes the following list as the trends driving robotic milking uptake (Sahlstrom, 2014):

- Labour constraints, human resources complexity and cost, especially on family farms.
- Demand for a flexible lifestyle.
- Requirement for high utilisation on invested capital.
- A trend towards business sustainability where robots can improve cow longevity, deliver consistent food safety standards and optimise output.
- Farmers wanting more time to manage the herd.

Despite these box milking robotic systems having been available in Australia for at least 15 years, widespread adoption has been limited. Currently robotic milking installations number approximately 28 farms across Australia with another six in construction (Kerrisk, 2014). The author speculates this limited adoption is the result of:

- The relatively high capital investment compared with traditional dairy design, especially where multiple boxes are required to milk more than 300 cows.
- The limited capacity of the box units requires voluntary cow traffic, necessitating whole farm change.
- Despite more farmer flexibility, without fixed milking times the extended operational hours of the system can result in the farmer feeling unable to 'shut off'.
- A reluctance of many farmers to rely on a technology they do not understand and they often question their ability to master the complexities of operation.

It is for these reasons the author expects that while new box installations will continue where suited to individual preference, wide scale adoption over time is unlikely to occur. Robotic milking solutions that facilitate high labour efficiency, whilst at the same time suiting grazing systems and being cost competitive for larger herds, are described below.

De Laval automatic milking rotary (AMR)

The De Laval 'AMR' is a relatively new concept where multiple robotic arms attach and remove milking cups in an internal rotary dairy design. The AMR is built with 24 bales and has a milking capacity of 70 - 90 cows per hour (Sahlstrom, 2014). When using voluntary or semi-voluntary cow traffic one AMR system can milk 700 – 800 cows on a daily basis. De Laval estimates that it would require 11 VMS boxes to match the AMR's capacity. Currently there are several AMR's in Australia with another about to be commissioned.

Advantages:

- One installation allows the farmer to increase herd size without adding additional boxes.
- For large herds it is a more economic proposition than multiple box units.
- The operator is not required at the AMR for milking.

Disadvantages:

- The rotary with stationary robot arm arrangement results in each cow having a one-off cup attachment opportunity.
- Requires the whole farm change to voluntary or semi voluntary cow traffic to milk more than 250 cows.
- The internal rotary design requires an additional installation in order to feed concentrate.

Photo 1: De Laval Automatic Milking Rotary at Camden, NSW, Australia.

Source: A Pellett August 2014.

GEA DairyProQ

The DairyProQ robot system from GEA Westphalia has a robotic arm attached to each bale on an external rotary platform. As the cow enters the bale and travels with the rotating platform, the robotic arm will in a single attachment clean the teat, pre-milk stimulate the teat, perform milking and then post-milk teat spray before the arm releases.

In designing this world first system GEA identified the challenges they wanted to overcome (Hille, 2014). These included:

- Finding and retaining labour on large farms.
- Ensuring food safety.
- Achieving high standards for animal health.
- Developing technology that can operate reliably 24 hours a day.

It was after this analysis that GEA started to develop the DairyProQ robotic system in 2012. Equipping each bale with its own robotic arm allows fewer incomplete milkings compared with a fixed robotic arm arrangement and the rotary size can be built to achieve the desired throughput. Importantly, this system ensures in-built reliability because any robotic failures can be isolated on one bale and do not stop the whole system operating. A rotary platform using the DairyProQ system requires the farmer to supervise the milking process.

The hourly milking capacity of a DairyProQ system varies from a 28 bale rotary milking 130 cows per hour to an 80 bale rotary milking 400 cows per hour (Hille, 2014). The application of this technology to the Australian environment offers significant benefits. This is the first robotic system that is capable of batch milking. The ability to batch milk using a robotic system is highly desirable for Australian conditions because:

- The farmer retains active control over pasture and forage management.

- It captures the physical stress relief and information capture of a robotic milking system, without the whole farm change required with voluntary cow traffic.
- The capacity to feed concentrate during the milking process.
- The ability to actively manage the milking frequency of late lactation cows and in adverse weather conditions.

This system has the potential to substantially increase the number of cows one person can milk, while retaining the farm system that already delivers optimum pasture harvest and the peace of mind of a system not operating 24 hours per day. As this report is written, the DairyProQ system is expected to be available in Australia within two years. Whilst pricing is commercially sensitive it is likely to compare favourably to multiple box systems setup to milk 400 cows or more (Burgt, 2015).

Photo 2: First commercial DairyProQ installation in Germany.

Source: A Pellett September 2014.

Robotics

The use of robotics in a dairy farm context has until now been limited to the milking process in grazing systems. Other robotic applications suitable for dairy farm activities are becoming feasible as technology develops and cost declines. The basic robotic hardware is often developed in other industries and requires adaption for grazing dairy systems.

Fetching robot

The Australian FutureDairy research and development program has created a customized robot capable of herding cows from the paddock autonomously. This is achieved using a generic skid steer platform equipped with a dairy cow specific algorithm.

Photo 3: Autonomous Robot trialled by FutureDairy in Camden, NSW, Australia.

Source: A Pellett August 2014.

The basic machine is a Clearpath Robotics™ product called a Grizzly (Clearpath Robotics). It is able to navigate the challenging dairy farm environment with electric four wheel drive, a 3 – 12 hour run time, 200mm ground clearance, 80 horse power and a robust frame that enables up to 600 kg of additional equipment to be mounted on the robot. The FutureDairy team has equipped and programmed this multi-purpose industrial robot to 'see' cows in a paddock and muster them as a herd (FutureDairy Project).

Using this type of platform there is the potential to develop additional functionality that automates other farm tasks. The FutureDairy project manager suggests it would be possible to extend the robot's capabilities to include (Kerrisk, 2014):

- Around the clock monitoring and reporting on calving events.
- Pasture quality and quantity assessment.
- Conduct routine paddock checks such as water supply, electric fence power.
- Soil sampling with GPS reference.
- The spot spraying of paddock weeds.
- Targeted fertiliser application related to soil test information and pasture assessment.

There are obvious savings in labour where farm activities can be automated. The use of robots with smart dairy-specific algorithms extends this benefit to include:

- Improved animal welfare, as a robot is not time constrained.
- Consistency and quality of farm activity.
- The capture of paddock information can be used to adjust fertiliser application based on yield and soil fertility, as well as more accurate pasture allocation.
- The analysis of animal observation information could facilitate better culling decisions, reduce animal health costs, and enable earlier treatment leading to improved animal performance.

Heavy activity paddock robots

The seasonal nature of pasture production relative to a farmers stocking rate necessitates time consuming fodder conservation and feeding activities. Robotic and autonomous tractors with implements have the potential to boost labour productivity.

An example of this capability is the autonomous mower currently in development by the Autonomous Tractor Corporation. This concept is based on a modular engine and drive unit customized for the work required (Tobe, 2014). Using robotic tractors for paddock activities also allows size and power requirements to reduce due to the continuous working potential of a robot. In addition to labour savings there is also lower fuel consumption and less risk of larger machinery causing ground compaction.

Conclusions

The introduction of the robotic rotary will significantly boost labour productivity of the milking process by allowing one supervisor to milk more than 500 cows, providing physical stress relief and individual cow information. The ability to batch milk cows provides a solution more suitable to the Australian context at a price comparable to the installation of multiple box systems.

Development of dairy-specific algorithms that control generic paddock robots will further expand the supervisory role of one operator. These are most likely to be developed within the Australian industry, due to the unique combination of large scale grazing systems and high labour costs, providing a catalyst for change.

The benefits of robotic technology extend beyond the automation of farm tasks. Robotic systems capture information that can be used to reduce costs, ensure quality, improve animal welfare, improve lifestyle, and increase yields.

Chapter 3: Higher yields from home grown feed

One of the most important factors contributing to a dairy farmer's profit is the amount of home grown feed consumed per hectare and per cow. In the Irish environment the relationship between increasing net profit and improved pasture consumption per hectare is calculated at 43 per cent (O'Donavan, 2014). The predominant feed source grown on farms in Victoria and Tasmania is ryegrass. As the quantity and quality of home grown forage increases, productivity improves as the farmer chooses the desired combination of increased stocking rate, more milk per cow or reduced purchased feed.

Enhancing the productivity of ryegrass

The DairyFutures Cooperative Research Centre (CRC) continues to develop a range of technologies that will, as Dr. David Nation describes, "address a fundamental business imperative for dairy farmers: making a profit from the biology of growing grass and producing milk". The CRC's designer forage program aims to deliver a more productive, nutritious and resilient forage base (Dairy Futures CRC, 2014).

Genomics assisted breeding

Knowledge of ryegrass Deoxyribonucleic acid (DNA) markers provide plant breeders with information on the diversity that is contained within existing elite cultivars. For instance, the yield range for individual plants can be very large and range from 50 to 250 grams (Nation, 2014). This illustrates the potential for targeted plant breeding using DNA markers for traits such as digestibility and yield.

The application of genomic selection by commercial plant breeding companies has the potential to double the rate of genetic gain in yield and persistence. This is largely because the typical breeding timeline of twelve years can be shortened to six years. The use of genomic information reduces the cost to bring a new ryegrass to the market as computer simulations reduce the number of field trials required (Dairy Futures CRC, 2014). As the

development of new cultivars is driven by commercial consideration, this technology with its reduced cost may allow profitable development of varieties suitable for specific Australian conditions.

Hybrid ryegrass

Unlike other crops (such as maize) creating a hybrid ryegrass plant has not been possible due to ryegrass self-fertilisation of seed production. The CRC is working on technology to overcome this barrier. Genomic selection of two unrelated seed lines could then be crossed (with 83 per cent seed set) producing a ryegrass variety benefiting from yield increases of 20 per cent (Nation, 2015). This hybrid vigour would remain for the life of the plant as seed set in commercial dairy pastures is not desirable.

Transgenic high energy ryegrass

The CRC has developed a genetically modified line of ryegrass developed with improved digestibility rates. The advantage of this ryegrass is that it gives similar or better yields to commercial cultivars but with available energy being one megajoule/kg higher. Significantly, the higher digestibility occurs in seasons outside of spring, when digestibility is most limiting to animal performance (Nation, 2015). For farmers the significance of this technology is to give a potential 10 per cent increase in milk solids produced per hectare, or reduced purchased supplementary feed.

It is beyond the scope of this report to debate the merits of genetic modification (GM) within the food chain. However, it is worth noting the significant challenges facing the commercialization of this ryegrass line:

- Will customers buy milk products where a large percentage of a cows diet has been declared to include genetically modified plants, and if so, at what price?

- Despite a scientific message defending GM, will society consent to farmers using this technology where the perceived benefit accrue exclusively to the farmer?
- How to make a business case for the Australian market to commercialize the GM ryegrass given the major seed companies are New Zealand based with a blanket ban on GM.

Endophyte selection

Endophytes are fungi that co-exist with grass plants living between the cell walls. They produce alkaloids that can provide the grass plant with protection from insect pest damage. Most grasses that are not selected with an improved endophyte have a naturally occurring wild endophyte. These wild endophytes contain a range of toxic alkaloids such as *Lolitrem b* that can cause grass staggers, and *Ergovaline*, which can cause heat stress.

In New Zealand, Cropmark Seeds has been breeding hybrid grasses called *festuloliums* for many years. One of the benefits of these ryegrass meadow fescue hybrids is that meadow fescue can contain an endophyte called *Neotyphodium uncinatum* which is not found in perennial ryegrass. This endophyte has no *Lolitrem b* or *Ergovaline* but has alkaloids called *Lolines*. Available through Cropmark Seeds the commercially available 'GrubOUT U2™' endophyte (a strain of *Neotyphodium uncinatum*) has several advantages. This *Loline* containing strain is safe for animals, toxic to a wide range of pasture pests, and is found in both the roots and leaves, unlike other endophyte (Cameron, 2014).

Pasture inoculated with the *Loline* endophyte is afforded protection from a range of pests including (Cropmark Seeds, 2014):

- Grass grub larvae.
- Black beetle adults and larvae.
- Argentine stem weevil (adults and larvae).

- Porina caterpillar (*Iolines* kill porina caterpillar in forced diet situations).
- Red headed pasture cockchafer.
  - Black field cricket.
  - Root aphid.
  - Pasture mealy bug.
  - Soil nematodes.

Photo 4: Cultivar Field Trials, Ashburton, New Zealand.

Source: A Pellett December 2014.

It is worth noting that the CRC is also developing new endophytes. Research has focused on identifying alkaloids that transmit successfully to different ryegrass cultivars and introducing a specific mutation designed to delete the toxins responsible for negative animal performance (Nation, 2015). The comprehensive knowledge about endophytes now makes it possible to design an endophyte for specific pastures and pests. The alternative approach is

far more time-consuming and expensive. For comparison, Cropmark Seeds last winter tested 85,000 individual plants for endophyte proteins.

The significance of selecting grass cultivars with new endophyte in enhancing productivity is threefold:

- Pasture yield is not constrained by pest and insect attack.
- Animal performance is not constrained as it might be with wild endophyte.
- The likely improved pasture persistence reduces the forced requirement for pasture renovation, reducing cost and allowing poorer performing paddocks to be targeted.

Cultivar selection tools

Recently both Ireland and New Zealand have launched comparison indexes to help farmers choose the best performing grass cultivars. Cultivars are ranked based on a calculated economic value and presented in an index format. This type of system is planned for Australia and is in development by Dairy Australia (Romano, 2015).

The pasture profit index - Ireland

The Irish dairy industry has a goal of increasing 2007 – 2008 milk production 50 per cent by 2020. One of the strategies to achieve this is by lifting pasture utilisation from an average 7.3 tonnes per hectare to 10 tonnes per hectare by 2020 (O'Donovan, 2014).

The recent introduction of the Pasture Profit Index by the Irish Agriculture and Food Development Authority is an initiative designed to deliver on the strategy. It is a total merit index designed to assist grass cultivar selection by farmers. Important grass performance traits such as seasonal dry matter production, quality, persistency, and silage yield are given varying economic values. Cultivars on a recommended list are given a ranking based on total economic merit (O'Donovan, 2014).

Table 1: Calculation weightings in the Irish Pasture Profit Index

Factor	Dry Matter Yield	Quality	Silage Cuts (1st & 2nd)	Persistence
Weighting	40%	15%	10%	35%
Pasture profit index - Euros per ha per year				

NB: Seasonal Dry Matter Yields are valued Spring 0.16, Summer 0.04, Autumn 0.11 in Euros

Source: (M. O'Donovan, 2014)

The information provided in this index is supported by another Irish initiative called the National Grassland Database and branded as PastureBase Ireland. This database is used by farmers to record their pasture assessments taken at 16 day intervals and with cultivars identified per paddock. With some 400 registered dairy farmers, half are regular users. The information is used to help benchmark the pasture management of the industry and provide relative cultivar performance using commercial farm data (O'Donovan, 2014).

The DairyNZ forage value index - New Zealand

Since 2012 New Zealand dairy farmers have been able to use the Forage Value Index to help support ryegrass cultivar selection. The index is produced by DairyNZ in conjunction with the New Zealand Plant Breeding and Research Association. Farmers can access the index via a web-based tool with the ability to filter selections on endophyte, geographical location, ploidy, ryegrass term and heading date. The addition of quality and persistence information is planned when evaluations can support this information (Bryant, 2014).

This index calculates an economic value presented in five star rankings, representing dollars per hectare. The economic value is calculated using a model called Farmax Dairy Pro and is

revised every year. This incorporates the effect of increased dry matter weighted by season and region on; animal performance, conserved feed and supplement saved. The index also provides seasonal performance values for winter, early spring, late spring, summer and autumn and are given different values depending on the region of New Zealand (DairyNZ, nd).

Table 2: New Zealand Forage Value Index Report Example.

CULTIVAR SELECTOR TOOL - FVI

Using the Forage Value Index (FVI), this tool allows you to objectively select the most suitable ryegrass cultivar for your farm. Select the relevant filters to find the cultivars that best fit your criteria.

Teal = selected. Grey = unselected

Filtered by: **UPPER SOUTH ISLAND, PERENNIAL RYEGRASS/AR1/AR37/NEA2/ENDO5/LE/SE/WE, DIPLOID, VERY LATE**

CULTIVAR	FVI (STAR RATING)	CONFIDENCE	WINTER	EARLY SPRING	LATE SPRING	SUMMER	AUTUMN	ENDOPHYTE	PLOIDY	HEADING DATE	M
			PERFORMANCE VALUES								
MATRIX SE	★ ★ ★ ★	9.7	3	4	2	4	4	SE	Diploid	Very Late	

FVI STAR RATING ($/HA)

★ ★ ★ ★ ★	$388 to $514
★ ★ ★ ★	$262 to $387
★ ★ ★	$135 to $261
★ ★	$9 to $134
★	-$117 to $8

Forage Value Lists for download:

Click on the region links below to open and download the forage value list.

Perennial Ryegrass: Upper North Island , Lower North Island , Upper South Island , Lower South Island

12 Month: Upper North Island , Lower North Island , Upper South Island , Lower South Island

Winter Feed: Upper North Island , Lower North Island , Upper South Island , Lower South Island

Source: DairyNZ website, feed section, cultivar selection, 2015.

Fodder beet

The attractiveness of growing fodder beet is its high yield potential. When grown successfully, yields of 20 - 30 tonnes of dry matter (DM) per hectare can be achieved (Pedofsky, 2014). For this reason it has grown in popularity in New Zealand since 2007 where it has been used to supplement lactating cows and as a winter feed source for dry cows and young stock.

Along with high yields the characteristics of fodder beet include (DairyNZ, nd):

- A high energy feed at approximately 12 MJ / kg DM.
- Low protein levels of 13 per cent.
- Low fibre levels of less than 20 per cent.
- High sugar content making the crop very palatable.

In New Zealand the potential for fodder beet is being assessed by the Beef and Lamb funded 'Fodder Beet Profit Partnership'. This is a group of 37 sheep, beef and dairy support farmers collectively sharing their fodder beet experiences. The program establishes yields, gross margins, growing cost, animal performance, and potential pitfalls. The information generated is used by farmers and industry providers to inform cultivar selection, refine agronomic practices, ensure maximum animal performance, and establish the crop's best fit within the production system.

The benchmark first year figures for 2014 indicate (Beef and Lamb New Zealand, 2014):

- Average yield of 18,200 kg DM per hectare (range 11,657 - 27,800).
- Average cost to grow of NZ $2,480 per hectare (range $1,865 - $3,451).
- An average cost of production of 14 cents per kg DM grown (range 8 – 26 cents).

NB: These results are for Canterbury foothill farms without irrigation at an average altitude of 305m, 37 different sites are included.

Photo 5: Farmers Fodder Beet Sowing Date Trial, Windwhistle, New Zealand.

Source: A. Pellett December 2014

Conclusions

Ryegrass is likely to remain the base of the Australian dairy grazing system. The ability to speed up improved cultivar development at reduced cost is an opportunity to place more emphasis on selecting grasses that perform best in Australian conditions rather than the broader Australia and New Zealand marketplace.

The inoculation of the best performing cultivars with novel endophytes will boost pasture production and animal performance. Pastures that persist for longer will allow a targeted selection of under performing pastures to be renovated lifting overall farm feed production.

Tactical use of fodder beet can increase overall farm feed production at a comparatively low cost of production.

As new breeding technologies enhance ryegrass performance, the widespread use of a pasture index in Australia will result in the best performing pastures for different needs being demanded. Plant breeders would be encouraged to focus research efforts on even more profitable cultivars as the index drives cultivars commercial success.

Chapter 4: Precision dairy

In the future it is clear that technology will become more important for the dairy farm business. The use of a broad range of technologies for monitoring and management can be described as 'Precision Dairy' or 'Smart Dairy Farming'. The productivity benefits of this emerging theme are a combination of:

- Increasing yield of both pasture and animals.
- Reducing costs as inputs are more targeted and timely.
- More efficient labour with reduced manual observation.

The term precision dairy has been defined as: "The use of information and communication technologies for improved control of fine-scale animal and physical resource variability to optimise economic, social and environmental dairy farm performance" (Eastwood, 2008).

The developing functionality of precision dairy goes beyond what, until recently, has largely been the automation of farm tasks focused on labour savings within the dairy shed. Now and in the future, intelligent use of information collected from individual animals, pastures, and soils will allow farmers to optimise production with far greater efficiency than has been achieved. Developments in this area will help address the challenges created by growing farm size, scarcity of labour, and complex production systems.

While the technology enables the collection and analysis of information, productivity gain will only occur when the farmer makes timely decisions.

Cow sensors

Photo 6: University of Kentucky Research Dairy Farm, Sensor Field Testing, United States.

Source: A. Pellett, December 2014

A range of available animal sensors capture information in the categories of (Bewley, nd):

- Nutrition - variable in dairy feeding based on health, size, and yield.
- Production.
- Health - mastitis, rumen condition, metabolic disorders, body temperature.
- Fertility – heat detection, pregnancy, and calving notification.

As an example of the range of options available, a comprehensive but non-exhaustive list of technologies can be found by accessing the web address: http://afsdairy.ca.uky.edu/files/extension/decision_aids/precision_dairy_technology_list.xlsm

DairyMaster MooMonitor+

This collar based cow monitor developed by DairyMaster in Ireland captures both cow health and fertility information with an algorithm designed to work in grazing systems. The MooMonitor+ is able to record when the cow is in heat, her feeding time, resting time, and rumination activity every 15 minutes. This information is transmitted up to one kilometre throughout the day, or saved for later upload as cows enter the dairy where a reader is present. The intensity of this measurement activity results in 210,000 data points per cow per year. The farmer can access the information either through a computer or mobile phone application, providing the ability for real time notifications. The MooMonitor+ software can draft cows automatically and has the added functionality of audible voice alerts during milking (Harty, 2014).

Using this type of information, in conjunction with milk production parameters, can add validity to a system-generated prediction. For example, confidence in a predicted mastitis event would be higher where cow activity, feeding / resting time, and milk production parameters are combined compared with using milk conductivity alone. The consolidation of data from multiple sensors will considerably improve decision support accuracy compared with single source technology.

Some insightful quotes highlight the relevance of precision dairy:

"There will be more focus on the individual cow in the future" (Harty, 2014), and

"The future of disease detection, should you check the cow or check the computer?" (Bewley,nd).

Herd navigator

The herd navigator product was launched in 2008 and is marketed by De Laval. It is yet to be released in the Australian market but is sold in many northern hemisphere markets. This

product can provide automated on-farm analysis of milk. This is combined with De Laval milking technology to form an automatic diagnostic tool and herd management solution.

The system is programmed to take samples from cows as they are milked automatically. These samples are selected only for cows that are due to be tested, from particular milking events, and on particular parameters. These samples can be tested on farm for (Herd Navigator):

- Timing of heat, pregnancy, and abortion by measuring progesterone.
- Mastitis, both clinical and subclinical, by testing the prevalence of an enzyme called LDH.
- Energy balance by testing for ketone levels.
- Diet optimisation by measuring urea indicating energy and protein balance.

This type of system has the potential to automate, standardise, and improve the accuracy of heat detection, pregnancy testing, mastitis detection, and identification of poor appetite and cow health events. Farmers benefit by treating cows earlier, thereby incurring less lost production and reducing the incidence of costly clinical cases. Automatic sampling of milk throughout a cow's lactation not only makes heat detection easier but removes the need for invasive procedures commonly used to confirm pregnancy.

Precision dairy in the paddock

The ability to remotely sense pasture yield and quality would be extremely useful. Receiving this type of information throughout the growing season would enable more accurate pasture allocation decisions. A more complete knowledge of what feed is available, at what quality and how fast it is growing would facilitate better grazing management.

The combination of Remote Piloted Aerial Systems, GPS navigation, and sensors has the potential to deliver pasture yield and quality measurements (Yule, 2014). Research at Massey University in New Zealand is being conducted using high definition imagery taken at 660 metres above ground in 350 metre widths. At present, quantifying pasture covers requires a lot of data processing. For example, in order to get high resolution, a pixel size of 2.5 centimetres on the ground equates to 16 million pixels per hectare requiring analysis. As technology continues to improve this approach has the potential to automate pasture assessment. As well as replacing the often time consuming manual methods, using high definition imagery may improve accuracy and consistency. Using this information in conjunction with ground based robots would enable automated weed control and variable fertiliser application.

Virtual fencing is another technology that has potential within the precision dairy area (Trotter, 2014). Control of pasture allocation can be achieved using a special collar worn by the herd. The farmer can allocate pasture by setting a virtual fence that the animal respects when warned by audible alarm and electrical charge. The application of virtual fencing could make multiple daily allocations possible and, when linked to remote pasture assessment, help manage grazing. In addition, for farmers with voluntary cow grazing systems, these collars may assist in prompting cow traffic flow.

Precision dairy challenges

With the adoption of most new technologies comes more data that can be turned into management information. However this additional information is only beneficial if farmers make better decisions. The most attractive technologies to farmers are labour saving in nature as these demonstrate a tangible cost/benefit comparison. Benefits gained from adopting technologies that increase efficiency can be more difficult to calculate and require a longer time frame to recover the investment (Edwards, 2014).

As technology rapidly evolves, any investment in new technology is quickly out of date. There is reluctance to invest in any particular system due to the risk of the purchased technology becoming quickly outdated. This could necessitate a new investment model such as a subscription based financing model. These short term leases on new machines and user information systems would ensure continued access to the latest technology (Smit, 2014).

Capturing, analysing and controlling data is becoming increasingly important. The information used to make optimum decisions is often generated within systems provided by private companies. This results in a number of challenges:

- Data from different systems cannot be aggregated and lacks standardised data definition.
- Knowledge is isolated from industry good organisations and accrues to private companies.
- Switching systems is difficult due to the level of investment and customised installation.

Optimising the value chain

The abundance of information generated by precision dairy technologies on farm in real time has potential to support a more responsive value chain.

Demand for farm inputs such as fertiliser could be predicted based on paddock yield, soil fertility mapping, historical application and forecast weather events. As a consequence of this prediction the timing of supply and price may adjust accordingly. In the Netherlands a program has been developed where the robotic milking system, having detected a cow is ready for breeding, provides the artificial breeding company with historical genetic information and production data that determines sire selection and requests an artificial

insemination (AI) technician (Roos, 2014). The farmer contracts a range of bulls at a fixed price and the service offering becomes integrated into the farm business.

Improved accuracy of forecast milk production would be of great value to the milk processor. Precision dairy technologies will allow more accurate predictions of future supply patterns based on the real time analysis. The ability to combine data such as milking cow numbers, lactation stage, production, pasture growth rates, soil temperature, soil moisture, weather forecast and supplement prices could be part of the milk supply arrangement between farmer and processor. Milk processors armed with this information could optimize product mix in response to customer demand. Development of dynamic price signals between the processor and farmer would encourage farm production to be adjusted according to marginal profitability much faster. The author expects that the faster matching of supply and demand through the supply chain would reduce price shocks.

Another benefit is that customers can more easily make purchasing decisions based on information collected on-farm. The process of guaranteeing quality is automated and the information generated provides traceability through the supply chain to the farm.

Conclusions

The development of precision dairy technology is in its infancy; it is likely both the cost/benefit and accuracy of such systems will improve over time.

Harnessing data from multiple sources on the farm improves the accuracy and confidence in precision dairy decisions. These systems can increase yields, reduce costly inputs and allow labour to focus on higher value management activities.

The improved capacity to generate farm based information in real time offers the potential to change the way the supply chain is integrated and how fast the demand and supply equation is balanced.

If Australian dairy is to enjoy the full benefits of precision dairy, investments need to be made to ensure the nature of the grazing system is considered. It would be sensible to collaborate with other countries focused on grazing systems.

Chapter 5: Cow efficiency

For most dairy farmers livestock represent the second largest business asset, therefore any increase in animal efficiency will provide significant productivity gain. With purchased feed being a major cost item any improvement in dairy cattle feed conversion efficiency would be of major benefit. This would allow feed costs to be reduced while holding production constant; more likely in a grazing system, an increase in stocking rate translating into more milk solids per hectare.

While animal efficiency is a major focus in the pig, poultry and beef industries and despite large increases in dairy cow total production, selecting for feed conversion efficiency has proved difficult in lactating grazing cows. Accurate assessments have proved difficult due to variation in rumen fill, changing bodyweight, and body reserves that are mobilized during lactation. The lifetime efficiency of a lactating dairy cow is also a more complex breeding goal than that of growing a pig, chicken or beef animal to a target weight (Macdonald, 2013).

What is cow efficiency?

Gross efficiency

The widespread use of artificial insemination to access improved genetics combined with better nutritional management of cows has contributed to increased milk production relative to bodyweight. For example, in the New Zealand dairy industry, the Livestock Improvement Corporation (LIC) estimates a one per cent gain per annum. This is a measure of gross efficiency achieved through dilution of the fixed costs of maintenance, while increased milk production drives increased feed intakes. The potential for ongoing improvement in gross efficiency is finite and is assessed to be four per cent of live weight as a maximum intake of pasture (Davis, 2014).

Feed conversion efficiency or residual feed intake

Greater feed conversion efficiency (FCE) does not necessarily relate to total levels of milk production. FCE is the difference between the actual amount of feed eaten and the expected amount eaten, this is referred to as residual feed intake (RFI) (DairyNZ, 2013). Of interest to the dairy farmer is that some cows, although of the same size, equivalent milk production and achieving similar reproductive performance, require less feed than other cows.

Is the RFI difference significant?

Research on RFI has recently been completed by very similar studies conducted in parallel in Australia and New Zealand.

The New Zealand study evaluated 80 cows for feed conversion efficiency over 35 days in early first lactation. The cows were measured in two groups of 40, classified as most and least efficient using the results of an earlier heifer calf study (Macdonald, 2013).

Table 3: Milk solids production and feed intake for high and low efficient cows

	Most efficient	Least efficient	SED	P
Milk solids (kg/cow/day)	1.05	1.04	0.01	0.82
Mean live weight (kg)	407	401	6	0.31
Feed intake (kg) DM/cow/day)	18.9	19.1	0.32	0.39
Divergence# (kg DM/cow)	-0.31	0.31	0.22	0.007

#Divergence is the difference between the high and low efficiency groups

Source: (Waghorn, 2013)

The significance of the range in dry matter intake required to produce the same amount of milk is that the most efficient cows require three to four per cent less dry matter.

The study in Australia was conducted in Victoria and measured 50 cows classified as feed efficient and 58 cows classified as feed inefficient based on the results of the heifer calf study mentioned earlier. These animals had RFI calculated in first lactation for 32 days by assessing dry matter intake of cubed lucerne hay and grain, while measuring milk production and live weight change. The findings of this study confirmed the New Zealand results. Differences in feed conversion efficiency identified as calves remained significant once the same animal was a lactating cow.

Is it a feasible breeding objective?

The difficulty in including RFI in a breeding program has been the high cost of widespread recording of feed intake in conjunction with changes to cow live weight and milk production. The impracticality of measuring these factors in a widespread progeny test program means that validation of RFI using actual sire daughter information is currently unlikely.

In New Zealand, LIC conducted an experiment to see if RFI could be predicted in a group of independent cows. Genotyping of 3359 cows born in 2005 or 2006 was completed using the Bovine SNP50 BeadChip. From this group 197 cows (representing the top and bottom 10 percent) were successfully evaluated for RFI after having been selected using genomic predictions for RFI.

These results show that dairy cows selected using a genomic prediction for RFI demonstrated actual differences in RFI. The use of genomic technology to form a prediction of RFI has allowed the recent development of the world first 'feed saved' Australian breeding

value. This is expected to be released within a breeding index during April 2015 (Dairy Australia, 2015).

Table 4: Actual difference in RFI when selected for RFI by genomic prediction

RFI Group	Low	High	SED
Efficiency	(efficient)	(inefficient)	
N	99	98	
Milk solids kg/day	1.38	1.34	.03 ns
Milk yield kg/day	16.8	16	0.5 ns
LW kg	514	511	5.6 ns
LW change kg/day	0.24	0.27	0.02 ns
DM intake kg/day	25	25.6	0.27 ns
RFI kg DM/day	-0.35	0.36	0.22 ***

(LW = live weight, ns = not significant, *** P<0.001)

Source: (Steve Davis, 2013)

Can RFI fit within a broader breeding objective?

As farmers have much broader breeding goals than just achieving a more feed efficient cow, selection for RFI will have to sit alongside many other desirable traits within a breeding program. Defining an industry-wide breeding objective is increasingly important as the rate of genetic gain speeds up due to genomic technology. Failing to define an all encompassing

future-looking breeding objective could have negative impacts on future dairy herd profitability (Berry, 2014).

Inclusion of RFI within a breeding objective will have some impact on the progress of other traits being selected for. This is the case even when RFI is independent of milk production as the selection intensity for other traits is reduced to accommodate an additional breeding objective.

Leading geneticist Donagh Berry suggests that a national breeding goal should be holistic and future-looking and nominates the following characteristics defining the ideal cow of the future (Berry., 2014):

- Produces a large quantity of milk (and meat).
- Good reproductive performance.
- Good health status.
- Good longevity.
- Does not eat a large amount of food.
- Easy to manage.
- Good conformation.
- Low environmental footprint.
- Resilient to external perturbations such as extreme weather and new diseases.

The message is not to breed for one characteristic in isolation and include traits that are likely to become more significant in the future.

It is important to note that although these characteristics will vary in heritability, the ability to achieve genetic gain is less reliant on the strength of heritability, thanks to the use of genomics. Rapid genetic gain in lowly heritable traits is possible. This is dependent on high

accuracy of selection and genetic variation. The extent of genetic variation across all traits is similar at approximately five per cent (Berry, 2014).

A method to improve accuracy of selection for the RFI trait collection of data from a large population at reasonable cost is required. A solution could be the profiling of dairy cows using the results of milk samples. Milk mid-infrared spectroscopy is regularly used for testing fat and protein and has the potential, once combined with prediction equations, to quantify feed intake, cow energy balance, feed efficiency and methane emissions (Berry, 2014).

Broader herd productivity

Genomic prediction

In the United States farmers can use a genomics-based product called 'Clarifide' that provides predicted animal profitability in a net merit index to inform breeding and management decisions (Zoetis, 2012). For example, heifers with predicted profitability less than the herd average could be culled before incurring rearing costs or sold through the export market in the knowledge that the herds best genetics have been retained. Elite heifers could be identified and submitted to a more costly sexed semen mating strategy instead of a blanket approach.

Precision genomic mating - designer matings

Once a broad breeding goal has been developed, the use of genomic information can assist in facilitating rapid genetic gain by highly targeted matings. This approach effectively predicts the additive merit of mating individuals, including which traits are likely to present themselves as dominant in the resulting progeny. This would allow selection of a sire with the best combining ability for individual or groups of cows with the guarantee of which traits the next generation will inherit and display (Berry, 2014).

Concerns about negative animal performance caused by inbreeding can also be reduced using genomic information in breeding decisions. This is due to the variation between the proportions of genes shared by related animals. Although very unlikely, two full siblings can be completely unrelated. Genomic information could be used to retain desirable elite genetics when breeding related animals. There would be less need to restrict breeding choices to eliminate undesirable inbreeding effects as genomic knowledge assures that blanket eradication of lethal genes is not required (Berry, 2014).

Genomic guided farm management

The term 'reprogenomics' is defined by Donagh Berry as how the genome of an animal affects its response to alternative reproductive treatments. This implies the use of genomic information to select what would be the most effective reproductive strategy for an individual cow. Productivity would benefit from the targeted use of synchronisation and sexed semen, in the knowledge that application of these more expensive approaches is used only where the cow is likely to have the best chance of pregnancy.

Understanding what animal health status a cow is predisposed towards by using genomics provides an opportunity to tailor preventative treatments. An example is the use of dry cow treatments only on predicted high risk cows.

As genomic predictions become more accurate, the richness of information will enable cows to be bred selectively for differing production systems. Management decisions would also be more informed and successful when based on the unique knowledge of a particular herd or individual. This may improve calving rates in seasonally calved herds as the use of controlled internal drug release (CIDR's) are guided by the predicted responsiveness of the individual cow.

Conclusions

Differences in feed conversion efficiency between lactating cows exist and are economically significant. Using a proving scheme for the trait in commercial herds is difficult and expensive. Currently the opportunity to breed for better feed conversion efficiency is guided by genomic prediction.

It is recommended that selection for better feed conversion efficiency is part of a wider breeding objective. Breeders should recognize that the use of genomic information can significantly speed the rate of genetic gain and hence the important consideration of likely future objectives.

Using genomics to understand an individual herd will allow the farmer to form an efficient customized approach to herd management. Moving beyond a blanket approach will achieve better results boosting productivity.

Recommendations

There is opportunity for dairy industry resources to re-focus research and development activities on robotic milking systems capable of batch milking cows at commercial scale.

Greater uptake of desirable robotic technologies would be enhanced by the introduction of a new technology access finance model. The dairy industry can play a role in proactively developing a new model.

Assessment of the potential for fodder beet in Australian dairy conditions is required and would be a valuable industry resource. Independent regional trials are needed to quantify the best performing cultivars, recommended sowing dates, harvest dates, and weed management strategies. Guidelines such as these would provide farmers with the technical information to experiment on farm and analyse the potential fit within different production systems.

As the range of systems available to capture and interrogate farm data expands there is a growing challenge in consolidating data from multiple proprietary systems. Consideration should be given to forming a dairy data co-op owned by farmers. This entity would enable management of farm level information from multiple sources, provide control and security for the farmer, be accessible for industry good research, and mitigate the cost and technology capture by global providers.

Dairy Australia has a perennial ryegrass cultivar selection index in development expected to be available in the next two to three years. Extending this excellent concept to an online knowledge bank would assist farmers grow and consume more pasture per hectare. Additional information uploaded by both participating farmer and research sites could

include cultivar growth rates, leaf emergence rates, endophyte type, soil fertility, soil moisture, plant population, and pasture establishment and renovation techniques. Pasture treatments such as fertilisers, pesticides, and gibberellic acid could easily be noted and evaluated by farmers.

To explore and promote the possibilities of precision dairy technology the dairy industry should establish a demonstration farm. This would be a unique model that combines robotic and autonomous systems both in the milking process and around the farm. The focus of the farm is to quantify the commercial benefits and determine the possibilities for the whole farming system. Of additional interest would be the impact this farming system may have on the wider value chain.

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Plain English Compendium Summary

Project Title:	**Improving productivity for Australian pasture-based dairy farming.**
Nuffield Australia Project No.:	1416
Scholar:	Aubrey Pellett
Organisation:	A O Pellett & J A Morrison
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Objectives	To identify the new technologies, management practices and other factors that are likely to improve dairy farm productivity in the future.
Background	In the past decade productivity growth on Australian dairy farms has slowed. As farm profitability is determined largely by international milk prices, rising input costs and variable seasonal conditions; long term productivity improvement is required to maintain and increase real returns.
Research	Research involved travel for in excess of 20 weeks to countries including Australia, New Zealand, United States, United Kingdom, Ireland, Germany, the Netherlands, Sweden, China, Canada and the Philippines. Information was collated from interviews with farmers, academics, commercial product managers, farm consultants, scientists, and review of published and un-published papers as well as internet searches.
Outcomes	Significant productivity opportunities have been identified in the areas of batch milking robotic systems, paddock robots, genomic assisted ryegrass breeding, pasture selection indexes, development of novel endophytes, growing fodder beet as a high yielding crop, incorporating feed conversion efficiency into a livestock breeding index, using genomic information to guide herd management decisions, mining the data that precision dairy makes available and sharing farm information to facilitate greater supply chain integration.
Implications	To promote the adoption of these productivity opportunities the dairy industry could; support development of a new technology finance model, publish fodder beet guidelines for Australian conditions, facilitate a dairy data co-op, provide a ryegrass cultivar selection index and set-up a new demonstration farm to showcase precision dairy.