DAIRY RESEARCH FOUNDATION

CURRENT TOPICS IN DAIRY PRODUCTION

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WELCOME TO THE DAIRY RESEARCH FOUNDATION 2012 SYMPOSIUM

It is with pleasure that we present to the Australian dairy industry, our 2012 Dairy Research Foundation Symposium. The Symposium is designed to integrate with the annual meetings of the Dairy NSW Regional Development Program and NSW Farmers' Association Dairy Section – which means having NSW dairy industry's entire major groups meeting at a single point.

The 2012 Symposium has adopted the theme "Energising Dairy" – and looks at energy in all its shapes and forms. This theme embraces dairies, feeding systems, reproductive systems as well as people systems and by doing this we offer a very diverse program that is spearheaded by a combination of scientists and farmers.

The program framework begins on Wednesday July 4 with the Dairy NSW and NSW Farmers' Association Dairy Section industry meetings, followed by Day 1 of the symposium (July 5) at the Liz Kernohan Conference Centre on the University Campus. The second day (July 6) is much less formal, with a focus on participation, interaction and absolutely no powerpoint presentations – and staged at the Robotic Milking Research Farm.

While Automated Milking Systems – or robots – feature in only a small way this year – we are conscious that a visit to the Robotic Milking Research Farm for anyone who is yet to see this technology – is a well worthwhile activity. And, so while the program content of Day 2 is largely 'non robotic' – there is always the opportunity to view the robotic rotary whilst there.

A key philosophy of the Dairy Research Foundation is to nurture and promote young and emerging professionals in the dairy industry: Young scientists, young farmers and young service providers. Our approach to program design has been to integrate youth with experience and to do this in a manner that creates a really inter-personal experience for the delegates. We know from experience that delegates get very involved in the new work that our students are putting forward and it is simply good for the soul to see and hear youthful enthusiasm and a commitment to working in dairy science via this program.

Meanwhile, the Annual Symposium Dinner (sponsored by Dairy Australia) and the announcement of the Dairy Science Award will once again take place at Gledswood Winery – on the evening of July 5. This is sure to be a great night of fellowship.

Assoc Professor Yani Garcia

Chair, Dairy Research Foundation 2012 Symposium

DAIRY RESEARCH FOUNDATION 2012 SYMPOSIUM ORGANISING COMMITTEE

Associate Professor Yani Garcia, *University of Sydney*

Dr Kendra Kerrisk, *University of Sydney*

Dr Pietro Celi, *University of Sydney*

Dr Cameron Clark, *University of Sydney*

Ms Sherry Catt, *University of Sydney*

Ms Michelle Heward, *University of Sydney*

Mr Michael Perich, *Dairy Research Foundation*

Mr Bill Inglis, *Dairy Research Foundation*

Ms Kerry Kempton, *NSW Department of Primary Industries*

Ms Vicki Timbs, *NSW Department of Primary Industries*

DAIRY RESEARCH FOUNDATION 2012 SYMPOSIUM SPONSORS

The Dairy Research Foundation would like to acknowledge and thank the following companies for their support

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THE DAIRY RESEARCH FOUNDATION WOULD ALSO LIKE TO ACKNOWLEDGE AND THANK THE FOLLOWING EXHIBITORS FOR THEIR SUPPORT

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THE EMERGING DAIRY SCIENTISTS' PROGRAM

SPONSORED BY THE GARDNER FOUNDATION

The DRF is pleased to showcase the talents of 10 emerging dairy scientists at the 2012 event. These presentations have been integrated into our Day 2 program and all have been paired with a senior consultant or scientist to create a highly interactive series of discussions.

The objective of this process is to offer a quality professional development opportunity for these emerging scientists and to introduce them to and integrate them with our industry. The program is in the form of a competition, where we ask you, the audience, to assess the quality, relevance and interest of each presentation – with the audience scores combined to determine a winner – announced at the conclusion of Day 2.

The program clearly identifies those competing in the Emerging Scientists' Program – and we encourage your full participation which will do much towards encouraging our next generation of dairy science.

KEYNOTE SPEAKERS

JULIAN CRIBB

Julian Cribb is the principal of Julian Cribb & Associates and specialises in science communication.

A journalist since 1969, he was editor of the "National Farmer" and "Sunday Independent" newspapers, editor-in-chief of the "Australian Rural Times", and chief of the Australian Agricultural News Bureau. For ten years he was agriculture correspondent, science and technology correspondent and scientific editor for the national daily "The Australian".

He has received 32 awards for journalism including the Order of Australia Association Media Prize, the inaugural Eureka Prize for environmental journalism, the inaugural AUSTRADE award for international business journalism, the Dalgety Award for rural journalism, two MBF Awards for medical journalism and five Michael Daley Awards for science journalism.

His personal published work includes more than 8,000 print articles, 1000 broadcasts, 1000 media releases and 300 speeches as well as "The Forgotten Country", six editions of "Australian Agriculture", "The White Death", "Sharing Knowledge" and "Dry Times" (with Mark Stafford-Smith). His book on the global food crisis, "The Coming Famine" was published in August 2010.

DR JUDE CAPPER

JUDE L. CAPPER, Ph.D. is an Assistant Professor of Dairy Science in the Department of Animal Sciences at Washington State University (WSU). Born in the UK, she undertook her undergraduate and graduate degrees at Harper Adams University College (UK) before doing post-doctoral research at Cornell University. Her current position is split between teaching, extension and research, with her research focusing on modelling the environmental impact of livestock production systems. Current research includes comparisons of historical and modern production practices in dairy and beef industries; and the effect of technology use and management practices upon environmental impact.

REDUCING LOSSES THROUGHOUT DAIRY PRODUCTION

DR. JUDE L. CAPPER

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The importance of improving productivity in order to reduce the environmental impact of dairy production is without question. Advances in management, nutrition, genetics and animal welfare have improved milk yields over time, leading to reductions in resource use and greenhouse gas emissions per unit of dairy product. Continuous improvement will be of crucial importance in future food production systems to meet the dual challenge of producing sufficient dairy to supply the growing population while reducing environmental impact. Current research has focused on milk yields, yet a considerable knowledge gap exists as to the contribution made by other on-farm practices and herd dynamics, e.g. the effects of improved health, reproduction or animal bodyweight upon environmental impact. It is crucial that these knowledge gaps are filled in order for producers to make future management decisions based on environmental sustainability as well as economic viability. All stakeholders within food production need to gain a greater awareness of the multifaceted nature of sustainability in order to make informed dietary choices in future. This will offer conventional livestock producers the opportunity to reclaim the concept of sustainable food production, which is often perceived as only applying to niche production systems.

INTRODUCTION

The U.S. Environmental Protection Agency defines sustainability as “meeting society’s present needs without compromising the ability of future generations to meet their own needs” (US EPA, 2010b). In this context, food production comes under considerable scrutiny. Global food security and environmental issues are significant issues for governments and policy-makers who are conscious not only of the proportion of their population that is currently food-insecure, but also of the prediction that the global population will increase to over 9 billion people in the year 2050 (U.S. Census Bureau, 2008). The extent of population growth varies amongst regions with the greatest increases predicted to occur in developing nations such as Africa, China and India (Tilman, Cassman, Matson, Naylor, & Polasky, 2002). This is complicated by the suggestion that developing nations will enjoy a per capita income similar to that currently seen within North America. As incomes increase, so does the demand for high-quality animal proteins such as meat, milk and eggs, thus the Food and Agriculture Organization of the United Nations (FAO) suggests that total food requirements will increase by 70% by 2050 (Food and Agriculture Organization of the United Nations, 2009b).

In the event of considerable population growth, future competition for water, land and energy between livestock production and human activities will be augmented and the global dairy industry will face a significant challenge in producing sufficient milk to meet consumer demand, using a finite resource base. This issue is not confined to a future scenario – current concern over dwindling natural resources and climate change leads to debate as to whether the dairy industry should continue to intensify and improve productivity to feed the increasing population, or return to less-productive traditional methods? This paper will discuss the role of productivity in mitigating climate change with reference to some of the most commonly heard misconceptions relating to the environmental impact of dairy production

Myth: Livestock production is principally responsible for climate change

The environmental impact of livestock production is one of the most commonly discussed issues relating to global dairying. As a result of the recent influx of media articles, television shows and restaurant menus showcasing food choices that are perceived to be environmentally-friendly, a lexicon of previously-unfamiliar terms including "carbon footprint", "sustainability" and "local food" have entered everyday conversation. The rise of "ethical consumerism", defined by Singer and Mason (2006) as "an interest in the way in which food is produced, the practices employed and a concern for low environmental impact, high animal welfare and optimal worker conditions", has the potential to significantly influence the management practices and systems within dairy production. This may be considered to be a positive development, however it may only have positive long-terms effects if the views expressed and decisions made by consumers are based upon scientific evidence rather than philosophical ideology and misconceptions.

In 2006, the FAO released the oft-quoted report "Livestock's Long Shadow", which concluded that livestock production is responsible for 18% of global anthropogenic greenhouse gas (GHG) emissions (Food and Agriculture Organization of the United Nations, 2006). As a damning indictment of the global livestock industry's effect on the environment, this could hardly have been more suitable fodder for those groups opposed to animal agriculture. Indeed activist groups have quoted the aforementioned 18% statistic as evidence that abolishing animal agriculture would have a beneficial environmental impact (Koneswaran & Nierenberg, 2008; McMichael, Powles, Butler, & Uauy, 2007; The Humane Society of the United States, 2008). Despite its adoption by the majority of media and activist groups as scientific evidence for the principal role of livestock in causing climate change, the FAO report was not without its detractors and Pitesky *et al*. (2009) produced a detailed paper outlining the flaws within the report. The most notable issue related to the notorious 18% statistic, which was based upon a comparison between carbon emissions derived from a highly detailed and inclusive life cycle assessment of global livestock production, to the carbon emissions from the fuel combustion phase of global transport. As the FAO later admitted, differences in the methodology between predicted carbon emissions from livestock production and transport rendered the comparison invalid. The exact proportion of global carbon emissions produced by livestock production has yet to be quantified although it is suggested to be somewhat less than the original 18% estimate. Nonetheless, although the FAO report was seen as damaging by many within the livestock industry, it fulfilled two vital roles with respect to climate change – the magnitude and shock-value of the 18% figure ensured that climate change became a priority for industry groups, and carbon emissions from all livestock sectors came under scrutiny.

Regardless of potential flaws in the FAO report's methodology, which were been extensively discussed by Piteskey *et al*. (2009), the major issue with the results is not how they were derived, but how they were used. Global averages have a significant and over-arching flaw in that they cannot be applied to a regional production system with any degree of confidence, yet the 18% figure was widely quoted as being representative of individual regions regardless of inherent variation in system, management or productivity. For example, the U.S. EPA (2010a) quantified primary anthropogenic GHG sources within the U.S., concluding that total agriculture (livestock and crops) contributed 6.32% of total national GHG emissions in 2009. This 6.32% can be further partitioned into 3.12% from animal agriculture, with the remaining 3.20% allocated to human food crops. To reconcile the considerable difference between the global (18%) and national (3.4%) estimates of livestock's contribution to GHG emissions, it is therefore necessary to explore the data in more detail.

The global FAO figure attributes almost half (48%) of total carbon emissions to carbon released by clearing forestland to grow animal feed. This is exacerbated by competition for cropland between animal feed and biofuels, with a considerable amount of formerly feed-producing land being diverted into non-feed crops (Sawyer, 2008). Carbon emissions from deforestation are a major component of agricultural systems where a considerable portion of animal feed is derived from land that has recently been converted from forest or woodland, regardless of whether the feed is used domestically or imported, e.g. imports of soyabean meal from South America into Europe. By contrast, the majority of U.S. feedstuffs are produced domestically: cropland area has remained relatively stable (USDA, 2002) with increased crop yields compensating for increased demand for feed and food crop production. Indeed, the U.S. is actively reforesting, with an average increase in forestland area of 0.2%/year over the past 30 years (Smith, Miles, Vissage, & Pugh, 2005). Reforestation increases carbon sequestered from the atmosphere into plant tissue, with an average of 6.4 kg carbon sequestered annually per (mature) tree (Sampson & Hair, 1996), yet the mitigating effect of carbon sequestered by new forest growth is not accounted for in the U.S. EPA (2010a) calculations. Disregarding the contribution of deforestation to the global estimate of livestock's contribution to GHG emissions leaves a figure that still remains approximately 3x higher than the U.S. national estimate – a direct result of regional productivity variation.

Myth: Dairy systems are equally productive across the globe

Livestock's environmental impact is directly affected by system productivity (Capper, 2010, 2011a; Capper, Castañeda-Gutiérrez, Cady, & Bauman, 2008), yet by its very nature, the FAO's global average includes a wide range of regional system efficiencies. If we examine international trends in productivity, increased milk yield (expressed as energy-corrected milk per cow) has a mitigating effect upon carbon emissions on a global basis. As shown in Figure 1, major milk-producing regions (U.S, Canada, New Zealand and Europe) have all demonstrated an increase in average milk yield per cow since 1961, the rate of improvement varying from 129 kg/year and 117 kg/year for the U.S. and Canada respectively, to 77 kg/year and 24 kg/year for Euro-6 (an aggregate of the top-6 milk producing countries in Europe: Netherlands, UK, Germany, France, Italy, Poland) and New Zealand (Food and Agriculture Organization of the United Nations, 2009a). Productivity improvements in the U.S., Canada and Europe were facilitated by genetic selection for increased milk yield as well as advances in nutrition, management and animal health. Differences in the rate of improvement between various regions may be partially explained by the attitude towards technology and innovative management practices. The U.S. is generally pro-technology whereas Europe is less receptive (Moses, 1999; Wilcock, Pun, Khanona, & Aung, 2004). By contrast, the New Zealand system is pasture-based, has a lower emphasis on productivity than that displayed by the other regional dairy industries and has an average lactation length of only 252 days (LIC, 2008).

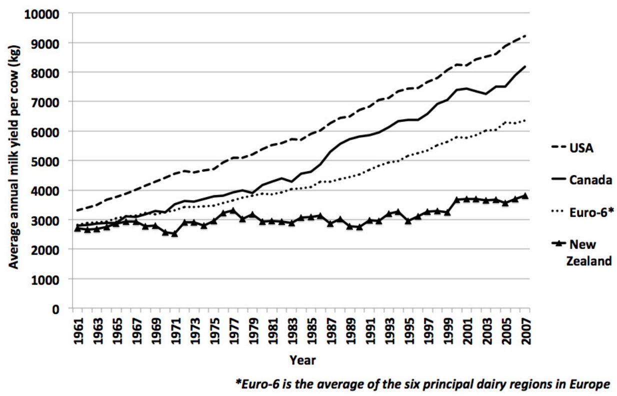

Figure 1: Average annual milk yield per cow for selected global regions between 1961 and 2007. Data from FAOSTAT (Food and Agriculture Organization of the United Nations, 2009a).

The environmental effects of regional productivity are exemplified by the results of a second FAO (2010) report that focused on modeling global and regional GHG emissions from dairy production using life cycle analysis (LCA). As production system intensity declines and the average milk yield shifts from approximately 9,000 kg/cow for North America to ~250 kg/cow for Sub-Saharan Africa, the carbon footprint increases from 1.3 kg CO2-eq/kg milk to 7.6 kg CO2-eq/kg milk (Figure 2). It is interesting to note that although ruminants are generally agreed to make a greater contribution to livestock's GHG emissions than monogastric animals as a result of enteric CH4 production, the FAO conclude that dairy production only contributes 4.0% to global GHG emissions. If this result had been released in the absence of the previous FAO (2006) report citing 18%

as a global livestock estimate, it is tempting to suggest that the current focus on GHG emissions from dairy production might have been considerably lessened.

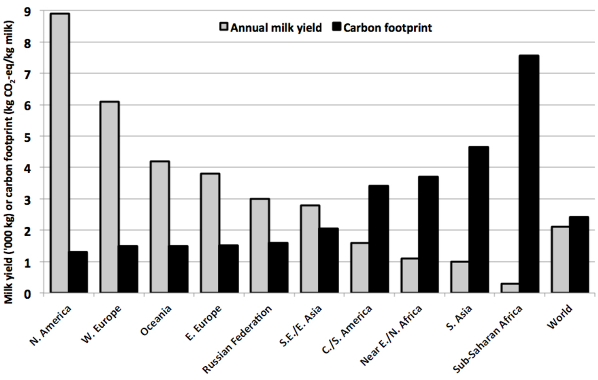

Figure 2: Average annual milk yield and carbon footprint per kg of energy-corrected milk for selected global regions, adapted from FAO (2010)

Sustainability often focuses on environmental or economic metrics, yet it must be assessed within the triumvirate of environmental responsibility, economic viability and social acceptability, with true sustainability occurring when these factors are in balance. Regional dairy system sustainability should not be limited to the environmental impact of the dairy system, but must also consider the economic and social implications. For example, use of a hormone such as recombinant bovine somatotropin (rbST) that reduces resource input, GHG emissions and economic cost per unit of milk fulfills two of the three criteria, yet may not be acceptable to the consumer (Capper *et al*., 2008; Kolodinsky, 2008). While the FAO data in Figure 2 could provoke the conclusion that all regions should adopt North American and Western European-style production systems in order to reduce the carbon footprint of dairying, or that production should be focused in these areas and be discouraged in less productive regions such as Sub-Saharan Africa and South Asia, the significant social (both status and nutritional) and economic value of dairying in less-developed regions must not be underestimated. The challenge for global dairy production is to optimize sustainability within each region rather than prescribing the best "one-size-fits-all" global system.

Myth: Efficiency is bad for the environment

The FAO (2010) assessment of GHG emissions from dairy production demonstrates that dairying in developed regions has a lower carbon footprint. However, intensification varies considerably between regions. Intensive dairy systems such as those represented by large farms in the U.S. are highly efficient, with a low carbon footprint per unit of milk, and within these populations dairy products are generally considered a staple food (USDA, 2005). However, intensive dairying may be at the greatest risk from a social acceptability standpoint, as such systems are perceived to be environmentally damaging. Although it is widely understood that improving efficiency and productivity reduces expense, resources and waste, the consumer often considers "efficiency" to have negative connotations when applied to large-scale contemporary food production. To better understand the impact of improved efficiency on GHG emissions an economic metaphor can be used in which economic fixed costs are a proxy for maintenance nutrient requirements (Capper, 2011b).

Consider a bakery producing bread with fixed costs of $1,000 (rent, taxes, etc) incurred each day, regardless of productivity. If the factory produces 10,000 loaves per day, the fixed costs can be divided by the total output ($1,000/10,000 loaves = $0.10/loaf] and the bread priced accordingly. If the bakery improves productivity so that 20,000 loaves are manufactured in the same time period, efficiency improves and fixed costs are spread over greater output ($0.05/loaf). The same concept can be applied to livestock production and is known as the "dilution of maintenance" effect. All animals in a dairy population have a nutrient requirement that must be fulfilled each day to support vital functions, minimum activities and non-lactation-related productivity (i.e. pregnancy, growth) – these may be considered as the "fixed costs" of dairy production. Improving productivity such that a greater amount of dairy product is produced in a set period of time thus reduces the total energy cost per unit of food produced. Figure 3 illustrates this concept: as milk yield increases from 22 kg/day to 31 kg/day in a lactating cow, maintenance requirements do not change, but are diluted out over more units of production and are thus reduced from 42% to 34% of the total energy requirement. Concomitantly, the daily metabolizable energy required per kg of milk is reduced from 8.1 MJ/kg to 7.2 MJ/kg. Daily energy requirements may be considered a proxy for resource use (feed, land, water, fossil fuels) and waste output (manure, GHG). Improving productivity therefore reduces environmental impact per unit of food. In this example, as milk yield increases, fewer lactating cows are required to produce a set amount of milk and the number of associated support animals (dry cows, replacement heifers, bulls) that serve to maintain dairy herd infrastructure is concurrently reduced. The environmental impact per unit of milk is therefore reduced through dilution of maintenance at both the individual cow and the dairy population level (Capper, Cady, & Bauman, 2009; Capper *et al*., 2008).

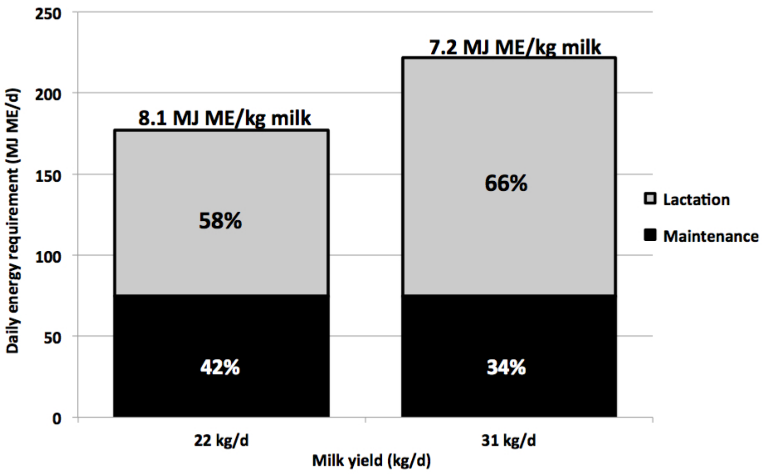

Figure 3: The impact of increasing daily milk yield on the proportion of daily energy used for maintenance vs. lactation – the "dilution of maintenance" effect.

Myth: Historical production systems had a lower carbon footprint

To quantify the effects of system intensification on GHG emissions from dairy production, we can compare and contrast a U.S. system characteristic of the "good old days" with modern dairy farming. The popular agrarian vision of dairy farming in the 1940's includes a small family farm with a red barn, green pastures and a herd of cows, each of which are known by name. This rural utopia appears to have been an untroubled life where milk could be drunk straight from the cow, neither cows nor manure produced GHG and the small tractor used to plow the fields used small quantities of fuel from an infinite supply. By contrast, the modern dairy farm with streamlined milking equipment, pasteurization processes, anaerobic digesters and specialized labor appears to some as a futuristic aberration. Indeed, modern dairy production is considered by anti-animal agriculture activists to be synonymous with "industrialized warehouse-like facilities that significantly increase greenhouse gas emissions per animal" (Koneswaran & Nierenberg, 2008). Production of CH4 from enteric fermentation is not a new phenomenon within the scientific community, yet the link between climate change and livestock production is a relatively recent notion. Consumers therefore often perceive that modern livestock production causes climate change, whereas extensive systems akin to historical management are far more environmentally-friendly. To put this historical supposition into context, the GHG emissions from enteric fermentation and manure produced by the 60 million buffalo that roamed the U.S. plains until mass extinction in 1880 are equal to double the carbon footprint produced by the U.S. dairy industry in 2007 (Figure 4).

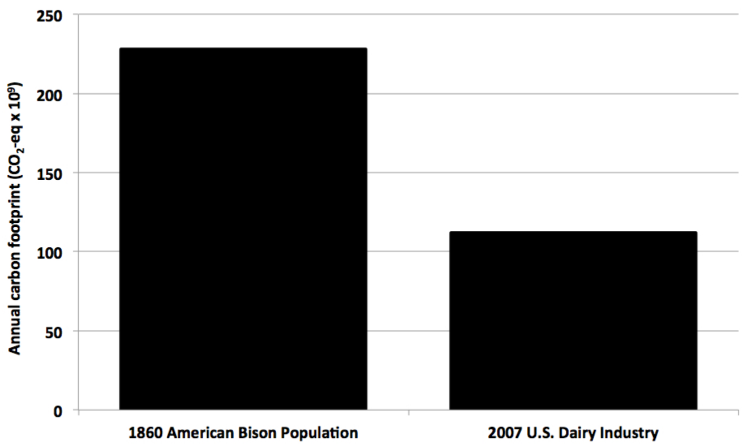

Figure 4: Comparative annual carbon footprints of the 1860 American bison population and 2007 U.S. dairy industry, adapted from Capper (2011b). The carbon footprint for American bison is based on CH4 and N20 emissions resulting from forage dry matter intakes for age-appropriate liveweights and population dynamics, emission factors are from U.S. EPA (2007).

European dairy cattle were first imported into the USA in 1611, providing the basis for the U.S. dairy industry. Considerable advances in productivity have been made since that time point: the earliest recorded U.S. milk production data relates to a Jersey cow that produced 232 kg of milk in a 350 day lactation in 1854 (Voelker, 1992). By 1944, the year in which the U.S. dairy herd peaked at 25.6 million cows, the average annual milk yield per cow was 2,074 kg (Capper *et al*., 2009) and U.S. dairy farms produced an annual total of 53.0 billion kg milk. The average herd contained six cows that were fed a pasture-based diet with occasional supplemental corn or soybean meal. Artificial insemination was in its infancy and neither antibiotics nor supplemental hormones were available for animal use. By contrast, the 2007 U.S. dairy herd contained 9.2 million cows producing 84.2 billion kg milk, the gains in productivity and efficiency facilitated by improvements in management, nutrition, genetics and the application of new technologies that led to a four-fold increase in milk yield per cow between 1944 and 2007 (Capper *et al*., 2009). This improvement in productivity and efficiency is a proof of concept for the dilution of maintenance effect – increased milk production per cow means that a reduced dairy population was required to produce the same quantity of milk. Indeed, compared to 1944, the 2007 U.S. dairy industry required only 21% of the dairy population and therefore 23% of the feedstuffs, 10% of the land and 35% of the water to produce a set quantity of milk. Manure output per unit of milk produced in 2007 was 24% of that in 1944 and the total carbon footprint per unit of milk was reduced by 63%. Despite the increase in total milk production between 1944 and 2007, the total carbon footprint for the entire dairy industry was reduced by 41%.

Myth: Pasture-based and organic production systems are better for the environment

It is clear that the transformation of the U.S. dairy industry from extensive pasture-based dairying to the modern intensive system has considerably reduced both resource use and GHG emissions per unit of milk. Nonetheless, a small yet vocal proportion of the population advocate for pasture-based or organic dairy systems (Gumpert, 2009; Pollan, 2007; Salatin, 2007), citing perceived differences in the healthiness and environmental impact of milk produced from cows grazing pasture. The organic food industry has also gained market share over the past decade within the United States, with consumers attributing positive characteristics to organic food including “chemical-free”, “healthier” and “earth-friendly” (Raab & Grobe, 2005). These perceptions are debatable, for example, a considerable body of knowledge indicates that organic dairy products may have minor increases in specific fatty acids, but these are a consequence of the increase in pasture-feeding in organic systems vs. total mixed rations in conventional systems, and are present in such small quantities that they have no measurable human health effects (Brown, Trenkle, & Beitz, 2011).

Pasture-based systems can only gain an environmental advantage over conventional dairying when they support milk production without negatively impacting yield or increasing resource use per unit of dairy. A recent analysis from the Organic Center intended to demonstrate the environmental advantages of organic dairy production was based on a flawed premise, namely that milk yield per cow does not differ between conventional and organic systems (Benbrook, 2009). By contrast, USDA data relating to milk yields in pasture-based vs. conventional dairy systems reveals a 26% decrease in milk yield per cow (Figure 5) and peer-reviewed papers comparing organic and conventional production cite decreases in milk yield ranging from 14% to 40% (Rotz, Kamphuis, Karsten, & Weaver, 2007; Sato, Bartlett, Erskine, & Kaneene, 2005; Zwald *et al*., 2004). As previously discussed, a reduction in milk yield means that the dairy population size must increase in order to maintain total fluid milk production. If we project out to the year 2040 when the U.S. population is predicted to plateau at 340 million people, to supply the entire population with their daily USDA-recommended 0.71 L of low-fat milk (or its equivalent) through organic production practices would require 3.5 million additional animals to be added to the national herd and land use to increase by 7.7 million acres (a 30% increase). When the reduction in productivity is combined with the propensity for high-forage and pasture-based diets to increase ruminal methanogenesis and thus enteric GHG emissions (Johnson & Johnson, 1995; Pinares-Patiño, Waghorn, Hegarty, & Hoskin, 2009), the carbon footprint of organic dairy production in 2040 would have a carbon footprint 13% greater than that of conventional production.

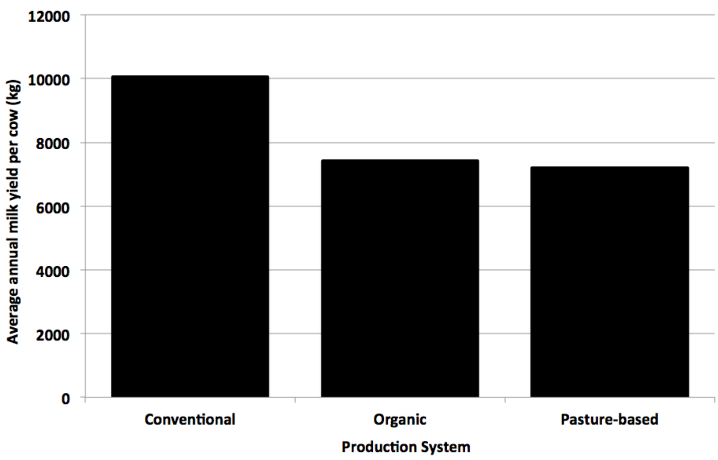

Figure 5: Average annual milk yield per cow in conventional, organic and pasture-based U.S. dairy production systems, adapted from USDA (2007).

Sequestration of carbon from the atmosphere into plant or soil biomass is often quoted as a major environmental advantage of pasture-based systems. However, pasture does not sequester carbon indefinitely, nor does it occur at a constant rate. Over time, soil carbon concentrations reach an equilibrium point, beyond which no further sequestration occurs unless land is subjected to significant management change (Post & Kwon, 2000; Schlesinger, 2000). The present body of knowledge indicates that the degree to which carbon may be sequestered by crop or pastureland is infinitely variable between systems and is highly dependant on a myriad of factors including land use change, tillage, organic matter input, soil type and crop/pasture species (Lal, 2004; West & Marland, 2002). Furthermore, CH4 has a global warming potential

25X than of CO_2, thus soil sequestration potential is unlikely to overcome the effects of low productivity and increased enteric CH_4 emissions from pasture-based systems.

Myth: Milk yield is the most important factor when assessing carbon footprint

One criticism often leveled at intensive dairy production systems is that high-producing cows tend to have an increased bodyweight, thus consume more feed and emit greater quantities of GHG on a daily basis. Data from the previously-discussed historical comparison validates this claim in that the shift from a population containing 54% smaller breeds (Jersey and Guernsey) in 1944 to 90% Holstein cows in 2007 increased milk yield, but also increased individual cow bodyweight and maintenance nutrient cost. If daily GHG emissions per animal are the correct metric by which to evaluate environmental impact, the 1944 system appears to show merit as the daily GHG output per animal was 13.5 kg CO_2-eq compared to 27.8 kg CO_2-eq in 2007 (Capper *et al*., 2009). Nonetheless, expressing results on a 'per head' basis fails to consider milk yield and other productivity indices that may have a significant effect upon population size and thus environmental impact, including milk composition, calving interval, age at first calving and longevity. Furthermore, as the population maintenance requirement is a function of both population size and mass, an increased dairy population size may not definitively lead to an increase in GHG emissions per unit of product. Capper and Cady (2012) therefore investigated the effect of breed-specific characteristics upon resource use and GHG emissions from dairy production, through production of sufficient milk to manufacture 500,000 MT of Cheddar cheese from a Jersey or Holstein population.

Jersey cattle confer two potential breed-specific advantages over the Holstein in terms of environmental impact. Firstly, despite their reduced milk yield (20.9 kg/day compared to 29.1 kg/day) they have an increased milk solids concentration (480 g/kg fat and 370 g/kg protein compared to 380 kg milkfat/kg and 310 g protein/kg for the Holstein) and thus a predicted Cheddar cheese yield of 125 g/kg compared to 101 g/kg milk. Secondly, mature U.S. Jersey cattle have an average bodyweight of 454 kg compared to 680 kg for the Holstein, thus individual animals have a smaller maintenance requirement. Within this comparison, Capper and Cady (2012) demonstrated that, in contrast to their previous work, dairy population size does not predict environmental impact per unit of dairy production as although an interaction between milk yield and milk solids concentration meant that the Jersey population required to produce 500,000 MT of cheese yield was 9% greater than the Holstein population required to yield the same quantity of cheese, the body mass of the Jersey population was reduced by 26%. Consequently, water use was reduced by 32%, land use by 12% and GHG emissions by 20% per unit of cheese yield. Within this comparison, the major productivity factors affecting environmental impact were milk yield, milk solids content and animal bodyweight, with lesser effects of age at first calving, calving interval and cow longevity. Nonetheless, it is important to note that this was a comparison based on two data points per factor (one average for each breed) thus further research involving a range of values for each factor is currently being undertaken.

Myth: Greenhouse gas emissions are more important than nutritional content

The need to assess environmental impact based upon nutrient density is of increasing importance to processors and retailers as well as producers, as greater product differentiation occurs between dairy products and other beverages. Some European retail grocery chains employ labels showing the 'carbon footprint' per unit of milk and such schemes may be adopted in the U.S. in future. This is a particular concern when comparing, for example, fluid milk to cheese. Given that it takes between 8-10 kg of milk to make one kg of cheese, a unit weight of cheese would be labelled with a carbon footprint approximately 10x that of the same unit weight of milk. This might lead the consumer to discriminate against products that have a larger carbon footprint, regardless of nutritional value.

Smedman *et al*. (2010) demonstrated that milk had the most favourable ratio of nutrient content to GHG emissions when compared to orange juice, soy and oat beverages and alcoholic drinks. The challenge is to communicate these results to consumers to whom milk is often regarded as either nutritionally unfavourable or environmentally unsustainable. This is of particular concern in the wake of recent reports claiming that consumers could considerably reduce their carbon footprint by forgoing animal protein. Initially popularised as "Meatless Mondays", this campaign garnered increased attention when the

Environmental Working Group (2011) published a report recommending that consumers should replace red meat and dairy products with chicken or vegetable protein products for one day per week. The original "Meatless Mondays" concept appears to originate from a paper published by Weber and Matthews (2008) in which the authors state that ""Shifting less than one day per week's worth of calories from red meat and dairy products to chicken, fish, eggs, or a vegetable-based diet achieves more GHG reduction than buying all locally sourced food." The lack of a "control" treatment against which to compare the removal of red meat and dairy products from the diet renders this comparison practically meaningless, nonetheless, it has been adopted by various vegetarian and vegan groups as proof that meat consumption is environmentally unfriendly. Citizens of most developed nations could arguably consume less red meat and dairy products without negatively impacting their health status, nonetheless, it is somewhat reckless to suggest that a small dietary change would have a major impact on national or global GHG emissions. For example, the U.S. population is generally considered to have the greatest annual red meat consumption per capita at 49.4 kg (CME Group, 2011) yet GHG emissions attributable to red meat and dairy production are equal to 3.05% of the national total (US EPA, 2010a). If every U.S. inhabitant removed red meat and dairy products from their diet (with a concurrent reduction in the by-products such as leather, adhesives and pharmaceuticals that are associated with these animal products), the reduction in U.S. GHG emissions would be equal to 0.44%. Any attempt to reduce GHG may be considered laudable, nonetheless, a 0.44% reduction (assuming that this concept was adopted by the entire population) would make very little difference to total emissions, especially since it is not expressed in the context of other human activities, for which we have at best a tenuous grasp of the potential environmental impact.

The Environmental Working Group (2011) should be commended in that the results are presented on the basis of maintaining dietary protein supply from animal vs. plant sources, although the authors demonstrate a limited understanding of livestock production systems which in some cases lead to underlying assumptions for their model that are entirely unfeasible. Nutritionally however, it is a fallacy to suggest that protein quality does not differ between various sources, especially when specific amino acids are required for human growth and development (Bauman & Capper, 2011). The oft-heard argument that livestock production competes for food resources with humans and that sufficient land exists to feed the entire population on a vegan diet suffers from the same assumption, albeit from the animal viewpoint. Grazing livestock systems provide for the conversion of human-indigestible plant material into high-quality animal protein for human consumption. The majority of land used for grazing ruminants is not suitable for growing crops for human consumption, indeed data from the USDA's Economic Research Service (Lubowski, Vesterby, Bucholtz, Baez, & Roberts, 2006) indicates that only 8% of U.S. grazed land is sufficiently productive to be classified as cropland pasture, therefore pasture-based dairy production provides an opportunity to feed the human population without competing for grain-based food resources. Beyond the use of pasture and grassland however, livestock production systems utilise a significant proportion of by-products from the human food and fibre industries that are inedible by humans. In a recent analysis of the quantity of human-edible protein input fed to livestock in the United Kingdom, Wilkinson (2011) demonstrated that both dairy and upland suckler beef systems generated a favourable ratio of human-edible protein input compared to output (0.71 for dairy and 0.92 for beef). The use of by-product feeds thus allows for production of high-quality animal protein from otherwise inedible material, which reduces competition for cropland and also reduces the environmental impact of production by utilising feed stocks for which the majority of carbon emissions can be attributed to human food or fibre.

Myth: Magic bullets exist to reduce dairy's environmental impact

Dairy production is a complex entity with interaction between a myriad of sub-systems, thus no "magic bullet" currently exists that can be applied to a single component or process within the dairy system to reduce environmental impact, without incurring potential negative trade-offs. A considerable body of research is currently devoted to reducing enteric CH4 emissions by feeding fish oil or other feed additives that inhibit rumen methanogenesis. Although laudable in intent, a shift in ruminal population away from methanogenic bacteria is often associated with a decrease in milk fat yield (Ahnadi, Beswick, Delbecchi, Kennelly, & Lacasse, 2002). In a market where the majority of milk production is directed into manufacture of dairy products such as cheese, butter and yogurt such as is seen in the U.S., a reduction in component yield becomes of critical importance as a greater quantity of milk is required to maintain milk solids production, thus potentially increasing resource input and GHG emissions per unit of dairy product.

Within the farm technology arena, anaerobic digesters are often cited as a providing a major opportunity to reduce GHG emissions, yet they have only been installed on a small number of livestock operations in the U.S. (The AgSTAR Program, 2009). The primary reason for low adoption rates is that digesters are not size-neutral technologies. Installation and maintenance requires significant capital investment and is not an economically feasible solution on small farms – at present it is suggested that digesters may only generate sufficient income to be financially viable investments on farms with >500 cows (The AgSTAR Program, 2007). According to USDA (2007), 76% of U.S. dairy farms have herds containing <100 cows and 95% have <500 cows, indicating that digester technology will have to become significantly more affordable before widespread adoption occurs. Manure CH4 emissions are reduced through digester use, however a negative trade-off may be observed as emissions of other air pollutants (e.g. NOx) may increase to unacceptable levels (Chianese, Harrison, & Lester, 2009). It is essential to remember that manure CH4 is only one component of total dairy GHG emissions – even if digesters were installed on every single U.S. dairy farm and worked at optimal efficiency, this would still fall short of meeting the U.S. dairy industry's pledge to reduce total GHG emissions by 25% by the year 2020 (Innovation Center for U.S. Dairy, 2010).

CONCLUSIONS

The global dairy industry faces a clear challenge in supplying the needs of the increasing global population, while reducing environmental impact. Advances in genetics, nutrition, management and welfare over the past century have conferred improvements in productivity that have allowed modern production systems to reduce both resource use and GHG emissions per unit of dairy. Assuming that productivity trends continue into the future, the dairy industry is well-placed to continue its tradition of environmental stewardship, yet the industry faces considerable opposition in terms of consumer misconceptions that may affect social sustainability. Demonization of specific sectors in favor of niche markets that intuitively appear to have a smaller carbon footprint further propagate the idea that conventional production systems are undesirable. In developed regions where food is readily available, consumers are afforded the luxury of making choices according to production system or technology use and that choice should continue to be available, yet many developing regions exist where the simple need for food negates such concerns. All dairy systems have the potential to improve productivity and reduce environmental impact regardless of region, management or breed - the industry needs to find ways to communicate the rationale behind differences in production systems using language and concepts that the majority of consumers understand, without denigrating other segments of the industry.

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GROWING MORE PASTURE AND YOUR PROFITS

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Farm profit will almost always increase alongside the amount of pasture grown and converted to milk. There is opportunity to grow and utilise more pasture on all Australian dairy farms according to the variability in pasture growth between paddocks. Pasture growth data from some of the most productive and profitable farms in the Waikato region of New Zealand highlighted this variability. Paddocks with similar management yielded from 10 to 26t DM/ha/year. This data highlights the value of monitoring pasture cover on an individual paddock basis and the opportunity to use this data to guide management decisions and increase the yield of poor performing paddocks. Management decisions to improve the productivity of these paddocks could be guided in the future by programs such as PGSUS (Pasture Growth Simulation Using Smalltalk) which learns from pasture cover data, fills in the gaps between pasture cover measurements, and highlights opportunities to increase pasture growth.

INTRODUCTION

With recent advances in technology and automation, there is great opportunity to reduce the costs of milk production, or alternatively increase milk production whilst maintaining costs. Technological advances have enabled individual cow and paddock data to be captured and as a result, farming according to averages is becoming a thing of the past.

Milk metering systems are now available that can monitor milk from each quarter of a cow's udder (see www.herdnavigator.com). These systems can monitor indicators such as:

i) Ketone bodies (a product of fat breakdown) to convey the energy status of dairy cow and guide appropriate feeding management to minimise metabolic disorders.

ii) Lactate dehydrogenase (LDH) and conductivity to minimise the incidence of sub-clinical and clinical mastistis and the associated loss of milk production.

iii) Progesterone to guide the timing of artificial insemination to improve conception rates and overall reproductive performance.

Looking to the future, exciting work being conducted at the University of Sydney uses thermal imaging to detect estrous in dairy cows (see current proceedings Talukder *et al*.). This same technology may also have application for detecting sites of infection associated with mastitis and lameness.

In parallel with the development of technology to monitor the health and reproductive status of individual dairy cows, the impact of varying feed inputs for individual cows to improve the efficiency of milk production has been investigated. As an example, research conducted within Future Dairy (Garcia *et al*., 2007) has shown the milk yield of cows offered a variable rate of concentrate, based on individual cow requirements, to be 9% higher than cows offered the same total amount of concentrate at a fixed rate. Although the quantity of pasture fed to the individual cows is fixed, there are systems available that enable pasture to be automatically offered at differing times of the day to the herd such as battery operated latches (www.grazetech.com.au) to allow cows to move to and from pasture, and robots that can offer varying amounts of pasture through the day by automatically moving a fence line across a paddock (www.lely.com).

The aforementioned research highlights the considerable amount of work and investment that has been, and continues to be, allocated to optimise the health and production of individual cows. What has been somewhat left behind is the development of technology to optimise the health and production of individual paddocks. This is a concern given that pasture is still one of the cheapest and highest quality feeds for dairy cows.

This manuscript highlights the considerable opportunity to increase the amount of pasture grown on all Australian dairy farms. The variability in pasture growth between paddocks from research conducted in New Zealand at DairyNZ by Alvaro Romera, Kevin Macdonald, Dave Clark and myself will be given. Suggested methods to capatilise on this data and improve pasture growth will also be provided.

1. The variability in pasture growth

A. Between Paddocks

Research was undertaken to characterise paddock to paddock annual dry matter yield variability for commercial and research dairy farms in the Waikato region of New Zealand (Clark *et al*., 2010), as a first step towards improving the amount of pasture grown and eaten by dairy cows. Pasture yield was monitored on two commercial farms and one research farm for two years, and another research farm for seven years in the Waikato region of New Zealand.

Pasture yield for individual paddocks across farms ranged from 9.5 to 26.1t DM/ha/year. Within farms the highest yielding paddock produced between 30 and 120% more pasture than the lowest yielding paddock. Three examples of this variability are provided in Figure 1. For research farm 1, individual paddock pasture yield ranging from 12t DM/ha/yr (2% of paddocks) to 22tDM/ha/yr (10% of paddocks) with 50% of paddocks yielding 18t DM/ha/yr. Commercial farms had a similar range between the lowest and highest yielding paddocks paddocks, however, the average yield of commercial farms was between 3 and 5t DM/ha/yr lower (a 25% decrease) than the research farm.

Acknowledging that there were minor differences in soil type and topography between research and commercial farms in this study, these findings show the ability of management on the research farm to increase the average level of pasture grown by creating high yielding paddocks from low yielding ones. The benefit to implementing such management across dairy farms would be large. For an average Australian dairy farm of 120ha (Australian Agricultural Assessment Report, 2001), increasing the average pasture yield of 13t DM/ha (Cullen *et al*., 2008) by 25% would result in an additional 3t DM/ha, or 360t DM across the farm. This equates to an additional <u>360,000L</u> for the average farm at a feed conversion efficiency of 1L/kg DM.

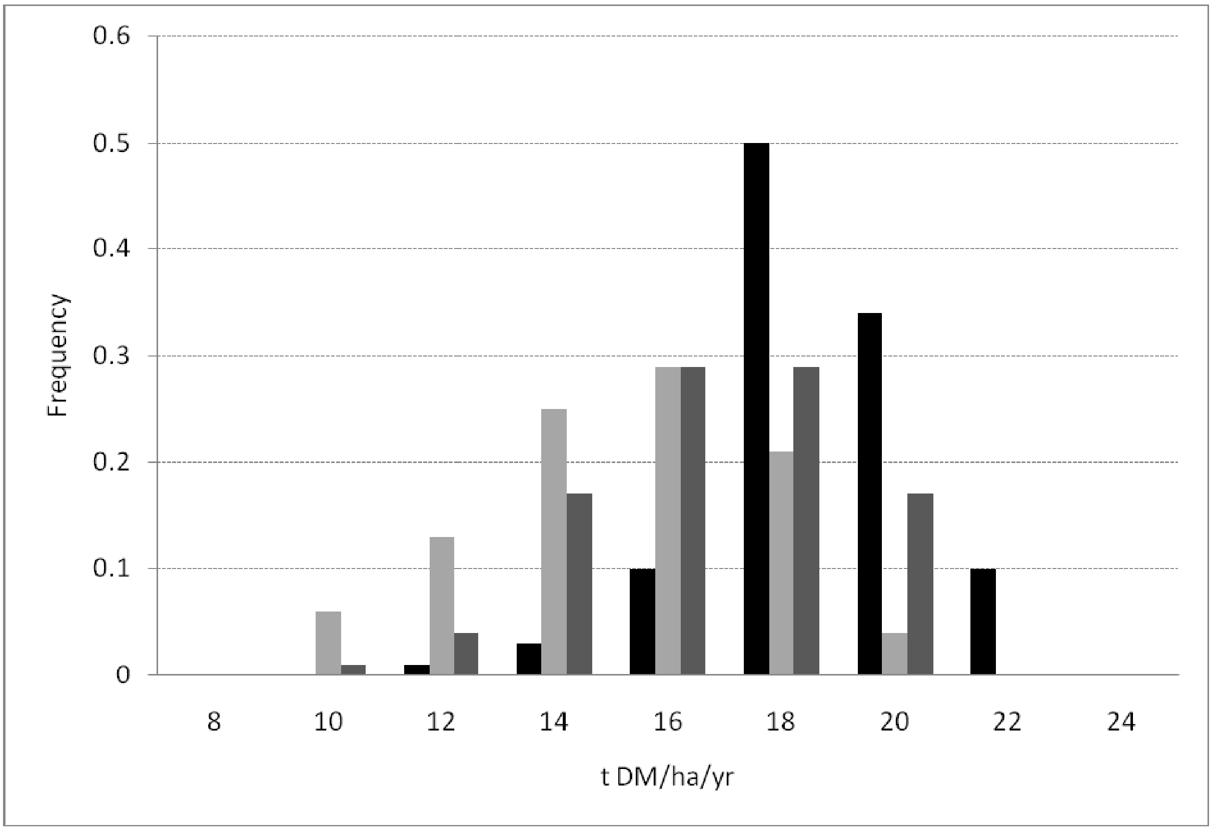

Figure 1. Paddock pasture yield (t DM/ha/yr) for research farm 1 (■), commercial farm 1 (■) and commercial farm 2 (■).

B. Within paddocks

New pasture monitoring technology has reduced the time taken to determine pasture cover across a farm. The C-Dax rapid pasture meter (Lawrence *et al*., 2007; www.pasturemeter.co.nz) and automatic pasture reader (www.pasturereader.com.au) determine pasture height and with calibration equations convert these measurements to pasture cover. This technology significantly increases the number of pasture cover measurements that can be taken in a paddock. For example, the C-Dax rapid pasture meter can determine height/cover 200 times per second and relate each of these measurements to location via GPS, enabling the variability in pasture yield within paddocks to be determined (see Figure 2). Similar to the findings between paddocks, this technology indicates that the variability in pasture yield within paddocks (range from <1,400 to 3,400kg DM/ha) is large.

These advances in technology have greatly increased the amount of data presented to dairy farmers. However, dairy farm management will only be able to capitalise on this data if the causes of pasture yield variability are known.

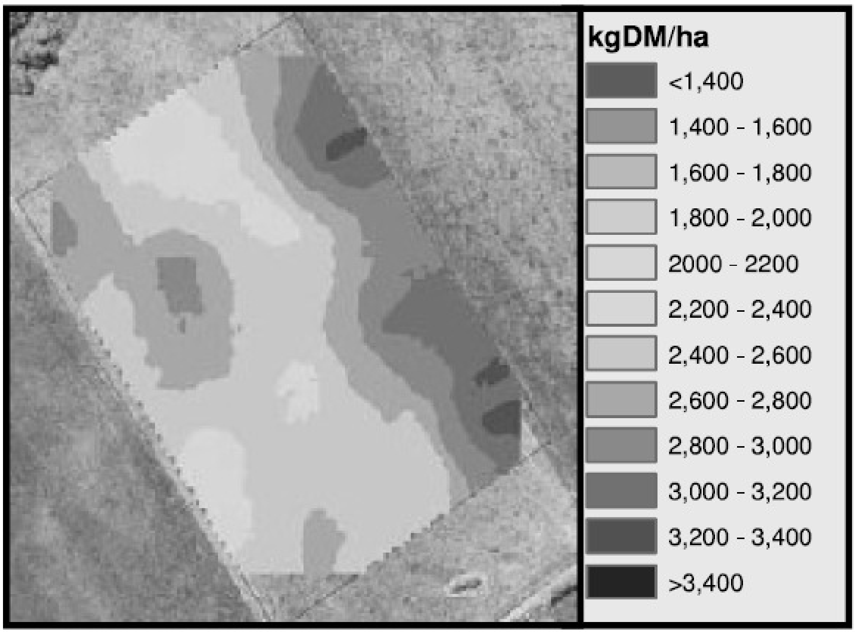

Figure 2. Pre-grazing pasture cover of a paddock from Massey No. 4 Dairy Farm measured using the Rapid Pasture Metre®(reproduced with permission by Lawrence et al., 2007).

2. Capitalising on pasture growth variability

To increase the pasture yield of poor performing areas, the cause of the poor performance must firstly be determined. However, pasture yields for the majority (≈90%) of paddocks in the work of Clark *et al*. (2010) were variable between years. These data suggest that the interaction between soil and climate should be considered when classifying paddocks according to yield. As an example, a water logged area in a wet year with low pasture yield may be one of the areas with high pasture yield in a dry year. Programs that learn from pasture yield across a farm as a response to climate can help to determine the cause of low pasture yields and to define areas for similar management. One such potential program is PGSUS (Romera *et al*., 2010).

PGSUS (Pasture Growth Simulation Using Smalltalk)

PGSUS is a climate driven model with the primary purpose of predicting herbage mass between herbage measurements. For instance, if weekly pasture cover estimates are required and a current estimate of cover was not available then PGSUS would predict the week's pasture growth rate for that particular paddock and add this on to the last observed measurement. The ability of this technology to accurately predict out pasture cover for individual paddocks is highlighted in Romera *et al*. (2010). PGSUS predicted pasture cover for individual paddocks out to a month from the last measurement with acceptable levels of accuracy (correlation between observed and estimated pasture mass $r > 0.8$). These data show the potential of this technology to forecast pasture growth levels for individual paddocks given the input of accurate forecasted climate data.

The accuracy of PGSUS relies on the pasture growth model (McCall and Bishop-Hurley (2003) as modified by Romera *et al*., 2009) learning from the response of pasture to climate. Parameters such as available water holding capacity and radiation use efficiency are fitted within the model using all available historic data for each paddock. In this process, areas of the farm are given their own parameters defining how pasture responds to the climate. It is parameters such as these that will form the future basis for improving pasture performance and could be used to create an Australian paddock performance database.

Within the paddock performance database, areas assigned very high WHC would be the first areas to be checked for poor drainage. Conversely, areas of low water holding capacity would be areas to check for compaction. If there was no compaction, plant species adapted to low soil moisture environments such as chicory or lucerne, or annual species with high levels of growth during seasons when rainfall is typically high, could be established. Areas assigned low radiation use efficiency would be checked for low fertility and/or low plant densities. Conversely, such a database would also provide the opportunity for management to learn from the high performance areas and potentially replicate the success of these areas across the farm.

Current application of these findings to increase pasture growth

This manuscript has highlighted future advances in the way that data is collected, analysed and presented back to the dairy farmer to increase pasture yields. Below are a few areas to be considered now.

- **Renewed focus on soil**

  - given the similar management of pasture across paddocks for commercial farms in the research given above, these findings suggest that what is going on below the pasture is having a large influence on pasture performance.

  - obtaining advice from a soil scientist may be one of the best investments currently available on farm.

- **Fertiliser**

  - some dairy farmers are now soil testing each individual paddock and applying fertilizer according to each result. The reduction in fertiliser costs have more than offset increased soil test costs.

- **Grazing days**

  - a record of grazing days for each paddock on the farm would highlight the performance of paddocks, particularly those at either end of the yield spectrum.

  - digging a few holes in low yielding paddocks may reveal the underlying cause of poor performance, particularly if the cause is compaction.

- **Cropping**

  - careful consideration should be given as to where to establish a crop. Replacing a paddock yielding 25t DM/ha of pasture with a crop of similar yield would most often result in reduced profit. Converting a poor performing paddock to one of the high yielding paddocks through cropping can only help the bottom line.

SUMMARY

- In an NZ study, paddocks with similar management yielded from 10 to 26t DM/ha/year. This data highlights the value of monitoring pasture cover on an individual paddock basis on Australian farms.
- There is significant opportunity to use this data to guide management decisions and increase the yield of poor performing paddocks.
- Management decisions to improve the productivity of poor performing paddocks could be guided in the future by programs such as PGSUS. Outputs from programs such as PGSUS will likely form the basis of an Australian Paddock Performance Database.
- If pasture cover is not currently monitored, recording grazing days for each paddock on the farm could identify poor performing paddocks.
- What is happening below the pasture is driving pasture growth. Getting advice from a soil scientist to improve the yield of poor performing paddocks would be a great investment.

- Carefully consider which paddocks are allocated to a crop as using an area for a crop, currently yielding high amounts of pasture, may result in a lot of effort for very little gain (or loss).

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A FARMING PHILOSOPHY TO AVOID WASTED ENERGY ON A NEW ZEALAND DAIRY FARM

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Energy on a dairy farm is the most valuable resource available to produce milk and meat; however, often it is wasted through poor planning and implementation techniques. This paper provides insights into how the energy in both pasture and fertiliser systems are adopted on a Taranaki, NZ dairyfarm using a basic but fundamental farming philosophy of plan, measure, manage and review. In the past four seasons on-farm milk production has increased by 38% and pasture production by 22%. Direct fertiliser costs over this period have been reduced from $26.13 to $2.69 fertiliser per t dm grown by adopting a differential spatial approach to fertiliser application based on individual paddock soil samples. In spite of this, soil nutrient status has been retained at or above soil critical nutrient status. It is concluded that using the discussed farm management approach can have increase gains in farm productivity across all farms.

INTRODUCTION

A dairy farming business contains a number of energy flows, physical, financial, environmental, and mental, all which need to be harnessed and balanced to ensure a functional and sustainable farming system. This paper introduces the farming philosophy used on our dairy farming unit (*Plan, Measure, Manage and Review*) and how it has been used to make sustainable physical and economic gains over the past four seasons since going dairy farming.

The 85ha eff. Milking platform is situated in the ring plain of Mt. Taranaki, 20km inland on the west coast of the North Island of New Zealand, 260m above sea level and is predominantly Egmont Loam soil. The farm for the last four seasons has been run as a two partner equity partnership. At the formation of the equity partnership 5yr physical and financial targets were set and by using the farming philosophy of *Plan, Measure, Manage and Review* the farm has been able to achieve these targets using sustainable business practices. Table 1 shows the changes in physical production and animal performance over that time period and how the 5yr production target is being met.

Table 1. Physical Milk Soilds production for the 85ha eff. Milking platform over the previous four seasons

	Takeover	**2008/09**	**2009/10**	**2010/11**	**2011/12**	***5yr Target***
No of Cows	215	220	225	230	235	*245*
Total KgMS	78,000	90,160	103,700	117,950	124,000	*130,000*
kgMS/cow	363	410	460	513	528	*530*
kgMS/ha	917	1060	1220	1390	1460	*1530*

The farming philosophy of *Plan, Measure, Manage and Review* can be broken down as having a Precise Plan, accurate and frequent measurements, using measurements to make proactive management decisions, and having a robust review process to constantly challenge your own thinking and ideas. This paper will concentrate on two facets of the production system, *pasture production and planning*, and the *fertiliser use policy*. The paper will aim to show how the adopted farming philosophy is applied to these facets of the farming business in order to maximise the efficiency of their use at the farm level.

PASTURE PLANNING PHILOSOPHY

High pasture utilisation and performance has long been known to be a key profit driver of both New Zealand and Australian dairy farms (Moran *et al*, 2000; MacDonald *et al*, 2010). This farm has used its adopted farming philosophy to drive pasture production and utilisation higher. Pasture production and management is broken down into three management levels strategic, tactical and operational. Specific tools have been developed in each of these areas to increase pasture production on farm over the previous four seasons from 14 to 18 tDM/ha (Figure 1). Using similar levels of inputs over the past three seasons it is obvious to see that pasture production is strongly linked to milk solids production on farm.

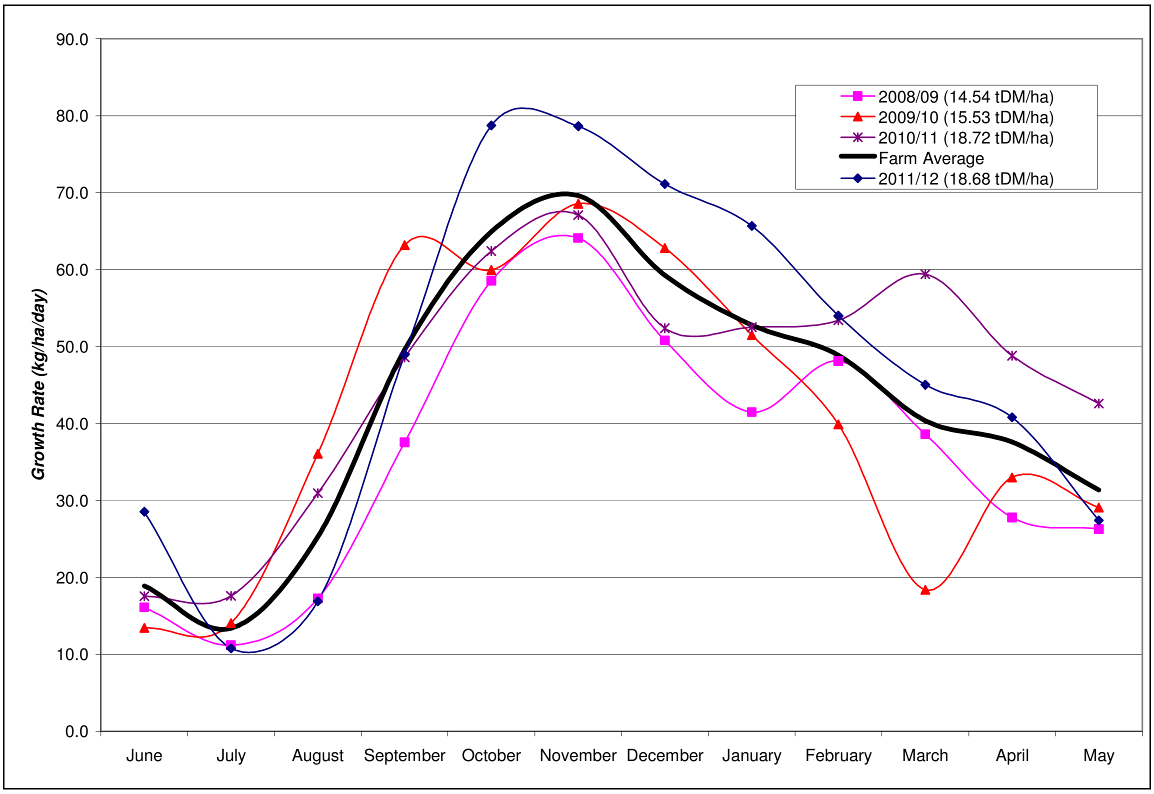

Figure 1. Average monthly pasture growth rates from 2008 until 2012.

Strategic Pasture Management

At the strategic level, a nutritionist is used to balance the pasture diet with available supplements annually at 15 day intervals throughout the year. Average monthly pasture production data has been collected on farm over the previous four seasons and is used to make these decisions at the strategic level (Figure 1). Table 2 shows an example of the strategic planning system for each 15 day period where a cows ration is balanced depending on her requirements (Milk Production (L), Milk Solids %, Liveweight change (kg), stage of pregnancy (weeks)). Pasture availability is set by historical growth measurement (Figure 1), a round length speed predictor (Figure 2), and planned available grazing area. This level of strategic feed planning is fundamental for everybody involved in the business (staff, nutritionist, co-owners, bankers and accountant) being able to understand the system and its cash flows so there are no surprises.

Table 2. Ration planner used to balance feed quantities and qualities with desired production parameters.

Ration	Ration Data								As Fed Data							
	Utilised %	DM %	NDF %	ME (MJ/kgDM)	CP %	RDP (%/CP)	UDP (%/CP)	$/t	AsFed (kg)	DM (kg)	NDF (kg)	ME (MJ)	CP (g)	RDP (g)	UDP (g)	Cost ($)
Pasture	85%	100%	40%	12.0	23%	75%	25%	0	17	14.5	5.8	173.4	3324	2493	831	$ -
Wheat	95%	88%	12%	12.7	11%	78%	28%	400	3	2.5	0.3	31.9	276	215	77	$ 1.20
Canola	95%	88%	20%	12.0	38%	65%	35%	560	0.5	0.4	0.1	5.0	159	103	56	$ 0.28
Pasture Silage	80%	35%	48%	10.5	14%	77%	23%	140	0	0.0	0.0	0.0	0	0	0	$ -
Palm Kernal	90%	92%	33%	11.5	16%	70%	30%	250	0	0.0	0.0	0.0	0	0	0	$ -
Straw	80%	88%	75%	6.0	40%	72%	28%	300	0.5	0.4	0.3	2.1	141	101	39	$ 0.15
							Totals		21	17.7	6.4	212.4	3899	2912	1003	$ 1.63
							Cow Req				6.6	221.6	3331	2615	717	
							Variance				-0.2	-9.2	568	297	286	

Table 4. Applied fertiliser rates and products for corresponding individual paddock soil nutrient tests.

Olsen P	**QT K**	**Fert Mix**	**Nutrient Values**	**Fert Type**
<40	>10	Full maintenance P, No K	50 P,0 K	550kg/ha Super P (Mix A)
<50	>10	Half maintenance P, No K	25 P, 0 K	275kg/ha Super P (Mix B)
<40	<10	Full maintenance P, Full maintenance K	50 P, 50 K	550kg/ha Super P + 100kg/ha KCl (Mix C)
<50	<10	Half maintenance P, Full maintenance K	25 P, 50 K	275kg/ha Super P + 100kg/ha KCl (Mix D)
>50	<10	No P, Full maintenance K	0 P, 50 K	100kg/ha KCl (Mix E)
N/A	N/A	Heifer maintenance P, Heifer maintenance K	30 P, 35 K	330kg/ha Super P + 50kg/ha KCl (Mix F)
N/A	N/A	No Application	0 P, 0 K	

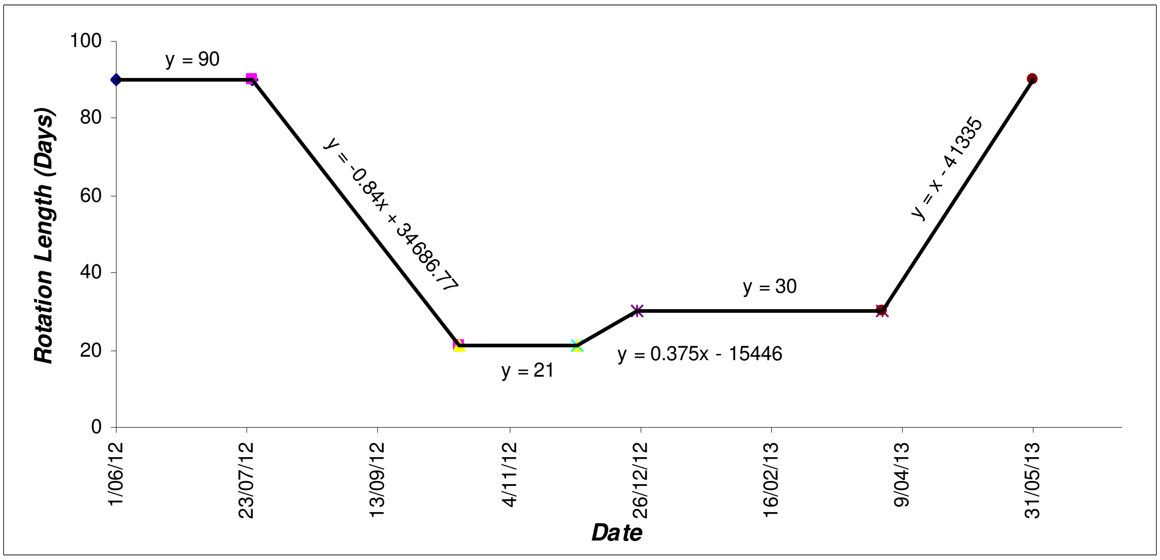

Figure 2. Rotation length planner and corresponding formulas used to meet desired rotation lengths

Tactical and Operational Pasture Management

At the tactical level pasture is measured every week in every paddock using a Rapid pasture meter, this data is used to make both tactical and operational decisions in accordance with the strategic feed plan. A feed wedge is produced using collected data to identify paddocks to be grazed and operational grazing decisions are made using a operational feed planning tool designed in Micorsoft Excel© that calculates kgDM/ha at grazing from last known measurement, total daily offered/cow (kgDM) and rotation speed. The operational feed planning tool is linked to data found in the feed wedge and allows the farm to maximize pasture and supplement efficiency whilst not compromising on milk solids production.

FERTILISER PLANNING PHILOSOPHY

Fertiliser is one of a farms major farm operating expenses, however, fertiliser is often overused, under utilised and applied by poorly calibrated equipment. For this reason it can also provide the biggest single cost saving when a structured, systematic approach is followed. The following describes the fertiliser philosophy used on farm to maximize the nutrient resource available whist achieving more sustainable farming practices. Target values for macro nutrients P, K, S are well defined in literature in terms of Olsen P, Quick Test K and Sulphate S for optimum pasture growth (NZFMRA, 2002). Farm target values have been set around these to ensure nutrients aren't being wasted (Table 3). Average farm soil test values for the past three seasons are also given in Table 3.

Table 3. Average soil nutrient status values for the past three seasons including the farm target range and critical optimum range for pasture growth to be maximised.

	Optimum Range (NZFMRA, 2002)	Farm Target Range	2009/10	2010/11	2011/12
Olsen P	30	40-50	62.4	70.0	70.8
Quick Test K	7-10	10	10.0	10.7	10.5
Sulphate S	10-12	12	11.0	12.6	10.6
pH	5.8-6.0	6.0	6.2	6.3	6.0

Farm average values do not allow for the spatial variation across the farm, therefore, individual paddock testing is used and a decision support system has been developed to apply the right type and amount of nutrients to each individual paddock. Figure 3 shows the spatial variation in Olsen P, Quick Test K, Sulphate S and pH at the inception of the program in the 2009/10 season. Olsen P ranged from 32 to 110, Quick test K from 5 to 20, Sulphate S from 6 to 18 and pH from 5.9 to 6.5. Seven different application types were used in the developed fertiliser program (Table 4) to account for these variations.

In the 2010/11 season variation in nutrient distribution was reduced meaning only three application types were used, in the 2011/12 season only two fertiliser mixes was used on the farm. Because of the lack of Super Phosphate fertiliser now been applied to the farm Sulphate S levels have been reduced, therefore Sulphur is now applied in with a May application of Urea to ensure pasture growth is not compromised over the Winter/Spring period.

It has now also been decided to include a liming program following similar spatial principles to those discussed above. Paddock application rates are now based on soils cation exchange capacity, base saturation calcium as well as pH using the formula below (eq. 1). Calcium is seen as important as it facilities the uptake of other nutrients into the plant and avoiding nutrient lockup.

Lime requirement (t/ha) = 26.2 - (4.4 x pH) + (0.07 x CEC)   (eq. 1)

Targeted fertiliser application has lead to a significant reduction in costs but as table 5 indicates that has not been to the detriment of pasture production with the $ Fert spent / T DM grown reducing year on year since the inception of the program.

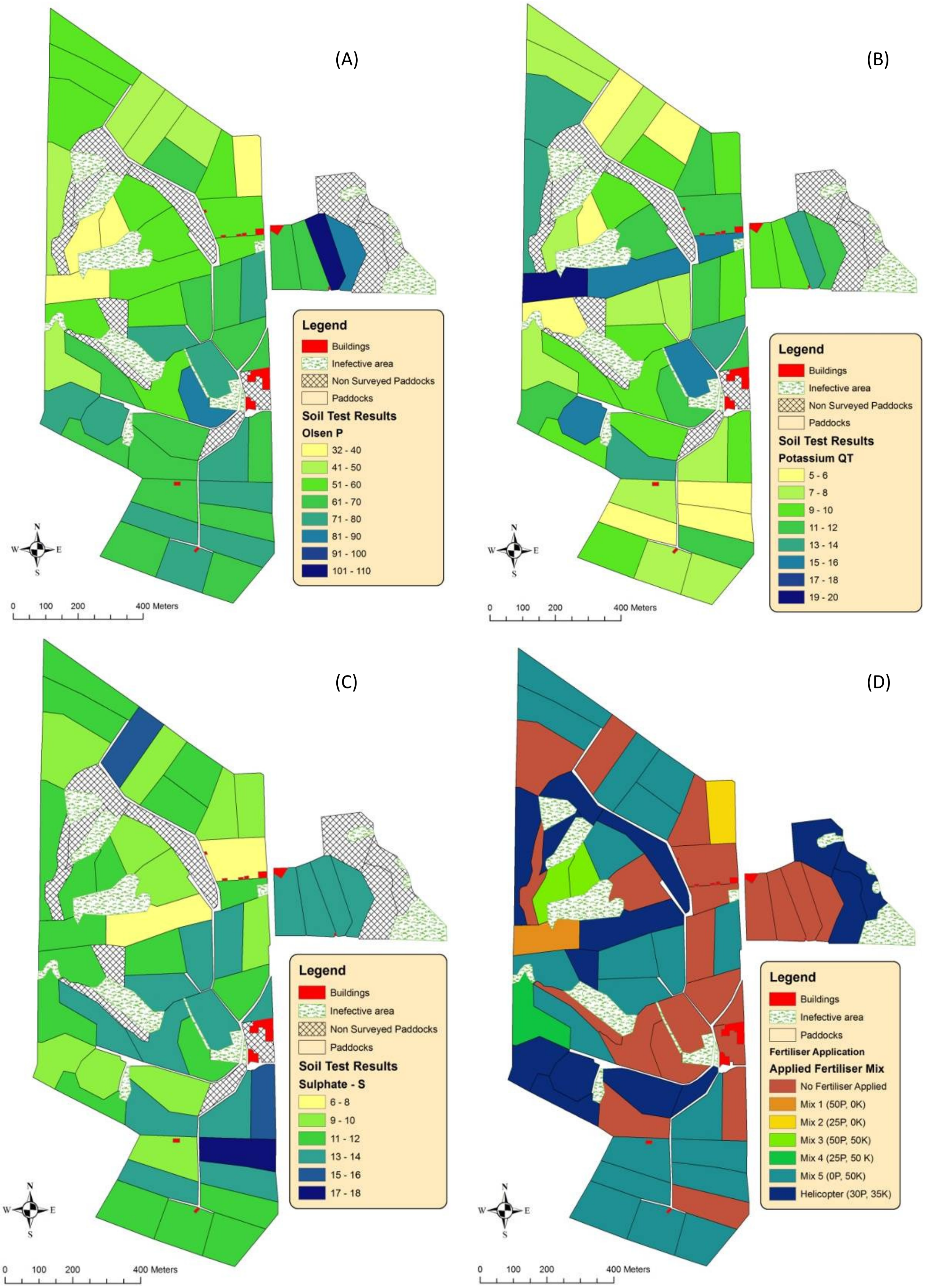

Figure 3. Spatial Variation in Olsen P (A), Quick Test K (B) Sulphate S (C) and the corresponding designed fertilser plan for the 2008/09 season.

Table 4. Total area (ha) of different fertiliser mixes applied and associated direct costs per T DM grown.

Fert Type	Previous Fert program	2009/10	2010/11	2011/12
(Mix A)	-	1.7 ha	7.6 ha	-
(Mix B)	-	1.6 ha	-	-
(Mix C)	-	2.1 ha	-	13.7 ha
(Mix D)	-	2.0 ha	-	-
(Mix E)	-	36.1 ha	35.6 ha	30.3 ha
(Mix F)	85.0 ha	21.9 ha	10.8 ha	-
No Application	-	19.6 ha	31.0 ha	41.0 ha
Fertiliser Cost	$32,300	$9,692	$6,460	$4,271
T DM grown	1236	1320	1591	1588
$ Fert/T DM grown	$26.13	$7.34	$4.06	$2.69

DISCUSSION AND CONCLUSIONS

This paper has presented two key themes around pasture and fertiliser utilisation on a working dairy farm and how a simple philosophy (Plan, Measure, Manage and Review) has been adopted not only to increase productivity but also reduce the environmental impact of the farming business. In essence the adopted farming philosophy allows the farm to reduce the energy inputs required to produce products in the form of milk and meat.

Some of the biggest challenges in the pasture utilisation program undertaken include predicting pasture growth, in the future it is hoped that using existing data collected on farm (pasture growth, soil moisture, soil nutrient status, sunshine hours and pasture species) an accurate model can be built that will allow for an increase in accuracy of operational and tactical management decisions.

For the undertaken fertiliser program to become widespread within the agricultural industry improvements in data recording, interpretation and transfer need to occur between the farm, advisor and agronomic level allowing for spatially disturbed data to be taken into account.

In the future it is hoped that both pasture and fertiliser use programs as shown here can be adopted across the wider industry enhancing the economic output of any dairy farming business.

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PASTURE MASTER – CASE STUDY 1
GLENCRAIG JERSEYS - FROM COBARGO TO BEMBOKA

STEVE SALWAY

Dairy farmer, Bemboka NSW

'GLENCRAIG' COBARGO, NSW

- Purchased the Jersey herd off Dad and Mum in June 2006;
- Herd purchased consisted of 110 cows; 65 young stock
- Commenced my dairy business on 1 July 2006;
- Milked off the home farm 'Glencraig'; Cobargo is about 30 minutes north of Bega on the NSW Sapphire Coast

'GLENCRAIG' SPECIFICATIONS

- Farm size - 160ha
- Effective milking area - 100 ha
- Rainfall - 800mm
- Irrigation - None
- Cows – average 130 up to 150
- Dairy – 8 unit walk through
- Feeding System – ad lib pellets through milking

THE CATALYST

- The home farm 'Glencraig' was part of the estate of my great grandfather and my grandfather had a life interest in the farm;
- In September 2006 the loss of my grandfather caused the sale of the property and our move to Bemboka.

'FARMHILL' BEMBOKA, NSW

- Commenced a lease dairy farm at Bemboka in February 2007; Bemboka is about 30 minutes west of Bega on the NSW Sapphire Coast

'FARMHILL' SPECIFICATIONS

- Farm size – 197ha
- Effective Milking Area – 140ha
- Rainfall – 5 year average of less than 500mm
- Irrigation – 60ha bike shift
- Cows – 150 increasing to 300
- Dairy – 16 unit swing over with headlocks
- Feeding System – Cablevey with open trough

PRODUCING MILK

- Pasture based system with high amounts of pellets and introduced fodder;

- Herd Mix - 1/3 Holstein and 2/3 Jersey;
- Production – Jersey herd – 5,500 – 6,000 litres / cow / year
- Holsteins – 7,500 – 8,500 litres / cow / year
- Diet – 2 – 2.5 ton of pellets / cow / year combined with pasture, cereal hay and silage

PRODUCTION FOR THE 'FARMHILL' YEARS

2006 / 2007

- 1,028,550 Litres Produced
- 47,262.72 Kg Butterfat
- 35,971.23 Kg Protein

2007 / 2008

- 1,308,888 Litres Produced
- 60,286.43 Kg Butterfat
- 45,854.64 Kg Protein

2008 / 2009

- 1,388,709 Litres produced
- 66,047.92 Kg Butterfat
- 50,634.99 Kg Protein

2009/2010

- 1,519,020 Litres Produced
- 69,123.80 Kg Butterfat
- 54,335.60 Kg Protein

2010/2011

- 1,969,538 Litres Produced
- 86,766.45 Kg Butterfat
- 68,876.07 Kg Protein

FROM 'FARMHILL' TO 'FAIRVIEW'

- July 2011 commenced leasing 'Fairview';
- January 2012 commenced milking at 'Fairview'

ACCEPTING TECHNOLOGIES ON OUR DAIRY FARMS

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Technology has certainly arrived to stay. It has intertwined in our everyday life, from cars and microwaves, to computers, internet and mobile phones. Denying its use makes no logic to any sensible person. On-farm acceptance, introduction and adoption of technology is usually much slower, and lags behind other activities. Examples include wireless weather stations linked to irrigation systems, tractors working with GPS trackers, the whole new area of possibilities which becomes available through a simple thing such as the electronic identification of cattle, in line milk quality monitor devices and last but not least automatic milking systems including the recently introduced world's first 'robotic rotary' (Automatic Milking Rotary; AMR™, DeLaval, Tumba, Sweden) developed to be able to milk larger herds either in a voluntary or batch system. Furthermore, it is nowadays more common to see 'farming' linked to words such as 'precision', 'smart', and 'robotic'.

A trend of a decreasing number of dairy farms can be observed, with a relatively stable number of dairy cows. At the same time improved genetics and management have resulted in a dramatic rise of the production of the cows. Together with all this, the fact is that costs of production have escalated at a much higher rate than milk price, therefore pushing the boundaries of profitability to a limit. As a result, farmers need to adapt to this constant and dynamic activity if they are to remain competitive and maintain their position in the industry. A drive for internal efficiency requires a change in the way farmers manage their operation.

The use of different tools and applications, have allowed farmers to reduce time and labour issues, as well as ensuring the consistency of tasks. It has also made the whole process of information management, decision making and monitoring much quicker and more efficient, allowing farms to increase their overall profitability.

Particularly within the dairy industry, there has been a growing adoption of technologies in the last couple of years, to accommodate the increase in herd size, cow production, and labour constraints. According to the 2008 - 2009 ABARE report on technology and management practices within the Australian dairy industry, the main technologies incorporated are; backing gates, vat cleaning systems, cup removers and teat sprays. It also mentions that almost 90% of farms utilise a computer for financial reasons, whilst 65-70% of farms use them for management of milking or breeding records.

Managing a dairy farm is a multitask activity, which requires the administration of a set of variables affecting milk production, in aspects such as pasture management, feeding, milking, calf rearing, reproduction, health management, labour and interaction with the society. The aim of the present work is to outline some tools and/or applications that are already available, which address some of the main challenges farmers face when managing their business. We believe most of them are quite applicable to a wide range of farmers, who will hopefully identify with some of the issues they focus on. It is not about big, fancy, expensive tools, but more about simple things that can create a big difference!

PASTURE MANAGEMENT

The Grains2Milk project and Dairy Australia have defined five main feeding systems utilised by Australian dairy farmers, by classifying them according to pasture and supplement usage during the year. They range from a System (1) with pastures, forages and up to 1 tonne of concentrate per cow per year, through to System (5) with zero grazing, cows housed and fed a TMR ration. Grazed pastures are used by 98% of farmers in Australia. Pasture and forage crops are the cheapest source of feed, and it is therefore of paramount importance for farmers to manage them accordingly, in order to utilise a greater amount of lower cost home grown feed. The use of tools that allow the user to measure, allocate and monitor pasture (in conjunction with GPS's), together with collation of KPI data , is increasing. Yet, according to the 2008 - 2009 ABARE report, less than 20% of farmers utilise computer systems to manage pasture/cropping/irrigation/rotation records. Users are expected to see a great benefit in how they use their cheapest source of feed by minimising wastage. But it is also about growing more feed (and utilising it correctly). According to ABARE, only 57% of farmers conduct regular soil tests, and 80% of them use those results to implement fertilising programs accordingly to grow more feed.

FEEDING MANAGEMENT

According to the "Performance profit and risk in pasture based dairy systems" report from Dairy Australia 2011, feed accounts for approximately 56% of the operating costs (with a range between 19 – 73%), primarily related to supplements fed to cows. Feeding management therefore is deemed to have a severe impact on farm profitability. Several options are available to manage this, which we believe can offer quite a good amount of information, useful to assess current and future situations, manage feed stocks, targeting high efficiency when feeding supplements. In this way farmers manage and control their feed, and see a real economic benefit, that covers any initial software cost.

MILKING - HERD TESTING

Not everything is about quantity, but also about quality. Mastitis is probably the highest impact health issue on dairy herds around the world. It not only causes an increase in somatic cells, which affect overall milk quality, but has a negative effect on milk production, as well as costs associated with treatments, dumping milk and culling. Overall it has a great cost and image impact on the dairy industry. Tools which could potentially help farmers manage this ongoing battle would be welcome if proven effective. Time is an issue, and any application able to speed up the detection of potential clinical cases, would result in a great benefit. Simple things like milk pick up text message reports on your mobile phone, or available testers or counters, which can help in the detection of mastitis. Most of the latter ones are based on milk conductivity which changes even prior to the cow showing signs of clinical infection. Many farmers manage to use conductivity meters to maintain milk quality within the limits required by the factory to ensure payment bonuses are secured. In New Zealand for example, a joint venture between farmers, commercial companies, milk industry and local vets, concluded in the development of a platform in which information is gathered together from different sources, easily accessible for farmers, which make management and daily actions more efficient.

ANIMAL MANAGEMENT

It was shown in a recent ABARE report, that 65-70% of the farms use computer management to run their business. A substantial growth in, so called, 'smart phones' has been observed, by which it becomes easier to access all the data on your PC, anywhere and at anytime. By installing remote 'control programs', it is quick and easy to check cow data, feed rations and for example when using AMS, even *control* the system. With these programs we become less dependent on the PC, as we do not have to be in the office to access data. 'Apps' for Apple, Android, Windows and Blackberry devices have been developed for agriculture purposes at very affordable prices. It is now easier to take notes while carrying out work, without having a large number of papers lying around. Other innovations include weather stations connected to a sprinkler system in a holding yard for example, whilst automating the sprinkler activation it can also alert the user to this by phone.

LABOUR MANAGEMENT

While the trend of an increased farm operation size continues to take place, keeping and organising staff in an efficient way becomes more and more challenging. The use of 'note taking' apps, increase the efficiency of employees being able to observe a problem and take down a corresponding note, without having to rely on paper or white boards. The 'cloud' technology even allows all these notes to be synchronised with PCs, laptops, notepads and telephones connected to a main server. The same principle is used by 'task killing' apps. A manager is able to assign certain tasks to particular employees, which need to 'tick' the task when it has being carried out. As internet becomes more accessible, the introduction of remote controlled IP cameras also offer another tool in regards to supervising and controlling the farm, be it either animal or people. Wherever you are you have the opportunity to, for example, keep an eye on the calving pad and assist with any problems if necessary. More controlled working tasks and protocols could lead to a more efficiently operated dairy farm. Technology increasingly creates opportunities for remote monitoring and management of the dairying operation.

SOCIAL MEDIA AND AGRICULTURE

In addition to the tools discussed, we need to think about the applications/potentials the Web has created. We have entered a new type of internet: "Web 2.0". A Web 2.0 site allows users to interact and collaborate with each other in a social media dialogue, in contrast to traditional websites where users are limited to the passive viewing of content that was created for them. Web 2.0 sites include social networking sites, blogs, wikis and video sharing sites. Social media has applications to dairy farmers. It has been described by Wikipedia as: "*the use of web-based and mobile technologies to turn communication into an interactive dialogue*". To name a few interesting social media stats; Facebook has over 800 million active users, Twitter over 380 million and LinkedIn 135 million, an average Facebook user has 130 "friends" and is connected to 80 community pages, groups and events, on average 250 million photo's are uploaded per day on Facebook, Barack Obama has 11.4 million followers on Twitter a and he has used this in his presidency campaign, a billion Tweets are sent per day, 3 billion videos are watched per day and every minute 48 hours of videos are uploaded on YouTube. If Facebook were a country it would be the world's 3rd largest population AND 80% of companies use social media for recruitment.

There is a great potential for the integration of social media on farms because it changes the way of communication between organizations, communities and individuals.

The image of agriculture has been put to the test in several occasions. Recently the publicity around export of live animals to Indonesia has had a bad influence on the image of agricultural businesses as has the recent campaign on Animal Australia; "Demand animals not be treated as 'waste products'." These examples remind us of how much pressure consumers can put on our industry. If we are not part of the solution then maybe we are part of the problem. As an industry we have every ability to use social media to create the positive perceptions to counterbalance the negative campaigns.

The Supermarket milk price wars escalated partly due to some very 'clever' use of social media by the supermarkets. As voices of the industry we can continue to be price takers or we can create our own impact through promotion of our industry, our products, home grown concepts, pasture to plate advantages and the list goes on. Generate empathy so that people understand the true impact of our industry on Australia's economy and what the long term impact of that cheap bottle of milk might be. If we cannot generate a better milk price ourselves, we should be smart enough to use the voice of the people to help us generate it.

Networking with people has never been easier! Social media is the way to get connected with people. It allows you to follow politicians, board members, CEOs or any decision makers, to stay up-to-date with new developments while communicating your ideas, thoughts and concerns to a wider audience. It has never been easier to speak up and share your opinion or at the very least, hear other people's opinions and the responses of the decision makers.

The latest statistics published by ABARE, shows that the highest rates of participation in sharing knowledge are in farmer discussion groups (49% of farms) and field days run by the private sector (42% farms). This shows the large interest of farmers to share knowledge with colleagues. Social media can be a, THIRD more interactive, possibility to share knowledge with each other and particularly with select groups of farmers with a common system type or area of interest. Geographical distance is no longer a barrier to knowledge sharing. Use social media to ask specific questions, follow colleague farmers and stay up-to-date with the latest challenges and resolutions they face. It is easy to find related comments and discussions to specific topics you're seeking an answer for. Become a member on Facebook and follow companies sharing knowledge and ideas with the world. Don't limit your thinking to: "*I don't dwell on Facebook or Twitter at all because I just don't need to get into that area of someone's life. I've got so much going on in my own.... So I'm looking for weather reports and market reports mostly* (www.slideshare.net)" There is so much more knowledge on the Web, free of charge, for us to use! Of course one has to be careful, filter the knowledge that is shared and do your homework before you make radical changes to your business.

Even though it takes some time to use social media, "*We don't have a choice on whether we DO social media, the question is how well we do it*" (E. Quallman; www.socialnomics.net). We believe the same happens with technology. As the saying goes, it is not the stronger one that will survive, it is the one that is able to adapt. The opportunities are out there, with a whole range of tools and applications, which could potentially be the next step in the dairy industry, making your 'farming life' easier.

LEAKY COWS, LEAKY SOILS, LEAKY WALLETS: CAN WE USE NUTRIENTS MORE EFFICIENTLY ON AUSTRALIAN DAIRY FARMS?

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The changing nature of Australian dairy operations, increasing fertiliser prices, and increasing pressure that farm practices are minimizing environmental impacts, requires improved nutrient management practices. Recent studies have found that most dairy farms are importing more nutrients than they export in products. Nitrogen (n), phosphorus (p) and potassium (k) balances are positively correlated ($p<0.001$) with stocking rate and milk production per ha. Many farms have already high soil fertility levels with likely limited production gains from further fertiliser expenditure. Increasing cow numbers and a greater reliance on imported feed, has resulted in high nutrient loads in specific areas across the farm. An essential starting point is farm-scale assessments of nutrient balances and use efficiencies, as well as routine soil testing, to guide fertiliser, effluent and manure applications. In the future, more sophisticated approaches will likely be required which quantify nutrient flows through feed and manure; capture and store a greater proportion of excreted manure; determine nutrient loading rates in areas across the farm; and ensure that fertiliser and manure is applied under the most favorable soil and climatic conditions for optimum plant uptake. These improved technologies and practices will assist in developing appropriate industry benchmarks for nutrient balances and benefit both productivity and environmental outcomes.

INTRODUCTION

Dairy production in Australia has continued to intensify, as measured by the volume of milk per hectare. While the number of dairy farms in Australia has declined by around 70% over the past 25 years, the average farm herd size and milk production per cow have increased, with national cow numbers having stayed roughly the same (Dairy Australia 2011). There is an ongoing trend for fewer, but larger, more capital intensive operations, with increased stocking rates. Associated with these increases in intensity of production is often a reliance on greater inputs of fertiliser and feed (Gourley *et al*. 2012; Weaver *et al*. 2008). For example, dairy farmers are using between 4 and 10 times the amount of N fertiliser compared with what they did 20 years ago. Approximately 180,000 tonne of fertiliser N is applied to dairy pastures in Australia annually; costing around $200m and equivalent to $30,000 per farm on average. The cost of manufacturing fertilisers, principally associated with the cost of fossil fuels, is expected to rise substantially in real terms in coming decades and consequently fertiliser decisions will become a larger part of dairy farm operating costs.

Total N and P inputs onto dairy farms, mainly in the forms of feed, fertiliser and N fixation by legumes, are usually much greater than the outputs of P and N in milk, animals, and crops (VandeHaar and St-Pierre 2006). These surpluses tend to increase as farms intensify and stocking rates increase. Excess P on dairy farms can result in increasing soil P levels beyond agronomic requirements (Gourley 2010; Weaver and Reed, 1998), which may also increase the concentration of dissolved P in surface runoff (Sharpley 1995), and leachate (Fortune *et al*., 2005). Unlike P, N is not significantly buffered by soils, and where N is applied in high concentrations such as in dung, urine or fertiliser, losses through volatilization and leaching can be high (Rotz *et al*., 2005).

The challenge of optimising the production potential and profitability of nutrient inputs in animal agriculture while reducing negative environmental effects is faced by most industrialized countries (Steinfeld *et al*. 2006) including Australia. Animal agriculture is now commonly recognised as the dominant contributor of nutrient inputs to water bodies because of its extensiveness (Department of Water 2010).

The purpose of this paper is to present recent information which has quantified the efficiency of nutrient use on dairy farms in Australia and discuss ways to enhance the productivity and profitability of nutrient use while at the same time reduce losses to the broader environment.

Nutrient balances and efficiencies in dairy production systems

Historically, agriculture largely depended on naturally available soil nutrients, nutrient recycling from animal manure or biological-N fixation by legumes. Innovations in fertiliser manufacturing, declining fertiliser and feed costs relative to other inputs such as labour and land, and the ability to transport agricultural inputs and outputs cheaply and extensively has led to a spatial disconnect between nutrient flows required for livestock production systems. Since the middle part of the 20th century, fertiliser use expanded greatly in Australia, US, Europe and other parts of the industrialized world (Cordell *et al*. 2009). Expressed in today's currency, world fertiliser prices have declined by 20 to 50% since 1960.

In much of the industrialised world the conversion of nutrients applied to pastures and crops into milk and meat are often low and consequently N and P application frequently exceeds requirements (Powell *et al*. 2010; Weaver and Wong 2011). For example, a national Australian study of nutrient use on dairy farms (Gourley *et al*. 2012) found that whole-farm N surplus (the difference between total nutrient imports and total nutrient exports) ranged from 47 to 601 kg ha^{-1} yr^{-1} and N use efficiency (the ratio of total nutrient exported in product divided by total nutrient imported at the farm scale) ranged from 14 to 50%. They also found a strong correlation between total N imported and milk production per ha (Fig. 1a) while N surplus was also strongly related to milk production (Fig. 1b) with the slope of this linear relationship (0.0121; SE = 0.0015) providing an estimate of the productivity N surplus, equivalent to 12.1 g N $litre^{-1}$ milk produced. Similar ranges in N surpluses and use efficiencies have been reported on commercial dairy farms in Europe (Raison *et al*. 2006; Fig. 1c) and also in New Zealand (Ledgard *et al*. 2004) and the USA (Hristov *et al*. 2006).

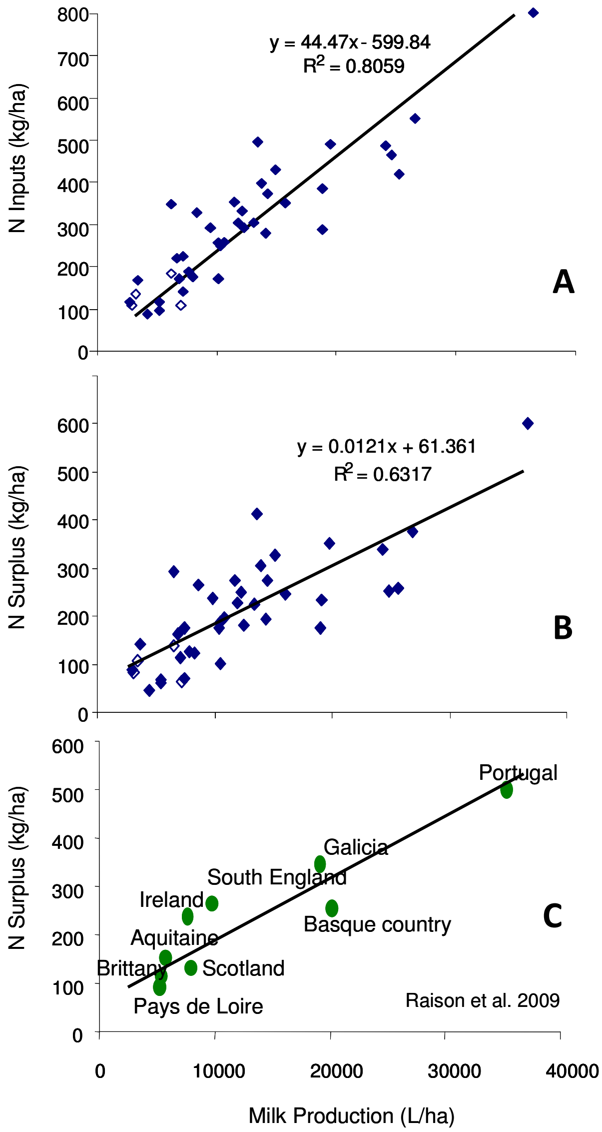

Figure 1. Relationships between milk production and (a) whole-farm nitrogen inputs and (b) nitrogen surplus for 41 contrasting dairy farms across Australia, and (c) average dairy nitrogen surpluses for dairy regions in Western Europe. Unshaded symbols represent organic dairy farms. Modified from Gourley et al. 2012.

Long-term fertiliser and manure applications have created P surpluses on soils used for dairy production throughout many parts of the industrialised world, including Europe (Fanguerio *et al*. 2008; Tunney *et al*. 2007; Behrendt and Boekhold, 1994), the USA (Mekken *et al*., 2006; Ketterings *et al*., 2005) and New Zealand (Monaghan et. al. 2008). In a recent analysis of P use in dairy, beef and sheep systems across Australia, Weaver and Wong (2011) determined that median P use efficiency was 29%, 19% and 11% respectively, and the systems were often characterized by positive P balance and P accumulation (Fig. 2). These authors also noted a high degree of variation, with some farms having P use efficiencies of >100%, when inputs were low or nil, and hence existing soil P reserves were utilised.

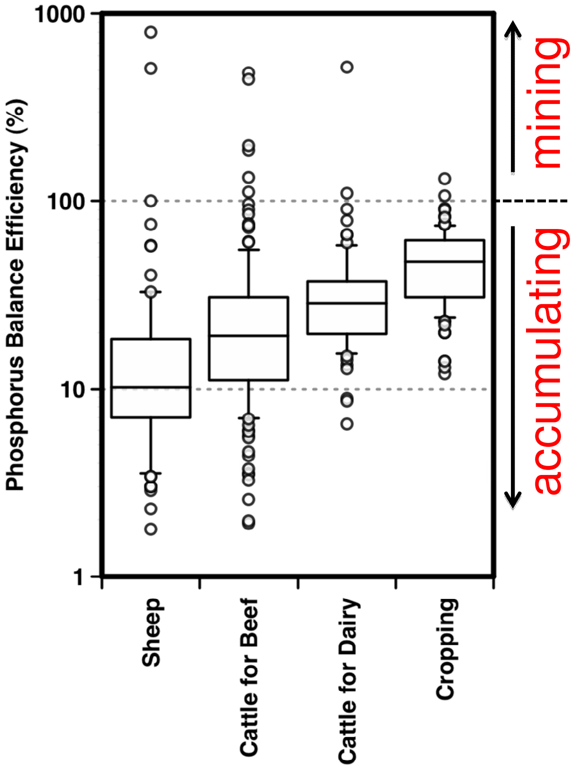

Figure 2. Phosphorus balance efficiency (outputs divided by inputs at the farm scale) for sheep, beef, dairy and cropping enterprises in Australia (adapted from Weaver and Wong 2011).

Accumulation and distribution of nutrients on dairy farms

A positive P balance is beneficial when the soil is deficient in P and good agronomic efficiency of applied fertiliser offsets low efficiency of use. Typically between 30 and 40% of fertiliser N and P applied to soil may be utilised by pasture and crops. Whilst residual available soil P can be relatively low, over time soil P levels increase beyond the point where agronomic responses occur.

The issue of nutrient accumulation in dairy soils was highlighted in the recent Accounting for Nutrients project (Gourley *et al*. 2010). In this study, more than 2000 individual dairy paddocks were soil sampled from 44 contrasting dairy farms across Australia, and additional information about the paddock use, distance from the dairy shed and grazing intensity, collected.

While there was a large range in soil P and potassium (K) levels from grazed pasture paddocks (Olsen P levels ranged between 3 and 189 mg/kg and the Colwell K levels ranged from 14 to 3400 mg/kg), only 20% of the paddocks sampled had soil P or K values below the recommended agronomic optimum (Olsen P of 20 mg/kg and Colwell K of 180 mg/kg), while 50% of the paddocks sampled were 1.5 times or more times the recommended agronomic optimum (Figure 3).

At the high fertility end, 20% of paddocks sampled had Olsen P or Colwell K levels at least 3 times the agronomic requirements. These results support recent assessments in Australia that suggest that excess nutrients place considerable pressure on the environment in some agricultural systems, but conversely, nutrient deficiencies may also be undermining crop productivity (OECD 2008). Soil testing to determine available soil P (i.e. Olsen 1954; Colwell 1965) is therefore an important tool to manage P build-up and maintenance.

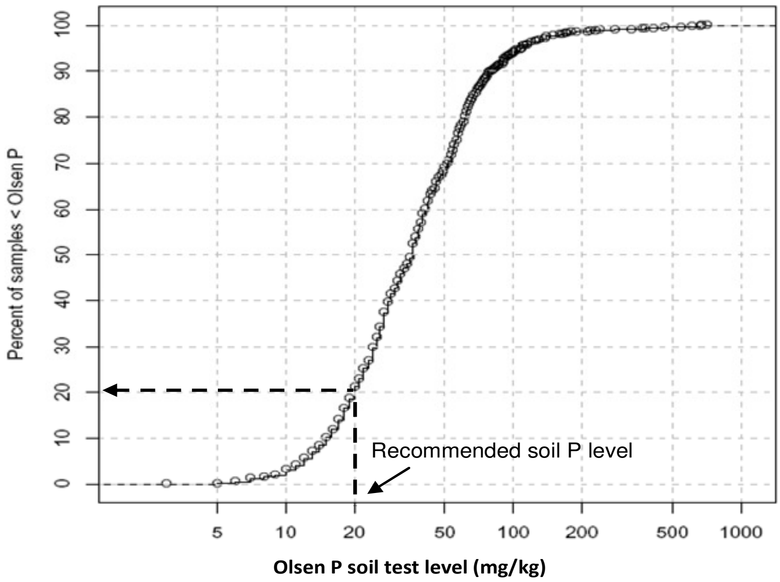

Figure 3. The proportion (%) of paddocks less than corresponding Olsen P soil test level (Gourley et al. 2010) and recommended soil P target (>2000 individual paddocks).

Nutrient accumulation can also be attributed to the high trophic level of grazing systems and the high proportion of consumed nutrients excreted by grazing animals (Odum 1971), which is further exacerbated by high stocking rates. In particular, dairy farms generally have high nutrient loading rates in specific parts of the landscape, due to the management of animal movements through controlled grazing as well as uncontrolled heterogeneous distribution of dung and urine by grazing animal (Aarons and Gourley 2011). Consequently, land use and grazing management can have a substantial impact on soil fertility levels. Gourley *et al*. (2010) found that areas with high animal densities, such as calving paddocks, feed pads, holding area and sick paddocks, had substantially elevated soil nutrient levels when compared to the overall pasture paddocks (Table 1). In contrast, low intensity areas such as 'other animal' and treed areas had much lower fertility levels.

Table 1. Mean soil pH, available P, levels of different land uses from 40 dairy farms.

Management/Use	**Distance to dairy (m)**	**pH (CaCl2)**	**Olsen P (mg/kg)**	**Colwell P (mg/kg)**
Pasture n=1773	881.4	5.3 (0.7)	35.6 (20)	127 (76)
Bull paddock n=6	444.0	5.3 (0.9)	48.8 (26)	169 (82)
Feeding areas n=12	53.1	6.8 (1.2)	319.9 (285)	1151 (1286)
Holding area n=13	400.4	5.8 (0.9)	143.5 (171)	510 (685)
Sick paddock n=16	46.9	5.6 (0.9)	71.4 (61)	280 (282)
Other animal n=104	na	5.1 (0.6)	27.4 (15)	100 (58)

** n= number of paddock areas sampled* *^ Standard Deviation in parenthesis*

Production gains from fertiliser inputs

With further anticipated increases in fertiliser prices, continued over application of N, P and K fertilisers may challenge the on-going profitability and sustainability of many dairy farm businesses. Recent research in Australia, including the 'Greener Pastures' project in WA (Staines *et al*. 2012), and Accounting for Nutrients project (Gourley *et al*. 2012) have demonstrated that the efficiency of nutrient use from fertiliser applications is variable and often low. For example, Staines *et al*. (2012) reported that half the dairy farmers in WA were using more N than the agronomic optimum.

Gourley *et al*. (2012) investigated the relationship between N, P and K fertiliser inputs and milk production from home-grown pasture on 41 commercial dairy farms nationally (Figure 4). While they found that milk production from home-grown feed increased with increasing N fertiliser input, there was a high variation and uncertainty around milk production gains (Fig. 4a), suggesting substantial improvements in N fertiliser responses could be achieved on many farms. The relationship improved slightly when additional N from the fixation of atmospheric nitrogen by pasture legumes was included (Fig. 4b).

In contrast there was no relationship between P and K fertiliser applications and milk production attributed to home-grown feed (Fig. 4c and d). The lack of a defined relationship between P and K fertiliser inputs and productivity is supported by the generally high levels of soil P and K measured. Under these high soil P and K conditions, additional pasture and crop production from the application of P and K fertiliser would not be expected and therefore neither would an associated increase in milk production from home grown feed. Moreover, the milk production from farms with low or no P or K fertiliser inputs but with adequate levels of soil P or K, suggest that these soil reserves can be utilized without a resulting decline in milk production.

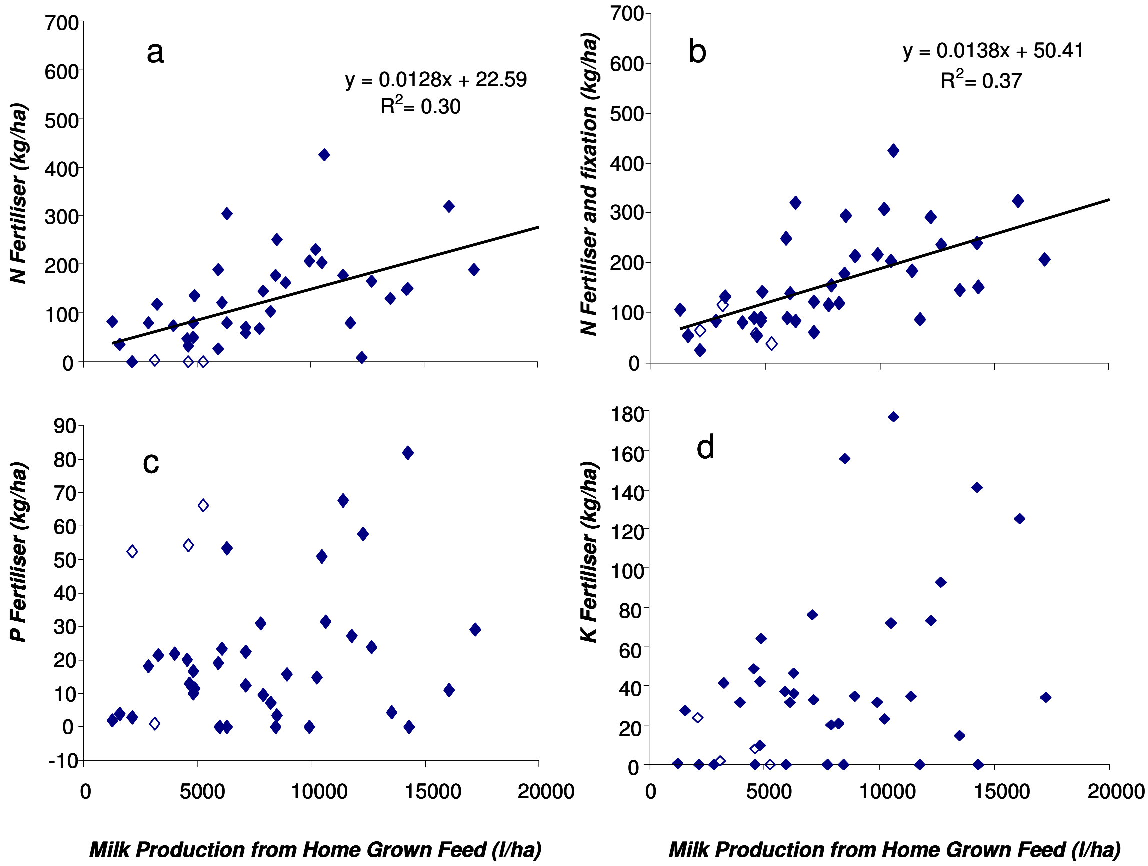

Figure 4. Relationships between milk production from home-grown feed and (a) N fertiliser input, (b) N fertiliser plus N fixation, (c) P fertiliser input and (d) K fertiliser input. Open symbols represent the organic dairy farms. Modified from Gourley et al. 2012.

Opportunities to increase the efficiency and profitability of nutrient use

The current efficiency of nutrient use determined on Australian dairy farms suggests that there are substantial opportunities for improvement, which can enhance production and profitability, and reduce nutrient losses to the broader environment. While there are stronger regulatory drivers for reduced nutrient losses from dairy farms in Europe and the USA than in Australia (Gourley and Weaver 2012), recommended intervention strategies used overseas should also improve nutrient use efficiency on Australian dairy farms. These key management strategies within the major components of nutrient cycles (Fig. 5) include: a reduction in, or more strategic use of inorganic fertilisers, optimizing the use of home-produced manure, reduced grazing time and lowering nutrient concentrations in the ration (Oenema *et al*. 2011). These strategies have resulted in substantial reductions in N and P surpluses and increases in use efficiencies on dairy farms in the Netherlands (Groot *et al*. 2006), Flanders (Nevens *et al*. 2006), South-west England (Cherry *et al*. 2011), Northern Portugal (Fangueiro et. al. 2008) as well as contrasting dairy systems in the USA (Jonker *et al*. 2002; Kohn *et al*. 1997).

Improving fertiliser decisions

Currently many dairy farmers use excessive fertiliser nutrients because they, and their advisors, make decisions on average and not marginal responses, do not know enough about the uncertainty in pasture response functions and at best do superficial analysis of the likely economic benefits. This approach and an insurance mentality of 'more just to make sure' creates incentives for excessive fertiliser use.

The potential milk production benefits of applying P, K and S fertilisers should be strongly scrutinised as limited milk production gains are likely from further fertiliser inputs when soil P, K and S levels are already high (Gourley *et al*. 2010; Gourley *et al*. 2012). A strategic soil sampling approach should be used to monitor soil P, K and S reserves and when above agronomic requirements, these may be utilised for a period of time without a resulting decline in milk production.

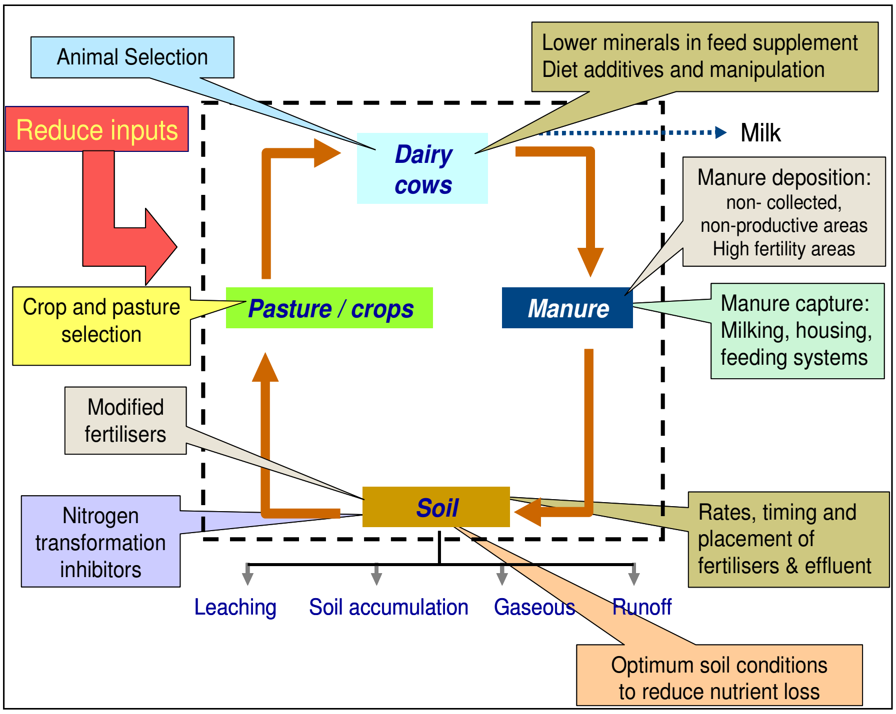

Figure 5. Components of nutrient cycling within dairy farms and key points of intervention to increase the efficiency of nutrient use.

Increasing complexity in dairy farm businesses makes more informed decisions about N fertiliser applications essential. There is a need to move from generalized average and linear predictions of pasture production responses (e.g. 10 kg DM / kg N applied on average, or, 1 kg N/ha/day of grazing) to advice that is profit-based and tailored to the system/farm business taking into account the climate and management conditions under which a farm operates (MacKenzie et. al. 2003a,b). This is particularly the case with N fertiliser where the benefits are determined by important interactions between parts of the farm system (e.g. feed production, stock policies and feed utilisation).

Improving dietary intake

Balancing nutrient intakes and reducing the concentration of excreted nutrients may be more difficult on grazing-based dairy farms, particularly when pasture comprises the majority of the diet. Nutrient intakes in pasture can vary significantly between farms and seasons, and excess levels of dietary N, P and K intake are common, particularly during spring (Jacobs and Rigby 1999). This is further exacerbated with regular use of fertilisers and the application of dairy effluent. McKenzie *et al*. (2003c) found in Victorian dairy pastures that increasing rates of N fertiliser consistently elevated whole sward crude protein content, with this effect still evident three months after the last N application. Better balanced diets can be manipulated through improved selections of imported feeds. For example, the use of by-products such as brewer's grain has the potential to increase nutrient concentrations in the diet, while in contrast, the use of concentrates and cereal and maize silage presents opportunities to better balance energy and crude protein levels in dairy feeds.

Improving manure distribution

As a result of the common practice of year-round grazing, a much smaller proportion of dairy manure is usually collected in Australia than from housing systems overseas (Gourley *et al*. 2011) and generally from concreted areas such as the dairy shed, holding yards and feed pads. Collected manure in grazing based systems is more frequently applied to readily accessible paddocks adjacent to the holding dams (Gourley *et al*. 2007). As cow numbers and reliance on feeding systems increase, continued poor redistribution of collected and uncollected manure has the potential to result in greater nutrient loads and nutrient losses in the future. Consequently, further investment in collection, storage and redistribution systems may be required to overcome current and future inefficiencies in the recycling of manure nutrients.

CONCLUSIONS AND RECOMMENDATIONS

- Flows of nutrients into water and the air are an inevitable consequence of dairy production. If current nutrient management practices persist and dairy farms continue to intensify, nutrient surpluses are likely to further increase with greater nutrient losses to the broader environment.

- Nutrient use efficiency in dairy production is limited by the biological potential of cows to transform feed nutrients into milk and of crops and pastures to convert applied nutrients into forage and other agronomic products.

- The overall industry estimate of whole-farm N use efficiency (the proportion of imported N exported in product) is 26%, with around 12 g of N lost to the broader environment for each litre of Australian milk produced. Whole-farm N surplus is strongly linked to milk production per ha, and is comparable to similar systems in other industrialised dairy industries such as New Zealand, the EU and USA.

- Key indicators of elevated soil P and K fertility are overall stocking rate and milk production per ha. These indicators reflect the intensity of the dairy operation and likely higher amounts of nutrients imported in feed and fertiliser.

- Within farm soil nutrient heterogeneity is substantial, irrespective of the intensity of the dairy operation. Higher soil nutrient levels of P, K (and N) are driven by paddock stocking density, proximity to the dairy, frequency of effluent applications, and feeding strategies.

- High nutrient loading from the deposition of animal excreta is a key driver of elevated soil nutrient levels. Paddocks with high densities of animals per ha can have high nutrient accumulation while those infrequently visited and with low stock densities will generally have lower soil nutrient levels.

- There are opportunities on many dairy farms to reduce or exclude fertiliser inputs in the short to medium term. The relatively small costs associated with a strategic and on-going soil sampling program are likely to be returned many times through the potential savings in unnecessary fertiliser expenditure. Where applications are warranted, appropriate rates and blends of fertiliser should ensure profitable increases in pasture and crop productivity.

- In the future, more sophisticated approaches will likely be required which quantify nutrient flows through the continuum of feed, milk production and manure; increases the capture and store of excreted manure; determines nutrient loading rates in areas across the farm; and ensures that fertiliser and manure are applied under favorable soil and climatic conditions for optimum plant uptake.

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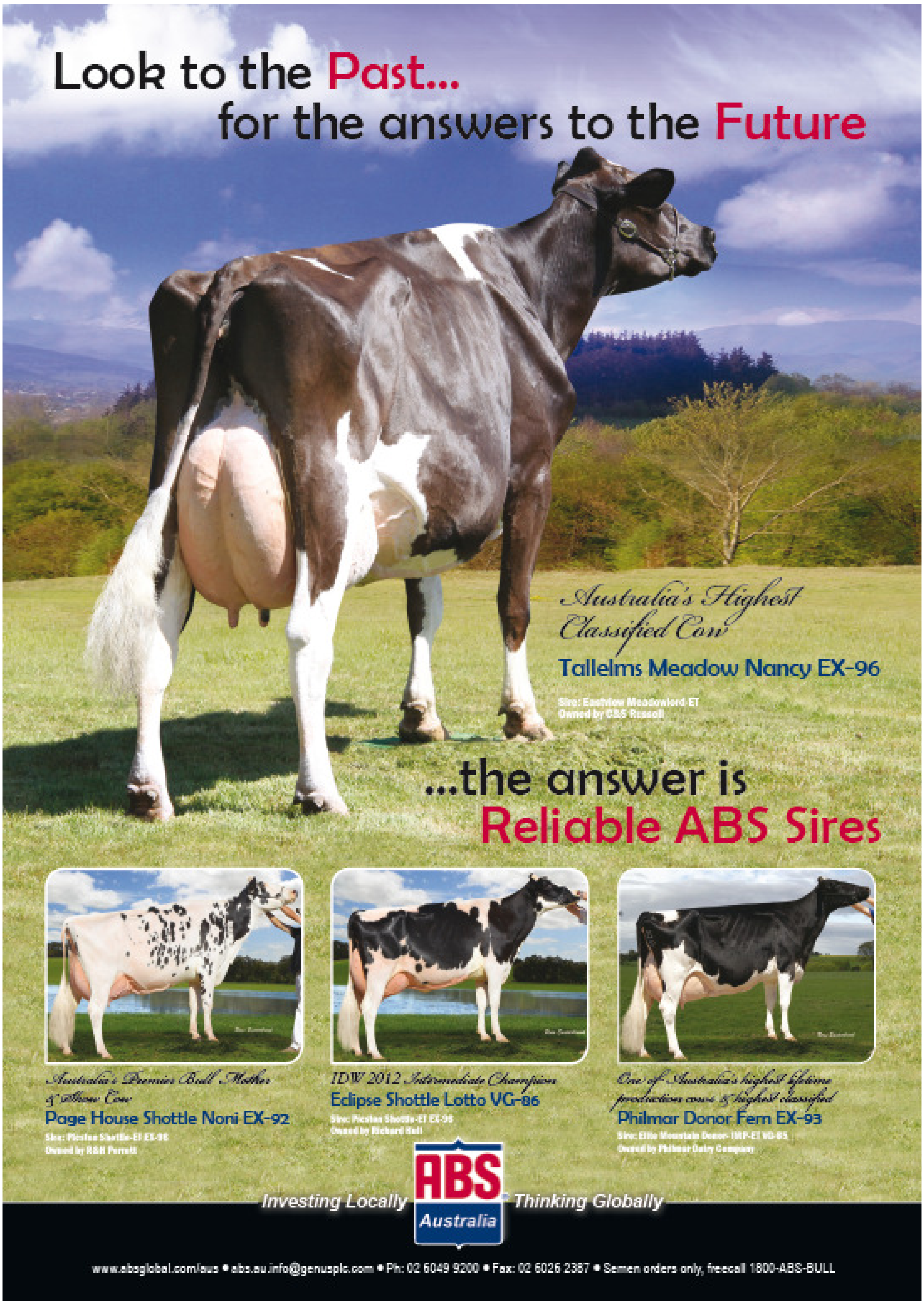

HOW COMPLEMENTARY FORAGE SYSTEMS CAN HELP FARMERS TO REDUCE 'WASTAGE' AND INCREASE PRODUCTIVITY

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Complementary forage systems (CFS) are a combination of crop rotations and pasture designed to increase, directly or indirectly, milk production from home-grown feed. Complementary forage systems can be implemented in many different ways according to individual farms' needs. The principles behind CFS have been developed and tested by FutureDairy 1 and 2 over the last 7 years. They can be used in an integrated way to achieve maximum productivity benefits or individually to help farmers with specific feedbase related challenges. This paper summarises how the principles and application of the CFS concept can help dairy farmers save time and money, by increasing productivity efficiency and reducing wastage.

INTRODUCTION

Complementary forage systems (CFS) are any combination of pasture and planned (complementary) forage crop rotations (CFR) designed to increase the amount of feed grown on farm and, from this, productivity (Farina *et al*., 2011).

The term CFR refers to any planned forage crop rotation (double or triple crop, grazable, harvestable or a mix of both, etc.). The common factor of all CFR's options is that they can potentially achieve a much higher forage production than pasture alone (Garcia *et al*., 2008). However, the actual impact of CFR on the whole system (CFS) will depend on the particular combination of CFR and pasture areas. This in turn, depends on individual situation and needs of each farm.

The potential impact of a CFS (see Figure 1) includes increased forage production, more milk from home-grown feed, improved nutrient efficiency and risk management.

The concept, principles, knowledge and information developed by FutureDairy (feedbase) can help Australian farmers to reduce 'wastage' and increase production efficiency. Key ways in which this can occur are through saving of time, nutrients, grain, risk and money.

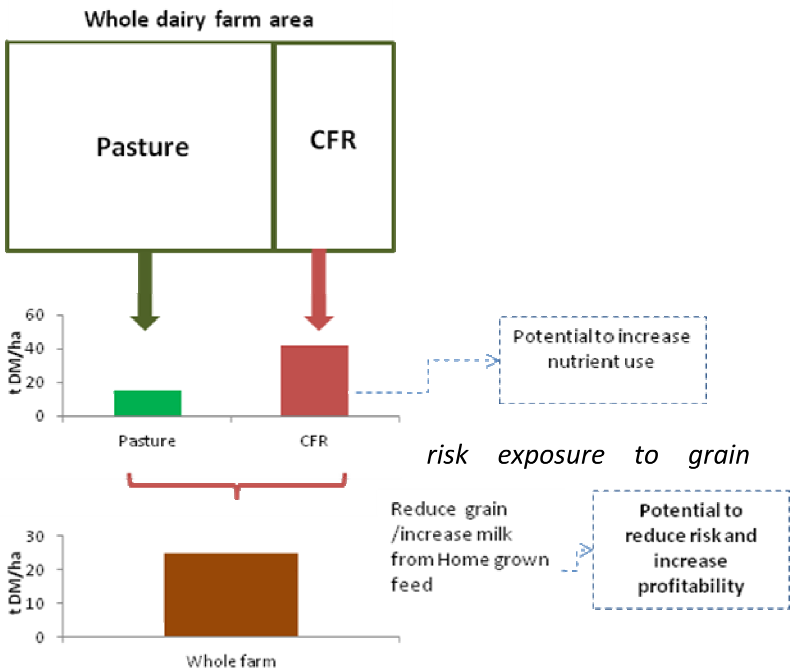

Figure 1: A combination of CFR and pasture areas can increase total home grown feed and milk production, reducing risk exposure to grain prices and increasing effiency of nutrient use.

SAVING TIME

Time is probably the most valuable asset for dairy farmers. It is not uncommon to see Australian farmers work long hours every day, 7 days a week. In addition, the upward trend in labour costs means less staff on farm and more tasks left to be done by the farmer. Time is both money and lifestyle and clearly farmers will have to manage their time much more efficiently in the future.

Arguably, the most important thing that can help save time –in practically any business or activity- is planning.

Planning is paramount to efficient dairy farming. Planning can easily identify the strengths and weakness of any system with clarity, allowing better and more organised decisions in relation to labour required (amount and level of skill) and operational tasks (distribution, responsibilities) to be made.

How can CFS help?

The application of CFS principles starts with a planning process. Complementary forage systems can be used to meet a need for additional home-grown feed, so ensuring this need exists is crucial to ensure success.

A CFS may be an option if a farmer needs to maximise feed production from limited land and/or limited irrigation water. However, if the amount of feed produced on farm is not the main limiting factor of that farm, then CFS will not be the solution.

FutureDairy implemented an innovative, proactive, efficient and challenging approach to planning, starting with setting business goal/s which drive production, system and feedbase goals. These steps are shown in Figure 2.

Figure 2: The 'Goal' sequence in Future Dairy's planning process

In addition, FutureDairy developed a Feedbase planner (Figure 3) that can help farmers with the above process in a quick and easy way. Once farmers have determined their business goals and the amount of milk that needs to be produced, they can use the FutureDairy Feedbase Planner tool to quickly set up current status of their farms (number of cows, calving pattern, milk yield, pasture and crops areas). The Feedbase Planner provides graphical outputs of whole system energy balance (total energy requirements and total energy offered by each forage and supplement source). Users can easily change area of crops and pasture, or type and amount of supplements to correct energy balance (see examples in Figures 4 and 5).

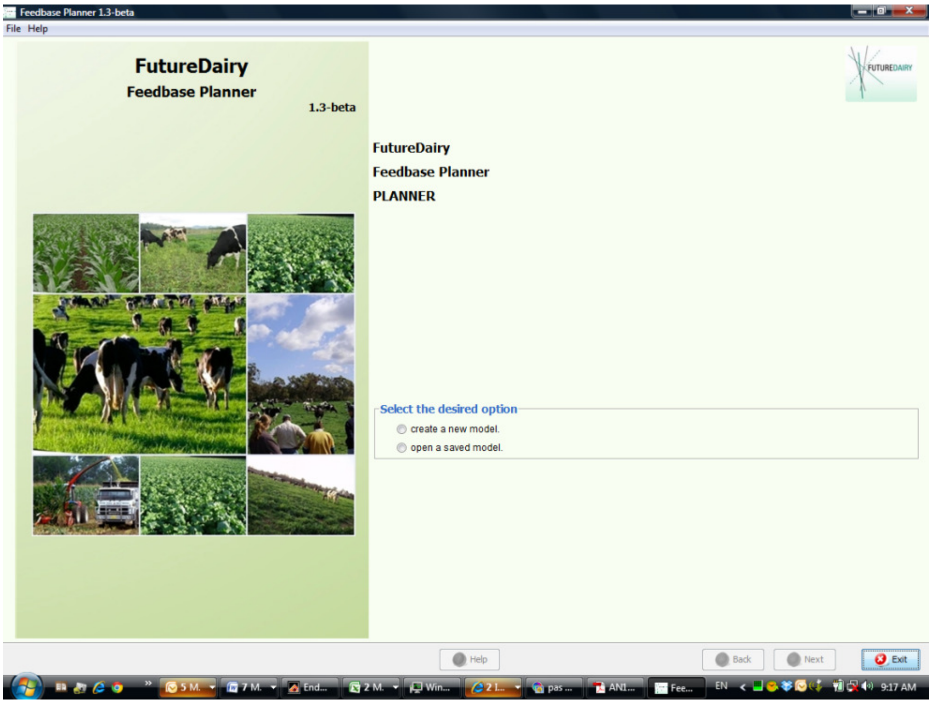

Figure 3: FutureDairy's Feedbase Planner interface

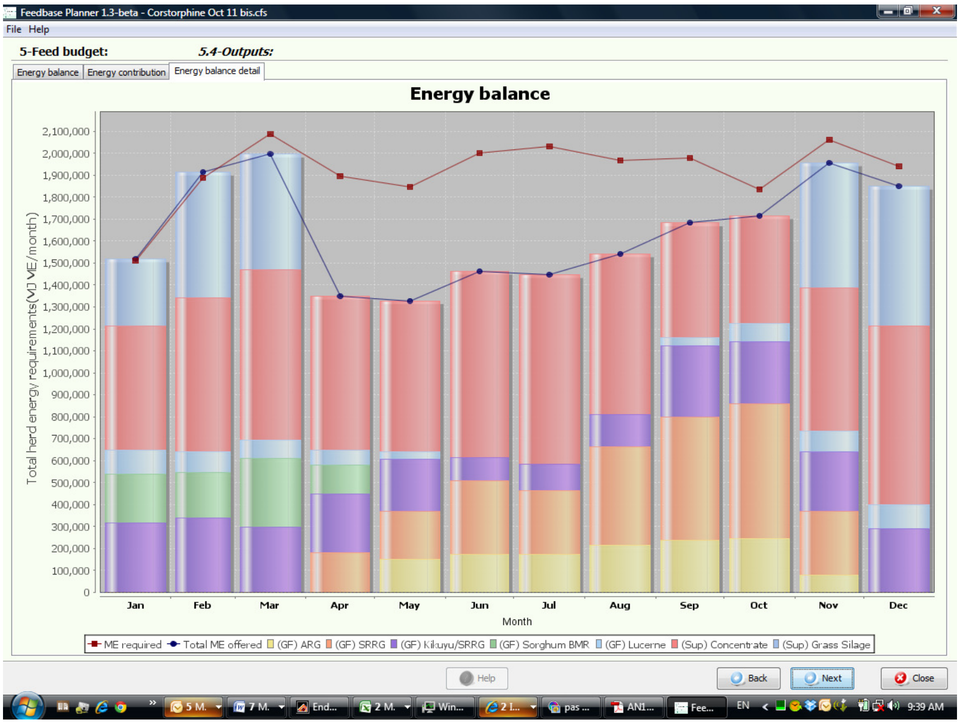

Figure 4: Feedbase Planner showing a deficit of energy (gap between the 2 lines) from April to October

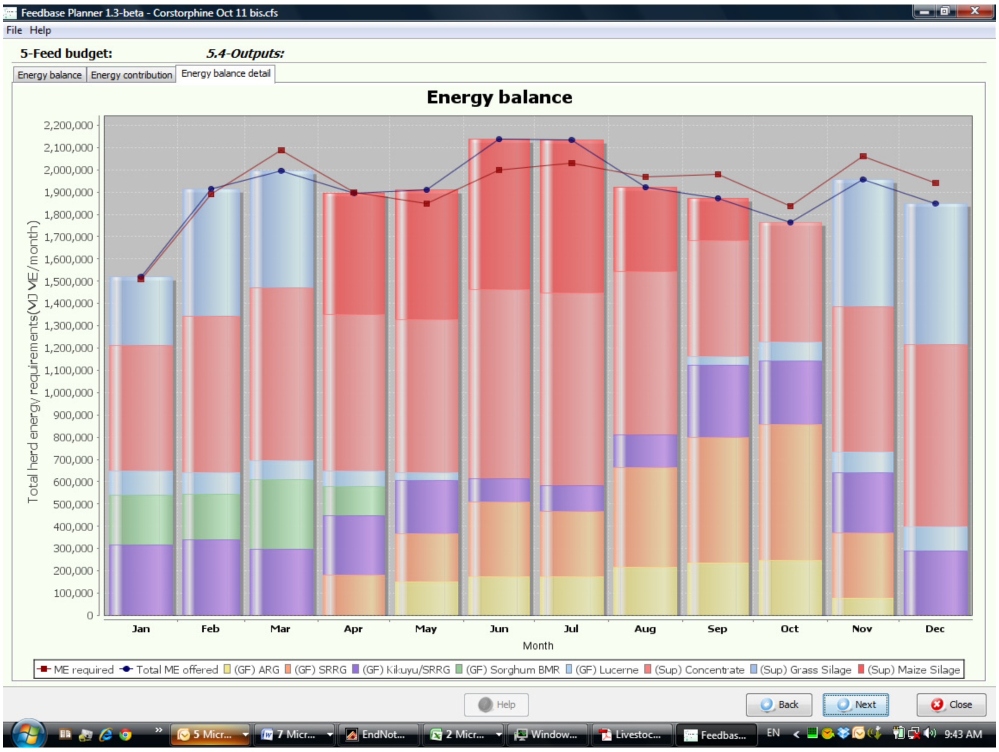

Figure 5: Feedbase Planner showing adequate whole system energy balance after including supplementation with maize silage from CFR area

SAVING MONEY

1. By increasing efficiency of key inputs

Water (W) and nitrogen (N) are quantitatively the two most important limiting factors of forage production. In the future, the cost of irrigation W is expected to increase due to decreased availability of W. This is consequence of new government policies (e.g. Murray –Darling basin plan) and competition with other activities (other agricultural activities, urbanisation and mining). Similarly, the cost of urea is expected to increase in the future in line with increased cost of fossil-derived energy.

How can CFS help?

Complementary forage systems can substantially increase efficiency of W and N use compared to typical pasture systems. FutureDairy's work has demonstrated that similar amounts of W and N are required to maximise yield of crops or pasture. As a triple crop forage rotation can yield twice as much as a well managed pasture the efficiency of nutrient use also doubles (Garcia *et al*. 2008) (Figure 6).

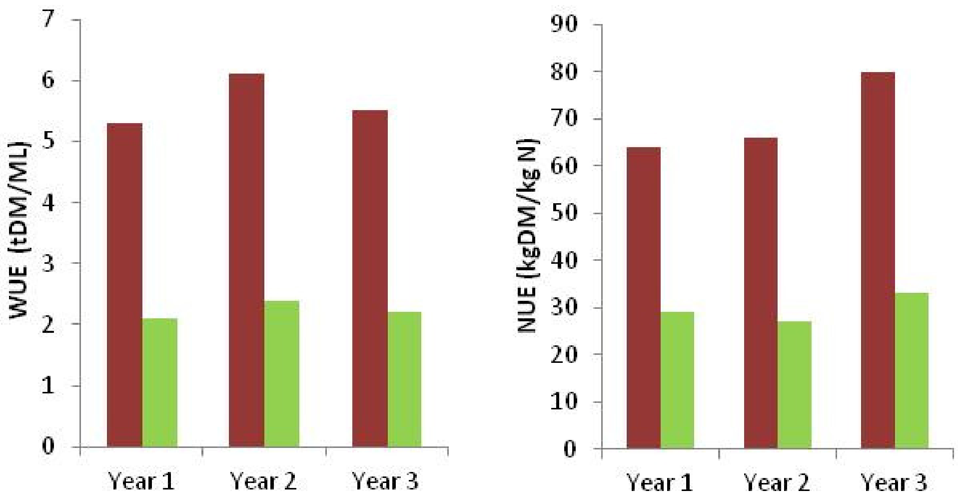

Figure 6: Irrigation water (left) and nitrogen use efficiency of CFR (dark bars) and pasture systems (Garcia et al 2008)

The above-mentioned work was carried out with no limitation of W and N. More recent work by FutureDairy has been conducted to fine tune water use efficiency (WUE) and nitrogen use efficiency (NUE). This involved a whole range of N for triple crop forage rotations all under 4 different irrigation regimes. This study showed that:

- WUE decreases as irrigation increases and NUE decreases as N fertiliser rate increases.
- However, there is strong synergic effect between W and N (ie, NUE increases with irrigation and WUE increases with N rate)
- Full irrigation increased NUE by at least ~30% compared to no irrigation. The effect of irrigation on NUE increased as N rate increased. However, the maximum marginal increment in NUE due to irrigation occurred at moderate-high (~400 kgN/ha) rather than maximum levels of N input (Figure 7).
- Similarly, the increase in WUE due to N level was higher at 66% of irrigation in comparison to 100% irrigation treatment.

Thus, these results indicate that significant gains in both WUE and NUE can be obtained by using moderate-high levels of nutrients rather than maximum levels. Clearly, optimisation of nutrient use will be key to efficiency gain in the future.

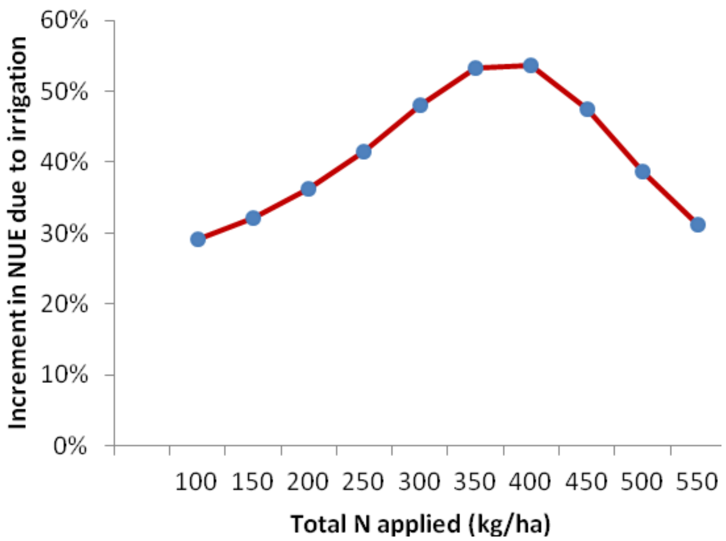

Figure 7: Relationship between N input (kg/ha) and increment of NUE due to irrigation (% over control with no irrigation). Moderate-high levels of N (~400 kg/ha) maximised effect of irrigation on NUE (kg DM/kg N)

2. By producing more milk from home grown feed

Energy-based concentrates are typically the single most expensive cost of producing milk in Australia. Cost of concentrate fluctuates with cost of cereal grains, which in turn depends on both external (international market) and internal (e.g. seasonal conditions) factors. Australian dairy farms use an average of ~1.7 t concentrate/cow (~30-35% of total dietary requirements).

The cost of concentrates is expected to rise in the future. This is mainly due to pressures on land availability to grow grains coupled with increased demand of grain for feed and fuel usages. In addition to the cost, the use of grain to produce animal protein will be increasingly questioned in the future. This is because grains are edible feed and therefore can be consumed directly by humans; and animal protein, at least ruminant animal protein, can be produced efficiently from non-edible feeds (forages) (Wilkinson, 2011).

Thus reducing farms' dependence on concentrate and increasing feed conversion efficiency (FCE) may become increasingly important for Australian dairy systems in the future.

How can CFS help?

FutureDairy's feedbase work has shown that:

- FCE in well managed pasture based system can be in the order of ~1.3L/kg DM for a medium to high stocking rate and medium to moderate production per cow. The key to achieve high FCE is to ensure that supplements, including grain, are fed to cows primarily when true pasture- (or better, grazed forage-) deficits exist.
- Almost 30,000 L/ha can be produced from home-grown feed and using relatively small amount of concentrate (~1 t/cow) when a full CFS is implemented. The key to achieve increased milk production from home grown feed is to properly integrate CFR into the pasture based system, producing more feed per ha.

3. By helping farmers managing risk

Risk has different meaning for different people. In the context of dairy production and from an economic viewpoint, risk can be quantified in terms of probability of not achieving a given target. Farmers however, intuitively associate risk with chances of a financial loss due to adverse outcomes and/or the size of the loss (Little, 2011).

There are five types of risk associated with a CFS: climate, price, human, financial and environmental risks (Farina, 2010).

Climate risk relates to variable seasonal conditions and/or adverse climate-related events (e.g. floods and droughts) and is generally perceived as the largest risk of introducing forage crops in pasture-based systems. The probability of occurrence is moderate (provided reliable irrigation water is available) but the potential impact very high when it occurs (e.g. flooded paddocks or wet, cold weather at harvest of a maize crop).

However, FutureDairy's work has shown that:

- Risk associated to forage production is reduced by good nutrient and water management. Irrigation in particular is crucial in reducing risk of crop failure and/or poor yields (Farina, 2010) (see Figure 8).
- Risk associated to fluctuations in grain price can be reduced by implementing CFS (see above)
- Compared to a pasture plus concentrate system, a CFS system is less risky in economic terms (potentially achieving economic target more consistently over a long period of time)

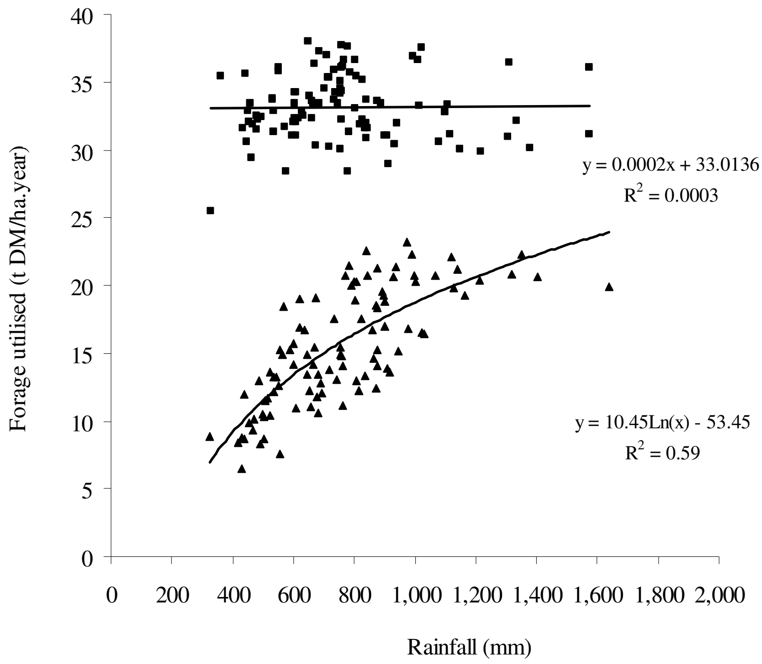

Figure 8: Relationship between simulated total utilised forage yield (t DM/ha.year) and annual rainfall (mm) for forage crops (▯) and pasture (▯) of the CFS (Farina 2010). For this simulation of over 100 years using APSIM, up to 4.5 ML or irrigation water were used on each individual year. The graph shows that using limited amounts of irrigation water on CFR can result, compared to pasture, in a higher and more consistent (less variable) total forage annual yield. This is because pasture systems require relatively larger amounts of water in summer with relatively lower water use efficiency than high yielding summer crops like maize.

In summary, the concept of CFR and its integration into the pasture system (CFS) can clearly help farmers to increase production efficiency, and from this, profitability.

Planning is the essential first step in the application of CFS principles and can help farmers to save time (a crucial and very limited asset!). This is the key to survival and growth of individual farms and the industry as a whole.

In addition, the principles and practices of CFS can be applied on individual farms to increase home grown feed (and partially reduce dependence on more expensive supplements); increase water and nitrogen use efficiency and reduce risk. All together, this can pave the path to increase overall production efficiency and, from this, profitability.

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GREEN CLEANING™ SYSTEMS – 12 MONTHS ON

ANNETTE ZURRER

Dairy Farmer, Gippsland Region, Vic

Green Cleaning™ systems are milking machine wash systems that operate at low temperatures, re-use the cleaning solutions and are energy efficient. The various makes and models now available comprise an automated cleaning unit that is capable of capturing, storing and re-using the wash solutions.

They use chemicals that are specifically designed for re-use, and to work at lower temperatures (less than 50°C).

Figure 1. The Green Cleaning ™ System installed by GEA Farm Technologies (WestFalia) on the Victorian case study trial farm.

In some models the wash solutions are heated using energy from renewable sources such as solar or heat recovery. The storage tanks are well insulated to minimise any heat losses.

A website has been established specifically for information about Green Cleaning™ systems at www.agvetprojects.com.au/greencleaning

It's been over a year since the first commercial Green Cleaning™ systems appeared on four farms in different areas of Victoria. The dairy farmers who installed the systems were doing so for a range of reasons; energy and cost savings being integral factors.

These early systems functioned as 'trial systems' for the companies making them. It was an opportunity to monitor, adjust, and enhance the systems before they were offered more widely.

SO, ONE YEAR ON, HOW HAVE THEY PERFORMED? HAVE THERE BEEN SAVINGS? AND IF SO, WHERE HAVE THEY BEEN?

Three different companies – Ecolab, GEA Farm Technologies and Milka-Ware – have Green Cleaning™ systems installed. Each system is different but they all aim to achieve the essential elements of Green Cleaning, that is: operate at low temperatures, re-use the cleaning solutions, and be energy efficient.

Over the year, all farms have experimented with different re-use chemicals, different cleaning programs, and different operating temperatures. Fine tuning is continuing (as of May 2012) to further reduce energy consumption.

One of the farms where the principles of Green Cleaning have been fully deployed the savings have been substantial, and serves as a good case study example of what can be achieved.

RESULTS FROM A COMMERCIAL CASE STUDY FARM

Our case study farm is typical of many; a herd size of around 400 cows, milking twice a day through a 50 unit rotary. There is an automatic wash system to clean the milking machine. The original wash program was similar to that used on other dairy farms; cold rinse, hot wash (alternating between alkali & acid) and a warm rinse as the final cycle.

All solutions were discarded after use. Water used for cleaning the milking machine was heated to 90oC using a 1,800-litre conventional dairy hot water service.

The Green Cleaning™ system was installed on this farm in February/March 2011. It comprised three 750 litre, well insulated tanks to store the cleaning solutions, a heat recovery unit (on the refrigeration system) to pre-heat water, and the control system.

The Green Cleaning project was delivered by AgVet Projects on behalf of GippsDairy, and was funded through the Victorian Government's Sustainability Fund and the Gardiner Foundation.

Water heated in the heat recovery unit is used for the pre-rinse (1st cycle), and to top up the hot water service (HWS). The hot water from the HWS is used to top up the alkali tank (~120 l/day) and as a means to heat the alkali to the required temperature (initially 60oC but now 50oC).

The thermostat in the hot water service was turned down to 70oC to reduce standing heat losses in the HWS.

THE SAVINGS

The table on the next page compares the two cleaning systems. The Green CleaningTM System has resulted in reductions in electricity use, chemicals, water, and greenhouse gas emissions.

For this farm, the overall milking machine cleaning costs have been reduced by 38.5% - a good outcome but significant improvements are still possible.

Table 1: Comparison of conventional and Green Cleaning machine cleaning systems on case study farm.

	BEFORE *original wash system* *(single-use)*		**AFTER** *Green Cleaning™ System* *(re-use)*		**IMPACT**
	AM	**PM**	**AM**	**PM**	
1st cycle	Warm pre-rinse	Warm pre-rinse	Warm pre-rinse	Warm pre-rinse	
2nd cycle	Hot alkali wash	Hot acid wash	Combined warm alkali wash & sanitizer	Combined cold acid wash & sanitizer	
3rd cycle	Warm rinse	Warm rinse			
Cycle volume (L)	400	400	400 (rinse) 550-575 (Alkali sanitizer)	400 (rinse) 550-575 (Acid sanitizer)	
Total hot water used (L)	600	600	120	0	90%
Total water used i.e. discarded (L)	1,200 (400/cycle)	1,200 (400/cycle)	520 (400 for 1st cycle & 120 to top up alkali)	520 (400 for 1st cycle & 120 to top up acid)	57%
Electricity use (kWh/day)	114		43		62%*
Daily Greenhouse gas emissions	140.7 kgCO2 –e		52.9 kgCO2 –e		62%
Daily electricity cost**	$8.09		$3.04		62%
Total chemical use (L/day)	2.3		1.7		26%
Daily chemical costs	$9.57		$7.83		18%
TOTAL DAILY COSTS	**$17.67**		**$10.87**		**38%**

* Standing heat losses in the HWS were estimated to be 25 kWh/day. Minimising heat loss would see electricity use decrease by 85%.

** Average electricity off-peak tariff rate was 7.07 cents/kWh – lower than the 10-14 cents/kWh found on many farm electricity bills.

FURTHER IMPROVEMENTS IN THE PIPELINE

Using the original HWS – at a lower temperature – as a heat source for the alkali tank seems a logical and cost effective option. However, a review of energy use of the case study farm identified that this may not be the best option. This is because of the standing heat losses in the HWS.

Of the 43 kWh used in the Green CleaningTM system, 25 kWh was attributed to HWS heat losses, which means 58% of the energy consumed was actually lost through poor insulation of the HWS.

Removing the HWS and using an alternative way of heating the alkali solution (such as having a heating element inside the tank itself), or by improving insulation of the HWS would see electricity use drop to around 18 kWh per day – representing an 85% reduction in electricity consumption.

Similarly, additional savings in water and chemical use have also been identified and AgVet Projects is working with each of the manufacturers to improve the efficiency of the various commercial systems on offer.

Stable operating conditions (chemical concentrations, temperatures and water quality) result in consistently good cleaning efficacy and milk quality.

Alarms on the automated systems help to ensure the systems are operating as intended.

TOTAL COSTS OF OWNERSHIP

A good way to compare the financial merits between a conventional cleaning system and a Green CleaningTM system is to work out the total cost of ownership for each option.

The total cost of ownership is a financial tool that can help determine the total cost of a piece of equipment over its lifetime. It includes the initial capital cost as well as the operating costs during its practical service life.

Taking the findings from this case into consideration – but using better insulating properties and more representative electricity tariff rates – a TCO comparison between the Green CleaningTM system and the pre-existing system can be made. This is shown in the figure below.

Like most energy efficient equipment, the initial capital cost of the Green CleaningTM system is likely to be greater than conventional auto-wash systems, but the on-going operating costs are lower. In this case, the there is an existing system so no capital outlay is required.

A Green CleaningTM System costing $40,000 installed is used for the comparison.

For the first 6½ years the total cost of ownership for the Green CleaningTM system is greater than the conventional auto-wash system. After this time the total cost of ownership will be less for the Green CleaningTM system.

After 10 years, the existing system has cost $26,884 more to own and operate.

If the same conditions were applied to a new dairy where the options were:

- a conventional auto wash (with large HWS) costing $20,000 installed or
- a high-end Green CleaningTM system costing $40,000 installed

then the total cost of ownership becomes less for the Green CleaningTM system after 3.25 years, saving $46,884 (in today's dollars) over a 10 year lifespan.

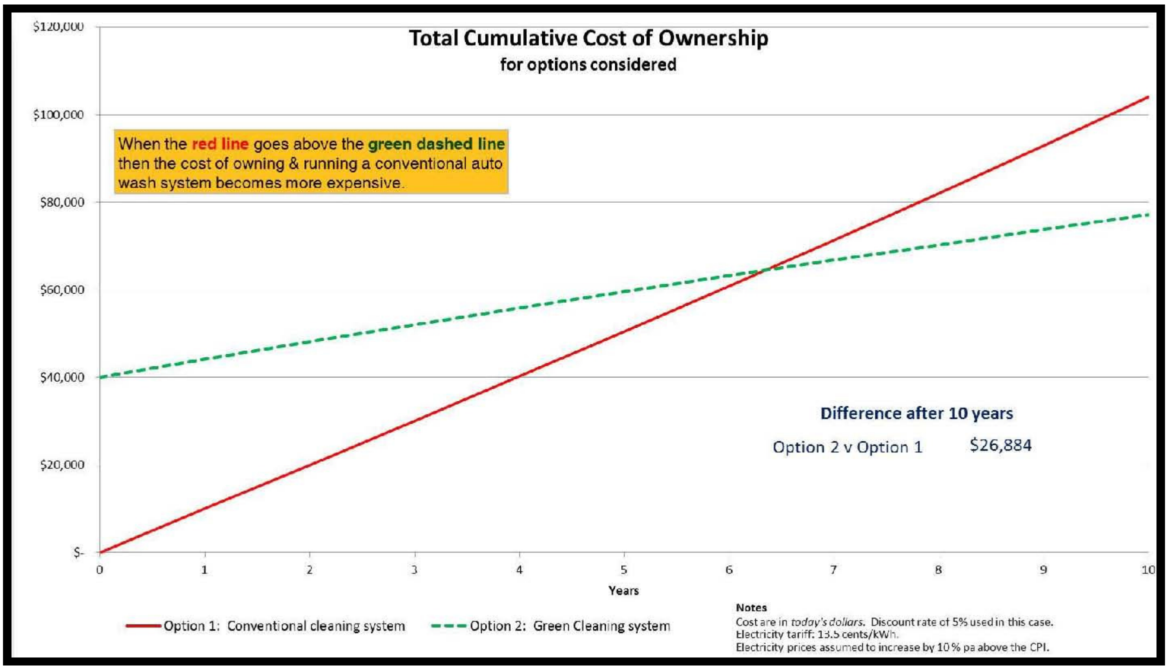

Figure 2: Total cost of ownership. This shows that after 6.5 years the cost of each option has been the same. After 10 years the Green CleaningTM system will have cost $26,884 (in today's dollars) less to own and operate.

DOING YOUR SUMS

We expect that the savings are likely to improve further as the companies continue to refine their systems. Consequently the case for installing a Green CleaningTM system will become increasingly compelling.

A website has been established specifically for information about Green CleaningTM systems www.agvetprojects.com.au/greencleaning. It also contains an economics calculator so specific options can be compared and analysed.

Contact your local milking machine or dairy detergent supplier for more information on the Green CleaningTM systems available in your area.

Article by Gabriel Hakim & Rob Greenall

AgVet Projects, Warragul

Ph (03) 56111 020

www.agvetprojects.com.au


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REDUCING THE DIVIDE
CONVERSATIONS FOR CHANGE

STEPHANIE TARLINTON

DAIRY FARMER, COBARGO, NSW

Knowledge is largely acquired by experience and education which has the ability to empower individuals and conversely highlight issues of separation.

Australia is increasingly facing this issue of knowledge disparity in regards to consumer awareness about food and fibre production, agricultural industries and issues. This disconnect is commonly referred to as the 'rural – urban divide' which signifies that based on your location there is a divide or separation in your everyday lifestyle. This division can be seen in geographic terms on the eastern seaboard with the Great Dividing Range however it is increasingly becoming a common term used to express the distance between the individuals whom produce the nation's food and fibre and those whom merely consume products. It suggests that based on your location being rural or urban you will or will not have knowledge of food production and associated topics. This highlights an opportunity for both consumers and producers to have conversations of change which will ultimately increase the knowledge of both parties on issues removed from their daily lives. By acquiring education from individuals whom have firsthand knowledge in agricultural fields will enable those divided by urban boundaries to have informed opinions and increased understandings.

A conversation between two individuals has the amazing ability to inspire, inform, and change perceptions which creates an opportunity for change. With a considerable amount of Australia's population living in urban centres those classified as rural including the countries farmers have an important role to play in reducing the separation between communities. Engaging in a conversation with someone who has little knowledge of how their food moves from the farm gate to their plate has the potential to give them insights into the real story of modern agriculture.

Connecting with consumers on shared values increases the possibility of forming trust in farming and those whom participate in agricultural business. Sharing personal stories allows consumers to gain insight and confidence in farming systems, ultimately building connections and breaking down barriers in society which further decreases the divide. A conversation which has the potential to lead to knowledge transfer is one that allows each party to listen and engage on a topic of common interest. So therein lays the question; who is interested in stepping outside of their segment?

As a consumer you are able to vote three times a day; breakfast, lunch and dinner which is determined by your values, knowledge and experience. Members from either side of the divide consume food in order to survive which is therefore a fundamental feature of unity and mutual dependency.

A simple discussion on the origin of a food product has the potential for rural person A to connect with urban person B to produce an outcome of greater understanding C.

A + B = C highlights the impact a single conversation can have if society will allow itself the simple pleasure to connect and challenge perceptions.

To quote Ghandi, '*be the change you want to see in the world*' reinforces the challenge that in order to create ways in which to build relations between the two sectors of society one must accept their role and be prepared to create opportunities for conversation. For the agricultural sector to develop positive images and perceptions of farming practices and lifestyle individuals who align themselves with this segment must be prepared to participate in the dialogue.

Building trust in and empathy with rural and remote areas of the country is in many ways the change that will reduce the misunderstandings that result in the 'divide'. By participating rather than watching as is commonly done by agriculturalists allows for the change of public perception around the individuals whom grow our food and fibre. It is necessary for a collaborative approach from industries however each individual involved in the business that is agriculture have the opportunity to engage and educate through conversations.

Telling the story of modern innovative farming businesses during discussions aids in challenging the stereotype portrayed in traditional media of people involved in agriculture. Breaking down such stereotypes also has the potential to reduce the disconnect between rural and urban communities as greater understanding allows for a more informed approach to thinking about the reality of one another's daily life. To recreate the image of farmers in the mind of modern consumers conversations need to be had which allow for positive connotations to be formed reinforced by fact which builds trust. As other sectors of the community have done in recent media, the agricultural community has to actively seek out and celebrate the people who are generating change for the greater good of all involved.

In summary, to offer one's knowledge also allows them to have power and in modern society consumers hold significant power which is expressed in daily decision. By providing opportunities for knowledge transfer between the two sectors decreases the misunderstanding and lack of esteem shown toward one another. Conversations provide the key to reducing the disconnect which is present in today's society of consumers.

Having open and informed discussions create a basis for relations to be built with trust and empathy as influential outcomes. By highlighting areas of unity through shared values allows conversations to be a forum to engage and educate which are paramount in linking the two sectors together. Connecting producers and consumers or as it is commonly referred to, rural and urban audiences requires individuals to become part of the change they want to see.

Actively participating in the conversations is essential for progress to be made in reducing the disparity of knowledge, experience and education in terms of food and fibre production. Challenging stereotypes through highlighting connections has the ability to show how together as people both have a mutual dependency on food and therefore one another as a producer and a consumer. As knowledge is power, every individual has the power to share knowledge regardless of which side of the classroom divide, they take a seat during story telling.

DORNAUF DAIRIES

NICK AND CHRIS DORNAUF

Dornauf Dairies consists of six dairy properties:

1. **St Omer:**
   Spring-calving herd of 210 milkers, average production 650 kg MS/cow; 64 ha irrigated property; 2 full time equivalent (FTE) labour units.
2. **Weegena**:
   Spring-calving herd of 575 milkers, averaging 600 kg MS/cow; 250 ha (50% irrigated); 4.5 FTE labour units.
3. **Stephens Hill:**
   Autumn-calving herd of 315 milkers, 600 kg MS/cow; 3 FTE labour units; 123 ha dryland.
4. **Harvey's**
   Dry stock farm, 188 ha dryland used for rearing replacement stock.
5. **Christmas Hills:**
   Calf Rearing Facility, 25ha, 12 x DeLaval CF-150 auto calf feeders; 400 calf capacity; 1 FTE.
6. **Gala:**
   Greenfield site near Deloraine where DeLaval AMR™ (automatic milking rotary) has been installed.

Gala Farm

Physical Data:

- Farm Size: 280ha
- Dairy Platform: 200ha
- Rainfall: 42”
- Irrigation: 55ha (increasing to 130ha in October 2012)
- Cows: 250 (increasing to 550-600 over next 2 years)
- Dairy: 24 Bail DeLaval AMR
- Feeding System: 20 DeLaval Out-Of-Parlour Feeders

  Voluntary ‘3 way grazing’ system

  200 cow feed pad

Animal Production System:

- Pasture Based system with moderate-high grain feeding + conserved fodder
- Animal: 550kg LIC Friesian
- Production: 8000L @ 4.2%F and 3.7%P (632kg MS)
- Diet: 3.5t/DM Pasture

  2.2t/DM Grain

  0.9t/DM Pasture Silage and Lucerne Hay
- Reproduction: 7 weeks AI followed by Jersey Bulls
  7% Empty after 12 weeks of Mating

AMR™ implementation at Gala

Reasons for installing DeLaval AMR™

The key reasons for installing the AMR were to improve our ability to attract, recruit and retain labour within the business. We believe this will be achieved primarily through the increased flexibility of farm management and the improved lifestyle and stimulation generated for all involved. The attractiveness of freeing up time (which would otherwise be spent milking cows) to focus on managing the dairy system is also very appealing. In addition to the 'time factor', our ability to access data at all levels (individual cows, groups within the herd and across the herd) is already allowing us to make sound and timely management decisions.

Development Progress

- 1 March 2011: construction began.
- From 10 August 2011: first calving at Gala; 220 heifers calved over 6 weeks and were milked through a small herringbone facility adjoining the new dairy.
- 15 October 2011: first cows milked manually on the AMR™.
- 13 February 2012: robotic milking started.
- June 2012: will start to use feed pad.
- Later in 2012:

  Transition from 'batch' to 'voluntary' milking as we gain confidence in the new farm management system; voluntary milking means the cows move on their own from the paddock to the dairy and back to the paddock again. This is important for achieving the full labour and lifestyle benefits of automatic milking.

BUSINESS TRANSITION AND SUCCESSION PLANNING

MARK SCANLON
Consultant, NextRural

UNDERSTANDING BUSINESS TRANSITION

Overview

Business transition means different things to different business owners. Each owner faces their own particular issues surrounding their business, their family and their future. Whether it is the succession of the business to the next generation or it is time to sell the business and move on, proper planning and guidance is required so that a clear path can be developed and followed.

This paper will outline how to develop a sound Business Transition and Succession Plan. It has been based on actual experiences of completing the process with many families in the dairy industry. The process is designed by Next Rural with additional online resources provided by Dairy Australia's The People in Dairy program at:

http://www.thepeopleindairy.com.au/planning-for-the-future/planning-future-insight.htm

By utilising the framework and tools developed for dairy farmers, business owners will achieve:

- Clear objectives and a future action plan
- Cost effective solutions
- Definite outcomes in realistic timeframes

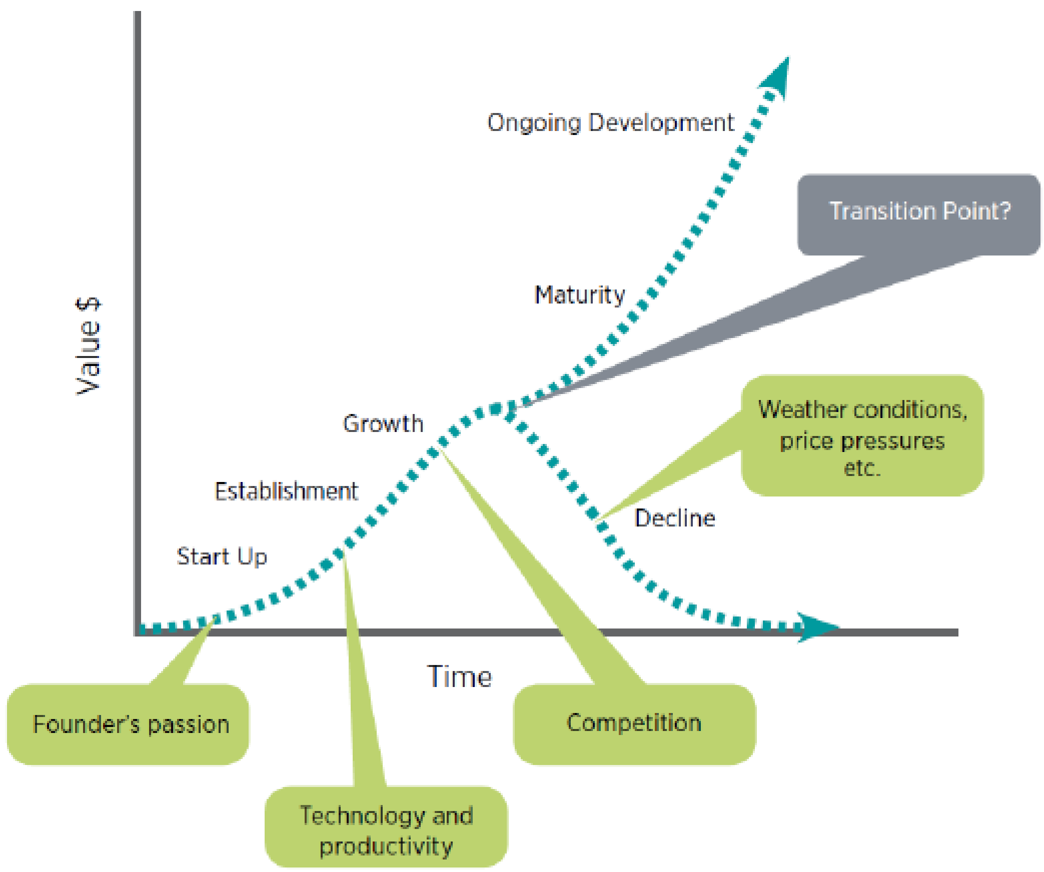
The following provides an understanding of the business transition and succession planning process. It will equip business owners with knowledge and tools on how they can obtain real results that will allow them to move through the transition process.

This paper has been specifically prepared for **you,** as the business owner.

YOUR BUSINESS LIFE CYCLE

Your Business Transition Plan will outline the way your business will be managed through a business transition and beyond.

All businesses go through a business life cycle.....



It is important to establish where your business currently fits in the business life cycle and how you can successfully manage future growth and development.

To understand this better, we should examine each stage of the cycle.

Start Up

The start up of a business is very much tied to the original owner.

Cash flow and capital is often tight and everyone pitches in to do what has to be done. Management meetings consist of conversations from the tractor or across the kitchen table. Business information is kept on bits of paper. No job descriptions exist and the employees and the business live from day-to-day.

There are many opportunities such as the farm next door coming on the market, but there is little available capital to take advantage of them.

Establishment

During the establishment period, cash flow becomes more predictable. Suppliers and bankers look more favourably on the business.

The potential to build capital starts to emerge along with a profitable bottom line.

The business is still strongly linked with the original owner and forward planning is still fairly informal.

Growth

Production is growing. Cash flow is improving and investment back into the business is increasing. With improved capital, there are opportunities for growth and development.

New properties come onto the market and the size of the holding is increased. More people have to work on the farm and organisation becomes complicated.

The potential for conflict increases. New challenges start to emerge.

Decision Time

Growth has been good, however the risks are higher.

Changes in weather conditions or commodity prices can have a significant effect.

It is time to make some important decisions. The business is now more complex to run and requires more formality in its planning and operations.

There are three choices:

1. Ignore the challenges and continue to run the business as it was in the past. Keep things informal and ad hoc

   If this course of action is taken, then sooner or later the business will fall into decline

2. Sell the business and move on

   If the business has become too much of a burden and a more rigid structure doesn't suit, then it may be a good time to sell i.e. while the business is still strong

3. Move the business strategically and operationally to the next phase

   By doing this, significant rewards can be gained from the 'maturity' phase of the cycle

Maturity

Production is growing and the business is operating more effectively.

Price pressures continue, however production and input costs are less. Critical mass has been achieved and increased access to capital means opportunities for growth can be realised.

Ongoing development

To ensure the ongoing development of a mature business, a focus must be maintained on key elements of the business:

- **Innovation**: Are you using the latest production techniques and machinery?
- **Markets**: Are your commodities suited to a changing and demanding marketplace?
- **Diversification**: Have you spread your risk in terms of production e.g. prices and competition?

- **Business Risks**: Are you adequately insured against all risks? Have you had an occupational health and safety assessment?

- **Skills and Knowledge**: Is your knowledge adequate and up-to-date? If not, consider undertaking training course in order to improve your skills and be able to efficiently handle a demanding and changing business world.

- **Financial Management**: Do you have the right structures in place? Are your reporting systems adequate? Have you effectively forecast your profit and loss projections and capital requirements?

- **Planning and Strategy**: Have you "professionalised" your business? Do you have a strategic plan that clearly determines:

    - Where you are now?
    - Where you want to be?
    - How are you going to get from here to there?

WHAT IS BUSINESS TRANSITION?

You may have reached a time where you need to make some important decisions regarding your business and your family's future.

It may be time to:

Prepare to transition the business to the next generation

A succession plan will outline the way your business will be managed and owned after the retirement of the current owners and provide planning for the continuation and success of the business. It will help enable the next generation to manage effectively without conflict and the current owners to satisfactorily fund their retirement. It will also take into account the needs and expectations of family members not working on the farm.

Sell the business and move on

If the business has become too much of a burden, it may be a good time to sell; perhaps the business is still strong and/or the property has increased in value and you can realise a financial gain. You may simply need to limit any future losses. If this is the best course of action, you should begin by preparing a Business Exit Strategy. This will ensure that you maximise your returns and minimise potential for taxation liabilities.

Have a partial release of ownership/management

A partial release of ownership and/or management can have a number of beneficial effects:

- Realise much needed cash for development, to reduce debt or pay outstanding bills
- Reduce the physical burden of managing the property/business
- If partial ownership or management is passed on to the next generation, it will allow them to develop their skills and derive income in preparation for a future transition of the whole business.

Lease the property to the next generation or an outside party

There are at least 2 types of leasing arrangements:

1. Fixed term lease with renewable extensions which are predetermined

2. A lease with the option to purchase

Leasing offers the landowner a more certain financial return than share farming. The returns to the landowner are not subject to variations in farming ability, seasonal conditions or commodity prices and offer a more certain future for the leasee.

Share Farming

Share farming agreements should be in writing. All parties must be satisfied they are receiving a fair share of the income and that the cost sharing arrangements are appropriate for the amount of capital invested.

Review funding for future development

Perhaps your debt and banking facilities can be better structured to meet your needs. Your finance should be appropriately arranged to meet your immediate and future requirements. You may need to negotiate with financiers/banks to achieve your goals. This restructuring may reduce costs and/or free up development funds for further investment.

Other ways of transitioning the farm

If you would like to sell your land but stay involved in the industry, it may be possible to manage a farm for someone else or to provide labour to another farm. Large landholders and corporate farmers offer the opportunity to stay involved in agriculture in this way.

WHY IS YOUR BUSINESS TRANSITION PLAN IMPORTANT?

The most important aim of the Business Transition planning process is to bring about a smooth transition of the family farm and at the same time, improve business confidence and maintain family harmony.

A Business Transition Plan evaluates business and personal circumstances in light of current and possible future options in order to develop a preferred course of action from a range of alternatives, importantly, while the business owners are still in a position of control.

It will provide planning for the continuation and success of the business. It will enable the next generation to manage effectively without conflict and the current owners to satisfactorily fund their retirement.

It will also take into account the needs and expectations of family members not working on the farm.

Business transition management and planning addresses the complexities involved in transitioning the ownership of a business, usually from one generation to the next.

A Business Transition Plan outlines the way a business should be owned and managed after the retirement of the current owners and provides for the smooth continuation of the business.

COMMON PROBLEMS WITH THE BUSINESS TRANSITION PLANNING PROCESS

Too many transition plans are thought about but not acted upon. Often when they are started, they do not come to a conclusion. Some of the common reasons that transition plans stall include...

- *The Business Transition Plan is not clearly documented*
- *Families defer opening discussions for fear of conflict*
- *Not facilitated by an impartial, qualified professional*
- *Unclear goals, needs and wants by family members*
- *Agreements do not have consensus of family members*
- *Incorrect advice leads to tax and stamp duty problems*
- *Plans are not reviewed as situations change*
- *Formal transfers do not take place*
- *Family conflict prevents resolution*
- *Retirement funding of previous owners not adequate*
- *No clear future for the business*
- *It is left until the last minute to start planning*
- *No distinction between ownership and management*
- *No clearly defined timeframes*

BUILDING YOUR BUSINESS TRANSITION PLAN

A structured approach- “The four phases”

This part of the paper outlines each stage of the process. How quickly you complete each stage will depend on a number of factors.

The business transition may take place over a number of years and your Plan should accommodate changing future circumstances

Undertaking a Plan will take you through a four stage process. Within each stage, there are a series of sub-sections designed to address specific issues.

1. KEY FINDINGS PHASE

Conducting the first family meeting

Open communication

The first and most important step, or pre-step before entering the transition process, is to open the lines of communication between the generations. Once the generations are talking, everyone will start to think about his or her involvement in the future of the farm business.

Business transition and succession planning cannot be approached as a one-time event. Instead, it is a process that should begin long before the owners plan to exit the business. Starting the conversation early also ensures you can select from the widest range of options available to you.

Some tough decisions may need to be made such as whether parties wish to hand over property, the business or assets and whether the other parties are willing to accept that ownership. Consideration may need to be given to the financial capability of the future owners to meet ongoing costs and to provide sufficient funds to meet the current owner's retirement expectations.

An effective way to start the conversation is to conduct a formal family meeting to better understand the attitudes of the participants to a business transition and succession process.

Objectives

The objectives of the family meeting are to achieve the following:

- A commitment from all family members to the process and to the goal of achieving a positive outcome.
- Gain and share a better understanding of the history of the property, the family legacy and the needs and expectations of all the participants.
- Collect the legal, accounting and financial information necessary to prepare a draft plan.
- Identify any potential impediments to a successful outcome.
- Ensure that the process is undertaken in a way that maintains family harmony and business prosperity.
- An understanding of the retirement lifestyle goals and aspirations of the current owners, and future goals and aspirations of other family members.

MAINTAINING THE LEGACY

Many rural family business owners perceive themselves as the custodians of a family legacy which has often been passed on through many generations of property ownership. It is the objective of the Business Transition Program to help maintain this legacy for generations to come.

If there has been a tradition of keeping the business in the family, current owners often have a desire to continue this tradition into the next generation and this is a good starting point to begin the process of Business Transition planning.

For many current owners, the idea of continuing the legacy is part of their dream. They can look back with pride and satisfaction at the results of their willingness to take risks, to work hard and to engage in self sacrifice along the way.

It has probably been an exciting and challenging journey, however business transition is a matter of "when" and "how best" rather than "if". Even when the founders are no longer present in the business, their influence will live on. Many next generation owners believe they have a key responsibility to keep the previous generations' dreams alive.

Knowing that transition is inevitable, Next Rural will assist the current owners in making the process a satisfactory one for their family, their business and themselves.

Starting the discussion

An important objective of the family meeting is to better understand the attitudes of the various participants to a business transition and succession process. The following list of questions and subjects can help to open discussions:

- What would the ideal outcome be from the business transition planning process for the business?
- What about the outcome for the family?
- What are the key issues that would need to be resolved to reach an outcome that would satisfy everyone?
- What would make you feel the process was successful?
- What would be the consequences if this process wasn't undertaken? For the business? For the family?
- List the top three issues that you think could put a good outcome at risk

It is important that any issues are clearly identified and a resolution and commitment is achieved.

A family meeting may help to identify the potential for any conflicts or difficulties amongst family members that may inhibit the planning process. A meeting should also help all participants understand in an open and honest manner the feelings and attitudes of the various stakeholders.

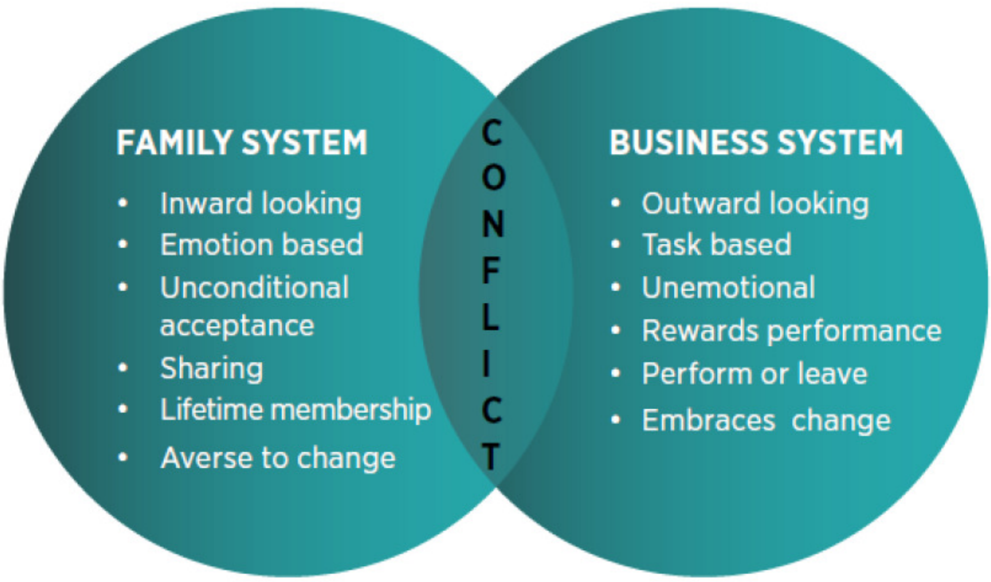
The stakeholders need to participate honestly and openly without fear or favour, to gain maximum benefit.

Ensuring harmony between the family and the business

The key to achieving a successful outcome to the business transition planning process is for all stakeholders to be committed to the process.

A family business is a unique business structure and we must achieve the delicate balance of effectively combining the family system and the business system, while also keeping them separate enough to avoid conflict.

The communication systems between a family and the business are complicated. For the planning process to be successful, all parties need to be considered.



Checklist for gathering information

For the initial family meeting you will need to collect certain information and give consideration to a range of issues.

At this meeting you will discuss your needs and expectations. This will assist in preparing a draft structure of your plan and will include some or all of the following points.

INFORMATION CHECKLIST FOR YOUR TRANSITION PLAN

- ☐ Details of all stakeholders and participants
- ☐ Roles and responsibilities of participants
- ☐ Expectations and aspirations of all participants
- ☐ Any overt or hidden conflict or difficulties amongst family members that may inhibit the planning process
- ☐ Consideration of family members not involved in the business and their expectations
- ☐ What options have been considered regarding the future of the business
- ☐ Attitude of current and future owners towards business transition
- ☐ The current business structure and land/ property ownership
- ☐ Details of any companies, trusts, partnerships and trading entities
- ☐ Details of balance sheets and profit and loss statements
- ☐ Most recent wills and testaments
- ☐ Any Powers of Attorney
- ☐ Existing debt and capital accounts
- ☐ Banking/finance details
- ☐ Valuation and market appraisals
- ☐ Value of improvements
- ☐ Water entitlements
- ☐ The consideration to be paid including such items as:
  - Payments to the current owners
  - What expenses incurred by the exiting owners will continue to be met, such as telephone, rent, motor vehicle etc?
  - What housing arrangements will be made for the exiting owners?
  - How will income be distributed?
- ☐ What security will be provided to ensure future transition payments?
- ☐ Estate planning issues including review of wills
- ☐ Capital gains tax issues and consequences
- ☐ Current superannuation entitlements

Preparing a draft Business Transition Plan

During this stage the information gathered during the family meeting will be analysed and the needs of each party determined.

There will be a different expectation from all involved. The current business owners will want a graceful exit. They will want to know that the business will be in good hands and that they have established a sound retirement or semi-retirement income.

The future owners/managers will need the Plan to ensure their future is secure and not burdened by too much debt.

Other members of the family not involved in the business, will want to know the Plan values their position appropriately.

The whole family will want a smooth transition without creating tensions and acrimony.

In essence, the Plan must deal with the sometimes conflicting needs and aspirations of:

- The business owners both current and future
- The family
- The business itself

Objectives

The objectives at this stage of the program from each of the above perspectives are:

The Business Owners (Current and Future)

To determine effective estate planning and retirement funding for the current owners

Institute appropriate financial structures

- Determine the nature, structure and term of the transition process
- Agree on the actual value of the business/property and the value to be applied to the transition
- Establish sufficient liquidity to fund the current owners retirement and transition to retirement
- Align the needs and expectations of the current owners with the requirements and manageability the future owners

The Family

- To determine future equity ownership
- If appropriate, establish income streams to beneficiaries not involved in the business
- Ensure adequate risk protection exists on family members receiving an income stream to avoid family disputes in the event of premature death of the beneficiary
- Establish correct legal and accounting structures

- Document a transition agreement to assist in the avoidance of future disputes

The Business

- Determine the nature and term of the transition
- Determine management transition/ownership transition timetable and conditions
- Establish suitable equity ownership for all stakeholders
- Determine any debt requirements and seek favourable arrangements
- Ensure there are appropriate rewards for both family and non-family members
- Conduct a review of all business risks including occupational health and safety, loss of income through injury, illness or death, financial, taxation risks etc.
- Determine any buy/sell arrangements and ensure they are appropriately supported by adequate insurance protection
- Agree on an actual value of the business and property and a transition (transfer) value to the future owners
- Ensure that the structures adopted protect the assets from potential liabilities and risks

2. RECOMMENDATION PHASE

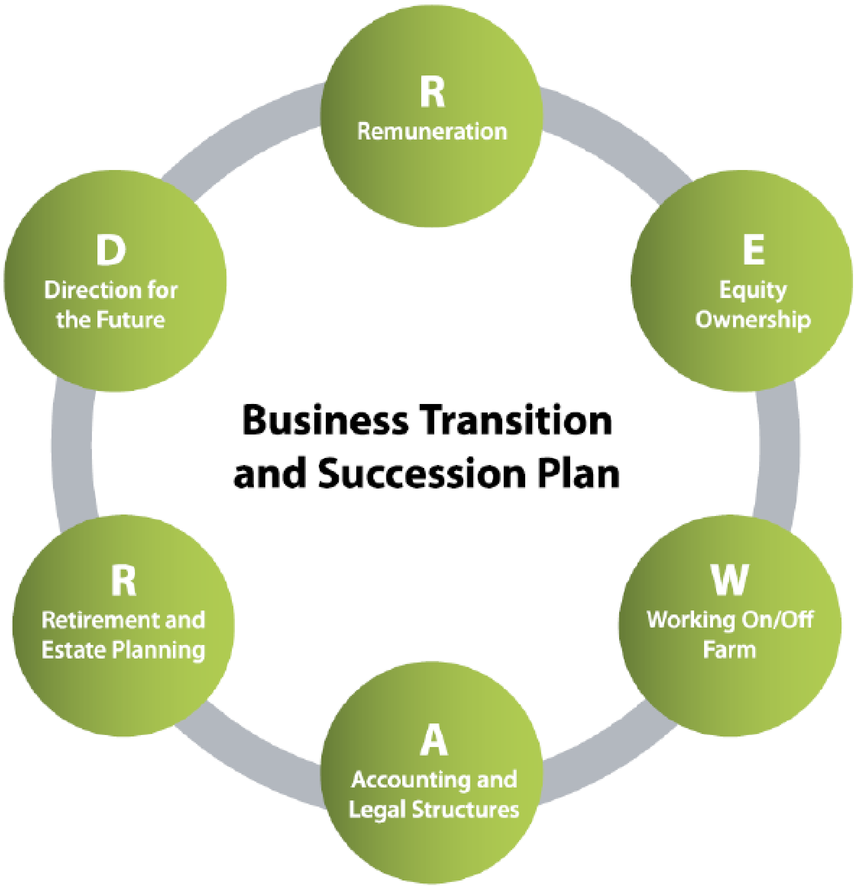
The structuring of a solution

Business transition planning is not simply a matter of passing the business to the next generation. Many issues will need to be dealt with.

Establishing goals and objectives, values, suitable structures, term of the transition, minimising tax and funding retirement are but a few of the necessary considerations.

'Circle of REWARD'

Next Rural's 'Circle of REWARD' is a systematic way of structuring your Transition Plan. It separates each area of consideration and enables the family to assess the proposed solution through a step-by-step plan.



Remuneration planning

Attitudes to remuneration are often coloured by personal circumstances and relationships within the business, particularly where members of the family are involved.

Some of the areas to be considered include:

- What has been the history of remuneration and reward for past effort?
- How do you pay different salary levels to different family members?
- How do you reward "sweat for equity"?
- What should the basis be for establishing different salary levels within the business?
- How do you manage the expectations of non-family members who do similar jobs, but are not paid the same?

Equity ownership by family members

Equity ownership amongst a family needs to be structured to ensure that the business can be effectively managed on a day-to-day basis. Sometimes, the allocation of equity to family members not working on the farm can make business decisions difficult.

These issues should be dealt with early in the business transition process. If left unresolved, they can cause problems for the future owners especially where the property and business values increase as a result of their decisions and efforts.

Some of the areas to be considered are:

- How should control be released and over what term?
- How is equity to be paid for?
- If sold, should this only be to family members or outsiders as well?
- How should equity be transferred and under what conditions?
- What financial and legal structures should be utilised to transfer the business/ownership and how should these structures be documented?
- How will equity issues be dealt with, in the unfortunate event of the death of any of the parties?

Working on/off the farm

Managing the expectations between different family members (those actively involved and those not involved in the business), is essential to meet their needs and at the same time, provide for the future success of the business.

- Some of the areas covered here include:
- Should ownership be based on active participation in the farm?
- Under what conditions are family members introduced into the business?
- Does the next generation have the skills and knowledge to manage the business?
- How are the differing ages of children managed?
- What rights, if any, do family members not working on the farm have in the day-to-day running of the business?
- Does the Business Transition Plan consider those family members wishing to return to the farm in the future? If so, under what conditions?
- Should there be a financial distribution to family members not working on the farm, and if so, in what form and over what term?

- What has already been provided to non-working family members e.g. university education and off-farm career path?

__Accounting and legal structures__

This is often a crucial issue for owner-managed businesses. The financial structure should provide maximum flexibility in running the business and should be tailored to individual circumstances and needs.

It is important that the financial and legal structures used to bring about the transition and to conduct the ongoing business, are effective from taxation, legal and risk perspectives.

Some of the areas covered here include:

- Do the financial and legal structures reasonably reflect the intent of the Business Transition Plan and expectations of the key stakeholders?

- Are the structures effective in protecting assets?

- Do they protect against changing circumstances such as a death or divorce?

- Are they effective from a stamp duty and capital gains tax perspective?

- What legal documentation and structures are in place to safeguard against changes to the current owner's wills?

The People in Dairy website provides a good overview of the different business structures available at http://www.thepeopleindairy.org.au

__Retirement and estate planning__

In both personal and business terms, planning for the retirement of the current owners is an essential component of your Business Transition Plan. Not only does this enable a smooth transition to the next generation, but can also help to minimise tax liabilities. Estate planning is a continuing process and should be reviewed on a regular basis to ensure that needs are met.

Some of the areas covered here will include:

- What is a fair price to be paid by the next generation for the business/property?

- Has the retiring generation planned for adequate liquidity to meet tax liabilities?

- Who will inherit the assets?

- How will the business be transferred and over what timeframe?

- Have the retiring generation planned effectively for retirement?

- Do the current owners have a sound financial plan? Have they determined how much income they require for retirement?

- Do the wills accurately reflect the wishes of the current owners and are they still relevant following the transition process?

Direction for the future

Every business, regardless of its size, needs to decide what its objectives are and how these are going to be achieved. For family businesses it can be more complex, with a need to take into account personal and family considerations.

Some of the areas covered here include:

- Where is the business now?
- Where do you want it to be?
- How are you going to get from here to there?
- Are the financial and legal structures tax effective?
- Do the financial and legal structures minimise risk?
- Have all the potential business risks and liabilities been addressed?
- Are the finance facilities cost effective and can the debt levels be managed?
- What legal documentation or structures can be put in place to reduce reliance upon, or safeguard against, future changes to the current owner's wills and testaments?

For the current owners transitioning into retirement, the plan will assist them to establish their new goals and objectives.

3. IMPLEMENTATION PHASE

Consideration of the Plan

Following the preparation of a Draft Recommendations Report, a family meeting should be arranged so the Plan can be presented and discussed. At this point, you may wish to make amendments or take some time to discuss the suggested Plan with other family members, stakeholders or advisors.

Once the Draft Recommendations Report has been agreed upon, a draft Heads of

Agreement should be prepared for consideration.

Heads of Agreement

This agreement can be a formal legal document or simply a written creed that is adopted by the family. It can be either binding or non-binding. In either case, it is worthwhile to have all parties sign the document to avoid confusion and a dispute at a later date.

The Heads of Agreement should document all major decisions.

This may include decisions on:

- The current business structure and land/property ownership
- The business/property restructure

- The restructure of existing debt and capital accounts
- The transfer of the farm including:
  - Water entitlements
  - Valuation and market appraisals
  - Value of improvements
  - Adjustments
- The consideration to be paid including:
  - Payments to the current owners
  - What expenses incurred by the exiting owners will continue to be met, such as telephone, rent, motor vehicle etc?
  - What housing arrangements will be made for the exiting owners?
- How will income be distributed?
- What security will be provided to ensure future transition payments?
- Estate planning issues including review of wills
- Capital gains tax and stamp duty issues and consequences

The Heads of Agreement will also include legal documentation necessary to complete the transition.

The supporting documentation required will vary according to the particular circumstances and may typically include:

Succession planning documents

- Deed of Family Arrangement to guarantee parents' entitlements
- Options to purchase
- Lease/license to occupy – containing right of first refusal if needed
- Contracts for transfers of farmlands including specified special conditions applicable to the farm transfer
- and agreed terms of the transfer

Farmlands

- All Transfer documents
- Subdivision documents
- Easements documents
- Tenders for sale or lease

Water

- Contracts for sale and purchase of water
- Subdivision of entitlements
- Mortgage over water entitlements

Securities/Asset Protection

- Mortgages (registered or unregistered)
- Guarantees
- Bills of Sale/Personal Property Securities, caveats

Trusts and Companies

- Discretionary Trust Deeds
- Unit Trust Deeds
- Unit Holders/Shareholders
- Transfer of Units/Shares documentation
- Registration of company

Other Legal documentation

Buy/Sell Agreements

- Lease documents
- Deed of Assignment of Lease
- Power of Attorney
- Last Will and Testament and Testamentary Trust (if applicable)

Implementation

Once the Heads of Agreement has been signed and adopted, it is now time to put the Plan into effect.

Following a thorough review of the timing, structure, financial and risk outcomes, the Plan must be implemented. Many effective transition plans remain as 'a piece of paper on the shelf'.

It is important that once the Plan has been agreed to, it is implemented without delay.

The financial outcomes

The Plan will need to meet the retirement needs of the current owners. The ongoing debt and funding requirements will be established and must be capable of being managed within the capacity of the business by the new owners.

Most importantly, the terms of the transition must be agreed upon and match the needs and expectations of all stakeholders.

The requirements of family members not involved in the business may also need to be taken into account.

The Current Owners

The current owners will want to re-evaluate their retirement lifestyle goals aspirations and need to know the level of funds available for investment. How much is available for retirement and what funds can be allocated to family members who have not benefited from the transition of the business/property?

The Future Owners

The future owners should be able to identify their financial commitments and the transition cost. This should be summarised to enable cash flow management to be easily monitored into the future.

All costs will need to be identified and indicate any debt servicing and vendor term obligations to the previous owners.

Non-Working Family Members

Benefits to family members not working on the farm will need to be determined. This may include the nature and term of any income distribution arrangements.

The transition payment and schedule

The transition payment and schedule is the financial outcome of the Business Transition Plan.

The transition payment is the final amount that is calculated to enable the future owners to purchase the farm and the current owners to enjoy a retirement lifestyle that meets their goals and aspirations. It provides a simple and concise means of establishing and monitoring the key financial components of the transition.

It provides certainty and clarity for all stakeholders including the present owners, the future business owners and those family members not working on the farm.

Final reports

Business Transition Plan - finalised and agreed by all parties

Transaction Schedule - finalised and agreed by all parties

Financial Plan – completed and reviewed by current owners. Following agreement, the Plan is then implemented

Debt (Finance Facility) Plan - completed and reviewed by future owners. Following agreement, the

Plan is then implemented

Risk Assessment - completed and reviewed by current and future owners. Following agreement, the

Plan is then implemented

This will complete your Business Transition and Continuance Plan2

4. NEW BEGINNING PHASE

Realising Objectives

Following the business transition, both the current and future owners will face a new beginning. They will need to revaluate their definition of success.

The retiring owners may wish to take that long overdue holiday or spend more time contributing to their local community.

In this phase of the program your transition payments will be matched against your short, medium and long term goals.

As an example, your objectives may be:

Short term:

- An overseas holiday
- A new house, on or off the farm
- A caravan or boat

Medium term:

- Spend more time playing golf
- Pay regular visits to see the grandchildren
- Become more involved in voluntary community work

Long term:

- Maintain financial security and well being
- Enjoy a good lifestyle

Whatever your dreams and aspirations may be, you should seek support you along the way and help you achieve your new goals and objectives.

For the new owners, they will want to know that the key elements of their business are being managed effectively, and will have personal goals and objectives such as wealth creation and work-life balance.

As described earlier, all businesses go through a business life cycle. As the new owner you should establish where your business currently fits into the business life cycle and how you can successfully move into the next phase.

Further information and tools for dairy farmers regarding business transitions (including leasing) is available at The People in Dairy website:

www.thepeopleindairy.org.au

THE NEXT RURAL TEAM

With collective experience of over 90 years in business, accounting and financial services, our principals bring value adding skills and expertise to our clients across rural Australia from a broad range of business segments.

Our key Principals, Ric Moffitt, Mark Scanlon and James Benson are recognised throughout Australia for their expertise and experience in helping hundreds of rural family businesses.

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HANNAM VALE

KEN ATKINS

Dairy farmer, Hannam Vale NSW

Ken and Margaret Atkins milk 160 cows - two thirds Jerseys and the rest Holsteins at Hannam Vale just north of Taree on the Mid North Coast of NSW.

The farm is on well drained red volcanic soils, with average annual rainfall of 1650mm with summer/autumn dominance. Even though the farm has a 12 hectare irrigation licence Ken has not had to irrigate for the past two seasons.

Ken over sows his permanent kikuyu pastures with annual ryegrass on the 95 ha leased property. A further 25 ha is owned nearby for the heifer run.

The Atkins family moved to the farm from the Hunter Valley five years ago and quickly learned to adjust to managing a large quantity of home grown feed - now accounting for 80% of intake. Ken targets to make at least 600 round bale silage predominately from annual ryegrass clover pastures.

The base pasture consists of kikuyu which can provide some feed year round. Ken is realistic about the role of kikuyu as a forage base as he says, “it can be your best friend or worst enemy”.

To achieve the best out of kikuyu Ken maintains a tight rotation when it is growing rapidly and quickly identifies surpluses to be conserved and taken out of rotation.

Last year production per cow averaged 7,027 litres with a 4.3% fat and 3.5% protein. Production is around 1 million litres per annum.

ENERGY EFFICIENCY IN THE DAIRY

NICK BULLOCK

NBA Consulting, NSW

BACKGROUND

Energy costs in NSW have increased by over 60% in NSW over the last 4 years and further increases are expected. NBA Consulting has worked with over 500 dairy farmers over the last 4 years in NSW and other states including Western Australia, Queensland and South Australia to:

- benchmark energy costs at the dairy
- identify cost efficient tariffs
- identify costs and savings achievable from a range of energy efficiency upgrades.

In 2007, the Mid North Coast Dairy Advancement Group (DAGs) identified adjusting to climate change as a major issue for local dairy farmers, particularly in terms of increased costs.

DAGs have a history of helping local farmers with local and relevant issues, and were recognised in 2009 with the NSW Environment and Landcare Award. The projects have included designs for dairy effluent systems, access to funding to improve farm infrastructure such as laneways, stock watering systems, workshops on how to cool cows and minimise the impacts of climate change.

Since 1998, the DAGs have managed several large Natural Resource Management projects that have directly benefited their farmers. One of these projects Efficient Energy Water and Nutrients on dairy farms (EWEN) was delivered between 2008 and 2011. EWEN was funded primarily by Caring for our Country and Mid Coast Water.

The EWEN project has developed an energy audit and assessment procedure to compare and benchmark energy use at dairies and identify cost effective solutions to improve energy efficiencies: from low cost checks to equipment upgrades.

The implementation of EWEN has worked in with a NSW Government initiative by Department of Energy Climate Change and Water: the Efficient Energy for Small Business Program (EESB). The EESB provides $5,000 in funding to dairy farmers to upgrade electrical equipment on farm to improve energy efficiencies.

ENERGY USE AND COSTS: VARIATIONS ACROSS THE DAIRY INDUSTRY

The audits have included all the energy costs to run the dairy business excluding irrigation: milk cooling, hot water, milk harvesting, effluent and cleaning, stockwater, feed milling and processing, lights and shed costs. From the energy audits conducted, the general trend is that larger herds use more energy. However, there is a large variation in energy use across herd sizes.

Energy costs at the dairy are dependent on the energy consumed and the tariffs paid. Figure 2 shows the general trend and the spread of actual costs

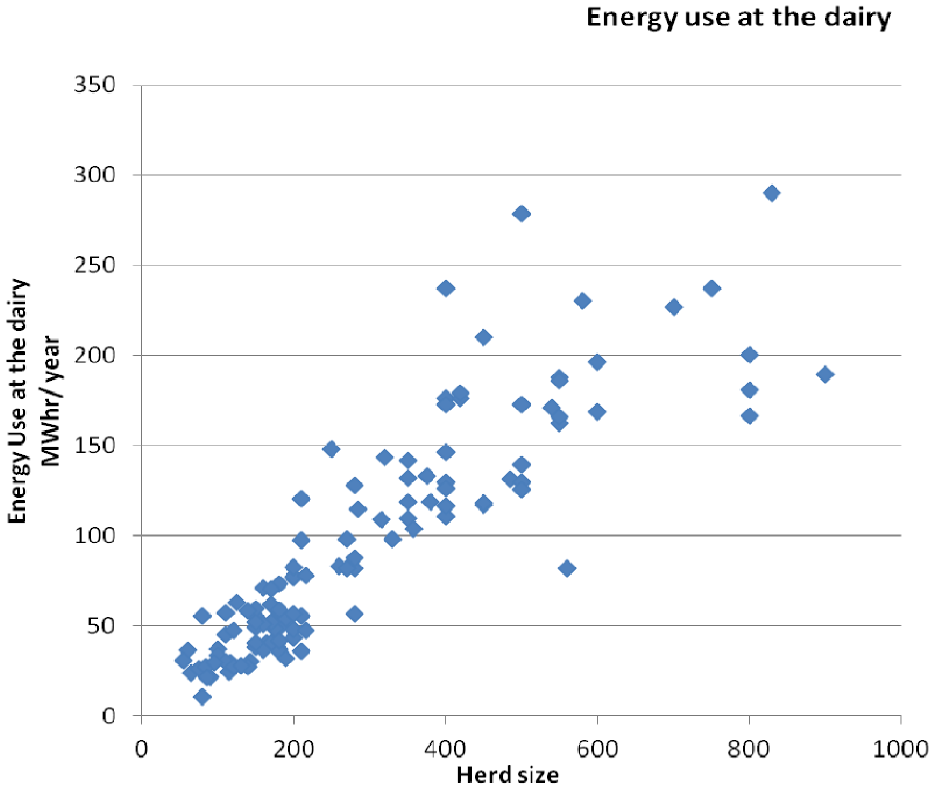

Figure 1: Energy use at the dairy

Data from energy audits carried out in NSW, Queensland, Western Australia and South Australia.

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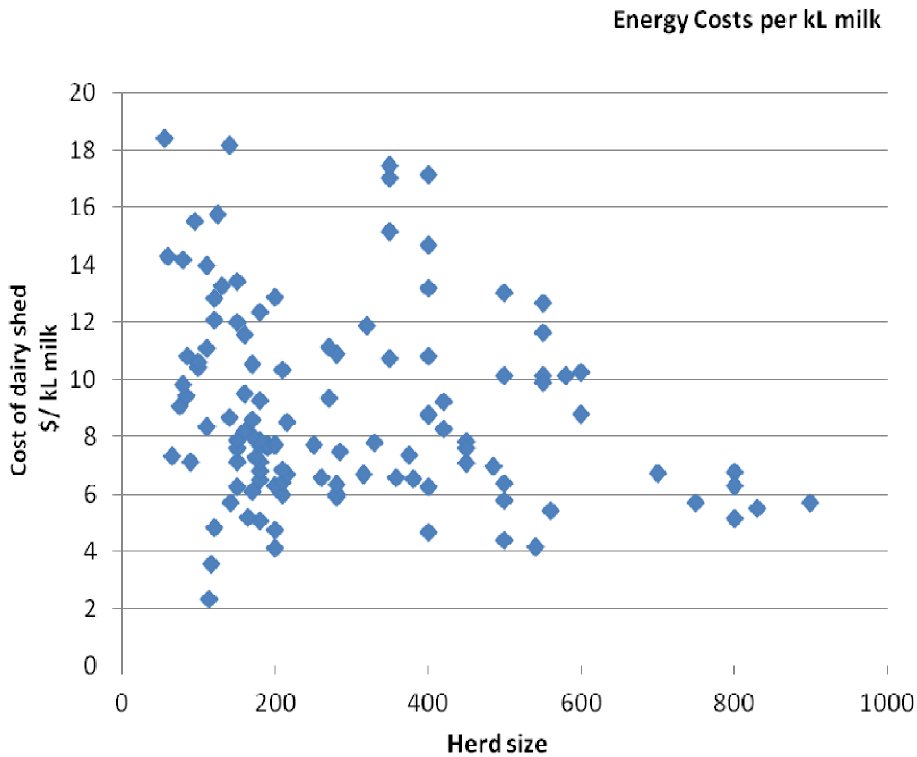

Figure 2 Energy Costs

To compare costs of energy between farms energy costs in $ per kL milk produced has been adopted

There is significant variation in the cost of energy at the dairy in terms of $ per kL milk produced. A small portion of this variation is due to different equipment at the dairy: eg some farms mill and mix feed whilst others buy-in processed feed in the form of pellets or pre-mix; some farms use town water with no stockwater pumping costs, whilst most farmers have pumping costs for stockwater.

This benchmark can be a useful guide for farmers to start to understand how their costs compare to their neighbours. The chart can also be used to identify potential energy savings at the dairy: for example, a 200 cow herd with energy costs at $10 / kL milk can potentially save up to $5.0 / kL milk: for production of 1.5 ML/year, a $ 7,500 annual saving.

The two main factors that impact on total energy costs at the dairy are: (i) the tariff structure for each farm (ii) the energy efficiency of equipment on the farm.

TARIFFS IN NSW

Careful selection of tariffs to match the equipment and timing of operations at the dairy can reduce total energy costs for the dairy. Tariffs in NSW vary between suppliers and lower tariffs can be negotiated. Many farmers in NSW have changed to "time of use" meters saving many $1 ,000s of dollars each year.

Whilst low tariffs can result in low annual costs, Figure 3 below shows that even with a low average tariff, total costs of energy per 1000 L of milk can be high.

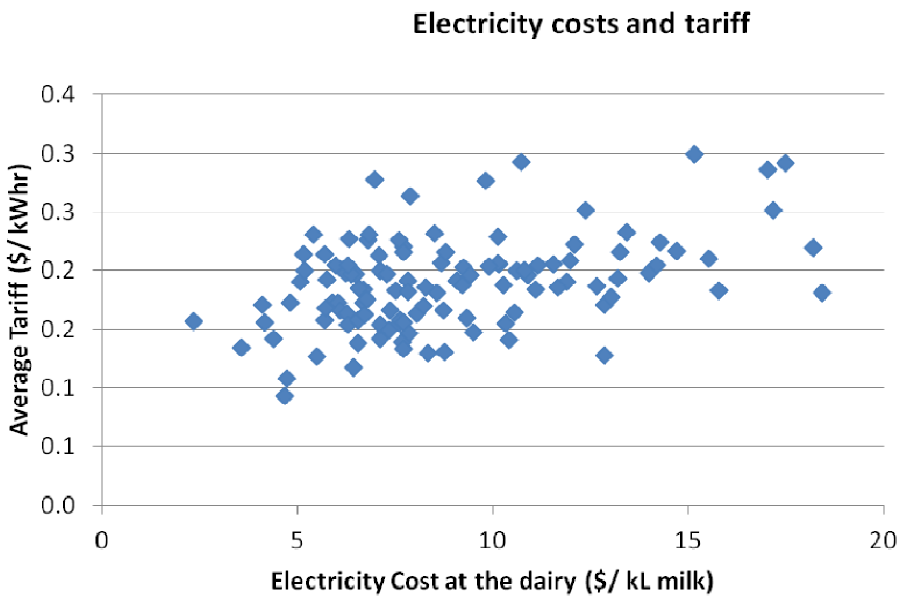

Figure 3: Tariff Costs

Average tariff depends on the energy supplier, the amount of off-peak power used, whether time of use meters are in use and the timing of operations at the dairy.

Example: two farms with average tariff of $ 0.20 / kW-hr (ie low): farm 1 has actual costs of $5.0/ kL milk, whilst farm 2 has actual costs of $14.0/ kL milk.

IMPROVING THE ENERGY EFFICIENCY OF EQUIPMENT AT THE DAIRY.

The EWEN energy assessment provides a reconcilation of actual energy bills for the dairy to the estimated costs of running the motors and equipment at the dairy. Each dairy audited has an accurate breakdown of the actual energy costs at the dairy. Figure 4 shows the range of energy use for the main components at the dairy.

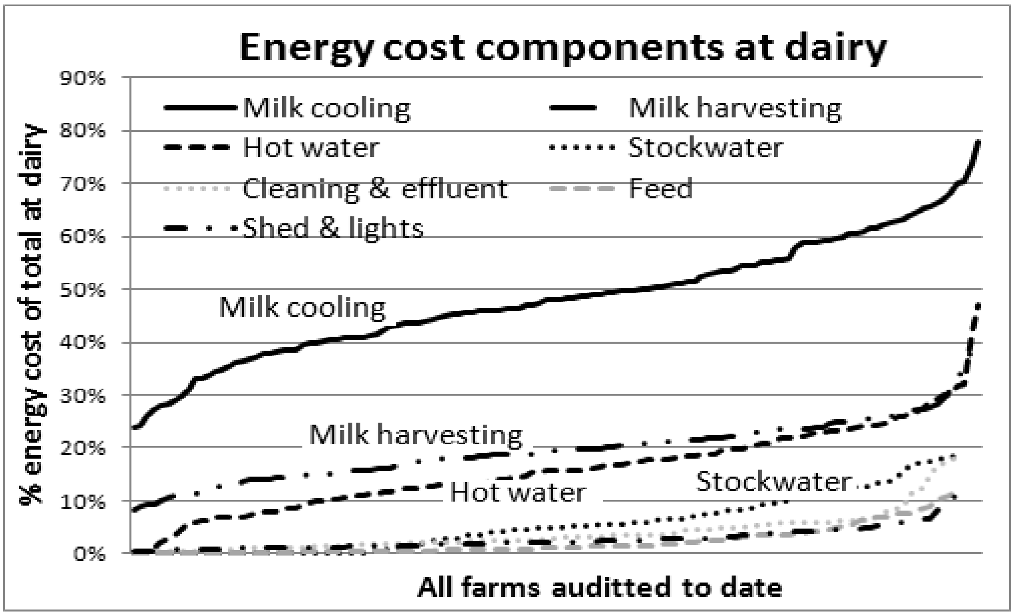

Figure 4: Breakdown of energy use at the dairy

Milk cooling is the highest cost at the dairy and accounts for 40-60% of energy cost of dairy.

Milk harvesting 15-25%; Hot water 10-25%; Other (stockwater, cleaning, feed, shed) 10-25% total

Equipment upgrades have been targeted at the specific breakdown of energy costs for each individual dairy in the EWEN energy assessment. However, the main three energy uses at the dairy offer the biggest gains in energy use efficiency: milk cooling, milk harvesting, and hot water.

IMPROVING ENERGY USE EFFICIENCY: ACTIONS IMPLEMENTED

Projects implemented on farm as part of the EWEN project have used existing technology that can be maintained by local service providers. The EWEN project has monitored with meters actual costs and benefits of changes made in the dairy and developed a series of case studies and fact sheets based on actual data. Projects implemented to improve energy efficiencies have included low cost to higher cost actions that attract a rebate in NSW under the Office of Environment and Heritage (OEH) EESB program.

Milk Cooling:

Low cost actions: correcting flow rate and direction in plate cooler, sourcing the coolest water for the plate cooler, removing restrictions to airflow through fins at compressor, protect refrigeration unit from direct sunlight.

Higher cost actions: installation of new more efficient plate coolers, modify existing plate cooler installation to achieve improved milk to water ratios, increased storage for plate cooler water, off-peak chiller with underground insulated storage.

Hot water:

Low cost actions: check heater elements are wired to correct power supply, check CIP procedures and storage fill, check thermostat setting, changing anodes and elements, changing to off-peak, reducing the volume of hot water used.

Higher cost actions: new efficient hot water system, pre-heating with solar, heat exchange unit or heat pump.

Milk harvesting:

Low cost actions: remove restrictions to airflow at vacuum pump.

Higher cost actions: variable speed drive on either existing vacuum pump (if suitable) or with a new vacuum pump.

PAYBACK PERIODS

Payback periods are site specific as no two dairies are the same. The range of payback periods for actions identified by the EWEN audits are shown in Figure 5.

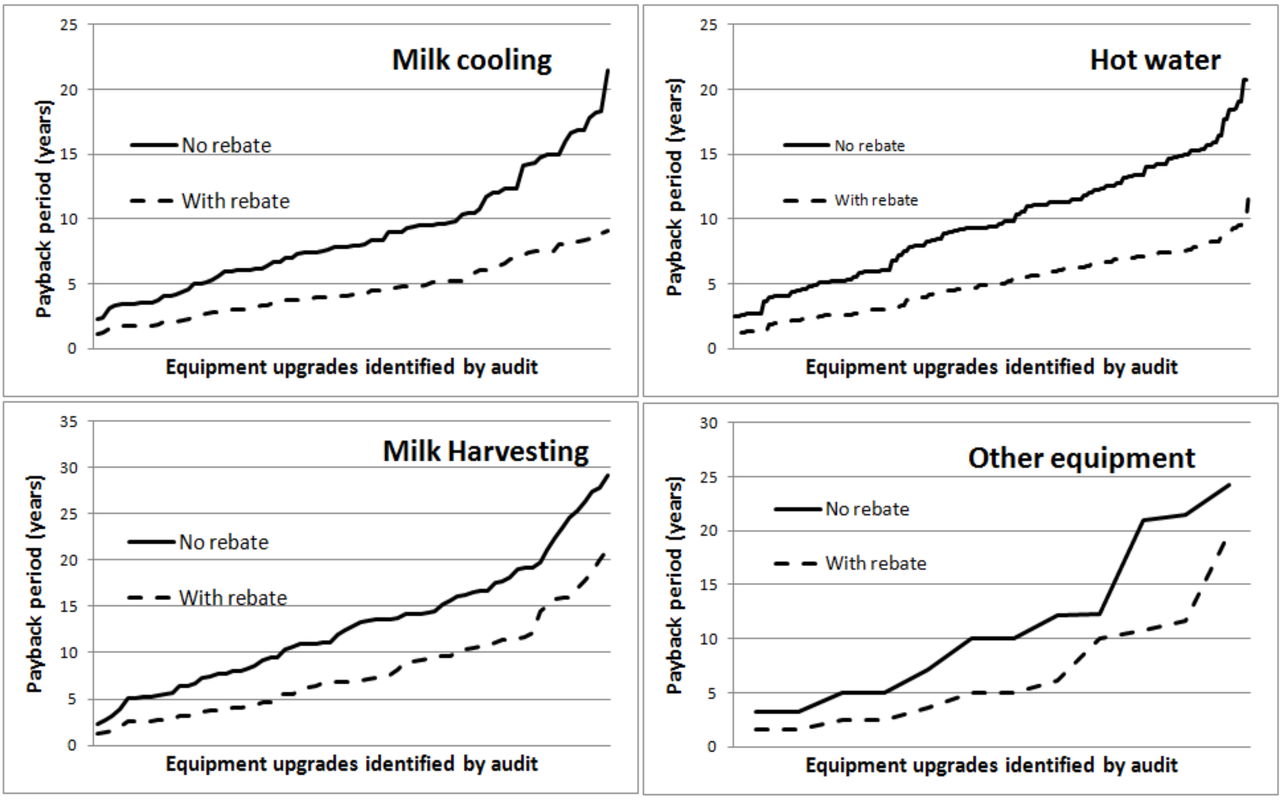

Figure 5: Payback periods for actions identified by energy audit.

Actions identified with long payback periods have generally not been implemented. Typical payback periods for projects actually implemented have been in the range 2½ to 8 years, not taking into account the NSW DECCW rebate. If the rebate is taken into account, typical payback periods are 1½ - 5 years.

In NSW approximately 400 audits have been carried out with an uptake rate of 40-50% with the current rebate program.

BROMBIN, VIA WAUCHOPE

LEO AND LUKE CLEARY

Dairy Farmers, Wauchope, NSW

Leo and Luke Cleary were involved in all three aspects of the Efficient, Water, Energy & Nutrient Project (EWEN) conducted by the Mid Coast Dairy Advancement Group. Through the project efficiency audits were conducted on irrigation and energy consumption. Whole farm soil testing occurred with a nutrient budget produced which allowed them to modify fertiliser inputs and incorporate a new dairy effluent plan.

As part of the EWEN Project they changed all the metered power in the dairy, except for water heating, from normal business tariff to Time of Use tariff. This has saved them more than $5,500 per annum.

BACKGROUND

Leo and Luke Cleary operate a 120 hectare (300 acre) dairy farm at Brombin, near Wauchope. In March 2009, they completed building a new 24-aside swing-over rapid exit dairy to reduce milking times. It took 7½ hours each day to milk 300 cows with the old milking plant.

The new dairy has reduced milking times to six hours per day. Morning milking starts at 5.45 am with cups off by 8.45 am. The afternoon milking is another three hours from 3 pm to 6 pm. Plant washing takes nine minutes after each milking.

When the new dairy was installed, Leo and Luke were required to upgrade the power supply to meet current regulations and safety standards. Polyphase meters were installed, one of which has Time of Use metering capability. It records kilowatt hours used during the peak, shoulder and off-peak times of the day. The hot water heaters for the vat and plant wash were wired to a separate polyphase meter operating on the Controlled 2 (CL2) tariff.

BENEFITS OF THE EWEN PROGRAM

An energy audit of the dairy was conducted on 31st July, 2009. An analysis of power bills for the three month period from August to November 2009 was also carried out.

Polyphase meters record both the total kilowatt hours used and the time when the electricity is being consumed. This data can be accurately analysed to determine the power being used during each of the three periods – peak, shoulder and off-peak. Switching to Time of Use (TOU) tariffs has the potential to save money. However, the service charge for Time of Use is considerably higher than the normal service charge and must be taken into account when calculating the savings.

For Leo and Luke, the final analysis showed that nearly 50% of the total power was being used at the dairy during off-peak times. Even with the extra service charge, considerable savings could be made by changing to Time of Use tariffs. Since the polyphase, Time of Use capable meter was already installed, all it took was a phone call to Country Energy to request the tariff change. There was no charge to make the change.

THE BOTTOM LINE

In the 180-day period to 8th February, 2010, Leo and Luke saved $2,755 from their power bill by switching to the Time of Use tariff from the normal business tariff.

THE EPREG - A NON-INVASIVE PREGNANCY DETECTION SYSTEM FOR CATTLE

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HEARD Systems Pty Ltd is developing a farmer-operated, cost-effective, real-time, rapid and digital pregnancy diagnostic system. Diagnostic approaches are novel and are based on physical detection of foetal cardiac signals (audio and electrical) from patented sensor systems placed against the external surface of the cow. Pregnancies have been detected from the 5th week of gestation. Current focus is on refinement of hardware to optimise data capture, signal processing systems to effectively filter captured data and on detection algorithms for accurate classification of pregnancy status. The objective is for test sensitivity and specificity to be 95% (or greater) – current performance is approximately 90% for both parameters. Extensive field-testing is underway as the company seeks performance targets before commercial release.

INTRODUCTION

Pregnancy status of individual cattle is essential management information for commercial beef and dairy producers. Research and development organisations such as Meat & Livestock Australia and Dairy Australia strongly recommend the use of pregnancy testing as part of effective management cycles[1,2]. Current commercial methods of pregnancy testing rely upon use of a skilled operator/contractor such as a veterinarian. The commercial cattle industries seek a farmer-operated, cost-effective, real-time, any-time, rapid and digital pregnancy diagnostic system that does not require extensive operator skill. Such a tool will help farmers manage individual animals in a timely manner.

Manual pregnancy diagnosis by veterinarians or contractors is mainly via per-rectum examination of cattle. This task provides (albeit small) risks to the cow and operator of acute physical injury. The trend towards larger herds and bigger cows has increased the workload for operators and increasing numbers report repetitive strain injuries. The emergence of specialised rectal ultrasound equipment has reduced the amount of 'arm work' but not eliminated the practice, as manual rectal examination may be necessary to confirm the absence of a pregnancy or to confirm pregnancies greater than 100 days.

These expert-based methods are essentially 'bulk buy' services — applied at the herd level. It is usually not economical or practical for producers to use these services for individual animals or for small numbers. Similarly, reliance on a third-party contractor make unscheduled 'on the spot' pregnancy diagnosis impossible for the majority of farmers. The value of individual animals has increased over recent years, especially for dairy cows. Increasing herd size and greater reliance on employed labour has lifted demand for both individual animal pregnancy testing and objective herd data gathering.

The ePreg system is digital. Sensor data is processed using an analogue-to-digital converter to allow mathematical processing of data. Results can therefore be directly integrated into farm management software systems. The increased uptake of unique whole-of-life digital identification systems (such as NLIS in Australia) provides opportunity for automated pregnancy data recording. Analogue methods – such as ultrasound – require manual transfer of results and the associated transcription errors are an underestimated source of commercial loss for producers. A digital diagnostic system that incorporates a NLIS tag reader allows direct assignment of pregnancy status to specific animals whilst 'cow side'. Future releases of the ePreg are planned to incorporate a RFID tag reader and this capacity.

EXISTING MODALITIES

A summary of the practicalities of existing pregnancy testing modalities is provided in Table 12.

Table 12: Practicalities of existing pregnancy diagnosis methods for cattle

Method	Operator skill level	Farmer convenience	Single animal use	Universal test	Accuracy	Real time	E-data	Cost
Manual palpation	High	Low	Not economic	Yes	High	Yes	No	Mod
Ultra-sound	High	Low	Not economic	Yes	High	Yes	No	Mod
Blood test	Mod	Mod	Not economic	Yes	Variable	No	Possible	High
Milk test	Low	Mod	Not economic	No	Variable	No	Possible	High
IDEAL TEST	Low	High	Economic	Yes	High	Yes	Yes	Low

An ideal pregnancy diagnostic test is one that can be applied quickly, safely and cost-effectively to female cattle of any physiological status (dry, lactating) by lay operators who do not require extensive training in the technique. Results are provided in real time and of sufficient accuracy (status and foetal aging) and in a form that can be readily integrated with herd management software systems. These principles guide the development of the ePreg by HEARD Systems. Foetal heart signals were identified as a potential physical indicator of pregnancy around 2007. This signal has suitable qualities that may support a pregnancy detector including early onset of cardiac activity (day 35), persistence throughout pregnancy (for live births), dual (or more) modality (audio and electrical), radiating nature (detectable at an external surface) and characteristic signal nature (identifiable signal shape and spectral density distribution).

The signal-to-noise ratio (SNR) in data captured using external sensors is low and the desired signal is typically not visible in plots of raw data. This is one of the reasons why application of various human diagnostic devices (such as ECGs) on large animals has not been successful in the past. Effective contact between the sensors and the subject are essential for capture of signal. For the ECG component this requires effective electrode contact with the cow. This is difficult to achieve on unprepared cow hide using human electrodes.

Raw data signals can be improved before analysis. Techniques such as filtering (for controlling noise within set frequency ranges) when combined with electronic gain (to increase signal amplitude) within a circuit of high resolution (capable of detecting signals with small amplitude) and wide dynamic range (to minimise clipping) can strip extraneous noise (such as DC common-mode noise) and provide data with acceptable SNR. HEARD has developed patented circuitry for this purpose. These circuits, when combined with specialised sensors, have enabled the capture of foetal cardiac signals from pregnant cows from the 5-week stage onwards.

On-board classification algorithms then process digitised signals to provide a diagnosis in real time and with sufficient accuracy. Algorithm development and refinement is currently the primary focus of the company.

Large-scale field data collection is underway to build a dataset suitable for algorithm training, testing and validation. As a result current ePreg configurations do not include an active algorithm. This is to ensure that unbiased (Gold Standard) manual pregnancy status for individual animals and data files are captured concurrently with ePreg sensor recordings.

Data gathering and algorithm refinement will be completed before the end of 2012 along with a limited (controlled) release of the ePreg to selected producers for commercial field testing.

A HEARD hand-held research field prototype is presented in Figure .

Figure 1: HEARD ePreg hand-held device prototype

An example of practical use of the ePreg is presented in Figure .

Figure 2: Field use of the ePreg

CONCLUSIONS

HEARD Systems has been actively involved in development of a farmer-operated, hand-held, rapid, real-time, cost-effective pregnancy diagnosis tool since 2007. Current focus is on improving the performance of the diagnostic algorithms (sensitivity, specificity, time required) and on the development of a commercial product with suitable performance, operator and cost characteristics prior to commercial release.

ACKNOWLEDGEMENTS

HEARD Systems would like to thank Allen & Buckeridge, Meat & Livestock Australia, and Sydney Angels Nominees for financial assistance.

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USING ULTRASONOGRAPHY ON DAIRY FARMS TO IMPROVE HERD REPRODUCTIVE PERFORMANCE AND IN FOETAL SEXING

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Ultrasonography is being used increasingly by dairy veterinarians to improve herd reproductive performance and to provide additional services that are beyond the scope of manual palpation. Routine pregnancy testing from 32 days enables earlier detection of non-pregnant cows while accurate diagnosis of ovarian structures enables treatment with hormone protocols tailored to the individual cow. When combined with regular routine visits this technology can be used to help farmers rebreed non-pregnant cows sooner, resulting in improved 100 day in-calf rates, fewer days to conception and shorter average calving intervals. Ultrasound can also be used to sex the 58 -100 day bovine foetus.

INTRODUCTION

Good reproductive management is essential to the productivity and profitability of dairy farms. It is widely recognised that dairy cows have an optimal calving interval of 12 -13 months and therefore a well managed year-round calving herd will have a target calving interval of less than 400 days. Farms benefit from good reproductive performance in several ways (Morton *et al*, 2003):

- A higher proportion of the herd in peak lactation results in higher average daily milk production.
- Fewer excessively fat transition cows results in better dry matter intakes and less negative energy balance in periparturient cows, less metabolic disease in post-parturient cows and better fertility during the next lactation. (Good reproductive management this lactation has a bearing on fertility next lactation).
- Fewer stale cows to dry-off early.
- Fewer cows culled for reproductive reasons enables farmers to cull more low-producing cows and chronic mastitis cows.
- Increased calving frequency enables dry cow therapy to occur more frequently, increasing the potential to cure chronic and subclinical mastitis cows.

At Livestock Veterinary Services routine fertility visits occur every 2 - 4 weeks on most year-round calving farms, but will even occur weekly in the largest herds. When used to scan the uterus and ovaries, ultrasound is an important tool that allows earlier diagnosis of pregnancy, earlier rebreeding of empty cows and administration of treatments based on accurate identification of ovarian structures and uterine pathology.

Ultrasound can also be used to sex the 58 – 100 day foetus; a service that is beyond the scope of manual pregnancy testing.

THE 32 DAY PREGNANCY DIAGNOSIS AND ASSESSMENT OF FOETAL VIABILITY

Uterine fluid can first be observed via ultrasound from 26-27 days gestation and therefore it is possible to diagnose pregnancy from 27 days. In many cows, the early foetus will be located very close to the uterine wall and between folds in the endometrium (DesCoteaux *et al*, 2005). This can make it difficult to identify the foetus and therefore difficult to distinguish between pregnancy and mucometra. As pregnancy progresses beyond 30 days the volume of fluid present increases, distending the uterus and projecting the foetus into the lumen of the uterus. This allows for better visibility of the echogenic (white) foetus and amnion against the contrast of the anechogenic (black) fluid. DesCoteaux *et al* (2005) reports the predictive value for a negative pregnancy test at 28 days to be 95%, whereas the predictive value for a negative test from 31 days is 100%. This reflects the better visibility of the foetus from 31 days.

Cattle can be routinely pregnancy tested at 32 days post-mating. This enables accurate diagnosis to be made earlier than by manual palpation, while avoiding the need to recheck cows scanned at 27-31 days when pregnancy may be difficult to distinguish from mucometra. More importantly, earlier diagnosis enables farmers to rebreed empty cows earlier, which helps to reduce the average number of days from calving to conception.

Ultrasound also allows the veterinarian to assess foetal viability. Observation of the foetal heart beat by ultrasound confirms the presence of a live foetus.

Observation of a degenerating foetus may enable embryonic loss to be detected as it is occurring. Again, this information enables the farmer to induce oestrus and rebreed the cow sooner.

When pregnancy testing cows early, there is a need to remember that late embryonic loss is normal for a proportion of pregnancies. Walsh *et al* (2011) estimates that 7% of lactating cows will lose their foetus between day 24 and day 80, with almost half of these losses occurring between day 28 and day 42. For this reason, routine fertility visits should also target cows approaching mid-gestation for reconfirmation of pregnancy. By structuring herd health programs in this manner there is the opportunity to diagnose and rebreed empty cows as early as possible, while continuing to have a system in place to detect cows in which late embryonic loss has occurred.

DIAGNOSIS OF OVARIAN STRUCTURES

When a cow is anoestrous or non-pregnant, scanning of her ovaries allows for accurate diagnosis of the ovarian structures present, allowing the vet to tailor hormonal treatments to the individual cow. In many circumstances hormone treatments that are inappropriate (given the ovarian structures present) will be ineffective. For example, prostaglandins induce oestrus by causing luteolysis of a Corpus Luteum (CL). If there is no CL present, a prostaglandin injection will not induce oestrus.

Scanning may reveal one or more of the following structures:

- Corpus Luteum (CL)
- Follicles
- Follicular Cyst
- Luteal Cyst
- No structure (small anoestrous ovaries)

A large number of treatment protocols have been devised to induce oestrus, synchronise ovulation or treat ovarian cysts. Table 1 gives examples of appropriate treatment decisions.

Table 1. Examples of hormonal treatments appropriate to specific ovarian structures

Structure	**Appropriate treatment**
Corpus Luteum	Prostaglandin injection and heat detect
Corpus Luteum	Ovsynch (fixed-time AI) if heat detection is poor
Follicles	Ovsynch (fixed-time AI)
Follicles	Vaginal progestagen-releasing device (eg. CIDR)
Follicular Cyst	High dose GnRH
Luteal Cyst	High dose GnRH
Luteal Cyst	Prostaglandin injection
Anoestrous	Vaginal progestagen-releasing device (eg. CIDR)
Anoestrus	Time (if cow is still low DIM)

By tailoring treatments to the ovaries of the individual cow, cows can be mated sooner and ineffective treatments can be avoided.

DIAGNOSIS OF UTERINE PATHOLOGY

Pyometra, endometritis and mucometra can also be detected via ultrasonographic visualisation of exudates within the uterus.

An endometritis exudate may vary in appearance from isoechoic (grey-white) fluid to hyperechoic material floating in anechoic fluid (white material surrounded by black fluid). Ultrasound is particularly useful for the detection of low-grade endometritis, which may go undiagnosed during palpation if there is too little fluid present to palpate.

Mucometra (excessive mucus) will appear as anechoic fluid in the absence of a foetus, foetal membranes and placentomes.

The nature of an exudate detected by ultrasound can be confirmed by metricheck or vaginal examination.

FOETAL SEXING

The bovine foetus can be sexed from 58 – 100 days gestation, although 58 – 80 days is optimum.

Within the first 50 days of gestation the male and female foetus are indistinguishable. Between days 50 and 58, the male and female genitalia of the foetus become differentiated as the genital tubercle, urogenital folds and genital swellings migrate (DesCoteaux *et al*, 2005).

At day 50, the genital tubercle; a swelling located on the ventral midline of the abdomen begins to migrate. In the male foetus the genital tubercle migrates cranially toward the umbilicus where it will form the penis. The surrounding urogenital folds will form the prepuce. Meanwhile the genital swellings migrate caudomedially to form the scrotum (DesCoteaux *et al*, 2005).

In the female foetus the genital tubercle migrates caudally to the base of the tail where it will form the clitoris. The surrounding urogenital folds will form the vulval labiae. Meanwhile the genital swellings atrophy and disappear (DesCoteaux *et al*, 2005).

The migration of the genital tubercle will be complete at day 58.

On sonographic examination, the male foetus will appear to have a hyperechoic swelling just caudal to the umbilicus, whereas a female foetus will appear to have a hyperechoic swelling at the base of the tail.

Sexing of the foetus relies on the ability of the ultrasonographer to position the ultrasound probe against the gravid uterus adjacent to the foetus. As the foetus increases in size and sinks deeper into the abdominal cavity, it may become more difficult for the ultrasonographer to position the foetus satisfactorily relative to the ultrasound probe. For this reason sexing should ideally occur at 58 – 80 days.

Curran *et al* (1989) showed that experienced ultrasonographers can distinguish between the male and female foetus from day 53, however migration of the genital tubercle is not complete until day 58 and therefore the disparity between a male and female foetus becomes more obvious from day 58.

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INVESTIGATION INTO THE CHALLENGES ASSOCIATED WITH REPRODUCTIVE MANAGEMENT ON COMMERCIAL DAIRY FARMS UTILIZING AUTOMATIC MILKING SYSTEMS

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Automatic Milking Systems (AMS) are a relatively new technology worldwide in pasture based systems, introduced mainly to combat increasing labour costs within the dairy industry. Much work has been done on the reproductive management of dairy herds, but it has yet to be seen how much of this work is applicable to AMS herds in pasture based systems. AMS dairies require the voluntary actions of the cows to present themselves to the milking unit for milking, which yields variability between cows within a herd in terms of milk yields and milking frequency. As these systems within Australia are generally incorporated into a pastured based system, this may create difficulties in terms of heat detection, insemination timing and decreased reproductive performance relating to increased negative energy balance if milk yield and/or milking frequency is increased. The purpose of this study is to investigate the reproductive management procedures in use in AMS dairies within Australia and New Zealand, determine reproductive performance levels, and determine specific challenges that occur within AMS herds with respect to reproductive management. Ultimately, finding potential solutions to those challenges will drive the research direction.

INTRODUCTION

The introduction of automatic milking systems (AMS) first occurred commercially in the Netherlands in 1992 and within Australia since 2001 (de Koning and Rodenburg 2004). By 2003, there were over 8000 commercial AMS dairies worldwide (de Koning 2010) with unpublished claims that the global number of installations now exceeds 15,000. At the time of writing there are 16 commercial AMS dairies operating in Australia, with at least 5 additional systems being installed (Kerrisk pers. comm.). Worldwide, labour and lifestyle factors have been among the major motivators for implementation of AMS technology on farm (de Koning and Rodenburg 2004). When taking these drivers into account, saving labour associated directly with milk harvesting may or may not result in redeploying that labour to other aspects of the farm enterprise, including reproductive management. It is well known that successful farm businesses are consistently striving for improved efficiency and productivity. As the goal of dairy farming is to produce milk efficiently and profitably, getting cows pregnant efficiently is an integral step (Senger 2002). If the time to conception post calving is extended, then potential milk production declines and profitability is negatively impacted.

Accurate and timely oestrus detection is necessary if target calving intervals are to be achieved. Within a dairy enterprise, oestrus detection amounts to as much as 30 % of labour costs (Firk *et al*. 2002; Sanders 2005). Cattle may show signs of oestrus at any time during the day or night, and as such, monitoring for oestrus would ideally take place continuously. Without detection aids, monitoring for oestrus behavior 2 to 3 times per day for a total of 30 minutes results in an accuracy of detection rate approximating only 12-19% of cows on heat (Saint-Dizier and Chastant-Maillard 2012). While this type of heat detection alone seems unfeasible, problems arise from the majority of herd management tasks now being combined, leading to less effective monitoring time per cow (Caraviello *et al*. 2006). Also, cows in an AMS system present themselves voluntarily to the milking unit at varying intervals and frequencies (de

Koning 2010). Depending on the timing, methods and frequency of herd monitoring, this may result in some cows being consistently missed if alternative detection methods are not incorporated. The consequence is that incorrect or inadequate heat detection leads to missed/untimely insemination, loss of income due to calf production, increased cost of semen per conception and loss of marginal milk yield, as cows spend more of their lactation in the later and lower producing stages (Firk *et al*. 2002; Overton 2006). While there is potential for oestrus synchronization programs to alleviate some of this problem, the voluntary nature of presentation for milking may make drafting and treatment timing difficult in an AMS herd. Other automated heat detection systems may be of benefit, however the costs can be significant; for example approximately $6000 US for a pedometer style system, to more than $50000 US for an in line milk progesterone assay per system, with ongoing disposables costs (Saint-Dizier and Chastant-Maillard 2012; Roelofs *et al*. 2010).

Missed or untimely inseminations raise potential concern in both conventional and AMS dairies. Work in conventional dairies involving blood or milk progesterone assays suggest that 5 to 30% of inseminations occur in cows that are not in heat (Lima *et al*. 2009). Others discuss the timing of insemination as being approximately 12 to 18 hours post peak oestrus activity (Bar 2010; Roelofs *et al* 2010). Similar to the difficulties in compliance of synchronization protocols, if cows are presenting themselves to the milking unit and are subsequently drafted for breeding at varying intervals, there is a reasonable possibility that the ideal breeding interval will be missed, and conception rates subsequently lowered. To date, there has not been any work conducted to determine practical and feasible le solutions to ensure timely inseminations are consistently achieved in pasture based AMS.

Within an AMS herd, milking frequency is another potentially interesting and complicated issue. As cows present themselves for milking voluntarily, there is a potential for a large variation in the timing and milking frequency of each cow. It is known that an increase in milking frequency can result in an increase in milk yields (provided milking frequency is the most limiting factor) as can be seen from moving from twice a day milking to three times a day (Amos *et al*. 1985). However, there has been much controversy over whether or not increasing milk yields result in a decrease in reproductive performance (Amos *et al* 1985; Weiss *et al* 2004; Senger 2002). While transition to AMS by a thrice daily milking herd would expect a loss of 5-10% of milk yields (de Koning 2010) a similar transition with a twice daily milking herd has the potential to create an increase in milk yields. To date there is insufficient knowledge to be sure of the effects the variability in milk yields and milking frequency will have on overall herd reproductive performance, nor the effects on individual groups of cows within the herd.

This study aims to investigate the reproductive management practices currently used in AMS dairies within Australasia, determine how well these practices are working, and identify system level challenges and/or problem cow demographics. This will position us to inform future adopters of the technology of realistic expectations with regard to achievable reproductive performance levels and practical management practices in pasture-based farming systems. If there are specific challenges that arise we will investigate the potential for technologies that are either available or currently in development that may assist in managing these challenges.

MATERIALS AND METHODS

The study will be divided into three phases. The first phase involves conducting a paper survey to determine what reproductive management practices are currently employed in AMS dairies, what changes have occurred recently been implemented on farm, and what challenges have been encountered. This phase will also survey conventional (i.e. non-robotic) dairies in corresponding regions, to determine if changes in management that have occurred have been specific to AMS dairies, or if they are general trends within regions, or within the wider Australian dairy industry.

The second phase involves quantitative evaluation of reproductive performance within commercial AMS herds. This will provide insight into the levels of performance being achieved in AMS dairies, and highlight potential problem areas that may be causing issues (for example heat detection or conception rates through timing of insemination, challenges associated with bull management etc). Analyzing the data with respect to demographics will determine "at-risk" groups of cows, which may assist in development of best-practice guidelines, which are likely to help improve reproductive performance on farm. Potential "at-risk" groups could include cows that milk at a particular frequency (as their presentation to the milking unit is voluntary), or cows eating over or under a particular level of supplements.

The final phase will involve assessment of the results and available/developing technologies to determine methods of addressing or improving specific challenges that arise through the first two studies.

The results of these studies will be published in scientific journals and be presented to scientific audiences. They will also be used in presentations and fact sheets to the dairy industry to assist producers in avoiding or dealing with challenges that arise in reproductive management of AMS dairies, thereby making the transition to this technology more streamlined and helping to ensure high levels of farm productivity can be achieved.

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SUPPLEMENTATION OF HAND-REARED NEONATAL CALVES WITH NUCLEOTIDES AND EFFECTS ON GROWTH, HEALTH AND IMMUNITY

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Calf morbidity and mortality in the dairy industry result in significant economic losses in terms of treatment and management of sick calves and potential production losses at maturity. Diarrhoea is a common health problem in young calves and causes severe water loss, resulting in rapid health decline and death. Nucleotide supplementation has been shown to reduce diarrhoea and improve growth and aspects of immunity in infants and other species. This study aimed to investigate effects of nucleotide supplementation of calf milk replacer with mixed nucleotides at a rate of 2g/day on health and immunity in Friesian bull calves hand-reared to 2 weeks of age. There was no effect of nucleotides on calf growth, health or the overall incidence of diarrhoea throughout the study. However, the incidence of severe, watery diarrhoea was significantly reduced in nucleotide supplemented calves in comparison to control calves. There were also no differences in immune parameters measured between treatments. Numbers and types of circulating leukocytes and serum IgG concentration were similar between treatment groups throughout the study. A beneficial effect of nucleotide supplementation on immunity was not evident in 2-week old neonatal dairy calves, except for the reduction in the incidence of watery faeces.

INTRODUCTION

Mortality rates in Australian dairy calves are between 2 and 10%, (Moran, 2002) and rates of morbidity are much higher. Whilst calf deaths represent an obvious economic and industry cost, recent evidence has also shown that a reduction in health and nutrition early in life can affect heifer productivity upon herd entry (Svensson & Hultgren, 2008). It is therefore imperative for the industry to have the ability to rear cost-effective, healthy, productive calves (Place, Heinrichs, & Erb, 1998).

Diarrhoea caused by enteric pathogens is a significant problem in Australian dairy herds (Izzo, *et al*., 2011) and is still the biggest cause of morbidity and mortality in neonatal calves (Foster & Smith, 2009). An ability to reduce diarrhoea incidence, or at least reduce the severity of the disease would therefore significantly improve calf health outcomes and economy on-farm.

Nucleotides are semi-essential nutrients found in relative abundance in bovine colostrum (Gil & Sanchez-Medina, 1981), but their concentration in milk replacers is usually low (Kehoe, *et al*. 2008). Supplementation of infant formula with nucleotides has been shown to improve growth (Cosgrove, *et al*., 1996), reduce diarrhoea incidence (Brunser, *et al*. 1994) and improve immunity (Carver *et al*, 1991).

Two recent studies in calves (Kehoe, *et al*., 2008; Mashiko, *et al*., 2009) have shown conflicting results for the benefits of nucleotide supplementation. Kehoe, *et al*. (2008) showed positive effects on severity of diarrhoea at 2 – 4 weeks of age, as well as a reduction in the number of treatments for disease during the pre-weaning period when calves were supplemented with nucleotides containing a mixture of adenine, cytosine and uridine. These authors did not observe any effects on immunity (Kehoe, *et al*., 2008). In contrast, Mashiko, *et al*. (Mashiko, *et al*., 2009) did not record specific effects on calf health with supplementation of uridine only, but observed positive effects on mucosal and innate immunity in calves supplemented from 4 days of age to 11 or 56 days of age.

Mashiko, *et al*. (2009) used a much higher rate of supplementation (2g/day) than Kehoe, *et al*. (2008) (approximately 175mg/L) and as such the observed effects may be a dose response to the rate of supplementation, or a difference in the action of mixed versus single nucleotides. However, given that Kehoe, *et al*. (2008) observed effects on diarrhoea with much lower concentrations of mixed nucleotides, it is useful to investigate this dose response further. This study, therefore, aimed to examine the effects of mixed nucleotide supplementation at a rate of 2g/day of neonatal dairy calves to 2 weeks of age on calf growth, health, serum IgG concentration and numbers of circulating leukocytes.

MATERIALS AND METHODS

Thirty-two purebred Friesian bull calves were obtained at 2-5 days of age from the Dept Primary Industries (DPI) Vic. Ellinbank Centre between July and September 2008.

Calves were hand-reared on the La Trobe University Agricultural Reserve (Bundoora, Victoria) in a naturally ventilated Ecoshelter (*Redpath Ecoshelters®*, Bendigo East, Victoria, Australia), in group pens (3 calves/pen, approximately 2.5 x 3m) for 2 weeks. Calves were fed *Veanavite Full Cream Extra* (*Rivalea Australia*, Corowa, N.S.W.) calf milk replacer (CMR) twice daily at approximately 0800 and 1600 hours in individual feeders. Water, oaten hay and calf meal (*Southern Livestock Nutrition*, Murgheboluc, Victoria, Australia) were available ad libitum throughout the study.

Calves were randomly assigned to control (CON, N = 16) or nucleotide (NUCL, N = 16) groups, commencing treatment at 5 days of age. CON calves were fed CMR only throughout the rearing period and NUCL calves were fed CMR plus 2/g day (1g/feed) of *Ascogen™* (*Chemoforma*, Augst, Switzerland); a commercial preparation of mixed nucleotides.

Calves were monitored daily and assigned health scores for feeding and other behaviours, rectal temperature, eye and nasal discharge, coughing and faecal consistency. The percentage of study days on which calves presented with different scores were calculated for analysis, with a focus in this study on the percentage of study days on which calves presented with diarrhoea or abnormal faecal consistency. Calves were weighed at commencement of the study and again at 10 and 12 – 14 days of age. Blood samples were taken by jugular venipuncture at 5, 10 and 13 – 14 days of age.

Serum samples were collected from blood clotted for 24 hours at 4˚C and centrifuged at 3000 x g for 15 minutes. IgG concentration was measured by capture-ELISA using a Bovine IgG ELISA Quantitation Kit (*Bethyl Laboratories Inc.*, Montogomery, TX, USA). Total leukocyte counts were completed using whole blood within 48 hours of collection. Differential counts were completed under oil immersion with Giemsa-stained whole blood smears (made within 12 hours of collection).

Statistical differences between groups were determined with *IBM SPSS Statistics 19.0* (*'GradPack'*, *IBM Corporation*, Somers, NY, USA). Data was tested first for normality and where violation occurred, data was analysed using a Mann-Whitney U Test. 'Normal' data was analysed with an Independent Samples T-Test. Data was significant when $p < 0.05$.

RESULTS

Weight gains of both CON (3.2 ± 0.8% of initial liveweight) and NUCL (4.7 ± 0.9% of initial liveweight) groups were similar over the 2 week rearing period and there were no differences in liveweight at any age. Supplementation with nucleotides had no effect on the incidence of moderately high (39.4 – 39.9˚C) rectal temperatures (3.7 ± 1.7% in CON and 5.9 ± 3.3% in NUCL calves). No calves from either group presented with temperatures above 39.9˚C throughout the study. There were no differences between treatments in calf behaviour, eye and nasal discharge, or coughing.

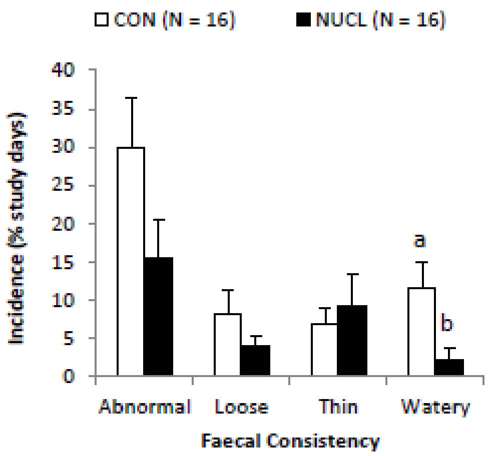

Figure 1: Incidence of abnormal faecal consistency (% study days) in Friesian bull calves hand-reared from 5 days to 2 weeks of age with CMR only (CON), or CMR supplemented with nucleotides at 2g/day (NUCL) (means ± SEM, different letters represent significant differences at p < 0.01)

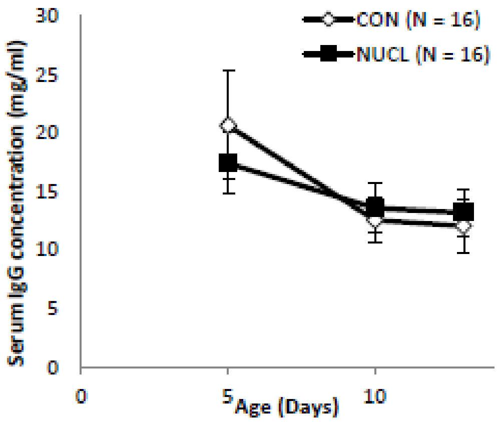

Figure 2: Serum IgG concentration (mg/ml) in Friesian bull calves hand-reared from 5 days to 2 weeks of age with CMR only (CON), or CMR supplemented with nucleotides at 2g/day (NUCL) (means ± SEM)

There were no differences between groups in the percentage of days calves presented with (normal or) abnormal faecal consistency. However, the percentage of days calves presented with watery faeces, (indicative of severe diarrhea) was significantly ($p = 0.005$) reduced in NUCL calves (2.1 ± 1.5%) in comparison to CON calves (11.7 ± 3.3%) (Figure 1).

Figure 2 shows the decline in serum IgG concentration to be similar in both CON (-8.6 ± 2.7mg/ml) and NUCL (-4.2 ± 1.0mg/ml) groups from 5 to 13 – 14 days of age. No differences between groups were observed at 5, 10 or 13 – 14 days of age.

Total numbers of leukocytes were similar between CON (range: 68.3 ± 5.9 – 81.5 ± 8.3 x105 cells/ml whole blood) and NUCL (range: 65.7 ± 7.1 – 89.7 ± 8.8 x105 cells/ml whole blood) calves at 5, 10 and 13 – 14 days of age (Table 1). Similarly, numbers of lymphocytes, monocytes, neutrophils, basophils and eosinophils did not differ between groups at 5, 10, or 13 – 14 days of age (Table 1). Subsequently, neutrophil to lymphocyte ratios were similar throughout the study, ranging from 0.3 ± 0.1– 0.4 ± 0.1 in CON calves and 0.3 ± 0.0 – 0.7 ± 0.2 in NUCL calves.

*Table 1: Total leukocytes (x105/ml whole blood) and percentage of cells per differential leukocyte subset in whole blood of Friesian bull calves hand-reared from 5 days to 2 weeks of age with commercial CMR without additives (CON) or CMR supplemented with nucleotides at 2g/day (NUCL) (means ± SEM) *N = 15*

Age (in days)	Treatment Group	Total Leukocytes (x105/ml whole blood)	Lymphocytes (%)	Monocytes (%)	Neutrophils (%)	Basophils (%)	Eosinophils (%)
5	CON	68.3 ± 5.9	74.5 ± 3.4	6.1 ± 0.9	19.0 ± 3.1	0.1 ± 0.1	0.4 ± 0.2
	NUCL	65.7 ± 7.1	71.4 ± 3.0	8.4 ± 1.1	17.0 ± 1.9	0.1 ± 0.1	0.3 ± 0.2
10	CON*	81.5 ± 8.3	66.6 ± 2.5	5.7 ± 1.1	27.7 ± 2.6	0.0 ± 0.0	0.0 ± 0.0
	NUCL	82.8 ± 8.6	61.9 ± 4.3	5.0 ± 1.0	33.1 ± 4.8	0.0 ± 0.0	0.2 ± 0.1
13 - 14	CON	73.1 ± 7.2	77.2 ± 3.2	4.6 ± 0.9	18.1 ± 3.3	0.1 ± 0.1	0.1 ± 0.1
	NUCL	89.7 ± 8.8	72.6 ± 2.9	5.9 ± 1.3	21.3 ± 3.2	0.0 ± 0.0	0.3 ± 0.1

Although contrary to previous work in infants (Brunser, *et al*., 1994; Carver, *et al*., 1991; Cosgrove, *et al*., 1996) where nucleotides produced beneficial effects on diarrhoea, immunity and growth, the lack of effect of nucleotide supplementation on growth and health parameters was consistent with previous work in young calves (Kehoe, *et al*., 2008; Mashiko, *et al*., 2009). The results reported here for improvements in faecal consistency with dietary supplementation of 2g/day of mixed nucleotides are consistent with those of Kehoe *et al*. (2008) using approximately 175mg/L nucleotides in calves aged 2 – 4 weeks.

Those authors also noted an increase in the persistence of less severe diarrhoea in nucleotide supplemented calves in comparison to control calves from birth to weaning (Kehoe, *et al*., 2008). This result was reflected in an increase in milk refusals in nucleotide supplemented calves, but a decrease in disease treatment. This indicated less severe, but more prolonged disease in the nucleotide calves (Kehoe, *et al*., 2008). Whilst there are obvious advantages in terms of reduction in labour and economic costs (and antibiotic use) to not having to treat sick calves, the effects of long-term subclinical disease on animal welfare and productivity in comparison to acute bouts of more severe infection have not been adequately addressed. Although there was no difference in milk refusals in the current study, it is important to note that no differences were observed between groups for the overall incidence of abnormal faecal consistency, which may reflect similar patterns of low-grade infection to Kehoe, *et al*.'s (2008) work.

In comparison to the immune parameters measured in this study, in which no significant treatment effects were found, Mashiko *et al*. (2009) using purified uridine at the same rate of supplementation did show significant increases in immune responses. Concentration of secretory IgA (sIgA) at the mucosal surface of the ileum of nucleotide supplemented calves was almost double that of control calves at 24 days of age when calves had been supplemented from 1 – 11 days of age (Mashiko, *et al*., 2009). This suggests that whilst supplementation may have no effect on circulating antibody concentration (such as serum IgG measured here and by Kehoe *et al*. (2008)), innate immunity may be stimulated.

Such an effect in terms of numbers of circulating leukocytes was not observed here. However, Mashiko *et al*. (2009) observed an up-regulation of a non-specific cellular response to CD3 mitogens in 56 day old calves supplemented for the entire rearing period, which suggested nucleotides act most strongly on T-lymphocytes. Considering the increase in sIgA following supplementation (Mashiko, *et al*., 2009), it could also be that nucleotide supplementation exerts its effects most strongly in the gut-associated immune system of calves.

Whilst elucidating the method of action warrants further research, it is clear that nucleotide supplementation reduces the severity of diarrhoea in 2 week old calves.

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A RETROSPECTIVE STUDY INTO THE ASSOCIATION OF MATERNAL PERICONCEPTIONAL METABOLIC STRESS ON PROGENY PERFORMANCE: THE DAIRY COW PARADIGM

EPIGENETICS AND FOETAL PROGRAMMING – THE CAUSE OF FAILING FERTILITY?

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Periconceptional developmental programming is likely to have profound implications for the efficiency of livestock production. The decreasing reproductive performance of Holsteins, due to selection pressure for high milk yield, is having a significant effect on farm profitability and cow longevity in the herd. It is thought that an environmental factor (metabolic stress of the dam at conception) may be involved. During early lactation, dairy cows usually experience metabolic stress, including negative energy balance, especially in pasture based systems where nutritional intake can be limited or of lesser quality. The mechanism of periconceptional developmental programming is thought to be epigenetic, where DNA methylation and histone modification alters the expression of the genes by controlling which sections of DNA are folded to restrict expression, and which are folded to allow expression.This paper will outline the proposed influence of the dam's metabolic status at conception on offspring production which forms the basis of this PhD project. It is hypothesized that cows that are inseminated during periods of negative metabolic status will produce offspring who will have a decreased performance in lactation and reproduction.

In a pilot study, calves recorded as being born in December 2009 with complete records for both dam and offspring (n=29) were assessed for a relationship between dam test day production data at conception, and offspring reproductive performance as indicated by days to first conception as heifers. No significant correlation was found, however this is not expected to be indicative of the broader study which will involve the analysis of data from many thousands of heifers.This study endeavours to highlight the need for tightly controlled studies where a dam's metabolic status is accurately measured and regulated. There is also a need for studies that clearly elucidate the mechanism of action by which the dam's periconceptional metabolic stress affect progeny performance. This is hoped to provide real world solutions for the management and nutritional issues facing the dairy industry in its quest to maximise production and profitability.

BACKGROUND

In recent years a decline in fertility in the Holstein has been demonstrated along with a massive increase in production. Holsteins now take a longer time to return to oestrus, have poorer conception rates and have an increased rate of early embryo loss (Roche, *et al* 2011). But what is the cause of this failing fertility? Could it be that maternal nutrition at conception is the answer to solving this major issue?

Typical demands of a continuous breeding system require a 365d calving interval which necessitates a cow to conceive in as short a time as 60 days postpartum. Whilst this is proving to be increasingly difficult for the industry to achieve, the challenge for the dairy cow are numerous and far-reaching. Conception often occurs during peak yield and therefore peak metabolic demand when the cow diverts the majority of nutrients towards the mammary gland (genetic selection for high milk yield) (Roche, *et al*., 2011). Embryo development might be affected metabolic stress and these effects might become evident only in adult life. Cows not in peak lactation and heifers are less metabolically stressed due to the absence of a huge lactation demand (Kirkland & Gordon, 2001). Although significant gains have been made in recent years towards understanding the nutritional management of the transition period, dairy cows still commonly experience a negative metabolic status in early and peak lactation. This is the critical time for development of both the oocyte and the embryo. Thus, what are the consequences of metabolic stress at conception on offspring health, reproduction and production?

Periconceptional Metabolic Programming

The concept of the mother's nutrition affecting performance after birth has been discussed for decades. Barker showed in humans that offspring who suffered malnutrition, and were born small had a higher risk of developing disease as an adult (Barker, 1995; Godfrey, *et al*, 1996; Godfrey, *et al*, 1997). It was proposed that somehow the foetus was programmed, without alteration to the genes themselves, to suit its expected environment. This also possibly benefits the mother by reducing the metabolic demands of gestation during times of nutritional stress. In other words babies of a small birth weight, due to a malnourished gestation, would go through a catch up growth in an unexpectedly good nutritional environment. They fulfill a predisposition to obesity and go on to suffering from adult onset disease states. This concept of the 'thrifty phenotype' and the 'developmental origins of adult disease' was renamed "the Barker Hypothesis" by the British medical Journal.

Researchers postulate that this type of modification to expression occurs with ramifications outside of chronic disease (Mathers & McKay, 2009).

Epigenetics

Epigenetics or 'above genetics' is a term used to describe modifications to genetic expression without altering the genetic code itself, but rather how the genes are expressed.

There is now substantial evidence that maternal nutrition at conception alters the genetic expression and therefore foetal development, thus providing a probable mechanism of this periconceptional developmental programming (PDP) (Leroy, *et al*., 2011; Mathers & McKay, 2009).

What about dairy cows? Has metabolic stress during early lactation around conception and gestation been demonstrated to affect offspring performance?

There is a paucity of studies in the dairy cow but observations in sheep indicate that nutrient restriction during the periconceptional period altering the methylation status of the DNA at specific sites, resulting in heavier, fatter and insulin resistant adult offspring with high blood pressure. Interestingly this was more obvious in male offspring (Sinclair, *et al*., 2007). Complications of insulin resistance in cattle includes diabetes, fatty liver syndrome, ketosis, milk fever and infertility (Sinclair, 2010) If calves are born small because of malnutrition during gestation, it is thought they might develop diseases once they start lactating and they might be culled earlier than calves that are within normal birth liveweight ranges.

In dairy cows it was found that offspring survival and performance were negatively affected by prepartum milk production or related factors (namely nutrition) experienced as an oocyte, embryo or foetus (Berry, *et al*., 2008).

Another study (Pryce, *et al*, 2002) using dairy cows suggests there is no effect on daughter reproductive performance when compared to dam parity, milk production, dry matter intake or body condition score (BCS) in the first or second 13 week postpartum period from the previous parity. However the dataset used in this study was limited in number and diversity of management systems.

Maternal body condition during gestation has been shown to correlate positively with daughter BCS, non-return rate, and number of inseminations per conception, therefore suggesting a better fertility status. Changes to the Dam's BCS during gestation did not affect daughter performance significantly (Banos, *et al*, 2007).

To the best of our knowledge, there are no studies that have compared metabolic status at conception to offspring performance in the dairy cow.

Therefore, the purpose of this research is to establish if a correlation between maternal periconceptional nutritional status and offspring performance exists in dairy cows. This could provide real solutions for the Australian dairy industry in its quest to improve reproductive management of the national herd.

It is hypothesized that maternal periconceptional metabolic stress will result in a reduced lactational and reproductive performance in the offspring.

METHODOLOGY

Retrospective confirmation of correlation

The retrospective confirmation of correlation involves the analysis of reproduction and production data from daughters and dams in the Australian Dairy Herd Improvement Scheme (ADHIS) national database for the period of 2000 to 2011. Data will be extracted for Holstein herds with a year round, split and seasonal calving systems.

As a pilot study calves born to multiparous dams, with complete lactation and reproductive records in December 2009 were selected (n=29). Dams of offspring were stratified for metabolic status using production variables including test day Yield, Milk Protein and Fat at conception, determined by using a standardized gestation length of 285 days.

A linear interpolation between the two closest test day records surrounding the calculated date of conception was adopted. Using univariate linear regression analysis, an association between lessened offspring performance (as indicated in the pilot study by days to first conception) and maternal periconceptional metabolic status was assessed.

RESULTS

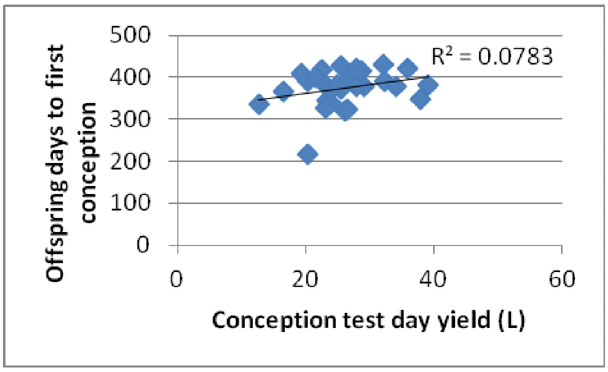

Figure 1 – Dam conception test day Yield vs. Offspring Days to first conception

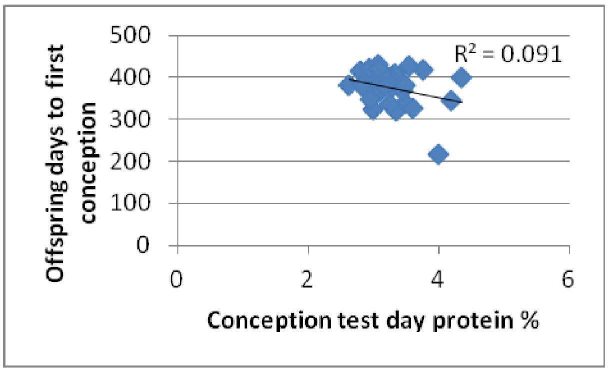

Figure 2 – Dam conception test day protein percentage vs. Offspring Days to first conception

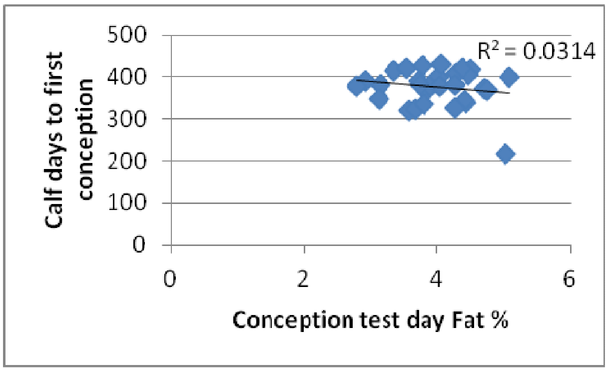

Figure 3 – Dam conception test day fat percentage vs. Offspring Days to first conception

Figure 1 illustrates a no significant association (r^2=0.08) between dam test day yield and days to first conception in the offspring. Similar no significant relationships between dam test day protein (r^2=0.09) and fat (r^2=0.03) levels and offspring days to conception were observed.

DISCUSSION AND CONCLUSION

Whilst these results do not show a significant correlation between maternal nutritional status at conception and offspring days to first conception, only 29 dam daughter pairs were assessed and it is anticipated that with a wider study of the broader dataset there will be a positive correlation between these, as well as other reproductive and production characteristics of both the dam and offspring. Further analysis will include multivariate analysis of metabolic measures such as fat to protein ratio, days in milk, and stratification of before and after peak lactation. Inclusion of a large number of herds will also allow the removal of other influences such as nutrition, herd genetics, and database record accuracy.

In addition to the retrospective study, controlled studies should be undertaken to confirm or rule out any association.

The advantage of a prospective study is that maternal metabolic status can be accurately measured using physiological indicators, once they are established, as well as having the ability to regulate nutritional intake. This approach will then establish a foundation for the investigation of exact mechanisms involved with the epigenetic alteration of genetic expression, thereby affecting offspring reproduction and lactation. If a relationship between periconceptional metabolic stress and offspring performance will be proven, it will be possible to device nutritional intervention to prevent this from occurring.

Studies are needed to confirm the association and mechanism of failing fertility and as a result provide the industry with the knowledge and tools to address this significant issue.

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VALIDATION OF AN ACIDOSIS MODEL

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The lack of consistent techniques to diagnose ruminal acidosis is a major challenge for management of dairy and feedlot cattle. Developing better diagnostic tools will help farmers and their advisors identify cows and herds at risk of acidosis. It is important to validate the model that Bramley et al. (2008) developed to define ruminal acidosis using newly gathered data. The model (Bramley et al., 2008), classified cows into three categories: 1) acidotic, 2) suboptimal rumen function, or 3) normal. The classification was based on analysis of rumen volatile fatty acid, lactate, ammonia and pH measures from 800 cows from 100 commercial dairy herds in Southern Australia. In order to validate the model, measures from five independent carbohydrate challenge studies were incorporated into the existing dataset and cattle were classified for acidosis status. Category classifications from the five studies were consistent with anticipated status based on examination of the raw data, physiological observations and current biological understandings. Our approach can identify crucial biochemical shifts occurring in the rumen suggesting that it is effective at diagnosing acidosis severity, which occurs along a continuum of ruminal conditions from mild to severe. Receiver operating characteristic (ROC) methods showed that valerate (sensitivity = 0.90; specificity = 0.90; area under the curve (AUC) = 0.954) and propionate (sensitivity = 0.93; specificity = 0.87; AUC = 0.955) are key indicators of acidosis status, while pH taken using stomach tube (sensitivity = 0.68; specificity = 0.84), or rumenocentesis pH (sensitivity = 0.74; specificity = 0.79) are less useful and low milk fat: protein ratio (sensitivity = 0.54; specificity = 0.81) is not sensitive. Development of a rapid, low-cost cowside test to measure valerate or propionate concentrations could assist in rapid on-farm diagnosis of acidosis using rumen fluid samples.

INTRODUCTION

Acidosis is a major challenge in dairy and feedlot cattle worldwide. It is caused by the consumption of diets high in readily fermentable carbohydrates such as grain and low in effective fibre which lead to organic acids exceeding the buffering capacity of the rumen (Nagaraja and Tigemeyer, 2007). Acidosis occurs in a range of forms, varying in severity from very mild, where symptoms can be subclinical, to peracute resulting in death. The initial step in treatment and prevention of a disease is accurate diagnosis of cases with minimal false positive and negative cases. There are currently no consistent definitions for the accurate diagnosis of acidosis. Ruminal pH is often used; however, there are discrepancies in the thresholds defining acidosis severity (Nagaraja and Tigemeyer, 2007). Rumen pH may not be an accurate indicator of acidosis, this reflects the daily fluctuations of rumen pH, and that a rumen sample used may not accurately represent the entire rumen contents. Bramley *et al*. (2008) collected diet, health, production and rumen fluid data from 800 cows from 100 randomly selected commercial dairy herds across Southern Australia. The data was used to create a model by K-Means cluster and discriminant analysis that classified cattle based on the rumen pH, individual volatile fatty acids (VFA), ammonia and D-lactate concentrations into one of three categories 1) acidotic, 2) suboptimal rumen function, or 3) normal. Bramley *et al*. (2008) also showed the VFAs valerate and propionate were the most important variables in acidosis prediction.

The primary objective of this paper was to examine several different methods to detect ruminal acidosis for their value as diagnostic tests.

We also aimed to validate the acidosis model by analysing independent studies using the Bramley model and compare these results with anticipated acidosis status based on diet composition, clinical signs and rumen fermentation data.

MATERIALS AND METHODS

Carbohydrate (CHO) Challenge Datasets: Data from five challenge studies; four from independent CHO challenge studies conducted using a similar protocol, and a fifth from a longer period challenge diet study, were used to validate the acidosis model. A description of these studies is briefly outlined here.

Dairy CHO: Thirty Holstein dairy heifers were randomly allocated to five treatment groups: 1) control (no grain); 2) grain [triticale fed at 1.2% of bodyweight (BW)]; 3) grain (0.8% of BW DMI) + fructose (0.4% of BW DMI); 4) grain (1.2% of BW DMI) + histidine (6 g/head); and 5) Grain (0.8% of BW DMI) + fructose (0.4% of BW DMI) + histidine (6 g/head) in a partial factorial arrangement (Golder *et al*. 2012).

Beef CHO: Eighteen beef cattle (9 heifers and 9 steers) were divided into a control (no grain) or treatment group (1.2% of BW Triticale) (Lawrence, 2010).

Twenty grains: Forty dairy Holstein heifers were fed 1 of 20 test grains which included: oats (n = 3), wheat (n = 6), barley (n = 4), triticale (n = 4) and, sorghum (n = 3) cultivars at 1.2% of BW. Heifers were re-assigned to a different grain after a 9 day washout period (n = 4 heifers/grain) (Lean & Rabiee, 2007a).

Rumen modifiers: Data were pooled from two similar independent challenge studies. A total of 58 Holstein heifers were allocated to 1 of 14 treatment diets in an incomplete factorial arrangement. All groups were fed 1.2% of BW wheat and one of the following rumen modifiers: 1) Grain only, 2) Fermenten (Fe), 3) Flavophospholipol (FL), 4) Tylosin (T), 5) Monensin (M), 6) Fe+FL, 7) Fe+T, 8) Fe+M, 9) FL+T, 10) FL+M, 11) T+M, 12) Fe+FL+T, 13) Fe+FL+M, 14) Fe+T+M (Lean & Rabiee, 2007b). In the four above datasets, cattle were fed a forage-based diet during a pre-adaptation period of up to 21 days followed by an adaptation period where 0.5-1 kg/d of grain was added to the forage-based diet (4-11 days). A total of five rumen fluid samples were taken from each cow via a stomach tube. The first sample was collected 0-5 minutes after diet consumption, the second 60 minutes later and 3 subsequent samples at 45-50 minute intervals.

Grain vs. partial mixed ration (PMR): Twenty mixed age lactating Holstein cows were allocated into a control (wheat + silage) or PMR group and were fed at one of the following rates: 8, 10, 12, 14 or 16 kg DM/d (75:27 cereal grain:forage DM; n = 2 cows/diet/rate). Rumen samples were collected via a rumen fistula at 10 time periods at approximately 2.4 hour intervals over a 24 hour period.

Validation

Data from each time period of the five independent studies for rumen pH, ammonia, individual VFA and D-lactate were added one independent study and one time period at a time to the existing Bramley *et al*. (2008) dataset. Existing categories were used to determine categories for the newly added data based on standardized Z-scores for each variable using discriminant analysis. A new set of standardized Z-scores for each variable incorporating the existing data was calculated (PASW Statistics 18, SPSS Inc., Chicago, IL, USA). The process was repeated for each of the five studies.

Receiver Operating Characteristic (ROC) Curves

The Bramley *et al*. (2008) dataset was analysed using ROC methods to estimate the area under curve (AUC) and determine the diagnostic value of individual rumen VFA, rumen pH and milk fat:protein ratio for the detection of ruminal acidosis in cattle. The ROC analysis provided an estimation of the sensitivity, specificity, AUC and cut-off point for each variable. Sensitivity is a measure of the ability of the diagnostic test to correctly identify a positive case of acidosis. Specificity is a measure of the number of false positives detected by the diagnostic test. The closer the sensitivity and specificity values are to 1.0 the more reliable the test is. The AUC measures the ability of the diagnostic test to discriminate between cattle with or without ruminal acidosis and ranges from 0.5-1.0 with 1.0

representing perfect performance and 0.5 being of no value. The cut-off point represents a value for a particular variable with optimized diagnostic characteristics. The variables that were assessed in this study were; rumen concentrations of acetate, butyrate, propionate, valerate, rumen pH measured by stomach tube or rumenocentesis and milk fat: protein ratio.

RESULTS

The classification of acidotic cattle using the data from the five independent carbohydrate studies was successfully performed. In the Dairy CHO study 140 out of 150 rumen samples were ranked as category 2 and 10 rumen samples as category 3. Seven of the 10 category 3 heifers were from the control group. In the Beef-CHO study, 53 out of 90 rumen samples were classified as category 2 and 37 rumen samples belonged to category 3. In the Twenty grains study; rumen samples obtained from heifers fed triticale and wheat were the most acidotic and acidotic status over the sampling time increased. A total of 202 out of 400 rumen samples were classified as category 2 and 198 of rumen samples were considered as category 3. In the Rumen modifiers study; there was little variation among the rumen samples collected from heifers in the 14 different groups, with 264 out of 295 rumen samples classified as category 2 and 31 rumen samples classified as category 3. Data obtained from the Grain versus PMR study showed that cows became more acidotic as rate of concentrate increased and cows in the control group were more acidotic than the PMR fed cattle. A total of 30 rumen samples were classified as category 1 (30/200= 15%), 144 were in category 2 (72%) and 26 were in category 3 (13%). Twenty of the category 1 rumen samples, were from the control group and 25 of the category 1 cows were fed at a rate of 14 or 16 kg/d from either the control or PMR group.

Table 1. Sensitivity (Se), specificity (Sp), area under the curve (AUC) and cut-off points from receiver operator curves for the acidosis diagnostic value of rumen and milk measures. ST = stomach tube

Measure	**Se**	**Sp**	**AUC**	**Cut-points**
Acetate (mM)	0.94	0.27	0.627	36.7
Butyrate (mM)	0.94	0.20	0.530	5.28
Propionate (mM)	0.93	0.87	0.955	23.10
Valerate (mM)	0.90	0.90	0.954	1.62
pH (Stomach tube)	0.68	0.84	0.801	6.54
pH (Rumenocentesis)	0.74	0.79	0.822	5.96
Milk Fat:Protein	0.54	0.81	0.716	1.02

ROC curves comparing the value of ruminal and milk parameters as diagnostic tests for acidosis are shown in Figure 1. Sensitivity, specificity, AUC and cut point are reported for each variable in Table 1. Rumen concentrations of acetate and butyrate had the highest sensitivity; and lowest specificity. The specificity and AUC of rumen concentrations of valerate and propionate were higher than other rumen parameters. Sensitivity was also high for these variables. The AUC and cut point for valerate are shown in Figures 2 and 3. The rumen pH that were measured using stomach tube and rumenocentesis pH produced lower values for both sensitivity and specificity than the VFA. Stomach tube pH had a higher specificity in comparison to rumenocentesis pH which had a higher sensitivity. The milk fat to milk protein ratio was specific but not sensitive. It had an AUC greater than that of acetate and butyrate but lower than that of propionate, valerate and pH.

DISCUSSION

Classification of categories 2 or 3 rumen samples were consistent with anticipated categorisation based on the absence of clinical signs of acidosis, amount of changes in ruminal pH, VFA and ammonia, diet composition and feeding management (Lean & Rabiee, 2007ab; Lawrence, 2010; Golder *et al*., 2012). Rumen samples that were classified as Category 1 were only observed in the Grain vs. PMR study with 83% of the rumen samples fed 14 or 16 kg/d of ration, observations which are consistent with VFA and lactate data, and lower milk fat content in these cows than cows fed 12 kg/d of ration. Lactating cows in this study were fed rations at higher rates and over a 14 day period compared to the other four challenge studies where challenges were fed abruptly in a single feed. The consistent classifications suggest the Bramley model is an effective method of diagnosing acidosis in cattle.

The Bramley data was collected from commercial dairy herds in contrast to the experimental data used for validation.

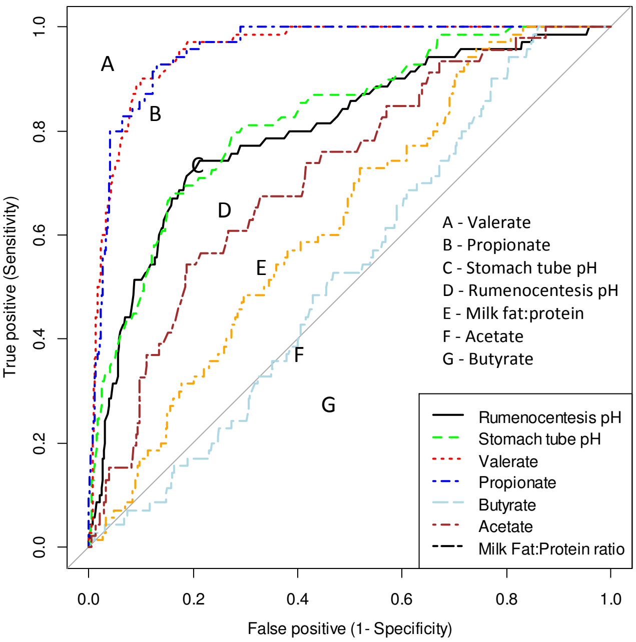

Figure 1. Receiver operator characteristic (ROC) curves comparing the value of [A]valerate, [B]propionate, [C]stomach tube pH, [D]rumenocentesis pH, [E]milk fat to protein ratio, [F]acetate, [G]butyrate as diagnostic tests for acidosis in cattle

Valerate and propionate had the greatest diagnostic value for acidosis detection, a finding consistent with Bramley *et al*. (2008). Butyrate and acetate were reported as the next most important predictors by Bramley *et al*. (2008), but our results showed these variables although sensitive were of overall poor diagnostic value due to the high risk of false positives, as indicated by the low specificity. Rumenocentesis pH measurements are considered to be more accurate than those obtained by a stomach tube where there is a risk of saliva contamination (Norlund and Garrett, 1994). Our results show overall both methods are equally effective as diagnostic tools. However, stomach tube measurements had a lower number of false positives (higher specificity) and rumenocentesis was more sensitive.

Milk fat to milk protein ratio can easily be obtained by farmers and advisors and is as specific as using rumen pH measures for acidosis diagnosis. It is however not as sensitive as using VFAs or pH for detection. It may be of benefit to develop a cowside test for valerate or propionate concentration to be used in conjunction with existing methods of testing rumen pH and assessment based on clinical observations and diet composition and management. The ROC were produced from the Bramley dataset only. Therefore, there is a need to use ROC methods to assess the diagnostic value of the same rumen and milk measures from other independent datasets such as the Grain versus PMR data.

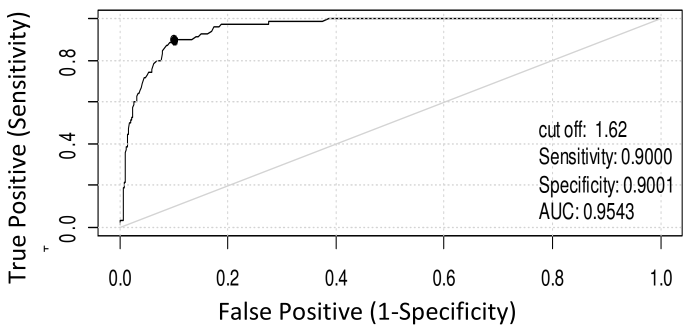

Figure 2. Receiver operator curve showing the value of ruminal valerate concentration as a diagnostic method for acidosis in cattle. The dot represents the valerate concentration where diagnostic ability is optimized (cut off).

The Bramley acidosis model uses biochemical shifts occurring in the rumen to effectively diagnose acidosis severity. Acidosis exists as a continuum of ruminal conditions, a finding reflected in the challenge studies. Further validation from acute CHO challenges and commercial farms will provide additional insights to the causes and means of preventing acidosis. Valerate and propionate have potential for development into cowside tests for acidosis. Milk fat to protein ratios have value in identifying cows at risk of acidosis. While a cow with a low fat:protein test may not be acidotic, an acidotic cow is very likely to have a low fat:protein ratio. This test is as effective in terms of specificity as ruminal pH samples.

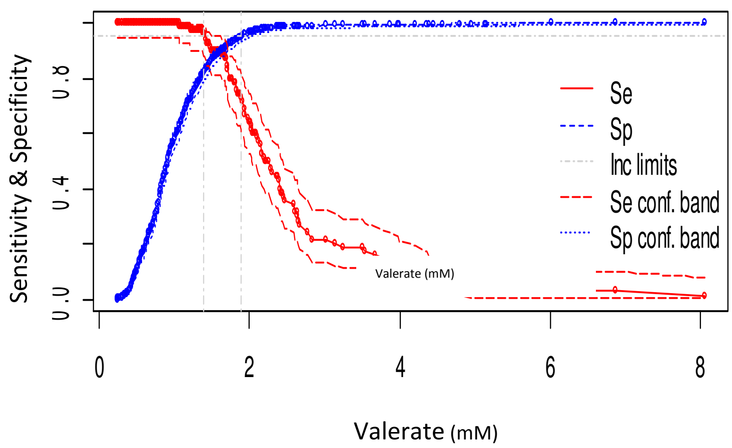

Figure 3. Two-graph receiver operator characteristic (ROC) curve for ruminal valerate concentration. The intersect represents the valerate concentration where diagnostic ability is optimized (cut off)

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CHARACTERISTICS OF EXTENDED LACTATION AND PERSISTENCY IN AUSTRALIAN DAIRY COWS

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Extended lactation is a novel aspect for the dairy industry as it takes the period for which cows are milked from standard 305 day lactation to an open ended (longer) lactation as long as cows remain productive. Extending lactation has been used as a management tool to manage the decreasing fertility problem seen in some of the Australian dairy herds and retain high milking cows for longer, resulting in healthier, more productive cows and increasing profit for the dairy producer. The aim of this research is to understand the variation that exists between Australian dairy cattle in their milk yield profiles (lactation curves) over an extended lactation and obtain derived traits that could be used in the genetic analysis. The Wood model was fitted to milk yield records from a random subset of 6,022 pure Holstein cows with 250,929 test day records to obtain parameters which describe the different shapes of lactation curves. Two traits of interest, namely persistency and extended lactation were quantified and relevant descriptive parameters derived. Variation among cows in their abilities to maintain high production over a longer period of time was evident with all measures expressing a high degree of variation (CV range 8%-75%). An average representation of the shape of the lactation curve seen in Australian dairy cows has been presented based on the Wood model parameters obtained. Findings showed that milk production during extended lactation phase (from day 305 to day 610 of lactation) is on average 40% of the production of day 305 (standard lactation) with an average milk yield over the extended lactation of 8,968 L. The derived traits and Wood model parameters obtained will now be utilised in the estimation of genetic parameters and breeding values for extended lactation traits. This research will provide dairy farmers with a breeding tool to select cows that are best suited to milk for longer than the traditional 305 days.

INTRODUCTION

There has been a shift especially in Victoria Australia for herds having a seasonally concentrated calving pattern (63%) in 2004 to 41% in 2006 (Auldist *et al*., 2007; Grainger *et al*., 2009). The reason for such a shift is from improved feeding of cows and the introduction of new germplasm from North American Holstein Friesian animals into some Australian dairy herds. Such impacts have resulted in an increase in the genetic potential of cows to produce more milk, while at the same time causing a decrease in reproductive performance largely as a consequence of changes in metabolic and physiological requirements of being milked. The result is an ongoing trend of cows being milked beyond the traditional 305 day system as a management tool to manage decreasing fertility and retain super milking cows for longer, resulting in healthier, more productive cows and more profit for the dairy producer.

Lactation curve models are useful tools in helping to define and estimate lactation characteristics of individual cows for genetic selection (Dekkers *et al*., 1998; VanRaden *et al*., 2006), predicting milk yields and milk components, analyse responses of yield to environmental and management changes, and identify opportunities for maximising net value effectively (Dematawewa *et al*., 2007; Dijkstra *et al*., 2010). Thus a fundamental aspect of evaluating extended lactation is the modelling of extended lactation and persistency traits in Australian dairy cattle based on industry herd recording data.

While trait definitions differ, heritability estimates for extended lactation are in the range of 0.19 to 0.30) and for persistency traits 0.03-to 0.30). These moderate heritability estimates suggest that these traits have the ability to respond well to selection. Limited information available for Australian dairy cows (Haile-Mariam and Goddard, 2008) suggests there are both phenotypic and genetic differences in the ability of cows to continue to milk for long periods. Furthermore predictions of which cows are better at milking for longer can be made based on their previous traditional 305 day milking performance. This current project examines the genetic differences observed in Australian dairy cows that can be successfully milked for longer than 305 days. Estimated breeding values (EBVs) for these cows will be derived, which are predictions of the ability of an individual to produce offspring that also can be milked for a longer period. This information is not available to date. For this paper the main focus will be on some preliminary exploration of phenotypes and the variation that exists between cows in their milk yield profiles (lactation curves) over an extended lactation and obtaining parameters and derived traits that will go onto be used in the genetic analysis of Australian industry herds.

METHODS AND MATERIALS

Data were obtained from ADHIS including ~158 million test day records from 1985 to 2010 derived from ~7 million cows. Extended lactation milk traits include milk yield, fat, protein, lactose percentage, Australian Selection Index (fat + protein-volume) and energy outflow of fat, protein and lactose as a measure of energy per lactation. Extended lactation curves will be modelled using two methods, namely the Wood model and random regression model (RRM) to derive persistency and extended lactation traits to be used in the genetic analysis**.** Genetic parameter estimates and estimated breeding values for these traits will be derived using linear mixed animal models using the ASReml-R program.

For this paper some preliminary analyses are presented looking at only milk yield using a random subset of 6,022 pure Holstein cows with 250,929 test records after data filtering. The variation in the shapes of lactation curves of cows across different herds in Australia has been explored by fitting the wood model to the milk yield test day data. The Wood model contains three parameters namely (*a*) an overall scaling factor, parameter (*b*) related to the rate of increase prior to the peak yield and parameter (*c*) related to the rate of decline after the peak (Figure 1) (Wood, 1967).

In this study persistency of lactation and extended lactation of just milk yield has been examined. Other yield and milk component traits will be examined subsequently. In the context of this study persistency is defined as the ratio of model-based milk yield at day 305 to model-based milk yield at peak (Hall, 2008; Jonas *et al*., 2011) and extended lactation is defined as the ratio of expected milk yield from day 305 to day 610 (given that cattle are in lactation for 2 years) relative to the cumulative yield up to day 305. Statistically extended lactation and persistency are measured as a ratio of yields (Figure 1)

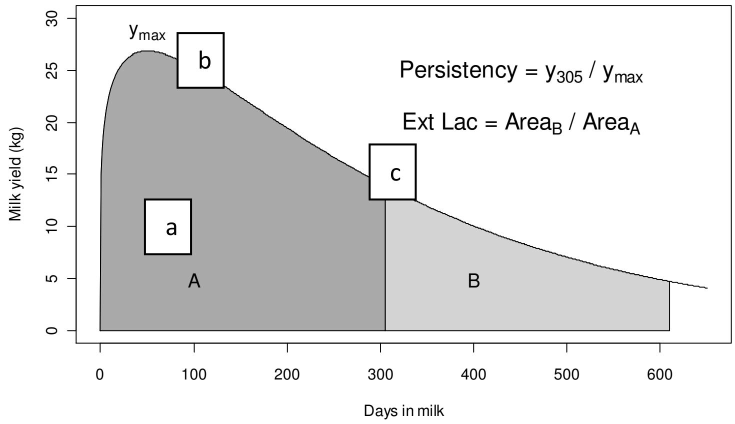

Figure 1: Definition and statistical measure of extended lactation and lactation persistency as a ratio of yields

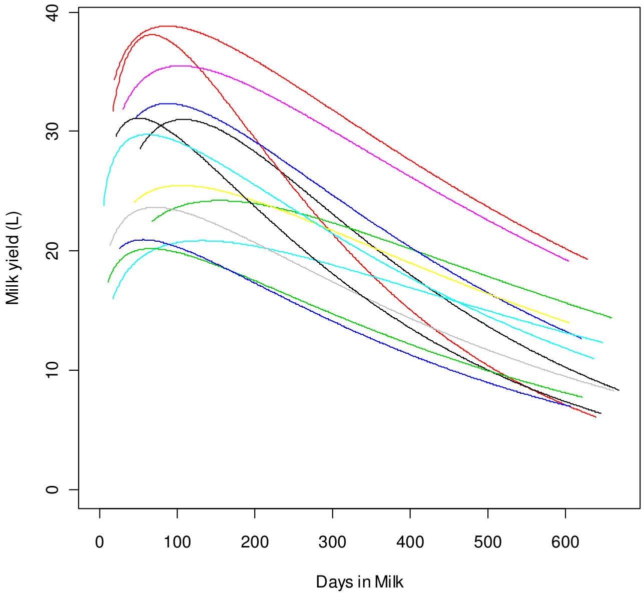

Figure 2: Different shapes of lactation curves of a sample of 13 cows selected with extended lactations (~600 days) also showing that there are cows that are more persistent flatter curves, slower rate of decline in milk production after peak milk yield, more than others. Illustrating best (top red) and worst (bottom blue) cow lactation curves and the variation in their lactation curve shape.

RESULTS AND DISCUSSION

As can be seen from Figure 2 there is variation in the shapes of the lactation curve of different cows with extended lactation (beyond the traditional 305 day lactation). This is also supported with all measures expressing a high degree of variation (CV range 8%-75% Table 1). Some cows have a steeper rate of decline where we see a rapid drop in milk production straight after peak lactation while other cows have a slower rate of decline in milk yield after peak lactation.

The latter are more persistant cows and tend to have flatter curves than traditional 305 day lactation curves. Figure 2 also shows two different lactation curves, one illustrating not an ideal lactation curve (worst cow) and the other illustrating best lactation curve (best cow) in terms of high persistence while maintain peak production over a longer period of time. The best cow has a more persistant lactation (0.92) curve where peak production is maintained for a longer period of time (c=0.001847, smaller than the average (Table 1). Whereas with the worst cow the rate of decline (c) is high (0.004361) out of all the other curves and persistency is higher than average (Table 1) but lower (0.552331) when compared to the best cow (Figure 1).

It is also evident that some cows that have extended lactation may not necessarily be highly persistent and vice versa this is illustrated by the two red curves in Figure 1 one is highly persistent and with high yield while the other has a rapid decline from peak production (low persistency) and has a lower yield. This demonstrates that persistency and extended lactation always equivalent.

Table 1 below shows summary statistics of wood model parameters and derived persistency and extended lactation traits from a subset of 6000 pure Holstein cows as an average representation of the full dataset (population).

Milk production during extended lactation phase (from day 305 to day 610 of lactation) is on average 40% of the production of day 305 (standard lactation) with an average milk yield over the extended lactation of 8,968 L. Cows have on average, almost 50% ability to maintain peak yield from peak to day 305 of lactation (persistent).

CONCLUSION

Overall there is considerable variation between cows in the Australian dairy herds in persistency of their lactation and extended lactation. There are certain cows that have higher persistency than others and who are able to maintain production over a longer period of time (extended lactation). The derived parameters adequately describe such differences between cows and could be used as input variables in genetic analyses. Genetic parameters such as heritability, genetic, phenotypic, environmental correlations and more importantly breeding value estimates for extended lactation can now be derived for extended lactation and lactation persistency. Thus the findings of such research will provide dairy farmers with a breeding tool to select cows that are best suited to milk for longer than the traditional 305 days.

Table 1: Summary Statistics for wood model parameters (k(log a),b,c) of milk yield for subset of 6000 pure Holstein cows and derived traits persistency(r305) extended lactation (XLAC) and cumulative yield up to day 610

Trait	*Mean*	*SD*	*Min* *Max*	*CV (%)*
k(log a)	18.62	1.468	4.25 **87.79**	8%
b	0.1377	0.103	-0.277 **0.553**	75%
c	0.0039	0.0016	0.0001 **0.0103**	41%
r305*	0.4747	0.148	0.0884 **1.891**	31%
XLAC^	0.3969	0.147	0.0475 **1.1531**	37%
CUM YT610+	8,968	2,710	2,936 **31,466**	30%

**r305=Persistency, ^XLAC=extended lactation, +CumYT610=cumulative yield (L) total up to day 610, CV= coefficients of variation (%)*

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CAN PRE – FEEDING REDUCE MILKING INTERVALS OF COWS MILKED IN A PASTURE-BASED AUTOMATIC MILKING SYSTEM?

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Cows milked in pasture-based automatic milking system (AMS) tend to have a lower daily milking frequency (MF) in comparison with cows milked in indoor AMS. Milkings with intervals beyond 16 h have previously been reported to have a negative impact on yield and udder health, and therefore it is important to minimise their occurrence. Given that feed is the main incentive to encourage cows to move around the system, a field experiment was design to compare two different supplementary feed placement strategies. Cows would traffic from the paddock to the dairy, and either receive feed prior to, or after being milked (Pre and Post Feeding treatments, respectively). The hypothesis was that Pre Feeding would create a stronger incentive to come back from the paddock to the dairy, due to the reward being more immediate, thereby reducing their milking interval and increasing daily milking frequency and milk yield. Cows in the Pre Feeding group took over an hour and a half less to return to the dairy, but surprisingly spent more time in both the feeding and waiting areas, creating a net increase in milking interval. No significant difference in daily milk yield was observed between cows in the Pre Feeding and Post Feeding groups.

INTRODUCTION

Adoption of AMS has increased significantly in the last 10 years, with currently over 10,000 farms operating with the technology (De Koning, 2011).
Milk harvested per cow at any given milking is directly related to the time since previous milking, commonly described as milking interval (MI). This relationship is not continuously linear; hence the aim is to minimize the frequency of milkings occurring with intervals beyond 16 hours, which are known to have a reduced milk yield (in kg of milk accumulated per hour of MI) (Lyons, unpubl. data). It has been previously reported that in pasture-based systems, around 30% of all milkings have intervals above 16 hours (Lyons, unpubl. data), which is much higher than the 4.2% reported in indoor systems (Hogeveen, *et al*, 2001).
It is well accepted that feed is the main incentive encouraging reliable cow traffic around the system (Prescott, Mottram, & Webster, 1998a, 1998b). It therefore becomes imperative to plan the farm layout and manage the incentives in such a way as to encourage frequent cow traffic around the system.
Previous exploration of cow traffic data from cows milked in the pasture-based AMS research herd of the FutureDairy Project, has shown that the main factor explaining extended MI is the time it takes cows to return to the dairy, where up to 94% of milkings with intervals above 16 hours, had return times over 14 hours (Lyon, unpubl. data). Yet during that period, whenever supplementary feed was on offer it was available after milking on the way out to the paddock. Previous studies have compared different cow traffic management (Bach, *et al*, 2009; Hermans *et al*, 2003; Ketelaar-de Lauwere, *et al*, 1998; Melin, *et al*, 2005) and different concentrate allowances (Bach, *et al*, 2007; Halachmi, *et al*, 2005) on attendance to the milking station and milk production. Yet to date, no data have been published addressing the impact of location of supplementary feed in a pasture-based AMS on MI, as well as on time spent in different animal areas (pasture, feeding area or pre-milking waiting area).

The aim of this study was to compare two different supplementary feed placement strategies, made available to cows at the dairy either prior to or immediately after milking, Pre and Post Feeding Treatments respectively (referred to as PRE and POST from here onwards), on the cow traffic and milk production, of cows milked within a pasture-based AMS. It was hypothesised that cows which were allocated supplementary feed prior to being milked would traffic back to the dairy (from the paddock) after shorter intervals than cows that were offered supplementary feed after milking and that this would result in a lower average MI and a reduced incidence of MI's exceeding 16-hr.

MATERIAL AND METHODS

A pilot trial was conducted between September, 12th and October 10th 2011, at the FutureDairy Automatic Milking Research dairy (Elizabeth Macarthur Agricultural Institute, Camden, Australia). The herd was comprised of 175 cows (30% primiparous and 70% multiparous cows) mixed Holstein and Illawara breed.

Cows were managed under a two way grazing system in which they were granted access to 2 fresh breaks of pasture per 24-hr period, referred to as "*day*" and "*night*" breaks, with a 40:60 ratio of pasture allocations in the day and night paddocks respectively. Cows presenting at the dairy with no milking permission (based on a minimum milking interval of 4 hours since last milking) or leaving the dairy after milking, were automatically drafted to the day paddock between 9am and 9pm. Likewise cows were drafted to the night paddock between 9pm and 9am so that each paddock had a 12 hour 'active access period'. Each active access period was followed by a 10 hour 'voluntary exit' period, during which cows were expected to voluntarily traffic to the next pasture allocation. At the end of each voluntary exit period, i.e. at 7am for day breaks, and at 7pm for night breaks, any cows that had not volunteered out were fetched and encouraged to the dairy.

Total target dry matter intake was 23 kg DM/cow/day with 60% of their daily ration provided as pasture and 40% by supplements (Table 1).

Supplements were offered in a feeding area located at the dairy, and consisted of pelleted concentrates supplied through four automatic feed stations (FSC400, DeLaval, Tumba, Sweden), and a PMR ration on an adjacent feeding area (hay, maize silage and pelleted concentrates).

Table 1: Daily ration for the herd

Type	Allocation	Feed	kg DM/cow/d
Pasture	Day	Pasture	6.00
	Night	Pasture	8.00
Supplements	PMR	Cereal Hay	0.69
		Maize Silage	2.70
		Concentrate	2.67
	Feed Stations	Concentrate	2.67

Cows were randomised into two groups balanced for stage of lactation (days in milk). Treatments were then allocated to each group in a cross over design trial with 2 periods of 14 days. Cows were milked using a 16-bail prototype Automatic Milking Rotary (AMR™, DeLaval, Tumba, Sweden).

STATISTICAL ANALYSIS

Data was analysed using linear mixed modelling, with parameters and estimates calculated using Restricted Maximum Likelihood Procedures (REML) in Genstat 13th Edition (VSN International, UK).

Individual MI times were subdivided into 3 main components: time to return to the dairy (TR = time elapsed from exiting the dairy to re-presentation back at the dairy), feeding time (FT = time elapsed from the entry to feeding area to exit from feeding area, and waiting time (WT = time elapsed from entry to the pre-milking holding yard to milking start). Milk yield (MY = yield of milk at a particular milking, in kgs milk/cow/milking), milking frequency (MF = number of milkings in a 24 hours period) and daily yield (DY = yield of milk on given day, in kgs milk/cow/day) were also explored.

The models included the main effects of treatment sequence, period , treatment (PRE and POST), stage of lactation (Early ≤ 100 days in milk (DIM); Mid >100 to ≤ 200 DIM and Late > 200 DIM), parity (primiparous or multiparous) and milk yield category (based on pre-trial 7-day average milk yield, cows were allocated into one of three equally sized categories,: Low, Mid or High), as well as the interactions treatment x stage of lactation, parity and milk yield. The random term included sequence nested within animal, to account for repeated measures on the same animal. Significance was determined at $p < 0.05$.

RESULTS

Mean (±SEM) MI (hh:mm) for cows fed PRE milking was 10% higher than for cows fed POST milking (14:58 ± 0:11 and 13:38 ± 0:10 respectively). Furthermore, pre-fed cows had an extra 9% of milkings with intervals exceeding 16-h (46.8% vs. 37.7% for PRE and POST-fed cows, respectively) (Figure 1).

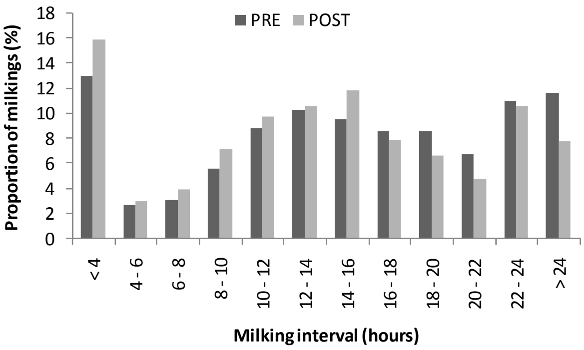

Figure 1: Histogram of milking interval (MI) distribution of cows in a pasture-based AMS fed PRE or POST milking

Treatment had no significant interaction with any main term on TR, FT, MI, MY, MF and DY. Treatment was significant in explaining differences in TR, FT, MI, MY and MF (Table 3). Only the interaction between treatment and milk yield was significant for WT (Table 3). Cows in the PRE feeding group took an hour and a half less to return to the dairy, yet they spent more than double the time at the feeding area. An increase of milk yield was associated with a numerical decrease in WT in both treatments. Low yield cows which were PRE fed waited significantly more time to be milked, in comparison with cows with higher yield in either treatment. Mid and high producing cows seemed unaffected by a change in feed placement. Overall, cows in the PRE feeding group had a milking interval of one hour longer than the Post Feeding treatment group which impacted in a significant 5% higher milk yield per milking. Pre feeding cows also had a 5% lower MF, yet no significant difference was observed in DY (Table 4).

Table 2: Predicted means of a REML for time to return from the paddock (TR), feeding time (FT), waiting time, milking interval (MI), milking yield (MY), milking frequency (MF) and daily yield (DY)

Outcome		**PRE**	**POST**	**P - value**
TR (hh:mm)		11:51[a]	13:17[b]	<0.001
FT (hh:mm)		0:55[a]	0:23[b]	<0.001
WT (hh:mm)	Low Milk Yield	2:38[a]	1:55[b]	0.005
	Mid Milk Yield	2:05[ab]	1:55[b]	
	High Milk Yield	1:56[b]	1:34[b]	
MI (hh:mm)		15:18[a]	14:15[b]	<0.001
MY (kgs/cow/milking)		12.6[a]	11.95[b]	<0.001
MF (milkings/cow/day)		1.4[a]	1.5[b]	0.004
DY (kgs/cow/day)		19.33[a]	19.58[a]	0.457

Note: Different upper case letters within an effect for a particular outcome are significant at p<0.005

DISCUSSION

Pre-feeding cows had a significant effect in reducing the time it took cows to return from the paddock. They had a 1.5 hour shorter TR. The provision of supplementary feed upon arrival at the dairy appears to be a strong incentive for cows to volunteer out from the paddock. Previous research conducted by Prescott, et.al. (1998) suggested that the ‘cost’ (effort) involved in getting a certain reward could affect the willingness to search for it, which could be the case of the POST fed cows. Reducing TR could have a positive impact on the proportion of voluntary milkings, therefore not requiring to be fetched before the subsequent allocation opened.

Long TR were probably due to the fact that in pasture-based systems, feeding and resting behaviours take place in the same area. The condition on pasture is in some ways similar to free cow traffic layouts in indoor AMS, whereby cows typically tend to show a lower MF than in controlled traffic situations (Bach *et al*., 2009; Ketelaar-de Lauwere *et al*., 1998).

However, the apparent initial advantage of a reduction in TR of PRE fed, was offset by changes in behaviour at the dairy. Compared to POST fed cows, PRE feeding cows spent more than double the amount of time in the supplementary feeding area. The reason, by which POST fed cows spend less time in the feeding area, is likely to be related to time on concrete. Cows prefer a soft non abrasive surface on their hooves and by the time POST fed cows arrived at the feeding area they had spent an average 1.5-2.0 hours on concrete. This may have impacted their willingness to stay in the feeding area for an extended period.

It appears that cows that walk from the pasture allocation up to the dairy and received an immediate feed reward spend more time in that area. Behaviour in the holding yard, was explained by an interaction of milk yield category with treatment. Low producing cows which were PRE fed, seemed to be the slowest to move across the holding yard (highest WT), spending more than 2.5 hours (average) in the holding yard. Low levels of production are usually related to lower feed requirements, therefore resulting in a weaker appetite/motivation for feed and less willingness to voluntarily walk on the platform and get milked. PRE fed cows may have a further reduced motivation to move onto the milking platform, because milking itself is not a strong reward for them (Prescott *et al*., 1998b) and the access to PRE feed may have been sufficient to abate their appetite. On the other hand the POST fed cows, which have walked up to the dairy in search for fresh feed, were more motivated to be milked and receive some supplementary feed after milking. Research conducted in an indoor system to quantify usage relationship between facilities, indicated a strong association between milking procedure and feeding in a concentrate station in the exit lane (Halachmi, Metz, Maltz, Dijkhuizen, & Speelman, 2000), suggesting that feeding after milking was an effective way of managing cows. Yet the comparison was not made with the reverse order, of feeding before milking. Comparable results were found in a past trial that compared the presence or absence of a small feed allocation on the platform. When the feed was not offered, cows took twice as long to traffic across the holding yard (Scott, unpubl. data).

The difference of behaviour at the dairy translates to a benefit from the MI point of view, for cows that receive feed after milking. The PRE fed cows had a one hour longer MI, which related to a significant 5% increase in MY at each session (12.6 ± 0.20 and 11.95 ± 0.20 kgs milk/cow/milking for PRE and POST treatments respectively). The significant difference in MF (1.4 vs. 1.5 milkings/cow/day for PRE and POST groups), did not translate to a difference in DY with both groups producing an average of 19.46 ± 0.36 kgs/cow/day.

Given the lack of difference on daily milk production, it is possible that best results could be obtained from a combination or mixed system, by which some feed is offered PRE and other POST. Further investigations into the dataset will allow us to determine the overall impact on MI for different groups of cows which could help to determine whether one strategy better suits different groups within the herd.

CONCLUSION

Pre feeding cows can reduce the time to return to the dairy of cows milked in a pasture based AMS, although it also increases the time spent in feeding and waiting area, resulting in an overall higher milking interval. No difference was observed in daily milk yield. Design of dairy and feeding layout for AMS installations, should consider the allowance for flexible management for different levels of supplementary feeding. Future research and analysis should focus on trying to reduce the time cows spend in feeding and waiting area, to be able to achieve the potential benefits of a higher milking frequency.

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INVESTIGATING THE EFFECT OF A FORAGE CROP ON VOLUNTARY COW TRAFFIC IN A PASTURE-BASED SYSTEM

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Feed is known to be one of the greatest motivators for voluntary cow traffic in Automatic Milking Systems (AMS). It has also been shown that cows have preferences for certain crops over others, with soybean being a preferred forage crop. The use of forage crops may be a useful strategy for encouraging cows to exit a stale pasture break in anticipation of accessing the 'preferred' crop. This study investigated the effect of soybean, compared with a mixed species grass paddock, on voluntary cow traffic in a pasture based Robotic Rotary (RR) system. Preliminary results indicated that soybean did not significantly affect cow movement, with P>0.05 for milking interval, waiting time in the pre-milking waiting yard, and return time. Results suggested that cows milked at night had shorter milking intervals than those milked during the day, however further investigations are required to fully understand the causes of this increased movement.

INTRODUCTION

Automatic milking systems (AMS) were introduced in The Netherlands in 1992 in an attempt to address challenges associated with increased labour costs. It is now estimated that over 11,000 farms across 25 countries operate with AMS (Koning 2011). In Australia, the first AMS installation was in 2001 in Victoria. Since then, the number of operational AMS farms has grown to 16, with a further 5 currently installing units (Kerrisk, *pers comm*). It is expected that adoption rates of AMS in Australia will continue to rise.

It is widely accepted that the average herd size in pasture-based regions is larger than that of the indoor-housed systems common in Europe – where AMS was originally developed. In Australia, average herd size is approximately 230 head (www.dairyaustralia.com.au), while in New Zealand it is 376 head (www.lic.co.nz). The combination of large herd size with pasture-based farming means that walking distances between the dairy and paddock increase with an increasing milking platform area (the area required to sustainably graze and support the milking herd).

For batch milked herds, walking distance would most likely have very little impact on milking frequency due to the farmer fetching and milking the herd at defined intervals. However research by Lyons (unpublished) has indicated that when operating a voluntary cow traffic system, distances exceeding 800 metres can reduce voluntary traffic, and subsequently milking frequency.

Continued improvements in efficiency, and therefore throughput capacity of AMS (ie. the number of milkings an individual AMS unit can complete), along with the development of an Automatic Milking Rotary - AMR™ (DeLaval, Tumba, Sweden), have lead to opportunities for AMS to be more readily adopted by farms with large herds. Therefore it is necessary to understand the challenges presented by large herd sizes, coupled with walking distance, in a voluntary pasture-based AMS.

A study was designed and conducted in February 2012 to investigate the potential for using forage crops in a pasture-based AMS, with the potential to combine CFS (Complementary Forage Systems) with AMS. It is known that feed is a strong motivator for cow traffic in AMS (Jago *et al*, 2007; Scott (unpublished)). It is also known that cows show clear preferences when offered a selection of grazing forages (Horadagoda *et al*, 2009), with more recent work by Horadagoda (unpublished) demonstrating cow preference for soybean over Cowpea and Lablab. Forage crops have the potential to increase cow traffic through providing a feed motivator in the paddock, but could also assist in reducing walking distances with paddocks producing greater dry matter yields/ha.

Through increasing cow traffic and milking frequency, it is possible to gain a higher milk yield (Nixon *et al*, 2009), potentially leading to increased efficiency and productivity of the system. Therefore it is important to understand how to increase cow traffic in order to maximise the benefits from this system. The current study aimed to understand whether a forage crop (soybean) could impact cow traffic in a RR. It was hypothesised that the use of a preferred forage crop would increase cow traffic through the dairy and to the paddock from stale breaks. Preliminary results from this investigation are presented in this paper.

MATERIALS AND METHODS

Research was conducted at the AMS research farm on the Elizabeth Macarthur Agricultural Institute (EMAI) site, Camden, NSW, Australia. Ethics approval was granted through the EMAI Animal Ethics Committee (NSW Department of Primary Industries) prior to the commencement of this project.

A total of 191 mixed parity and mixed breed (Holstein x Illawarra, Holstein Friesian and Illawarra) dairy cows were used in the trial herd. The herd had been milked on the prototype RR for over 12 months with full voluntary and distributed cow traffic. All animals were capable of completing successful gate passages and unassisted milkings prior to the commencement of this study.

Animals were managed as a single herd, and automatically drafted by electronic drafting gates based on treatment group. Each animal was randomly allocated to one of two treatment groups (A or B), with groups balanced for Days in Milk (DIM), daily yield and age (parity) (Table 1).

Table 1. Summary of the average DIM, Daily yield and Parity (age) between treatment groups.

		DIM	Daily yield	Parity
Group A	Mean	171.04	20.57	2.57
	SE	2.04	0.03	0.03
Group B	Mean	171.01	20.56	2.66
	SE	2.04	0.13	0.03

The study was run with a cross-over design, where Group A began the study with a mixed grass (predominantly Ryegrass, kikuyu and summer grass) treatment paddock and Group B with a Soybean (variety A6785) treatment paddock. After seven days, the groups were swapped and Group A was allocated a Soybean treatment paddock while Group B was allocated a mixed grass paddock. Treatment paddocks were of similar walking distance from the dairy.

Paddock allocations were managed with a novel variation of 2-way grazing (split between a "day" and a "night" paddock allocation). Treatment paddocks were opened daily at 09:00, and active access (ability for cows to enter the paddock) ceased at 15:00. To complete the 'day' allocation, a 'common kikuyu' paddock was allocated for access by cows in both treatment groups and was available from 15:00. This was provided to prevent adverse health effects of over-grazing the soybean crop. Paddock allocations and active access times can be seen in Table 2.

Table 2. Summary of paddock allocations.

Paddock	Active access	Fetched	Max. time in paddock	Allocation
Treat. Soybean	09:00-15:00	17:00	8hr	3kg/cow
Treat. Mixed Pasture	09:00-15:00	17:00	8hr	3kg/cow
Common Kikuyu	15:00-21:00	07:00	16hr	4kg/cow
Night Kikuyu	21:00-09:00	19:00	22hr	4kg/cow*

**The night paddock allocation was supplemented with 4kg/cow maize silage/hay ration on the feedpad*

Prior to 15:00, cows exiting their treatment paddock were sent directly to the dairy and were returned to their treatment paddock after a milking or if milking permission was not granted. After 15:00, cows leaving their treatment paddock were sent to the common kikuyu paddock without a forced visit to the dairy. Therefore a complete day allocation was made up from 50% treatment and 50% kikuyu (total of 7kg/cow, 12hr active access). The night allocation was shared by both treatment groups.

Cows were allocated an average of 21kg DM/cow/day. As can be seen in Table 2, 11Kg of this total daily allocation was fed in the paddock. A further 4kg/cow (80% maize silage and 20% lucerne hay) was allocated at the feedpad to supplement the night paddock allocation. Pelleted concentrates (6kg/cow, at 18% protein) were fed through feeding stations in the post-milking area and daily concentrate consumption levels were recorded electronically. The feedpad ration was available from 21:00-09:00 daily whilst the pelleted concentrate was available across the 24hr day. Water was available *ad lib* within the dairy and laneways.

The 16-bail prototype RR operated 24 hours a day although voluntary cow access was denied during batch milking of abnormal milk cows and subsequent machine washing twice-a-day. Washing took place at approximately 07:00 and 18:00, totalling 2.5hr per day. Day and night voluntary milking sessions commenced at approximately 08:30 and 19:00 respectfully.

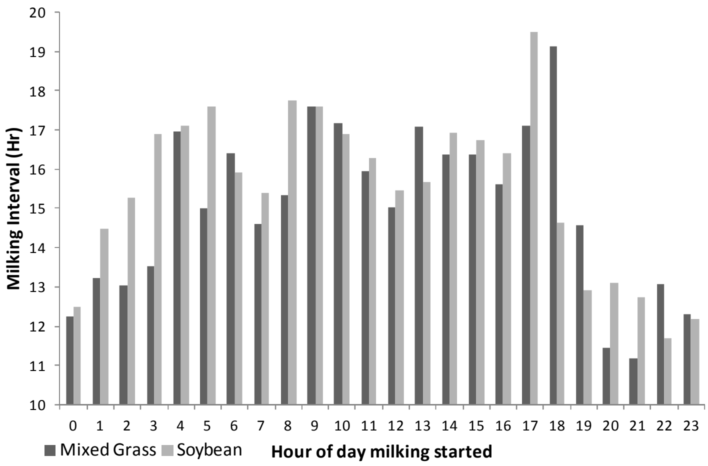

Figure 1. Mean milking interval predicted across each hour of the day dependent on treatment.

Throughout the study, 8 of the total 16 milk points (MP's) were activated. This was done in order to reduce the impact of underutilisation (the herd size was approximately half the capacity of the RR). A small, unmeasured quantity of concentrate pellets (approximately 300g/cow.milking) was fed as a reward at each milking as cows accessed the milking platform.

The entire herd was given access to the soybean crop and trained to use one-way gates along the laneways for two days before the first trial period. At the commencement of the first period, cows were split into treatment groups and trained for two days. A habituation period of two days was then given to settle cows into their treatment. During this time, human interference in the dairy (encouraging cows onto the platform, drafting and sorting cows) was minimised. The habituation period was followed by a 3-day experimental period prior to the cross-over of treatments.

Voluntary waiting time in the pre-milking holding yard was recorded as the time from entering the holding yard until presenting on the RR platform for milking. Activities in the dairy were recorded in order to allow for waiting time to be defined as proportions of forced vs. voluntary waiting.

Milking interval was recorded as the total time between consecutive milkings provided the cow was sent to the paddock between milkings. Incompletely milked animals (for example, failed attachments or kick-offs) were automatically drafted back through the dairy for a second attempt at milking. Milking permission was granted after a minimum of 4 hours since previous milking or immediately if previous milking was incomplete.

Electronic data was captured on-farm using the support software DelPro (DeLaval, Tumba, Sweden). Data was cleaned and sorted in Microsoft Excel 2007. Descriptive statistics provided a simple summary of data to assist in explaining preliminary results. Data was analysed using GenStat version 13.1 (VSN International Ltd.), modelling effects using Linear Mixed Models (REML).

RESULTS

Preliminary results indicate that treatment did not significantly affect MI, waiting time in the pre-milking waiting yard, or return time to the dairy (the time from leaving the dairy to the paddock until first returning) ($P>0.05$). However there was a significant interaction between treatment and time of day (the time of day that a milking commenced) ($P = 0.012$, df = 23, F stat = 1.80) for milking interval (Figure 1).

Figure 1. Mean milking interval predicted across each hour of the day dependent on treatment.

Results indicated that cow age, DIM and average yield significantly impacted waiting time in the pre-milking holding yard, along with MI and return time. Younger cows averaged shorter waiting times, with a shorter MI, while high producing cows also averaged shorter waiting times and MI (data not presented here).

Period and Group did not significantly affect waiting time, MI or return time ($P>0.05$).

DISCUSSION

Preliminary results presented here indicated that offering soybean as a forage crop, alternative to pasture species common for this time of year, did not significantly affect cow traffic, as seen through similar MI, waiting time in the dairy and return time. However the data presented here included cow traffic across the entire 24hr day, and was not specific to the traffic leading up to a milking with access to treatment paddocks. It is possible that a difference in treatment could be seen when focusing only on milkings in which access to treatment paddocks was granted, and a more complete analysis of the data set will be necessary to ensure a full understanding of the role of forage crops in voluntary pasture-based AMS is generated.

It may be possible that the incentive of soybean as a forage crop was not strong enough to impact waiting times in the dairy. Within the dairy, it is possible to manipulate cow movement through the strategic placement of feed (both in a feedpad and pellet feeders, and on the RR itself) (Scott, unpublished). However, it is unknown as to how the strength and success of a feed incentive interacts with time or energy expenditure (through walking to the feed) after the desired event occurred (in this case, voluntary movement). When training animals, the immediacy of a reward directly following the desired behaviour can be important for repetition of that behaviour. This may also be the case here, and further research into this area could provide a greater understanding of voluntary cow traffic in a pasture-based AMS, through which improved management recommendations could be developed.

As the first study into incorporating a forage crop in a pasture-based voluntary RR, it was unknown as to how far the crop should be planted from the dairy, or how the cows would respond to the crop. While preliminary results did not indicate an effect on traffic, potentially due to a dilution effect of using the entire traffic data and not traffic associated with a milking given access to the treatment paddocks, it could be that weather and plant maturity reduced the “appeal” of the crop during the trial. Weather has been previously reported as altering cow behaviour in a pasture-based AMS (Ketelaar-de Lauwere and Ipema, 2000). High and consistent levels of rain were experienced during the entire trial, and plant maturity increased as the trial progressed.

Interestingly, cow factors (DIM, yield and parity) significantly affected cow traffic throughout the whole farm system. As expected, young animals trafficked the fastest across the system, as did high producing cows. This is consistent with previous research, where heifers learned to use a voluntary system faster than multiparous cows (Jago and Kerrisk, 2011), and in research by Scott (unpublished), where heifers moved through the pre-milking waiting yard the quickest. It is unknown how slow trafficking cows impact on the overall performance of the herd, and research into this in the future could assist in devising strategies to better manage groups within the herds based on these criteria.

It was found that there was an interaction between treatment and the time of day of milking on MI (Figure 1). It can be seen that cows milking themselves at night had a shorter MI than cows milked during the day. This could suggest cows had better traffic during the night. However there appears to be greater variance in MI between treatments when cows were milked at night. It is unclear as to what is causing this difference in traffic throughout the day, and further investigations and a more complete analysis, focusing on traffic surrounding access to treatment paddocks, aim to determine the cause of this trend.

CONCLUSION

Preliminary results have indicated that soybean did not significantly increase cow traffic in a voluntary, pasture-based RR when compared to grass species. Cow traits (DIM, yield and parity) did significantly affect cow traffic, regardless of treatment. Younger cows displayed higher levels of movement, as did high producing cows. Further investigations into behaviour on soybean, as well as tracking the movement of individual animals will be useful in understanding the potential role of forage crops in pasture-based AMS.

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COMMERCIAL REALITY OF INTEGRATING FORAGE CROPS ON A PASTURE BASED DAIRY

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The pasture-based dairy industry in Australia has been looking for ways to increase the quantity of forage produced above that of grazed pasture alone. In recent years a new technology of a complementary forage rotation was reported to be able to grow 40tDM.ha in one year. It involved a triple crop rotation that would be grown a 35% of the farm area. This has been termed a complementary forage system. This concept has been tested at a research farm level but not in a commercial farming situation. The aim of this study is to model the impact of implementing a CFS on 5 case study farms across two different dairying regions. The results showed that all 5 farms could benefit from utilizing a CFS through an increase in total forage yields across the farm and a higher gross margin. The largest benefits of implementing a CFS can be seen by farms that have relatively lower pasture utilization. Further research should be directed at fully understanding the cost of implementing a CFS as all the modeling has been conducted in a steady state presently.

INTRODUCTION

The pasture-based dairy industry in Australia has been looking for ways to increase the quantity of forage produced above that of grazed pasture. An option for farmers to increase the quantity of forage produced on farm is to integrate crops and pastures in sequence. The use of complementary forage crops to provide additional home-grown feed in a pasture based dairy system has been investigated by Garcia *et al.,* (2008). Garcia and Fulkerson (2005) developed a concept of a system of forage crops that could be grown in sequence and potentially increase the production of home-grown forage above the yield of pasture alone. This system was termed a complementary forage rotation and involved growing maize as a bulk silage crop, forage rape for an autumn grazing and a field pea crop for silage.

To investigate this concept further Garcia *et al.* (2008) conducted a paddock scale experiment resulting in a yield of over 40tDM.ha.yr for the 3 years of the experiment. Garcia *et al.* (2007) conducted a modeling exercise of these results and concluded that the optimal area for the CFR in a commercial dairy would be 35% of the land area with the other 65% left as pasture for grazing.

This CFR concept was then further explored by Farina *et al.* (2011) by conducting a farmlet study integrating the CFR with pasture and this was termed a complementary forage system (CFS). It was found that it was possible to achieve 25tDM.ha yield across the whole farm (33.1tDM.ha from CFR, 22.4tDm.ha from pasture) and over 27,000litres.ha of milk. Farina *et al.* (2011) concluded that a triple crop complementary forage system had the potential to allow an increase in production from the same land area without the need for additional bought-in feed.

The economic impact of this CFS on a commercial farm has been investigated by Alford *et al.* (2009) by utilising a whole-farm economic model of a representative farm constructed from various information sources including the physical data from the trial conducted by Farina *et al.* (2011), ABARE, and the NSW DPI. It was concluded from this work that even at the lower realized production levels that Farina *et al.* (2011) reported compared to Garcia *et al.* (2008) the CFS compares profitably with other strategies to increase production such as increasing pasture utilization and concentrate feeding level.

A limitation of this economic analysis is that it used a representative farm rather than a real case study farm. Malcolm (2004) suggests that the use of real case study farms enhance the use of model farms when evaluating new technologies and outlines the limitations of using the representative farm.

Isalm *et al.* (2012) was able to validate the Agricultural Production Systems Simulator (APSIM) as an effective tool to simulate the yield of a CFS in different dairying regions in Australia.

With this background information it was decided that the next logical step would be to investigate the impact of a CFS on a commercial farm. In this study it is hypothesized that the use of a CFS on real commercial case study dairy farms will provide a profitable way to increase milk production from the land resource already available to the farmer independent of their current production levels.

MATERIALS AND METHODS

A modeling approach was adopted to investigate the effect of adopting a CFS on commercial pasture based dairy farms.

The case study farms used in this study are located in two different dairying regions, Northern Victoria irrigation area and the Hunter Valley, NSW. A total of 3 farms were in the Hunter Valley and 2 farms in Northern Victoria.

The farms were monitored on a fortnightly basis with production data collected along with feed samples and ration composition. This information provided the robustness needed to ensure that any modeling conducted is a fair representation of the individual farm.

The complementary forage rotation adopted in this study was drawn from the previous work of Garcia, *et al.* (2008) and Islam *et al.* (2012). The cost of the various forages was taken from the economic study of the CFS by Alford, *et al.* (2009). The CFR yields and cost are outlined in Table 1.

The logic of the modeling was to develop a base year for each of the farms which relied on the actual farm data collected. The CFR area was set at 35% of the land area available to each of the farms as recommended by Garcia, *et al.* (2008). The logic of decision making in the modeling process was that the extra yield harvested from the CFR area would first be used to replace any bought-in fodder. Once all the bought in fodder had been replaced then an increase in cow numbers proportional to the extra metabolisable energy produced on the CFR area was allowed. Metabolisable energy was chosen as the method to compare the yields from the different scenarios as it takes into account the quality of different forage systems.

The fitness of the model to the actual farm data was determined by using the Root of the Mean Square Prediction Error (RMSPE) method on four production elements of total farm milk solids, total farm fat, total farm protein, and total farm litres. Once the RMSPE was below 20% it was determined that the model was calibrated.

Table 1. Yield and Cost data used in each region

Region	**Northern Victoria**		**Hunter Valley**	
	Yield (tDM. ha(	Cost ($.ha)	Yield (tDM. ha)	Cost ($/ha)
Maize	16.2	$3200	23.9	$3200
Forage Rape	10.5	$900	11	$900
Field Peas	2.9	$400	4	$400

Each of the case study farms was modeled using UDDER, a decision support model that predicts the milk production of dairy herds grazing under different management regimes.

To account for the different levels of genetics and production from the individual herds no change was made to the concentrate feeding levels and so all extra milk production would be assumed to be coming from the increased forage yields from the CFR area and the extra cows being run.

Pasture utilization for each farm was determined from the actual farm data inputted into UDDER.

THE CASE STUDY FARMS

A brief description of the case study farms is provided in Table 2. All of the farms are pasture based grazing dairies with different levels of milk production and feeding.

RESULTS

Table 3 provides a summary of the results of the modeling study.

The largest impact of implementing the CFS was on Farm 4 which resulted in over a 60% increase in gross margin and more than double the forage yield from the base year.

All five case study farms were able to increase milk production, forage yield and gross margin when a CFS was modeled over a base year.

Table 2. Brief description of case study farms

	Farm 1	**Farm 2**	**Farm 3**	**Farm 4**	**Farm 5**
Region	***Nth Vic***	***Nth Vic***	***Hunter***	***Hunter***	***Hunter***
Peak Cow No	250	675	140	164	453
Area	110	424	50	78	112
Litres/ha	9809	11226	20046	13821	31692
Solids/ha	874	795	1378	1030	2176
Concentrate/lactation (tDM)	1	2	1.6	2	2.7
Av Milk Price c/L	0.44	0.32	0.49	0.55	0.56

Table 3: Key performance results from UDDER

	FARM 1		FARM 2		FARM 3		FARM 4		FARM 5	
	Base	**CFS**	**Base**	**CFS**	**Base**	**CFS**	**Base**	**CFS**	**Base**	**CFS**
Solids (kgMS.ha)	874	1338	795	1176	1378	1699	1030	1904	2176	2505
Litres (L.ha)	9809	14809	11226	16254	20046	24491	13821	24534	31692	36319
Peak Cow No	250	348	675	830	140	176	164	288	453	521
Total Forage Yield (tDM/ha)	7.6	13.9	5.9	10	14.5	15.2	7	15.2	13.2	19.4
Feed Costs ($)	139,451	273,957	496,605	929,101	132,796	193,445	154,760	329,700	554,518	714,562
Gross Margin ($)	152,869	208,790	591,611	741,697	259,860	286,643	306,056	499,769	1,113,712	1,206,364

DISCUSSION

The main objective of this study was to examine the effect of implementing a CFS on five case study dairy farms across two regions. The results showed that in all situations the farms are able to increase total forage yields, milk production and gross margin.

When all the five farms are compared the largest impact of utilizing a CFS on profitability is a result of increasing total forage yield. These results show that the CFS technology can be applied across a range of farms and production systems with positive results.

Total forage yields increases for the two farms located in Northern Victoria were 82% and 70%. In the Hunter Valley the total forage yield increases were 5%, 112% and 47%. With these small number of farms it is not possible to establish a trend based on regions. It appears from these results that farms with lower total forage harvest at a base year can actually benefit more than those farms who are already harvesting relatively larger amounts of forages.

It is generally accepted that farmers should focus on increasing pasture utilization before embarking on implementing a CFS. The results of this study show that it is possible to use a CFS to increase production on farms that have relatively low pasture utilization rate and so might provide an option for farms that are finding it difficult to increase pasture utilization.

A limitation of this study is that it is examining the case studies in a steady state. This means that the cost of implementing the CFS has not been accounted for. It would be beneficial to examine the cost of implementing this technology on these farms and determine the appropriate payback period.

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