Contribution of farmlet scale research in New Zealand and Australia to improved dairy farming systems

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ABSTRACT

The New Zealand dairy industry has continued to expand with milksolids (MS) increasing from 7.1 billion litres of milk processed in 1990/91 to 16.0 billion litres of milk processed in 2008/09, over the same period the Australian dairy industry has increased from 6.3 billion litres in 1990/91 to 9.4 billion litres. Farmlet and other research has made this increase possible, while development and extension have disseminated this information and managerial skills on-farm have turned research results into reality. The numerous farmlet experiments in New Zealand and Australia over the past 60 years can be classified into three main categories: animal evaluation, feed supply and feed demand, with results usually subjected to economic analysis and, more recently, environmental analysis. The evaluation of dairy breeds and strains has been a success in both countries. Farmlet experimentation expanded the initial question from whether overseas Holstein-Friesians were suited to pasture-based systems, to broader ones of whether the animal evaluation index was adequately predicting the economic performance of cows in seasonal, pasture-based systems and whether the various traits in the index were appropriately weighted to ensure future cows were more profitable. Farmlet research since the 1940s has continued to emphasise the importance of correct comparative stocking rate (CSR; kg liveweight/kg dry matter) as a determinant of profitability. Farmlet evaluation of home-grown and off-farm feed supply has developed and demonstrated decision rules and technologies that allow complex systems to be effectively managed on a daily, seasonal and annual basis and ensured that overall feed costs remain competitive.

Keywords: dairy; farmlets; milksolids**.**

INTRODUCTION

The New Zealand dairy industry has continued to expand with milksolids (MS) increasing from 7.1 billion litres of milk processed in 1990/91 (Livestock Improvement Corporation, 1993) to 16.0 billion litres of milk processed in 2008/09 (NZ Dairy Statistics, 2009), over the same period the Australian dairy industry has increased from 6.3 billion litres in 1990/91 to 9.4 billion litres (DairyAustralia, 2010) but with a peak of 11.3 billion litres in 2001/02. The expansion in New Zealand has resulted from a combination of land use change from sheep, beef and cropping to dairying, and from increased use of purchased feed supplements (MAF Statistics, 2010). In Victoria, concentrate fed increased from near zero in the 1980s to > 1.5 t/cow per year in 2002 (Fulkerson & Doyle, 2001).

Research, development and extension have assisted farmers to manage the substantial risks associated with such a major expansion. It is not possible to disentangle the precise impact of any one contributor in such a complex enterprise. This paper discusses the contribution of dairy farmlet research in Australia and New Zealand and recognises a long- term focus on grazed pasture as the foundation feed for profitable dairy systems in both countries. The first "demonstration farm" in New Zealand was established at Momohaki, Wanganui in 1894. The rationale for using 'farmlet' studies is the need to integrate results from 'component' experiments into an economically feasible farm management system. Candler (1962) considered there were only four ways to achieve such integration: farm budgets, small farm (farmlet) experiments, contract on-farm adoption and Monte Carlo analysis. He considered farmlet experimentation to be the only really satisfactory way of <u>testing</u> different management systems because farm budgets only formulated hypotheses about what might happen; on-farm contracts posed major risks and difficulties if more than trivial changes were incorporated; and Monte Carlo analyses (farm simulation models), despite providing predictions of farmlet behaviour, provide no physical results.

Candler (1962) acknowledged the confusion surrounding the different uses of farmlet experiments, a confusion which still arises, and identified four possible uses: field scale experimental plots, high production experiments, testing of different management <u>practices</u> and testing different farm management systems. Table 1 provides some examples from the New Zealand and Australia dairy literature. Field scale plots are able to examine important pasture-animal interactions but without measuring treatment effects over a full year, they are valuable when long-term carryover

TABLE 1: Different uses of farmlet experiments from the New Zealand and Australian dairy literature (categories based on Candler, (1962)).

Farmlet type	Example	Comment	Authors
Field scale experimental plots	Early spring grazing management	Immediate and carryover effects of pasture allocation decisions	Bryant, A.M. 1984
	AR1/ AR37 Endophyte evaluation	Combination of field and indoor evaluation of a new endophyte strain	Thom, E.R. 2010
High production experiments	1.75 t milksolids/ha	Goal oriented project to test profitability of feed input combinations	Macdonald, K.A. 1999.
	SuperProductivity prototype	Feasibility of using best options to reach 1.75 t MS/ha goal from home-grown feed	Glassey, C. B. 2007
Testing of different management practices	Nitrogen fertiliser inputs	Profitability of different levels of N inputs	Bryant, A.M. 1983; King, K.R. & Stockdale, C.R. 1980
	Phosphorus fertiliser inputs	Evaluation of P inputs to test recommendations	Thomson, N.A. *et al*, 1993; Gourley, C.J.P. 2001
Testing different farm management systems	Holstein-Friesian strain trial	Evaluation of genetic strains in different feed systems	Macdonald, K.A *et al.,* 2008b; Fulkerson, W.J., *et al.,* 2008
	High input systems	Wide range of inputs to examine economic and environmental trade-offs	Jensen, R.N. *et al.,* 2005; Staines, M. vH. *et al.*, 2007; Valentine, S. *et al*., 2009
	ABC; Lincoln University Demonstration Farm	Demonstration farms as part of wider extension programme to increase farm profit	Grainger, C. 2000; van Bysterveldt, A. & Christie, R. 2007

effects are not expected. Goal oriented research such as the 1.75 t MS per ha trial (Macdonald, 1999) is often commissioned when industry progress is perceived to have slowed. Where management practices are being used on-farm there are often questions about their profitability – these can be answered by testing different levels or intensity of an input. The most complex research acknowledges the importance of interactions between major variables and tests different management systems to decide, for example, if feeding systems need to be adjusted for cow genotype (Macdonald *et al*., 2005; Fulkerson *et al*., 2008).

A critical, and often overlooked fact, is that it is the management system and not any single component of that system, e.g. stocking rate or feed input, which is tested. It is, therefore, incorrect to criticise such experiments for confounding several component factors, providing these are sensible inputs to a new management system. In fact the contrary applies, it is a waste of resource to, for example, hold stocking rate constant when significant changes are made in feed or fertiliser inputs, rather stocking rate should be increased commensurate with the likely increase in feed supply. It is, however, important to define and implement a comprehensive set of decision rules. Wherever a test comparison is required there must be at least two farmlets. Farmlet experiments require a set of decision rules and a serious attempt to allocate treatments such that non-experimental variables, e.g. soil type or cow breed do not unduly influence the results. In contrast, demonstration farmlets require only a set of decision rules and one farmlet may suffice, because the sole objective is to demonstrate the physical feasibility or profitability of a new management system, or the decision rules themselves. An excellent recent example is the Lincoln University Demonstration Farm (van Bysterveldt & Christie, 2007). Given these differences it is critical that demonstration farms are not used for comparative purposes.

Setting up and monitoring any farmlet is expensive and interpretation of results has often been equivocal because the fundamental variables of pasture growth rate, DM intake and the nutritive value of that intake are difficult to measure. These difficulties led Fulkerson *et al*. (1986) to test the relationship between predicted energy requirements and measured energy intake at pasture. Their results support the 'back calculation' of energy consumed from knowledge of more accurately measured variables such as liveweight and milk yield, and standard energy allowances.

The numerous farmlet experiments in New Zealand and Australia over the past 60 years can be classified into three main categories: animal evaluation, feed supply and feed demand (Table 2), those at No. 2 Dairy, Ruakura, have been catalogued by Macdonald (2004). Recently, environmental

TABLE 2: Summary of a subset of farmlet scale research in Australia and New Zealand outlining questions addressed and the contribution the research made to industry progress.

Category/Authors	On-farm question	Industry Contribution
Animal evaluation		
Carter, A.H. 1964	What is the value of AI and genetic improvement?	Demonstrated superiority of AB bred cows over non-AB bred leading to widespread industry uptake
Campbell, A.G. 1977	What is the effect of crossbreeding to increase Friesian content?	No advantage to crossbred cows in transition to Friesians leading to continued industry change to Friesians.
Ahlborn, G. & Bryant, A.M. 1992	Which breed is more profitable?	Demonstrated that at optimal stocking rate for both breeds Jerseys had 5% higher profit than Holstein-Friesians. Insufficient advantage to initiate change back to Jerseys.
Fulkerson, W.J. *et al*., 2008; Macdonald, K.A. *et al*., 2008b	Are overseas genetics suited to a pasture–based dairy system?	Demonstrated that Holstein-Friesian cows with high overseas genetic content were less suited to pasture-based systems that Australian or New Zealand Holstein-Friesians. Led to breeding indices weighted more for survivability traits but Australian systems especially changed to accommodate overseas genetics (high supplements, non-seasonal calving).
Feed – home-grown		
Campbell, A.G. *et al*., 1978	Can home-grown crops increase farm profit?	Demonstrated potential of maize to increase MS/ha from home-grown feed but with reduced profit. Led to agronomic improvements and overseas cultivar selection that 20 years later made maize silage a major dairy supplement.
Bryant, A.M. 1984	What is the best way to allocate scarce winter pasture?	Demonstrated that if pasture cover was low at start of calving pasture rationing would increase MS yield in late spring. Led to standard procedures for post-calving grazing management.
Thomson, N.A. *et al*., 1988; Thom, E.R. & Prestidge, R. 1988	Are there profitable alternative grasses to ryegrass?	Demonstrated that tall fescue and Phalaris grasses could grow more pasture in dry summers but did not lead to better overall MS yield. Demonstrated that Matua Prairie grass was not a viable option for dairy pastures. Perennial ryegrass remained the standard NZ dairy pasture.
Crush, J.R. *et al*., 2006	Are new ryegrass and clover cultivars better than older cultivars?	Demonstrated that although modern ryegrass cultivars are more persistent than older ones they do not increase MS yield. Led to continued questioning of the breeding objectives of perennial ryegrass.
Bluett, S.J. *et al*., 2005	Does the novel endophyte AR1 increase milk production?	Demonstrated that ryegrass with AR1 endophyte produced more MS than standard endophyte. Led to acceptance of novel endophyte technology, somewhat tainted by the failure of AR1 ryegrass where black beetle exists.
Feed – off-farm		
Bryant, A.M. 1983	Is N fertiliser profitable?	Demonstrated that N fertiliser use was unprofitable at existing costs and milk payouts. Led to continued use of ryegrass- white clover pastures.
Thomson, N.A. *et al*., 1993; Gourley, C.J.P. 2001	Are there production benefits to increasing Olsen P levels above recommended levels?	Demonstrated the advantages in MS yield of achieving recommended rates of Olsen P. Led to general acceptance of importance of P fertiliser for pasture development and maintenance. In Australia led to recommendations to avoid eutrophication by avoiding excess P.

Table 2 cont.

Category/Authors	On-farm question	Industry Contribution
Thomson, N.A. *et al*., 1998	What is the effect of supplementing maize silage at different times of the year?	Demonstrated that supplements were best used to increase DIM. Led to increased use of maize silage and later PKE to increase MS/ha.
Macdonald, K.A. 1999	Is it profitable to increase production by using N fertiliser and supplements?	Demonstrated that high stocking rates together with N fertiliser and low cost supplements could increase profitability above pasture alone. Led to increased dairy intensification and land use change into dairying associated with years of higher dairy payout.
Feed demand		
McMeekan, C.P. & Walshe, M.J. 1963	What is the effect of pasture allocation methods on milk production?	Demonstrated the stocking rate drives pasture utilisation to a much greater extent than pasture management. Led to NZ dairying accepting lower MS/cow in order to maximise profit and the development of a low cost dairy system based on pasture.
King, K.R. & Stockdale, C.R. 1980; Macdonald, K. A. *et al*., 2008a	How does stocking rate affect milk production?	Demonstrated that very high stocking rates are needed to maximise MS yield on irrigated, N fertilised pastures. Demonstrated the ability to farm profitably at a range of stocking rates provided standard decision rules are used. Led to continued increase in industry stocking rates.
Thomson, N.A. *et al*., 1984	What effect does timing of conservation have on milk production?	Demonstrated that early conservation leads to more profit than later conservation. Led to earlier, smaller crops of silage rather than later, higher yielding hay crops.
Auldist, M.J. *et al*., 1997; Garcia, S.C. & Holmes, C.W. 1999	What is the effect of calving at different times on milk production?	Demonstrated the potential of autumn calving to 'flatten' the milk production curve in a pasture-based system. Led to management improvements for autumn calving systems.
Environment		
Jensen, R.N. *et al*., 2005; Staines, M. vH. *et al*. 2007; Valentine, S. *et al*., 2009	What are the economic and environmental consequences of dairy intensification?	Demonstrated that high stocking rates together with N fertiliser and low cost supplements could increase profitability above pasture alone, but lead to increased financial and environmental risks. Led to increased debate around the environmental footprint of intensive dairying.
Demonstration		
Grainger, C. 2000. van Bysterveldt, A. & Christie, R. 2007	How can farmers increase profitability by changing management practices?	Demonstrated 'best practice' pasture management and feed budgeting principles associated with planned multi-media extension exercise. Led to immediate changes on-farm especially related to optimal stocking rates and profitable off-farm feed use.
Glassey, C. B. 2007	Can N leaching be decreased by current management/technologies?	Demonstrated that current technologies were not capable of reaching strategy goals of MS production and N leaching. Led to continued search for better technologies and management systems to control N leaching.

monitoring has been added to some experiments. Farmlet research has also played a part in the evaluation of once daily miking and automatic milking systems. Table 2 provides examples from each category together with the on-farm question addressed and the contribution that the research made to the industry.

Figure 1 shows the change in MS yield per ha (corrected for N fertiliser and supplement input) from research farmlets from 1950-2004 in the Waikato. Major increases occurred at Ruakura from 1950 -1980 with a plateau after that time, subsequent increases up to 3000 kg MS/ha (in actual MS/ha from farmlets and commercial farms) can largely be attributed to increased use of brought-in feed or fertiliser N. The 'feed barrier' identified by Hodgson (1989) for non-irrigated New Zealand pastures at 15-18 t DM/ha/yr still exists in 2010. New Zealand and Australia commercial dairy statistics show a steady increase of 2.5 and 4 kg

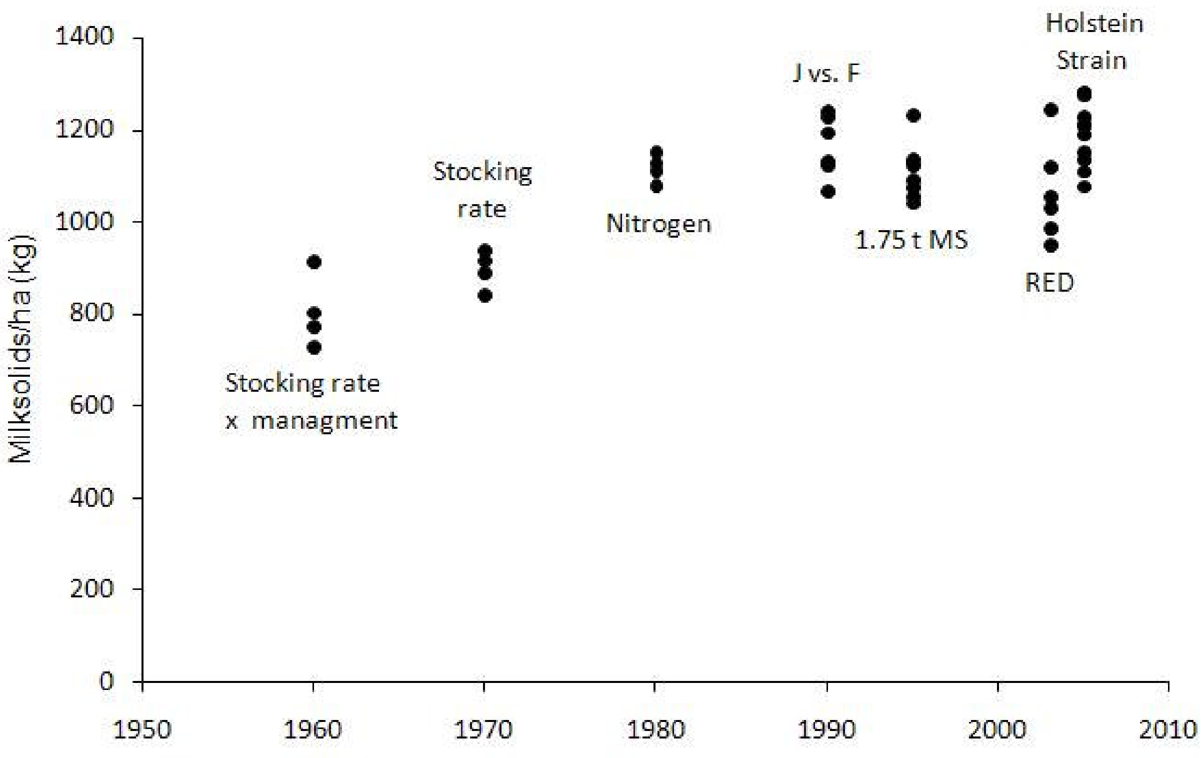

FIGURE 1: Corrected milksolids yield from research farmlets at No. 2 dairy unit, Ruakura and Scott Farm, Newstead from 1950 - 2004. (Stocking rate x management, (McMeekan & Walshe, 1963); Stocking rate, (Bryant & Parker, 1971); Nitrogen, (Bryant, 1983); Jersey vs. Friesians, (Ahlborn & Bryant, 1992); 1.75 t milksolids per ha (Macdonald, 1999); Resource efficient dairying (RED), (Jensen et al., 2005); Holstein-Friesian strain, (Macdonald et al., 2008b). All treatments receiving either N fertiliser and/or off-farm supplements had milksolids yield per ha corrected for these inputs by assuming a standard 10 kg DM/kg N response to N fertiliser and a 67 g MS/kg DM response to extra feed either grown or supplemented.

MS/cow per year respectively and 15 kg MS/ha/year for New Zealand from 1950 - 2005 (Holmes, 2007). Farmlet and other research has made this increase *possible*, while extension has disseminated this information and managerial skills on-farm have turned these research results into *reality.*

FARMLET CATEGORIES AND THEIR CONTRIBUTION

Animal evaluation

In 1955, Jersey cows comprised 75% of the New Zealand dairy herd. From 1961-1965 at Ruakura, a farmlet experiment extended the earlier stocking rate and grazing management research by including a comparison between young AB Jersey cows from the high genetic merit research herd with young cows from commercial farms, with half these cows sourced from tested herds not using AB. The AB bred Ruakura cows produced, on average, 27 kg more milk fat than the cows from commercial farms, this advantage was consistent for all four stocking rate x grazing management combinations over four years (Carter, 1964).

From the late 1960s the national herd moved from predominantly Jersey to Holstein- Friesian in response to low milk prices and high beef prices for Holstein-Friesian dairy beef bulls for the US market. Research at Ruakura from 1972-1976, comparing Jersey with Friesian-Jersey crossbred cows of similar genetic merit showed no advantage to crossbreeding during the transition phase (Campbell, 1977).

Interest in breed comparisons continued into the 1990s with a comparison of Jerseys with Holstein-Friesians at different stocking rates (Ahlborn & Bryant, 1992). Optimum stocking rates were 3.0 and 3.7 cows per ha for Holstein-Friesians and Jerseys respectively, with net income at optimum stocking rates being 5% higher for the Jerseys. Despite this result the ‘Holsteinization’ of the New Zealand dairy industry continued (Harris & Kolver, 2001), and in 2001 was 50% HF, 25% HF-Jersey crossbred, 20% Jersey and 5% other breeds. In their review of studies of North American Holstein and New Zealand HF cows under intensive pastoral dairy farming in New Zealand, Harris & Kolver (2001) concluded that the economic performance of the former was lower due, in part, to their lower fertility and survival. They suggested that rather than exclude North American Holsteins from selection programmes, the national evaluation system should take account of fertility traits. The recognition from many sources that North American Holstein genetics were having a profound effect on farm system performance, led to farm system experiments in both Australia (Fulkerson *et al.,* 2008) and New Zealand (Macdonald *et al.,* 2008b).

In Australia, a farmlet experiment at Wollongbar, New South Wales from 1994-1999 compared High genetic merit (HGM) and Low genetic merit (LGM) cows at three levels of concentrate on kikuyu-based pastures (Fulkerson *et al.,* 2008). Their results showed a genotype x environment (level of feeding) interaction on both reproduction and milk yield. HGM cows ate 11% more DM than LGM cows and had a greater response to concentrate feeding, 1.56 and 1.29 kg of milk/kg of DM concentrate fed respectively. There was little evidence that the HGM cows had higher feed conversion efficiency, either for milk or MS, than the LGM cows, although given the difficulty of estimating grazed pasture intake, doubt must remain for this variable. They concluded that if selection for milk production continued, farmers in Australia would have to either feed higher levels of concentrate or abandon seasonal calving or both with the attendant increase in cost of milk production. In 2010, it appears that the Australian industry has continued to select for milk production and accept the required system changes.

In New Zealand, a farmlet experiment at Ruakura from 1999 to 2004 compared three strains of HF using an unbalanced design of eleven feeding allowances (Macdonald *et al*., 2008b). The strains were: a 1970s strain of NZ Friesian representative of the breeding policies of the period (NZ70); a 1990s strain of NZ origin (NZ90); and a 1990s strain representative of North American breeding policies (NA90). The proportion of North American genetics was <7, <24 and >91%, respectively. Annual total feed allowances (pasture and supplement) ranged from 4.5 to 6.0, 5.0 to 6.5 and 5.5 to 7.0 t DM/cow for NZ70, NZ90 and NA90 respectively. Their results showed that genetic selection within New Zealand during the last 20 years had resulted in NZ90 cows being capable of producing 16 and 23% more milk and MS respectively than NZ70s cows under pasture-based systems. In contrast, NA90 cows could only realise their production estimated breeding value at feeding levels uncommon in New Zealand dairy farming. The wide range of genetic material used in the experiment identified that decision rules developed over decades for pasture-based systems with New Zealand HF were no longer completely adequate for all systems studied.

The Australian and New Zealand experiments, and an associated experiment in Ireland (Horan *et al*., 2005), complemented herd test surveys and short term experiments. The net effect was recognition by dairy genetic companies that even traits with very low heritability (e.g. fertility) need to be included in breeding indices, if cows are to contribute profitably in sustainable dairy systems. Unusually for farmlet experiments, both the Australian and New Zealand results were accepted for publication in Journal of Dairy Science, perhaps because the results and discussion concentrated on per cow performance rather than system performance. Both experiments deserve close scrutiny for their system implications. A comparison of NZ70 and NZ90 cows at a common stocking rate of 3.1 cows/ha and similar feed input of approximately 19 t DM/ha (from Macdonald *et al*., 2008b) shows that the latter produce 10.7% more MS/ha, and the advantage to NA90 compared with NZ70 is only 4.4%. Kolver *et al.* (2004), using data from the earlier years of this experiment, calculated that economic farm surplus per ha was maximised at 5.5, 6.0 and 6.5 t DM/cow per year for NZ70, NZ90 and NA90 respectively. The NZ90s cow is an efficient and profitable cow for those farmers using moderate amounts of supplementary feed in a pasture-based system, but this combination of cow and feed system is moving New Zealand dairying away from its traditional low-cost advantage over other dairying nations. This experiment identified the system advantages that can accrue when a cow with high merit for MS can be fed sufficient feed, unfortunately, as will be shown later, this feed has not been low cost pasture that supports high intake. Farmlet experimentation expanded the initial research question from whether NA HF were suited to pasture-based systems to broader ones of whether the animal evaluation index was adequately predicting the economic performance of cows in seasonal, pasture-based systems and whether the various traits in the index were appropriately weighted to ensure future cows were more profitable (Kolver *et al*., 2004). Results from these farmlets have made a major contribution to the debate around “which cow for which system?”, in fact given the ongoing evolution of both cow and system, a strong argument is made for industry good investment in a long-term, continual experiment that provides a continuous stream of data for all those concerned with an area so critical to future profitability.

Feed supply

Home-grown

Management of the seasonal variation of pasture growth was the subject of a series of farmlet and component experiments in the Waikato, Taranaki and Manawatu in the 1970s and 1980s. The Waikato research, summarised by Bryant (1990), showed that pre- and post-calving pasture management and their interaction with BCS were important determinants of future milk production; however, grazing management during the rest of lactation was less important providing stocking rate and conservation policy allowed pasture control to be maintained. Important feed budget tools such as the pasture wedge and the spring rotation planner (DairyNZ, 2010a) developed from the understanding gained in this work.

The importance of phosphate (P) fertiliser for increasing white clover growth, nitrogen (N) fixation and hence ryegrass DM yield has long been accepted in both Australian and New Zealand dairy systems. In New Zealand, a national series of plot trials under cutting has resulted in recommended levels for major nutrients that will ensure 95% of potential yield (Anon, 2009). In setting these guidelines the fertiliser industry has recognised the potential for environmental problems, if excess nutrients are applied. Thomson *et al*. (1993) in New Zealand and Gourley (2001) in Victoria responded to calls from farmers to evaluate the response to P fertiliser under the more realistic conditions associated with self-contained farmlets. Thomson *et al*. (1993), after a 3-year trial in Taranaki, concluded that at Olsen P levels of 20-30 production increased by 4.2 kg MS/kg P applied and 1.8-2.0 kg MS/kg P applied when Olsen P was above 30, although the results have wide confidence intervals and the research has not been repeated either on the same or different soil types. Gourley (2001) used a 4-year trial with four levels at P at three stocking rates, from their published relationship of cumulative milk yield vs. applied P, a response rate of approximately 1.3 kg MS/kg P applied can be calculated for Olsen P levels around 16 when P application increases from 20-30 kg P/ha. Although there was an increasing trend with time they could find little evidence for increased milk yield/ha as rate increased from 35 to 70 or 140 kg P/ha (corresponding to Olsen P values of 13, 20 and 30 mg/kg respectively). Farmers in both countries have accepted the importance of increasing Olsen P levels to 25-30 as a prerequisite of developing a profitable dairy unit; in New Zealand anecdotal evidence from farmers has led some to continue to apply P fertiliser well past the levels recommended by current guidelines. There is little doubt that the somewhat confused debate could have been assisted by rather more and longer term farmlet scale trials and rather fewer small plot trials. The importance of P as a nutrient and a pollutant would justify further research in this area.

Early attempts in the late 1970s at increasing home-grown feed by either maize silage (Campbell *et al*., 1977) or N fertiliser (Bryant, 1983) were successful but considered to be uneconomic due to the low milk price: feed cost ratio. Limiting factors for maize were low yields and agronomic issues such as weed and insect control. Fifteen years later, yield increases from improved hybrid cultivars and agronomic practice meant that maize silage grown off-farm was the feed chosen in the 1.75 t MS/ha per year trial (Macdonald, 1999). This experiment demonstrated to farmers that the milking platform could be used to generate much larger gross farm income than with a solely pasture-based system (van der Poel, 1996).

In a review of six New Zealand farmlet experiments using N fertiliser, Clark (1997) calculated that the maximum MS response per ha occurred at 450 kg N/ha/year but there was a poor relationship between N applied and economic farm surplus (EFS) per ha. At commercial rates of 80-150 kg N/ha/year, responses varied from -25 to 160 kg MS/ha per year with EFS varying from -$260 to $350/ha per year. Despite this variability and the low average EFS response of $100/ha per year overall, N fertiliser use steadily increased on New Zealand dairy farms. New Zealand N fertiliser use rose from 50,000 t in 1989/90 to 350,000 t in 2007/08 (Fert Research, 2009) with the majority attributed to dairy farming. The reasons for this increased use are not clear-cut but may include: availability and ease of use, decreases in white clover N fixation due to invasion by clover root weevil (*Sitona lepidus*); the move to earlier, concentrated calving patterns increasing late winter feed deficit; increased stocking rates; the increase in the milk price: N cost ratio; and the increased use of responsive annual ryegrasses. The development of cows with a higher intake demand and greater loss of BCS post-calving may also have led to increased use of N and bought-in supplements. It is unlikely that N fertiliser is used tactically in most circumstances because so few farmers use either formal feed assessment or feed budgeting (Mata *et al.,* 2007) rather, farmers seem to now apply N fertiliser in much the same way other fertiliser is applied – as an annual requirement. It would, therefore, seem to be a long-term risk management strategy rather than a short-term response to a seasonal feed deficit.

There have been several attempts to evaluate the use of alternative grass species or new ryegrass cultivars in dairy systems. In Taranaki, Thomson *et al*. (1988) compared a 30 year-old perennial ryegrass farmlet with a tall fescue/phalaris (67:33) one and found that although the latter grew 18% more pasture (2.75 t DM/ha per year) there was no difference in milk fat yield. At Ruakura, a replicated comparison of an established ryegrass-white clover pasture, a renovated ryegrass-white clover (50:50 Ellett: Nui with Pitau white cover) and a 50:50 mix of renovated ryegrass with Matua Prairie grass – Pitau white clover – Pawera red clover was established in 1986. Neither of the renovation options increased either pasture yield or milk fat yield per ha (Thom & Prestidge, 1988). The potential advantage of Prairie grass was not realised because of a severe autumn fungal infection followed by Argentine stem weevil and Hessian fly infestations. A further attempt was made in 1991 to increase home-grown feed by introducing new perennial and annual ryegrasses into existing perennial ryegrass pastures. Treatments were: Control (existing pasture), Perennial (85% of farmlet undersown with Yatsyn and 15% spray/drilled with mixed perennial ryegrass cultivars) and an annual ryegrass, Concord (85% of farmlet undersown with Concord and 15% spray/drilled with Concord). Average pasture growth over two years was 16.3, 16.8 and 14.9 t DM/ha per year respectively with no difference in MS yield per ha (Thom & Bryant, 1996). In summary, these farmlet experiments demonstrated the difficulty of translating recorded plot yield advantages of new ryegrass cultivars or alternative species into higher MS yield. The failure of annual ryegrasses to show an advantage in a farmlet comparison has not stopped their widespread use in the provision of winter and early spring feed; and under sowing is still a feature of pasture renovation despite serious questions around its effectiveness (Thom & Prestidge, 1996).

Since the 1980s the seed industry has introduced novel endophytes in to new ryegrass cultivars in an effort to retain the insect deterrence offered by wild endophyte but without the negative animal health consequences. These attempts produced the AR1 endophyte which was evaluated in a three-year farmlet trial at Newstead (2000-2003). 'Bronsyn' ryegrass infected with wild endophyte was compared with AR1-infected ryegrass both sown with Aran and Sustain white clover. Averaged over three years the AR1 farmlet produced 8.9% more MS per ha with no difference in annual pasture yield but the AR1 pastures had greater white clover content than wild, 9.3 and 5.7% respectively.

Strategic goals for increased MS yield per ha and improved productivity in the late 1990s led to a call for an evaluation of the contribution that new perennial ryegrass and white clover cultivars were able to make to these goals. A substantial NZ experiment was set up at Scott Farm, Newstead to compare 1980s with 1998s bred ryegrass cultivars with 1960s and 1998s bred white clover cultivars: 80R (Ellett, Nui and Yatsyn ryegrass), 98R (Aries HD, Bronsyn and Samson ryegrass) 60C (Huia and Pitau white clover) and 98C (Challenge and Sustain white clover) in a 2 x 2 factorial design: 80R/60C, 98R/60C, 80R/98C, 98R/98C replicated three times (reduced to two in June 2001), and conducted for three years from 1999/00 to 2002/03 (Crush *et al*., 2006). There was no consistent effect of either ryegrass or white clover cultivar type on cow MS yield or EFS. They concluded that progress had been made in cultivar development because 98C clovers and 98R ryegrasses had improved persistence and the former could exploit favourable summer growth conditions. The removal of one replicate was due to the failure of both 1980s and 1998s ryegrass cultivars to thrive on the summer-dry Te Rapa peaty silt loam soil. Their finding that increased yields measured for new cultivars in small plots do not necessarily translate into improvements at the farmlet level, is consistent with other research reviewed here.

Despite these consistent findings by competent researchers the seed industry continues to ignore this research in favour of largely irrelevant results from small plots where important interactions are absent. Further, researchers have largely ignored the important findings by Crush *et al*. (2006) as evidenced by a Google scholar citation search revealing only 2 citations since publication, one a review and the other not focussed on the issue of progress in plant breeding. In contrast, recent farmlet research on animal breeding progress has attracted major interest as evidenced by citations and associated component research. The New Zealand dairy industry has accepted the results from farmlet research and taken these results into consideration when altering national breeding objectives (Pryce *et al*., 2006). This lack of balance across the areas of plant vs. animal breeding must be of serious concern to an industry that is struggling to remain internationally competitive and where imported feed use is increasing and adding to the cost of MS production.

The general reliance on short-term pasture and animal component experiments for evaluation of new endophyte releases has lead to significant confusion in the farming community. For example, AR1 was evaluated for three years in a farmlet system and showed 9% higher MS yield than wild endophyte (Bluett *et al*., 2005), however general use of AR1 cultivars in areas prone to black beetle infestations may lead to very poor pasture persistence (Popay & Baltus, 2001). Recent experimental work has shown AR37 cultivars can resist black beetle attack but their use may lead to lower summer-autumn MS yield (Thom, 2010). This has led to further confusion. Future research on new endophyte releases merits a more planned approach that coordinates component and farmlet experiments with a greater emphasis on MS production. Farmlet experimentation of sufficient rigour will delay the release of cultivars but it is the only realistic way to examine the trade-off between pasture persistence and total MS yield. Results in other areas of research have shown that farmers have accepted results from farmlet results, in the case of plant breeding they have accepted the negative results and do not see pasture renewal as a high priority.

Off-farm

The formation of Dairying Research Corporation in 1990 coincided with an increased recognition that dairy systems based on pasture alone could not support continued increase of MS from the home milking platform. This coincided with increasing availability of maize silage from dairy support blocks in Waikato and Bay of Plenty and by-product feeds and off-farm grazing in other areas. The Dexcel strategy set a goal of 1.75 t MS/ha/yr to be obtained by a combination of N fertiliser, maize silage and maize grain. For the first time in dairy farmlet experimentation at Ruakura a dairy farm computer simulation model UDDER (Larcombe, 1999) was used to calculate optimum stocking rates, timing and amount of feed inputs, N fertiliser application and grazing management. The attainment of the target production was unsurprising, but the experiment provided a wealth of data for use in economic analyses (Macdonald, 1999) that led quickly to farmer adoption by those looking to expand their business without necessarily purchasing expensive land (van der Poel, 1996). A number of important tools and messages arose from the stimulus of this trial. The DairyNZ Farmfact 1-56 "Returns from feeding supplements in autumn" integrates the knowledge from farm systems experiments to allow on-farm use (DairyNZ, 2010b). A further development was that of "Comparative stocking rate" defined as kg liveweight/ t DM, this parameter allowed researchers, advisors and farmers to balance feed demand (kg LW/ha) with feed supply (t DM/ha) in a way that took account of variations in cow size, bought-in supplements, N fertiliser use or off-farm grazing (Penno, 2000). A key finding was that pasture-fed cows kept at the same stocking rate were unable to increase MS production enough, when fed supplements, to provide a profitable return. Only when stocking rate was increased commensurate with level of supplements introduced, could extra profit be made. Farmlet experiments also led to the practice of using supplementary feed in late summer and autumn to extend days in milk (Clark, 1993), rather than in spring when substitution of high quality grass by lower quality supplements could easily lead to poor responses and expensive conservation of pasture surplus.

The 1.75 t MS/ha trial demonstrated that the 'Control' treatment using no N fertiliser at 3.34 cows/ha was only exceeded in profitability by 200 and 400 kg N/ha at the same stocking rate, with no advantage to the higher level at a payout of $3.50/kg MS. At a higher stocking rate of 4.42 cows/ha, N fertiliser was less profitable than 'Control' at 200 and the same as 'Control' at 400 kg N/ha. At 4.42 cows/ha and 200 kg N/ha adding maize grain, maize silage or a 'balanced ration' at approximately 5 t DM/ha/yr led to the same profitability as the 'Control' for maize silage, but $1000/ha less profit for the other two options, due to much higher feed costs in relation to the current payout. Many farmers developed System 3-5 farms (Roche & Reid, 2002) based around the higher profits that accrue from such systems in high payout years if feed costs can be controlled. These systems are less vulnerable to climatic variation but become very vulnerable to milk price volatility and have greater environmental impacts than System 1 options based around well-utilised pastures with minimal supplementation.

Feed demand

Farmlet research at the No. 2 dairy unit, Ruakura began in the 1940's with a classic series of trials examining the interaction of grazing method (rotational or set-stocking) with stocking rate (McMeekan & Walshe, 1963). Stocking rates of 2.35 and 2.95 cows per ha were used, results showed that a high stocking rate was required to fully exploit the advantages of controlled (rotational) grazing. The higher stocking rate was associated with higher milk fat yield per ha but lower per cow than the lower rate. This result occurred at a time when the physiology of pasture growth and the variation of nutritive value with stage of growth were not well understood. McMeekan's results caused considerable academic debate, but farmers gradually adopted the principles of higher stocking and the practice of "day" and "night" paddocks became less common. The results added impetus to electric fence development (e.g. the development of low-impedance electric fencing by Doug Phillips) and 'controlled' grazing paved the way for future developments around pasture allowance and grazing residuals. The book "Grass to Milk: a New Zealand philosophy" (McMeekan, 1960) was widely read and ensured that research data reached farmers, their staff and extension agents in an easily grasped form. The Ruakura field days, initiated in 1949, were an important vehicle for providing farmlet and other research results directly to farmers.

From at least as early as 1964, Ruakura farmlet trials used visual, calibrated assessment, to record pasture DM (kg/ha) on each paddock. Operator visual 'grades' were converted to pasture DM yield by cutting pasture to ground level with a modified shearing handpiece, pasture was then washed and oven-dried. "From the weekly grading of the whole farm, paddocks are ranked from heaviest to lightest, and this determines the subsequent stock grazing rotations and general feed reviews" (Parker, 1973). This quotation contains the essence of what has become pasture assessment by a range of methods (e.g. Rising Plate Meter, Rapid Pasture Meter and Pasture Probe), short term pasture allocation (e.g. "Feed Wedge") and longer term feed budgeting (e.g. "Feed Plan Pro"). Parker questioned "Without pasture assessment how can farmers or their advisers quantitatively ration feed to stock? Such a technique should be recognised as an integral part of improved feed budgeting, for without competent pasture assessment a feed budget can be neither accurate nor a real check on the efficacy of the feeding standards being used."

By 1976, a major gap had opened between milk fat production per ha at No. 2 Dairy, Ruakura and the average Waikato dairy farm. The reasons for this discrepancy were analysed in detail by Campbell *et al*. (1977). They concluded that the difference between 2.1 cows per ha on commercial farms and 3.25 on No. 2 Dairy accounted for 66% of the difference in net farm income, a further 25% was explained by a combination of cow genetic merit and management expertise, with recognition that stocking rate increases are not independent of management expertise. This paper identified research results from the No. 2 dairy unit as a platform from which extension campaigns could be launched to persuade farmers of the benefits of increased stocking rate to make use of feed already available, in conjunction with a range of management techniques and improvements in the genetic quality of their stock. Their paper provides important insights into management protocols at No. 2 dairy unit 34 years ago that became accepted as industry "good practice". Breeding records were recognised as an important tool for making decisions around drying off dates and winter feed budgets. Drying off and culling decisions were seen as crucial to ensuring production in the next lactation was not compromised in the current one. A "condition grading" system was used at research stations in Australia and New Zealand from the 1960s and extended to the industry by advisors and researchers. In relation to all of the above, the records or system *per se* were not novel, but their use in guiding major management decisions in a dairy system of considerable complexity because of weather variability was certainly novel and of critical importance to future on-farm practice in New Zealand. A final feature of the analysis was the calculation that, despite extra labour and other variable costs associated with a higher stocking rate, the No. 2 dairy unit returned a net farm income 230% higher than an average commercial dairy farm.

Environment

Until the 1990s farmlet experimentation was almost completely focussed on production and profitability, despite early indications that intensive grazing of ryegrass-white clover pastures could be increasing nitrate leaching (Ball & Ryden, 1984). The application of 0, 200 and 400 kg N/ha to farmlets in the 1.75 t MS/ha trial provided an ideal opportunity to monitor nitrate leaching (Ledgard *et al*., 1996). The finding that nitrate leaching losses increased dramatically above 200 kg N/ha per year may have influenced farmers to restrict N use rather than continue to apply at levels where MS responses were still likely.

Later, the Resource Efficient Dairy (RED) trial used different inputs of N fertiliser, irrigation and off-farm maize silage to study the trade-offs between profitability and environmental impacts with stocking rates ranging from 2.3 to 7 cows/ha that matched the variation seen in commercial dairying (Jensen *et al*., 2005). These farmlets provided field laboratories in which to measure nitrate leaching (Ledgard *et al*., 2006), nitrous oxide emissions (Luo *et al*., 2008) and data for OVERSEER™, DairyNZ Whole Farm Model, Farmax modelling and life cycle assessment (Bassett-Mens *et al*., 2009) of pastoral dairy farming. The monitoring showed a close correlation between feed inputs and environmental emissions and led to the development of the Prototype "Tight N" farmlet to examine the feasibility of using stand-off areas, nitrification inhibitors and intensive feed budgeting to control timing and amount of N fertiliser input (Glassey, 2007). This farmlet had the goals of producing 1200 kg MS/ha/yr with < 25 kg N leached/ha/yr by using standing off, a nitrification inhibitor, and pasture monitoring and feed budgeting to ensure optimum amounts and timing of N fertiliser use (Glassey, 2007). Despite not achieving these goals in the first phase, the farmlet has acted as a focal point for farmers and rural professionals to debate options available for farmers in nitrate-sensitive lake catchments.

CONCLUSIONS

Farmlet research has made important contributions to dairy farming in Australia and New Zealand by;

1. Testing management practises and systems for profitability and feasibility at a scale that farmers and rural professionals can relate to, and learn from.
2. Applying and demonstrating decision rules and technologies that allow complex systems to be effectively managed on a daily, seasonal and annual basis.
3. Evaluating genetic strains of plants and animals and providing feedback to geneticists to allow a better fit between the genetic composition of the dairy population and the environment provided by our farming systems.

Farmlets will continue to be an important research and demonstration tool. The expense of such research means that the excellent farm simulation models now available should be used as the first option for tackling the objectives outlined in Table 1. Farmers will continue to ask system questions that the best models will be unable to answer; and long-term farmlets will become valuable in ways impossible to predict at the outset. Questions around plant and animal genetics and their management will continue to be important and a long-term, continuous investment in farmlet research on these subjects will be a sound investment.

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