FUTURE FARMING SYSTEMS

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Summary

- There is considerable scope to increase milksolids (MS) production on Canterbury farms from the annual average of 1271 kg MS/ha (2008-09) to the 1700 kg MS/ha produced by the Lincoln University Demonstration Farm (LUDF) and beyond
- But future farming practices may be constrained by land area, irrigation water, and environmental pollutants.
- Computer models were used to explore two scenarios to improve milk production, profitability and environmental impact (as assessed by nitrate leaching) compared with the current LUDF performance
- A More Milk (MM) option using higher BW cows, more N fertiliser and purchased grain at 5 cows/ha gave 27% more milksolids/ha than current LUDF production
- The More Milk option increased operating profit/ha by $460/ha compared with LUDF
- The More Milk option increased N leaching from 23 kg N/ha per year at LUDF currently to 43 kg N/ha per year
- A Greater Efficiency (GE) option used very high BW cows, with less N fertiliser and purchased grain at 3.5 cows/ha to produce 8% less MS/ha than current LUDF production
- The Greater Efficiency option produced the same operating profit/ha as current LUDF
- The Greater Efficiency option reduced N leaching to 18 kg N/ha/year
- If extra land was not available for dairy farming, it would still be possible to expand milk supply in Canterbury and increase profitability by using the More Milk option. This would increase the environmental footprint per ha but could still be feasible if the total footprint from dairy plus other enterprises was within a community agreed level.

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- If extra land was available for dairy expansion but there were serious constraints on environmental footprint, then the Greater Efficiency scenario offers opportunities to maintain profitability with lower N leaching than the current LUDF and much lower than the MM option. Increased milk supply on a regional basis could still occur as extra farm land was developed for dairying.
- The scenarios presented are propositions about how farming systems may develop based on model results, and these propositions will be investigated in a farmlet experiment as part of the Pastoral 21 research programme in Canterbury.

Key issues for Canterbury dairy farming

The Strategy for New Zealand Dairy Farming produced by DairyNZ (2009a) has been developed to guide the investment and activities of the industry from 2009 to 2020. It considers two key questions: firstly, what will increase the profitability, sustainability and competitiveness of New Zealand dairy farmers; and, secondly, how will dairy farmers farm in the future? A unifying theme of the Strategy is that outcomes will only be achieved by a farming systems approach. Key outcomes are: increasing farm profitability by $110/ha/yr; enhancing industry reputation (for producing a quality product through stewardship of land and water resources) locally and globally; and achieving shared goals through genuine partnership between industry, government and the wider community.

Table 1. Key dairy statistics for Canterbury dairy farming 2009-10 (LIC, 2010)

Region	Herds	Cows	Herd size	Stocking rate (cows/ha)	Milksolids (kg/cow)	Milksolids (kg/ha)
N. Canterbury	649	475,245	732	3.35	384	1283
S. Canterbury	242	176,085	728	3.33	372	1241
Canterbury (total)	891	651,330	731	3.34	380	1271
New Zealand	11,691	4,396,675	376	2.81	327	920

Canterbury dairy farmers will have a major role in achieving these outcomes. Some key statistics for Canterbury dairy farming are shown in Table 1. Extrapolating existing dairy cattle numbers by 4% per annum to 2020 implies Canterbury could have 1.5 million dairy cattle (1million milking cows) by then. An increase in cow numbers together with increases in milksolids yield per cow will lead to major increases in feed demand which will be met from on-farm, support land and imported supplementary feed. Sourcing this feed at a cost low enough to ensure a net profit will be a major challenge. Table 1 shows that dairying in Canterbury is already more intensive than New Zealand as a whole with higher stocking rates, higher MS per cow and hence higher MS per ha. These production levels are driven by irrigation, high use of N fertiliser, grazing off during winter, and use of regional and imported supplements.

Most of the shallow groundwater in Canterbury has nitrate-N concentrations > 3 mg/L and 8% of wells exceed the Ministry of Health maximum acceptable value of 11.3 mg /L (Abraham and Hanson, 2010). *E. coli* bacteria are also present in many of the shallow bores in Canterbury. Both these measures of ground water contamination will increase with the expansion and intensification of dairy farming. Given this situation, it will be necessary for farmers to adopt a range of technologies and managements that ensure future inputs are used more efficiently. Canterbury dairy farmers are leading users of the nitrification inhibitor eco-N^{TM}, a product designed to reduce nitrate leaching and nitrous oxide emissions from grazed pasture, but Smith (2011) concluded that inconsistent research messages, limited ability to quantify on-farm benefits and variability in the results from eco-N^{TM} use on farm have restricted uptake.

This paper uses computer simulation models to examine the effect of better resource use efficiency on milksolids production, profitability and environmental sustainability from Canterbury dairy farms. The implications for future farming systems, and the research requirements to support the development of these systems, are discussed.

Testing some future options

The Lincoln University Demonstration Farm (LUDF) was used as a baseline against which to test two future farming scenarios. LUDF represents a well–documented commercial scale farm with excellent production and economic performance (van Bysterveldt and Christie, 2007). One scenario - More Milk (MM) - represents further intensification along the current pathway and assumes cows with increased genetic merit, greater use of nitrogen fertiliser,

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higher stocking rate and the option of using large amounts of supplementary grain feeding. This scenario aims to deliver more milk and profit per farm but will come with a greater environmental footprint, and so could operate only if new technologies can reduce this footprint or lenient regulations exist. Another scenario – Greater Efficiency (GE) - represents an alternative pathway with cows of even higher genetic merit, reduced N fertiliser, lower stocking rate and lower grain input than MM. The Greater Efficiency option aims to equal current LUDF milk production (although it represents an increase of 35% from current Canterbury average MS per ha) and profit, but with a reduced environmental footprint. All three scenarios included two applications of a nitrification inhibitor (10 kg a.i. /ha) in late autumn and early spring to reduce nitrate leaching associated with urine patches and fertiliser application. Some key characteristics of LUDF and the future scenarios are given in Table 2.

Table 2. Key features of Lincoln University Demonstration Farm (LUDF) and two future farm scenarios, More Milk (MM) and Greater Efficiency (GE).

	LUDF	MM	GE
Stocking rate (cows/ha)	4.15	5.0	3.5
Cow's genetic merit (BW, $)	92	150	180
N fertiliser (kg N/ha/year)	200	400	150
Nitrification inhibitor use	Yes	Yes	Yes
Grain (kg/cow)	none	variable	100

The DairyNZ Whole Farm Model (WFM) (Beukes et al., 2008) was used to firstly simulate the actual production from measured inputs for LUDF and secondly to simulate production from the MM and GE scenarios. The WFM is an integrated framework of sub models that simulate pasture growth from climate input (Romera et al., 2009), and cow metabolism and production from feed intake and quality (Hanigan et al., 2009), in a dynamic manner. It operates at the individual cow and paddock level and outputs from these levels are integrated to predict herd and farm performance. Feed demand for BW 150 and 180 cows was predicted to increase by 1.4 and 2.0 % respectively compared with a baseline BW 90 cow. Milk production from BW 150 and 180 cows fed to demand was predicted to increase by 3.7 and 5.5% respectively compared with a baseline BW 90 cow. The OVERSEER® nutrient budget model (Overseer) (Wheeler et al., 2003) was used in conjunction with output from WFM to estimate farm-gate N surplus and nitrate leaching losses under the three scenarios.

Prices for 2008-09 from Economic Farm Survey were used in the simulation (Table 3) with the milk payout assumed to be $6.10/kg MS. For all scenarios, replacements were produced on farm but grazed off together with all dry cows. Variable costs were a driver of differences in operating profit because the three scenarios differed quite markedly in cow numbers. No allowance was made in the scenarios for differences that may arise in labour skills required, extra milking time because of milk yield differences, or differences in animal health or reproductive performance. The calculation of economic parameters followed DairyNZ Economic Survey guidelines (DairyNZ, 2009b).

Table 3. Economic input data (based on 2008-09 DairyBase) used for simulations

Item	Cost
Variable costs ($/cow)	
Wages & unpaid labour	321
Dairy & electricity	66
Animal health & breeding	123
Grazing off per week	12
Fixed costs ($/ha)	
Weed & pest control & regrassing	82
Fuel	156
Repairs & maintenance	300
Freight	47
Nitrification inhibitors	150
Overheads	258
Fertiliser & irrigation	
Urea ($/t)	695
Potassic Super ($/t)	414
Application ($/ha)	10
Irrigation ($/ML)	67
Supplements ($/t DM)	
Pasture silage	290
Maize grain	520
Barley grain	480

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Pros and cons of future options

It is extremely important to note that for all three scenarios no account was taken of the effects of winter grazing off or forage or grain crop production off farm on environmental outcomes. It has become increasingly accepted that a full Life Cycle Assessment (LCA) of any agricultural enterprise must take account of the environmental effects of all factors associated with food production. In their LCA of NZ and European milk production systems, Basset-Mens et al (2005) found that the NZ pasture system had a three fold lower eutrophication potential (nitrate and ammonia emissions) and two fold lower energy use than either Swedish or German conventional systems. The reason for the higher environmental impact from the latter was their much higher use of land for maize silage and forage crop production. The MM scenario modelled here would move Canterbury dairying closer to the European system of milk production with the associated risk of greater environmental impact. Work in Canterbury by DairyNZ, Lincoln University, AgResearch and Plant and Food funded by the Pastoral 21 programme will commence in 2011 to gain a clearer understanding of these issues.

Feed

The WFM was able to simulate the actual total production and the annual pattern for LUDF very well; this lends confidence to the model predictions for the two new scenarios. The LUDF scenario showed a system wholly based on pasture and forage crops either grazed in situ on farm during lactation, fed as conserved silage in early and late lactation, or grazed on support blocks when cows were dry (Figure 1A). The MM scenario had a higher stocking rate and therefore had no surplus to conserve as pasture silage; large quantities of grain were used in early and late lactation to provide extra milk yield and days in milk (Figure 1B). The GE scenario was very similar to LUDF except that extra feed in late lactation comprised a mixture of pasture silage and grain (Figure 1C).

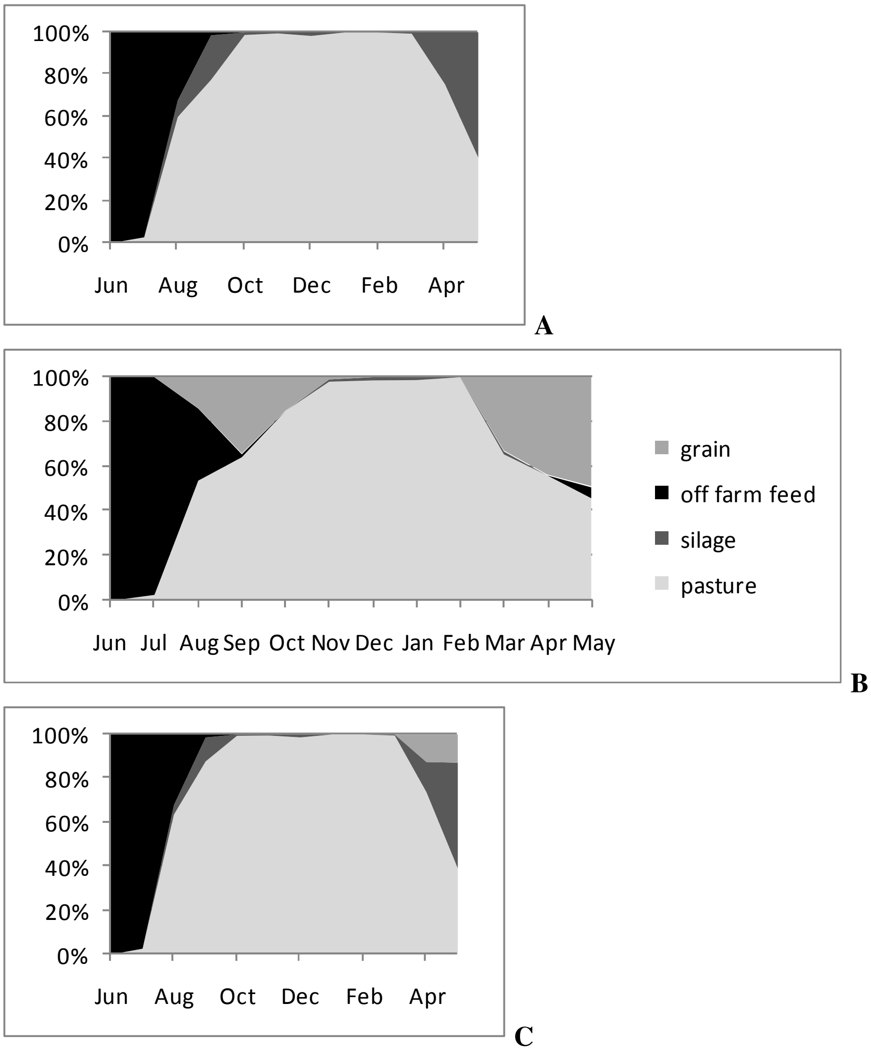

Figure 1. Diet composition (%) consumed by cows throughout the year (A= LUDF; B= More Milk; C = Greater Efficiency). Labels represent feed type: light grey = on-farm pasture; black = off-farm grazing (pasture or crops); mid grey = grain; dark grey = pasture silage

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Table 4. Milksolids production, feed allocation and intake, stocking rate and calving and drying off dates for Lincoln University Demonstration Farm (LUDF), More Milk (MM) and Greater Efficiency (GE) simulated farmlets

	LUDF	MM	GE
Milksolids produced (kg/cow)	414	437	453
Milksolids produced (kg/ha)	1,718	2,184	1,588
Pasture harvested (grazed plus cut for silage kg DM/ha)	16,814	18,105	16,025
Purchased feed (kg DM/cow)	305[1]	800[2]	100[3]
Intake mature cow (kg DM/cow)	4,745	4882	4,989
Mean calving date	18-Aug	18-Aug	18-Aug
Mean dry off date	11-Mar	25-May	22-May
Peak cows milked (cows/ha)	4.15	5.0	3.5
Mean lactation length (days)	266	280	277
Total cow days in milk (days/ha)	1102	1400	969

[1]= pasture silage [2]= barley grain [3] = maize grain

Milksolids

Predicted milksolids per cow increased by 5.6 and 9.4% for MM and GE scenarios respectively compared with LUDF (Table 4). The model included the option of increasing MS yield per cow substantially for MM because of the large amount of grain fed, but the most profitable option was to target only slightly increased per cow yield and use the extra feed to support a higher stocking rate because this allowed the cheapest feed, grazed pasture, to be used most efficiently. Predicted pasture harvest in MM exceeded LUDF by 1.3 t DM/ha per year, or about 8% (Table 4). For GE, the higher MS per cow was possible because of higher genetic merit cows that had a higher intake potential. Milksolids per ha changed by 27% and -7.6% for MM and GE scenarios respectively compared with LUDF. The result for the former was driven by the stocking rate of 5 cows per ha; for the latter, although MS yield per cow was high, the constraint on N fertiliser and grain use meant that a stocking rate of only 3.5 cows per ha could be supported. Although lactation length was increased for both MM and GE scenarios compared with LUDF it was mainly stocking rate differences that determined total cow days in milk.

Table 5. Irrigation, N inputs as fertiliser and effluent, farm-gate N surplus, N leaching and phosphorus loss for Lincoln University Demonstration Farm (LUDF), More Milk (MM) and Greater Efficiency (GE) simulated farmlets

	LUDF	MM	GE
Irrigation (mm/year, includes effluent)	564	579	551
N fertiliser (kg/ha/year – whole farm)	147	287	105
N in effluent (kg/ha/year – effluent area)	99	109	90
Farm-gate N surplus (kg N/ha/yr)	209	339	154
N leached (kg N/ha/yr)	23	43	18
P loss (kg/ha/yr)	1	1	1

Nitrogen

The Overseer model was able to simulate the actual total N leaching for LUDF very well, with 23 kg N leached/ha /year predicted compared with a mean of 22 kg N leached/ha/year from the LUDF North Block measured by Cameron (2008). This gives confidence in the results from the MM and GE scenarios. None of the scenarios used all the N fertiliser potentially available to them and there was little difference in the N applied per ha as effluent (Table 5). Farm-gate N surplus (the difference between N inputs into the farm and export of N in milk and animal sales) changed by 62.2% and -26.3% for MM and GE respectively compared with LUDF, driven mainly by changes in N fertiliser plus N effluent applications. Nitrogen leaching changed by 87% and -20.7% for MM and GE respectively compared with LUDF, driven mainly by changes in N fertiliser application. Phosphorus losses did not differ between three scenarios. It is very likely that total actual losses of N and P for LUDF and simulated losses for the other

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scenarios would be higher if off farm grazing and land used for grain cropping were included. Wintering on kale crops is quite common and this has the potential for large losses of N by leaching, e.g. 52 kg N leached/ha/year (Monaghan et al., 2010) and of P by surface runoff. Land cultivated for grain crops can also result in large leaching losses after crops are harvested.

The MM scenario showed clearly what happens to farm gate N surplus and N leaching when attempts are made to achieve the full milk production potential of a system based on grazed pasture. The combination of high temperatures and solar radiation for 9 months of the year and alleviation of soil water deficit by irrigation means that pasture will respond to high levels of N fertiliser. Returning urine to pasture by 5 cows per ha for 9 months results in large N leaching losses from urine patches, even with the use of a nitrification inhibitor. A further modelling exercise (results not presented) examined the effect of standing lactating cows off pasture on a pad for 12 h per day from 1st March until cows left the farm at drying off. Even with the reduction in urine return, the predicted N leached decreased only slightly, from 43 to 39 kg N/ha/ year. It is difficult to see how N leached from the milking platform could be reduced further under this scenario whilst maintaining both production and profitability.

Table 6. Dairy cash income, farm working expenses, cash operating surplus, net adjustments and operating profit for Lincoln University Demonstration Farm (LUDF), More Milk (MM) and Greater Efficiency (GE) simulated farmlets

	LUDF	MM	GE
Dairy cash income			
Milk sales (net of levies)	10077	12835	9340
Net livestock sales and other	1471	1763	1246
Net dairy cash income	11548	14598	10586
Farm working expenses	6141	8647	5350
Cash operating surplus[1]	5407	5951	5236
Net adjustments[2]	-1059	-1141	-902
Operating profit[3]	4348	4810	4334

[1] Cash operating surplus = Net dairy cash income – farm working expenses
[2] Adjustments – include changes in livestock and pasture cover and depreciation and labour adjustment
[3] Operating profit = Net dairy cash income- farm working expenses – net adjustments

Economics

Dairy cash income changed by 26.4% and -8.3% for MM and GE respectively compared with LUDF reflecting differences in milksolids produced per ha. Farm working expenses changed by 41.8% and -13.2 % for MM and GE respectively compared with LUDF reflecting the increased variable costs associated with a move to 5 cows per ha and the cost of extra N fertiliser and grain for MM; for GE a lower stocking rate reduced variable costs as did the lower inputs of N fertiliser.

Implications for More Milk scenario

Scenario MM could represent a situation where more milk is required but where, extra land is not available to expand the Canterbury region milking platform. At current milksolids payout and feed input prices MM is an attractive scenario – however moving to such a system represents significant management and financial risks, e.g. if payout decreased to < $5.00/kg MS then it would become the least attractive scenario. Likewise, if grain, N fertiliser or grazing off prices increase then it is more vulnerable than the other two scenarios. The much higher stocking rate will require an expansion of support land for rearing replacement stock, grazing-off dry cows and growing grain. Farm-gate N surplus and N leaching (kg/ha/year) were predicted to increase substantially under this scenario which means that it would only be feasible if a low cost technological solution was available, environmental regulations were lenient, or community rather than individual farm targets were imposed for N and other pollutants.

Implications for Greater Efficiency scenario

Scenario GE represents a situation where there are no feasible technological solutions to reduce pollutants and there are stringent regulations concerning N leaching and other pollutants at the individual farm level. In this situation, the models predicted that MS output per farm would decrease, although operating profit could be maintained. At a regional level it would still be possible to increase milksolids production providing extra land was available for expansion.

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Because of the low leaching losses, 18 kg N leached/ha per year, the total N leached on a regional basis could still be reduced. The requirement for support land would be substantially reduced because of the lower stocking rate.

Implications for Research

The scenarios presented are propositions about how farming systems may develop based on model results, and these propositions will be investigated in a farmlet experiment as part of the Pastoral 21 research programme in Canterbury. Both scenarios pose significant research challenges. The More Milk scenario eventually leads to options such as year round milking and extended lactations and the use of housing or stand-off pads to reduce pasture damage and avoid wastage of supplementary feed. Although we can use overseas technology to develop these systems, the major challenge will be to provide supplementary feed, housing systems and effluent use options at costs that ensure profitability at all levels of future payout. Simply importing overseas technology will make these systems infeasible in low payout years. At very high stocking rates, effluent use on the milking platform becomes infeasible and cost-effective ways must be found to return effluent to those areas providing winter grazing or grain crops.

The Greater Efficiency scenario also presents major challenges. Lower stocking rates have the potential to deliver better lifestyles, increased financial returns and a reduced environmental footprint. The same production, but from a lower stocking rate, requires increased DM intake per cow and this may not be possible until ryegrass intake characteristics are improved. Kolver and Muller (1998) showed that while cows fed a total mixed ration (TMR) could produce 43 kg milk per day; similar cows grazing pasture were limited to 29 kg milk per day. Sixty percent of the TMR advantage could be attributed to higher DM intake, 23% to reduced walking and grazing activity and 11% to reduced energy costs associated with excreting excess dietary N. Even a partial solution to the DM intake problem would allow some reduction in stocking rate. Current research by DairyNZ and Lincoln University aims to increase intakes by offering pastures containing grass, legumes and herbs (e.g. chicory and plantain). Increasing cow genetic merit will also increase intake drive and milk production; however, this must be associated with better general health and reproductive performance.

One of the major factors driving both economic and environmental performance is a low replacement rate. Lowering replacement rate from 22 to 16% per year, together with a lower stocking rate, would reduce the amount of off farm grazing needed and hence the total environmental footprint associated with milk production. Lower stocking rates associated with high intake potential would reduce the amount of feed needed on the milking platform but would direct a greater proportion of this feed into lactating cows. The lower feed requirement would reduce N fertiliser input, leading to a lower farm gate N surplus. The growing of small amounts of grain on farm would aid pasture renewal, provide an area for effluent application, and supply extra energy needed by cows of high intake potential. In the future, such a redesigned dairy system should be able to produce 1750 kg MS/ha/year from 3.2 cows/ha producing 550 kg MS/cow – a stocking rate reduction of 23% compared with the LUDF modelled scenario.

To achieve this vision, plant breeders must deliver traits that increase the intake potential ryegrass, and a white clover with condensed tannins in leaves; agronomists must develop low cost, stable diverse pastures; and animal breeders must identify cows with higher energy and N conversion efficiency. Current research attacks all these challenges.

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