Use of a Whole Farm Model for Exploring Management Decisions in Dairying

[1]Beukes, P., [1]C. Palliser, [1]W. Prewer, [1]V. Serra, [1]J. Lancaster, [1]G. Levy, [2]C. Folkers, [3]M. Neal, [1]B. Thorrold and [1]M. Wastney

[1]Dexcel Ltd, [2]Agriculture Software Limited, [3]University of Sydney E-Mail: Pierre.beukes@dexcel.co.nz

Keywords: *Farm systems, Pasture-based, Stocking rate, New Zealand, Climate driven.*

EXTENDED ABSTRACT

Pasture-based dairying in New Zealand presents challenges to both farmers and researchers. Farmers want to increase production, reduce costs and remain profitable under variable climatic and economic conditions. Researchers want to understand and keep track of the complex biological interactions on a farm, integrate this with economic variables, and give sound management advice. The Whole Farm Model (WFM) is a VisualAge Smalltalk (IBM) framework, linking sub-models of pasture growth and cow metabolism written in different languages, and designed to simulate the complex interactions of climate, pasture, animals and management on a farm. The model was specifically designed to extend farmlet trial results and to simulate trial designs before implementation. Here we attempt to show the potential of the WFM as a research tool to be used in collaboration with rural professionals working with commercial farmers.

Observed animal, paddock, and management data for two farms with different systems and in different climate regions of New Zealand were used to initialize the model. Lincoln University Dairy Farm (LUDF) in the Canterbury region of the South Island, is a top producing farm with a system based on irrigated pastures and high pasture utilization, whereas David and Louise Powick's farm in the Lower North Island (30 km from Palmerston North) is a typical farm for this region, based on cropping and bought feeds to supplement the much lower pasture yields. For LUDF the model predictions of monthly pasture growth rates were compared with observed for the last three seasons (2002/03 to 2004/05), and predicted weekly milksolids (MS) production compared with observed for 2002/03 season. Further questions were put to the WFM relating to the decision of LUDF to raise the stocking rate in 2003/04 from 3.65 to 4 cows/ha. For the Powick farm, model predicted annual pasture yield and MS production were compared with observed data for 2003/04 season. The WFM was used to explore the question about raising the stocking rate from 2.4 to 2.9 cows/ha.

Model predictions of pasture growth rates followed the observed patterns for LUDF, but under-predicted in winter and autumn, and over-predicted in summer probably because of more annual ryegrass and more modern ryegrass cultivars at LUDF that tends to grow better under lower temperatures and slower under higher temperatures. Predictions of weekly MS production closely followed the observed for 2002/03 season. Results showed that the increase in production from 1411 kg MS/ha (2002/03 at 3.65 cows/ha) to 1684 kg MS/ha (2003/04 at 4 cows/ha) could be partly explained by the higher pasture yield in 2003/04 (20 t dry matter (DM)/ha vs 18.3 t DM/ha), which provided the feed to carry the higher stocking rate, but also by a better than normal (10 year average) autumn, which reduced the normal need for silage feeding during this time, and resulted in a higher per cow performance because of better quality feed.

For the Powick farm the model predicted a pasture yield of 11.5 t DM/ha compared to an observed of 10.5 t DM/ha for 2003/04. MS yield was predicted at 407 kg/cow with 853 kg DM supplements/cow compared to the observed of 423 kg MS/cow with supplements of 705 kg DM/cow. Raising the stocking rate from 2.4 to 2.9 cows/ha on this farm has the potential to increase MS yield per hectare by 24%, but with a predicted increase in supplement feeding of 72% per cow. The costs and benefits of such a decision will have to be explored properly by doing a risk analysis with WFM over a number of different climate years.

The WFM succeeded in simulating two commercial farms with different systems and climates, and showed its potential as a tool for exploring relevant "what if?" questions.

1. INTRODUCTION

Dairying in New Zealand is based largely on low-cost, pasture-based systems. The country has been divided into a number of dairying regions, each with its own unique combination of soil and climatic conditions that require different approaches to managing a pasture-based dairy farm. The challenge is to cope with the given environmental conditions in these regions by developing management strategies that ensure dairy farms remain profitable. Dexcel has developed a climate-driven whole farm model that can be used to simulate the effects of different management strategies (e.g. stocking rate, supplement feeding, grazing-off, irrigation), and climates on animal and pasture production and on farm profitability. The model, developed initially for research, is being used increasingly in extension. It links mechanistic models for pasture growth and cow metabolism with daily climate and management policies. This approach is being used in the DAFOSYM model (Rotz *et al.* 1989), the INRA model (Coléno *et al.* 2002), and DAIRYMOD in Australia (Johnson *et al. 2003*). The WFM has been evaluated against data from various systems in New Zealand, including split-calving trials (Beukes *et al.* 2005a), once-a-day milking trials (Beukes *et al.* 2004), irrigated systems (Beukes *et al.* 2005b), and from animal studies with different genetics and feeds. It is now able to simulate a variety of systems under a range of environmental conditions. The aim of this paper is to give a brief overview of the Whole Farm Model (WFM), and to demonstrate the flexibility of the model by comparing predicted results with observed from two regions in New Zealand with very different climates and management systems. Relevant management questions from the two farms were put to the WFM and results discussed.

2. THE WHOLE FARM MODEL

Overview. The WFM was developed to assist in analyzing and designing farm systems trials. It consists of a framework written in VisualAge Smalltalk (IBM), and sub-models that are written in various modelling languages (Figure 1). These sub-models are dynamic and mechanistic and simulate cow metabolism and pasture growth, which is driven by daily climate. Each animal (and paddock) is represented by a copy of the relevant sub-model initialized for that individual. For example, the age, breed, and other characteristics that are unique to an individual are used for each cow model, while for each paddock the pasture cover, and soil characteristics, such as water holding capacity are specified. The user can select from many management policies and production, environmental and economic outputs of the farm system are calculated. Features under development are the addition of crops, multiple year simulations and the ability to optimize on a system. A description of the software was described previously in Wastney *et al.* (2002). Here we provide an update on recent advancements relating to inputs, outputs and management. The model is about 10 MB in size and runs on a PC.

Use. The user sets up a farm through an interface. The ‘Simulation’ page is where the start date (the date the state of the animals and pasture relate to), the climate, the length of the simulation and the sub-models to be used are selected. The sub-models differ in complexity, and hence affect the solution speed. Information on the animals (breed, age, live weight, and calving, mating and drying-off dates and milk production value of each animal) are entered directly through the interface or imported from a file. Likewise information on the paddocks (area, initial cover, soil holding capacity of each paddock) are entered through the interface or imported from a file. The ‘Feedstore’ page is where the available feeds (type, amount and quality) are selected. The policies are grouped into pasture and supplement feeding policies, pasture treatment (cutting, fertilizer and irrigation), paddock usage (use, assignment and conservation) and cow management policies relating to milking frequency, mating, grazing off, and drying off.

Results of a simulation are shown graphically, and the user has the option of showing results for every animal, some or all of the animals, and has flexibility in the frequency or data density. All results can be exported to a spreadsheet. Reports summarize the farm production and economic results.

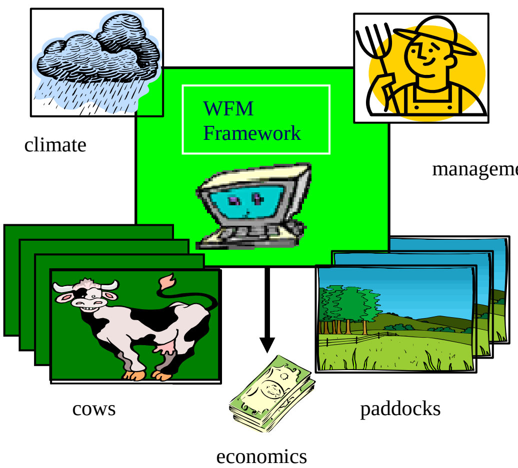

Figure 1. The Whole Farm Model (WFM)

3. MODEL SET-UP FOR CANTERBURY REGION

The Lincoln University Dairy Farm (LUDF) is an important benchmark farm for dairying in the Canterbury region of New Zealand. LUDF was selected as example farm for this region because of its status and because detailed observed data is readily available for this farm. The WFM was used to answer the following questions for LUDF:

1. How well do WFM predictions of monthly pasture growth rates and weekly milksolids production compare with observed for 2002/03 season?
2. How well do WFM predictions of monthly pasture growth rates compare with observed for the two most recent seasons, 2003/04 and 2004/05?
3. Was the production increase in 2003/04 because LUDF increased their stocking rate from 3.65 to 4 cows/ha or was it an exceptionally good climate year?
4. If we model the LUDF system at 4 cows/ha over the last decade of climate years, what can we conclude about the risk they take at 4 cows/ha?
5. What recommendations can we make to help LUDF cope with climatic variability?

Observed animal, paddock and management data from LUDF were used to initialize the WFM for 2002/2003 season. An animal input file was compiled using observed data from 44 cows from the LUDF monitor herd at the start (1 June 2002) of the season. Observed initial liveweight, age, calving and dry-off dates were used to initialize individual cows in the model.

A land input file was compiled using the observed covers for the 21 paddocks at the start of the 2002/03 season. Paddock sizes were proportionally reduced from observed to model input to give a stocking rate of 3.65 cows/ha (44 cows on 12.05 ha).

The observed amounts of grass and maize silage fed over the 2002/03 season were used to set the size of the initial grass silage reserve (70 t wet mass @ 25% DM content) and maize silage reserve (14 t wet mass @ 33% DM content). Feed out loss factors were set to 10% for both reserves.

The management policy for feeding supplements was set to feed both dry and milking cows pasture first, as long as there was adequate pasture available (according to each day’s fixed break size), then to feed grass silage to depletion, followed by maize silage. For conservation of silage, paddocks could be closed when there was excess pasture (according to rules derived from Macdonald and Penno 1998) during the period 1 September to 1 April. Silage made was added to the grass silage reserve with a loss factor of 15%.

The average climate of the Canterbury region necessitates irrigation [648 mm rainfall per year, 2100 sunshine hours, 85 wet days (=> 1 mm), and mean temperature of 12.1°C]. All paddocks received irrigation water to a maximum of 6 mm per day according to the observed schedule for the 2002/03 season, totalling 600 mm for the year. Irrigation water was added to rain water in affecting the behaviour of the pasture model. N-fertilizer was added to individual paddocks according to the observed schedule for 2002/03 season of 20 kg/ha/month for the period August – May totalling 200 kg N/ha/year.

The observed grazing-off strategy was simulated by fully feeding all cows off farm between 1 June and 22 July. LUDF decision rules regarding pasture cover targets for winter and at planned start of calving, targets for grazing residuals, and rotation planner based on a breakeven date of 20 October was implemented in the model.

The LUDF 2002/03 scenario was simulated with WFM using observed climate data (rainfall, temperature, evaporation, solar radiation) from Lincoln University weather station for 1 June 2002 to 31 May 2003. This scenario was then adjusted to 4 cows/ha (by increasing the herd to 48 animals on 12.05 ha), and with the same irrigation schedule (as for 2002/03), the scenario was run for nine other seasons (1995/1996 to 2004/2005) using observed climate data. These scenarios were started with a large enough grass silage feed store so that cows were always fed to demand. Model predictions of silage fed per cow over the different climate years were an indication of pasture deficits and a general indication of pressure on the system to feed the cows adequately at a stocking rate of 4 cows/ha.

4. MODEL SETUP FOR LOWER NORTH ISLAND REGION

Dairying in the Lower North Island region of New Zealand is restricted by low solar radiation and few opportunities for irrigation [967 mm rainfall per year, 1733 sunshine hours, 121 wet days (=> 1 mm), and mean temperature of 13.3°C]. Annual pasture productions are in the lower range (10 to

15 t DM/ha) compared with the upper range (15 to 20 t DM/ha) of the irrigated Canterbury farms. Cropping is an important aspect on many dairy farms in this region and it was important to incorporate this into the modelling exercise. The monitor farm of David and Louise Powick was used as an example of a typical dairy farm of the region, and observed climate data were obtained from the weather station at Palmerston North, approximately 30 km from the farm. The WFM was initialized for 2003/04 season using observed herd age structure, live weights at 1 June, calving dates, mating dates and dry-off dates. Observed paddock numbers and covers, as well as available feed stores (hay, baleage, maize silage, grass silage, cereal silage) at the start of the season (1 June) were used to set up the scenario. According to farm records, WFM was set up to cut two paddocks out of rotation in October 2003, and to grow turnips on one and kale on the other until grazed in January and February 2004. The two paddocks were re-sown with pasture and returned to the rotation in April and May respectively. Currently the model does not simulate crop growth and yields for these two crops were user settings (70 wet t/ha for turnips and 100 wet t/ha for kale). The model was also set up to feed the observed amounts and types of supplements to the dry and milking mobs throughout the rest of the year (1 June 2003 to 31 May 2004). Other settings included observed grazing residuals, rotation lengths, wintering off of 58% of the herd until 25 July, closing and cutting paddocks for silage, and the application of 200 kg N/ha. The WFM did not simulate the 32% of the farm topped in October and November. Topping is expected to improve pasture quality and therefore cow performance.

The WFM was used to answer the following questions for Powick's farm:

1. With the farm system and climate of 2003/04 season, how do the model predictions of pasture production, milksolids production and supplements fed compare with observed data?
2. If the stocking rate could be increased from 2.4 to 2.9 cows/ha, what would pasture deficits look like, and what amounts of maize silage and palm kernel should be fed to keep milksolids production above 400 kg/cow?

With the observed amounts and timing of supplements fed as settings in WFM some cows' milk production crashed because of feed deficits during September to December when farm records showed no supplement feeding. This was corrected by feeding cows some supplements during this time. The second question was answered by increasing the stocking rate in the model and adding another feed store, palm kernel, and by adding maize silage to the start feed store.

5. RESULTS AND DISCUSSION

5.1 Canterbury Region

Observed and predicted average monthly pasture growth rates (kg DM/ha/day) and daily milksolids production (kg milksolids/ha/day measured once a week) for LUDF 2002/03 season are shown in Figures 2 and 3. Observed and predicted pasture growth curves for LUDF seasons 2003/04 and 2004/05 are shown in Figures 4 and 5.

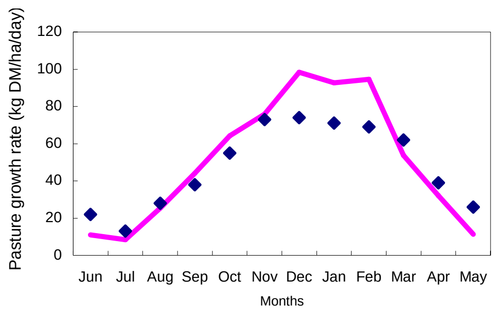

Figure 2. Observed (blue) and predicted (pink) average monthly pasture growth rates for LUDF 2002/03 season

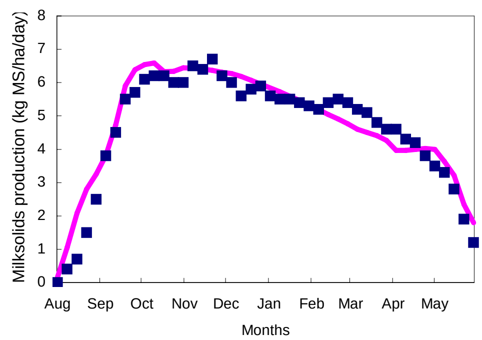

Figure 3. Observed (blue) and predicted (pink) weekly milksolids production for LUDF 2002/03 season

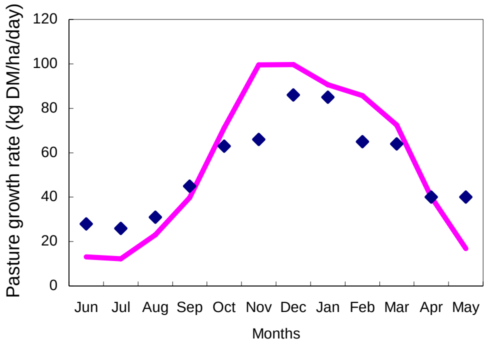

Figure 4. Observed (blue) and predicted (pink) average monthly pasture growth rates for LUDF 2003/04 season

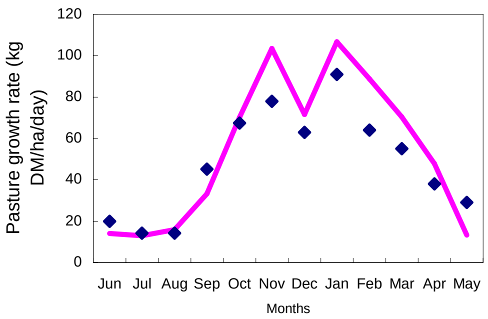

Figure 5. Observed (blue) and predicted (pink) average monthly pasture growth rates for LUDF 2004/05 season

The trend for WFM was to under-predict pasture growth rates in the winter months of May to July and over-predict in the summer months of November to February. A possible explanation for the under-prediction in winter is the presence of annual ryegrasses in two paddocks at LUDF, which may have resulted in higher observed winter growth rates compared to the model predictions. The pasture sub-model may also need to be adjusted for modern perennial ryegrass cultivars that grow better under lower temperatures. The over-prediction in summer could be the result of the model predicting more moisture availability from irrigation compared to reality i.e. in reality there is more evaporation losses. The pasture sub-model is also calibrated for a certain ryegrass/clover mix, and in reality this mix may contain more clover, which will lower summer growth rates. Nevertheless, overall the predicted pattern for pasture growth rates was close to the observed, that gave confidence to use WFM to explore questions about management and climate variability in the Canterbury region. Predicted milksolids production also showed a satisfactory visual comparison with observed results for 2002/03 season (Figure 3).

LUDF's annual milksolids production was 1684 kg/ha for the year 2003/04 compared to 1411 for 2002/03. This raised the question whether the good performance was due to raising the stocking rate from 3.65 to 4 cows/ha in this year, or was 2003/04 a good climate year compared to the average for the region? Figure 6 shows that the pasture growth curve for 2003/04 season was close to following the average pattern over the last ten years. Autumn (March-April) was slightly better than the average, probably resulting in less grass silage feeding and contributing to the higher production. Increasing the stocking rate by 0.35 cow/ha would require approximately 1.75 t DM/ha more, and the model predicted that the total annual pasture production for 2003/04 was 20 t DM/ha compared to 18.3 t DM/ha for 2002/03. Although 2003/04 was not an exceptional season, LUDF had enough feed to support the higher stocking rate and therefore produce more milksolids. However, the higher stocking rate cannot explain all of the increased production and the fairly good autumn requiring less grass silage feeding must have played a role by providing cows with better quality feed and therefore resulting in higher per cow production.

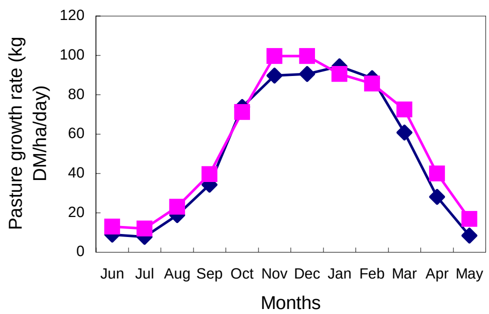

Figure 6. Average predicted pasture growth rates for LUDF over ten seasons (1995/96 to 2004/05) (blue) compared to predicted growth rates for 2003/04 season (pink)

This raises the question of how often LUDF can expect a season with below average pasture growth e.g. late spring growth and/or poor autumn growth, which will force them to feed more grass silage and accept a decrease milk production per cow, and generally put them under pressure at 4 cows/ha.

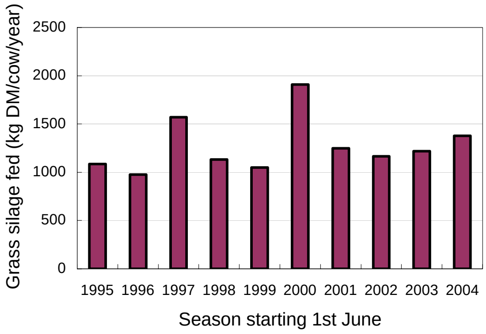

Figure 7. Predicted amounts of grass silage fed at LUDF over ten different climate years

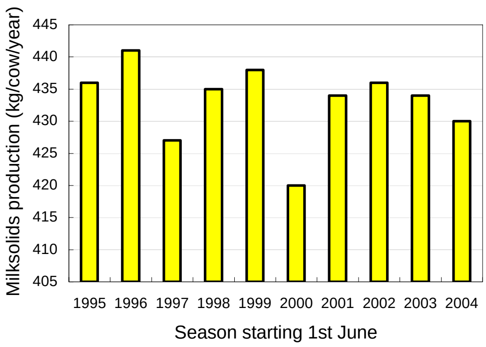

Figure 8. Predicted milksolids production from fully-fed cows at LUDF (4 cows/ha) over ten different climate years

The WFM predicted that on average 1.3 t DM grass silage/cow/year is required to feed cows to demand when the farm is stocked at 4 cows/ha. This is more than double the amount of supplements actually fed (about 500 kg DM/cow/year). This discrepancy can probably be explained by the runoff block of 17.2 ha periodically used, and cows not always being fed to demand in reality. Nevertheless the model predicted that LUDF would have to feed more supplements than they fed in 2003/04 in three of the ten climate years (30% of the time) (Figure 7), and as a consequence would have to accept lower production per cow for those years (Figure 8). The decision of whether or not to stay with 4 cows/ha will certainly depend on the economics of the system, amongst others supplement and milk prices. It is however important to notice that a season like 2000/01 can occur in the Canterbury region (Figures 7 and 8), and that even a top farm like LUDF will experience pressure to find adequate feed for the cows.

Predicted pasture and silage eaten and farm covers for 2000/01 season showed that flexibility in dry-off date would be an important management tool in similar seasons in the future. Drying cows off in middle-March instead of middle-May would save a lot of supplement feeding in a poor autumn, but also sacrifice days in milk and therefore milk production. However, cow condition and reproductive success in the following season might benefit from this strategy.

5.2 Lower North Island Region

Model predictions for pasture and milksolids production were relatively close to the observed for Powick's farm, but the predictions show that cows may have required more supplements to achieve the observed level of production (Table 1). No data of cow live weight or body condition score were available, but it is possible that in reality cows were underfed at some stages and had to draw on their reserves. The model cows were not as resilient as real cows and lost unacceptable amounts of live weight unless fed better.

Table 1. Results for Powick's with the farm system and climate of the 2003/04 season

	Observed	Predicted	Predicted
Stocking rate (cows/ha)	2.4	2.4	2.9
Annual pasture production			
(t DM/ha)	10.5	11.5	11.7
Milksolids			
(kg/cow)	423	407	411
Milksolids			
(kg/ha)	1016	963	1191
Total supplement usage			
(kg DM/cow)	705	853	1463
Maize silage			
(kg DM/cow)	110	106	460
Palm kernel			
(kg DM/cow)	0	0	351
Intake			
(t DM/cow)		5	5

Milksolids production can be increased substantially by increasing the stocking rate to 2.9 cows/ha (Table 1), but the consequence will be deeper and longer pasture deficits (Figure 9) that will require a 72% increase in supplement usage per cow (Table 1). The cost of the predicted requirements for maize silage and palm kernel to support 2.9 cows/ha (Table 1) will have to be weighed against the benefit of the higher milk production. Before a higher stocking rate system is adopted, it will be important to do a risk analysis of this system over different climate years and with different milk and supplement price scenarios (Neal 2004).

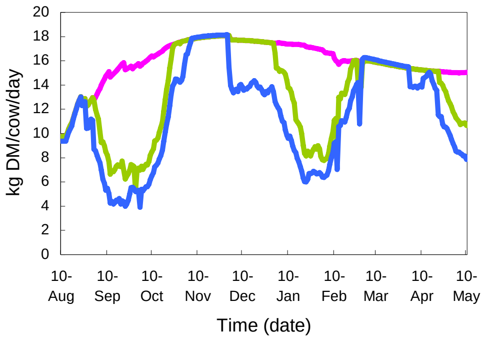

Figure 9. Daily herd averages for the milking cows (kg DM/cow). Feed demand (pink), pasture eaten at 2.4 cows/ha (green) and pasture eaten at 2.9 cows/ha (blue)

Model results showed that September and October are months that will require supplement feeding (Figure 9). Shorter rotation lengths or lower residuals may alleviate the feed pinch, but to the detriment of farm covers and feed conservation for the latter part of the season (Beukes *et al.* 2005c).

6. CONCLUSIONS

The WFM succeeded in simulating two dairy farms in New Zealand with very different systems and climates. More importantly, some relevant "what if?" questions could be put to the model, and these were answered within acceptable time frames (days). Optimization and Risk Analysis are two capabilities of the model that in the future can be used with great benefit for both farms.

7. ACKNOWLEDGMENTS

Thanks to David and Louise Powick for providing data for their farm. We acknowledge the financial support of Dairy InSight (project 10079) and Foundation for Research Science and Technology (project DRCX0301).

8. REFERENCES

Beukes, P.C., B.S. Thorrold, M.E. Wastney, C.C. Palliser and D.A. Clark (2004), Modelling farm systems with once-a-day milking, *Proceedings of the New Zealand Society of Animal Production* 64, 237-240.

Beukes, P.C., B.S. Thorrold, M.E. Wastney, C.C. Palliser, K.A. Macdonald, K.P. Bright, J.A.S. Lancaster, C.A.J. Palmer and M.J. Auldist (2005a), Modelling the bi-peak lactation curves of summer calvers in New Zealand dairy farm systems, *Australian Journal of Experimental Agriculture*, 45, 1-7.

Beukes, P.C., B.S. Thorrold, M.E. Wastney, C.B. Glassey, C.R. Burke and A.M. van Bysterveldt (2005b), Modelling the effects of zero-inductions on profitability in dairy systems, *Proceedings of the New Zealand Society of Animal Production* 65, 132-136.

Beukes, P.C., B.S. Thorrold, M.E. Wastney, C.C. Palliser, G. Levy and X. Chardon (2005c), Modelling the effect of breakeven date in spring rotation planner on production and profit of a pasture-based dairy system, *Proceedings of the XX International Grassland Congress*, Dublin, Ireland, 26 June-2 July, p. 881.

Coléno, F.C., M. Duru and L.G. Soler (2002), A simulation model of a dairy forage system to evaluate feeding management strategies with spring rotational grazing, *Grass and Forage Science* 57, 312-321.

Johnson, I.R., D.F. Chapman, A.J. Parsons, R.J. Eckard and W.J. Fulkerson (2003), DairyMod: a biophysical simulation model of the Australian dairy system, *Proceedings of the 1st Australian Farming Systems Conference*, Toowoomba, Australia, 7-11 September.

Macdonald, K.A. and J.W. Penno (1998), Management decision rules to optimize milksolids production on dairy farms, *Proceedings of the New Zealand Society of Animal Production* 58, 132-135.

Neal, M. (2004), Optimising return in a whole-farm model under conditions of risk, *Proceedings of the Annual Australian Agricultural and Resource Economics Conference* 48: 1-19.

Rotz, C.A., D.R. Buckmaster, D.R. Mertens and J.R. Black (1989), DAFOSYM: a dairy forage system model for evaluating technologies and management strategies in forage conservation, *Journalof Dairy Science* 72, 3050-3063.

Wastney, M.E., C.C. Palliser, J.A. Lile, K.A. Macdonald, J.W. Penno and K.P. Bright (2002), A whole-farm model applied to a dairy system, *Proceedings of the New Zealand Society of Animal Production* 62, 120-123.