

## New Zealand Society of Animal Production online archive

This paper is from the New Zealand Society for Animal Production online archive. NZSAP holds a regular annual conference in June or July each year for the presentation of technical and applied topics in animal production. NZSAP plays an important role as a forum fostering research in all areas of animal production including production systems, nutrition, meat science, animal welfare, wool science, animal breeding and genetics.

An invitation is extended to all those involved in the field of animal production to apply for membership of the New Zealand Society of Animal Production at our website [www.nzsap.org.nz](http://www.nzsap.org.nz)

[View All Proceedings](#)

[Next Conference](#)

[Join NZSAP](#)

The New Zealand Society of Animal Production in publishing the conference proceedings is engaged in disseminating information, not rendering professional advice or services. The views expressed herein do not necessarily represent the views of the New Zealand Society of Animal Production and the New Zealand Society of Animal Production expressly disclaims any form of liability with respect to anything done or omitted to be done in reliance upon the contents of these proceedings.

This work is licensed under a [Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License](https://creativecommons.org/licenses/by-nc-nd/4.0/).



You are free to:

**Share**— copy and redistribute the material in any medium or format

Under the following terms:

**Attribution** — You must give [appropriate credit](#), provide a link to the license, and [indicate if changes were made](#). You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use.

**NonCommercial** — You may not use the material for [commercial purposes](#).

**NoDerivatives** — If you [remix, transform, or build upon](#) the material, you may not distribute the modified material.

<http://creativecommons.org.nz/licences/licences-explained/>

## A whole-farm model applied to a dairy system

M.E. WASTNEY, C.C. PALLISER, J.A. LILE, K.A. MACDONALD,  
J.W. PENNO AND K.P. BRIGHT

Dexcel Ltd, Private Bag 3221, Hamilton, New Zealand

### ABSTRACT

The complex interactions between the biological, physical and management aspects of a farm can be represented mathematically using a computer model. A whole-farm model has been developed that links published sub-models for cow metabolism together with climate-driven pasture models, in a framework that allows for different management options. The model framework is written in VisualWorks Smalltalk, with submodels written in several programming languages linked to the framework using Microsoft COM protocol. Predictions of the whole-farm model have been compared with pasture and animal production data obtained from a dairy system trial at Dexcel in the Waikato. The system consisted of a herd of 19 cows, at a stocking rate of 3.2 cows/ha. The Whole Farm Model was used with Baldwin's MOLLY cow model of metabolism, the McCall (1984) model of pasture growth, daily climate data and a management policy whereby daily activities on the farm were enacted by the framework. These activities included, for example, assignment of paddock for grazing, closure and cutting of paddocks for conservation, calving and drying off dates of each cow, and supplement feeding. At the end of each season the whole-farm model predicted 75% of pasture growth compared with observed values assessed by visual assessment, 98% of milk yield and 98% of cow live weight. In addition to annual production by the whole farmlet, the whole-farm model can simulate individual animal and paddock production on a monthly and daily basis, so that patterns of change can be compared over the whole season. The whole-farm model is being used as a tool to design and analyse new dairy farm systems.

**Keywords:** farm system; model; computer model; simulation

### INTRODUCTION

One challenge to the New Zealand dairy industry is to balance high production with sustainability. Economics and resources limit research into the array of options available, for identifying systems that meet both criteria. Because modelling integrates knowledge of components of a farm system and their interactions, it forms a powerful tool for exploring scenarios and management strategies to maximise production and minimise environmental impact. Over 20 years ago, it was stated that the agricultural industry "cannot afford to pass over such a potentially valuable means for pointing the way to increased productivity" (Christian, 1981).

The models currently proposed for investigating farm systems can be divided into two general categories: empirical and mechanistic. In empirical models, relationships between components are described by any type of function that fits the data. They may be algebraic, or statistical (e.g., regression). Examples of empirical models are GrazingSystems (Ridler *et al.*, 2001), SEPATOU (Cros *et al.*, 1999), Stockpol (Marshall *et al.*, 1991) and UDDER (Larcombe, 1990). These programs are designed for on-farm use and are generally commercial. By contrast, relationships in mechanistic models are described by functions representing the actual biophysical processes. For example, in mechanistic models, milk production is a function of metabolites delivered to the mammary gland rather than a function of dry matter (DM) intake. Mechanistic models are generally used for research purposes. Some mechanistic models focus on one aspect of the farm system such as pasture management GRASIM (Mohtar *et al.*, 2000) or animal production either for a particular point in time such as CNCPS (Fox *et al.*, 1995) or over a whole lactation, such

as MOLLY (Baldwin, 1995). Only a few attempts have been made to link multiple aspects (animals, pastures or crops, soil nutrients, climate, management and economics) into farm systems models. These include DAFOSYM (Rotz *et al.*, 1989; Soder & Rotz, 2001), Lincoln sheep model (Cacho *et al.*, 1995), and the Dexcel Whole Farm Model (WFM) (Sherlock *et al.*, 1997).

The WFM has been developed to fill the gap of a farm-system model for simulating the rotational-grazing system of a New Zealand dairy farm (Bright *et al.*, 2000). The philosophy behind the development of the WFM was to make it as powerful as possible, current and flexible. It was designed as a research tool and so it needed to be able to address detailed questions relating to pasture management and cow metabolism, contain the latest research information, and represent any realistic farm management scenario. The model is designed for scientists to predict results of farm systems trials. It has potential for also being used by farm consultants to assess farm management decisions. The fitting of a cow submodel in the WFM to lactation data was described previously (Palliser *et al.*, 2001a). Here, simulation results of the WFM for pasture and animal production are compared to observed data from a farmlet trial.

### METHODS

#### Model description

WFM consists of a framework, written in VisualWorks 5i4 (Cincom Systems, Inc), and sub-models that are written in various modelling languages (Neil *et al.*, 1997). The framework orchestrates messaging between the sub-models (Neil, 1998; Neil *et al.*, 1997; Neil *et al.*, 1999). Solution of the WFM is on a daily time step. An object-oriented approach was chosen because the objects in the

real system (such as cows and paddocks) could be represented by software objects with their own state and messaging system (Sherlock & Bright, 1999; Sherlock *et al.*, 1997). Each animal (and each paddock) is represented by its own sub-model, with characteristics (e.g., age, breed) that are unique to that animal. A farm is described initially by information provided in spreadsheets on the herd (breed, age, live weight, and calving, mating and drying-off dates of each animal) and land (area of each paddock, minimum grazing residual and pasture composition) as well as the feed stores (hay, grass- or maize-silage).

To simulate a farm, a management policy needs to be selected and the period of the simulation specified. A policy called 'Tracking Policy' is used when the results of WFM are to be compared with observed farm data. Daily events that occurred on the farmlet are specified in a file (e.g., paddocks grazed, paddocks closed for conservation, supplementary feed given to the animals). The WFM reads the file and mimics each event as it occurred. A second policy, called Decision Rules is selected if the model is to be used for prediction. With this policy, WFM is managed according to the conditions (Macdonald & Penno, 1998). For example, WFM decides which paddock is to be grazed next, based on pasture cover. In addition to specifying the state of the farm and type of management it is necessary to specify the climate. The climate data are read from a file and consists of daily maximum and minimum air temperature, radiation, wind run, rainfall, and evaporation.

Once the farm is specified, component models are selected for updating the farm. For pasture, the choice can be either McCall (McCall, 1984) or Woodward (Woodward, 1999; Woodward, 2001). For cow production, either a simple energy-based model or a more comprehensive energy-based model (Vetharanim *et al.*, 2001) parameterised for cows, or the MOLLY cow model (Baldwin, 1995) can be selected.

While the simulation runs, graphs of average herd milk production, live weight, DM intake and pasture cover are displayed. Model-calculated values for every animal and each paddock for each day are saved into spreadsheet files, for loading into a database and comparing with the observed farm values.

### Farm trial

Observed data were from the Whole-Farm Efficiency trial at Dexcel No 2 Dairy stocked at 3.2 cows/ha and 19 animals. The farmlet was simulated during the 1998-99 season. Data consisted of cow live weights (kg), milk yield (kg) measured weekly, and pasture growth rate (kg DM/ha), determined weekly by visual assessment as well as pre- and post-grazing (Lile *et al.*, 2001). Visual assessments were calibrated each week using eleven 0.3m<sup>2</sup> quadrats cut as close as possible to ground level with a motorised sheep shearing handpiece, washed, oven dried for 48 hours at 95-100°C, and weighed. Pasture growth rates were estimated on a monthly basis using the average of the four weekly assessments. Animal intake (kg DM/cow) was estimated from pasture removed (visually assessed pre- and post-grazing) plus any supplements fed.

### Model simulation

WFM was solved using the McCall pasture model (McCall, 1984) and MOLLY cow model (Baldwin, 1995). Modifications to the MOLLY cow model to simulate a New Zealand animal included adding a function to represent live weight changes due to pregnancy and changing the decay rate for a hormone associated with milk production in older cows, (Palliser *et al.*, 2001a; 2001b). To simulate management as it actually occurred on the farmlet, it was necessary to include in the WFM, 'visitor' cows (because mobs from several farmlets were combined early in the season), break-feeding of the paddocks, grazing of more than one paddock/day, removal of cows from the farmlet at drying off, and bringing in replacement animals during the season. WFM calculated daily pasture growth rates, feed conserved, animal intakes (determined from the amount of feed supplied to meet animal demand), live weight and milk yield. Results were collated on an annual basis or by month.

### Statistical methods

The model was evaluated by comparing the ratio of model-predicted to observed data.

## RESULTS

Values calculated by the WFM and the observed annual farmlet data for one season are shown in Table 1. The simulation occurred from 1 July 1998 - 31 May 1999. Pasture production is only compared from August - May as pasture growth was not routinely recorded during July of 1998. Pasture production and feed conserved calculated by WFM was lower than the observed values while intake, cow live weight and milk yield are close to observed values. Table 2 compares the ratio (and SD) of calculated-to-observed values during the season. Even though the

**TABLE 1:** Annual production of one farmlet (stocking rate 3.2 cows/ha) over the 1998-1999 season. Observed values from the farmlet are compared to values calculated by the whole-farm model.

	Observed	Calculated
Pasture production (kg DM/ha) <sup>a</sup>	16,195	13,865
Feed conserved (kg DM)	1,786	1,402
Intake (kg DM/cow)	4,104	3,554
Cow live weight (kg)	491	478
MilkYield (kg)	3,887	3,790

<sup>a</sup>Determined from Aug 1998-May 1999

**TABLE 2:** Ratio of production calculated by the whole-farm model and observed values for one farmlet (stocking rate 3.2 cows/ha) over the 1998-1999 season.

	Ratio <sup>a</sup> (Calculated/Observed)
Pasture Growth Rate (kg/DM/ha/d) <sup>b</sup>	1.06± 0.74
Pasture production (kg DM/ha) <sup>b</sup>	0.75± 0.18
Intake (kg DM/cow/d) <sup>c</sup>	0.86± 0.11
Cow live weight (kg) <sup>d</sup>	0.98± 0.05
MilkYield (kg/cow) <sup>d</sup>	0.98± 0.07

<sup>a</sup>Mean±SD

<sup>b</sup>Values were compared on a monthly basis.

<sup>c</sup>Observed intake was calculated based on pasture removed at each grazing.

<sup>d</sup>Live weight and milk yield are values measured at the end of the season (n=19).

ratio of pasture growth rate was close to unity (Table 2), there was variability because the McCall model under-predicted pasture growth rate during August and September and over-predicted during March and April (Data not shown). Calculated cow intake, cow live weight and milk yield were all close to the observed values with small (<15%) variability (Table 2).

## DISCUSSION

The WFM has been compared to actual data from a farmlet for a whole season. The model predicted milk yield and cow live weight within 2% of actual values. Pasture production however, was lower than observed values resulting in lower model predictions for the amount of feed conserved than actually occurred. Initial tests performed by increasing radiation caused an increased in pasture production particularly in early spring, This suggested that the McCall model may be not sensitive enough to radiation levels.

The WFM differs from UDDER (Larcombe, 1988) in that it simulates individual animal production. It was because of this feature that a difference was detected in milk production of older cows (Palliser *et al.*, 2001b). In addition, WFM uses climate as a driver for pasture growth. Thus, it can be used to simulate farm production in other regions of New Zealand by selecting the appropriate climate file (Lile *et al.*, 2002). WFM solves on a daily time step compared to UDDER, which is designed for farm management, and solves on a 10-day time step. UDDER, like some other models includes an economic component (e.g., Dafosym, (Rotz *et al.*, 1989)). The WFM is currently being expanded to include crop and soil nutrient models. This will enhance its ability to model productivity and sustainability. It is also being tested against data from two additional seasons, and from a range of stocking rates. The nutritive value of pasture is to be adjusted seasonally, based on data from Dexcel trials. Because WFM is a general farm systems model, it could be used to simulate a variety of farm systems by merely replacing the dairy cow model with a sheep, beef or other animal model. Likewise, different crop models could replace (or be added to) the pasture model to simulate feeding systems. An important use of the WFM will be to design new farm systems by identifying key variables in the farm system, and then varying the values of these variables to maximise farm performance.

## REFERENCES

- Baldwin, R.L. 1995: *Modeling Ruminant Digestion and Metabolism*. Chapman & Hall, London.
- Bright, K.P.; Sherlock, R.A.; Lile, J.; Wastney, M.E. 2000: Development and use of a whole farm model for dairying. Pages 382-389. *Applied Complexity-From Neural Nets to Managed Landscapes*. New Zealand Institute for Crop & Food Research Ltd., Dunedin, New Zealand.
- Cacho, O.J.; Finlayson, J.D.; Bywater, A.C. 1995: A simulation model of grazing sheep. II. Whole farm model. *Agricultural systems* 48: 27-50.
- Christian, K.R. 1981: Simulation of grazing systems. Pages 361-377 *In* Morley, F.H.W. *Grazing Animals*. Elsevier, Amsterdam.
- Cros, M.-J., M.; Duru, F.; Garcia, Martin-Clouaire, R. 1999: A DSS for rotational grazing management: Simulating both the biophysical and decision making processes. Pages 759-764 *In* L. Oxley, F. Scrimgeour, and A. Jakeman, eds. *MODSIM99 - International congress on modelling and simulation*. Modelling and Simulation Society of Australia and New Zealand, Hamilton, New Zealand.
- Fox, D.G.; Barry, M.C.; Pitt, R.E.; Roseler, D.K.; Stone, W.C. 1995: Application of the Cornell Net Carbohydrate and Protein Model for cattle consuming forages. *Journal of animal science* 73: 267-277.
- Larcombe, M. 1990: UDDER: a desktop dairyfarm for extension and research. *Proceedings of the 7th Seminar Dairy Cattle Society of the New Zealand Veterinary Association* New Zealand: 22-25 May 1990. 151-152.
- Larcombe, M.T. 1988: DAIRYMAN: A simulation model to predict the production of dairy herds fed pasture. *Proceedings of the Australian Society of Animal Production* 17: 372.
- Lile, J.A.; Bright, K.P.; Palliser, C.C.; Prewer, W.E.; Wastney, M.E. 2002: Modelling dairy production in different regions of New Zealand. *Proceedings of the New Zealand Society of Animal Production* 62: (in press).
- Lile, J.A.; Blackwell, M.B.; Thomson, N.A.; Penno, J.W.; Macdonald, K.A.; Nicholas, P.K.; Lancaster, J.A.S.; Coulter, M. 2001: Practical use of the rising plate meter (RPM) on New Zealand dairy farms. *Proceedings of the New Zealand Grassland Association* 63: 159-164.
- Macdonald, K.A.; Penno, J.W. 1998: Management decision rules to optimise milksolids production on dairy farms. *Proceedings of the New Zealand Society of Animal Production* 58: 132-135.
- Marshall, P.R.; McCall, D.G.; Johns, K.L. 1991: Stockpol: a decision support model for livestock farms. *Proceedings of the New Zealand Grassland Association* 53: 137-140.
- McCall, D.G. 1984: A systems approach to research planning in North Island hill country. PhD Thesis. Massey University, New Zealand, Palmerston North.
- Mohtar, R.H.; Zhai, T.; Chen, X. 2000: A world wide web-based grazing simulation model (GRASIM). *Computers and electronics in agriculture* 29: 243-250.
- Neil, P. 1998: Distributed simulation using DCOM. Modeling cows with COM. *Distributed computing*: 15-18.
- Neil, P.G., Bright, K.P.; Sherlock, R.A. 1997: Integrating legacy subsystem components into an object-oriented model. Pages 1133-1138 in A. D. McDonald and M. McAleer, eds. *MODSIM 97 International congress on modelling and simulation*. Modelling & Simulation Society of Australia, Hobart, Australia.
- Neil, P.G.; Sherlock, R.A.; Bright, K.P. 1999: Integration of legacy subsystem components into an object-oriented simulation model of a complete pastoral dairy farm. *Environmental modelling & software* 14: 495-502.
- Palliser, C.C.; Bright, K.P.; Macdonald, K.A.; Penno, J.W.; Wastney, M.E. 2001a.: Adapting the MOLLY cow model to fit production data from New Zealand animals. *Proceedings of the New Zealand Society of Animal Production* 61: 234-236.
- Palliser, C.C.; Wastney, M.E., Bright, K.P.; Macdonald, K.A.; Penno, J.W. 2001b: Modelling the lactation curves of New Zealand cows. Pages 1853-1858 in Ghassemi, F. White, D. Cuddy, S. and Nakanishi, T. eds. *MODSIM 2001 International congress on modelling and simulation*. Modelling and Simulation Society of Australia and New Zealand, Canberra, Australia.
- Ridler, B.J.; Rendel, J.M.; Baker, A. 2001: Driving innovation: Application of Linear Programming to improving farm systems. *Proceedings of the New Zealand Grassland Association* 63: 295-298.
- Rotz, C.A.; Black, J.R.; Mertens, D.R.; Buckmaster, D.R. 1989: DAFOSYM: a model of the dairy forage system. *Journal of production agriculture* 2: 83-91.
- Sherlock, R.A.; Bright, K.P. 1999: An object-oriented framework for farm system simulation. Pages 783-788 *in* Oxley, L.; Scrimgeour, F.; Jakeman, A. eds. *MODSIM 99 Proceedings of the international conference on modelling and simulation*. Modelling & Simulation Society of Australia & New Zealand.
- Sherlock, R.A.; Bright, K.P.; Neil, P.G. 1997: An object-oriented simulation model of a complete pastoral dairy farm. Pages

- 1154-1159 In McDonald, A. D.; McAleer, M. eds. MODSIM 97 International congress on modelling and simulation proceedings. Modelling & Simulation Society of Australia, Hobart, Australia.
- Soder, K.J.; Rotz, C.A. 2001: Economic and environmental impact of four levels of concentrate supplementation in grazing dairy herds. *Journal of dairy science* 84: 2560-2572.
- Vetharaniam, I.; McCall, D.; Fennessy, P.; Garrick, D. 2001: A model of mammalian energetics and growth: model development. *Agricultural systems* 68: 55-68.
- Woodward, S.J.R. 1999: Validating a model that predicts daily growth and feed quality of New Zealand dairy pastures. Pages 777-782 In Oxley, L.; Scrimgeour, F; Jakeman, A. eds. MODSIM 99 International congress on modelling and simulation. University of Waikato, Hamilton, New Zealand.
- Woodward, S.J.R. 2001: Validating a model that predicts daily growth and feed quality of New Zealand dairy pastures. *Environment international* 27: 133-137.