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Modelling dairy system efficiencies

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ABSTRACT

The Dexcel Whole Farm Model (WFM) is being developed to simulate dairy systems based on the interaction of system components. The WFM was fitted against observed data from the Resource Efficient Dairying (RED) trial, Scott Farm, Hamilton (Treatment A, 2002/2003 season) and used to explore the effects of different stocking rates on measures of system efficiency, i.e. feed utilisation (FU) and feed conversion efficiency (FCE). At the same stocking rate as RED treatment A (3 cows/ha), and with the observed 'best-practice' management principles in place, the WFM predicted a FU 7% higher compared with the observed (73% vs 66%). Increasing stocking rate in the WFM resulted in an increase in FU, but the predicted FCE did not decrease as was expected. The model showed the importance of adhering to proven management principles to reduce feed wastage and thereby improve system efficiencies.

Key words: stocking rate; simulation modelling; pasture utilisation; dairy farm.

INTRODUCTION

In all-pasture dairy systems the efficiency of pasture utilization and milksolids production are related to stocking rate. As stocking rate is increased, milksolids production per cow decreases while pasture utilisation increases (L'Huillier, 1987; Penno *et al.*, 1999; Macdonald *et al.*, 2001). Farm management practices should be evaluated on the basis of system efficiencies. For example feed utilisation (FU, kg DM eaten/kg DM provided), and feed conversion efficiency (FCE, kg milksolids/t DM eaten) are key measures of system efficiency. They serve as an index of the proportion of the feed that was provided but not consumed (FU), and also the proportion of the feed that entered the producing animal, but because of a number of controllable and uncontrollable inefficiencies in the cow the feed was never converted into a product (FCE). In this paper we use observed data from a systems trial and a farm systems modelling tool to explore the importance of stocking rate as a management factor affecting system efficiencies.

Since 2001 the Resource Efficient Dairying (RED) trial of Dexcel, Hamilton has generated production and management data from six different treatments in a farmlet study (Jensen *et al*., 2004). The principal variables over the different treatments include stocking rate, feed amount, feed type and feeding system. The control treatment (Treatment A) was stocked at 3 cows/ha with 160 kg N/ha, and cows were fed pasture and grass silage but no bought in supplements. From this most basic farm system the observed data for 2002/2003 season was used to calculate efficiencies. This farmlet was simulated as the benchmark system in the modelling exercise and used to explore stocking rate as a management practice for improving system efficiencies.

The Whole Farm Model (WFM) developed by Dexcel can simulate individual cows and paddocks and can be used as a tool to analyse systems. The model consists of submodels of climate, pasture and cow [of which 'Molly' is the most complex (Baldwin 1995)] as well as a management model covering pasture treatment, paddock usage and cow management policies (see Bright *et al*., 2000). Wastney *et al.* (2002) showed that the WFM was able to predict pasture growth, milk yield and cow live weight for a spring calving herd under New Zealand conditions.

The objective of this exercise was to match the observed inputs and outputs of the RED trial treatment A with the WFM predictions for the 2002/2003 season, and to use the WFM to explore the effects of changing stocking rate for that specific farmlet and season on system efficiencies.

METHODS

RED trial Treatment A and model fitting

Treatment A in the RED trial enables the economic, animal and environmental performance of an all-pasture dairy system to be monitored over several seasons. The trial has a planned feed allowance of 85 kg live weight/t DM (Comparative Stocking Rate, CSR) (Speight, 2002), and a 160 kg N/ha/year fertilizer input. Management decision rules follow 'best-practice' dairy farming as described by Macdonald and Penno (1998) and are summarised in Table 1 along with other observed data for the 2002/2003 season. The observed pasture yield (Table 1) was estimated from weekly visual scores of standing pasture. The visual scores were calibrated with 10 x 0.33 m^2 quadrat cuts (4 post grazing and 6 pre grazing) to ground level, with cut material washed, dried and weighed. The weight of the dried material was regressed against visual scores for the cut quadrats and a linear regression derived. The regression was then applied to the visual scores for each paddock and the corrected value used to give average herbage mass from which pasture growth could be calculated (Smeaton & Winn, 1981).

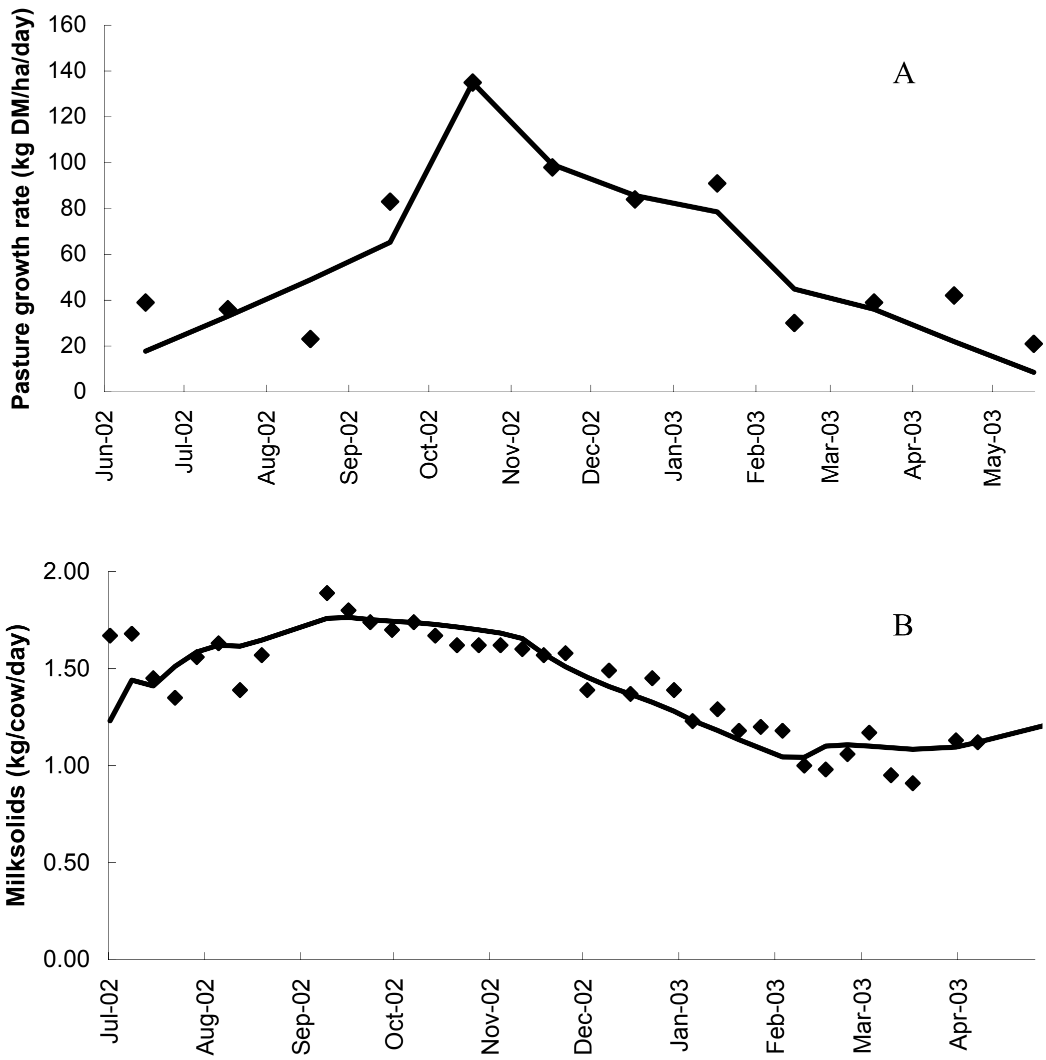
The WFM (version 8.8.1.0) was set up with 'Molly' cow model (as modified for New Zealand conditions (Palliser *et al.*, 2001)), and the McCall pasture model (McCall & Bishop-Hurley, 2003) was driven by local climate data from the Ruakura Meteorological station for the 2002/2003 season. Each of the 21 cows in the treatment A herd was initialised using observed live weight, condition score, age, calving date and dry-off date at the start of the season on 1 June 2002. The potential peak daily milk was set at 5.8% of live weight (Table 1). Individual paddocks were initialised with observed covers, and using the actual amount of silage available at the start of the season, an allocation was set at 155 kg DM/cow on 1 June 2002. Management policies in the model followed the observed management, except for N applications where time and rates were changed to achieve the observed 22 t DM/ha/year yield (Table 1). The timing of N application was altered so the predicted seasonal growth pattern matched the observed pattern (Figure 1).

TABLE 1: Observed and modelled input and output parameters for Resource Efficient Dairying (RED) trial treatment A, 2002/2003 season.

Parameter			Observed	Whole Farm Model
Input	Land	Area (ha)	7	7
		Number of paddocks	14	14
		Farm cover on 1 June 2002 (kg DM/ha)	1934	1934
		Pasture lignin content in spring and summer (%)	Not measured	15 and 25[a]
	Cows	Breed	Friesian	Friesian
		Mean calving date	31 Jul	31 Jul
		Stocking rate (cows/ha)	3	3
		Av. initial live weight (kg)	526	526
		Av. days in milk	266	266
		Potential peak daily milk (% of live weight)	N/A	5.8[b]
	Management	Start grass silage stack (kg DM/cow)	155	155
		Fertilizer (kg N/ha)	160	270[c]
		Max. rotation length (winter)	100	100
		Min. rotation length (spring)	14	14
		Grazing off	none	none
		Topping	none	none
		Close for conservation	Oct-Nov	Oct-Nov
		Time of N application	Jun-Feb	Jun-Feb
		Mean dry-off date	23 Apr	23 Apr
Output	Pasture	Production (t DM/ha)	22.0	20.9
		Silage made (kg DM/cow)	299	1242
	Cows	Milksolids (kg/cow)	380	380
		Milksolids (kg/ha)	1139	1141
		Av. end live weight (kg)	512	477
		Estimated intake (kg DM/cow)	4864[d]	5085
		Silage fed (kg DM/cow)	66	157

a. Increased to match milk yield
b. 'Molly' parameter
c. Increased to match pasture yield
d. Estimated using factorial energy requirements based on production and live weight (Holmes *et al.*, 2002)

FIGURE 1: Observed (diamonds) and predicted (solid line) pasture growth rate (A) and milksolids (B) for the Resource Efficient Dairying (RED) trial, Treatment A, 2002/2003 season.



Predicted pasture growth is adjusted for quality using 18 feed components (Baldwin 1995) so that four sets of feed component parameters were compiled to represent pasture quality changes over the four seasons. The main differences between seasons were in the protein, fibre and soluble carbohydrate fractions. Initial default values for pasture quality resulted in an over-prediction of milk production. Pasture quality actually declined more rapidly during the 2002/2003 season than the default values and required lignin feed component to be increased for the spring and summer seasons (Table 1). This change resulted in comparable model prediction of milk yield with observed values (Figure 1).

Model scenarios with different stocking rates

Comparative Stocking Rate (CSR, kg live weight/t DM) is a measure of how much cow biomass a manager allocates to a tonne of feed dry matter and is considered a biologically more sensible way of expressing stocking rate than number of cows per unit land area (cows/ha) (Speight, 2002). CSR can be derived from the average cow live weight, stocking rate (cows/ha) and total amount of feed available (annual pasture production + imported supplements = total feed available, t DM). For the 2002/2003 season the CSR for RED Treatment A was calculated as 71 kg live weight/t DM. The WFM was set up to simulate Treatment A with the observed stocking rate. Two alternative CSRs were also chosen (60 and 83 kg live weight/t DM), and modelled for Treatment A. The CSRs of 60 and 83 were chosen because published results on system efficiencies were available for these values (Macdonald *et al.*, 2001). In order to model the CSR of 60 kg live weight/t DM for Treatment A for the 2002/2003 season, five cows were randomly dropped from the model herd, and to model a CSR of 83 four randomly selected cows from the herd were each duplicated for simulation.

RESULTS

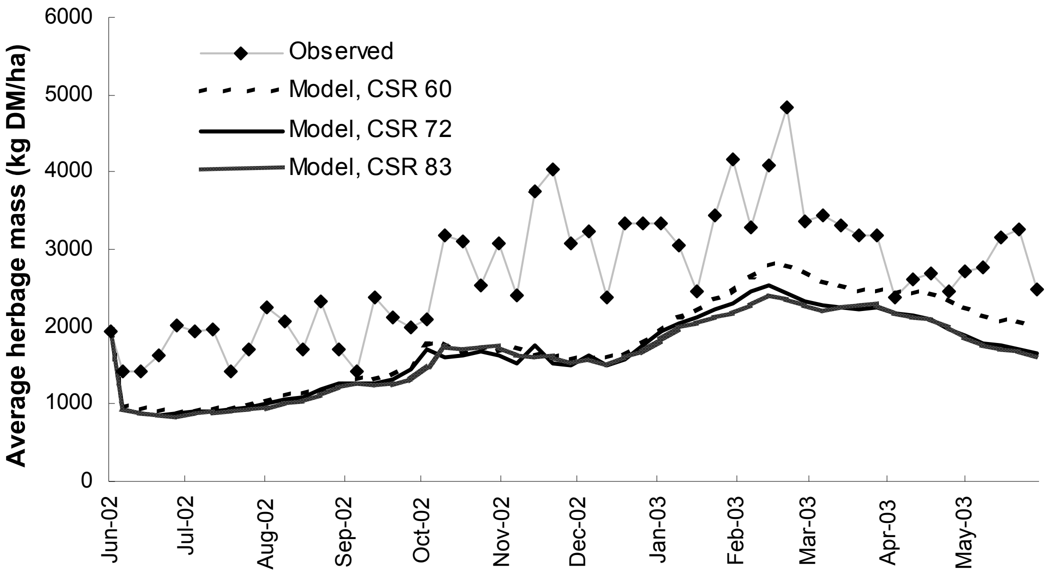
After adjusting the amounts and timing of N fertiliser input into the WFM, decreasing the potential peak daily milk yield of each individual cow, and lowering the pasture quality in spring and summer by increasing lignin content, the WFM prediction of seasonal pasture growth and milksolids (MS) production matched the observed values for treatment A 2002/2003 season (Figure 1 A and B).

At a CSR of 72 kg live weight/t DM the WFM predicted a feed utilisation (FU) of 73% compared to the observed of 66% for treatment A 2002/2003 season (Table 2). A change in CSR from 60 to 83 in the model resulted in a downward trend in MS per cow and an upward trend in FU that corroborates published data (Table 2). However, contrary to what was expected, predicted FCE remained constant when stocking rate was increased (Table 2).

TABLE 2: Results for the Resource Efficient Dairying trial treatment A season 2002/2003 (RED observed), predicted with the Whole Farm Model (WFM), and from the Whole Farm Efficiency (WFE) trial for comparable CSRs (Macdonald *et al.*, 2001).

	RED observed	WFM			WFE		
CSR (kg live weight/t DM)	71	60	72	83	62	73	83
Stocking rate (cows/ha)	3	2.3	3	3.6	2.2	2.7	3.2
Net herbage accumulation (t DM/ha)	22.0	19.7	20.9	21.5	17.5	17.9	18.8
Average cow live weight (kg)	519	517	502	493	495	487	486
Intake (kg DM/cow)	4864	5319	5085	4827	5060	4647	4236
Milksolids (kg/cow)	380	401	380	360	435	380	353
Feed Utilisation (FU)	66	62	73	81	64	70	72
Feed Conversion Efficiency (FCE)	78	75	75	75	86	82	83

FIGURE 2: Observed (diamonds) and predicted herbage mass at comparative stocking rates (CSR) of 60, 72 and 83 kg live weight/t DM for the Resource Efficient Dairying (RED) trial, Treatment A, 2002/2003 season.



Comparisons of predicted against observed herbage mass (kg DM/ha) showed the model's ability to strictly implement pasture and paddock management policies and maintain average available herbage mass below that observed for treatment A (Figure 2).

DISCUSSION

At CSRs of 72 and 83 kg live weight/t DM the model predicted higher FUs compared to the observed for treatment A, and compared to published results from another trial (Whole Farm Efficiency, WFE, Macdonald *et al.*, 2001). Model predicted intakes followed the expected downward trend when stocking rate was increased, but they were higher than the observed data. Higher intakes in the model were possible because the model reduces feed losses compared with a real farm by implementing strict feed allocation policies following prescribed rotation planners and residuals. The model did not allow herbage mass to increase to the extent of observed values, but fed the cows to demand when possible, with excess conserved as silage (Table 1). The high observed herbage masses in treatment A (Figure 2) could result in substantial feed losses from the system through decay. In contrast, the model appeared to rigorously implement prescribed feed allocation policies. This may be unrealistic, but it partially explains the higher predicted FUs.

Model predictions showed minimal response in FCE when stocking rate was changed. In reality as stocking rate increases, feed availability becomes limited, intake decreases and a relative smaller proportion of the intake, above maintenance requirements, is available for milk production (Macdonald *et al.*, 2001). This means lower FCE values. It would appear that the cow sub-model ('Molly') in the WFM compensates for lower intakes by mobilising more body reserves in an attempt to maintain milk production. This is evident from the decline in average live weight as CSR was increased (Table 2). Energy and nutrient partitioning in 'Molly' is possibly less dynamic than in reality, resulting in smaller fluctuations in FCE when intakes change, but at the expense of body reserves.

The model predicted a MS response of 41 kg MS/cow to a decrease in CSR from 83 to 60, which is substantially less than the response of 82 kg MS/cow over the same range in the Whole Farm Efficiency (WFE) trial (Macdonald *et al.*, 2001). The response in the WFE trial was mainly due to more days in milk (DIM) as CSR decreased (260 DIM at CSR 83 vs 296 DIM at CSR 62). In the model comparisons presented here, average DIM was not altered with different CSR scenarios and accounted for the lower predicted milksolid response. There is a need for further evaluation of 'Molly' over a range of CSRs and dry-off dates to test her ability to model changes in FCE.

The WFM could be fitted to an observed data set and confirmed that a measure of system efficiency, e.g. feed utilisation, can be improved by altering a management factor, i.e. stocking rate. Outputs from the model compared favourably to published measures of efficiency. For a specific farm and season, management decisions could be altered and likely outcomes predicted without re-running the trial. The model also emphasized the importance of strict adherence to proven 'best-practice' management decision rules to reduce feed wastages and to achieve optimum utilisation of available resources.

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