Regular estimates of paddock pasture mass can improve profitability on New Zealand dairy farms

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Abstract
Paddock selection is an important component of grazing management and is based on either some estimate of pasture mass (cover) or the interval since last grazing for each paddock. Obtaining estimates of cover to guide grazing management can be a time consuming task. A value proposition could assist farmers in deciding whether to invest resources in obtaining such information. A farm-scale simulation exercise was designed to estimate the effect of three levels of knowledge of individual paddock cover on profitability: 1) "perfect knowledge", where cover per paddock is known with perfect accuracy, 2) "imperfect knowledge", where cover per paddock is estimated with an average error of 15%, 3) "low knowledge", where cover is not known, and paddocks are selected based on longest time since last grazing. Grazing management based on imperfect knowledge increased farm operating profit by approximately $385/ha compared with low knowledge, while perfect knowledge added a further $140/ha. The main driver of these results is the level of accuracy in daily feed allocation, which increases with improving knowledge of pasture availability. This allows feed supply and demand to be better matched, resulting in less incidence of under- and over-feeding, higher milk production, and more optimal post-grazing residuals to maximise pasture regrowth.

Keywords: modelling, paddock selection, pasture cover

Introduction
The focus on grazing management is becoming more critical with increased use of supplements, new environmental objectives and a need to retain the competitive advantage of the New Zealand dairy industry. Grazing management can be divided into three levels, strategic, tactical and operational, with paddock selection a key interface between the tactical and operational. Paddock selection is largely undertaken using criteria such as pasture cover (or pasture height as a proxy), or days since last grazing. Paddocks are ranked from highest to lowest cover to determine the grazing sequence for the near future e.g. next 7 days. Rotation or round length is normally part of this planning process and determines the proportion of the farm grazed each day. For each grazing event the area allocated plus the cover in the selected paddock determines pasture allowance per cow, which has important consequences for pasture dry matter intake and utilisation. The cover of the selected paddock then has consequences for the height to which swards are defoliated (i.e., the post-grazing residual), pasture regrowth, sward structure, quality of subsequent available pasture, and for supplement feeding decisions (Fulkerson *et al*. 2005).

Although it appears beneficial to perform regular (e.g., weekly) cover assessments, the benefits would have to be substantial, as considerable effort is required. The objective of this study was to use a farm-scale model to evaluate the potential production and economic benefits of measuring cover on New Zealand dairy farms with the aim of applying the acquired knowledge for improved paddock selection decisions.

Methods
The DairyNZ Whole Farm Model
The DairyNZ Whole Farm Model (WFM; Beukes *et al*. 2008) was developed to assist with analysis and design of dairy farm system experiments through scenario testing under various system interactions that occur over multiple years. The WFM simulates a farm on a daily time step, rotating dry and lactating cow herds through the paddocks separately according to a user-specified rotation policy. Post-grazing residuals are determined by the model as a function of the feed demand of the herd, grazing hours and herbage allowance on that day. The user can specify minimum residuals in time blocks of 10 days below which animals are not allowed to graze. In the WFM, the residual influences pasture regrowth of the paddock, but the total impact on pasture quality is not yet captured. Pasture quality in WFM is a user-defined input of feed composition values per month for green pasture, and one set of feed composition for dead pasture. Paddocks can be closed for silage by removing them from the grazing round and allowing biomass to accumulate before cutting for silage. Supplements (home-grown or imported) can be fed to cows according to policies created by the user (e.g., dates, which cows, type of feed, amounts, where

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fed, and fed before or after pasture). Other user-defined policies related to cow management include breeding, grazing off farm, standing on a loafing pad for certain hours per day, drying off, culling and replacement.

Model improvements

The default paddock selection policy in WFM selects the next available paddock, or break in a paddock (portion of a paddock), that has the highest cover. The paddock selection policy is based on "perfect knowledge" of energy demand, and cover for every paddock on a daily basis, which is only realistic in a modelling context.

Two alternative paddock selection policies were developed representing more typical on-farm approaches. In the one, the model assumed the farmer would estimate cover with an average error of 15% (an average error of 450 kg DM/ha on a paddock with an actual cover of 3000 kg DM/ha). In this "imperfect knowledge" policy the model applies an "error" to the actual cover per paddock to generate an estimated cover that mimics what happens in real life. These "errors" were generated by using a normally distributed scalar of 1±0.15, and applying these scalars to the actual cover for each paddock before paddock selection for the next grazing. In a second alternative policy it was assumed that the farmer does not assess cover, but records the sequence in which paddocks are grazed and simply continues moving through the paddocks by always selecting the next paddock based on the longest time since the last grazing or cutting event. This "low knowledge" policy ignores differential growth between paddocks and the potential for faster growing paddocks to come up for grazing sooner than the policy dictates. This policy is used on actual farms because it does not require any estimate of cover, but relies on a very basic recording of which paddock has just been grazed or cut, which by implication also provides the information on the paddock that was grazed or cut the furthest back in the past.

Differential pasture yield

One major factor that farmers have to deal with in pasture management is the difference between paddocks in how pastures grow and respond to grazing (Romera *et al*. 2010). Since the focus of this modelling exercise is to determine the value of using knowledge of pasture cover to make better management decisions, it was essential to capture some of these differences.

Weekly calibrated growth rates from DairyNZ's Scott farm, Hamilton were used to estimate annual pasture yield for 26 paddocks for the period 1 June 2011 to 31 May 2012 and paddocks were ranked according to relative yield (Figure 1). The relative yield was used in adjusting the fertility factor (default 1.0)

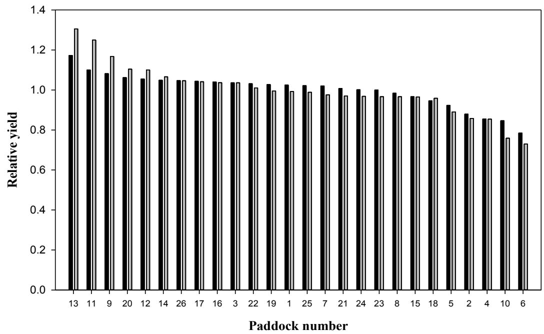

Figure 1 Observed (black) and predicted (grey) relative annual pasture yield for 26 paddocks at Scott farm, Hamilton. Average yield = 1.0.

for each paddock in the initialisation page of WFM. On this input page the model user identifies each paddock, defines the soil type, defines the herbage type (e.g., ryegrass-clover), the paddock area, biomass at the start of the simulation, and the fertility factor. The fertility factor is a scalar that adjusts the daily growth rates as predicted by the pasture model and can be used to adjust the annual pasture growth curve up or down depending on specific growth conditions for a particular paddock.

For this modelling exercise the 2012/13 farm season was used in developing the baseline scenario (see next section). After the WFM was set up for the farm it was simulated with NIWA weather data from the Ruakura meteorological station for the period 1 June 2012 to 31 May 2013. The fertility factor for individual paddocks was adjusted in an attempt to represent the observed variability in annual pasture yield. Figure 1 shows the inter-paddock variability in annual pasture yield as predicted by WFM for the 2012/13 season. The result was regarded as an adequate representation of the observed differences in paddock performance.

Scenario development and assumptions

The WFM was initialised for a typical pasture-based Waikato farm for the 2012/13 season (baseline scenario). The three paddock selection policies were available; using perfect knowledge, imperfect knowledge, or low knowledge of covers for paddock selection. The rotation policy used the default in the model, which varies the rotation length from as long as 100 days in winter to 70 days at start of calving, which is then reduced stepwise to the shortest round at balance date of around 20 days. The residual policy was set to 1500 kg DM/ha as the minimum residual allowed throughout the year for all scenarios. Three climate years (Ruakura meteorological station, NIWA) were simulated for each paddock selection policy – 2004/05 representing a "good" pasture yield of c. 20 t DM/ha; 2013/14 representing a "normal" pasture yield of c. 17.5 t DM/ha; 2012/13 for a "poor" pasture yield of c. 16 t DM/ha. All scenarios started on 1 June with paddock covers distributed to give a feed wedge with an average farm cover of 2500 kg DM/ha on that date. Cows were dried off on 7 May in all scenarios. It was assumed that farmers will import more supplements in dry years to keep cows milking until 7 May. The dry-off date was kept constant between scenarios, allowing supplement costs to vary between climate years and paddock selection policies.

Two management policies differed between the three paddock selection options: surplus pasture, and supplement feeding. In the perfect knowledge scenario the surplus pasture policy looked for an average residual >1700 kg DM/ha; when this was triggered all paddocks >3500 kg DM/ha were cut and the surplus made into pasture silage, accounting for 15% wastage. The assumption was that this manager has the knowledge to identify a rising residual early, and will also accurately identify the correct paddocks with surplus pasture for cutting. In the case of imperfect knowledge the manager monitors covers, albeit with a margin of error, therefore he will also be relatively early in identifying a rising residual >1700 kg DM/ha, but there will be some error in identifying the tallest paddocks to cut, so it was assumed only paddocks >4000 kg DM/ha would be cut. As pasture cover is not assessed by the low knowledge manager, identification of a rising residual and of the correct paddocks for cutting will be problematic, so the rule was altered to cut all paddocks >4000 kg DM/ha when the average residual is >2000 kg DM/ha.

In the perfect knowledge scenario the supplement policy resulted in cows being fed supplement to meet their energy requirements whenever there was a pasture deficit. Supplements were taken first from the pasture silage feed store until it ran out, and then purchased palm kernel expeller (PKE) was fed. At the end of the simulated year the feed store was topped up to the starting amounts with the costs reflected in the operating profit. The starting pasture silage feed store was 20 t DM for all scenarios. With perfect knowledge it was assumed that feed demand and pasture allowance were known, which meant that supplements could be fed in exactly the right amounts after pasture feeding, i.e., no under- or over-feeding on any particular day. In the imperfect and low knowledge scenarios pasture allowances, deficits, and exact amounts of supplement to feed are not known with complete accuracy. This situation was mimicked in the model by feeding the supplement amounts extracted from the perfect knowledge scenario in the imperfect and low knowledge scenarios, but in the case of the latter two, supplements were fed before cows were put to pasture so that paddock selection and, therefore, pasture allowance dictated the overall level of feeding. This resulted in less accurate feed allocation in the imperfect and low knowledge scenarios.

All scenarios were run with economic input for 2012/13 year (DairyNZ Limited 2014) with prices of

Table 1 Model output for a typical Waikato farm with three paddock selection policies for three pasture growth years; poor – 2012/13, normal – 2013/14, good – 2004/05. Operating profit is based on a milk price of $6.33/kg milksolids.

		Perfect knowledge	Imperfect knowledge	Low knowledge
Annual pasture yield (t DM/ha)	poor	16.7	15.9	15.5
	normal	18.1	17.1	16.9
	good	21.2	20.4	19.5
	Average	**18.7**	**17.8**	**17.3**
Milksolids production (kg/ha)	poor	1287	1267	1211
	normal	1280	1291	1230
	good	1281	1284	1190
	Average	**1283**	**1281**	**1210**
Cost of supplements ($/ha)	poor	1994	2013	1985
	normal	1622	1759	1729
	good	589	701	699
	Average	**1402**	**1491**	**1471**
Operating Profit ($/ha)	poor	2557	2377	2082
	normal	3005	2902	2585
	good	3970	3833	3289
	Average	**3177**	**3037**	**2652**

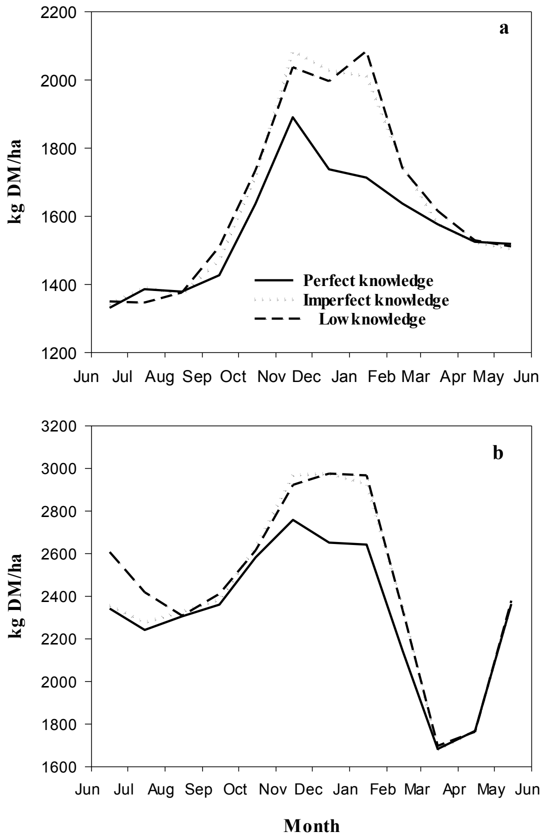

Figure 2 Monthly average post-grazing residual pasture mass (a) and farm pasture mass (b) for three paddock selection policies.

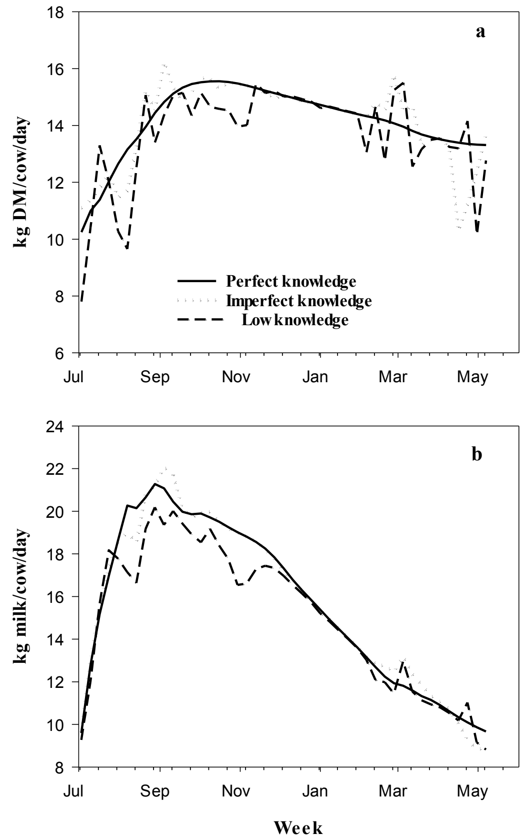

Figure 3 Weekly average feed eaten (a) and milk production (b) for three paddock selection policies for the 2013/14 climate year.

$290/t DM for bought-in silage, $270/t DM for PKE, $140/t DM for cutting silage from the milking area, and $40/t DM for feeding supplements. The milk price was $6.33/kg milksolids, but sensitivity was tested for $5 and $7. Outputs collected for the three paddock selection policies for three climate years were monthly pasture covers, annual pasture yield, milk production, supplement costs and operating profit.

Results and Discussion

Annual pasture yields increased from low knowledge to imperfect to perfect knowledge scenarios (Table 1). The higher pasture yield in the perfect knowledge scenario is explained by lower average farm covers and post-grazing residuals in November to February compared to the imperfect and low knowledge scenarios (Figure 2). Lower average covers and residuals reflect a combination of perfect paddock selection and a timely and accurate surplus pasture policy where increasing residuals are identified early and the correct paddocks cut for silage. Although differences in average covers and residuals were less obvious between imperfect and low knowledge scenarios, the lower covers in June-July and lower residuals in September resulted in approximately 0.5 t DM/ha more pasture yield in imperfect compared to low knowledge scenarios. More pasture is grown by keeping average pasture cover in the rapidly growing phase of the grass growth curve. This is achieved by having good post-grazing residuals, around 1500 to 1700 kg DM/ha, and not letting covers at the top end of the paddock wedge get too high (Parsons *et al*. 1988).

There was no difference in milk production per hectare between the perfect and imperfect knowledge scenarios, but much lower production was observed in the low knowledge scenario (Table 1). Milksolids production per hectare was the result of feeding and production per cow as shown in Figure 3. The relatively smooth profiles for feed eaten and milk production with perfect knowledge was the result of known pasture allowances and therefore perfect allocation of supplements to fill pasture deficits. In contrast, both imperfect and low knowledge resulted in periods of under- and over-feeding resulting in fluctuating intakes and milk production. Periods of under-feeding were more frequent and more severe in low knowledge compared to imperfect knowledge, indicating that paddock selection and, therefore, pasture allowance was more often wrong in the low knowledge scenario. The occasional over-feeding in both of these scenarios, and the consequent increase in milk production during these periods, was the result of substitution of pasture for supplements. This substitution wasted pasture, but increased total dry matter intake during these periods (Stockdale 2000). In the case of pasture silage and PKE, the substitution rates were assumed to be 0.7 and 0.5 kg DM pasture/kg DM supplement, respectively. In essence, both under- and over-feeding stems from poor paddock selection and supplement feeding based on unknown pasture allowance.

Milksolids production and cost of supplements were the main factors that influenced operating profit and the differences predicted for the three paddock selection policies. Profit was approximately $140/ha higher in perfect compared to imperfect knowledge scenarios (Table 1), mainly driven by higher cost of supplements in imperfect knowledge because of less pasture grown, less silage made, and more PKE purchased. The higher profit of approximately $385/ha in imperfect compared to low knowledge scenarios was mainly driven by lower milk production in the low knowledge scenario, the result of more frequent and more severe under-feeding of lactating cows because of no knowledge of pasture cover and allowance. The value of $385/ha was sensitive to milk price and changed to $290/ha at $5, and $430/ha at $7/kg milksolids.

The combined potential benefit of $525/ha for estimating pasture covers resulting in improved paddocks selection, feed allocation and management of surpluses, or $385/ha when estimates include an average error of 15%, must be compared with an estimated cost of $23/ha/year for weekly pasture assessments over 46 weeks in a year (Crawford *et al*. 2015) and a small cost for improved operational grazing management decisions.

Conclusion

The results suggest that pasture cover monitoring and paddock selection based on this knowledge, accepting an average error of 15%, combined with good surplus management and inevitably more uniform feeding of the herd, increases farm operating profit to the value of $385/ha on a typical pasture-based dairy farm, with a further $140/ha on offer for perfect pasture knowledge. These estimated value propositions should be used by farmers when evaluating the cost of time and equipment for improved pasture monitoring and grazing management.

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