Evaluating the benefits of restricted grazing to protect wet pasture soils in two dairy regions of New Zealand

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Abstract. Many dairy farms in the Manawatu and Southland regions of New Zealand have poorly drained soils that are prone to treading damage, an undesirable outcome on grazed pastures during the wetter months of the year. Removing cows to a stand-off pad during wet conditions can reduce damage, but incurs costs. The objective of this study was to evaluate the impact of different levels of restricted grazing (from 0 to 10 hours grazing time/day for lactating cows) on pasture yield, damage and wastage, feed and stand-off expenses, and farm operating profit. A simulated farm from each region was used in a farm systems model. This model simulated pasture-cow-management interactions, using site-specific climate data as inputs for the soil-pasture sub-models. Days to recover previous yield potential for damaged paddocks can vary widely. A sensitivity analysis (40 to 200 days to recover) was conducted to evaluate the effect of this parameter on results. Full protection when there is risk of damage (0 grazing hours/day) appeared to be less profitable compared with some level of grazing, because the advantages of reduced damage were outweighed by the disadvantages of managing infrequently grazed pastures. The differences in operating profit between full protection and some level of grazing became less as the recovery time increased, but for both regions grazing durations of 6-8 hours/day when a risk of damage is present appeared to be a sensible strategy irrespective of recovery time.

Keywords: Treading damage, pasture utilization, profitability, simulation modeling, stand-off area.

Introduction

Treading damage (also referred to as pugging) is prevalent on many dairy farms in the Manawatu and Southland regions of New Zealand (Drewry *et al.* 2000), and is regarded by many farmers as inevitable. In a review describing the natural recovery of soils affected by treading damage, Drewry (2006) states recovery times range between a period of weeks to, in some cases, years. This variation largely reflects the extent to which subsequent grazing events coincide with high soil moisture contents. In practice, the application of restricted grazing (standing cows off pasture) with the intention of protecting soil structure needs to be balanced against other concerns. For instance, standing cows on a stand-off area during wet conditions adds capital and maintenance costs, may require feed supplementation to ensure adequate intakes, and may result in increases in average herbage mass with a consequence of depressed net pasture growth rates because of greater losses through senescence (Chapman and Lemaire 1993).

The objective of this study was to use a farm systems model, representing pasture-cow-management interactions, to evaluate the impacts of different levels of restricted grazing (from 0 to 10 hours grazing time/day for lactating cows) on pasture yield, pasture damage and wastage, feed and stand-off expenses, and farm operating profit.

Methods

The DairyNZ Whole Farm Model and modifications

The DairyNZ Whole Farm Model (WFM; Beukes *et al.* 2008) has been developed to assist with analysis and design of dairy farm systems experiments through scenario testing under various system interactions that occur over multiple years. The pasture-soil model in WFM (Romera *et al.* 2009) is climate-driven using weather data provided by the National Institute of Water and Atmospheric Research (NIWA) from the nearest weather station. A standard soil water balance is used to predict soil water content. The water balance is modelled for two soil horizons. Surplus rain water is considered to drain through the profile or run off on the soil surface. Water is also lost from the soil through evapo-transpiration, which is a function of potential evapotranspiration and available soil water (Romera *et al.* 2010). Pasture growth responds to nitrogen fertiliser (N) applied as either mineral fertiliser or effluent applied as irrigation. Paddocks are grazed rotationally and a particular herd of cows may take several days to graze all the breaks in a particular paddock depending on rotation length at the time. Post-grazing herbage mass (residual) is determined by the model as a function of the feed demand of the herd, grazing hours, and the herbage allowance on that day. The WFM is coded to allow an average pasture intake of 2 kg

DM/cow/hour following the results of Gregorini *et al.* (2009). The residual herbage mass influences pasture re-growth rate of the paddock. Paddocks can be eliminated from the grazing rotation for all or part of the year as part of a cropping regime using *e.g.* maize, cereal or brassica crops. Paddocks can be closed for conservation and cut for pasture silage according to user-defined settings for maximum allowable herbage mass and soil moisture conditions that allow machines to enter the paddock. Supplements (home-grown or purchased) can be fed to cows according to policies created by the user. Other user-defined policies related to cow management include breeding, grazing off the farm, stand-off, drying off, culling and replacement.

Two modifications had to be made to the WFM code for this study. The first was to implement a treading damage module representing the loss of pasture re-growth potential when cows are allowed to graze a paddock when soil moisture levels exceed a certain threshold. In the model, this threshold is a user-defined moisture percentage below which there is no damage, but above which a loss of pasture growth potential occurs. The loss is a function of stocking density (animals/ha for a particular break) and grazing duration (hours/day). This pasture loss function was coded following the work by Betteridge *et al.* (2003). Time on pasture or grazing duration is determined by user-defined settings for time in the dairy parlour, time on the races or lane ways, time on the feed pad (concrete surface with feed bins; user-defined in the supplementary feeding policy and dependent on type and amounts of supplements fed), and time on the stand-off pad (user-defined in the stand-off policy; this can vary from 19 hours stand-off for no pasture grazing to 0 hours stand-off for 19 hours on pasture for lactating cows). The WFM was coded to accept a user-defined recovery time (days), during which the initial percentage loss diminished linearly to zero. For example, Betteridge *et al*. (2003) observed that a dairy pasture fully recovered after 55 days following severe damage that reduced initial pasture re-growth potential by 50%. A further simplification was required when pugging damage compounds on the same paddock due to two consecutive pugging events. The solution was to integrate the total percentage loss left from the first pugging event (area under the curve: percentage loss versus days left to recover) and combine it with losses calculated following the second grazing event.

The second modification was to develop a wastage module that represents the increasing loss of herbage trodden to or below ground level with increasing soil moisture levels (Sheath and Boom 1997). Data from a historical report by D.C. Causley (unpublished 1975) indicated that herbage wastage increases linearly up to field capacity at which point losses averaged 16%. Average wastage on saturated soils (exceeding field capacity) was 40%. This was implemented in the WFM by allowing no wastage up to 50% field capacity, then a linear increase in wastage up to 16% at field capacity. The pasture-soil model in WFM does not simulate soil moisture above field capacity but shows drainage when it rains on a soil already at field capacity. A drainage factor (5 mm increments) in the model was used to simulate increased wastage from 16 to 40% on rainy days when the soil was at field capacity. The wastage loss (%) was deducted in a ratio of 1:1 from the potential herbage intake of a herd of cows (kg DM), and from the potential post-grazing herbage mass under dry conditions (residual, kg DM/ha). Calculating the loss from potential intake is important because it makes wastage dependent on stocking density, in that more stock increases potential intake resulting in more wastage in absolute terms. The loss from potential post-grazing herbage mass is also important because it places the pasture at a disadvantage where re-growth is compromised depending on how low the post-wastage residual is. In the model, wasted pasture (kg DM/ha) was added to litter and disappeared as a result of decay.

Simulations and measurements

The WFM was initialised for a representative farm in each region for the 2010/11 farming season (1 June 2010 to 31 May 2011, Table 1) using climate data for actual sites. A series of factorial experiments were set up in the WFM by stepwise alteration of stand-off hours to achieve grazing times of 0, 2, 4, 6, 8, or 10 hours on pasture/day whenever there was a pugging risk on paddocks before grazing. The stand-off rules were designed assuming 4 hours/day were required for milking twice a day, and 1 hour/day was required for time on the lane ways. Home-grown or purchased supplements were fed when grazing times did not allow cows to obtain their daily requirements from grazing alone. A sensitivity analysis was conducted to evaluate the effect of recovery time. Time for a pugged paddock to recover fully (days) was altered from 40 to 200 with increments of 40 days, creating 6 x 5 factorial combinations. In an attempt to capture the effects of climate variability, each combination was run over three climate blocks (using historical climate data from NIWA) for three consecutive farming seasons each, 2002-2005, 2005-2008, and 2008-2011, giving a total of 180 simulations. The same economic input (2010/11 cost structure and a milk price of $7.36/kg milksolids) was repeated for all simulated climate years to avoid potentially confounding effects of variable economic inputs on treatment effects. Results from the first year of each three-year simulation were discarded because

Table 1. Physical input parameters describing the simulated farms in the Southland and Manawatu regions of New Zealand.

	Southland	Manawatu
Milking platform area (ha)	170	188
Support block area (ha)	102	0
Stocking rate (cows/ha)	2.82	2.7
Planned start of calving	10-Aug	1-Jul
N fertilisation (kg/ha/yr)	140	150
Supplements purchased	Pasture silage	Pasture silage, maize silage, palm kernel expeller
Wintering of non-lactating cows	On the stand-off pad on the milking platform	Grazed on the milking platform

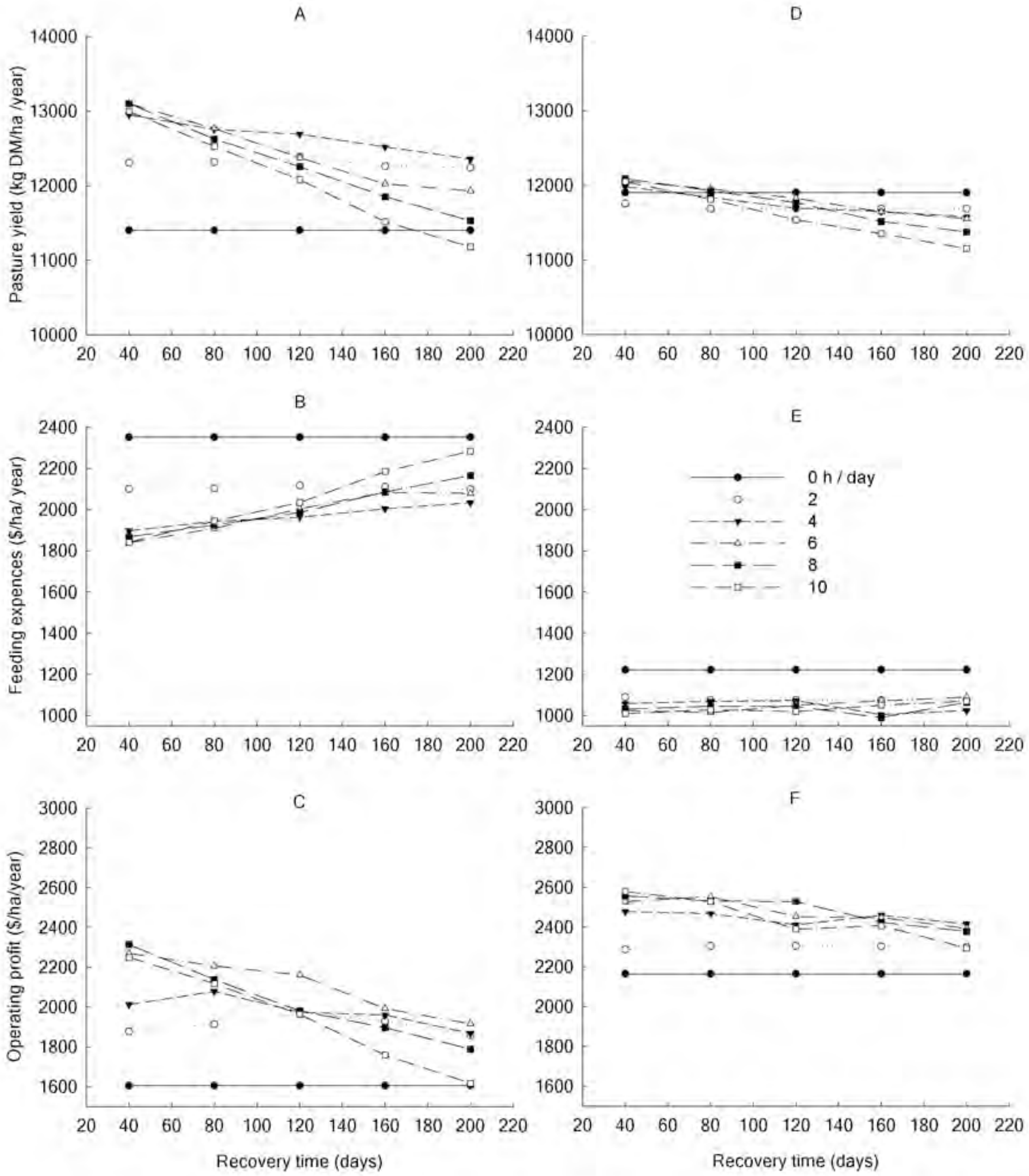

Figure 1. Predicted results for scenarios with different stand-off treatments (grazing time varying from 0 to 10 hours/day) and pugging recovery time for the Manawatu (graphs A, B, C) and Southland (graphs D, E, F) regions of New Zealand. The legend is shown in graph E.

it was regarded as a run-in year allowing soil moisture and pasture covers to stabilise. Model outputs were averaged over years two and three of the three-year climate blocks and are presented as graphs with days for pasture growth rates to recover from pugging damage as the independent variable. Stand-off costs were divided into fixed (depreciation and interest depending on capital costs) and variable costs (*e.g.* maintenance, labour, extra insurance and effluent disposal), of which the latter were calculated based on model predictions of usage (number of cows × hours on stand-off pad).

Results

In both regions the scenario with full grazing restriction (0 grazing hours/day when pugging was a risk) showed the lowest operating profit, irrespective of recovery time (Fig. C, F). In Southland the main reason for this was the high feeding expenses associated with full restriction Fig. 1E), and in Manawatu it was a combination of lower pasture yield (Fig. 1A) and high feeding expenses (Fig. 1 B) associated with full restriction.

Higher pasture yields with partial grazing restriction in the Manawatu suggested that some form of grazing, especially by dry cows in winter, resulted in lower residuals that kept pastures in a faster growth phase. With slower growth rates in winter, no dry cow grazing and about double the number of pugging risk days compared to Manawatu, Southland did not show the same gains in pasture yield with some form of partial grazing restriction.

Conclusion

Full protection (0 grazing hours/day when pugging risk) appeared to be less profitable compared with some level of grazing (6-10 hours/day), because the advantages of reduced damage were outweighed by the disadvantages of increased pasture senescence and the costs of making and feeding silage and/or importing supplementary feeds. When pastures growing on wet soils are fully protected in a rotational grazing situation, pasture cover builds up in front of the cows resulting in slower daily growth rates (as a result of shading), higher senescence rates and, therefore, lower net herbage accumulation. Silage cutting machines cannot access wet soils resulting in permanent herbage losses that could outweigh the benefits of protection. The difference in operating profit between full protection and some level of grazing was less as the recovery time increased, but for both the Southland and Manawatu regions grazing for between 6 and 8 hours/day when a pugging risk was present appeared to be a sensible strategy irrespective of recovery time.

References

Betteridge K, Drewry JJ, Mackay, AD, Singleton PL (2003) Managing treading damage on dairy and beef farms in New Zealand. Publication by Land and Environmental Management, AgResearch Ltd, Hamilton, New Zealand.

Beukes PC, Palliser CC, Macdonald KA, Lancaster JAS, Levy G, Thorrold BS, Wastney ME (2008) Evaluation of a Whole-Farm Model for pasture-based dairy systems. *Journal of Dairy Science* **91**, 2353-2360.

Causley DC (1975) A preliminary investigation of the importance of herbage losses due to treading of grazed pastures. Unpublished Internal Report, Grasslands Division, DSIR, New Zealand.

Chapman DF, Lemaire G (1993) Morphogenetic and structural determinants of plant regrowth after defoliation. Proceedings of the XVII International Grassland Congress. Pp. 95-104.

Drewry JJ (2006) Natural recovery of soil physical properties from treading damage of pastoral soils in New Zealand and Australia: A review. *Agriculture, Ecosystems and Environment* **114**, 159-169.

Drewry JJ, Littlejohn RP, Paton RJ (2000) A survey of soil physical properties of sheep and dairy farms in southern New Zealand. *New Zealand Journal of Agricultural Research* **43**, 251-258.

Gregorini P, Clark CEF, Jago JG, Glassey CB, McLeod KLM, Romera AJ (2009) Restricting time at pasture: effects on dairy cow herbage intake, foraging behaviour, hunger-related hormones, and metabolite concentration during the first grazing session. *Journal of Dairy Science* **92**, 4572–4580.

Romera AJ, Beukes PC, Clark C, Clark DA, Levy H, Tait A (2010) Use of a pasture growth model to estimate herbage mass at a paddock scale on dairy farms. *Computers and Electronics in Agriculture* **74**, 66-72.

Romera AJ, McCall DG, Lee JM, Agnusdei MG (2009) Improving the McCall herbage growth model. *New Zealand Journal of Agricultural Research* **52**, 477-494.

Sheath GW, Boom CJ (1997) Impact of beef cattle grazing systems on treading damage and forage supply. *Proceedings of the New Zealand Grassland Association* **59**, 87-92.