Developing decision support tools for restricted grazing managements to mitigate environmental impacts

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Abstract. A project funded by the New Zealand Government in support of the Livestock Research Group of the Global Research Alliance investigated the development of a soil moisture-based decision tool for applying restricted grazing strategies to wet soils to reduce nitrous oxide emissions, pugging damage and nitrate leaching. Two industry workshops tested the decision support framework and potential implementation strategies. The North Island group, with little experience, learned the complexity of restricted grazing, compared to their previous thinking. The South Island group, practicing forms of restricted grazing, had developed practices that suited their farms, based on their current knowledge and observation. The inexperienced group wanted cost-benefit analyses and detailed grazing plans, while the experienced group required detail about how a mitigation tool would be implemented. These findings confirm that previous experience must be accounted for in the interpretation and development of implementation pathways of a new technology.

Keywords: dairy systems, decision support, nitrate leaching, nitrous oxide, pasture growth, soil pugging.

Introduction

Nitrous oxide (N_2O) emissions from soils beneath grazed and fertilised pasture are highly regulated by soil water content. This provides an excellent opportunity to develop an on-farm decision support system (hereafter, DSS) tool with potential to reduce annual emissions by connecting the timing of livestock grazing and N applications (fertiliser and manure) to soil water conditions.

In pasture-based grazing systems, N_2O emissions come primarily from urine patches and/or fertilisers and manures. Under non N-limited conditions, N_2O production is highly sensitive to soil water content (e.g., van der Weerden et al. 2012). The effect of rainfall on soil water content and therefore N_2O production will be influenced by a soil's drainage rate. Soil compaction from livestock treading will also reduce the oxygen diffusion rate and drainage rate (Houlbrooke & Laurenson 2013; van Groenigen et al. 2005).

A project funded by the New Zealand Government in support of the Livestock Research Group of the Global Research Alliance commissioned an assessment of the potential reduction in N_2O emissions from pastoral farms using a soil water-based DSS. This approach needs to be able to provide guidance on optimised timing of stock movements and N inputs (fertiliser, manure) in order to avoid periods when soils are above a pre-determined water content threshold. A similar framework has been developed for determining where and when to apply effluent (Houlbrooke et al. 2010).This research builds on this and used discussions with farmers to determine the practicalities of moving stock on and off paddocks based on soil water content to reduce N_2O emissions.

Co-benefits of this project include reduced soil compaction and deformation during wet periods if animals are removed from 'at-risk' paddocks onto standoff pads or feed pads (e.g. Betteridge et al. 2003; Beukes et al. 2013), and a potential to reduce nitrate leaching (Di & Cameron 2002). This ensures soil structure, drainage and pasture production are maintained, while also reducing the risk of sediment loss (Monaghan et al. 2007).

Initial assessments of potential reduction in N_2O emissions focused on dairy systems because of the greater associated N inputs and excreta deposition (N load per urine patch) per unit area compared to sheep and beef systems. The project had four objectives:

1. Identification of key soil moisture thresholds relating to N_2O emissions
2. Development of a decision support approach to reduce N_2O emissions
3. Quantification of potential reduction in N_2O emissions at the field/paddock and farm scale
4. Assess the practical implementation of decision support tool and associated validation of effect

This paper focuses on the process and outcomes from end-user engagement in the development of one aspect of the DSS: an on-farm soil water-based tool to assist with timing of stock movement.

Methodology

Detailed information obtained from process-based modelling (APSIM; Keating et al. 2003) and data mining was used to develop a DSS for discussion with farmers at two workshops (Table 1). The workshop sites were chosen to represent regions with the greatest risk of waterlogged soils during grazing. The proposed DSS identified a recommended management approach for two soil risk categories in relation to estimated soil water content when stock may be grazing. An initial investigation of this approach, in conjunction with a whole farm systems experiment, identified significant issues with the whole day/several day approach to restricting grazing by cows (Laurenson et al. 2014). This resulted in modification of the approach to investigate the use of partial grazing periods each day to balance the provision of nutrition to the cow and protection to the soil. The project team also identified that cows might be removed from the paddock periodically (i.e. 13 hours a day) during autumn (March to May) with the intention of reducing $NO_3^{-}N$ leaching. The impact of restricted grazing, including 'on-off' grazing practices, on N_2O emissions, pugging and treading damage, pasture production and potential N leaching were assessed using a simplified spreadsheet approach. A partial cost:benefit approach was included.

Table 1. Version 1 of framework to assist farmers deciding on when to use restricted grazing practices to reduce pasture damage, based on soil water content.

Well drained		Poorly drained	
If VWC ≤ 105% of FC	If VWC > 105% of FC	If VWC ≤ 85% of FC	If VWC > 85% of FC
SAFE	CAUTION	SAFE	CAUTION

VWC = volumetric water content; FC = field capacity

The DSS along with some approximate costs associated with implementation (e.g. cost of feed, manure handling) and potential benefits from reduced N_2O emissions, nitrate leaching or pugging damage was presented and discussed with two farmer and industry user-groups, one in the Tararua and one in the South Otago region (Figure 1).

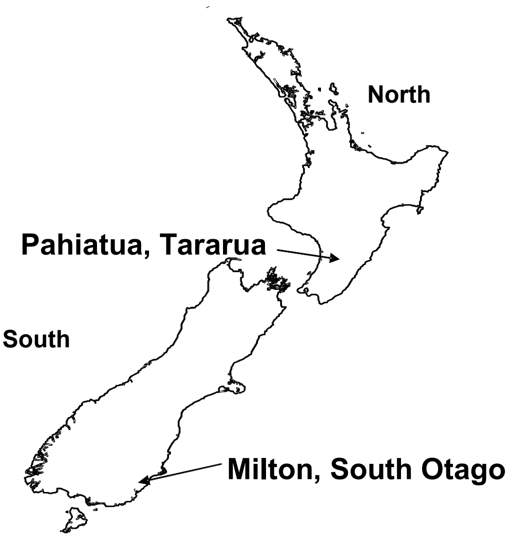
At this discussion forum, detail of potential impacts associated with implementation of this DSS on whole farm operations (i.e. feed requirements/supply, labour demand, economic cost/benefit and animal health) was provided in the following workshop approach.

Workshop outline

A three-hour workshop was run at each location. Attendees included farmers, agribusiness and regional authority representatives. The workshops began by exploring initial thinking around the concept of restricted grazing, including on-off grazing. This was followed by a discussion about current understanding of the concept and its implications for production and management. A science presentation delivered the current science associated with N_2O, pugging and nitrate leaching risks in the specific regional environment of the workshop. A cost-benefit analysis of different options was also presented. Following this the original questions were asked again and discussed to gauge development and understanding of the issues involved. Finally questions were asked to address the practical implementation of the management practices and what form the tool would need to take for implementation. The questions used for discussion and feedback on the DSS and outline of the workshop are presented below.

- Initial position of attendees
  - Would you consider some form of restricted grazing?
  - What options would you consider (feed-pad, barn etc.)?
  - What are pros and cons of these?
  - Group discussion of key points, plus main pro and con
- Science and cost-benefit presentations
- Post-presentation position of attendees
  - Would you consider some form of restricted grazing?
  - Which management option is applicable to your farm?
  - How & why could management be adapted?
- In an ideal world- what does the tool look like?

Figure 1. Location of farmer workshops in the North and South Island of New Zealand



Workshop results

There were 20 attendees at the Tararua workshop. Most of those present were rural professionals, with 6 farmers present. At the South Otago workshop there were 12 attendees and most of those present were farmers (9). Rural professionals included regional policy, agribusiness and education. The farmers represented a similar range of farm types at each workshop.

All attendees recognised a value in some form of restricted grazing. The systems that were considered (Figure 2) represented a wide range of options. Loafing pads were seen as the most likely choice, while the use of a lower stocking rate (SR) to reduce environmental impact was the least preferred.

Advantages and disadvantages of restricted grazing

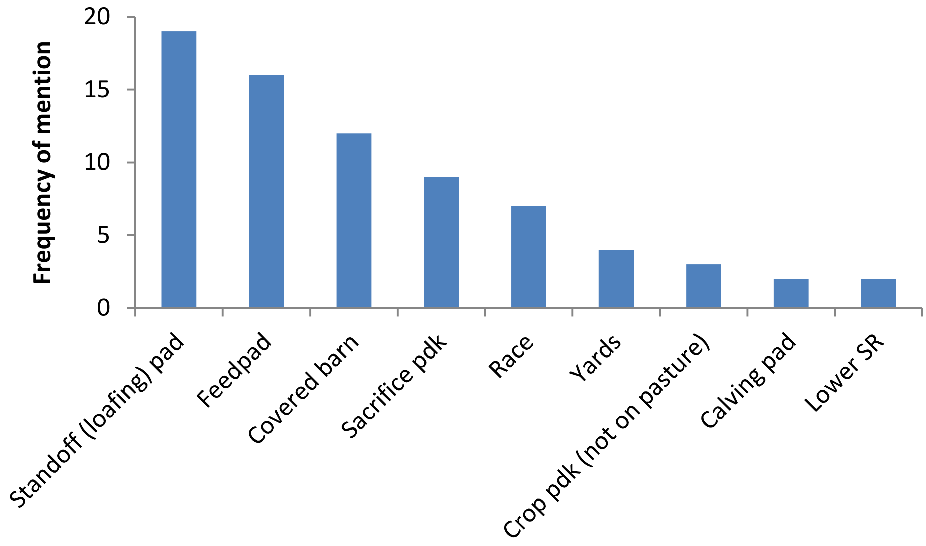
Participants at both workshops identified a similar list of advantages and disadvantages in restricted grazing systems. The extent of each advantage or disadvantage was unique to the different forms of restricted grazing that were identified in Table 2.

Tararua

Initial position of attendees. Farmers in the Tararua group were wintering cows on-farm and so restricted grazing approaches were applicable throughout the year. Most attendees were not formally practicing restricted grazing, but recognised the value of reduced pasture damage and increased feed utilisation on wet days. The cost (capital, effluent management and labour) made the option less attractive. It was strongly felt that it is difficult to quantify the cost:benefit, and examples of good execution of restricted grazing and thorough cost:benefit analysis were required. One farmer using a stand-off pad acknowledged that financial benefits could not be quantified because of a lack of monitoring or managing where efficiencies might be occurring. This highlights the complexity of the system i.e. an informed farmer will make a good decision, but an uninformed farmer may make a poor decision. This also highlights that any use of restricted grazing will need to include systems awareness training.

Animal welfare (lameness) was noted as a potential issue by several present, therefore clear guidelines are required in relation to animal health.

Figure 2. Summary of systems farmers would consider to achieve a restricted grazing strategy



Note: individuals were able to list a number of systems. Therefore sum of frequency exceeds workshop attendee numbers

Table 2. A list of the major advantages and disadvantages of restricted grazing identified in the two workshops

Advantages	Disadvantages
Lowering environmental impact (incl. nitrate leaching, GHG emissions)	Capital cost (incl. slow return on capital)
Reduced fertiliser inputs	Effluent management
Peace of mind (stock management)	Mastitis risk
Feed utilisation	Extra labour
Cow condition	Hard surfaces (increased lameness risk)
Pasture protection	Machinery requirements
Potential co-benefits were identified with some systems e.g. fully housed systems allow for full ration development and lower machinery running costs	System change (incl. necessary management changes required to ensure a return on investment)

Detailed summary of each workshop

Post-science presentation position of attendees. Following the science presentations, attendees acknowledged how much more complex the system becomes when using restricted grazing. One noted "no change to my thinking (regarding adopting restricted grazing), but I've got more to think about now". Feed quality and supplement requirements would influence when and how frequently to stand cows off, with weather forecasts in the early lactation period considered as helpful.

Pasture residual management was highlighted as one of the hardest aspects of the restricted grazing system to master. The practicality of achieving appropriate feed intake, while managing the current and potential future condition of the pasture, was a significant discussion point among attendees. The facts presented included cow intake rates under different conditions and how to use this information. For example, it takes about 4 hours to consume 80% of the requirement feed intake, so the discussion revolved around how to manage intakes and allowances to maximise intake, minimise pasture damage and minimise future declines in pasture quality. One of the challenges highlighted was not knowing when cows had consumed a specific proportion of the dietary requirement so that production loss from inadequate allowance would be mitigated.

It was noted that feeding cows on the pad with a small amount of supplement prior to opening the gate was preferable, because it is easier to control how much supplement to feed out. It was generally acknowledged that feed-use efficiency needed to be improved, which would require a higher average staff skill level.

It was generally felt that there was no one restricted grazing regime (e.g. 4 hours on - 4 hours off) that would work for a given farm. Instead, there is a need to retain flexible livestock, soils and feed management, within the constraints of labour availability.

South Otago

Initial position of attendees. Farmers in the South Otago group were wintering cows off-farm and so restricted grazing approaches were applicable during spring summer and autumn.

All farmers present practiced restricted grazing in some form, generally to reduce pasture damage and increase feed utilisation in the spring. The soil issues of reduced pasture utilisation and loss of future pasture production were well understood by attendees. The group identified capital and maintenance costs as the main disadvantages, with effluent management (cost, inconvenience and storage) also noted by several.

While the group were users of restricted grazing, the questions around cost:benefit and how feed quality and utilisation could be optimised were still apparent. Generally, the use of stand-off pads and sheds was part of the daily routine, rather than active restricted grazing management. One farmer did note that his milk production has increased due to taking cows off paddocks during wet spells and there was a marked improvement in soil quality. Each farmer had developed a solution that met his needs with the resource available. This created debate about what was best as each participant had a different understanding of how the practice worked.

Farmers acknowledged that council regulation may cause a shift towards restricted grazing (off paddock facilities) because of N leaching limits (Otago Regional Council Plan 6A) and public perception. Sacrifice paddocks were seen by several farmers as a low cost option, however this does not reduce the environmental (N_2O, N leaching) issues. Reduced stocking rate was also noted by several farmers as a low-cost option for reducing environmental impact. The use of laneways was considered low-cost but animal welfare and lane maintenance were detractors.

Post-science presentation position of attendees. Following the science presentations, awareness of autumn being a season for targeting restricted grazing as a way of reducing nitrate leaching was increased. This particular topic received a great deal of attention, as the attendees already understood the benefits of restricted grazing for reducing soil and pasture damage. For some farmers on autumn dry soils, there would be no benefit from reducing soil and pasture damage, but a benefit in reducing nitrate leaching. Refinements to existing structures were considered, such as adding a roof to exclude rainwater from ponds and then collect rainwater to be used when paddock conditions were dry.

Those with barns see them as providing peace of mind, with better feed utilisation and cow condition. Also, one farmer noted he prefers to avoid mud, and with his barn has achieved this. He also noted a reduction in fuel use and machinery maintenance, never needing to drive through mud anymore and no longer requiring 4WD. However, those without barns still struggled with the cost:benefit of such an investment, particularly with current low milk prices. Using crops as an alternative was also not very attractive, as one farmer noted it could take 15-16 months before land was back in pasture due to soil damage.

Participants had significant experience with managing feed with restricted grazing. Farmers had identified the use of stand-off facilities prior to paddock grazing. Farmers had developed experience in attaining their expected pasture utilisation (quoted by one farmer to be 'within 5% of target intake'), when cows were let onto paddocks following feeding on the pad/in the shed after milking. The fate of pasture is uncertain as it may be grazed or trampled in wet conditions. However, farmers were basing their utilisation of pasture on achieving their milk production expectations, rather than an understanding of any underlying biophysical processes. As noted in Tararua, there can be many applications of the principles, rather than selecting a single restricted regime. There was generally consensus that restricted grazing would best be practiced in early spring and late autumn, although decisions on when to restrict grazing was influenced by the farmer's objective (autumn for nitrate leaching and pasture damage, spring for pasture damage only) while also wanting to remain pasture grazing-based systems. From a farm system perspective, it was noted that for some farmers it wouldn't be possible for all the cows to be off at once – they would need to be rotated thereby reducing stocking rate. Also, the associated costs of machinery and labour would need consideration in relation to the size of the farm.

In an ideal world- what does the tool look like?

The type of assistance farmers wanted for decision making was similar at both workshops. This included on-farm soil moisture data as most important, with current (effluent) irrigation technology recognised as able to provide appropriate data. This would need to be associated with regionally specific known soil moisture threshold values or ranges. Two-day weather forecasting was also identified as a useful aid but current forecasting beyond 2 days was seen as less accurate.

Discussion

Each of the two groups identified similar advantages and disadvantages for the restricted grazing strategy. The key outcome for both groups was that the drivers of implementing such approaches were firstly production-based (limiting pasture damage and protecting future pasture growth). The second driver was the potential implications from changes in regional rules regarding water quality and nitrate leaching. Other drivers included animal welfare and systems fit, but N_2O emissions were of little importance. This was likely due to no existing incentive (financial or otherwise) for reducing greenhouse gas emissions.

The timing of implementing restricted grazing systems to prevent pasture damage is generally during spring and autumn, while potential to reduce nitrate leaching is during autumn only, and reductions in N_2O emissions are greatest with winter and early spring restrictions. These timings had some conflict with feeding systems and profitability of implementation which led to the choice of drivers by the farmers.

The two groups differed in their experience of restricted grazing management. The Tararua group were relative novices in their understanding and implementation of restricted grazing. The South Otago group were more expert. This led to different discussions around how the management would work. One group focussed on how to develop mixed grazing/supplementary feed systems, while the other group focused on how to achieve more impact (such as reducing nitrate leaching potential).

A key difference between the groups then was that one group had mainly theoretical knowledge, while the other group also had practical knowledge of the approach. This led to different issues being important to the two different groups. While one group wanted full cost-benefit analyses and detailed grazing plans, the other group understood these aspects and required more detail about how a mitigation tool would be implemented. Each group focused on different environmental impacts that were regionally important. These findings confirm that previous experience must be accounted for in the interpretation and development of implementation pathways of a new technology. Investigation into the development of this tool is on-going.

Summary – key points

- Farmers recognised the value of restricted grazing strategies for environmental and productivity benefits.
- Expert/practiced farmers understood the trade-offs and had developed practical ways to balance the advantages and disadvantages, while novice farmers were unsure of how to make the practice work.
- Value from implementing the technologies must include a financial component, as there may be costs associated with the new practice that must be met by improved productivity or reduced costs elsewhere.

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