PFR SPTS No. 11586

SLMACC – Recommendations for irrigation management and grazing timings to minimise N_2O emissions.

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November 2015
















Confidential report for:

MPI
Ref: SLMACC PFR30735
Milestone 9 report

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PUBLICATION DATA

Thomas S, Vogeler I, van der Weerden T, Carrick S. May 2015. SLMACC - Recommendations for irrigation management and grazing timings to minimise N2O emissions. Milestone 9. A Plant & Food Research report prepared for: MPI. Milestone No. 52246. Contract No. 29182. Job code: P/553011/01. SPTS No. 11586.

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EXECUTIVE SUMMARY

SLMACC – Recommendations for irrigation management and grazing timings to minimise N_2O emissions.

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November 2015

This report provides draft recommendations to MPI for irrigation management and withholding grazing timing to minimise N_2O emissions. These are largely based on the findings Sustainable Land Management and Climate Change (SLMACC)-funded programme (PFR30735) – Managing irrigation and grazing timing to reduce nitrous oxide emissions.

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1 INTRODUCTION

This report provides draft recommendations to MPI for irrigation management and withholding of grazing following irrigation to minimise N_2O emissions. These are largely based on the findings Sustainable Land Management and Climate Change (SLMACC)-funded programme (PFR30735) – Managing irrigation and grazing timing to reduce nitrous oxide emissions.

Findings from the programme of research (Thomas et al. 2013b) have been previously reported for three field plot experiments (Thomas et al. 2014; Thomas et al. 2013a), one lysimeter experiment (Thomas et al. 2014) and a simulation modelling exercise (Thomas et al. 2015).

The programme was designed to provide information to derive practical irrigation management recommendations to farmers so that they can minimise N_2O losses.

The overarching hypothesis for the programme:

> *irrigation management and grazing timing following irrigation are key drivers of N_2O emissions on irrigated pasture, and that the management of the amount, application rate and timing of irrigation in combination with timing of livestock grazing can be manipulated to reduce direct and indirect (from NO_3 leaching) N_2O emissions from urine patches.*

2 SUMMARY OF KEY FINDINGS

2.1 Irrigation frequency

- N_2O emissions and emission factors from urine and urea plots increased with irrigation frequency.
- The magnitude of emissions was strongly affected by soil type.
- Emissions from the poorly drained soil were a magnitude greater (EF_3 = 3.5%) compared to the freely drained soil (0.35%).

2.2 Withholding grazing after irrigation

- Soil compaction from simulated stock treading following irrigation increased N_2O emissions from a poorly drained soil.
- Withholding grazing by 6 days (EF_3 = 1.8%) on the poorly drained soil to allow drainage decreased emissions by more than 40% compared to 2 days (EF_3 = 3.1%).
- The withholding period on freely drained soils is expected to be lower, but needs to be established.

2.3 Irrigation intensity, direct and indirect emissions from a freely drained, shallow soil

- Irrigation intensity or application rate (mm/hour) had limited or no effect on direct N_2O emissions from urine patches on a freely draining, shallow soil.
- Direct N_2O emission were low (EF_3 = 0.5 to 0.6%).
- N leaching losses were about 15% of applied urine and were largely unaffected by irrigation intensity.
- Careful management of the timing and amount of irrigation water is required to reduce the risk of leaching losses.

2.4 Options for managing N_2O emissions – results from simulation modelling

- Modelling provides a powerful tool for understanding how climate, soil type, seasonal deposition of urine and irrigation management affect the amount of N_2O emissions.
- Simulations supported the field trial findings which showed that reducing irrigation frequency reduces direct and indirect N_2O emissions. Reducing the amount of irrigation water applied and benefiting from greater storage of rainfall will increase water use efficiency (i.e. kg DM/mm water applied), where pasture production is not penalised.
- N_2O losses reduce with increasing soil water deficits.
- Greatest nitrous oxide emissions are likely to occur from poorly drained soils.
- Dry matter losses occurred with the largest soil water deficits on the shallow soil when supply of available soil water was less than high summer plant demands.
- Rainfall during the irrigation season is an important factor for increasing N_2O emissions when it causes the soil water storage to refill or become saturated.

3 RECOMMENDATIONS

3.1 For irrigation timing and application amounts

That farmers:

- Irrigate at the lowest frequency possible without penalising dry matter production. Our measurements and modelling indicate that
  - bringing the soil back to field capacity or "full point' at each irrigation increases the risk of N_2O and nitrate leaching losses,
  - maximum production can still be achieved by allowing larger soil moisture deficits to build up with less frequent irrigation,
  - larger deficits can be maintained on deeper soils than shallow soils, thus allowing lower-frequency irrigation,
  - maintaining soil moisture deficits (i.e. applying irrigation at amounts that do not refill the soil to field capacity) increases the potential for rainfall capture, thereby increasing irrigation water use efficiency and reducing irrigation costs.
- Use irrigation scheduling tools (e.g. soil water budget with or without the use of soil moisture sensors, or employing irrigation scheduling consultants) to
  - monitor and manage soil water deficit,
  - ensure over-irrigation is avoided, and
  - avoid pasture production losses by optimising irrigation timing,

3.2 For withholding grazing after irrigation

That farmers:

- avoid grazing when the soil is wet following irrigation
  - wet soils are more susceptible to grazing compaction and pugging damage, leading to increased N_2O emissions. Urine deposition when soils are wet or saturated leads to increased nitrate leaching losses,
  - risk is greatest in soils that drain slowly and remain wet following irrigation,
  - the period of risk is reduced if soil moisture deficits are maintained enabling more rapid infiltration of irrigation water.

4 NEXT STEPS

We have some simple messages that can be used to inform a farmer of the potential consequences of their irrigation decisions on N_2O emissions and nitrate leaching losses, and some recommendations on how to best manage irrigation to minimise risk of high emissions and leaching losses without penalising production.

Based on these findings, we propose that we deliver this information via a simple, use friendly farmer guide or fact sheet. In our initial proposal this was suggested as a prototype look-up table, we no longer think this is the best or practical solution. We will approach Irrigation NZ and DairyNZ for feedback on the best method(s) to deliver this information.

Our proposed guide would include: (i) simple explanation of how irrigation can have an effect on the environmental losses of N_2O and nitrate (i.e. risks associated with maintaining high water contents); (ii) visual depiction of how soil water content responds to irrigation/rainfall; and (iii) some recommendations on how to achieve improved water use efficiency.

4.1 Proposed outline of Farmer Guide or Fact Sheet

Aspects covered:

Background:

- Environmental costs – N_2O losses and N leaching
- Potential co-benefits for production, profitability
- Concept of soil water deficits
- Applicability of guide to (or effects of) a range of irrigation equipment, soil types and climates

Example figures:

- Managing soil water deficits (inclusive of the range of irrigation equipment grouped by typical application depths)
- Deep soil versus shallow soil
- Soil water deficits versus production

Recommended practices:

- Irrigation scheduling
  - Measurement and scheduling services
  - Identifying your target soil water deficit
  - How to trigger irrigation based on the soil water deficit
  - How much to apply

4.2 Dissemination plan:

We intend to:

- Make the guide/fact sheet available electronically via website(s). We will discuss whether Irrigation NZ and DairyNZ will host and to help disseminate. It can be made available on Plant & Food Research website.
- Produce a media release.
- Draft an article for the Irrigation NZ newsletter.
- Draft manuscript on the results for the first year's experiments by the end of July 2015.
- Other scientific papers beyond the life of the programme.

4.3 Dissemination outputs:

An article for publication in the Irrigation NZ News Summer newsletter (Appendix 6.1) and a two-page farmer guide (appendix 6.2) are attached.

5 REFERENCES

Thomas S, van der Weerden T, Clemens G, Styles T 2014. SLMACC – Managing irrigation and grazing timing to reduce nitrous oxide emissions. Summary of results from year 2 field trials in Canterbury and Otago (Milestone 7). A Plant & Food Research report prepared for Ministry for Primary Industries. Ref: SLMACC 30735 (PFR) Milestone 7 report. Milestone No. 52244. Contract No. PFR30735. SPTS No. 10226.

Thomas S, Van der Weerden TJ, Clemens G, T. S 2013a. SLMACC – Managing irrigation and grazing timing to reduce nitrous oxide emissions (Milestone 3). Canterbury and Otago field trial summaries. A report prepared for: MPI. Pp. 22.

Thomas S, Van der Weerden TJ, Vogeler I, Kelliher F, Carrick S 2013b. SLMACC - Managing irrigation and grazing timing to reduce nitrous oxide emissions. Milestone 1- Final report outline. prepared for MPI. Contract No. 29182. SPTS No. 8307.

Thomas S, Vogeler I, van der Weerden T, Carrick S 2015. SLMACC – Progress report - Managing irrigation and grazing timing to reduce nitrous oxide emissions. Summary of findings from the simulation modelling. Milestone 8.

6 APPENDICES

6.1 Irrigation NZ News article:

Newsletter article submitted 30 October 2015 for publication in Irrigation NZ News Summer newsletter.

Irrigation strategies for reducing nitrous oxide and nitrate leaching.

Production benefits of irrigation are well established. However, intensive irrigated agricultural production can also lead to unintended environmental emissions and leaching losses.

A three year MPI-funded project has recently been completed to identify irrigation strategies to help reduce nitrous oxide emissions and nitrate leaching in pastoral systems without losing production. Results from MPIs Sustainable Land Management and Climate Change (SLMACC) programme have identified ways to achieve win-wins for production and environment.

Nitrous oxide in New Zealand agriculture is mainly produced from animal urine patches, especially when soils are warm, wet and compacted. Because of the high global warming potential of nitrous oxide compared to carbon dioxide, even relatively small emissions of nitrous oxide are important.

Nitrate leaching occurs when soil nitrate is transported below the plant root zone in drainage water. This is usually considered a winter issue because rainfall is often greater than the plant's capacity to use it. However, if soils are kept wet, the risk of drainage increases especially when a rainfall occurs soon after irrigation.

The research was conducted by Plant and Food Research, AgResearch and Landcare Research, and involved field trials in Canterbury and Otago, a lysimeter experiment and additional modelling to test management options. Research was focused on providing practical irrigation management options for reducing greenhouse gas emissions. This included changes in irrigation frequency, modifying irrigation trigger points and application depths, comparing irrigation application intensities and delaying grazing timing to reduce compaction.

Research findings:

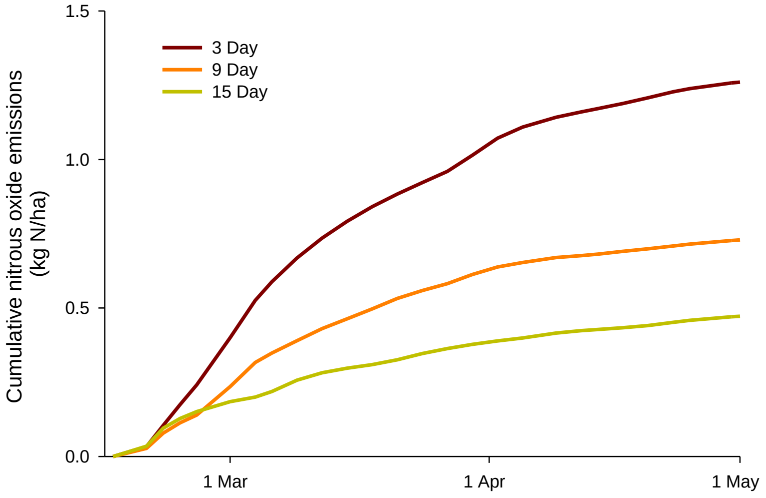


Figure 1 Cumulative nitrous oxide emissions from urine patches on a shallow stony Canterbury soil irrigated at high (every 3 days) to low frequencies (every 15 days).

Field trials showed that more frequent irrigation kept the soil wet increasing nitrous oxide losses (Figure 1). However if the soil was allowed to dry out more over longer irrigation return intervals, these losses could be reduced without penalising pasture production.

> Shallow stony soils have limited water storage potential —"small buckets".
>
> In most cases, modern irrigators have the potential to apply amounts that can still leave the "bucket" partially full, even in a shallow stony soil.
>
> This Eyre soil has about 70 mm of available water in the top 60 cm, or 35 mm of readily available water.
>
> Applying 15 to 20 mm of irrigation and triggering at or about 25 to 35 mm gives plenty of "headroom" to capture rainfall events.

Soil type is important. There were large differences in the nitrous oxide emissions from deep, poorly drained soils and shallow, freely drained soils. Nitrous oxide emissions were much greater from the poorly drained soils. This is because the poorly drained soils remained saturated for longer promoting more nitrous oxide production.

However, because deep soils can hold much more water they also require less irrigation over the season. Early in the season soil water storage delays the need for irrigation. Greater storage also allows these soils to capture more rainfall than the shallow soils. Therefore, irrigating these soils less frequently and letting the pasture use more of the stored soil water reduces nitrous oxide emissions.

Conversely, summer drainage and nitrate leaching from the deep poorly drained soil was less than from the shallow freely drained soil. This is because of the difference in ability of the soils to capture rainfall during the irrigation season.

Avoiding grazing for 6 days after irrigation on a poorly drained soil to allow plants to dry out the soil reduced nitrous oxide emissions by 40% compared to grazing within 2 days of irrigation.

The overall key finding from the research and modelling was that reducing the irrigation frequency by triggering irrigation at lower moisture contents could be achieved without penalising pasture production with the benefit of significantly reducing the risks of leaching, nitrous oxide emissions and soil compaction. Irrigation that brings the soil back to field capacity should be avoided if possible.

There are some caveats. In many cases, irrigation systems will struggle to meet peak plant water use demands in summer, especially on soils with low water holding capacities. During this time, the risk of drainage and nitrous oxide emissions are much lower as plants quickly deplete soil water.

Recommendation

Our recommendation is that farmers should focus on managing "shoulder periods". This is when most irrigation systems have the capacity to keep up with the plant water demands.

We have put together an information sheet to guide farmers on the benefits of managing soil water deficits. Benefits included a reduction in number of irrigations, saving $s, less drainage losses, less leaching and reduced nitrous oxide emissions.

The information sheet will be available from the MPI Climate Cloud website (www.climatecloud.co.nz).

Steve Thomas, Plant and Food Research

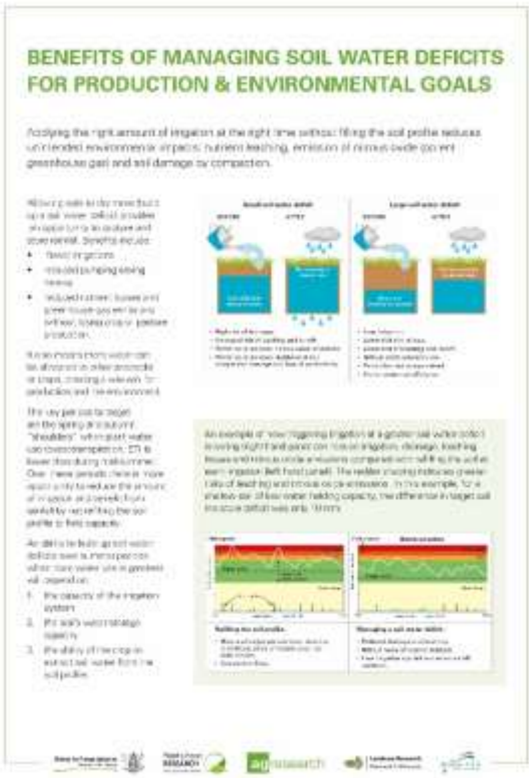


Figure 2 Information sheet on benefits of managing soils water deficits.

BENEFITS OF MANAGING SOIL WATER DEFICITS FOR PRODUCTION & ENVIRONMENTAL GOALS

Applying the right amount of irrigation at the right time without filling the soil profile reduces unintended environmental impacts: nutrient leaching, emission of nitrous oxide (potent greenhouse gas) and soil damage by compaction.

Allowing soils to dry more (build up a soil water deficit) provides an opportunity to capture and store rainfall. Benefits include:

- fewer irrigations
- reduced pumping saving money
- reduced nutrient losses and greenhouse gas emissions without losing crop or pasture production.

It also means more water can be allocated to other paddocks or crops, creating a win-win for production and the environment.

The key periods to target are the spring and autumn "shoulders" when plant water use (evapotranspiration, ET) is lower than during mid-summer. Over these periods there is more opportunity to reduce the amount of irrigation and benefit from rainfall by not refilling the soil profile to field capacity.

An ability to manage irrigation while maintaining soil water deficits over summer periods when plant water use is greatest will depend on:

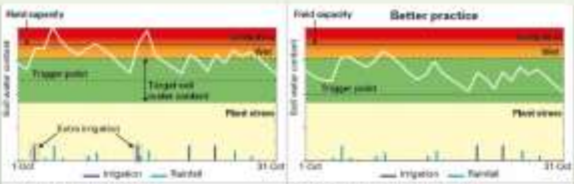
1. the capacity of the irrigation system
2. the soil's water storage capacity
3. the ability of roots to extract soil water fast enough to keep up with plant demand.

As a general rule plants can extract up to 10% of available soil water per day; i.e. if the plant demand is 5 mm of water per day then 50 mm of stored available soil water is needed.

Small soil water deficit:
- High risk of drainage.
- Increased risk of leaching and runoff.
- Wetter soils increase nitrous oxide emissions.
- Wetter soils increase likelihood of soil compaction damage and loss of productivity.

Large soil water deficit:
- Less irrigation.
- Lower risk of drainage.
- Lower risk of leaching and runoff.
- Nitrous oxide emission low.
- Production not compromised.
- Higher water use efficiency.

An example of how triggering irrigation at a greater soil water deficit in spring (right hand panel) can reduce irrigation, drainage, leaching losses and nitrous oxide emissions compared with refilling the soil at each irrigation (left hand panel). The redder shading indicates greater risks of leaching and nitrous oxide emissions. In this example, for a shallow soil of low water holding capacity, the difference in target soil moisture deficit was only 10 mm.



Refilling the soil profile:
- More and longer periods when leaching and nitrous oxide emissions occur as soils are wet.
- Compaction likely.

Managing a soil water deficit:
- Reduced drainage and leaching.
- Nitrous oxide emissions reduced.
- Less irrigation applied and more rainfall captured.

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To work out your irrigation trigger point for maintaining a deficit, you need to know:

- The size of your soil's "bucket" (available water holding capacity) – see below.
- The target soil moisture deficit for the crop.

To determine when and how much water to apply you need to know:

- The current soil water content – estimated from a soil water balance or measured using sensors.
- How much your irrigation equipment applies – check your actual amounts.
- Rainfall – recent or expected – check your local forecasts.
- Current and expected plant water use (ET).

SETTING THE IRRIGATION TRIGGER POINT:

Firstly, find out what the **available water holding** capacity is for your soil types. This is the amount of water that can be extracted by the plant. It varies according to soil type and plant rooting depth.

The best way of getting this information is to have the soils described and mapped on your property. Soil maps and soil water holding capacity information for a wide range of soil types are also provided by S-Map (http://smap.landcareresearch.co.nz).

If you have a site specific soil description then you can estimate the soil water-holding capacity using the Soil Profile Builder tool (www.irrigationnz.co.nz).

Target soil water deficit is the **trigger point** for irrigation. It should be set at or above the **stress point**, below which plant production is lost, and ideally this should be set so that irrigation does not fully re-fill the soil. The stress point will depend on the soil's available water holding capacity, crop and stage of crop development. Deeper-rooting crops will be able to extract more water from the profile than shallow-rooted crops. In mid-summer building up a water deficit may not be practical as the irrigation system may not have the capacity to keep up with high plant water use.

A rule of thumb often used for a range of pasture and crops is that the trigger point is about half the available water content in the rootzone. Note that for annual crops the rooting depth will increase as the plant develops.

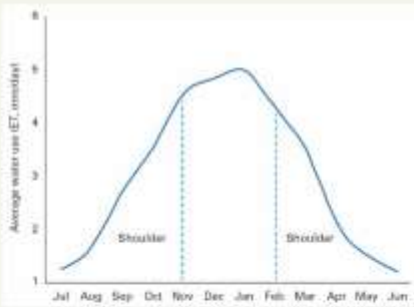
Soil water content can be measured directly using soil moisture sensors, or estimated from a soil water balance.

For more information on crop water requirements, stress points and soil water monitoring see the Foundation for Arable Research publication "Irrigation Management for Cropping - A Grower's Guide" and the DairyNZ "Guide to good irrigation".

Shallow stony soils have limited water storage potential —"small buckets".

In most cases, modern irrigators have the potential to apply amounts that can still leave the "bucket" partially full, even in a shallow stony soil.

This Eyre soil has about 70 mm of available water in the top 60 cm, or 35 mm of readily available water. Applying 15 to 20 mm of irrigation and triggering at or about 25 to 35 mm gives plenty of "headroom" to capture rainfall events.



Average daily water use for pasture at Lincoln. Water use for annual crops will depend on stage of development.

Further information:

Soil mapping and soil water:
S-Map (http://smap.landcareresearch.co.nz)
Contact a pedologist through Landcare Research or Soil Scientists at Waikato, Massey or Lincoln Universities.

Estimating available soil water content:
Soil texture and water and Determining soil texture fact sheets. Irrigation New Zealand. (www.irrigationnz.co.nz).
Soil Profile Builder tool. Plant & Food Research and Irrigation New Zealand. (www.irrigationnz.co.nz).

Crop water requirements:
Irrigation Management for Cropping - A Grower's Guide. Foundation for Arable Research. (www.far.org.nz/mm_uploads/las_04_Irrigation.pdf)
Guide to good irrigation. DairyNZ. (www.dairynz.co.nz/publications/environment/guide-to-good-irrigation-part-1/)

Soil water monitoring:
There are a range of soil water sensors available. Check with Irrigation New Zealand for guidance. There are also a range of irrigation scheduling services available.

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