AFTER REVIEW BY FRNL SCIENCE TEAM

Sensitivity testing for implementation of plantain in Overseer

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Contents

1. Executive Summary

The aim was to evaluate the effect of the suggested changes in the Overseer model on nitrogen (N) leaching estimates from plantain-rich pasture blocks. Following review, the finalised list of recommended changes will be used by Overseer Ltd to produce a development version of the model for further testing.

Sensitivity and sensibility testing were conducted using an Overseer Science version (OverseerSci) prepared for this work. Sensitivity testing focused on the main drivers that were identified by Shepherd (2020) as key to modelling the effects of plantain on N leaching in a farm system. Sensibility testing focused on (a) are the results broadly consistent with other modelling results and expert opinion and of the FRNL science team and (b) is the model responding appropriately to changes to parameters?

A single factor sensitivity analysis showed that the main factors affecting Overseer-estimated N leaching, in terms of factors identified as relevant to plantain implementation, were as follows:

Factor	Direction of change	Size of N leaching reduction (%)
Factor proposed to be changed in Overseer:		
Apportionment of excretal N as urine N	10% decrease	3-6
Urine patch N load	10% decrease	10
Other factors explored:		
Milk N concentration	10% increase	0-3
N fertiliser application	10% decrease	0-5
Rainfall (drainage)	10% decrease	20
Pasture ME	10% increase	6-12

Multi-factor sensitivity analysis suggested that these factors approximated to being additive over the range of values tested.

It was previously identified that the two candidate changes to Overseer to accommodate plantain would be urine patch (UP) N load and the apportionment of excretal N as urine N. Any potential associated reductions in N fertiliser (from better growth and/or more even spread of urine) would be captured by user inputs. It was also recommended that further work is required before changes to the drainage model and the inhibition of soil N processes could be considered. It was also assumed there was a linear response to the proportion of plantain in the diet, for the UP N load and apportionment of excretal N factors: i.e. between 0% plantain (no effect) and 60% (maximum effect).

Implementing these changes and testing them on 19 Overseer files, based on 11 FRNL monitor farms, showed a range of N leaching reductions. For example, assuming pasture contained 30% plantain, estimated N leaching reductions were in the range 11-30% for the farm's pasture area. The difference in size of the reduction between farms could be explained by 'intensity' of the farm system: larger %reductions were noted on more intensive farms, as judged by N fertiliser inputs.

The size of the N leaching reduction at the pasture block level generally reduced at the whole farm level (comparable range, a 3-28% reduction) because the overall effect for the farm was 'diluted' by N leached from any area of non-pasture.

Comparison with the few studies using the Whole Farm Model (WFM) showed reasonable agreement in the size of N leaching reduction, but there was tendency for Overseer leaching reduction estimates to be slightly larger. However, another modelling study (in prep.) using the APSIM urine patch framework indicated that the additional patch overlap caused by more UPs negated the beneficial effect of plantain on UP N load and apportionment of excretal N at higher stocking and N fertiliser rates. Overseer does not capture this mechanism and scales simply from UP to block.

Two recommendations for modification of Overseer are proposed to account for pasture plantain effects are: include algorithms for adjustment of the UP N load factor; and apply a factor to decrease the apportionment of excretal N as urine N. It is recommended that these factors are scaled by the proportion of plantain in the pasture, further modified by the amount of non-plantain feed also included in the diet (e.g. as supplement).

To further aid implementation, an estimate of seasonal variation in plantain content and how this relates to a single user input value for plantain content of the pasture is needed.

Next steps - a beta version will be built for testing in OverseerFM, following feedback on this report. Further evaluation of the new version would then be required, given the estimates of effectiveness in this report were generated using a simplified approach using the sensitivity tool in OverseerSci.

2. Background

Plantain-rich pastures are increasingly used by New Zealand farmers. Predominantly, plantain is sown with ryegrass/white clover, but can also be sown as a specialist crop (with or without clover and other herbs). It is important that the use of plantain in pastoral systems can be captured in Overseer, especially as there is increasing evidence that plantain-rich pastures can decrease nitrogen (N) leaching.

Shepherd (2020) reported recommended changes required to build the known effects of plantain[1] into the Overseer model, with supporting evidence for the changes, for review by the FRNL science team[2]. The aim of this report is to evaluate the effect of the recommended changes in the Overseer model on N leaching estimates. Following review, the finalised list of recommended changes will then be agreed by the FRNL science team, and this report will form the Change Document for Overseer Ltd.

2.1 Summary of previous recommendations from Shepherd (2020)

Plantain block(s)

- Plantain should be implemented as:
    - ***A pasture block type***, which means that it is a long-term pasture where plantain is part of a grass/clover-based sward. It is assumed that documented plantain levels are maintained by over sowing, direct drilling and/or good grazing management. As with other pasture blocks it can be fully grazed, fully cut and carry or a mix of grazing and cut and carry. It can also be an effluent block.
    - ***A specialist forage crop***, in place for two or more years. We need to agree with the FRNL science team how this is best modelled, e.g. as a forage crop rotating through the pasture platform or as a forage crop in a crop block. Whatever the final choice, cultivation of such a crop will result in N mineralisation which may offset some or all of the benefits of the crop.
- Plantain should also be available as a ***supplement type***, or a number of supplement types depending how they are used commercially. This ensures that farm systems using plantain supplementary feeds can be fully represented in an Overseer model set-up. However, unless the material is fresh cut and carry, there is currently insufficient data to assume that any effects from metabolites on, say urination, are carried through in the supplement.
- Plantain should be grazable by **all enterprise types**. This is based on the assumption that the effects observed in experiments based on dairy cattle and dairy pastures are reproducible in other ruminant enterprises. Indeed, research has shown plantain in the diet of sheep also reduced the N concentration in urine (Judson et al. 2018; O'Connoll et al. 2016).

[1] Most New Zealand research on plantain used the cultivar Ceres Tonic. This is a relatively winter-active, prostrate, large- but narrow-leaved plantain type (*Plantago lanceolata*), with a coarse root structure. Further characteristics of this type observed in the various FRNL trials, relevant to the effects described in this report, are its lower dry matter content and higher water soluble carbohydrate/nitrogen ratio compared with perennial ryegrass.

[2] The FRNL science team involved in plantain research and implementation of plantain in Overseer consisted of Mark Shepherd, Diana Selbie, Mike Dodd, Stewart Ledgard, Brendon Welten (AgResearch), Racheal Bryant, Keith Cameron (Lincoln University), Elena Minnée and Ina Pinxterhuis (DairyNZ). This final report has also been reviewed by Peter Kemp (Massey University).

- For pragmatic reasons, **a sliding scale** of effects on N cycling based on levels of plantain in the sward should be adopted. This encourages farmers to try plantain, because they will be able to enter the proportion of plantain that is achieved into Overseer, compared with only being able to get credit for plantain if a pasture has a high proportion of plantain. The proposed range is 0% to 60%.
- Written guidance should be provided to end-users to:
  - o describe what comprises a plantain pasture block type, including how to estimate plantain content.
  - o clarify that increases in animal production resulting from plantain-rich pastures need to be reflected in the user inputs: Overseer will not automatically change these.

Table 1 summarises the model changes that were considered by Shepherd (2020).

Table 1. *Summary of recommendations from Shepherd (2020)*

Model component	Recommendation/comment
Pasture ME and N concentration	There is no strong evidence of consistent relative differences in pasture N concentration or ME content between standard and plantain-rich pastures: use the current Overseer defaults for both pasture types
Pasture digestibility	Use the same digestibility calculation as for all other pasture types.
Pasture utilisation	Use the current Overseer default values for pasture utilisation by animals
Production	Changes in animal production are captured by user input changes in the model. This is important because these inputs are used in Overseer to back-calculate pasture production (Overseer does not model pasture growth directly).
Block relativity	For plantain/clover swards, set a default relativity of 1.1. For plantain/pasture blocks, set a relativity of 1
Seasonality of growth	There is more work to do to understand the FRNL data and differences between North and South Island We would expect the growth differentials to be clear in plantain vs pasture: and less of a differential between plantain/pasture and standard pasture There is still insufficient evidence to support the use of different seasonality of growth in different NZ regions. This is an aspect of further proposed research. To date it is reasonable to assume DM production by ryegrass/plantain mix is similar to ryegrass over a year, but the greater % plantain in the pasture the better late summer/early autumn production will be. This should be reflected in livestock performance.
Urine N partitioning	Partition more N to dung than the current Overseer calculation. To do this, adjust the Ledgard et al. (2003) equation, using a linear scale for the adjustment factor between the two extremes: • For <5% plantain, use Overseer default proportion of urine: • For a plantain sward (>60% plantain), urine proportion = 0.8* Overseer value, remaining N moved to dung

Model component	Recommendation/comment
	Longer-term, consider developing a new Ledgard et al. (2003)-type algorithm that includes factors such as non-structural carbohydrate (NSC) (Feed quality characteristics), rather than just N quantity alone
N in product	No change to N concentration in animal products. Any increases in N removal in product should be captured by changing the farm yield of milk or meat.
Drainage model	There is some indication from lysimeter studies of decreased drainage volume under plantain (attributable to lower water use efficiency). However, further evidence of the size of effect at the paddock level is required. Until then, use existing drainage model values for plantain-rich pastures
Background model	Use existing background model values for plantain-rich pastures
Urine patch N load	Modify N loads in a standard UP on a linear scale depending on proportion of plantain in the sward, based on these two extremes. For 0% plantain, UP N load = default 750 kg N/ha • For a plantain content >60%, N load = 60% of ryegrass UP, i.e. 450 kg N/ha Further sensitivity testing will demonstrate if these are appropriate
Pasture N uptake	Any increased pasture N uptake potential will be captured by adjusting seasonal growth rates (once sufficient data is available)
Clover content	No change to estimation of clover content for plantain-rich pasture blocks
N fixation	No change to current calculation of symbiotic N fixation for plantain-rich pasture blocks

2.2 Other issues

- If a pasture mix includes other species (i.e. other than ryegrass, white clover or plantain) the model for now should treat these other species similar to ryegrass/white clover.
- We assume that the energy sub-model is satisfactory and does not need to be modified to accommodate practices associated with plantain management, i.e. everything up to and including calculation of ME requirement is satisfactory.
- Overseer will not name specific cultivars: the benefits are assumed to be applicable to all cultivar types with the specific properties of lower DM%, higher NSC/CP ratio and less soluble and degradable N, i.e. properties that affect the parts of the model that we suggest should be changed to accommodate plantain: namely, affecting UP N dilution and urine N partitioning.
- **The report identified gaps that need addressing:**
    - o There is some indication of higher pasture ME values in the South Island than are used in Overseer. This needs to be followed up, although out of scope for this

project. It might be that a further South Island pasture type needs to be created, relating to well-managed, irrigated pasture.

- More information is required on if and how plantain-based supplements are used-on-farm and how this affects their nutritive value.
- Assess the evidence for decreased drainage at the paddock level under plantain. Decreased drainage could be one of the mechanisms for reduced N leaching.
- Issue where pure plantain swards are used as these are less winter active than standard pastures – or plantain/pasture mixes – and this will affect soil mineral N uptake; effects are likely to be small for the background model.
- Consider whether it is justified to build in deep recovery of N by plantain, as this would reduce N leaching by capturing some of the N that had moved below the nominal rooting depth of 60 cm for standard pastures
- Some experiments have shown a nitrification inhibition effect from grazed plantain but there is currently insufficient evidence to support implementing this across all situations. The BNI effect is variable and seems to be influenced by temperature.
- Given that the priority is N, use the current Overseer standard pasture default values for other nutrient concentrations of plantain-rich pastures until the databases have been interrogated to update these other nutrient values.

The next stage was to implement some of the changes in a test version and observe the effects on estimated N leaching values in Overseer. This is reported in the next chapter.

3. Methods

Sensitivity and sensibility testing were conducted using an Overseer Science version (OverseerSci) prepared for this work. OverseerSci is separate to OverseerFM, and has been set up specifically for the research community. This set-up allows Overseer Ltd to add additional functionality for specific projects, while keeping the overall engine the same as OverseerFM. Of particular value for the FRNL project was the sensitivity testing facility, which allows a number of parameters to be varied within set ranges, and outputs can be captured in .csv files for downloading and further analysis.

Sensitivity testing focused on the main drivers that were identified by Shepherd (2020) as key to modelling plantain effects on N leaching in a farm system (see summary in Chapter 2). Sensibility testing focused on (a) do the results look about right based on other modelling results and expert opinion and (b) is the model responding appropriately to changed inputs?

Based on identification of the key decision points around Overseer changes documented in the previous section, the following list of variables were included in sensitivity testing.

- Main candidates for change in Overseer to capture plantain effects:
  - Excretal N apportioning as urine
  - UP N load, due to the dilution effect
- Other factors of interest:
  - Environment: location, soil-type, climate – especially capturing differences between North and South Island environments
  - Drainage volume
  - Production (milk or meat) - impacts of more production and associated N removal in product at the same or lower N inputs
  - N fertiliser inputs – if the same level of production can be achieved for less fertiliser input in a plantain-based system, what are the impacts
  - Relative area of plantain on the farm
  - Pasture ME – sensitivity of changes to ME, which will result in changes to estimates of N eaten and excreted
  - Pasture N concentration

It was expected that factors that reduced the amount of urine produced would decrease N leaching (Source factors): a lower apportionment of excretal N as urine N; a higher proportion of N removed in product; lower fertiliser N inputs; higher ME (less DM – and N – eaten); and lower pasture %N. It was expected that factors that reduced transport of N would decrease N leaching: reduced drainage; and lower N load per UP (causing more N removal by uptake). The sensitivity analysis allowed these hypotheses to be tested and to also understand the size of effects on N leaching.

3.1 Sensitivity testing I – Single Factor analysis

Two farm files were used for a single factor analysis, one from each of the Waikato and Canterbury regions. Details of the farms, including soil properties, are summarised in Appendix I. The aim was to implement the sensitivity analyses across the farm but focus on results from a single plantain block. Because there were irrigated and unirrigated blocks on the Canterbury farm, both were included in the analysis. Single factors tested were:

Recommended to change:

- Apportioning less excretal N to urine N (and more to dung)
- Reduction in UP N load (dilution effect)

Not recommended to change in the model, but of interest to know sensitivity on calculated N leaching losses:

- Metabolisable Energy & %N in pasture
  - to see what effects a general change would have on calculated N leaching losses
- Drainage
  - In terms of lower water efficiency, plantain potentially will use more water and decrease drainage (although this will depend on timing of rainfall in relation to plantain growth; we don't test this)
- Partitioning more N to milk
  - Observed in some experiments, not in others; increased milk and protein yield is an input entered by the user
- Reducing fertiliser N inputs
  - This is a user input too; we're testing this because the same level of production may be able to be achieved with plantain in pastures due to a smaller proportion of urine-N being leached and hence potentially more available for plant growth

Environment effects, in the first instance, were captured by comparing results from the two farms (from Canterbury and Waikato). The next section describes that the interaction of soil-type and rainfall was also investigated.

3.2 Sensitivity testing II – Multiple factors combined

OverseerSci restricts the number of results that can be generated in a single sensitivity analysis to 1000 combinations. For the multi-factor analysis, the focus was on the two recommended component changes (excretal apportioning of N and UP N load) and we tested how they responded to other factors, namely:

- excretal apportioning of N × UP N load x change in proportion of milk N
- excretal apportioning of N × UP N load x change in drainage
- excretal apportioning of N × UP N load x interaction of soil-type and rainfall

This was done by using the two base farms (Waikato and Canterbury) and running all of the sensitivity combinations, as described above for each farm separately. Results were then combined to compare and contrast response in the two environments.

3.3 Sensibility testing I – use of Monitor Farms

Overseer files previously generated within the FRNL programme were used to evaluate the reduction in estimated N leaching achieved by combining the proposed Overseer factors for apportionment of excretal N to urine N and UP N load. There were 19 farm files based on 11 different farms (multiple years for some farms, which included slight system changes or with and without support blocks), provided by AgResearch and DairyNZ (Appendix II). The analysis was also re-run to include a blanket 20% reduction in fertiliser N application to examine the additional effect of achieving the same level of production from pasture but with reduced inputs.

The OverseerSci model did not allow differentiation between pasture and non-pasture blocks for application of these modification factors. An Excel spreadsheet was therefore generated from the block-level Overseer results to manually calculate total farm-level and pasture-level reductions in N leaching; for the farm-level calculations, it was assumed that there were no changes to N leaching from the non-pasture areas. Four scenarios were tested: all pastures converted to 15%, 30%, 45% or 60% plantain.

The results were examined for:

- Investigation of the range of reductions achieved across the 19 test files from the 11 monitor farms, and reasons for the differences between files
- Additional reductions in N leaching if fertiliser N inputs could also be reduced
- The effect of non-pasture area on overall farm-level reductions

3.4 Sensibility testing II – Comparison with other modelled values

Three modelling studies were available for comparison with Overseer:

- Four Tararua dairy farms and plantain scenarios have previously been modelled with the DairyNZ Whole Farm Model (WFM) with predicted N leaching reductions for a range of plantain contents in pasture. were compared with those modelled with Overseer.
- A modelling study of a Canterbury dairy farm was reported by Beukes et al. (2020), which tested combinations of different proportions of the dairy platform area in plantain-rich pasture (28 or 56%) and different plantain levels in the pasture (25% or 50%).
- A report on the Tararua sub-catchment included application of the WFM to 4 dairy farms to model the effect of 0-60% plantain levels in their pastures (Duker et al. 2019).

The published results from the separate modelling studies were compared with Overseer modelling by using Overseer files that had previously been set up by DairyNZ as part of the FRNL programme. These files represented baseline versions of the farms, i.e. without plantain. An estimate of the effects of plantain on modelled N leaching were achieved by running these files through OverseerSci with UP N load and apportionment of excretal N as urine N modified using the sensitivity tool in OverseerSci.

4. Results

4.1 Single factor analysis

Appendix III provides a summary of results of single factor changes calculated for plantain contents of 30% or 60% of pasture. The sections below provide an analysis of the continuum of changes to these values.

4.1.1 Factors recommended for change

Effect of proportion of N in urine (block result)

Sensitivity of estimated N leaching to changes in the amount of excretal N partitioned to urine was examined by using a range of values for this proportion expressed as a percentage of the Overseer-calculated value for that site and system (with the difference partitioned to additional dung N). The range used was 70% (a decrease in partitioning to urine: less urine-N excreted) to 100% (the Overseer default value).

The effect of change approximates to a linear relationship at both farms, but the effect is larger in the Canterbury farm block (Figure 1). A 10% decrease in the Overseer value for apportionment of excretal N to urine N decreased estimated N leaching by 2% (Waikato) and 6% (Canterbury).

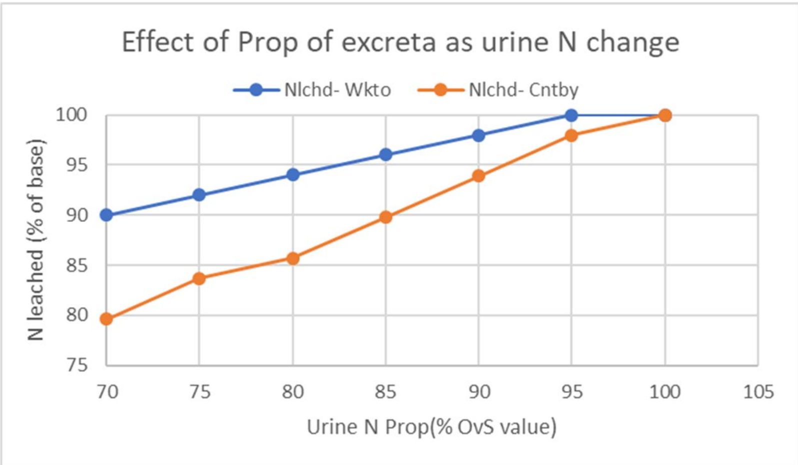


Figure 1. *Effect on Overseer-estimated N leaching from changing apportioning of excretal N to urine l in Overseer. Result expressed at a pasture block level (irrigated at the Canterbury site).*

Urine patch N load (block result)

Sensitivity of estimated N leaching to changes in the value for a 'typical' UP N load used by the model was examined by using a range of values expressed as a percentage of the Overseer default value. The range used was 60% (a lower N load per UP) to 100% (the Overseer default value). There was a large and approximate linear effect of decreasing UP N load in both farms tested. The suggested maximum reduction of 40% to individual UP N load suggested by Shepherd (2020) for plantain resulted in a 28% (Waikato) and 39% (Canterbury) reduction in N leaching in these two examples (Figure 2 and Appendix II).

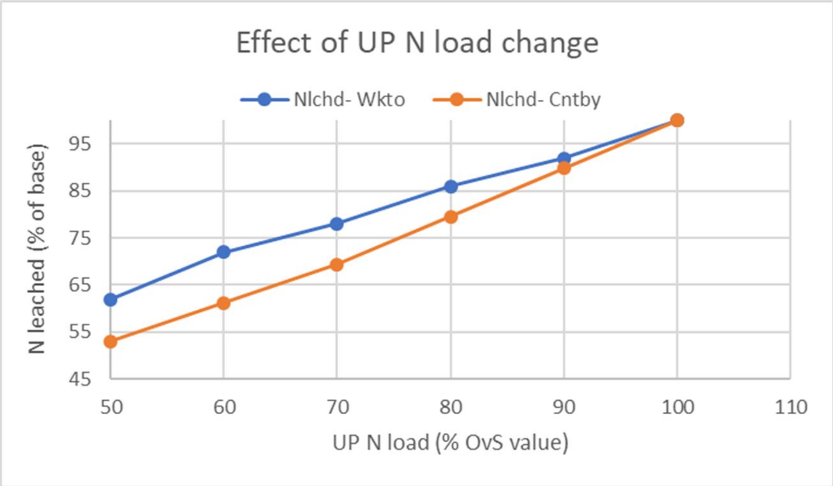


Figure 2. *Effect on Overseer-estimated N leaching from changing the urine patch N load used in the urine patch N model. Result expressed at a pasture block level (irrigated at the Canterbury site).*

4.1.2 Factors not recommended for change but of interest

Effect of proportion of N in milk (block result)

Sensitivity of estimated N leaching to changes in the amount of N removed in milk was tested by using a range of values expressed as a percentage of the Overseer-calculated value for that site and system. The range used was 80% (a decrease in milk N concentration) to 120% (an increase in milk N concentration). Figure 3 showed that there was a small effect of increased N partitioning to milk. The effect doesn't look linear, but this is probably due to rounding of the reported values by OverseerSci. A 5% increase in milk N offtake gave a 0-2% decrease in N leached.

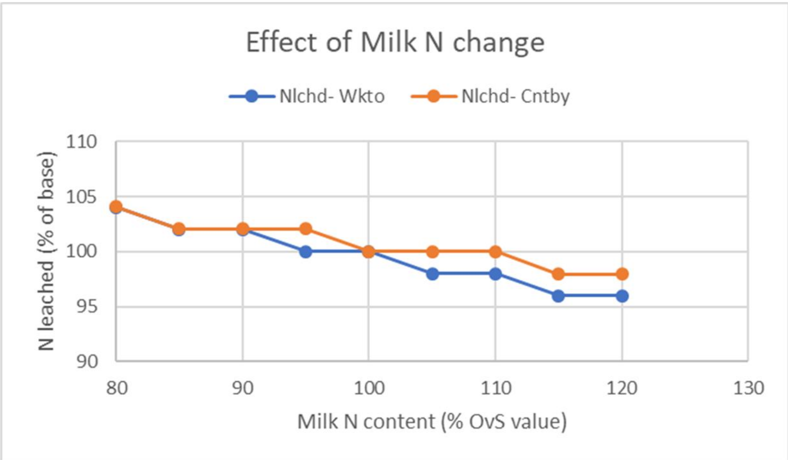


Figure 3. *Effect on Overseer-estimated N leaching from changing partitioning on N to milk. Result expressed at a pasture block level (irrigated at the Canterbury site).*

Effect of pasture ME & %N (block result)

Sensitivity of estimated N leaching to changes in pasture ME was tested by using a range of ME values expressed as a percentage of the Overseer-calculated value for that site and system. The range used was 80% (a decrease in pasture ME) to 130% (an increase in pasture ME). A 10% ME increase from base decreased N leaching by 12% (Canterbury) or 6% (Waikato), as shown in Figure 4 and Appendix II.

The facility in OverseerSci for testing sensitivity of estimated N leaching from pasture %N changes required use of actual values rather than a percentage of the Overseer-calculated value. The effects of changing the values between 2.5% and 4.5% are shown in Figure 4. The effects of changes are larger for the Canterbury site. For context, Overseer-estimated pasture N concentrations for these environments and systems would be c. 3% for Waikato and c. 4% for Canterbury. The effect of reducing pasture N% by 0.5 points from these levels on N leaching was minimal in the Waikato and a 12% reduction in Canterbury (Figure 4 and Appendix II).

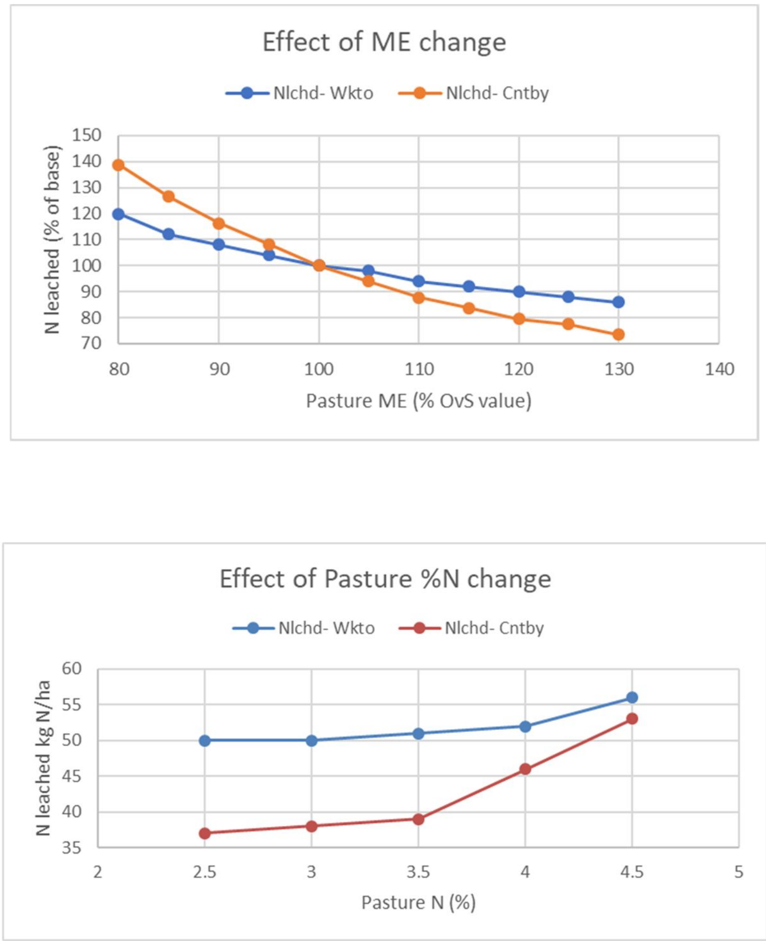
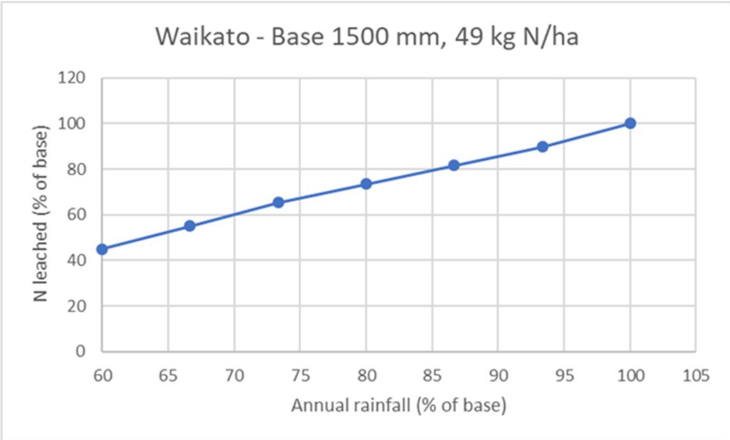


Figure 4. *Effect on Overseer-estimated N leaching from changing a) pasture metabolisable energy (Top graph) or b) nitrogen concentration (bottom graph). Result expressed at a pasture block level (irrigated at the Canterbury site).*

Effect of rainfall/drainage (block level)

Drainage amount was manipulated by changing the annual rainfall for each site while keeping all other inputs the same. Drainage was modified by expressing the rainfall as a percentage of the baseline value for that site. Figure 5 shows the results of changed rainfall (and hence drainage).

For the Waikato farm, there was a linear relationship with rainfall. A 20% decrease in rainfall resulted in a 27% decrease in N leached. In the Canterbury scenario, the relationship was less linear at this site but a 20% decrease in rainfall resulted in a c. 20% decrease in N leached.



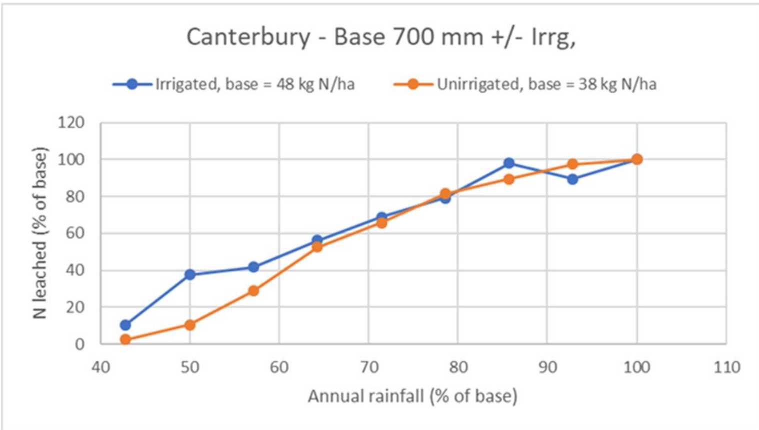


Figure 5. *Effect on Overseer-estimated N leaching from changing annual rainfall (and hence drainage) for Waikato and Canterbury farms. Result expressed at a pasture block level (irrigated and unirrigated at the Canterbury site).*

Fertiliser N (block level)

Sensitivity of estimated N leaching to changes in the annual amount of fertiliser N was examined by using a range of values expressed as a percentage of the baseline amount that was used when the Overseer file was set up. The range used was 50% (half the fertiliser N applied) to 100% (the baseline value). No other changes were made, i.e. the simple assumption was that the same level of production was achieved with the reduced inputs. Base annual applications to the block were 128 kg N/ha (Waikato) or 236 kg N/ha (Canterbury).

There was an approximately linear relationship between N fertiliser reduction (for the same outputs) and estimated N leaching (Figure 6). A 20% reduction in N inputs reduced N leaching by 6% (Waikato) and 8% (Canterbury).

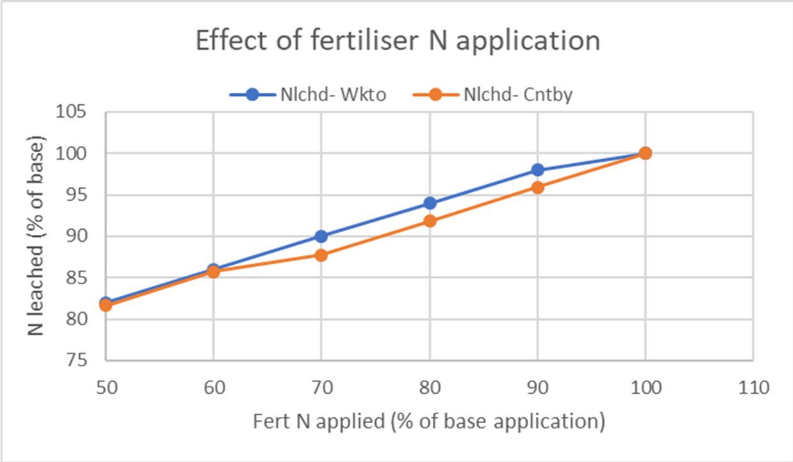


Figure 6. *Effect on Overseer-estimated N leaching from changing the annual amount of fertiliser N applied. Result expressed at a pasture block level (irrigated at the Canterbury site).*

4.2 Multiple factors combined

4.2.1 Urine patch N load × apportionment of excreta as urine

This interaction was investigated in a 3 × 3 level comparison with UP N load as 60, 80 or 100% of the Overseer default value and apportionment of urine N as excretal N as 80, 90 or 100% of the Overseer default value.

Figure 7 shows estimated N leaching as a combination of these two factors. Over the ranges tested, the UP N load effect on estimated N leaching was greater than the effect of apportionment of excreta as urine N. The lines approximate to parallel, indicating that the separate effects of the two factors are approximately additive in the range of values tested, i.e. likely no substantive interaction.

4.2.2 Urine patch N load × apportionment of excreta as urine × milk N concentration

The additional effect on estimated N leaching of increasing milk N partitioning was examined by adding this as a third factor to the UP N load × apportionment of excretal N combination, with or without an increased proportion of N in milk (100 or 110% of the Overseer default value).

By way of example, Figure 8 shows the effect of increased milk N concentration on estimated N leaching for a range of UP N loads when the apportionment of excreta as urinary N was fixed at the proposed maximum change (80% of Overseer default value). An increase in milk N concentration of 10% decreased N leaching by 1% (Canterbury) and 2% (Waikato) in the two farms tested.

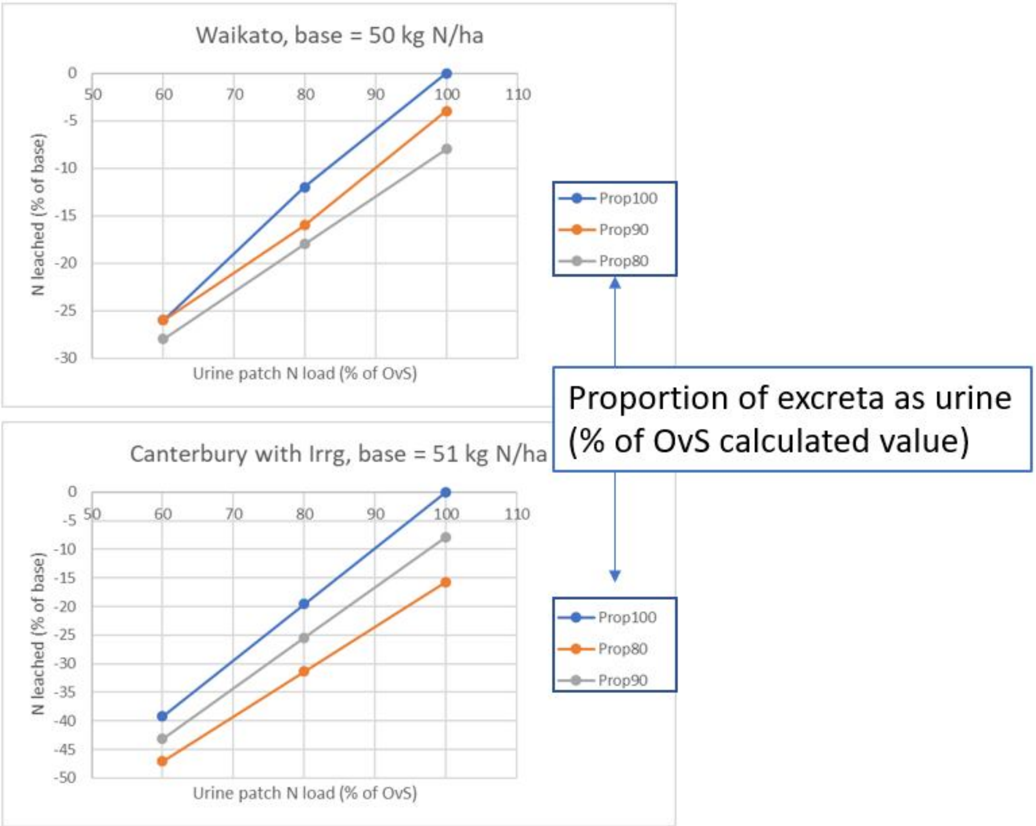


Figure 7. *Interaction of the apportionment of excretal N as urinary N and urine patch N load on estimated N leaching for two farms (block-level N leaching results). Reduction in N leaching is expressed as a % of baseline estimates (i.e. 100% of Overseer default values for both factors).*

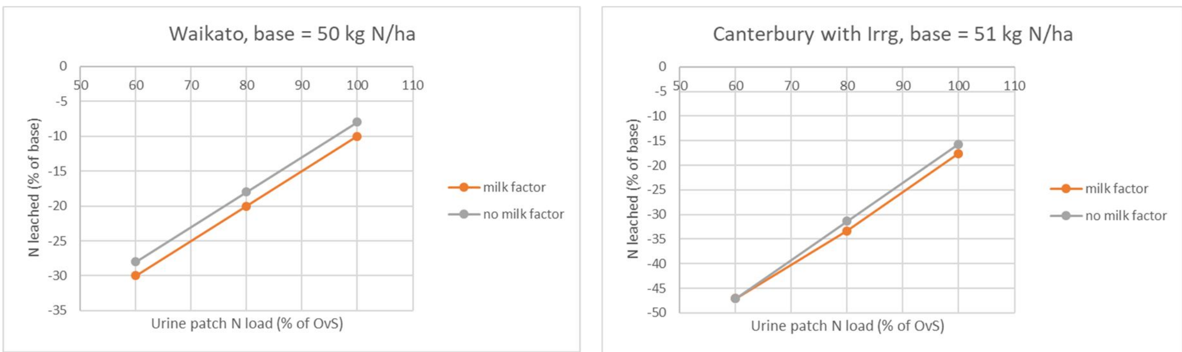


Figure 8*. Effect of increased milk N concentration (10% larger than the Overseer default value) on the interaction of apportionment of excretal N as urinary N and urine patch N load on estimated N leaching for two farms (block-level N leaching results). Reduction in N leaching is expressed as a % of baseline estimates (i.e. 100% of Overseer default values for all three factors).*

4.2.3 Urine patch N load × apportionment of excreta as urine × annual rainfall

The additional effect of decreased drainage on estimated N leaching was examined by adding this as a third factor to the UP N load × apportionment of urinary N combination (a 20% reduction in annual rainfall), as shown in Figure 9.

There was a large additive effect of decreased rainfall (and drainage) at both modelled sites; a 20% reduction in rainfall decreased N leaching by c. 20% in the Waikato farm and by 10-20% in the Canterbury farm, for the range of values tested.

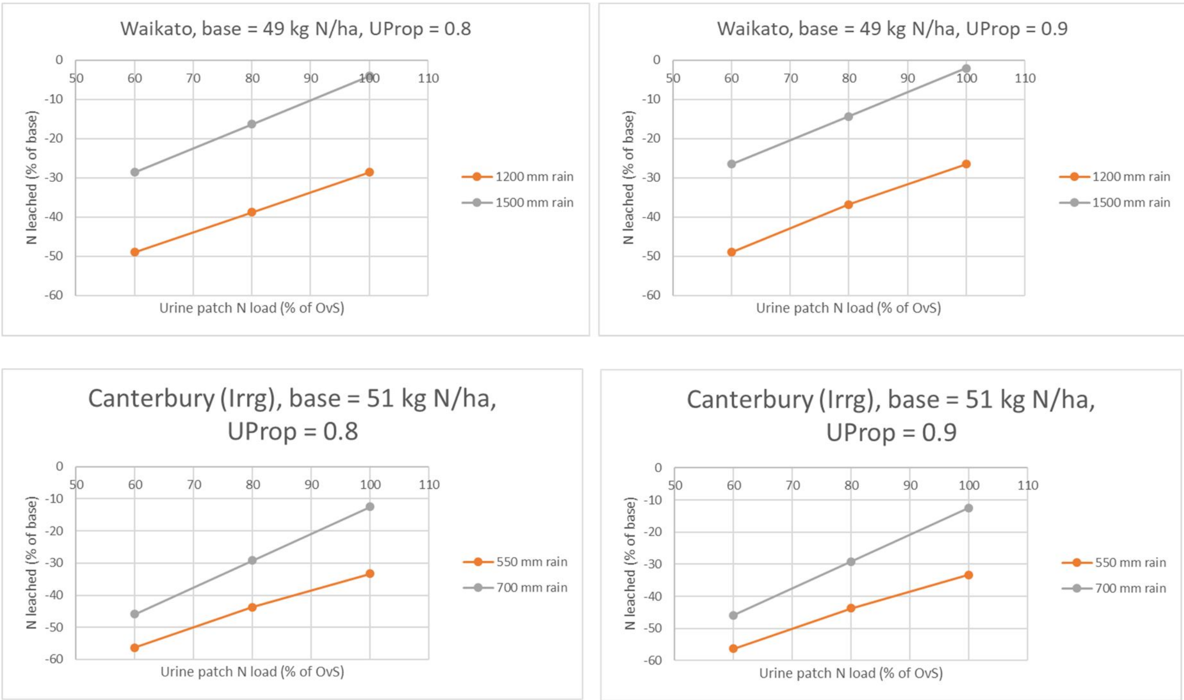


***Figure 9**. Effect of decreased annual rainfall (80% of the baseline value) on the interaction of apportionment of excretal N as urinary N and urine patch N load on estimated N leaching for two farms (block-level N leaching results). Reduction in N leaching is expressed as a % of baseline estimates (i.e. 100% of Overseer default values for all three factors).*

4.2.4 Urine patch N load × apportionment of excreta as urine × annual fertiliser N

The effect of reducing the annual fertiliser N input (for the same level of production) was examined by selecting one apportionment of excretal N as urine N value (80% of Overseer) and modelling N leaching for 70-100% of the base fertiliser N application for three UP N loads (60, 80, 100% of Overseer value), as shown in Figure 10.

Results showed an additive effect of fertiliser N at each UP N load tested. A 20% reduction in N fertiliser (with same production) generated an additional 6-8% reduction in N leaching.

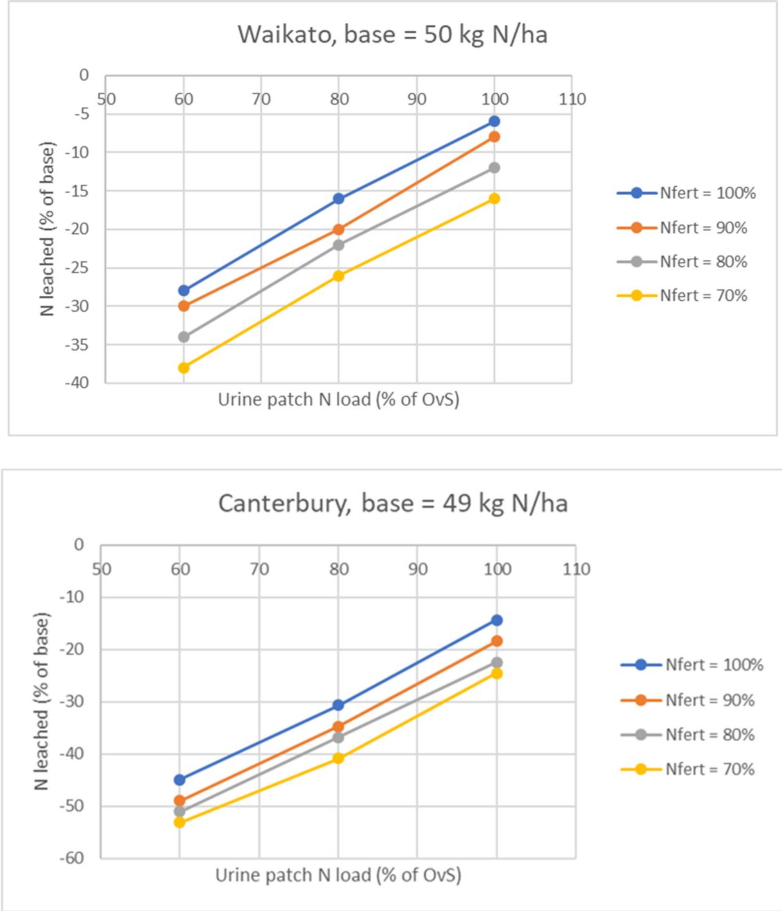


***Figure 10**. Effect of decreased annual fertiliser N (% of the baseline value) on the interaction of apportionment of excretal N as urinary N and urine patch N load on estimated N leaching for two farms (block-level N leaching results). Reduction in N leaching is expressed as a % of baseline estimates (i.e. 100% of Overseer default values for all three factors).*

4.2.5 Interaction of rainfall and soil-type

A sensitivity analysis for rainfall and soil-type combinations was done for both the Waikato and Canterbury base farm files. Five soil orders (allophanic, gley, granular, pallic and pumice) and eight levels of annual rainfall were applied. For each rainfall and soil-type combination, urine apportionment and UP N load combinations that equated to 0, 30 and 60% plantain in a block were simulated. (Figure 11).

The estimated reductions in N leaching were similar at both sites in a dry climate: c. 25% reduction at 800 mm annual rainfall at 30% plantain and c. 45% at 60% plantain. However, the decrease in effectiveness with increasing rainfall was more marked at the Waikato site compared to Canterbury, with plantain showing a reduction in N leaching, as a %, about twice as large as the Waikato site. There appeared more interaction between soil-type and rainfall at the Canterbury site. One possible explanation is the additional factor of irrigation at this site, with the interaction of irrigation and rainfall making the interpretation more complex.

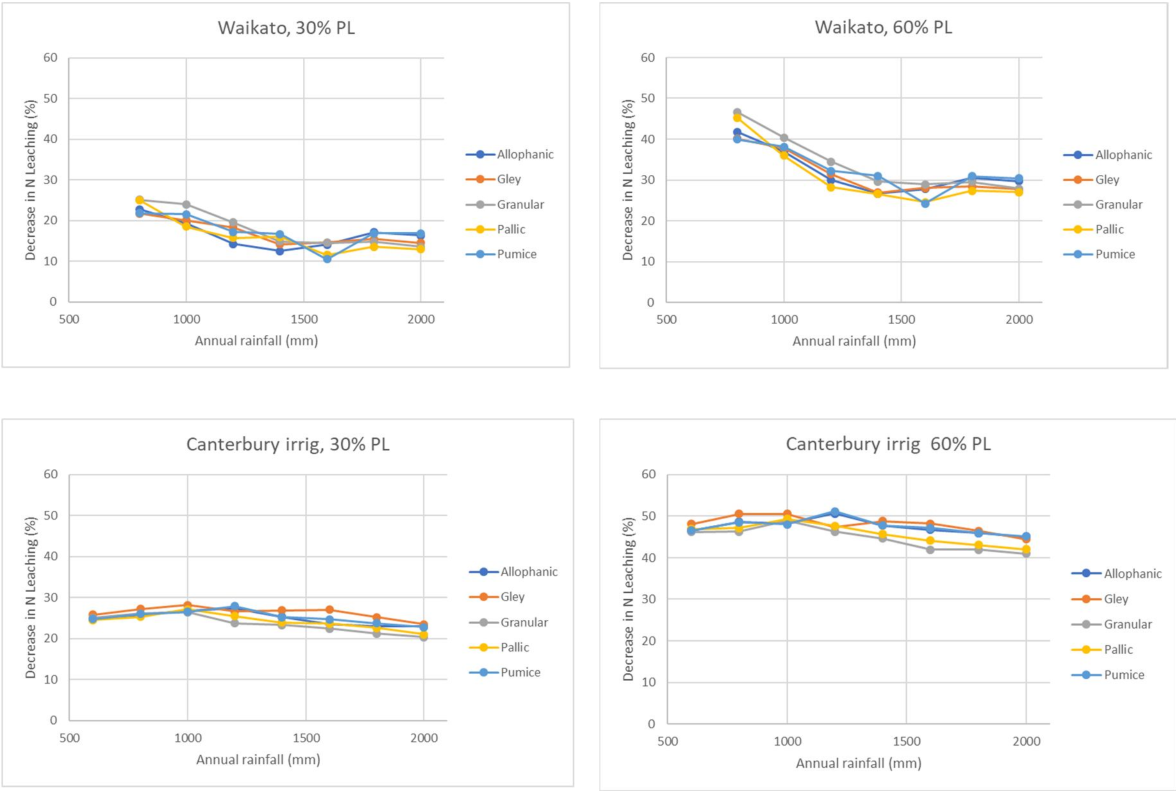


***Figure 11**. Effect of rainfall and soil-type interactions on the modelled % reductions estimated by Overseer for 30 and 60% plantain contents in pastures (block-level estimates of losses).*

4.3 Sliding scale of effect

The recommendation by Shepherd (2020) was to assume a linear effect of plantain content in mixed pastures between 0% plantain and 60% of plantain in the sward/diet. The suggested factors for apportionment of excretal N as urine N, and UP N load were scaled using the following equations:

User entered %plantain = P

Equations for calculating UP N load:

If P=0, UP Factor = 1
If P≥ 60, UP Factor = 0.6
If P=0 AND P< 60, UP Factor = 1 – ((P/60) × 0.4)
UP N load = 750 × UP Factor

Equations for calculating the urinary apportionment of excreta N (Uprop):

If P=0, Uprop Factor = 1
If P≥ 60, Uprop Factor = 0.8
If P=0 AND P< 60, Uprop Factor = 1 – ((P/60) × 0.2)
Urine proportion of excreta = Overseer value for ryegrass × Uprop Factor

Values for the sensitivity analysis for 0-60% plantain were then calculated using these equations and used in the sensitivity tool in OverseerSci (Table 2).

***Table 2**. Calculated 'plantain' factors deployed in the sensitivity analysis to assess the effects of a sliding scale of plantain levels on estimated N leaching. Calculated values are the % of the Overseer calculated values without plantain.*

% plantain	**10**	**20**	**30**	**40**	**50**	**60**
Apply a combination of these factors:						
urine proportion of excreta	0.97	0.93	0.90	0.87	0.83	0.80
UP N load	0.93	0.87	0.80	0.73	0.67	0.60

Combining components UP N load and apportionment of excreta N as urine gave an almost linear effect on N leaching, as affected by plantain content, at both regional sites (Figure 12). This is not surprising given that both factors are linear interpolations.

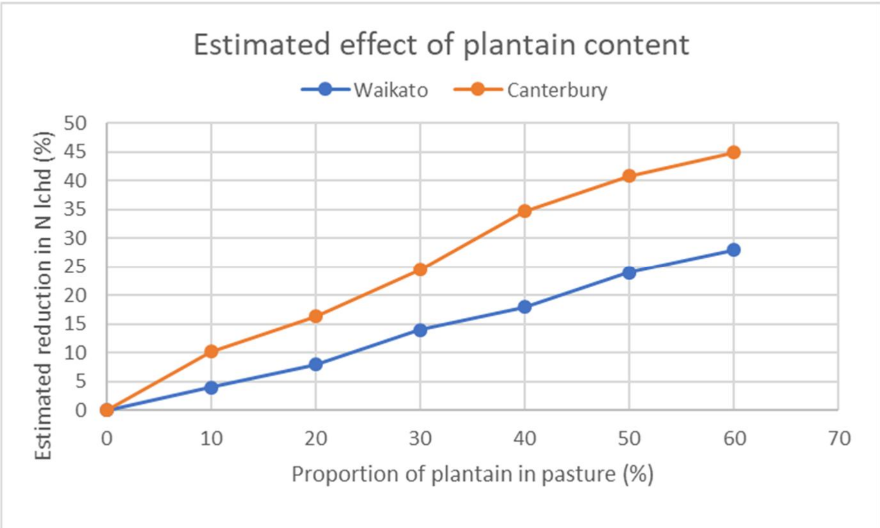
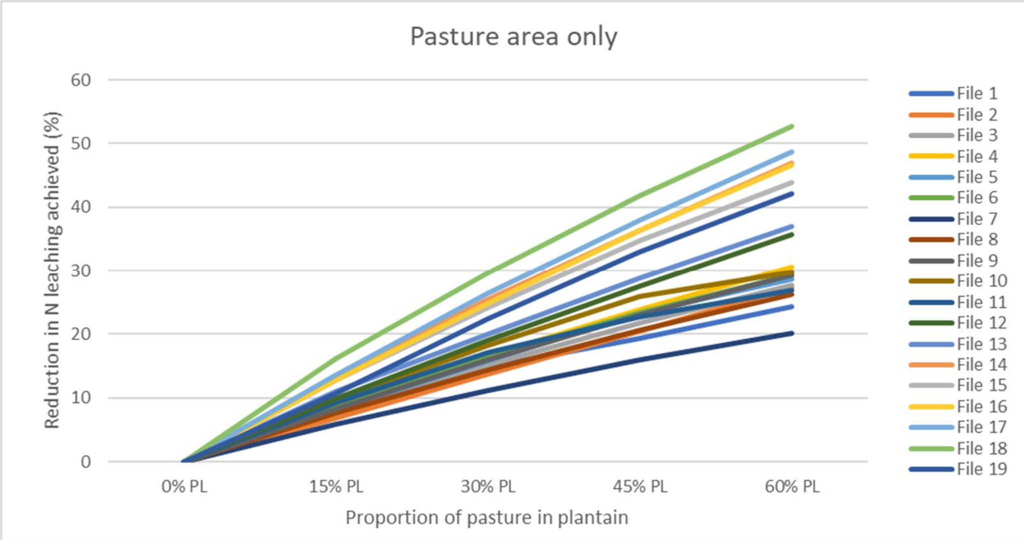


***Figure 12**. Effect of varying level of plantain on Overseer-estimated N leaching for the two farms (block level losses), based on linear interpolations of the two factors urine N apportionment and urine patch N load.*

4.4 Application to FRNL Monitor Farms

4.4.1 Range of reductions achieved across the test files

Figure 13 summarises the estimated % reduction in N leaching expressed for the whole farm or just the pasture. For both, there was a linear relationship between proportion of plantain in the pasture and size of reduction in estimated N leaching, as would be expected from the results in Section 4.3. Estimates of N leaching reduction, assuming pasture contained 30% plantain, were in the range 11-30% for pasture area and 3-28% for the whole farm.



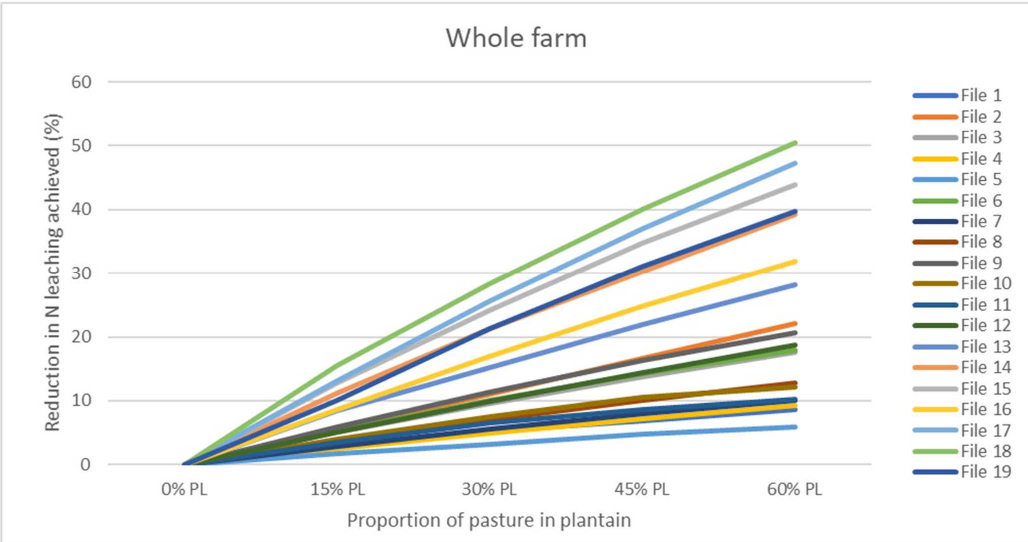


Figure 13*. Effect of plantain content of pasture on estimated N leaching losses (% of baseline losses) for the pasture area (top) or the whole farm (bottom).*

The main driver of the differences in % reduction in N leaching on the pasture platform was the 'intensity' of the system, measured either by baseline N leaching or N fertiliser use. Regression analysis showed that Individually, these factors explained 63% or 77% of the variance in % reduction (P<0.001). These two factors were highly correlated (r^2=83%). Note that the sites all had similar soil-types.

The % reduction in N leaching achieved on the pasture blocks generally decreased when the reduction was calculated at a whole farm level. This is because the non-pasture area of the farm 'dilutes' the effect. Generally, the larger the area of the farm not in pasture, the greater the dilution effect (Figure 14). It is probable that the dilution effect will be further modified by the amount of N leaching from the non-pasture areas, i.e. it will be dependent on the other land-uses on the farm.

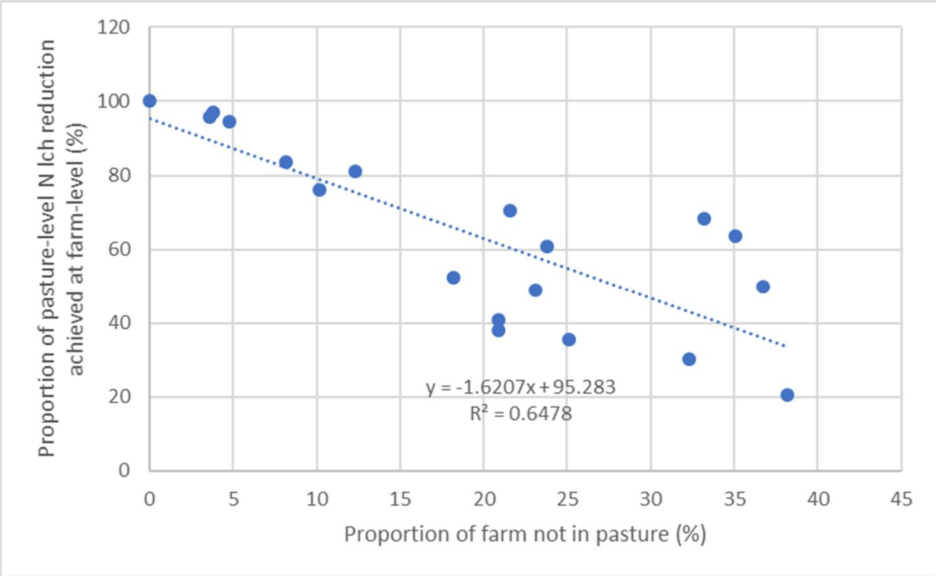
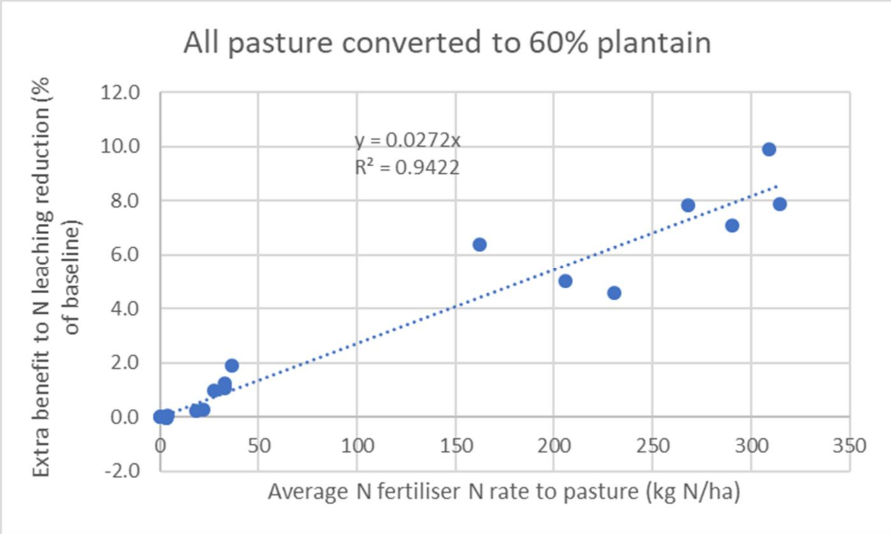


Figure 14. *The effect of the non-pasture area of the farming 'diluting' the benefit in N leaching reduction of using plantain on the pasture areas.*

4.4.2 Additional reductions in N leaching from reduced fertiliser N inputs

All of the analysis of the monitor farms described above assumed no change in fertiliser N inputs on the plantain-rich pasture. However, there might be scope to reduce fertiliser inputs on plantain pastures, yet still achieve the same outputs. To test the additional effects of reduced fertiliser N inputs, a blanket 20% reduction to all pastures was assumed and the Overseer model was re-run for UP N load and apportionment of urine factors equivalent to 0, 15, 30, 45 and 60% plantain. For simplicity this % reduction was applied to all fertiliser applications, rather than changing the timing of the fertiliser.

There was some additional reduction in estimated N leaching achieved as a result of the reduced fertiliser N inputs, ranging from zero to an extra 10% reduction in N leaching for a plantain level of 60% (Figure 15a), and ranging from zero to an extra 12% reduction in N leaching for a plantain level of 30% (Figure 15b). The size of the extra reduction was almost all explained by the amount of fertiliser N applied to the pasture, i.e. a linear response in the baseline scenario. The slopes of the lines in Figure 14 denote the extra reduction achieved per kg N fertiliser applied in the baseline scenario. The additional benefit decreased in proportion to the amount of plantain in the pasture: the slope was 0.038 at 15% plantain and 0.027 at 60% plantain.



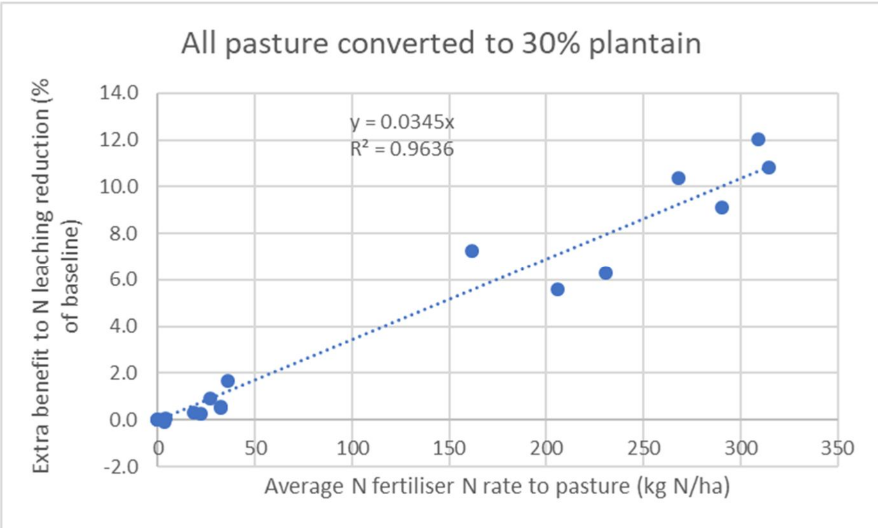


Figure 15*. The extra benefit to estimated N leaching of achieving the same levels of production from 20% less N fertiliser the initial for in the baseline scenario where all pasture has (a) 60% or (b) 30% plantain. Results for the pasture block only.*

4.5 Comparison with other models

4.5.1 Tararua

Application of the WFM to Tararua example farms showed a general linear response of reduction in N leaching to the proportion of plantain in the pasture, but there were differences between the four farms (Figure 16; Duker et al. 2019). WFM estimates of reductions followed the order Farm 4 > Farm 1 & Farm 3 > Farm 2. Baseline leaching losses were modelled in the range 34-55 kg N/ha.

In comparison, Overseer estimated N leaching losses were lower (24-36 kg N/ha). Overseer also predicted a linear response in N leaching reduction with increasing plantain content of the pasture, as indicated in Section 4.3. When compared with the WFM, three of the four sites showed reasonable agreement in the % reduction in N leaching (points clustered around the 1:1 line in

Figure 17), though there was a tendency for Overseer estimates of efficacy to be slightly greater than WFM estimates (i.e. points above the 1:1 line in Figure 16). The exception to this good agreement was Farm 2 where Overseer predicted much larger reductions in N leaching.

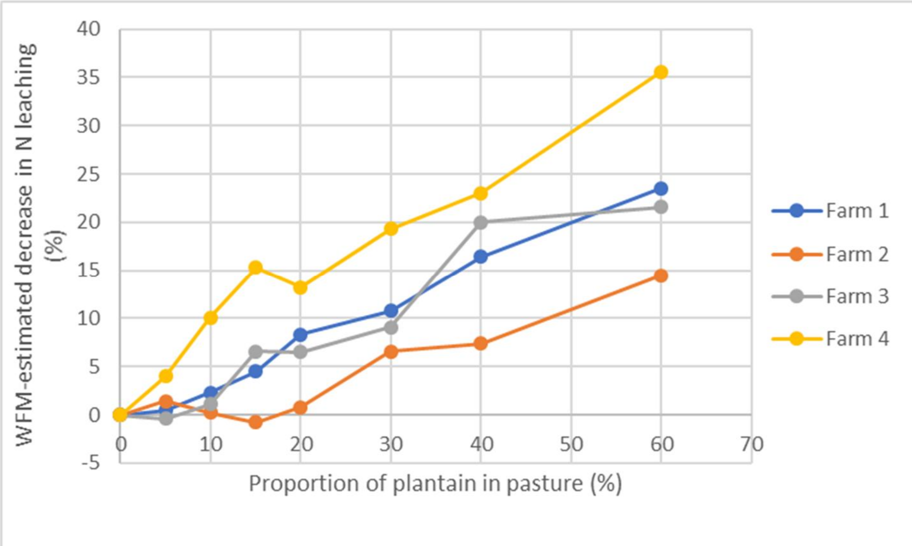


***Figure 16**. DairyNZ Whole Farm Model (WFM) modelled reduction in N leaching from differing levels of plantain in the pastures for four dairy farms in the Tararua sub-catchment (Source: Duker et al. 2019).*

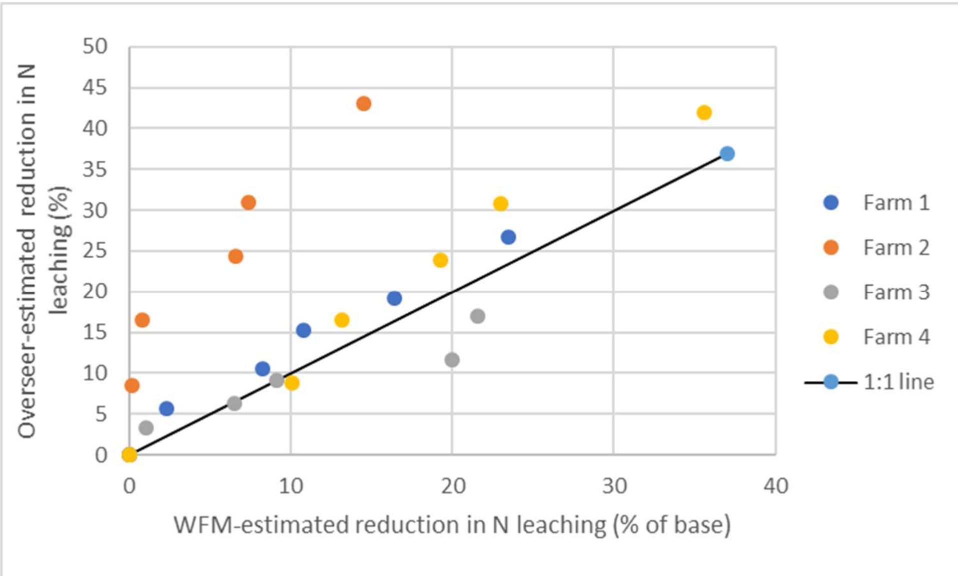


***Figure 17**. Comparison of Overseer and WFM modelled reductions in N leaching for four dairy farms in the Tararua sub-catchment.*

4.5.2 Ashburton, Canterbury

Beukes et al. (2020) reported the results of application of the WFM to a high input dairy farm in the Ashburton district of the Canterbury region. The WFM model was set up to model the farm comprising a fully irrigated dairy platform of 375 ha and a 244 ha support block, with about 30% of the diet imported as supplements. The WFM then estimated the effects on N leaching of converting 28 or 56% of the platform to a plantain-rich pasture comprising 25 or 50% plantain.

A similar Overseer file was set up by the FRNL team for the base farm (2017-18). Using the sensitivity tool in OverseerSci, the same scenarios were modelled for comparison with the WFM. Table 3 shows that overall N leaching estimates were similar for the year 2017-18. However, the results of implementing plantain into the farm were more effective in Overseer than the WFM.

***Table 3**. Comparison of Whole Farm Model (WFM) and Overseer (OvS) estimated reductions in N leaching achieved by various combinations of area of the dairy platform converted to plantain and plantain content of the pasture (Overseer file set up for 2017-2018).*

Scenario	**Area of plantain pastures (%)**	**Plantain content in pastures (%)**	**N leached (kg N/ha)**		**Reduction (% of base)**	
			WFM	**OvS**	**WFM**	**OvS**
Base	0	0	86	83	-	-
PLT-1	28	25	85	80	1	4
PLT-2	56	25	85	77	1	8
PLT-3	28	50	84	77	3	8

5. Discussion

5.1 Sensitivity analysis

The single factor sensitivity analysis based on Waikato and Canterbury Overseer files indicates that drainage and UP N load had the largest effects on N leaching estimates over the ranges simulated, with urine N proportion of excretal N and fertiliser application rate also having some effect.

Although the analysis was done at a block level, most of these results approximate to the effects at a UP level, given that Overseer scales up to the block from the UP. Results in Table 4 consider a 10% change from base. Factored in to the consideration should also be the potential for size of change of a factor; for example, Shepherd (2020) suggested that UP N load could be reduced by as much as 40%, and apportionment of urinary N by up to 20%.

Shepherd (2020) also suggested that drainage could be decreased due to lower water efficiency of plantain, but also that more research was required to understand the size of effect at the paddock scale (as opposed to lysimeters). The sensitivity analysis clearly shows that this has potential to significantly reduce N leaching, even if the adjustment is a 10% decrease in drainage.

System management effects have potential to further modify leaching estimates. For example, if plantain-rich pastures had better growth potential in the summer/autumn, this might allow reduced N fertiliser inputs. This modifies N leaching in two ways: potential for reducing pasture N concentration (and less N eaten) albeit a small effect (Shepherd & Lucci 2013); and less N fertiliser added to the top of a UP, which adds to the leaching risk (Shepherd & Snow 2014). However, plantain might require other adjustments to the farm system: for example, possibly compensate for slower growth in autumn/winter by more N imported through supplement. It is important that Overseer is able to capture these changes and, in that particular case it be by user inputs on increased supplement use.

One system management factor that could not be tested by the structure of the sensitivity testing in OverseerSci, was the potential for differential in production between plantain and non-plantain blocks on the same farm. If more production was attributed to plantain blocks, the model would assume more pasture grown (given the recommendation not to modify ME and %N concentrations; Shepherd 2020), more N eaten and N excreted, which might offset some of the modelled benefits in the sensitivity analysis.

Sensitivity tests comprising multiple factors showed additive effects, with little evidence for substantive interactions and individual effects in line with those in Table 4.

5.2 Comparison with other models

5.2.1 Scaling from urine patch to block

As already mentioned, Overseer scales up from UP to the block without considering the scope for changes in UP overlap: the single representative value used for a UP N load is said to encapsulate that variation. Thus, a 20% decrease in N leaching in a UP would equate approximately to a 20% decrease at a block level, though this would be modified by the estimated contribution to N leaching from between UPs.

Bryant et al. (2019) and Snow et al. (in prep) argue that level of overlap will be modified by stocking rate. They also argue that for plantain with more UPs (greater urination frequency is a feature of the diuretic effect), overlap would also increase in plantain compared with ryegrass/white clover pasture, as well as with stocking rate. Adding these factors into a scaling process, Snow et al. (in prep) suggest that much of the benefit of plantain is negated by the extra overlap and increase in leaching at stocking rates above 3 cows/ha with high N fertiliser rates (450 kg N/ha for these stocking rates).

The potential of more overlap of UPs and fertiliser at higher stocking rates and N fertiliser rates might be an explanation for the reductions modelled with Overseer generally being slightly greater (up to 8% points more) than with the WFM, which includes a UP framework. Taking this effect into account is a fundamental decision to agree upon. Some of this could be offset by a more conservative approach to UP N load reductions, but at this stage we do not implement a scaling factor for stocking rate: this has never been used in Overseer.

5.2.2 Other modelling reports

Comparison with other modelling approaches needs to acknowledge that we are not comparing like-with-like given that the WFM takes some different approaches and includes factors such as changes in pasture quality. Also, we note that the farm descriptions between Overseer and WFM were not completely aligned.

However, given these caveats, in general, results were of the same order. Overseer tended to give higher leaching reduction values that the WFM. As described above, some of this could be offset by a more conservative approach to UP N load reductions.

5.3 Monitor farms

Other monitor farms were not specifically modelled for plantain with the WFM, and therefore the Overseer files were used mainly as a resource for testing the effect of proposed changes across a range of farms. Three key points emerged:

- A range of % reductions in N leaching were achieved across the pasture blocks. This was easily explained by the 'intensity' of the system, with larger effects in higher intensity farms. This is in contradiction to the modelling by Snow et al. (in prep).
- The additive effect of fertiliser N reductions on size of reductions in N leaching – thus if there is scope for reducing inputs this would further decrease losses on a block.
- Dilution of effectiveness of the farm-level reduction in N leaching by non-pasture blocks

None of the comparisons have included supplement effects on plantain. Supplements could modify the estimated N leaching from plantain-based systems in two ways:

- Addition of significant amounts of non-plantain-based supplement in the diet will dilute the proportion of fresh plantain in the diet. The assumption is that this would similarly reduce the effects on UP N load and proportion of excreta as urine N. This could be another explanation of the slightly higher reductions in N leaching modelled with Overseer than with the WFM.
- The assumption is that there is no diuretic effect of plantain silage (based on Beatson 2019 and Bryant et al., in prep); any benefits accrue only if the plantain is freshly cut and carried.

The implications of these assumptions can only be tested during a beta test phase when the development version of the model has been constructed.

5.4 Specific feedback captured from FRNL scientists

Most of the feedback from the FRNL scientists to the proposed changes to Overseer have been captured in the body of this report. However, opinions on three specific areas were difficult to incorporate into the body of the report and so are summarised here.

5.4.1 Drainage

There was agreement that further work is needed on the potential drainage reductions with plantain, though there was some difference of opinion as to how likely this was to be a significant effect. While lysimeters suggest reduction in N leaching loss is often due to (i) the lower urine patch N loading rate coupled with (ii) a decrease in amount of drainage under plantain pastures, there is no evidence so far from our paddock scale drainage measurements that there is any difference in drainage volume from under plantain than under ryegrass/white clover. One hypothesis put forward was that, if anything, drainage might be greater from pastures with a lot of plantain in them due to lower growth through the cooler months. This supports the need for more research before inclusion in Overseer.

5.4.2 Accounting for UP overlap

There were divergent responses to the modelling of overlapping urine patches, but certainly some agreement that this needed further data, particularly as the inference of effect is based on modelling, with no specific field evidence. One opinion was that the effect in the urine patch framework is low. The Massey University paddock/large plot scale measurements of N leaching showed considerable effects of plantain, and the Overseer results are only slightly more optimistic than the WFM.

However, the modelling used very high N fertiliser rates for higher stocked farms, and therefore calculated high N leaching too: >100 kg N/ha at SR of 3 cow/ha to >300 kg N/ha at 4.5 cow/ha. Where a fixed rate of 100 kg N/ha fertiliser was modelled, the reductions were better (~6% for Canterbury and ~8% for Waikato at 3.5 c/ha at 50% plantain). This was also supported by paddock scale measurements at Massey University, albeit this trial did not use the high N rates.

The consensus was that we note the potential effect and that Overseer does not model this yet, and recommend modellers should have another good look at this for potentially future updates of the Overseer model. However, one option is to at least explore effects by implementing a 'high stocking rate factor' in the proposed beta version of the plantain model in Overseer, to scale back effects. This would allow further testing.

5.4.3 Seasonality of plantain

A number of experts raised the issue of slow winter growth of plantain and possible implications for affecting urine deposition characteristics in winter, compared with other times of the year. This needs to be reflected in the model, possibly be inclusion of a seasonality factor that could be used to adjust across the year the single user value for %plantain.

6. Recommendations

6.1 Model changes

- Proposed changes focus on two factors:
    - UP N load: 40% reduction in Overseer value for standard pasture at >60% plantain, 20% reduction at 30% plantain
    - Apportionment of excreta as urine N: 80% of Overseer calculated value for standard pasture at >60% plantain, 90% of value at 30% plantain
    - Apply a linear scaling of these two factors between 0% and 60% plantain: see p. 18. However, consider applying these factors in the results only if plantain content is ≥5%
    - Note: these values of % plantain, relate to % plantain in the diet, thus we need to take account of non-plantain sources of DMI in the calculation of % plantain in the diet.
- Inclusion of a “high stocking rate” factor
- Supplements: where supplements are fed:
    - Include supplement fed to calculate the ‘dilution’ of fresh plantain in the diet and use this to adjust the effects on UP load and apportionment of urine
    - Assume no diuretic effect of plantain silage; apply an effect if the plantain is freshly cut and carried
- Other system effects that might impact on plantain’s ability to reduce N leaching will be captured by user inputs, thus no model adjustment is required:
    - Fertiliser N applications
    - Relative production between blocks
    - Area of farm not in plantain
    - Changes to production
- Clear guidance on what constitutes a plantain pasture is required, including how plantain content is estimated and how this estimate (a user input) relates to seasonal variation in content: and annual variation.
- Seasonality of plantain content: Guidance on variation in plantain content through the year is required, at least by season. As a placeholder, implement a seasonal factor of 1 for each season. This factor should be used to adjust the single value user-input estimate of plantain content to account for variation through the year.
- Plantain should be grazable by all enterprise types. This is based on the assumption that the effects observed in experiments based on dairy cattle and dairy pastures is reproducible in other ruminant enterprises.

6.1.1 Implications of model changes

The recommendations listed above appear straightforward, but there are a number of issues that will need to be considered as they are implemented in the model. Below, are some of those considerations. However, the list is not exhaustive and others might need to be addressed during model implementation.

Dilution of plantain DM Intake by non-plantain feed sources

“Plantain%” drives the calculation of size of effects on UP N load and apportioning of excretal N to urine. If the grazing animal’s only source of DMI is a plantain-based pasture, the user estimate of plantain content of the pasture is used in the calculations. However, if other forages or fodders are fed, this dilution of plantain content for other sources needs to be accounted for. This needs to be accounted for at the monthly timestep used in the UP leaching model.

Example: if a mob of animals in a month graze plantain pasture with 30% plantain, but 50% of their DM intake comes from supplements, then the factor to use in calculating plantain effects is 15%.

Note that any supplements (other than fresh cut and carry) containing plantain are treated like any other supplement (e.g. 'dilute' any effect coming from grazed plantain) because the plant constituents that justify the changes to UP N load and apportioning of excretal N are lost in the treatment process of converting to silage etc. If plantain is cut and directly fed then this will affect those two values and needs to be accounted for in the calculation of plantain content in the diet.

Plantain and non-plantain pasture blocks on the same farm

The example above has to be applied to urine generation at a block scale. Therefore, if animals graze plantain and non-plantain blocks in the same month, then the model should not calculate plantain modification factors for UP N load and apportionment of excretal N combined for the two blocks but for the two blocks separately.

Differences in production between blocks can be acknowledged by the user input 'relativity between blocks'. However, this is likely to have only a small effect on N leaching estimates.

Seasonality of production

There is more work to do to understand the FRNL data and differences between North and South Islands. We would expect the growth differentials to be clear in plantain vs pasture: and less of a differential between plantain/pasture and standard pasture

To date it is reasonable to assume DM production by ryegrass/plantain mix is similar to ryegrass over a year, but the greater % plantain in the pasture the better late summer/early autumn production will be. This should be reflected in livestock performance, but will depend on the shape of the production curves used in Overseer and whether they can capture this difference in seasonality of production that might occur with plantain-rich vs standard pastures.

Seasonality of plantain content in a pasture

Another consideration of seasonality is variation in plantain content through the year. This affects seasonality of production as indicated above but it will also affect the size of effect on urine production and UP N load proposed in the recommended algorithms. We therefore need guidance on how to deal with this seasonality from industry. We should at least include a seasonality factor to adjust the single value for plantain content that users enter for a block, for example:

$\text{Plantain\%}_{autumn} = \text{Plantain\%}_{user\ input} \times \text{Plantain factor}_{autumn}$

Where $\text{Plantain factor}_{autumn}$ is a default value stored in an Overseer database but which can be over-ridden by user input?

Negation of some effects of plantain at high stocking rate

There is some suggestion, albeit from modelling only, that at high stocking rates, there is more UP overlap which negates some of the effect of reduced UP N load from eating plantain. This needs further investigation. One option is to include a 'high stocking rate factor' in the beta version of the plantain model to explore the effects of UP overlap on N leaching estimates. A proposed adjustment to the plantain-adjusted UP N load to account for a high SR for dairy cow is shown below:

IF SR> 4 cows/ha, UPNload-adj(plantain) = UPNload(plantain) x SR factor

IF UPNload-adj(plantain) >750, UPNload-adj(plantain) = 750

SR factor = 1.2: For the beta version we could make the SR factor a user input to check on sensitivity.

6.2 Other potential mechanisms not yet captured

Scientific understanding of plantain effects on N cycling is continuing to evolve. Therefore, implementation of a plantain model in Overseer could be considered a staged process with the model reflecting the current state of understanding and with scope for further refinement as that understanding grows. Two areas in particular have been noted:

- Drainage - Lysimeter studies have shown decreased drainage volumes under plantain and diverse pasture mixes (Malcolm et al. 2014; Woods et al. 2018; Carlton et al. 2019; Welten et al. 2019), sometimes up to a 28% reduction in drainage compared to standard pasture. This aligns with the suggestion by Neal (2011) that plantain has a lower water use efficiency than standard pasture. All of the lysimeter studies used high N application rates to simulate urine application; the question is, what is the overall effect at the paddock level when the between-UP areas are also factored in? Until then use the existing drainage model values for plantain-rich pastures.

  There are likely to be seasonal differences: plantain will use more water from the soil in late summer and early autumn when it is growing more than ryegrass, but will use less soil water from late winter to at least late spring. Soil moisture has been measured as higher under plantain in spring but no difference in drainage volume has yet been measured at Massey University (P. Kemp, Pers. Comm.).

- N process inhibition - Secondary metabolites within plantain have potential to slow nitrification via urine or directly in the soil. For example, Carlton et al. (2019) measured lower populations of ammonia oxidising bacteria under diverse pastures with plantain. However, Navarette et al. (2016) showed that the levels of inhibitory compounds vary through the season. Welten et al. (2019) measured reduced N leaching in lysimeters sown with plantain but results suggested seasonal variation in the contribution of inhibition to the reduction. Research has not detected consistent BNI effects if urine is applied at cooler temperatures (K. Cameron, Pers. Comm.).
- More information is required on:
  - the active compounds/mechanisms responsible for the effect
  - the consistency of effect, and the interaction with environmental factors such as temperature and rainfall
  - the fate of the ‘saved’ N

6.3 Future considerations for more fundamental changes to Overseer

While the focus has been on implementation of plantain in Overseer, this exercise has highlighted at least two areas where possible changes are applicable more widely than plantain alone, i.e. applicable to a broader range of forage types. It is recommended that these are considered in more detail outside of the FRNL programme as they are more fundamental to Overseer and impinge not only on plantain but on the pasture model as a whole.

- Pasture Metabolisable Energy - this is a key driver of N cycling because it is involved in back calculation of DMI and N eaten. Figure 1 showed ME impacts on calculated N leaching. There is anecdotal evidence that ME in well managed, irrigated pastures is higher than estimated by Overseer. Figure 1 shows that a 10% increase in ME could decrease estimated N leaching by up to 18% in the two examples used, because of a calculated lower DM intake. It is worth testing whether the ME estimates of Overseer for South Island, well managed irrigated pastures are in line with measurements from such pastures.

- Partitioning of the excretal N to urine and dung is driven in Overseer by the relationship developed by Ledgard et al. (2003) and is a function of the dietary N concentration. However, Minnée et al. (2019) argue that it is not just total N, but the composition of the N fraction that affects the partitioning between dung and urine. We have tried to accommodate this concept in Overseer by applying a plantain-specific scalar to the current Ledgard et al. (2003) equation. However, there will also be forages or fodders other than plantain that are structurally different to standard pasture. Therefore, a new approach could be considered for excretal N partitioning, aimed at accommodating some of the feed quality attributes. Having said that, the analysis in this report indicates that effects on N leaching estimates could be small.
- Excreta transfer rate – One area that may have been overlooked in the sensitivity analysis is the effect of plantain on the transfer of excreta between laneways, milking shed and paddock. Arguably, if plantain alters diurnal urine-N excretion the default excreta transfer rate may not be applicable.

6.4 Next steps

A beta version of the OverseerSci plantain model will be built for testing in OverseerFM, following feedback from this report. This process could unearth other issues during development (e.g. N balancing in the nutrient budget). It would also then allow inputs such as block relativity to be tested. However, the main purpose is to allow us to check the consistency of results with those generated in this report using the sensitivity tool.

7. References

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8. Appendices

APPENDIX I – FARM SET-UPS FOR WAIKATO AND CANTERBURY FARM BLOCKS USED IN THE SENSITIVITY ANALYSIS

Summary of the farm set-ups used for single factor analysis

Waikato:

Farm details

Total area	110 ha
Productive block area	110.00 ha
Nitrogen conversion efficiency (NCE)	27%
N Surplus	222 kg/ha
Region	Waikato/Coromandel

Total liveweight brought (kg/ha grazed)	313	Milk solids (kg/ha grazed)	1229
Total liveweight reared (kg/ha grazed)	69	Milking herd size (peak cows/ha grazed)	3.1
Total liveweight sold (kg/ha grazed)	354	Dairy stock rate (RSU)	3342
Default calving date	20 July	Dairy replacements stock rate (RSU)	0
Milk production per cow (kg milk solids / cow)	395.3		

Blocks

NAME	TYPE
Eff Horotui	Pasture
Eff Ngak_9a.1	Pasture
Non Eff Hototui1	Pasture
Non Eff Ngak_9a.1	Pasture
Turnips	Fodder crop
Other sources	Other

Farm soils

S-MAP REF	GROUP/ORDER	DRAINAGE CLASS
Ngak_9a.1	Volcanic/Allophanic	Well
-	Volcanic/Allophanic	Well

Canterbury

Farm details

Total area	350 ha
Productive block area	342.00 ha
Nitrogen conversion efficiency (NCE)	28%
N Surplus	268 kg/ha
Region	Canterbury

Total liveweight brought (kg/ha grazed)	319	Milk solids (kg/ha grazed)	1457
Total liveweight reared (kg/ha grazed)	64	Milking herd size (peak cows/ha grazed)	3.6
Total liveweight sold (kg/ha grazed)	362	Dairy stock rate (RSU)	10796
Default calving date	05 August	Dairy replacements stock rate (RSU)	126
Milk production per cow (kg milk solids / cow)	406.8		

Blocks

NAME	TYPE
Platform Irrigated	Pasture
Effluent Irrigated	Pasture
Platform Dryland	Pasture
Other sources	Other

Farm soils

S-MAP REF	GROUP/ORDER	DRAINAGE CLASS
Lism_2a.1	Sedimentary/Brown	Well

Summary of soil properties used

Waikato – Horotiu block: c. 25 RSU

SOIL	IRRIGATOR	PERCENTAGE	DRAINAGE	RUNOFF	TO 60CM FIELD CAPACITY	WILTING POINT	SATURATION	PAW
Volcanic	No irrigation	100%	686 mm	0 mm	241 mm	123 mm	342 mm	118 mm

Canterbury – Lismore (irrigated) block: c. 30 RSU

SOIL	IRRIGATOR	PERCENTAGE	DRAINAGE	RUNOFF	TO 60CM FIELD CAPACITY	WILTING POINT	SATURATION	PAW
Lism_2a.1	Linear and centre Pivot 1	100%	236 mm	0 mm	117 mm	54 mm	180 mm	63 mm

Canterbury – Lismore (dry) block: c. 16 RSU

SOIL	IRRIGATOR	PERCENTAGE	DRAINAGE	RUNOFF	TO 60CM FIELD CAPACITY	WILTING POINT	SATURATION	PAW
Lism_2a.1	No irrigation	100%	163 mm	0 mm	117 mm	54 mm	180 mm	63 mm

APPENDIX II – SUMMARY OF OVERSEER FILES FROM THE FRNL MONITOR FARMS

Farm ID	Location	Whole farm		Pasture					Predominant Soil[1]	Enterprise(s)
		Area ha	N leach kg N/ha	Area % farm	N intake kg N/ha	N leach kg N/ha	Drainage mm	N Fert kg N/ha		
1	CentralPlateau	440	22	75	217	10	301	18	Recent/YGE/BGE	Beef Sheep
2	CentralPlateau	219	11	88	221	11	134	4	Recent/YGE/BGE	Sheep Beef
3	CentralPlateau	397	14	65	248	14	142	0	Recent/YGE/BGE	Sheep Beef Other
4	CentralPlateau	441	38	68	230	17	560	27	Recent/YGE/BGE	Beef Sheep
5	CentralPlateau	442	50	62	251	17	554	36	Recent/YGE/BGE	Beef Sheep
6	CentralPlateau	380	18	76	202	14	182	3	Recent/YGE/BGE	Sheep Beef Other
7	CentralPlateau	379	12	63	138	9	142	0	Recent/YGE/BGE	Sheep Beef Other
8	CentralPlateau	380	17	77	213	11	147	0	Recent/YGE/BGE	Sheep Beef Other
9	CentralPlateau	380	18	78	253	16	156	3	Recent/YGE/BGE	Sheep Beef Other
10	CentralPlateau	440	25	79	249	13	343	33	Recent/YGE/BGE	Beef Sheep
11	CentralPlateau	440	26	79	237	12	345	33	Recent/YGE/BGE	Beef Sheep
12	CentralPlateau	441	24	82	262	15	359	22	Recent/YGE/BGE	Sheep Beef
13	CentralPlateau	388	57	90	458	48	898	162	Volcanic	Dairy DairyReplacements
14	CentralPlateau	383	74	92	568	68	935	206	Volcanic	Dairy DairyReplacements
15	Canterbury	319	47	100	691	47	185	268	Sedimentary	Dairy Beef
16	Canterbury	630	83	67	686	85	413	315	Sedimentary	Dairy
17	Canterbury	325	35	96	724	35	151	290	Recent/YGE/BGE	Dairy DairyReplacements Beef
18	Canterbury	347	56	96	858	55	277	231	Sedimentary	Dairy Beef
19	Canterbury	353	76	95	615	75	287	309	Sedimentary	Dairy

APPENDIX III – SUMMARY OF SINGLE FACTOR SENSITIVITY RESULTS FOR 30% AND 60% PLANTAIN

Variable	Factor		Effect - Waikato >60%PL		Effect - Waikato 30%PL		Effect - Cantbry >60%PL		Effect - Cantbry 30%PL		Effect - Cantbry >60%PL		Effect - Cantbry 30%PL	
			Unirigated				Irrigated				Unirigated			
	>60% PL	30% PL	kg N/ha lchd	% change	kg N/ha lchd	% change	kg N/ha lchd	% change	kg N/ha lchd	% change	kg N/ha lchd	% change	kg N/ha lchd	% change
Proportion of urine	0.8	0.9	47	-6%	49	-2%	42	-14%	46	-6%	32	-16%	35	-8%
UP N load	0.6	0.8	36	-28%	43	-14%	30	-39%	39	-20%	18	-53%	28	-26%
ME content of pasture	1.1	1.1	47	-6%	47	-6%	42	-12%	42	-12%	33	-13%	33	-13%
%N in pasture	0.50%	0.50%	50	<1%	50	<1%	42	-12%	42	-12%	33	-14%	33	-14%
More partitioning of N to milk	1.05	1.025	49	-2%	49	-1%	49	<1%	49	<1%	38	<1%	38	<1%
Rainfall	0.8	0.9	36	-28%	43	-14%	30	-39%	39	-20%	18	-53%	28	-26%