FRNL-Overseer integration:
Completed evaluation of FRNL data against Overseer

Mark Shepherd, Chris Smith, Diana Selbie

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Contents

1. Executive Summary

Three promising management interventions to reduce nitrogen (N) leaching have been identified in the Forages for Reduced Nitrate Leaching (FRNL) research programme: plantain-rich pastures[1]; feeding of fodder beet; and use of catch crops post-grazing of winter crops.

This report outlines the findings from an evaluation of Overseer against experimental data. It details recommended changes to the Overseer model to reflect the FRNL results of plantain, fodder beet and catch crops, and requirements for further research or data collection to enable the incorporation of these mitigation options in the Overseer model. N mass balance from plantain ingested by cows to validate model assumptions is also reported.

In summary, we found:

- Overseer animal N balance reasonably explained the urine N production of animals fed 'standard' ryegrass/clover pasture, diverse pastures and fodder beet-based diets. However, there is increasing evidence of differences in N composition between plantain and non-plantain pastures, which could potentially increase partitioning of excretal N into dung.
- Lysimeter studies suggest decreased N leaching from diverse pastures treated with urine
- To better represent N leaching from fodder beet (with or without a catch crop), further understanding of mineral N sources from non-urine sources is required, as this source of N is estimated to be large by Overseer. A change to root N content is being rolled into the live version very soon which should have some immediate effect on leaching from background. However, further investigation of this might be required.
- Crop coefficients that better capture the catch crop winter growth and luxury N uptake are required to improve Overseer's ability to model this management intervention.

Suggested changes to Overseer are:

- Update the crop composition database to better reflect the nutrient composition of fodder beet
- Introduce a plantain-rich block (with guidance on definition of 'plantain-rich') and create a database of nutrient and ME composition for this pasture-type.
- Change the 'standard' urine patch N load in Overseer's urine patch sub-model to better represent the dilution effect observed with plantain-based pasture (a value to be determined in conjunction with FRNL scientists).
- Similarly, a lower urine patch N load should be implemented in Overseer for fodder beet.
- Possibly, change the N urine partitioning equation to capture differences in N composition in plantain. More discussion on this is required.
- Implement new crop coefficients for catch crop N dynamics if these can be produced.

Next steps: Where gaps in knowledge still exist yet information is required to make changes in the model, expert consensus is needed. The FRNL research teams will review the work to date (this report) and meet to address, and agree on, a list of gaps.

[1] Considered to be >30% plantain

2. Background

Three promising management interventions to reduce nitrogen (N) leaching have been identified in the Forages for Reduced Nitrate Leaching (FRNL) research programme. These are: plantain rich pastures; feeding of fodder beet; and use of catch crops post-grazing of winter crops. The research programme has provided a considerable amount of information on the mechanisms of action of these interventions. The next stage is therefore to assemble these components into a farm system model, i.e. Overseer.

Three key activities have been identified as a step to implementation in Overseer:

1. Report outlining the findings of the work undertaken with details of recommended changes to the Overseer model to reflect the FRNL results of plantain, fodder beet and catch crops, and requirements (if any) for further research or data collection to enable the incorporation of these mitigation options in the Overseer model
2. N mass balance from plantain ingested by cows is reported to validate model assumptions
3. Documentation from Overseer on their proposed timing for incorporating the results of FRNL research into Overseer

This report covers Tasks 1 and 2.

3. Approach

The overall approach was to:

- Establish hypotheses as a basis for evaluating the relevant sub-models within Overseer
- Identify the data available from the FRNL programme for testing these hypotheses
- Work with FRNL researchers to collate the data for evaluation
- Determine how each dataset can be best represented within Overseer
- Complete an evaluation of Overseer using the experiment data

3.1 Establishing hypotheses

The starting hypothesis was that Overseer currently models these scenarios adequately. To test this, a number of sub-hypotheses covering separate parts of the N cycling process were established.

3.1.1 Plantain in pasture

Hypothesis 1 – the overall Overseer framework for estimating N leaching from grazed pasture is applicable to modelling plantain pasture (i.e. there are no extra processes that we need to model, such as nitrification inhibitory effects).

Overseer calculation of excretal N load

Hypothesis 2 – the amount of N eaten by a cow grazing plantain in pasture is not different to a cow eating ryegrass/clover pasture.

Hypothesis 3 – the current Overseer animal N balance calculation to estimate excretal N is appropriate for plantain in pasture.

Hypothesis 4 – the current Overseer relationship between dietary N concentration and proportion of excretal N as urine is appropriate for plantain in pasture.

Hypothesis 5 – a 'typical' urine patch N load (kg N/ha equivalent) is the same as for pasture (750 kg N/ha).

Overseer calculation of N leaching risk

Hypothesis 6 – the Overseer drainage model with monthly climate inputs adequately estimates drainage volume from plantain dominated pastures.

Hypothesis 7 – the urine patch model for pasture is appropriate for plantain in pasture.

Hypothesis 8 - the background model for pasture is appropriate for plantain pasture.

Hypothesis 9 – N leaching estimates from grazing studies are in line with Overseer estimates.

3.1.2 Fodder beet

Hypothesis 10 – the overall Overseer cropping model for estimating N leaching from a grazed forage crop is applicable to modelling grazed fodder beet (i.e. there are no extra processes that we need to factor in).

Overseer calculation of excretal N load

Hypothesis 11 – the amount of N eaten by a cow grazing fodder beet is correctly estimated by the current Overseer model.

Hypothesis 12 – the current Overseer animal N balance calculation to estimate excretal N is appropriate for fodder beet.

Hypothesis 13 – the current Overseer relationship between dietary N concentration and proportion of excretal N as urine is appropriate for fodder beet

Hypothesis 14 – a 'typical' urine patch N load (kg N/ha equivalent) is the same as for pasture (750 kg N/ha).

Overseer calculation of N leaching risk

Hypothesis 15 – the Overseer drainage model with monthly climate inputs adequately estimates drainage volume from bare soil after grazing fodder beet.

Hypothesis 16 – the current leaching model for grazed forage crops is appropriate for fodder beet.

Hypothesis 17 – the background model for pasture is appropriate for fodder beet.

Hypothesis 18 – N leaching estimates from grazing studies are in line with Overseer estimates.

3.1.3 Catch crops

Hypothesis 19 – the overall Overseer CROPPING MODEL for estimating N leaching from a grazed forage crop is able to correctly capture the benefits of a catch crop sown post-grazing.

Overseer calculation of excretal N load

Hypothesis 20 – Overseer correctly models catch crop growth.

Overseer calculation of N leaching risk

Hypothesis 21 – the Overseer drainage model with monthly climate inputs adequately estimates drainage volume from catch crops.

Hypothesis 22 – the current leaching model for grazed forage crops is appropriate for catch crops.

Hypothesis 23 – N leaching estimates from grazing studies are in line with Overseer estimates.

3.2 Critique of available experiments

Appendices I and 2 summarise the experiments that were available at the time of evaluation. For clarity throughout the report, we also allocated a study code to each project. We refer to these codes during our analysis of the results.

The plantain/diverse pasture experiments fell into two categories: grazing experiments and non-grazed lysimeter experiments. The grazing experiments compared different forage types and/or mixes (including different proportions of plantain fed), and measure production and urinary excretion. They were therefore of value in testing hypotheses 2-5, focusing on testing whether Overseer was able to estimate correctly amounts of urinary N production.

The level of detail on urinary N production (daily N load) depended on the type of experiment:

- Urine sensors (1 experiment)
- Metabolism stalls (1 experiment)
- Indirect estimates based on creatine (3 experiments)
- Spot measurement of urine N concentration (1 experiment)

The lysimeter experiments (four experiments) added urine at various rates onto pasture of varying composition, with or without irrigation. These experiments allowed us to test hypotheses 6-8 around leaching risk from urine patches and non-urine patches (where there was a zero N control).

The **fodder beet experiments** (three experiments) focused on feeding trials. These were either metabolism stall (2) or a grazing trial with urine sensors, focusing on different levels of fodder beet in the ration of either late-lactation or dry cows. These experiments provide a useful dataset for evaluating the calculation of N excretion (hypotheses 11-14).

Catch crop experiments (nine experiments) focused on comparing species and their management (e.g. sowing date) and effects on N leaching. These tended to be plot experiments (six experiments), established either after a grazed crop or in the absence of animals but with a large N application to simulate post-grazing. The latter approach at least has a known amount of N returned. Three experiments specifically tested grazing strategies and their interaction with catch crop management on N uptake and N leaching.

In addition, a plant **feed composition database** has been compiled as part of the FRNL programme. This is an essential resource for testing whether the feed composition default values in Overseer are in line with recent measured data, as these values have a large influence on estimates of N intake and consequent amounts of excreta produced.

3.3 Overseer modelling

3.3.1 Overseer public vs research platform versions

The catch crop experiments were simulated using the publicly available version of Overseer (https://secure.overseer.org.nz/live), using the cropping block.

For grazing/feeding experiments and lysimeter experiments, a specially adapted version of the model was used. A test environment has been developed with an Overseer version that exposes more of the intermediate output values such as calculated N intake (i.e. not just DM intake) and urinary N excretion (kg N/ha/month); the public version reports only monthly excretion without partitioning between dung and urine. The public version also does not have a 'lysimeter block'.

3.3.2 Animal feeding trials - diverse pastures or fodder beet

Animals were grazed/fed outdoors or housed in metabolism stalls. The best way to accurately represent the short-term experiment in Overseer was to apply the same methodology, irrespective of the experiment method, because this better enabled us to achieve the measured dry matter and nitrogen intakes:

- Cows fed in a housed facility for the trial measurement period.
- While in the housed facility the cows were fed an imported supplement, which matched the intake parameters reported for the pastures or the fodder beet/supplement from each particular study. This enabled the feed intakes, DM, N% and ME, to be closely matched to that reported, by means of adjusting feed imported or, in some cases, stock numbers.

This enabled us to expose the Overseer estimate of excretal N production for comparison with measured values in the experiments.

3.3.3 Cover crops

All the grazed fodder beet and cover crops were set up in the Overseer public version using the CROP model. In each case the treatments were set up as individual crop blocks with the following assumptions:

- Previous history assumed to be grazed pasture, unless otherwise stated in report/paper
- Crops not covered in Overseer, such as Sudan, entered as Triticale.
- Crops grazed using non-farm animals
- Cover crops were entered as autumn sown for April, May and June, and spring sown for July and August.

Husbandry was as close as possible to the experiment descriptions. Measured catch crop yields were entered into the model. The biggest uncertainty was the past history of the site: years previously in pasture can have a large impact on soil N cycling. We assumed 5 years in 10.

The cropping model reports overall N leaching estimates for the reporting year and monthly values of soil mineral N and crop N uptake. Data are graphed in the model output but hovering over each point provides a numerical value. We were therefore able to compare modelled values of N uptake and soil mineral N with measured.

'Plant N uptake' in Overseer includes N captured in roots and stover, not just the above-ground component. The factor for additional N is variable but c. 30% is typical (D Wheeler Pers Comm). We therefore adjusted Overseer reported values down by a factor 1.3 to provide an estimate of above-ground N uptake.

Plant N uptake is reported at month end. Therefore, if crop is harvested mid-month, maximum crop N uptake is not reported. We approximated what that value at the end of November (final harvest mid-November) was by assuming any reduction in mineral N between end Oct and end Nov was due to crop removal and this was added to crop uptake reported at the end of October.

3.3.4 Lysimeter studies

Lysimeter trials were set up in a Delphi version of the Urine Patch sub-model, specifically developed for testing lysimeter experiments. This allowed the details of the experiment to be fully replicated from the experiment reports, including:

- Urine N load (or zero for controls)
- Lysimeter depth and soil type
- Weather data (monthly time-step)

Further details of the process are described in Shepherd & Wheeler (2016).

4. Results

4.1 Plantain and fodder beet: calculation of excretal loads

Combined, the experiments provided 29 estimates of urinary N production for comparison with Overseer estimates, categorised as fed on fodder beet (plus supplements (FB), non-plantain pastures (NPP) or diverse pastures including plantain 'Plantain-rich pasture' (PRP) (Table 1). There also 2 treatments which were pure plantain swards (PL). Table 2 summarises the experiment and Overseer data for each treatment.

***Table 1**. Summary of experiment data with estimates of urinary N production.*

Description	No. data points	Code used in this report
Fodder beet with supplements	5	FB
Non-plantain pastures	13	NPP
Plantain-rich pastures	9	PRP
Plantain	2	PL

4.1.1 Assessment of individual experiments

Fodder beet

Study JJ – This study compared different supplements with fodder beet, so no comparison with a pasture diet was available. The straw supplement-based diet failed and the treatment was stopped early to animal welfare considerations. Results from this treatment should therefore be treated with caution. From fodder beet plus silage, daily urinary N production was c. 87 g N/cow/day.

Study KK – Less daily urinary N from fodder beet diet was attributed to lower N intake, compared to a pasture-based control. The reduced N excretion was expressed as less N per urination (c. 40% reduction, 11 urinations FB vs 10 pasture). This potentially has consequences for the Overseer urine patch model, indicating the need for a lower N load in the patch model.

Study MM – Fodder beet diets substantially reduced N intake and urinary N excretion compared with pasture only. 46-58% of excreta occurred as urine. The proportion of excreta as urine was inversely related to feed N concentration.

Plantain-rich pastures

Study AA – There was no effect of pasture type on daily urine N excretion (attributed to no significant difference in daily N intake). Pasture type affected the diurnal pattern in urine-N excretion with mixed pastures having a lower urine N loading per event during the day and higher urine N loading at night compared with PRG pastures. Again, this could have implications for the urine patch load used in Overseer.

Study DD – Even though cow daily N intake did not significantly differ between non-plantain and plantain-rich pastures, spot measurements of urine N concentration were significantly lower in plantain treatments. Two indirect methods of urinary N output estimation (based on milk urea or creatine) showed significant reductions in daily urinary N production with plantain-rich pastures, further supported by unreplicated calculations based on average volume and average N concentration. Note that the plantain sward showed a marked reduction in urinary N production in in early lactation compared with PRG, but this effect was not observed in late lactation.

Table 2: *Summary of experiment and Overseer results for urinary N production*

Expt code	Urine method	Treatment	DM Intake kg /cow/d	Feed N %	N intake g /cow/d	Urine N g /cow/d	Urine N % of intake	DM Intake kg/cow/d	Feed N %	N intake g /cow/d	Excretal N g/cow/d	Prop. urine %	Urine N g/cow/d	Urine N % of intake
AA	US	PRG	16.5	3.66[a]	604	195	32	16.4	3.66	598	493	74	364	61
AA	US	Forbe	15.2	4.19[a]	637	187	29	15.5	4.19	619	507	77	393	63
DD	Ind	LL-Pasture	13.5	4.59[a]	619	371	60	14.3	4.59	621	508	80	406	65
DD	Ind	LL-Plantain mix	14.9	3.48[a]	518	340	66	15.0	3.48	522	401	71	285	55
DD	Ind	LL-Plantain	15.9	3.74[a]	594	311	52	15.5	3.74	551	425	72	308	56
DD	Ind	EL-Pasture	18.5	3.52[a]	652	301	46	18.5	3.52	650	521	72	375	58
DD	Ind	EL-Plantain mix	18.5	3.40[a]	629	225	36	18.5	3.40	628	499	71	352	56
DD	Ind	EL-Plantain	20.7	3.23[a]	669	187	28	20.7	3.23	636	507	66	337	53
EE	Ind	PRG	14.0	4.19	590	438	74	14.3	4.19	570	452	77	349	61
EE	Ind	HS PRG	14.5	4.21	610	426	70	13.8	4.21	581	471	79	375	65
EE	Ind	HSD	14.5	3.79	551	354	64	14.3	3.79	513	403	73	293	57
GG/II	Ind	PRG+L summer	15.0	4.40	642	392	61	15.3	4.40	676	593	80	475	70
GG/II	Ind	PRG+L+P summer	15.0	3.25	487	238	49	15.3	3.25	492	415	68	283	58
GG/II	Ind	TF+L summer	15.3	4.11	629	399	63	15.3	4.11	629	547	79	431	69
GG/II	Ind	TF+L+P summer	14.9	3.34	497	272	55	14.6	3.34	456	368	67	247	54
GG/II	Ind	PRG+L spring	14.9	3.32	494	260	53	14.7	3.32	461	386	67	258	56
GG/II	Ind	PRG+L+P spring	16.5	3.01	497	198	40	15.5	3.01	464	389	66	256	55
GG/II	Ind	TF+L spring	16.7	3.59	599	341	57	15.5	3.59	558	483	72	350	63
GG/II	Ind	TF+L+P spring	16.5	3.70	610	301	49	15.5	3.70	572	494	74	367	64

Expt code	Urine method	Treatment	DM Intake kg /cow/d	Feed N %	N intake g /cow/d	Urine N g /cow/d	Urine N % of intake	DM Intake kg/cow/d	Feed N %	N intake g /cow/d	Excretal N g/cow/d	Prop. urine %	Urine N g/cow/d	Urine N % of intake
HH	MS	G	14.9	2.47	366	167	46	15.0	2.47	371	312	59	183	49
HH	MS	G+L	12.7	3.21	408	229	56	12.5	3.21	401	344	68	234	58
HH	MS	G+L+P	15.0	2.93	440	220	50	15.0	2.93	438	363	65	237	54
JJ	MS	70% FB+silage	8.3	1.75	144	87	60	7.9	1.75	131	107	50	53	40
JJ	MS	85% FB+straw	6.4	1.14	74	52	70	6.9	1.01	75	49	44	22	29
KK	US	Pasture+MS	12.0	2.83	339	173	51	12.2	2.83	358	307	64	198	55
KK	US	FB+Past silage	12.0	1.69	203	90	44	11.9	1.69	187	136	49	67	36
MM	MS	Pasture+MS	15.2	3.03	461	205	44	15.0	3.03	457	392	66	261	57
MM	MS	25% FB+pasture	15.3	2.66	407	155	38	14.3	2.66	360	290	60	175	49
MM	MS	40% FB+pasture	14.0	2.27	318	112	35	13.8	2.27	315	243	57	139	44

A = back calculated from reported DM and N intakes

Codes, urine method: Urine sensor = US; Metabolism stall = MS; Indirect = Ind

Codes: experiment treatments: PRG = Perennial ryegrass; HS PRG = high sugar PRG; HSD = diverse mix with high sugar perennial ryegrass; P= Plantain; TF = Trefoil; G = 'Grass'; FB = Fodder beet; MS = Maize silage; LL = Late lactation, EL = Early lactation.

Study EE – This experiment compared PRG with high sugar grass with or without plantain. There was a c. 13% reduction in N intake (not significantly different), with not much difference in milk protein content offtake between treatments. Nevertheless, urine N concentrations from the plantain-rich diet approximately halved. Urinary N load was also significantly reduced in HS with plantain (c 23% reduction). The authors hypothesised that N balance alone was insufficient to explain the reduction in urine-N and an alternative mechanism must have also been involved, e.g. composition of the forage.

Study FF - Consistent reductions in N excretion parameters for faecal N and urinary N concentration indicated that pastures containing forbs such as chicory and plantain offer an opportunity to reduce dietary N intake and to reduce soil N loading from urine events through lower urinary N concentration.

Study GG/II – In late lactation, inclusion of plantain in the diet decreased N intake and daily urinary N load (and urinary N concentration in spot samples). There was no effect of plantain on early lactation N intake, but it did decrease urinary N concentration, attributed to higher water intakes with plantain. There was also an indication of reduced daily urinary N load.

Study HH – Daily urinary N output increased with a diet including plantain, attributed to increased daily N intake.

4.1.2 Assessment of a combined dataset

There was a strong positive relationship between daily urinary N production and estimated daily N intake when all of the experiments were plotted on one graph, with the exception of four possible outliers (Figure 1).

Inclusion of fodder beet diets adds values at the lower part of the curve and therefore improves the fit compared with pasture diets only. Excluding fodder beet still generated a highly significant exponential relationship (r^2 = 70%, P<0.001).

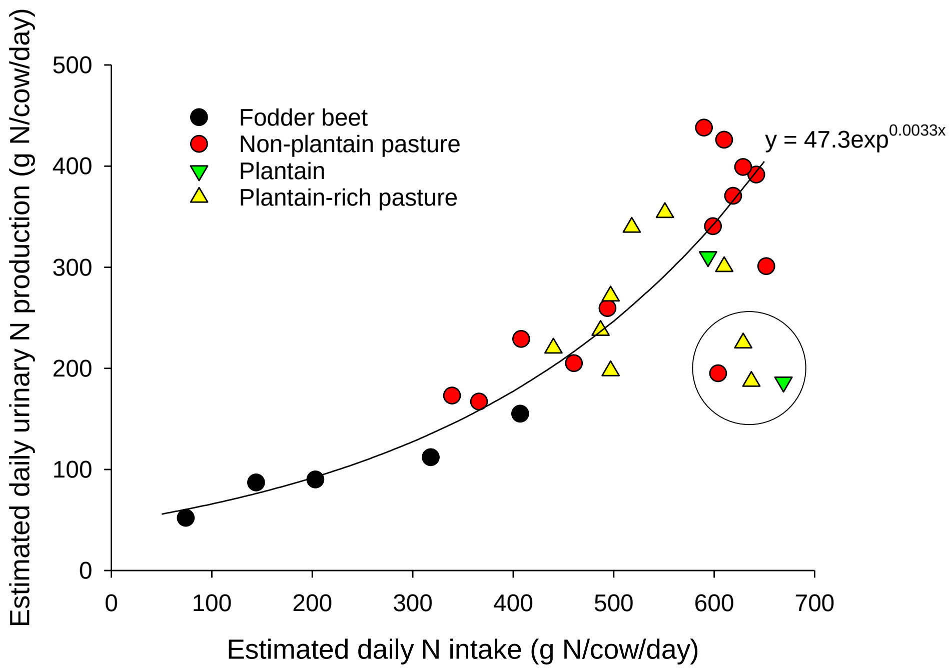

***Figure 1**. Compilation of experiment datasets. Relationship between estimated daily urinary N production and estimated daily N intake. Exponential curve fitted (P<0.001, r^2 = 80%). Excludes outliers in the circle.*

The outliers are difficult to explain and comprise one pure plantain and one plantain-rich pasture (Study DD), another plantain-rich pasture plus a perennial ryegrass pasture (Study AA). Further analysis is undertaken in the 'Discussion' section.

Section 3.3 explained how Overseer models were set up to represent the experiments. Given the importance of daily N intake as a driver of urinary N production (Figure 1), it was important that the Overseer models reflected experiment intakes. Figure 2 shows that good agreement was achieved between Overseer and experiment N intakes.

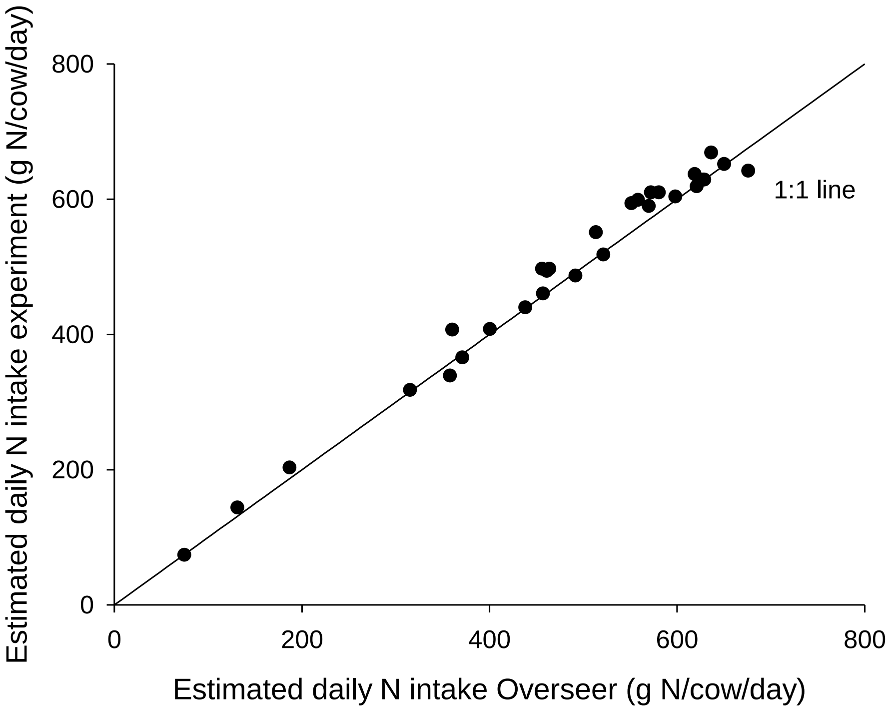

Figure 2: *Comparison of estimated daily N intakes from experiments and the associated Overseer model.*

Excluding the aforementioned outliers, there was good agreement between Overseer estimated and experiment estimated values of daily urinary N excretion (Figure 3). There was a non-significant intercept and a slope close to one.

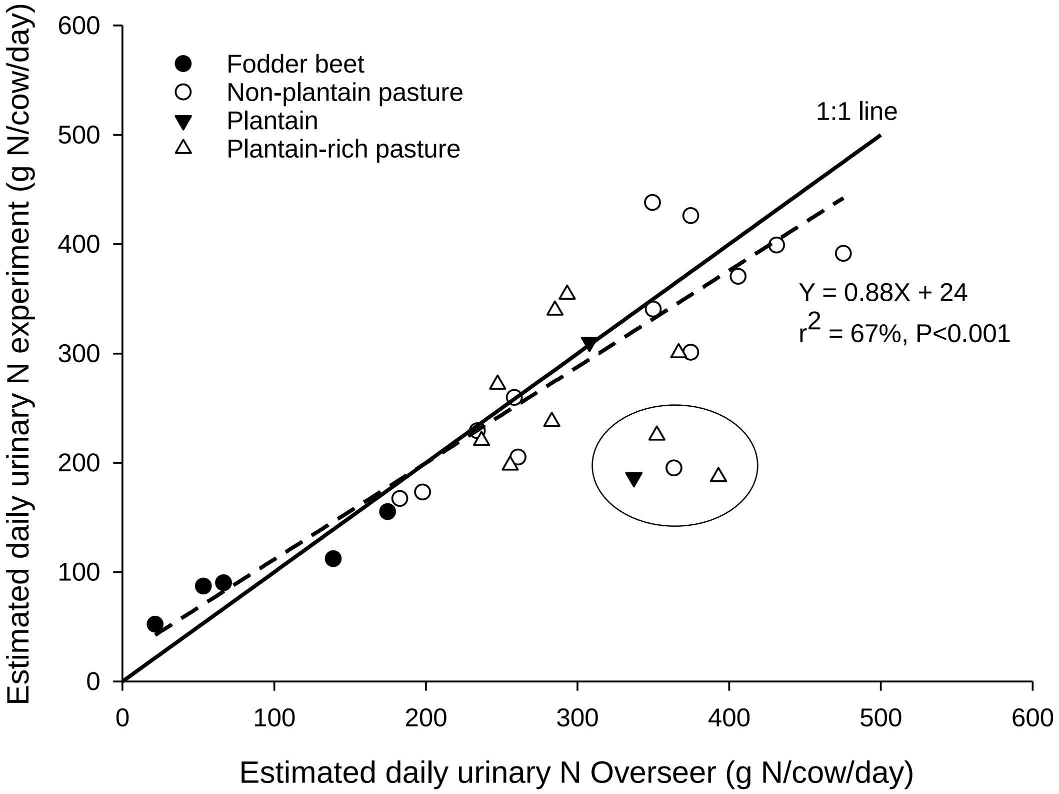

Figure 3: *Comparison of Overseer modelled and experiment estimated daily urinary N production from plantain and fodder beet diets. ALL data. Regression excludes 4 outliers.* Note: non-significant intercept, slope of fitted line changes to 0.96 (r^2 = 68%, P<0.001) when forced through zero.

Further comparison was made between Overseer and measurements using Study FF. This Study included only concentrations of urinary N from spot measurements. However, these measured concentrations were related to the daily N loads estimated from Overseer (Figure 4). The relationship differed between NPP and PRP due to the dilution effect in PRP observed in the other experiments too.

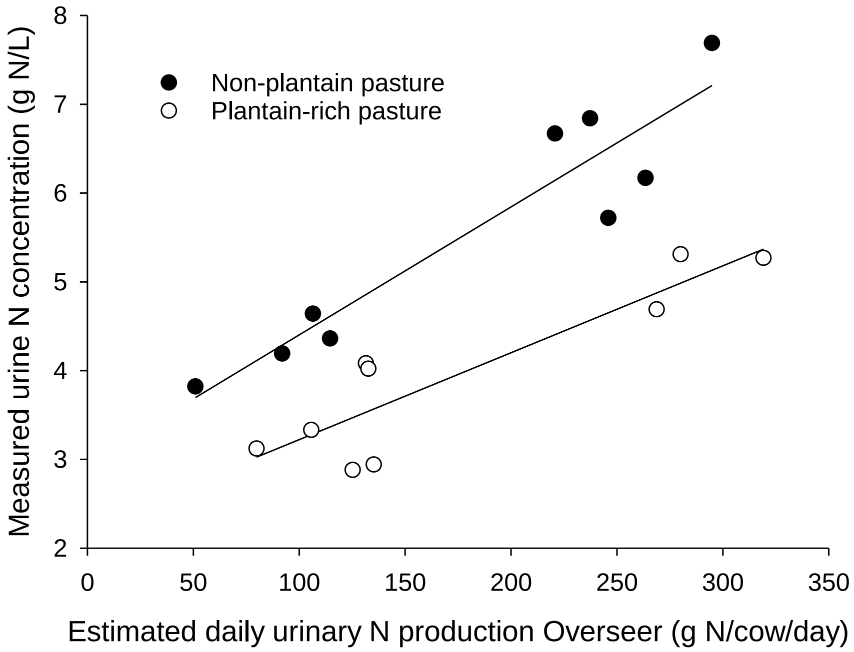

Figure 4*: Relationship between measured urinary N concentration and Overseer estimated load for non-plantain and plantain-rich pastures.*

Most of the experiments estimated urinary N load with sensors or indirect methods. There were few data that included an estimate of partitioning between dung and urine, and only one data point included plantain.

Therefore, we calculated the proportion of daily N intake that occurred as urine and compared this value for experiment and Overseer (data in Table 2). Overall, the range of urinary N proportions were similar between experiments (mean 50%, range 28-74%) and Overseer (mean 56%, range 36-70%). However, there was no relationship between individual values and a paired t-test showed, on average, a significant ($P < 0.05$) overestimate by Overseer of the proportion of feed N intake that occurs as urine. This difference was, on average, 6% in absolute terms. Further separation into plant species reduces the number of replicates but we were able to show a significant difference for both plantain and non-plantain pastures between experiments and measurements (Table 3).

Table 3: *Summary of estimated proportion of feed N intake that is excreted as urine N (%), comparing experiment and Overseer values. A paired t-test was completed on the three subsets of data.*

	Fodder Beet		**Plantain-rich**		**Non-Plantain**	
	Expt	**OvS**	**Expt**	**OvS**	**Expt**	**OvS**
sample no.	4	4	11	11	13	13
min	35	36	28	53	32	49
max	60	49	65	64	74	70
mean	45	42	47	57	55	61
P value	0.77		0.04		0.06	

4.2 Lysimeters - plantain

4.2.1 Study B

Overview of experiment

This was a lysimeter experiment comparing Perennial ryegrass/white clover (RYWC) with Italian ryegrass, plantain and white clover mix (IPM). A one-year old sward then taken into lysimeters (Templeton sandy loam). Three treatments for the two swards (six treatments in total): control, urine 'actual' (mimicking the urine rate from grazing the different swards) and urine at 700 kg N/ha (see Table). Experiment ran over two winters (2015 and 2016) to capture the residual effects of N leaching into the second winter. Rain was supplemented with irrigation.

Key features of the results

- Large differences in drainage between the treatments (see Table 4):
    - Nil-N drainage > urine N drainage
    - IPM drainage < RGWC drainage
- We calculated a relatively small N recovery in the system, based on data in the paper
    - 28-30% apparent N recovery in pasture from RGWC and 13-23% recovery by IPM
    - Apparent N recovery in plant and leachate: 45-47% and 22-26% for RGWC and IPM, respectively
- It took about 250 mm drainage to elute the soil profile, so a small amount of N carryover into the second year in treatments with less drainage (though not entirely clear from the paper)
- The assertion was that N leaching was reduced because of greater N uptake by the IPM but the uptake effects look to be marginal.

Table 4: *Results summary, Study B. Net uptake = difference in N uptake between control and urine N applied, i.e. recovery of urine N applied in herbage. Net Upt+Lch% = recovery of urine N applied in herbage and leaching.*

		Urine N applied	**N uptake**	**Net N uptake**	**N Leached**	**Net Upt+Lch**	**Net Upt+Lch**	**Drainage Year 1**
		kg/ha	**kg/ha**	**kg/ha**	**kg/ha**	**kg/ha**	**%**	**mm**
RGWC	control	0	542		<1			266
	actual U	664	744	202	113	315	47	200
	700 U	700	744	202	113	315	45	198
IPM	control	0	561		<1			214
	actual U	508	679	118	13	131	26	130
	700 U	700	656	95	62	157	22	155

Comparison with Overseer

When monthly climate data was used (monthly LT PET and temperature plus reported water inputs (again aggregated to a monthly value), estimated from the paper), drainage estimates with Overseer were much larger (c. 320 mm in year 1) compared with the reported results. Because of this overestimate in drainage, N leaching estimates were larger than measured (see Figure 6).

For the rest of the comparison, we therefore used the actual monthly drainage reported in the paper for each treatment. Using the actual drainage, Overseer N leaching estimates were in good agreement with measured from the RGWC sward but overestimated for IPM, particularly for the 'actual urine' treatment (Figure 5).

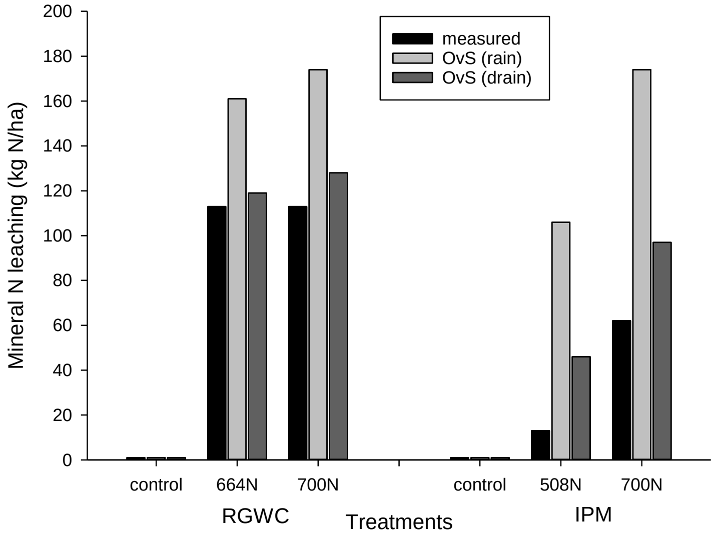

Figure 5: *Comparison of measured and modelled N leaching. 'OvS (rain)' uses water applications (rain+irrigation) as input data; 'OvS (drain)' uses actual measured drainage for each treatment.*

4.2.2 Study D

Overview of experiment

This was a lysimeter study, comparing two urine application times (December and February), two pastures (PRG/white clover with and without plantain), and three irrigation regimes (pivot, rotorainer and flood). See Table 5.

Key features of the results

- Most drainage from flood irrigation treatments; less drainage from pastures including plantain.
- More N leaching from February applications than December applications – although there was some N leaching from both of these timings.
- Much less N leaching from pastures with plantain included compared with standard ryegrass/clover. This was attributed to a nitrification inhibitor effect and less drainage.

Comparison with Overseer

Overseer overestimated drainage and, consequently N leaching losses. Even after re-running files with drainage that approximated to measured N leaching losses were larger than reported (although measured and modelled values were strongly correlated). This was particularly the case for the plantain pastures.

Table 5: *A summary of data from Study D, compared with Overseer estimates. Overseer modified refers to a comparison where drainage was entered to approximate to measured values.*

Treatment Pasture	Irrigation	Urine	urine applied (kg/ha)	Measured[1] drainage (mm)	Measured[1] N leached (kg/ha)	Overseer drainage	Overseer N leached (kg/ha)	Overseer modified drainage	Overseer modified N leached (kg/ha)
Standard	Flood	Dec	700	461	38	539	200	470	169
Standard	Flood	Feb	700	439	70	539	268	435	197
Standard	Pivot	Dec	700	370	45	437	163	365	126
Standard	Pivot	Feb	700	400	130	437	263	395	196
Standard	Roto	Dec	700	387	50	501	168	375	147
Standard	Roto	Feb	700	400	100	501	232	380	162
Diverse	Flood	Dec	700	373	4	539	170	370	107
Diverse	Flood	Feb	700	328	42	539	268	320	147
Diverse	Pivot	Dec	700	290	5	437	163	280	93
Diverse	Pivot	Feb	700	280	10	437	263	265	146
Diverse	Roto	Dec	700	302	18	501	168	285	98
Diverse	Roto	Feb	700	295	32	501	232	300	123

[1] Measured values are estimated from tables and graphs in the paper (red text). Other values were reported in the text of the paper (black text)

4.3 Catch crops

After evaluating a few of the available experiments against Overseer, it became obvious that there were consistent messages coming from the evaluation, that didn't necessitate analysis of all experiments. Here, we present two examples to demonstrate the findings.

4.3.1 Study F

Overview of experiment

A plot experiment using fertiliser to simulate urine applications, investigating the effects of catch crops. In this case, oats (Avena sativa) was used as a green-chop catch crop after (simulated) grazing of a winter-grazed forage kale (Brassica oleracea var. acephala) in a 3x2 factorial design (Oats sowing date x N fertiliser rate). Oats were direct-drilled either 'early' (1 July 2015) or 'late' (1 August 2015) plus a fallow control. N applications were 'high' (400 kg N/ha) or 'low' (0 kg N/ha) to represent urine-patch and inter urine-patch areas. Final harvest was mid-November (50% ear emergence). Measurements focused on yield and N uptake, and soil mineral N (mineral N).

Key features of the results

- Crops were slow to emerge: full cover achieved 17 August and 7 September for early and late sown crops.
- Crop growth:
    - >80% of the total biomass was accumulated after mid-October (crops were also irrigated Oct-Nov) (simulated urine treatments).
    - Importantly, similar results were noted with N uptake: 80-90% of N uptake measured on 19 Nov occurred after 14 October (simulated urine treatments).
    - Crop N concentration (estimated from graphs/tables in the paper) suggest %N was c. 1% with no applied N and c. 2% with applied N (See Table 6)
- Soil mineral N:
    - 45 kg N/ha net mineralisation in bare soil 9 June – 2 September (0-120 cm)
    - Soil mineral N fallow 2 September 55 kg N/ha (0-120 cm)
    - When urine was simulated most of the soil mineral N reduction occurred in the last 10 days, i.e. in November
    - Between 6 and 26 November:
        - Fallow plus fertiliser – soil mineral N increased by c. 200 kg N/ha
        - With catch crops, decreased by c. 200 kg N/ha

Table 6: *Summary of results from the paper. Some data estimated from graphs (DM production). %N calculated from these estimates. Final harvest in bold*

Sowing date	N rate kg N/ha	N uptake (kg N/ha) 14-Oct	19-Nov	26-Nov	DM production (t DM/ha) 14-Oct	19-Nov	26-Nov	Estimated %N
July	0	27	**55**		1.0	**6.2**		**0.9**
	400	40	**243**		1.0	**11.8**		**2.1**
August	0	19	61	**76**	0.5		**6.7**	**0.9**
	400	18	200	**229**	0.5		**10.8**	**1.9**

Comparison with Overseer

Reported N leaching was sensitive to the irrigation of the previous kale crop. Although we were not comparing measured and modelled N leaching, we noted that any assumptions around irrigation of the kale crop affected N leaching. Applying irrigation October-March to the kale crop increased calculated drainage through the following winter by 20-30 mm and N leaching by 4-18% depending on the treatment.

Soil mineral N levels and N cycling were extremely sensitive to previous paddock history. Figure 6 shows the effect of years in pasture on soil mineral N or leached N for nil-N and July-applied urine N. Clearly this is an important input to get right, as it strongly influences the estimated soil N supply within the Overseer model.

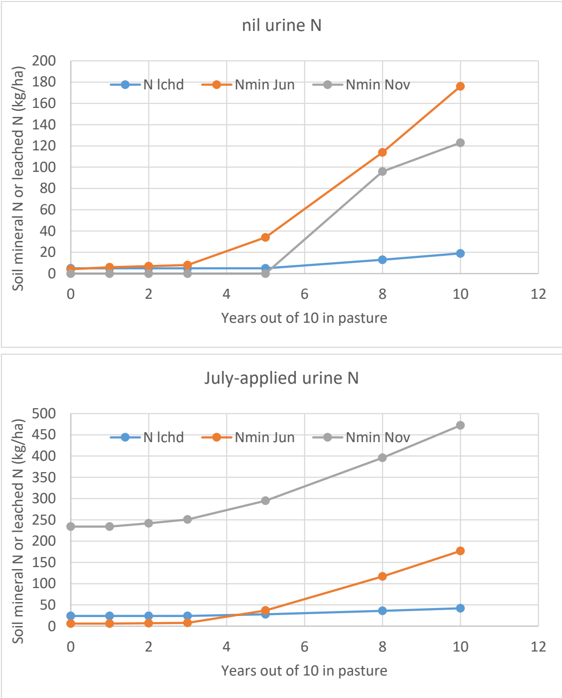

Figure 6. *Effect of years in pasture on modelled soil mineral N and leached N. Mineral N June represents estimated soil mineral N at harvest of the kale crop, Nov mineral N at the end of drainage.*

Overseer underestimated N uptake when urine was applied, with resultant implications for soil mineral N and N leaching estimates. Table 7 compares measured crop N removal and estimated N removal calculated from Overseer as described above. Overseer tended to underestimate N removal by mid-October, and by November Overseer tended to overestimate N removal in the nil-N (July-sown crop) and did not capture the luxury uptake with urine application.

Table 7: *Measured and Overseer-estimated crop N removal*

Sowing date	**kg N/ha**	**14-Oct**		**19-Nov - 26-Nov**	
		Measured	**Overseer**	**Measured**	**Overseer**
July	0	27	14	**55**	114
	400	40	20	**243**	125
August	0	19	10	**76**	78
	400	18	9	**229**	118

Overseer shows similar trends in soil mineral N as measured but absolute amounts vary. Table 8 shows modelled and measured soil mineral N. Note that they are at different total depths and also, some of the measured values look variable, particularly the apparent increase on the fallow plot of c. 250 kg N/ha in November.

***Table 8**. Measured and modelled soil mineral N (kg/ha)*

		Sampling date		
Treatment	**N rate**	**2-Sep**	**6-Nov**	**26-Nov**
Soil mineral N estimated from graph (0-120 cm)				
Fallow	0	50	80	110
	400	280	300	520
July	0	40	20	25
	400	220	280	80
August	0	50	30	80
	400	170	290	100
Overseer estimates (0-60 cm month end)				
Fallow	0	50	75	83
	400	404	395	352
July	0	47	0	0
	400	403	350	295
August	0	49	35	0
	400	403	380	305

To account for the different measurement depths, we compared the change in soil mineral N, using the 2-Sep measurement as the baseline. Figure 7 shows that modelled and measured values are correlated, but absolute values differ.

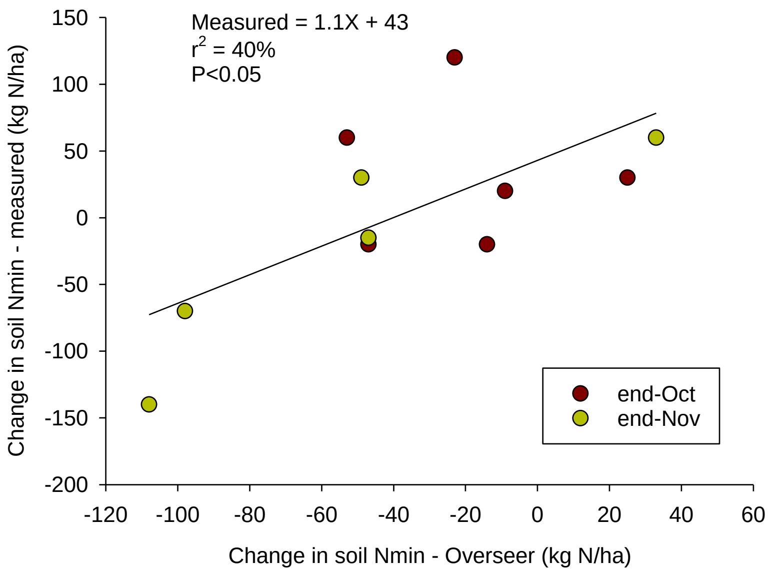

Figure 7. *Change in soil mineral N since 2-Sept. Comparison of Overseer and measured values*

4.3.2 Study G

Overview of experiment

Two plot experiments using fertiliser to simulate urine applications, investigating the effects of catch crops.

Study 1 (PFR) – Oats (Avena sativa) or Ryecorn were used as a green-chop catch crop after (simulated) grazing of a winter-grazed forage crop. In this case a winter crop was not grown; the site followed a wheat crop and the soil was left fallow barring weeds until treatments were applied in June. Catch crops were direct-drilled either 'early' (1 July 2015) or 'late' (1 August 2015) plus a fallow control. N applications were 'high' (400 kg N/ha) to represent urine-patch areas. A nil N treatment was included for the fallow only. Final harvest was early- to late-November (50% ear emergence), depending on species and sowing date. Measurements focused on yield and N uptake, and soil mineral N.

Study 2 (Lincoln Uni) - Ashley Dene Research and Development Station (ADRDS). Two trials with oats to measure growth and N uptake after different establishment methods (conventional, direct drill or broadcast) following grazing of either kale (Trial 1) or fodder beet (Trial 2).

Key features of the results

- Ryecorn emerged more quickly than oats, but this did not result in more biomass accumulation or N uptake for the ryecorn compared with oats.
- Crop growth:
  - 0.5-1 t DM/ha accumulated by 4 October, 3-5 t DM/ha by late October (both species and drill dates). 12 t DM/ha when oats were grown through to late November.
  - Thus crops didn't really 'take off' until mid-Oct onwards.
  - Most of the N taken up by the crops occurred in October and November, supporting previous work.
  - At green-chop maturity a total of 178–201 kg N/ha and 146–157 kg N/ha was taken up by the oats and ryecorn catch crop treatments, respectively. On 1 Oct uptake was 70 (Aug sown) or 30 (Jul sown) kg N/ha.
  - Crop N concentration (with applied N): See Table 9.

- Soil mineral N (0-120 cm):
    - c. 40 kg N/ha net mineralisation in bare soil 5 Sept – 4 Nov, suggesting not a 'high N mineralisation' site
    - Under catch crops:
        - 300 kg N/ha 5 Sept
        - 100-200 kg N/ha 4 Oct, the smaller amounts under earlier sown crops
        - <50 kg N/ha 4 Nov under all crops
- Water use
    - Evidence of water uptake down to 120 cm
    - Oats appeared to have greater water uptake at depth than ryecorn

Table 9*: Summary of crop N concentration, taken from the experiment report*

%N	Crop	26-Oct	maturity
July	oats	2.9	1.5
July	ryecorn	3.0	2.5
August	oats	3.9	1.5
August	ryecorn	4.2	2.2

Overseer underestimated N uptake, with resultant implications for soil mineral N and N leaching estimates. Table 10 compares measured crop N removal and estimated N removal. Note these numbers have not been adjusted for capture of N in roots. Overseer greatly underestimates N uptake by the catch crop.

Overseer over-estimated soil mineral N at all times – Overseer estimated that there was >500 kg N/ha in the top 60 cm at the end of August. This appears to be at least in part, that Overseer shows a large soil mineral N accumulation during the fallow phase between harvesting the previous wheat crop and the start of the experiment in June (Figure 8); thus the application of another 400 kg N/ha as fertiliser pushes the estimate to >500 kg N/ha. Note that this is only reported to 60 cm compared with measured 0-120 cm. It is common that soil mineral N is higher in the top soil than in lower layers, but the difference is so large it is unlikely that the Overseer estimates were close to actual values for 0-60 cm.

Table 10*: Measured (estimated from graphical summary) and Overseer-estimated crop N removal. NB Overseer estimates not adjusted for root N uptake.*

	Sow	End Sep		End Oct		End Nov	
Crop	date	Measured	Overseer	Measured	Overseer	Measured	Overseer
Rye	Jul	80	16	150	53		
	Aug	35	10	150	39		
Oats	Jul	80	33	165	104		
	Aug	35	16	165	65	200	152

__Table 11:__ Measured (estimated from graph in the report; 0-120 cm) and Overseer modelled (0-60 cm) soil mineral N (kg/ha).

Crop	Sowing date	End Aug		End Sept		End Oct	
		Measured	**Overseer**	**Measured**	**Overseer**	**Measured**	**Overseer**
Rye	Jul	300	548	80	548	<50	**519**
	Aug	300	545	170	550	<50	535
Oats	Jul	300	543	130	531	<50	468
	Aug	300	544	200	544	<50	508

Note measured is to 120 cm Overseer estimates to 60 cm

Overseer underestimates the reduction in soil mineral N due to catch crop uptake compared with measured reductions - Table 11 shows modelled and measured soil mineral N. Note that they are at different total depths. To account for the different measurement depths, we compared the change in soil mineral N, using the end Aug measurement as the baseline.

Overseer greatly underestimated the reduction in soil mineral N between end of August and end of October. Measured values were of the order of 250 kg N/ha; Overseer estimates were 10-75 kg N/ha.

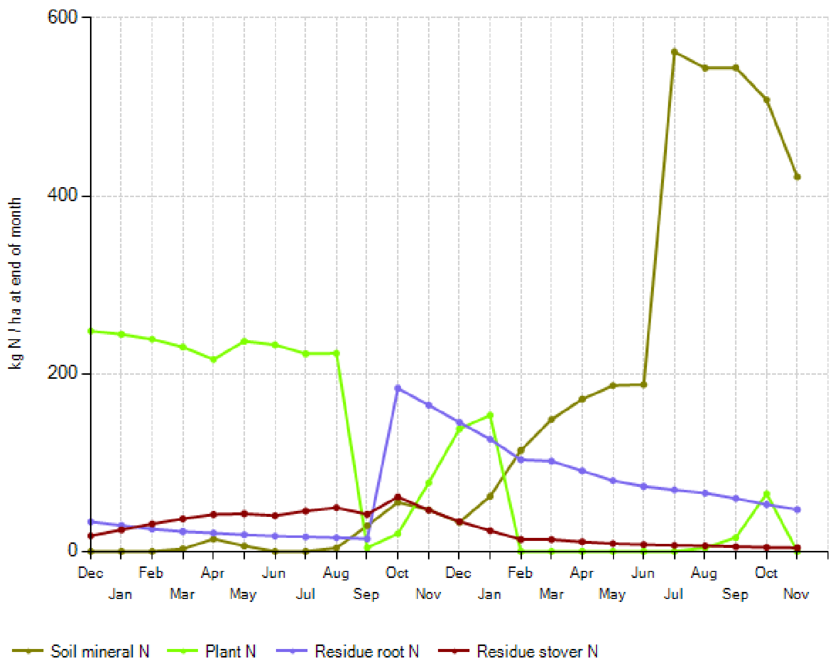

***Figure 8:** Modelled N pools in Overseer. Note the large accumulation in soil mineral N post December.*

5. Discussion

5.1 Dietary N partitioning

The positive relationship between dietary N excretion and N intake is well documented and explained by authors as either a linear or curved relationship. For example, Castillo et al. 2001, described urinary N as an exponential function; Vellinga et al. (2001) and Tas et al. (2006) used linear functions to describe urinary N production. Compared with a urinary N value of 246 g N/cow/day at an intake of 500 g N/cow/day from our fitted function in Figure 1, reported values were 210 (Castillo), 250 (Vellinga) and 240 (Tas). The main difference was that our function was fitted to a much wider range of N intakes due to the inclusion of fodder beet, whereas those three cited papers were in the range of 350-600, 450-750 or 300-700 g N/cow/day, respectively.

Four possible outliers were identified in Figure 1 and these also appeared as outliers in the comparison of Overseer estimated and experiment estimated values of urinary N production. Three of the four values were from pastures containing plantain. Several authors have argued that the composition of herb-rich pastures alter partitioning between dung and urine. However, in our dataset, the effects were inconsistent. For example, the Box et al. (2017) study (Study DD) repeated the same treatment in late lactation and these data points fall on the fitted function.

Furthermore, because most of the data were generated only from estimates of urinary N concentration, there is insufficient data to draw conclusions about partitioning between dung and urine. However, Table 3 suggests that Overseer-estimated urine N as a proportion of N intake is overestimated for both plantain and pasture. Although caution has to be exercised as the data set is small. One interpretation is that the Overseer overestimate is larger for plantain than for non-plantain pastures. This potentially can be supported by measured differences in the composition of plantain and standard pastures (FRNL data being collated).

There is clear evidence of a lower N concentration in urine from the diverse pastures, associated with water intake and resultant dilution, which has implications for the N load value used as a 'typical' urine patch N load in Overseer.

Summary, plantain:

Hyp 2	The amount of N eaten by a dairy herd grazing plantain-rich pasture is not different to a dairy herd eating ryegrass/clover pasture ("pasture characteristics and intake").	DEPENDS – on sward composition and N content. No evidence that plantain-rich pastures are consistently lower
Hyp 3	The current Overseer animal N balance calculation to estimate excretal N is appropriate for plantain in pasture ("total N excretion").	YES – more in milk and dung at 30% plantain? ME effect?
Hyp 4	The current Overseer relationship between dietary N concentration and proportion of excretal N as urine is appropriate for plantain in pasture ("partitioning").	POSSIBLY – some evidence that the N composition between plantain and standard pastures is different and more could potentially be diverted to dung.

Hyp 5	A ‘typical’ urine patch N load (kg N/ha equivalent) is the same as for pasture (750 kg N/ha).	NO – a typical N load would be lower due to dilution of urine

Summary, fodder beet:

Hyp 11	The amount of N eaten by a dairy herd grazing fodder beet is correctly estimated by the current OVERSEER model (“crop characteristics and intake”).	NO – Overseer crop composition values are too high. Different types of feed, leaf, bulb, both. Plus N fert effects – luxury uptake
Hyp 12	The current Overseer animal N balance calculation to estimate excretal N is appropriate for fodder beet (“total N excretion”).	YES
Hyp 13	The current Overseer relationship between dietary N concentration and proportion of excretal N as urine is appropriate for fodder beet (“partitioning”).	YES – level of certainty?
Hyp 14	A ‘typical’ urine patch N load (kg N/ha equivalent) is the same as for pasture (750 kg N/ha).	NO – a typical load would be lower due to lower N content of the crop. Will depend on the level of fodder beet in the diet. Might be the mechanism for capturing that?

5.2 Calculation of nitrogen leaching risk

With only a few lysimeter studies within FRNL (five), the results have to be set in the context also of other research and initiatives. Studies B and D indicated lower N leaching from plantain-based pastures, associated with one or more of the following: winter N uptake; less drainage; nitrification inhibition; lower N load per urine patch.

We agree the lower N load per urine patch needs to be captured within Overseer, as stated above.

Overseer-estimated drainage did not agree well with the measurements in studies B and D. This might have been due to the difficulty in representing a single year experiment in a long-term model such as Overseer, especially where irrigation was applied. However, other comparisons with lysimeter drainage have been shown to be in reasonable agreement with Overseer estimates, Shepherd & Wheeler, report in preparation). Wheeler & Bright (2015) also showed that Overseer and IrriCalc drainage estimates were well correlated. All of these comparisons, however, were made with ‘standard’ pastures, rather than plantain-based pastures (although, drainage comparisons with standard pastures in FRNL were not good). If water usage is greater by plantain pastures, this would need to be captured.

The two other possible mechanisms for decreased leaching under plantain, nitrification inhibition and N uptake similarly are not captured. More evidence of consistent effects of these two mechanisms is required if the N leaching model is to be changed.

Nil-urine controls indicated low N leaching losses from non-urine treated areas, which is in line with the Overseer Background N leaching model, which assumes non-urine areas are similar to 'cut and carry'.

Summary, plantain-rich pastures:

Hyp 6	The Overseer drainage model with monthly climate inputs adequately estimates drainage volume from plantain dominated pastures.	NO? If increased water usage by plantain can be confirmed
Hyp 7	The urine patch model for pasture is appropriate for plantain in pasture.	NO? If nitrification and/or greater winter N uptake need to be captured.
Hyp 8	The background model for pasture is appropriate for plantain pasture.	YES
Hyp 9	N leaching estimates from grazing studies are in line with Overseer estimates.	Insufficient information

There were no lysimeter studies in FRNL relating to fodder beet. We therefore base our assessment of the N leaching model for fodder beet on catch crop studies and research outside of the FRNL programme, such as P21. A synthesis of information was completed by Shepherd et al. (2017). In summary from that report, the indications were that Overseer, in some situations, over-estimated N leaching after fodder beet.

A part of the reason has possibly been solved by the FRNL programme suggesting that the N content of fodder beet used by Overseer as a default is too high. However, a second issue that was noted by Shepherd et al. was that:

> *"OVERSEER estimates N leaching from a forage crop as a combination of two sources: urinary-N and 'background' losses from soil organic matter (SOM) and crop residues. The model currently estimates that the soil/residues makes a contribution of at least the same or greater than the urinary-N source, which is counter-intuitive"*

Analysis of the catch crop experiments in FRNL highlighted a similar issue of the large mineral N pool that develops from Non-urine sources, and that this is strongly related to time in previous pasture. This large apparent 'background' loss needs to be verified.

Summary, fodder beet:

Hyp 15	The Overseer drainage model with monthly climate inputs adequately estimates drainage volume from bare soil after grazing fodder beet.	MAYBE. Compaction may important?
Hyp 16	The current leaching model for grazed forage crops is appropriate for fodder beet.	YES? Denitrification? Where does background N mineralisation fit – additive effect?

		Immobilisation due to sugar???
Hyp 17	The background model for pasture is appropriate for fodder beet.	NO, N mineralisation is overestimated
Hyp 18	N leaching estimates from grazing studies are in line with Overseer estimates.	NO, due to overestimation of urine N load and N mineralisation

5.3 Catch crops

The crop N model is an N balance calculation. Therefore, any differences in any component compared with actual values (in amount or timing) has implications for estimation of N leaching. The comparison (using soil mineral N as the comparator) highlights two areas for further investigation: soil mineral N release and catch crop N uptake

The effect of time in grass on subsequent N mineralisation needs to be checked. Time in grass beyond 4 years results in the model predicting large amounts of soil mineral N. This sets the base for all soil mineral N transformations – if wrong going into winter it will be wrong throughout: and N leaching estimates (and effectiveness of catch crop) will be incorrect.

Main sink for N will be catch crop uptake – results from FRNL suggest a need to change crop coefficients to capture amount – and timing – of N uptake. Currently Overseer underestimates N uptake in the presence of urine.

The experiments suggest that most of the N uptake occurs in spring. The timing of drainage (as well as amount) will therefore be important in modelling the effectiveness of the catch crop.

A large soil mineral N pool was predicted by Overseer due to accumulation during a fallow period – due to mineralisation of soil N sources. This did not agree with the measured amounts. We surmise that this greater than measured N mineralisation was also a reason why the soil mineral N did not decline as rapidly as measured – combined with lower estimated N uptake by Overseer.

Summary, fodder beet:

Hyp 20	Overseer correctly models catch crop growth.	NO
Hyp 21	The Overseer drainage model with monthly climate inputs adequately estimates drainage volume from catch crops.	Not tested
Hyp 22	The current leaching model for grazed forage crops is appropriate for catch crops	NO, N mineralisation is overestimated
Hyp 23	N leaching estimates from grazing studies are in line with Overseer estimates.	NO, due to underestimation of N uptake early in the season and overestimation of N mineralisation

6. Recommendations

The following list details recommendations for changes to Overseer from progress in the integration work to date. These recommendations need to be discussed, refined and agreed with the FRNL research team for scientific consensus, as well as Overseer Ltd as they relate to implementation into the model.

6.1 To implement plantain in Overseer

1. Until there is further evidence for a change in excretal N partitioning between urine and dung, and an understanding of how and when this occurs, **do not change Overseer's current model**. We understand there is a new meta-analysis available which may provide evidence for partitioning of N into dung, this needs to be considered.
2. **Create a database of ME and nutritive values for plantain-rich pastures**. This will require the following:
   - Monthly estimate of ME and/or digestibility, and N content (these are defaults used to populate the model but can be over-ridden by user data).
   - Relative seasonal growth pattern, including how it varies with temperature and soil water contents.
   - Relativity of annual production between ryegrass white clover and plantain pasture (used to set block relativity)
   - Trigger when transpiration starts to reduce due to soil water deficiency (if not available, the trigger for ryegrass/white clover pasture is assumed).
   - Relationship between soil test and plantain nutrient contents other than N (if not available, ryegrass/white clover pasture relationship is assumed).
   - Additional information may be required as the plantain model is integrated in Overseer.
3. **Provide user guidance on what constitutes a plantain-rich pasture** (accounting for threshold levels of plantain, longevity and seasonal variation)
4. Until there is more evidence for increased water usage, **use the existing Overseer drainage model**, but consider whether drainage should be adjusted under a urine patch to take account of the luxury growth caused by urine addition – this is not unique to plantain; this needs to be considered for all pasture types. NB: soil data.
5. **Identify a value that is representative of the dilution effect of plantain-rich pastures on urine-N concentration**. This needs to take account of the diurnal pattern and between-animal variation. Some sensitivity analysis on the estimates of urine patch N leaching and comparison with APSIM values (Minnée et al. 2018) will be required during the implementation phase.
6. **Without further evidence, assume no nitrification inhibitor effect**
7. **Assume low N leaching (equivalent to cut and carry pasture) in the background N leaching sub-model.**

Note we have not assessed the ME model that drives the DM intake calculations. There has already been several reviews of this model and some changes are being implemented as a result of these reviews.

6.1.1 Research gaps

- Excretal N partitioning, mechanisms are understood but need to know under which circumstances feed quality differences between standard pasture and pasture with plantain occur
- Deep rooted crops are rising as an issue, particulalry in terms of access to water below 60 cm (this can be modelled using existing metholodogies), and the ability to recover N at depth.
- Block level estimates of N leaching to compare with the Overseer estimates based on combining component models
- Nitrification inhibitor effects – size, and conditions for this effect to occur

6.2 To (better) implement fodder beet in Overseer

Fodder beet is already included in the crop block model of Overseer. The recommendations for improved implementation are as follows:

1. There is no evidence for a change in excretal N partitioning between urine and dung, therefore, **do not change Overseer's current model**.
2. **Create a better database of ME and nutritive values for fodder beet** to better reflect the low N content of the bulbs. Data is required for bulbs and tops, and how the ratio changes with feeding management and season of grazing.
3. **Review the urine patch N load value used for grazed fodder beet**. This is probably less important where urine is deposited on bare ground and where there is likely to be no significant plant N uptake for a few months afterwards. However, this consideration becomes more important where there is opportunity for plant N uptake after deposition, e.g.,
    a. Where cover crops are sown afterwards
    b. Where beet is fed in the shoulders and the animals then return to pasture
4. **Review the Overseer soil N mineralisation estimates** as affected by time in previous pasture – discussed in more detail under catch crops.

6.3 To (better) implement catch crops in Overseer

Catch crops are already included in the crop block model of Overseer. The recommendations for improved implementation are as follows:

1. **Develop crop coefficients** to better represent crop growth and luxury uptake of N under urine
2. Further investigation of Overseer to confirm the **possible causes of overestimation of N loss from non-urine sources**

6.4 Targeted sensitivity analyses

Sensitivity testing will be conducted for plantain, on effects of N partitioning to dung and urine patch N load on N leaching from the urine patch and block level. This will help to understand the potential impact of changes in the model on N leaching at a relevant scale.

6.5 Gain consensus from research team

Where gaps in knowledge still exist yet information is required to make changes in the model, expert consensus is needed. The FRNL research teams will review the work to date (this report) and meet to address, and agree on, a list of gaps.

7. References

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8. Appendix I – Summary of animal-based experiments

ALTERNATIVE PASTURES INCLUDING PLANTAIN		
CS 1.1.3	**Title**	Diverse pastures for reduced urinary N excretion
AA	**Contact(s)**	Racheal Bryant
	Objective	To measure the effect of feeding simple ryegrass clover pastures versus diverse pastures containing herbs on milk yield and urinary N excretion from grazing late lactation dairy cows. Add-on honours project to compare urine patch area.
	Type	Grazing
	Treatments	2 treatments
	Duration	5 days
	Supporting docs	Bryant et al (2018). Livestock Science 209
CS 1.1.3	**Title**	Effect of % plantain allocation on milk yield and urinary N
BB	**Contact(s)**	Racheal Bryant & Grant Edwards
	Objective	To determine the effect of grazing 0, 15, 30 or 60% plantain pasture on milk yield and urinary N excretion of lactating dairy cows in autumn
	Type	Grazing, with urine sensors
	Treatments	4 treatments
	Duration	Mar-16
	Supporting docs	
CS 1.1.3	**Title**	Plantain silage for reduced urinary N excretion
CC	**Contact(s)**	Racheal Bryant
	Objective	To measure the effect of feeding simple ryegrass clover pastures (RG) versus plantain pastures (PLA) with RG or PLA baleage on milk yield and urinary N excretion from grazing late lactation dairy cows. Includes an add-on honours project to compare urine patch area.
	Type	Grazing, with urine sensors

	Treatments	2 x 2 factorial, 2 replicated groups of 5 cows per group
	Duration	Apr-17
	Supporting docs	
CS 1.1.4	**Title**	Effect of plantain on milk yield and urinary N
DD	**Contact(s)**	Lisa Box & Grant Edwards
	Objective	To determine the effect of grazing simple ryegrass clover pastures versus plantain on milk yield and urinary N excretion of lactating dairy cows in autumn and spring.
	Type	Grazing
	Treatments	3 treatments repeated autumn and spring
	Duration	2 months
	Supporting docs	Box et al. NZSAP 2016, NZJAR, 2016
CS 1.1.3	**Title**	High sugar grass and diverse pastures for improved milk production and reduced urinary N concentration
EE	**Contact(s)**	Racheal Bryant & Grant Edwards
	Objective	To compare a binary grass clover pasture with high sugar grass in a binary or diverse pastures on milk yield and urinary N excretion from late lactation grazing dairy cows
	Type	Grazing
	Treatments	3 treatments
	Duration	Mar-10
	Supporting docs	Published in Journal of Dairy Science 2013. Totty et al.
CS 1.1.3	**Title**	Diverse pastures for milk production and reduced urinary N concentration
FF	**Contact(s)**	Racheal Bryant & Grant Edwards
	Objective	To compare the effect of feeding binary grass clover pastures with diverse pastures containing herbs on milk yield and urinary N excretion from grazing late lactation dairy cows. Add-on honours project to compare urine patch area.
	Type	Grazing

	Treatments	3 x 2 factorial
	Duration	Spring, summer and autumn (2010/2011 season)
	Supporting docs	Bryant RH, Miller ME, Greenwood SL, Edwards GR (2017) Milk yield and nitrogen excretion of dairy cows grazing binary and multispecies pastures. Grass Forage Sci 2017; 1–12. DOI:10.1111/gfs.12274.
CS 1.1.1	**Title**	Effects of species composition in the diet on nitrogen partitioning in dairy cows – metabolism stall experiment
HH	**Contact(s)**	Dawn Dalley
	Objective	To measure the effect of pasture species composition on nitrogen partitioning of dairy cows in metabolism stalls.
	Type	Metabolism stall
	Treatments	Tall fescue/Tall fescue + lucerne/ tall fescue + lucerne + plantain
	Duration	6 days
	Supporting docs	Paper accepted by Animal Production Science: Waghorn et al
CS 1.1.3	**Title**	Effects of species composition in the diet on nitrogen partitioning in dairy cows – spring grazing experiment with urine sensors
GG+II	**Contact(s)**	Dawn Dalley
	Objective	To measure the effect of pasture species composition and grazing management on both milk production and urinary N excretion in a **spring grazing** experiment with lactating cows.
	Type	Replicated herd grazing experiment with urine sensors
	Treatments	Perennial ryegrass + lucerne (RL) / Perennial ryegrass + lucerne + plantain (RLP) / Tall Fescue + lucerne / Tall Fescue + lucerne + plantain
	Duration	6 days for intake and milk production, 4 days for urine
	Supporting docs	Paper submitted: Dodd et al JOINT WITH STUDY II
CS 1.1.3	**Title**	Effects of species composition in the diet on nitrogen partitioning in dairy cows – summer grazing experiment
GG+II	**Contact(s)**	Dawn Dalley
	Objective	To measure the effect of species composition and grazing management on milk production and urinary N excretion in a grazing experiment in **summer/autumn**.

Type	Replicated herd grazing experiment
Treatments	Perennial ryegrass + lucerne (RL) / Perennial ryegrass + lucerne + plantain (RLP) / Tall Fescue + lucerne / Tall Fescue + lucerne + plantain
Duration	6 days
Supporting docs	Paper submitted: Dodd et al (JOINT WITH STUDY GG)

9. Appendix II – Summary of non-grazed experiments

ALTERNATIVE PASTURE SPECIES INCLUDING PLANTAIN		
CS 1.1.9	**Title**	Benefits of alternative species for nitrate leaching: Effects of plant characteristics on soil C and N transformation
A	**Contact(s)**	Brendon Welten/Leader Stewart Ledgard
	Objective	To assess the impact of plant characteristics of alternative plant species, including plant residues on soil C and N transformations (mineralisation and nitrification) and legume N2 fixation using 15N tracer studies.
	Type	Field 15N micro-plots in Waikato Critical N plot trial
	Treatments	Application of 15N-isotope to paired micro-plots to estimate the proportion of N derived from biological N2 fixation from alternative pasture species across a range of fertiliser-N inputs.
	Duration	1 year
	Supporting docs	Report prepared for FRNL1.1.9.MS1
CS 1.1.7 - 1.1.8	**Title**	Reducing nitrogen leaching losses in grazed dairy systems using Italian ryegrass-plantain-white clover forage mix
B	**Contact(s)**	Keith Cameron
	Objective	To determine the N leaching losses, dry matter yields and N uptake from the urine patch of an Italian ryegrass-plantain-white clover forage mix, and to compare this with perennial ryegrass-white clover forage.
	Type	Lysimeter
	Treatments	Perennial rg + white clover (RGWC) - no urine = control; RGWC + actual urine; RGWC + urine 700; Italian rg + plantain + white clover - no urine = control; Italian rg + plantain + white clover + actual urine; Italian rg + plantain + white clover+ urine 700
	Duration	27/3/2015 – 5/9/2016
	Supporting docs	Paper prepared and submitted to FRNL for approval (Woods et al.)
CS 1.1.7	**Title**	Nitrogen uptake and leaching measured in pure swards and diverse pastures differing in cool season growth and root architecture
C	**Contact(s)**	Brendon Welten/Keith Cameron Leader

	Objective	The purpose of this study was to examine the effects of alternative pasture species on nitrogen leaching losses from grazed pastures. More specifically, the key objectives of this study were: 1. Quantify the effect of alternative pasture species on nitrogen leaching losses. 2. Examine the effect of alternative pasture species on the fate of urinary-N in soil (using a 15N recovery technique).
	Type	Lysimeter
	Treatments	Year 1: 3 pasture types (ryegrass/clover, + plantain, + tall fescue) x 2 cow urine applications (autumn or winter) + nil-urine controls Year 2: 3 pasture types (ryegrass, plantain, Lucerne monocultures) x 3 cow urine applications (summer, autumn or winter) + nil-urine controls
	Duration	1 year per experiment
	Supporting docs	Waikato site: paper submitted to SUM Lincoln site: Maxwell et al 2018 NZJAR
CS 1.1.7 - 1.1.8	**Title**	Effect of irrigation type, forage type and urine application date on nitrate leaching losses.
D	**Contact(s)**	Keith Cameron
	Objective	1. Quantify the effect of three different irrigation types (pivot, rotorainer and flood) on plant N uptake and subsequent NO3- leaching losses from cow urine patches; 2. Determine the effect of forage type on NO3- leaching losses from urine patches; and 3. Determine the fate of early summer (December) and late-summer (February) deposited urine.
	Type	Lysimeter
	Treatments	The experimental design consisted of **12** treatments including three irrigation types (pivot vs. rotorainer vs. flood), two forage types (standard vs. diverse), two urine application dates (December vs. February) and one urinary–N application rate (700 kg N ha^{-1})
	Duration	10/12/2015 – 30/9/2016
	Supporting docs	Thesis chapter plus Carlton et al.
FODDER BEET		

CS 2.2.10	**Title**	Fodder beet followed by catch crop oats in rainout-shelter in response to contrasting water and nitrogen supply
E	**Contact(s)**	Edmar Teixerira
	Objective	To quantify long-term soil N and water dynamics and plant physiological responses that influence biomass accumulation and nitrogen uptake of a fodder beet and catch crop oats rotation subjected to a wide range of water and N supply. Data will be used to calibrate and test new fodder beet and catch crop oat models in APSIM next generation.
	Type	Rainout-shelter field facility
	Treatments	6 treatments as a combination of 3 nitrogen supply (0, 50 and 300 kg/ha) and two water supply (irrigated and dryland) for the fodder beet phase of rotation. The catch crop phase of rotation has irrigated plots subjected to additional drainage events and nitrogen topped up at surface to similar residual amounts (i.e. post fodder beet) from dryland plots.
	Duration	2017
	Supporting docs	NA trial in progress Possibly Khaembah et al Luxury nitrogen consumption by fodder beet crops. Proceedings of the 2018 European Society of Agronomy Conference, Geneva, Switzerland; 29-Aug-18
CATCH CROPS		
CS 1.2.12	**Title**	Oat catch crop after simulated winter grazing
F	**Contact(s)**	Brendon Malcolm
	Objective	To measure the effect of winter catch crop sowing date on yield, N uptake and soil mineral N following simulated winter forage grazing.
	Type	Field
	Treatments	Split plot, 6 treatments, 4 replicates
	Duration	2015
	Supporting docs	Agronomy New Zealand 46: 99-108.
CS 1.2.12	**Title**	Oat and ryecorn catch crops after simulated winter grazing
G	**Contact(s)**	Brendon Malcolm

	Objective	To compare the effectiveness of two winter catch crops on yield, N uptake, soil mineral N and soil water following simulated winter forage grazing.
	Type	Rainout-shelter field facility
	Treatments	Split plot, 6 treatments, 4 replicates: Fallow/Oats/Ryecorn x 2 sowing dates x 2 urea rates
	Duration	2016
	Supporting docs	Summarised in FRNL PMC report FRNLOP242.pdf
CS 1.2.12	**Title**	Effect of establishment method on catch crop performance after fodder beet and kale grazing in winter
H	**Contact(s)**	Brendon Malcolm
	Objective	To test the effect of establishment method (direct drill, conventional cultivation or broadcast) of a winter sown oat catch crop on yield, N content and N uptake after grazing of either kale (Trial 1) or fodder beet (Trial 2).
	Type	On-farm paddock trial
	Treatments	Two independently run trials (identical treatment structure for both), split plot design, 6 treatments, 5 replicates. Direct drill/conventional/broadcast x 2 urea rates
	Duration	2016
	Supporting docs	Agronomy New Zealand 47: 65-77 (2017). Summarised in FRNL PMC report
CS 1.2.12	**Title**	Catch crops to reduce the risk of N leaching following N loading in autumn.
I	**Contact(s)**	Adrian Hunt/Paul Johnstone
	Objective	To measure the effect of catch crop type and sowing date on yield, N uptake and soil mineral N following simulated autumn N loading.
	Type	Field plot trial
	Treatments	Italian rg/Oats/Triticale/Fallow x March/April/May sowing date
	Duration	2016 and 2017

	Supporting docs	Summarised in FRNL PMC report Waikato 2016: FRNLOP241.pdf Waikato 2017: FRNLOP047.pdf
CS 1.2.12	**Title**	Effect of catch crop species on environmental and production performance
J	**Contact(s)**	Brendon Malcolm
	Objective	To test the relative performance of different cereal catch crop species sown in winter under simulated winter urine deposition on yield (at green-chop, whole crop and grain maturity stages), N content and uptake, soil mineral N and rooting dynamics (development of root systems and N content).
	Type	Field trial
	Treatments	Randomised block design, 6 treatments, 4 replicates (all plots received initial N load of 400 kg N/ha as urea fertiliser). Fallow/Oats/Ryecorn/Triticale/Wheat/Barley
	Duration	2017
	Supporting docs	FRNLOP048.pdf FRNL milestone report
CS 1.2.8	**Title**	Effect of soil type and sowing date of an oat catch crop on nitrate leaching losses from simulated grazed fodder beet
K	**Contact(s)**	Brendon Malcolm
	Objective	The test the relative effect of two contrasting soil types and sowing dates on the ability of a winter-sown catch crop to reduce nitrogen leaching losses.
	Type	Field monolith lysimeter
	Treatments	Randomised block design, 2 treatments (fallow, catch crop), 8 replicates (4 buried suction cups in each plot)
	Duration	
	Supporting docs	
CS 1.2.8	**Title**	Paddock scale measurement of the effect of sowing oats as a catch crop to decrease nitrate leaching from winter grazed fodder beet
L	**Contact(s)**	Keith Cameron/Brendon Malcolm

	Objective	A paddock-scale approach to determine the effect of sowing a catch crop of oats on nitrate leaching losses from winter grazed fodder beet
	Type	Grazed field trial consisting of the newly developed Suction Cup and Lysimeter ARray system (SCALAR).
	Treatments	Randomised block design, 2 treatments (fallow, catch crop), 8 replicates/blocks (4 buried suction cups in each plot) – total of 64 cups
	Duration	2017
	Supporting docs	
CS 1.2.8	**Title**	Oat catch crops after winter grazing of fodder beet by dairy cows on a deep soil to decrease the risk of nitrate leaching
M	**Contact(s)**	Brendon Malcolm
	Objective	To determine the productive and environmental performance of an oat catch crop following four different winter grazing management approaches of fodder beet (22-hr grazing vs 6-hr grazing, with and without back-fencing), on a deep Templeton silt loam soil.
	Type	Grazed large plot field trial
	Treatments	Oats/Fallow, with and without back-fencing
	Duration	2017
	Supporting docs	
CS 1.2.8	**Title**	Catch crops after autumn grazing of fodder beet by dairy cows to decrease the risk of nitrate leaching
N	**Contact(s)**	Brendon Malcolm
	Objective	To determine the productive and environmental performance of two catch crops (Oats and Italian ryegrass) following either grazed or lifted (i.e. non-grazed) fodder beet.
	Type	Grazed large plot field trial
	Treatments	Fallow/Italian rg/oats x grazed/lifted x 2 allocations of DM/cow/day
	Duration	2017
	Supporting docs	