Spring milling wheat as a 'Nitrogen Scavenger' in the North Island

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Summary

The use of wheat in the farm system should be considered as an effective Nitrogen (N) mitigation technique particularly where the N is below the pasture root zone. The field trials and OverseerFM modelling did not indicate losses of N due to leaching and indicated that with good N management nitrogen use efficiency could be improved. The calculation of N leaching for the past season with extreme rainfalls indicated that at the Ohakune site there was a risk of N not utilised by the plant being leached below the pasture and wheat rootzones, whereas at Wairarapa any applied N leached would have remained in the wheat rootzone. In these trials, with lower than forecast yields, the financial performance of 10% of the farm in wheat was less than dairy alone (Wairarapa and Waikato) but it was better than other pastoral farm uses (Ohakune). The reduction in GHG emissions were significant for wheat in the dairy farm systems.

Although the extreme rainfall was not conducive to producing high yields and quality milling wheat, associated cultivar trials indicated good yields and quality can be achieved.

Field trials

The extreme rainfall throughout the growing season at both sites meant it was not a suitable season to investigate how effective spring sown wheat was in Scavenging Nitrogen. The extremely high rainfall at both sites (Wairarapa 188mm and Ohakune 390mm above long term average growing season) influenced the field trials by reducing establishment, reducing yield and therefore nitrogen use efficiency, impacting markedly on grain quality, particularly falling number, which meant it was not worth undertaking bake tests to understand protein quality.

Wairarapa

- Yield increased as applied N increased or as the N became available after GS32 but was lower than forecast and lower than previous years.
- Protein increased as total N increased or as the N became available after GS32.
- As yield increased protein increased indicating that N was not limiting yield. The soil N + applied N was adequate to produce the yield for each treatment assuming 25kg of N per ton.
- A concurrent cultivar trial in the Wairarapa produced reasonable yields of milling wheat. Given the season the quality, with the exception of falling number, was very good indicating milling wheat could be a valuable diversification in land use.
- The total N in grain and straw was less then the soil N + the applied N. The relatively high soil N at harvest indicates significant in season mineralisation.
- Nitrogen use efficiency (NUE) was highest where the lower N rates increased yield. At the high N rate there was excess N applied for the yield achieved and NUE reduced.
- Total N in soil at harvest was less than the N in soil at sowing + the N applied. While it is not able to determine the fate of the N, the calculation of leaching indicates that much of the N was taken up by the wheat.

- No evidence that as N application increased that N increased in the lower soil profile at the end of season.
- The calculated N leaching indicated that N would have moved 39cm down the profile from planting and 29cm down the soil profile from the GS32 treatment. The N contained in the 30-60cm zones could have leached below the 90cm and below the wheat root zone.

Ohakune

- Yield increased as applied N increased but was significantly lower than forecast and lower than previous years. The soil N + applied N was adequate to produce the yield for each treatment assuming 25kg of N per ton.
- Protein increased as total N increased or as the N became available after GS32.
- Protein varied as yield increased. The highest protein was from the N application at planting. This may reflect reduced uptake of N from the late applications due to the yield being impacted by the very wet period after GS32.
- The total N in grain and straw was less than the soil N + the applied N. The relatively high soil N at harvest indicates significant in season mineralisation.
- Nitrogen use efficiency (NUE) was lower for all treatments where N was applied than the soil only treatment due to the low yields achieved.
- No evidence that as N application increased that N increased in the lower soil profile at the end of season.
- Total N in soil at harvest was similar to the N in soil at sowing + the N applied. While it is not able to determine the fate of the N the calculation of leaching indicates that much of the N was taken up by the wheat.
- The calculated N leaching indicated that N would have moved 122cm down the profile from planting and thus could have been leached out of the rootzone. The N applied at GS32 could have moved 73cm and thus any not taken up by the plant could be in the lower rootzone.

OverseerFM modelling

- For Wairarapa and Ohakune there was no difference in modelled N or P loss between any of the treatments at either the block or whole farm level. In the Waikato the highest modelled N loss was for a treatment with N applied at GS32 and the N was not used to generate yield.
- For GHG emissions there was a small increase in nitrous oxide and carbon dioxide emissions associated with fertiliser application.
- OverseerFM adequately modelled the N loss for each treatment and there was no significant change in modelled loss between treatments which indicates N management was well targeted to the yield produced.

Financial

- The loss for the Waikato Dairy Farm is insignificant when calculated on a per ha (-$232) or as a percentage of EBIT (-5.2%).

- The loss for the Wairarapa Dairy Farm is insignificant when calculated on a per ha (-$166) or as a percentage of EBIT (-3.8%).
- The Ohakune property had a minor increase in its financial performance as a result of gaining a higher return for wheat production ($268/ha) than it does from its pastoral operation (EBIT 4.6%).
- The potential reductions in GHG emissions from introducing wheat into the farm system are substantial for the dairy system but insignificant for the Ohakune pastoral vegetable farm system.

The use of wheat as an N scavenger crop is effective, it does not add to the amount of N leaching and will utilise some N which is deposited in the deeper layers which are not able to be accessed by the pastures root system. For soils with large amounts of N sitting in the lower profiles, which are below the depth of root penetration of pastures, the use of wheat as an N scavenger is a worthwhile mitigation to reduce the risk of N leaching losses. In most seasons it is possible to produce high quality milling wheat and the use of wheat in a farm system has minimal impact on the financial performance of the farm.

Objectives

- Undertake trials at two sites, the Wairarapa and Ohakune, where milling wheat cultivars are assessed for their grain yield and milling characteristics to determine wheat of a milling quality can be produced in each region.
- To understand Nitrogen (N) uptake from the soil at these sites by the wheat crop by conducting deep soil N tests before sowing and after harvest and applying N at different rates and timings.
- To model N and P loss from the Nitrogen treatments and to model GHG losses at each site using OverseerFM.
- To undertake a financial assessment.

Field Trials

Methodology:

Sites

Two wheat paddocks (one sown in Cochise and the other in Conquest) were identified at the Wairarapa site for the N replicated plot trial work and a further paddock identified for the cultivar evaluation. The Cochise paddock was ex-ryegrass, sprayed out on with 3.5 L Glyphosate + Pulse/ha on the 11th of October 2022 and sown on the 29th of October 2022. The Conquest paddock was ex-rape and plantain, sprayed out with 3.5 L Glyphosate + 40 g Granstar + Pulse/ha on the 11th of October 2011 and sown on the 28th of October. The Cultivar Evaluation paddock was sown on the 27th of October 2022, with an application of 250 kg/ha Crop15 and a further application of 120 kg/ha N Protect on the 7th of November 2022. Sowing of all paddocks was by direct-drill with no-tillage.

One large paddock at Ohakune was identified for the N replicated plot trial work and the cultivar evaluation in the remainder of the paddock. The paddock was ex-pasture on a newly leased block of land and cultivation to prepare for the crop was minimal. Conquest wheat was sown in the paddock on the 19th of October 2022 following 3 L/ha Glyphosate on the 14th of October 2022. The remainder of the paddock received 250 kg/ha Crop16 at sowing following a base fertilizer application of Superten 440 kg/ha + MOP 250 kg/ha.

Soil Sampling

Within the paddocks, sites were identified for the N replicated plot trial work (area of 24 x 10 metres each) and soil samples taken using a Geotechnical Auger tool from the ranges 0 - 30 cm, 30 – 60 cm and 60 – 90 cm. Sampling occurred on the 2nd of October 2022 at the Wairarapa site and the 3rd of October 2022 at the Ohakune site. At the time of sampling, the paddocks were yet to be sprayed out in preparation for the wheat sowing.

N Treatments and timing of application

Treatments to be evaluated were:

1. Soil N only
2. Soil N + Urea at Planting (N to deliver 15 kg N/t wheat)
3. Soil N + Urea at Growth Stage 32 (N to deliver 15 kg N/t wheat)
4. Soil N + Urea at Growth Stage 32 (N to deliver 25 kg N/t wheat)

Results of the pre-sowing deep soil N tests and the yield obtained from the previous year were used to calculate applications of N on the basis of each ton of wheat requiring 25kg of N. The wheat yield achieved at Ohakune in the 2021/22 season was 10 t/ha and at the Wairarapa was 8 t/ha.

Plot size for the N treatments was 5 metres long by 2 m wide with a buffer zone between plots to ensure lateral spread of N following application had no impact on neighbouring plots. The treatments were replicated 4 times in a simple randomized complete block design.

Table 1: Timing and application rates of N, Wairarapa

	Wairarapa - Cochise		
	Soil N pre-sowing (kg/ha)*	N applied (kg/ha)	Date applied
Soil N only	96.5	-	-
Soil N + Urea at planting (N to deliver 15 kg N/t wheat)	96.5	23.5	29/10/22
Soil N + Urea at GS32 (N to deliver 15kg N/t wheat)	96.5	23.5	1/12/22
Soil N + Urea at GS32 (N to deliver 25kg N/t wheat)	96.5	103.5	1/12/22

	Wairarapa - Conquest		
	Soil N pre-sowing (kg/ha)*	N applied (kg/ha)	Date applied
Soil N only	89.5	-	-
Soil N + Urea at planting (N to deliver 15 kg N/t wheat)	89.5	30.5	29/10/22
Soil N + Urea at GS32 (N to deliver 15kg N/t wheat)	89.5	30.5	1/12/22
Soil N + Urea at GS32 (N to deliver 25kg N/t wheat)	89.5	110.5	1/12/22

*Soil N pre-sowing was a mean of the soil profiles 0 - 30 cm and 30 - 60 cm

While the objective was to apply fertilizer to treatments at Growth Stage 32, the Ohakune trial was closer to GS30 at the time of the 2nd December 2022 visit to the site.

Table 2: Timing and application rates of N, Ohakune

	Ohakune - Conquest		
	Soil N pre-sowing (kg/ha)*	N applied (kg/ha)	Date applied
Soil N only	67.5	-	-
Soil N + Urea at planting (N to deliver 15 kg N/t wheat)	67.5	82.5	29/10/22
Soil N + Urea at GS32 (N to deliver 15kg N/t wheat)	67.5	82.5	2/12/22
Soil N + Urea at GS32 (N to deliver 25kg N/t wheat)	67.5	182.5	2/12/22

*Soil N pre-sowing was a mean of the soil profiles 0 - 30 cm and 30 - 60 cm

Sampling and Harvest

The above ground biomass was sampled from N treatments at Growth Stage 32 (stem elongation) and leaf samples taken for nutrient analysis and samples dried for DM%. At this time the decision was made not to proceed with measurements from the N treatments in the Wairarapa Conquest paddock as establishment of the crop in the trial area was estimated at 70% of what was sown.

Straw samples were taken from treatments prior to harvest (8th March 2023 for Wairarapa and 9th March 2023 for the Ohakune site) and analysed for feed quality parameters. Soil samples were taken from all treatments to the ranges 0 - 30 cm, 30 – 60 cm and 60 – 90 cm at this time also. Harvest was pushed later than expected due to poor weather conditions.

The Wairarapa N trial was harvested on the 16th of March 2023 and the Ohakune N trial was harvested on the 20th of March 2023. Both were harvested by Kevin Sinclair of Plant & Food Research, Palmerston North using their small plot harvester.

Grain Tests

Test weights, dressing losses and thousand grain weights were processed by Kevin Sinclair as well. Grain quality tests were conducted by Champion Flourmills.

Cultivar Evaluation

Six wheat cultivars were evaluated at the Wairarapa site – Sensas, Cochise, Discovery, Reliance, Conquest and a trial line provided by PGG Wrightson Grain ‘2208’.

Three wheat cultivars were evaluated at Ohakune – Conquest, Viceroy and Cochise.

Management of the cultivar evaluations was as per the rest of the paddock. Harvest was undertaken by taking a strip of a known length from within each of the larger 'plots' by the Plant & Food Research harvester. Grain was retained for grain tests and quality tests.

Weather Data

Weather data for the Wairarapa is from a nearby NIWA Station (Martinborough Ews, 21938) but the CliFlo data for the Ohakune weather station (Ohakune Ews, 31621) lacked a full dataset for the period that the trial was running and farmer kept records of rainfall have been used in their place as they were of a high standard and more complete.

Wairarapa

	Total Monthly Rainfall (mm)		Excess rainfall above 10 Year Mean (mm)	**Mean Air Temperature (°C)**	
	10 Year Mean (2013-2022)	2022/23 Season		10 Year Mean (2013-2022)	2022/23 Season
October	50	43	-7	13	12
November	66	76	10	15	17
December	51	109	58	17	17
January	30	76	47	18	18
February	66	106	40	18	18
March	52	93	41	16	16
Accumulated excess rainfall above 10 Year Mean			188		

Ohakune

	Total Monthly Rainfall (mm)		Excess rainfall above 20 Year Mean (mm)
	20 Year Mean	2022/23 Season	
October	124	179	55
November	96	202	106
December	114	133	19
January	76	193	117
February	79	130	51
March	75	117	42
Accumulated excess rainfall above 20 Year Mean			390

Results:

Pre-sow Soil N

Wairarapa - Cochise

	Potentially Available N kg/ha	pH	Olsen P mg/L	Potassium mg/100g	Calcium mg/100g	Magnesium mg/100g	Sodium mg/100g
Trial area 0-30 cm	154	6.1	20	0.38	12.9	1.22	0.11
Trial area 30-60 cm	39	6.5	7	0.25	9.4	1.34	0.11
Trial area 60-90 cm	43	6.8	8	0.19	6.8	1.16	0.11

Wairarapa - Conquest

	Potentially Available N kg/ha	pH	Olsen P mg/L	Potassium mg/100g	Calcium mg/100g	Magnesium mg/100g	Sodium mg/100g
Trial area 0-30 cm	138	6.1	24	0.35	15.4	1.62	0.85
Trial area 30-60 cm	41	6.6	14	0.24	11.8	1.84	0.11
Trial area 60-90 cm	40	6.8	16	0.22	10.9	2.97	0.13

Ohakune - Conquest

	Potentially Available N kg/ha	pH	Olsen P mg/L	Potassium mg/100g	Calcium mg/100g	Magnesium mg/100g	Sodium mg/100g
Trial area 0-30 cm	78	6.1	23	0.36	4.3	0.69	<0.05
Trial area 30-60 cm	57	6.3	9	0.15	3.4	0.55	0.06
Trial area 60-90 cm	23	6.2	4	0.09	3.5	0.65	<0.05

For all three sites the N, P and K was highest in the top 30cm of soil as would be expected with significantly more N in the upper profile at all three sites, but this was less marked for the free draining Ohakune site. Other soil nutrients and pH were all in the acceptable range.

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Nutrient analysis and Biomass at Stem Elongation

Wairarapa

	Cochise			Conquest		
	Above ground Biomass at GS32			Above ground Biomass at GS32		
	tDM/ha	DM%	Nitrogen %	tDM/ha	DM%	Nitrogen %
Soil N only (and represents GS32 treatments)	2.18	16.4	3.9	1.5	16.5	2.6
Soil N + Urea at planting (N to deliver 15 kg N/t wheat)	2.53	16.9	4.8	2.18	17.7	2.6

Ohakune - Conquest

	Above ground Biomass at GS32		
	tDM/ha	DM%	Nitrogen %
Soil N only (and represents GS32 treatments)	1.62	24.6	2.1
Soil N + Urea at planting (N to deliver 15 kg N/t wheat)	2.17	27.1	2.8

As expected, the treatment receiving N at sowing had produced more biomass at the start of stem elongation and the tissue N was higher at this time for two of the three sites. The Dry matter % increased slightly when N was applied at planting but the levels of other nutrients were all in an accepted range.

Straw Quality

Wairarapa (Cochise) and Ohakune (Conquest)

	Wairarapa				Ohakune			
Treatment	Nitrogen %	Crude Protein %	Lignin %	ME %	Nitrogen %	Crude Protein %	Lignin %	ME %
Soil N only	0.7	4.2	13	5.3	0.5	3.4	13.5	5.5
Soil N + Urea at planting (N to deliver 15 kg N/t wheat)	0.6	3.6	13.6	4.9	0.8	5.1	12.5	5.3
Soil N + Urea at GS32 (N to deliver 15kg N/t wheat)	0.7	4.5	10.8	6.4	0.7	4.7	11.4	5.3
Soil N + Urea at GS32 (N to deliver 25kg N/t wheat)	0.7	4.3	10.9	6.3	0.7	4.9	12.3	5.5

There was no clear trend in the crude protein in the straw for any treatments at either site with the exception of a lower level for the soil only treatment at Ohakune. The ME of the straw was slightly increased by the N application at GS32 and the lignin was decreased. Other parameters were not affected.

Grain Yield & Grain Tests – N trials

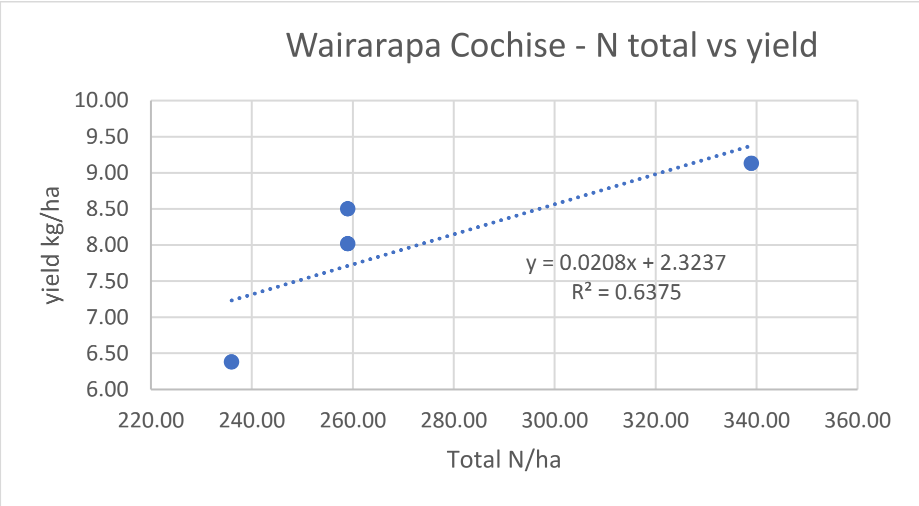
Wairarapa – Cochise

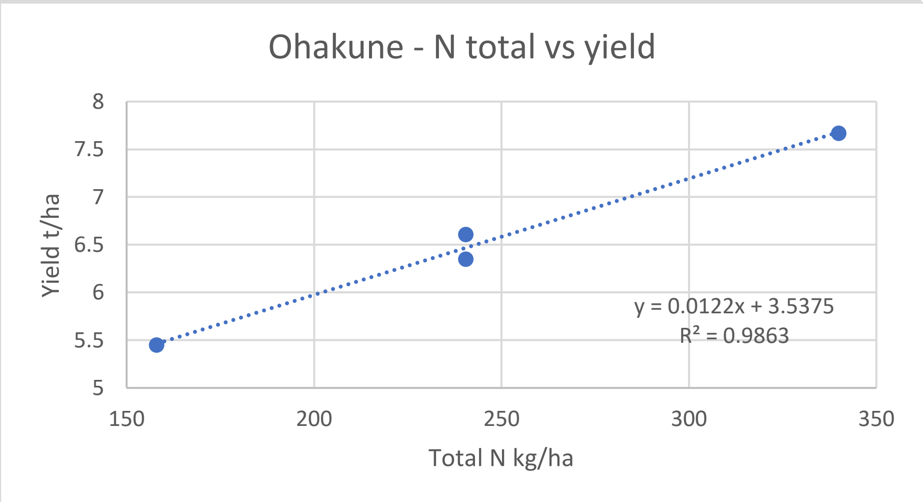
	Grain Yield t/ha	Moisture %	Test Wt. kg/hectolitre	Dressing Loss %	TGW g
Soil N only	6.38	12.4	68.4	2.5	51.2
Soil N + Urea at planting (N to deliver 15 kg N/t wheat)	8.02	12.3	67.7	3.0	50.8
Soil N + Urea at GS32 (N to deliver 15kg N/t wheat)	8.5	12.4	68.4	2.4	49.0
Soil N + Urea at GS32 (N to deliver 25kg N/t wheat)	9.13	12.3	68.6	2.6	47.2
R Square	0.92				
Correlation Coefficient	0.96				
Standard Error	0.45				
Significance - F Test	0.04				

Ohakune - Conquest

	Grain Yield t/ha	Moisture %	Test Wt. kg/hectolitre	Dressing Loss %	TGW g
Soil N only	5.45	18.9	72.9	2.2	37.4
Soil N + Urea at planting (N to deliver 15 kg N/t wheat)	6.35	19.3	71.6	3	36.2
Soil N + Urea at GS32 (N to deliver 15kg N/t wheat)	6.61	18.9	72.5	2.7	36.8
Soil N + Urea at GS32 (N to deliver 25kg N/t wheat)	7.67	18.9	72.5	2.6	35
R Square	0.96				
Correlation Coefficient	0.98				
Standard Error	0.33				
Significance - F Test	0.02				

Wairarapa grain yield results show a strong positive linear trend from treatments from the treatment 'Soil N only' through to the highest N application rate of 'Soil N + Urea at GS32 (N to deliver 25kgN/t wheat). There is a high degree of certainty that the treatment types influenced the yield results in this trial. Similarly, Ohakune grain yield results increased significantly as total N increased (p>0.01).

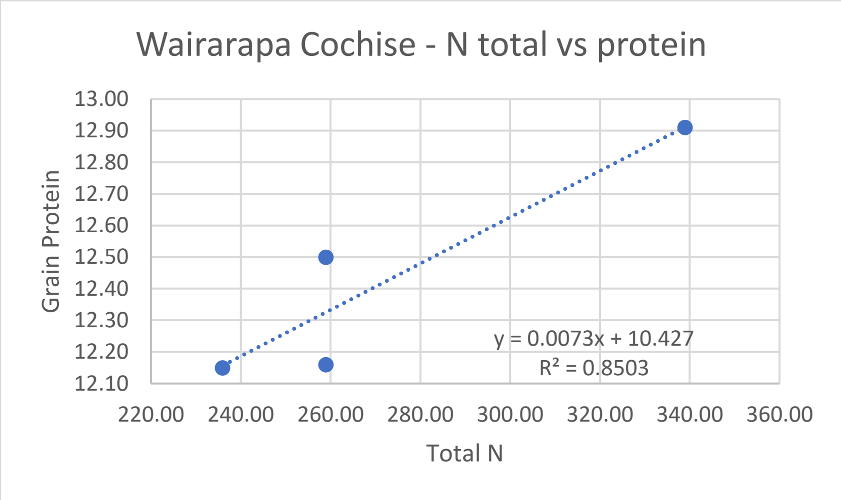


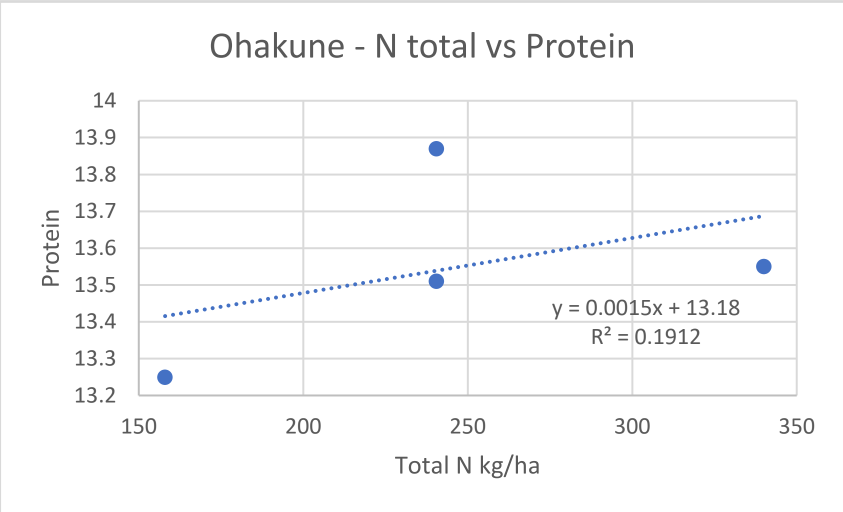


Grain Quality

	Wairarapa - Cochise		Ohakune - Conquest	
	Protein %	Falling Number	Protein %	Falling Number
Soil N only	12.2	92	13.2	197
Soil N + Urea at planting (N to deliver 15 kg N/t wheat)	12.2	83	13.9	181
Soil N + Urea at GS32 (N to deliver 15kg N/t wheat)	12.5	72	13.5	199
Soil N + Urea at GS32 (N to deliver 25kg N/t wheat)	12.9	83	13.6	226

In the Wairarapa there was a significant increase in protein as the total N increased (p>0.05) whereas in Ohakune protein did not increase significantly as total N increased. The falling numbers were representative of the very wet season and harvest and were very low in the Wairarapa. The falling numbers were reasonable in Ohakune even though visible sprout was evident at both sites.





Grain Yield & Grain Tests – Cultivar Comparison

Wairarapa

Cultivar	Grain Yield t/ha	Grain Moisture %	Test Weight kg/hectolitre	Dressing Loss %	TGW g	Protein %	Falling Number
2208	8.0	12.7	72.3	1.2	44.0	13.9	150
Sensas	7.8	13	74.5	0.8	42.4	13.5	270
Cochise	7.8	11.2	63.9	5.1	42.2	13.5	126
Discovery	6.8	11.2	63.2	4.9	41.0	13.6	135
Reliance	6.5	10.3	63.9	4.8	40.2	15.1	120
Conquest	6.5	10.4	67.7	2.8	34.6	15.2	139
Mean	7.25						
Range	1.57						
Sample Variance	0.54						

The cultivar comparison trial at the Wairarapa site showed the top three yield-producing cultivars to be 2208, Sensas and Cochise, with only 0.22t/ha difference between them. The other cultivars all produced at least 1t/ha less than the top three cultivars. Cultivar 2208 produced the largest yield and Conquest / Reliance produced the smallest yield with a range of 1.57t/ha between them. This yield difference was significant. These yields were similar to yields reported in the FAR Spring Wheat and Barley Cultivar trials booklet 2021/22 https://www.far.org.nz/articles/1680/202222-spring-sown-wheat-and-barley-cultivar-evaluations but were significantly (1-2 tonnes) less than those in a trial in the Wairarapa in 21/22 season (LFI trials).

The grain quality was surprisingly good given the weather through the growing season. Comparing the quality data with that reported in the FAR Cultivar trials booklet 2021/22, the test weight on average (67) is lower than in LFI trials in 21/22, a little lower than the average for the Southern North Island for the same cultivars (74), the TGW was the same 40 as for the cultivar trials but less than in the LFI trials 21/22, proteins were significantly better than in both the cultivar and LFI trials but the falling numbers were significantly lower than the average of 314 for the same cultivars in the Southern North Island and much lower than the LFI trials 21/22, with only Sensas having a good falling number.

Sensas and 2208 both look promising as cultivars in the Wairarapa as they had good yields and quality.

It is important to note that these results are only from one trial and therefore the same results may not be expressed if replicated elsewhere.

Ohakune

Cultivar	Grain Yield t/ha	Grain Moisture %	Test Weight kg/hectolitre	Dressing Loss %	TGW g
Viceroy	7.11	18.3	62.7	7.6	37.8
Cochise	6.91	19.5	74.4	1.4	41.6
Conquest	5.72	16.5	69.5	4.5	33.8

Results from a block (non-replicated) comparison of cultivars at Ohakune showed a 1.39 t/ha difference in grain yield between Viceroy and Conquest. Similar to the Wairarapa trial, Cochise performed better than Conquest. These yields are significantly less than the same cultivars in LFI trials in 21/22 where Cochise yielded 13t/ha, Viceroy 11.2t/ha and Conquest 10.3t/ha and reflect the wet season. Quality wise the test weights and TGW were higher for the same cultivars in LFI trials 21/22 than in this season. Protein and falling number were not tested for these cultivars.

Nitrogen use and losses

The unusual season means it is very difficult to interpret the nitrogen results with any confidence. The 503mm of rain in the Wairarapa during the growing season was 188mm above the 10 year average and the 954mm in Ohakune was 390mm above the 20 year mean. These weather conditions could have had three unplanned impacts on the nitrogen use. The yield at both sites was lower than forecast, and this may reflect reduced sunshine hours, so N uptake to grain was reduced, the high rainfall after N application at planting may have leached N below the root zone of the developing plant so this treatment may have had lower N uptake than usual and the high rainfall is likely to have resulted in greater leaching and, as such loss of more N from the lower profile.

At the Wairarapa site, for the yield achieved, the soil N at planting + applied N was adequate to produce the yield for each treatment. Further the total N in grain and straw was less than the soil N + applied N and the resultant N in the soil at harvest was also relatively high. This means a significant quantity of N was mineralised during the growing season. The mineralised N in the table is an underestimate as it does not account for N leached. The Nitrogen use efficiency (NUE) was maximised by the higher crop yield for the lower fertiliser N inputs but when 103kg of N was applied there was excess N available for the yield achieved and efficiency reduced.

Wairarapa Treatment	Total N = Soil N + applied N	N used @ 25kg/t yield	N in grain + straw kg/ha	N in soil @ harvest	Tot N for season = soil N harvest + N in G+S	N mineralised in season **	NUE (fert) Yield/fert N	NUE (bio) Yield/ (soil N + applied N)
Soil N 236	236	159	170	148	320	82		27
+ 23 planting	259	200	205	193	398	139	35	31
+ 23 GS32	259	212	231	158	389	130	37	33
+103 GS32	339	228	254	194	448	109	9	27

**Mineralised figure assumes no loss of N to leaching

At the Ohakune site, for the yield achieved, the soil N at planting + applied N was adequate to produce the yield for each treatment. Further the total N in grain and straw was less than the soil N + applied N and the resultant N in the soil at harvest was also relatively high. This means a significant quantity of N was mineralised during the growing season. The mineralised N in the table is an underestimate as it does not account for N leached. The Nitrogen use efficiency (NUE) was lower for the higher applied N inputs as the yield achieved was significantly less than predicted. The NUE is highest for the no fertiliser N due to the low yields of the other treatments.

Ohakune Treatment	Total N = Soil N + applied N	N used @ 25kg/t yield	N in grain + straw kg/ha	N in soil @ harvest	Tot N for season = soil N harvest + N in G+S	N mineralised in season **	NUE (fert) Yield/fert N	NUE (bio) Yield/ (soil N + applied N)
Soil N 158	158	136	144	131	275	117		35
+ 82 planting	240	159	193	140	333	92	78	27
+ 82 GS32	240	165	190	109	299	59	80	28
+ 182 GS32	340	192	221	124	345	5	42	23

**Mineralised figure assumes no loss of N to leaching

Soil N at Harvest

Wairarapa (Cochise) and Ohakune (Conquest)

		Wairarapa	Ohakune
Treatment	Soil profile	Potentially Available N	
		kg/ha	kg/ha
Soil N only	0-30 cm	101	106
Soil N only	30-60 cm	31	15
Soil N only	60-90 cm	16	10
Soil N + Urea at planting (N to deliver 15 kg N/t wheat)	0-30 cm	139	88
Soil N + Urea at planting (N to deliver 15 kg N/t wheat)	30-60 cm	24	36
Soil N + Urea at planting (N to deliver 15 kg N/t wheat)	60-90 cm	30	16
Soil N + Urea at GS32 (N to deliver 15kg N/t wheat)	0-30 cm	100	77
Soil N + Urea at GS32 (N to deliver 15kg N/t wheat)	30-60 cm	34	22
Soil N + Urea at GS32 (N to deliver 15kg N/t wheat)	60-90 cm	24	<10
Soil N + Urea at GS32 (N to deliver 25kg N/t wheat)	0-30 cm	129	98
Soil N + Urea at GS32 (N to deliver 25kg N/t wheat)	30-60 cm	45	16
Soil N + Urea at GS32 (N to deliver 25kg N/t wheat)	60-90 cm	20	<10

N leaching

At harvest the total N in the soil was highest in the top 30cm for all treatments. Although the crop had taken up N and there had been significant amount of rain the N levels in the soil were high and the distribution in the profile did not indicate significant N had been leached from the upper profile to accumulate in the lower profile.

Using the following equation:
N movement in soil (cm) = mm rain *10 / soil field capacity (FAR Arable Update Maize #36 2006) it is possible to calculate the expected leaching for each soil type for each N application time.

In Wairarapa the total N in the soil profile was less at harvest than at planting for all treatments with most of the N still in the top 30cm. The field capacity for the soil (Bramley S map) is around 130mm to 60cm depth. Therefore, for the whole growing season 22/23, 503mm*10/130 = 39cm, the N applied at planting could have leached into the 30-60cm zone where the wheat roots would be actively taking up nitrogen. The rainfall for an average season is 315mm in which case N could have leached 24cm and all N applied would remain in the top 30cm. The N applied at GS 32 (1st December) received 384mm of rain, 384*10/130 = 29cm so the maximum leaching of this N would not be below the top 30cm, but the higher N level in the 30-60cm zone at harvest than at sowing for the high N treatment suggests some N may have leached into this zone. The lower levels than at planting in the 60-90cm are likely to be due to both leaching and root uptake although root uptake from this zone would be limited.

For Ohakune the total N in the soil profile was less at harvest than at planting for all treatments with most of the N still in the top 60cm. The field capacity is around 78mm (volcanic soil no S map data for Ohakune). Therefore, for the whole growing season, 954mm*10/78 = 122cm indicates that N applied at planting could have leached below the wheat rootzone. The rainfall for an average season is 564mm in which case N could have leached 72cm and N applied could leach to below 60cm where the wheat root activity is less. Whereas the N applied at GS32 (2nd December) received 573mm of rain 573*10/78 = 73cm should not have N leached below the 90cm. The low levels of N in the 60-90cm zone suggest little N leaching from the surface indicating the wheat has utilised much of the N available.

At the Wairarapa site the pH in the 0-30cm decreased from sowing for all treatments.

OverseerFM Modelling

As an objective of the Land and Water Nitrogen Scavenger Project, nitrogen and phosphorus losses were modelled using OverseerFM for each of the trials and their treatments. Additionally, greenhouse gasses are reported.

Three regions have been modelled, Ohakune, Wairarapa and Waikato, it is important to note that field trials were only carried out in Ohakune and Wairarapa and the Waikato farm is a modelled trial. Each trial site had four different treatments, subsequently for each location, four OverseerFM models have been carried out.

Each section provides a summary of the farm system, OverseerFM modelling notes and an analysis of results. Overall, it can be seen there is no significant difference in nitrogen loss or phosphorus loss at a whole farm and block level between the different treatments at the different locations.

Model one – Ohakune Property.
Farm System Discussion

- Property is partially leased by various landlords including A S Wilcox and is owned by Sue Joe and Sons.
- A S Wilcox grows cereals (Wheat), potatoes and carrots.
- When the land is not in the above crops they are in grass for sheep and beef which is managed by the landowners.
- The stocking rate is 10 ewe equivalents.
- Green feed oats are sown post the wheat. Land after carrots and potatoes have been grown is fallow due to their winter harvest date.
- Crop yields that have been modelled are below:
    - Potatoes – 75t/ha
    - Carrots – 120 t /ha
    - Wheat 10t/ha (last season)
    - Greenfeed oats (have assumed 4t/ha).

Overseer Modelling Discussion

- S-map data on the soil type is not available at the sight location. The soil type that has been modelled in OverseerFM is Allophonic, well-drained soils.
- Soil test data has not been overridden – OverseerFM defaults have been used.
- 50 hectares (ha) of pasture and 10 ha of each rotation has been modelled to represent the farm system.
- Assumed 8ha (10%) of unproductive area.
- Green feed oats, is grazed from June through to August by the ewes.
- 550 Romney ewes have been modelled throughout the season to replicate the stock on farm.

Table 1 Ohakune Blocking

Block Name	Area (Ha)
Pasture	50
Carrot>Wheat>Green Feed Oat>Potatoes	10
Potato>Carrot>Wheat	10
Wheat>Green Feed Oat>Potatoes>Carrots	10
Total Effective Area	80
Total Farm Area	88

Table 1 displays the block set-up in OverseerFM. Due to the multiple cropping rotations, three crop blocks have been modelled and one pastoral block. The block that is modelled in the trial is Potato>Carrot>Wheat.

Table 2 Ohakune fertiliser summary per treatment.

Treatment	Nitrogen applied (Kg/ha)	Date Applied
Treatment 1	0	
Treatment 2	82.5	29/10/2022
Treatment 3	82.5	2/12/2012
Treatment 4	182.5	2/12/2022

Table 2 provides a summary of fertiliser applied at each treatment. Due to four different treatments, there are four OverseerFM results, these are displayed in Table 3.

Overseer Reports and Analysis

Table 3 displays a summary of the nitrogen and phosphorus loss of each treatment at Ohakune. Due to four different fertiliser treatments, four different OverseerFM models have been completed. The nitrogen and phosphorus loss results have been reported at a whole farm and at a trial block level.

Table 3 OverseerFM losses for the Ohakune Trial

			Whole Farm				Block Level			
Overseer File Name	Yield Used	N Fertiliser was applied on the block. (Kg N/ha/yr.)	N Loss per ha (Kg N/ha/yr.)	Total N Loss (Kg N/yr.)	P loss per ha (Kg P/ha/yr.)	Total P Loss (Kg P/yr.)	N Loss per ha. (Kg N/ha/yr.)	Total N Loss (Kg N/yr.)	P loss per ha (Kg P/ha/yr.)	Total P Loss (Kg P/yr.)
Ohakune Treatment 1	5.45	0	32	2841	0.2	16	98	983	0.1	1
Ohakune Treatment 2	6.35	83	33	2896	0.2	16	104	1037	0.1	1
Ohakune Treatment 3	6.61	83	32	2840	0.2	16	98	982	0.1	1
Ohakune Treatment 4	7.67	183	32	2839	0.2	16	98	981	0.1	1

Table 3 demonstrates that there is no difference in overall nitrogen loss at a whole farm level, additionally, there is minimal change in block losses for nitrogen and phosphorus. The block nutrient budgets have been included in Appendix 1.

Table 4 provides a summary of the greenhouse gas emissions (GHG) for Methane, Nitrous Oxide and Carbon dioxide. It is important to note the Carbon Dioxide calculation only includes the dissolution of nitrogen fertiliser and lime, the other factors in OverseerFM are around transport and manufacturing.

Table 4 GHG emissions from each treatment on a whole farm level

Trial	Methane	Nitrous Oxide	Carbon Dioxide	CO_2- E Kg/ha/yr.
	CH_4	N_20	CO_2	Total
Ohakune Treatment 1	1198	670	0	1868
Ohakune Treatment 2	1198	703	15	1916
Ohakune Treatment 3	1198	701	15	1914
Ohakune Treatment 4	1198	743	33	1974

Nitrogen Pool Graphs for each Trial Site

To understand the block losses more in-depth the nitrogen pool graphs are a good way to understand the Plant Nitrogen, Residue Nitrogen, Soil Inorganic Nitrogen and Residue Stover Nitrogen changes throughout the reporting period. There were no significant changes in the graphs for any of the treatments. These have been included in Appendix 2.

Model two – Wairarapa Property.
Farm System Discussion

- Ahiaruhe Farm is operated by Michael & Karen Williams
- The property is a mixed arable and livestock system, growing a mixture of Barley, Ryegrass, Wheat, brassica seed, Pak Choi, peas, and red clover.
- Stock on the farm are Bull Beef and Trading Lambs, see Table 5 below.

Table 5 Wairarapa Stock Numbers

Name	Breed	JUL 2022	AUG 2022	SEP 2022	OCT 2022	NOV 2022	DEC 2022	JAN 2023	FEB 2023	MAR 2023	APR 2023	MAY 2023	JUN 2023
Trading Lambs	Romney	2100	1800	800	350	-	-	-	-	-	-	-	-
Trading Lambs	Romney	-	-	-	-	-	-	-	260	840	1070	-	-
Trading Lambs	Romney	-	-	-	-	-	-	-	-	-	-	2150	2150
Bulls	Friesian	-	-	-	-	-	-	-	-	-	-	64	64
Bulls	Friesian	64	64	64	-	-	-	-	-	-	-	-	-
Bulls	Friesian	-	-	-	-	110	110	110	110	110	110	110	110
Bulls 2 yr	Friesian	-	-	-	7	7	7	7	7	7	7	7	7

Overseer Modelling Discussion

- Climate has been calculated by OverseerFM on a block level, the average for the whole property is a rainfall of 911mm, and for the trial site a rainfall of 899 mm has been modelled by OverseerFM.
- Soil test data for the blocks has not been overridden, OverseerFM defaults have been used.
- Soils on the trial site have been modelled as Bramley, Greytown deep silt loam (Bram_8a.1), Waimakariri Greytown deep silt loam (Waim_1b.2), Ahikouka deep silt loam (Tait_36a.1) and the properties of each is shown in Table 6.
- Table 7 provides a breakdown of each model's fertiliser treatments.

Table 6 Wairarapa Soils gained from S-Map.

S-Map Reference	Group	Order	Drainage Class	Description	Total Area
Bram_8a.1	Recent/YGE/BGE	Recent	Imperfect	deep, imperfectly drained, silt	74.2 ha
Waim_1b.2	Recent/YGE/BGE	Recent	Well	deep, well drained, silt	39.7 ha
Waka_27a.1	Recent/YGE/BGE	Pallic	Imperfect	deep, imperfectly drained, silt	15.8 ha
Waka_26a.1	Recent/YGE/BGE	Pallic	Imperfect	deep, imperfectly drained, silt over clay	12.7 ha
Ashb_32a.1	Recent/YGE/BGE	Raw	Well	shallow, well drained, sand	7.4 ha
Temp_2a.3	Recent/YGE/BGE	Pallic	Moderately well	moderately deep, moderately well drained, silt	6.8 ha
Mair_24a.1	Recent/YGE/BGE	Pallic	Poor	moderately deep, poorly drained, silt over clay	6.1 ha
Tait_36a.1	Sedimentary	Gley	Poor	deep, poorly drained, silt	5.4 ha
Ashb_31a.1	Recent/YGE/BGE	Raw	Well	shallow, well-drained, sand	4.6 ha
Eyre_1a.2	Recent/YGE/BGE	Recent	Well	shallow, well-drained, silt	3.7 ha
Waka_28a.1	Recent/YGE/BGE	Pallic	Imperfect	moderately deep, imperfectly drained, silt	3.7 ha
Ruam_11a.1	Recent/YGE/BGE	Raw	Well	moderately deep, well-drained, silt over sand	3 ha

Table 7 Timing and application rates of each treatment.

Treatment	Nitrogen applied (Kg/ha)	Date Applied
Treatment 1 - Cochise	0	-
Treatment 2 - Cochise	23.5	29/10/2022
Treatment 3 - Cochise	23.4	1/12/2012
Treatment 4 - Cochise	103.5	1/12/2022
Treatment 1 - Conquest	0	-
Treatment 2 – Conquest	30.5	29/10/2022
Treatment 3 – Conquest	30.5	1/12/2022
Treatment 4 - Conquest	110.5	1/12/2022

Overseer Reports and Analysis

Table 8 provides a summary of nitrogen and phosphorus loss for the Wairarapa trial.

Table 8 Wairarapa Trial Overseer Results Summary

			Whole Farm				Block Level			
Overseer File Name	Yield Used	N Fertiliser was applied on the block. (Kg N/ha/yr.)	N Loss per ha (Kg N/ha/yr.)	Total N Loss (Kg N/yr.)	P loss per ha (Kg P/ha/yr.)	Total P Loss (Kg P/yr.)	N Loss per ha (Kg N/ha/yr.)	Total N Loss. (Kg N/yr.)	P loss per ha (Kg P/ha/yr.)	Total P Loss (Kg P/yr.)
Wairarapa Treatment 1 Cochise	6.38	0	15	2791	0.4	80	5	39	0.4	2
Wairarapa Treatment 2 Cochise	8.02	24	15	2791	0.4	80	5	39	0.4	2
Wairarapa Treatment 3 Cochise	8.5	24	15	2791	0.4	80	5	39	0.4	2
Wairarapa Treatment 4 Cochise	9.13	104	15	2791	0.4	80	5	39	0.4	2
Wairarapa Treatment 1 Conquest	6.38	0	15	2791	0.4	80	5	39	0.4	2
Wairarapa Treatment 2 Conquest	8.02	31	15	2791	0.4	80	5	39	0.4	2
Wairarapa Treatment 3 Conquest	8.5	31	15	2791	0.4	80	5	39	0.4	2
Wairarapa Treatment 4 Conquest	9.13	111	15	2791	0.4	80	5	39	0.4	2

It can be seen from Table 8 that although there are different fertiliser rates and timings for the different yields for each of the treatments, there is no impact on the nitrogen or phosphorus losses at a farm level or block/paddock level. This is due to the yield increasing with the additional nitrogen fertiliser applications so the plant utilising the additional nitrogen.

The block individual nutrient budgets and the soil pool graphs have been included in the appendix. Due to the minimal changes between each treatment, it can be determined that by increasing the yield with the additional fertiliser inputs, there is minimal changes in the organic pools.

Table 9 provides a summary of Methane, Nitrous Oxide, Carbon Dioxide and total GHG losses for each trial.

Table 9 Greenhouse Gas Emissions for the Wairarapa Trials

Trial	Methane CO_2- E Kg/ha/yr.	Nitrous Oxide CO_2- E Kg/ha/yr.	Carbon Dioxide CO_2- E Kg/ha/yr.	Total CO_2- E Kg/ha/yr.
	CH_4	N_20	CO_2	
Wairarapa Treatment 1 Cochise	1998	1037	145	3180
Wairarapa Treatment 2 Cochise	1998	1040	147	3185
Wairarapa Treatment 3 Cochise	1997	1040	147	3184
Wairarapa Treatment 4 Cochise	1997	1050	157	3204
Wairarapa Treatment 1 Conquest	1998	1037	145	3180
Wairarapa Treatment 2 Conquest	1998	1041	147	3186
Wairarapa Treatment 3 Conquest	1997	1041	147	3185
Wairarapa Treatment 4 Conquest	1997	1052	152	3201

Table 9 demonstrates there is no significant change in emissions. There are some slight variances However this is due to rounding. The main variations that can be seen is due to the changes in nitrogen dissolution, the more nitrogen added the higher the dissolution results are.

Model Three – Waikato Property.

Farm System Discussion

- Property has been modelled based on a dairy unit in Morrinsville, it is important to note that this is not an actual property it has been modelled to best represent a farm system in the area.
- Total area of the property is 155ha, 150 ha effective and 5 ha non-effective (3%).
- Stocking rate over the whole farm is 3.4 cows/ha, Calving 516 MA F x J Cross cows and peak milking 494 cows. Producing 261,559 Kg Milk solids/yr.
- Effluent area is 39.6ha, applying 146 Kg N/ha/yr. through effluent.
- Fertiliser regime has been differentiated for effluent and non-effluent blocks, to consider the additional nitrogen from effluent. Fertiliser for the pasture block modelled is listed below:
    - Effluent:
        - 25 Kg/ha of SustaiN was applied in September, November, February, and April.
        - 60 Kg/ha of Phased N Quick Start applied in August.

- Non-Effluent
  - 55 Kg/ha of SustaiN was applied in September, December, February, and April.
  - 45/kg/ha of SustaiN was applied in October, November, and January.
  - 85 Kg/ha of Phased N Quick Start applied in August.

Overseer Modelling Discussion

- Soil types modelled in OverseerFM are displayed in Table 10. The soils modelled are predominant soils from around the Waikato area.
- Soil tests have not been overridden, OverseerFM defaults have been used.
- The cropping rotation is Pasture>Wheat>Pasture. The wheat is sown in October and harvested in March with the straw removed. The wheat has been conventionally sown and the new grass direct drilled in April.
- Fertiliser for each treatment (amount and timing) is displayed in Table 11.

Table 10 Waikato Soil Types

S-Map Reference	Group	Order	Drainage Class	Description	Total Area
Morr_13a.1	Volcanic	Granular	Moderately well	deep, moderately well drained, clay over loam	90 ha
Otor_74a.2	Volcanic	Allophonic	Well	deep, well-drained, silt	44.9 ha
Temu_97a.1	Sedimentary	Gley	Poor	deep, poorly drained, clay	15.1 ha

Table 11 Waikato Fertiliser Regime for each trial.

Treatment	Nitrogen applied (Kg/ha)	Date Applied
Treatment 1	0	0
Treatment 2	23.5	29/10/2022
Treatment 3	23.5	1/12/2022
Treatment 4	103.5	1/12/2022

Overseer Reports and Analysis

Table 12 provides a summary of whole farm and block level nitrogen and phosphorus losses.

Table 12 Waikato Nutrient loss summary

			Whole Farm				Block Level			
Overseer File Name	**Yield Modelled** (T/ha)	**N Fertiliser was applied to the block. (Kg N/ha/yr.)**	**N Loss per ha (Kg N/ha/yr.)**	**Total N Loss (Kg N/yr.)**	**P loss per ha (Kg P/ha/yr.)**	**Total P Loss (Kg P/yr.)**	**N Loss per ha (Kg N/ha/yr.)**	**Total N Loss. (Kg N/yr.)**	**P loss per ha (Kg P/ha/yr.)**	**Total P Loss (Kg P/yr.)**
Waikato Treatment 1	10	0	34	5,268	0.8	125	54	839	0.2	3
Waikato Treatment 2	10	24	35	5,365	0.8	125	59	915	0.2	3
Waikato Treatment 3	10	24	35	5,353	0.8	125	58	899	0.2	3
Waikato Treatment 4	10	104	37	5,700	0.8	125	69	1,077	0.2	3

The findings from modelling the four different treatments demonstrate that there is a significant difference of 3 Kg N/ha/yr. at a whole farm level from Treatment 1 to Treatment 4. The lowest N loss is when no fertiliser is applied (Treatment 1), allowing the plant to utilise the soil nitrogen. The highest loss is Treatment 4, this is due to the high soil mineral nitrogen and the additional fertiliser applications allowing more in the soil to be lost. The percent change between the two losses is an 8% increase at a whole farm level. There is no change in Phosphorus losses.

Table 13 displays the greenhouse gasses.

Table 13 Greenhouse Gas emissions for the Waikato Treatments.

Trial	Methane CO_2- E Kg/ha/yr.	Nitrous Oxide CO_2- E Kg/ha/yr.	Carbon Dioxide CO_2- E Kg/ha/yr.	Total CO_2- E Kg/ha/yr.
	CH_4	N_20	CO_2	
Waikato Treatment 1	10,466	3,261	211	13,938
Waikato Treatment 2	10,466	3,271	215	13,952
Waikato Treatment 3	10,466	3,270	215	13,951
Waikato Treatment 4	10,466	3,305	228	13,999

Table 13 demonstrates that there is no significant change between each of the treatments. The total CO_2- E Kg/ha/yr. increases slightly (0.4%) due to the increase in nitrogen fertiliser added. There is no change to methane.

General Discussion

Overall results.

Over the two trial sites, and the Waikato farm model, OverseerFM has demonstrated there are no significant changes in nitrogen or phosphorus losses at a whole farm or block level. This is due to the correct timing of fertiliser inputs to meet yield demand as well as the soil type's ability to hold onto the nitrogen efficiently.

Overseer limitations

OverseerFM is a science-based modelled that helps understands the nutrient flows within a farm system. The model allows an understanding of the nutrient inputs and nutrient outputs of a farm system. It is important to note, although it is a great tool to help understand the nutrient cycles, there are some limitations that the model has had as part of this trial modelling these are listed below:

- Climate:

OverseerFM uses long-term climate over 30 years (1918-2010) data. The annual climate data inputs include rainfall (mm/yr.), annual potential Evapotranspiration (PET, mm/yr.) and annual average temperature (^{0}C). Annual rainfall is an important driver of nitrogen drainage and nitrogen cycling.

The limitation of using the long-term climate model for this trial is the difference in the annual rainfall that has occurred over the trial and the long-term climate OverseerFM has modelled. As discussed in each of the trial site descriptions, the difference between OverseerFM and farm data for the 2022/23 season is significantly different with a higher rainfall recorded. Meaning that the drainage and nitrogen loss could be higher for the season than what OverseerFM has modelled.

- Soil mineral N levels.

There is no ability to include the soil mineral N results that were gained as part of the trial. The soil mineral N results are the main driver of what is in the soil at the time and fertiliser decisions. By not including these, the results are relying on “modelled” soil nitrogen levels, not actual data.

Background

The financial modelling was designed to:

- Create farm financial models for the farm systems in their current state and with the intervention of spring sown wheat.
- Compare the results for both the with and without the intervention and the resultant change in Earnings Before Interest and Tax will be compared against other possible mitigations.
- These results will be compared on a unit of reduction in both the nutrient losses and greenhouse gas emissions in order to get an idea of how the intervention performs against a range of alternative mitigations from a financial perspective.

Results

The results of the Nitrogen (N) profiles of the soil across the three sites is shown in Table . Both the Wairarapa Cochise and the Ohakune trials have a pre sowing and an after harvest result while the Wairarapa Conquest result doesn't have an after harvest result.

Table 1: Nitrogen profile across three of the trial results (N/ha).

	Pre sowing Wairarapa Cochise	After Harvest Wairarapa Cochise	Pre sowing Wairarapa Conquest	Pre sowing Ohakune	After Harvest Ohakune
Trial area 0-30 cm	154	101	138	78	106
Trial area 30-60 cm	39	31	41	57	15
Trial area 60-90 cm	43	16	40	23	10

The results were described as follows:

- For all three sites the N, P and K was highest in the top 30cm of soil as would be expected with significantly more N in the upper profile at all three sites but less marked for the free draining Ohakune site.
- At harvest the total N in the soil was highest in the top 30cm for all treatments. Although the crop had taken up N and there had been significant amount of rain the N levels in the soil were high and the distribution in the profile did not indicate N had been leached from the upper profile to accumulate in the lower profile.
- The N levels at this depth don't suggest significant N leaching from the surface indicating the wheat has utilised much of the N available.

What we can take from these results is that at worst the use of wheat as an N scavenger crop is effective in at least not adding to the amount of N leaching and at best it does in fact consume the N which is deposited in the deeper layers which are not able to be accessed by the pastures root system. In both the Wairarapa trial the amount of N in the 60-90 cm profile was significantly

diminished while in the upper profiles it was diminished. In the Ohakune trial while the amount in the upper profile increased the amount in the lower two profiles was significantly diminished.
For soils with large amounts of N sitting in the lower profiles, which are below the depth of root penetration of pastures, the use of wheat as an N scavenger is a worthwhile method of reducing the risk of N leaching into waterways.
The use of wheat as a means of reducing the amount of Greenhouse Gas emissions is also worthwhile in any animal based farming system.

Financial Comparison

In order to demonstrate the impact of using wheat as an N scavenger on the financial performance of farming systems in the North Island context we have modelled its use in Dairy farming in the Waikato and Wairarapa and the combined livestock vegetable production system at Ohakune.
The financial performance of each of these is shown in Table 12.

Table 12: Individual financial results of the farming systems.

	Dairy Waikato	Sheep and Beef Ohakune	Vegetable Production Ohakune	Dairy Wairarapa	Wheat	Maize
Gross Farm Revenue	9,250	1,939	34,125	8,557	5,600	6,600
Total Farm Operating Expenses	4,562	1,274	17,706	4,000	2,659	3,576
Earnings Before Interest and Tax	4,688	666	16,419	4,556	2,941	3,024

The dairy financial performance is taken from models of Regional financial performance produced by DairyNZ, the Sheep and Beef performance is taken from Beef and Lamb NZ's Western North Island Class 5 Finishing model the wheat performance is taken from FAR's wheat Gross Margin and the Maize performance is taken from Pioneers Maize Grain cost calculator.
Maize is shown because it is an alternative to wheat in the North Island and as can be seen the financial performance is very similar to wheat. Wheat is a more attractive option to pastoral farmers because it is harvested in February / March whereas Maize is harvested in May. This means that it is possible to resow pasture after the N scavenger crop earlier and get significant amount of growth on it before the winter.
In the results shown in

Table 13 the use of wheat has been assumed at a rate of 10% of the total area.

Table 13: Individual financial results of the farming systems with and Without Wheat ($ / property).

	Dairy Waikato		Ohakune		Dairy Wairarapa	
	Without Wheat	**With Wheat**	**Without Wheat**	**With Wheat**	**Without Wheat**	**With Wheat**
Gross Farm Revenue	1,433,763	1,377,187	779,465	816,072	1,197,921	1,164,929
Total Farm Operating Expenses	560,046	550,310	372,202	390,027	560,046	550,310
Earnings Before Interest and Tax	637,875	614,619	407,263	426,045	637,875	614,619

The net financial impact of incorporating wheat into the farm systems is shown in Table 4.

Table 14: Net financial impact of incorporating wheat into the farming system ($ / property).

	Dairy Waikato	Ohakune	Dairy Wairarapa
Loss Total	-35,916	18,781	-23,256
Loss / ha	-232	268	-166
Percentage of EBIT	-5.2%	4.6%	-3.8%

In Table 14 we can see that:

- The loss for the Waikato Dairy Farm is insignificant when calculated on a per ha or as a percentage of EBIT.
- The Ohakune property had a minor increase in its financial performance as a result of gaining a higher return for wheat production than it does from its pastoral operation.
- The loss for the Wairarapa Dairy Farm is insignificant when calculated on a per ha or as a percentage of EBIT.

We can conclude from the financial performance work that the loss to the two dairy farms is insignificant when considered on a per Ha or as a % of EBIT and for the Ohakune example is a financial benefit.

Comparison on a unit of reduction basis.

1.1 N Reduction

We have not been able to calculate the N reductions because the reductions that are made in introducing wheat into each farming system have not been able to be quantified and because the technique is designed to be used in situations where the N in the soil profile is below the level of the N that can be mitigated in a pastoral system.
That being said, it should be considered to rank very favourably against the majority of N mitigation techniques because it is a technique which has very little cost.

GHG Reduction

The amount of N reduction that is achieved and the cost of achieving it is shown in Table 15.

Table 15: Reduction of GHG's and the cost of achieving them. (kg/ ha)

	Without	With	Change	Cost / GHG
Waikato	14,077	12,707	-1,370	0.17
Ohakune	3,820	3,802	-19	-14.50
Wairarapa	13,123	11,848	-1,275	0.13

As can be seen from Table 15 the amount of GHG reductions which are possible by the introduction of wheat into the farming system are quite substantial for the two dairy systems and insignificant for the Ohakune system. The costs per kg of GHG's are insignificant for both of the dairy farms and are positive for the Ohakune farm although insignificant in volume.

The cost of achieving GHG mitigations are virtually nil from this farm system change and so it will rank very favourably with the other mitigation techniques.

Knowledge exchange

Presentations of the results from this work were presented by zoom to two groups in June 2023. The groups were made up of farmers from the Wairarapa, Ohakune, Southern Hawkes Bay, Central Plateau and Waikato, Champion Flourmills and Breadcraft. Information was also discussed with independent bakers and NZ Flourmills and some results were forwarded to these parties.

We had some engagement with Ātihau Whanganui as Māori land owners and farmers in Ohakune who have shown interest in growing wheat. Due to the wet season we did not engage with Ngāti Kahungunu to show them the Wairarapa trials.

Due to the impact of weather we do not feel the results from the field trials of this work will reflect a more normal season and thus we do not think it is suitable for publication in the NZ Agronomy Journal.

This project has created significant interest from farmers, millers and bakers in the North Island. We have had requests from all these parties to continue this work as they see it as essential in contributing to a viable wheat production and milling system in the North Island and are currently seeking on-going support for this work.

Acknowledgements

We wish to thank the following for their input into this project.

- Mick & Karen Williams of Ahiaruhe Farm, Wairarapa. Scott Harvey and Adrian Godfrey of A S Wilcox, Ohakune for allowing us use of their farms for this work.
- Garth Gillam and Champion Flourmills for grain quality testing.
- Kevin Sinclair, Plant & Food Research for harvesting trials.
- PGGW for supplying seed for some trials.
- Our Land and Water for funding this work.

Appendix 1 Ohakune Block Nutrient Budgets

Ohakune Treatment 1 Block Nutrient Budget

LOSSES FROM ROOT ZONE

	TOTAL LOSS (KG/YR)	LOSS PER HA (KG/YR)
Nitrogen	983	98
Phosphorus	1	0.1

NUTRIENTS ADDED (KG/HA/YR)	N	P	K	S	CA	MG	NA
Effluent added	0	0	0	0	0	0	0
Fertiliser, lime and other	0	0	0	0	0	0	0
Irrigation	0	0	0	0	0	0	0
Supplements	0	0	0	0	0	0	0
Rain/clover fixation	2	0	1	3	2	3	8

NUTRIENTS REMOVED (KG/HA/YR)	N	P	K	S	CA	MG	NA
Leaching, runoff and direct losses	98	0.1	7	4	120	29	58
As product	216	73	428	23	8	9	16
Transfer	0	0	0	0	0	0	0
To atmosphere	21	0	0	0	0	0	0
As supplements and crop residues	38	6	104	10	14	6	11

CHANGE IN POOLS (KG/HA/YR)	N	P	K	S	CA	MG	NA
Organic pool	-134	-10	0	-28	0	0	0
Standing plant material	-66	-23	-177	-7	-2	0	-5
Inorganic mineral	0	9	-26	0	-3	-2	-9
Inorganic soil pool	-180	-59	-335	0	-136	-39	-63
Root and stover residuals	8	3	0	1	0	0	0

Ohakune Treatment 2 Block Nutrient Budget

LOSSES FROM ROOT ZONE

	TOTAL LOSS (KG/YR)	LOSS PER HA (KG/YR)
Nitrogen	1,037	104
Phosphorus	1	0.1

NUTRIENTS ADDED (KG/HA/YR)	N	P	K	S	CA	MG	NA
Effluent added	0	0	0	0	0	0	0
Fertiliser, lime and other	83	0	0	0	0	0	0
Irrigation	0	0	0	0	0	0	0
Supplements	0	0	0	0	0	0	0
Rain/clover fixation	2	0	1	3	2	3	8

NUTRIENTS REMOVED (KG/HA/YR)	N	P	K	S	CA	MG	NA
Leaching, runoff and direct losses	104	0.1	7	4	125	29	58
As product	228	77	432	23	9	10	16
Transfer	0	0	0	0	0	0	0
To atmosphere	32	0	0	0	0	0	0
As supplements and crop residues	43	7	116	11	16	7	12

CHANGE IN POOLS (KG/HA/YR)	N	P	K	S	CA	MG	NA
Organic pool	-134	-10	0	-31	0	0	0
Standing plant material	-64	-23	-174	-7	-2	0	-5
Inorganic mineral	0	9	-26	0	-3	-2	-9
Inorganic soil pool	-132	-64	-355	0	-143	-41	-65
Root and stover residuals	8	3	0	1	0	0	0

Ohakune Treatment 3 Block Nutrient Budget

LOSSES FROM ROOT ZONE

	TOTAL LOSS (KG/YR)	LOSS PER HA (KG/YR)
Nitrogen	982	98
Phosphorus	1	0.1

NUTRIENTS ADDED (KG/HA/YR)	N	P	K	S	CA	MG	NA
Effluent added	0	0	0	0	0	0	0
Fertiliser, lime and other	83	0	0	0	0	0	0
Irrigation	0	0	0	0	0	0	0
Supplements	0	0	0	0	0	0	0
Rain/clover fixation	2	0	1	3	2	3	8

NUTRIENTS REMOVED (KG/HA/YR)	N	P	K	S	CA	MG	NA
Leaching, runoff and direct losses	98	0.1	7	4	120	29	58
As product	230	78	433	24	9	10	16
Transfer	0	0	0	0	0	0	0
To atmosphere	30	0	0	0	0	0	0
As supplements and crop residues	44	7	119	11	16	7	12

CHANGE IN POOLS (KG/HA/YR)	N	P	K	S	CA	MG	NA
Organic pool	-133	-10	0	-31	0	0	0
Standing plant material	-64	-23	-174	-7	-2	0	-5
Inorganic mineral	0	9	-26	0	-3	-2	-9
Inorganic soil pool	-128	-65	-359	0	-139	-41	-65
Root and stover residuals	8	3	0	1	0	0	0

Ohakune Treatment 4 Block Nutrient Budget

LOSSES FROM ROOT ZONE

	TOTAL LOSS (KG/YR)	LOSS PER HA (KG/YR)
Nitrogen	981	98
Phosphorus	1	0.1

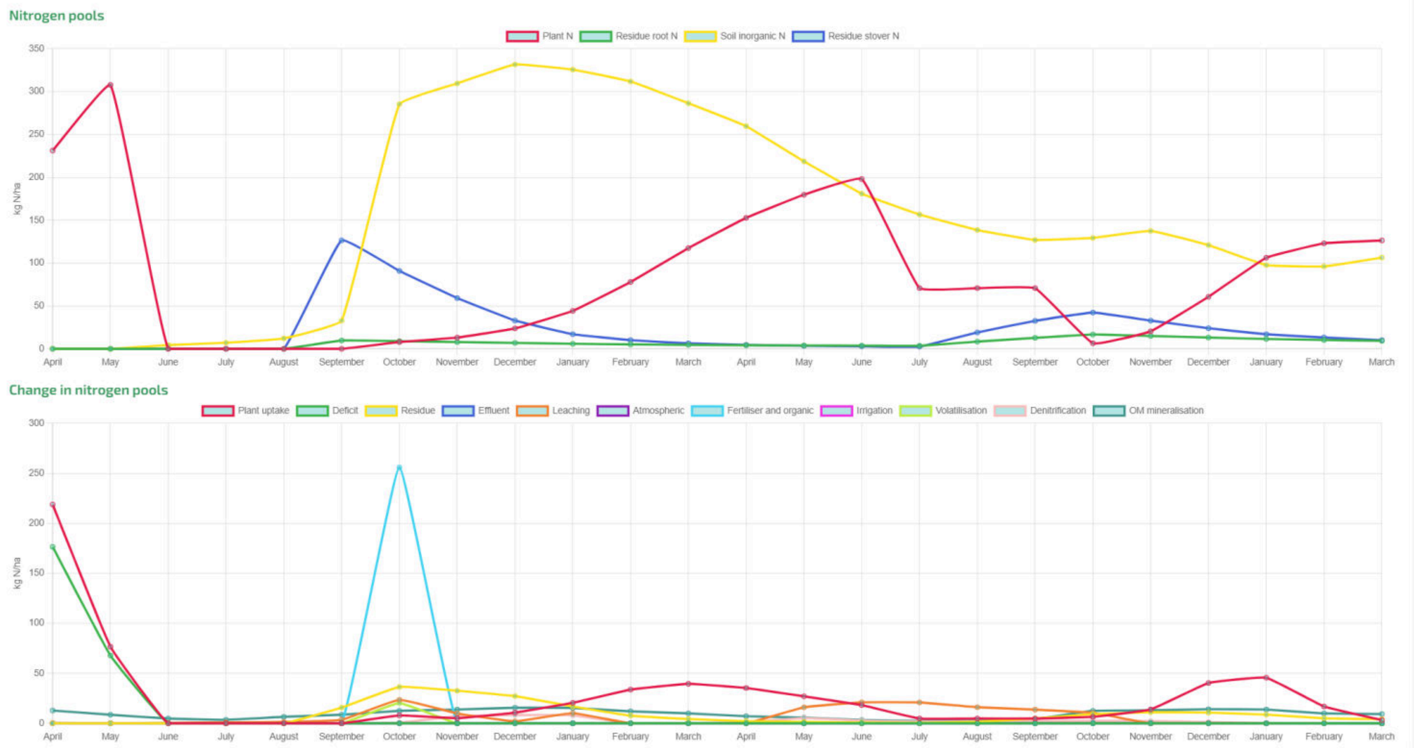
NUTRIENTS ADDED (KG/HA/YR)	N	P	K	S	CA	MG	NA
Effluent added	0	0	0	0	0	0	0
Fertiliser, lime and other	183	0	0	0	0	0	0
Irrigation	0	0	0	0	0	0	0
Supplements	0	0	0	0	0	0	0
Rain/clover fixation	2	0	1	3	2	3	8

NUTRIENTS REMOVED (KG/HA/YR)	N	P	K	S	CA	MG	NA
Leaching, runoff and direct losses	98	0.1	7	4	120	29	58
As product	244	83	438	25	9	12	16
Transfer	0	0	0	0	0	0	0
To atmosphere	50	0	0	0	0	0	0
As supplements and crop residues	49	8	134	13	18	8	14

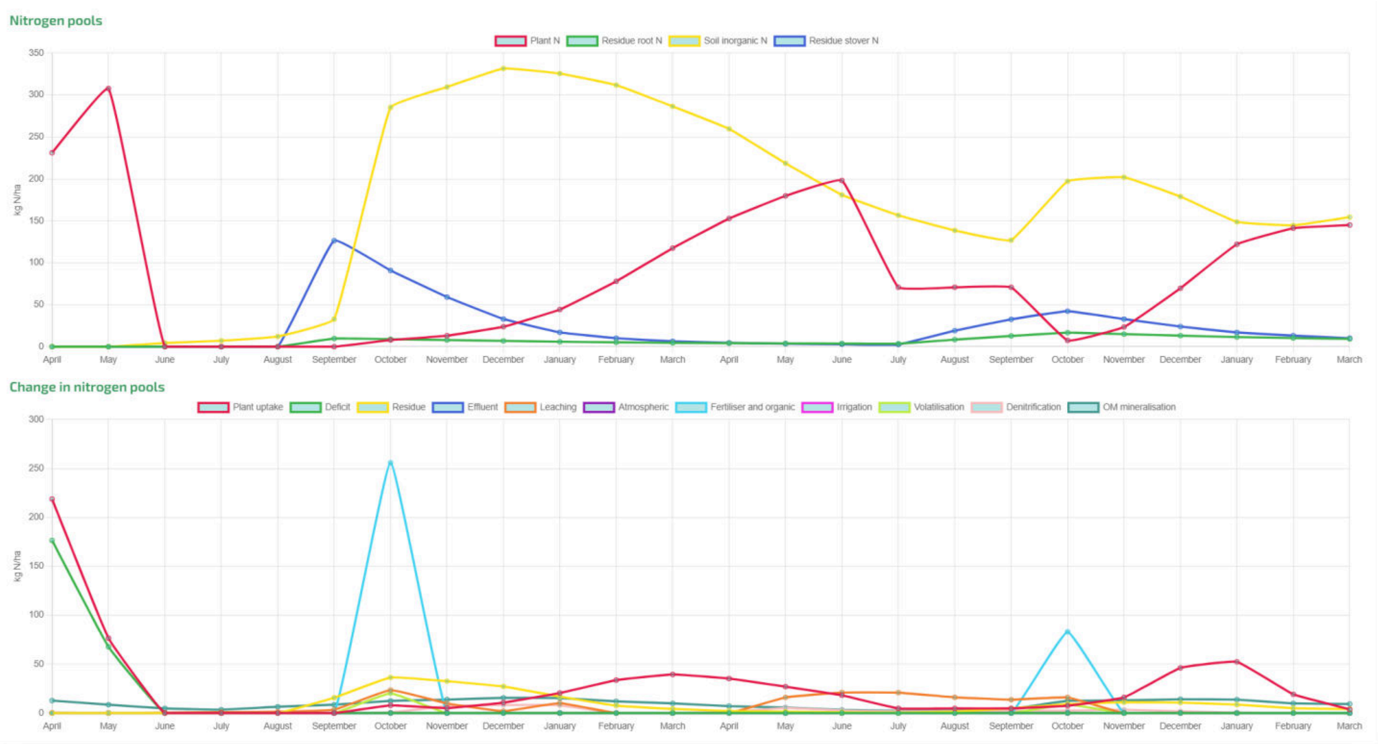
CHANGE IN POOLS (KG/HA/YR)	N	P	K	S	CA	MG	NA
Organic pool	-133	-10	0	-34	0	0	0
Standing plant material	-62	-22	-171	-6	-2	0	-4
Inorganic mineral	0	9	-26	0	-3	-2	-9
Inorganic soil pool	-71	-70	-381	0	-141	-43	-67
Root and stover residuals	8	3	0	1	0	0	0

Appendix 2 Ohakune Soil Pool Graphs

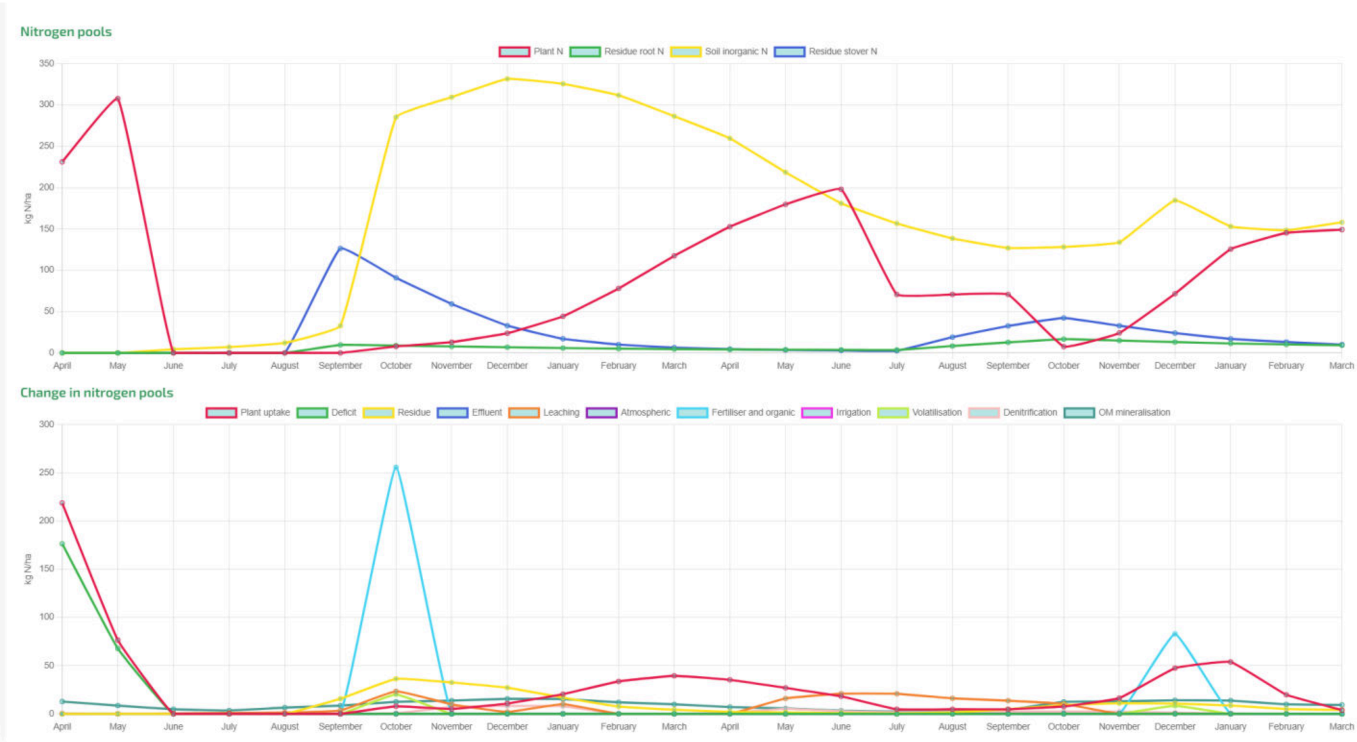
Ohakune Treatment1 Nitrogen Pool Graphs



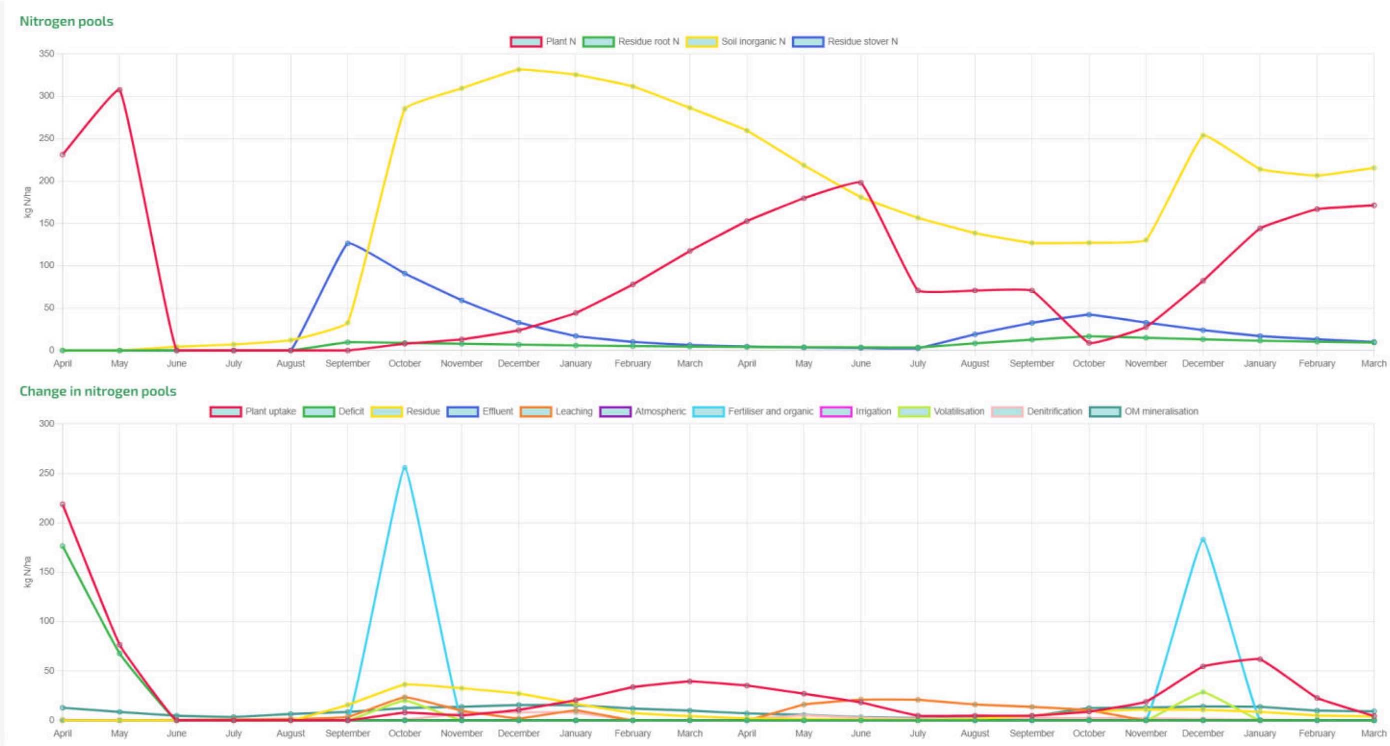
Ohakune Treatment 2 Nitrogen Pool Graphs



Ohakune Treatment 3 Nitrogen Pool Graphs



Ohakune Treatment 4 Nitrogen Pool Graphs



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Appendix 3: Block Nutrient Budgets - Cochise

Wairarapa Treatment 1 (Cochise) Block Nutrient Budget

LOSSES FROM ROOT ZONE

	TOTAL LOSS (KG/YR)	LOSS PER HA (KG/YR)
Nitrogen	39	5
Phosphorus	2	0.4

NUTRIENTS ADDED (KG/HA/YR)	N	P	K	S	CA	MG	NA
Effluent added	0	0	0	0	0	0	0
Fertiliser, lime and other	0	0	0	0	0	0	0
Irrigation	0	0	0	0	0	0	0
Supplements	0	0	0	0	0	0	0
Rain/clover fixation	2	0	2	4	2	4	18

NUTRIENTS REMOVED (KG/HA/YR)	N	P	K	S	CA	MG	NA
Leaching, runoff and direct losses	5	0.4	10	14.5	27	3	19.9
As product	84	27	29	6	3	7	1
Transfer	0	0	0	0	0	0	0
To atmosphere	0	0	0	0	0	0	0
As supplements and crop residues	43	7	116	11	16	7	12

CHANGE IN POOLS (KG/HA/YR)	N	P	K	S	CA	MG	NA
Organic pool	-160.4	-1.7	0	-22.7	0	0	0
Standing plant material	-194	-21	-204	-11	-20.9	-13.9	-8.8
Inorganic mineral	0	1.6	-8.9	0	-7.5	-12.1	-14
Inorganic soil pool	159.1	-21	92.9	0	-5.7	15.1	7.9
Root and stover residuals	65.4	8.2	-34	5.2	-9	-3	0

Wairarapa Treatment 2 (Cochise) Block Nutrient Budget

LOSSES FROM ROOT ZONE

	TOTAL LOSS (KG/YR)	LOSS PER HA (KG/YR)
Nitrogen	39	5
Phosphorus	2	0.4

NUTRIENTS ADDED (KG/HA/YR)	N	P	K	S	CA	MG	NA
Effluent added	0	0	0	0	0	0	0
Fertiliser, lime and other	24	0	0	0	0	0	0
Irrigation	0	0	0	0	0	0	0
Supplements	0	0	0	0	0	0	0
Rain/clover fixation	2	0	2	4	2	4	18

NUTRIENTS REMOVED (KG/HA/YR)	N	P	K	S	CA	MG	NA
Leaching, runoff and direct losses	5	0.4	10	10	27	3	19.9
As product	104	33	36	8	3	9	1
Transfer	0	0	0	0	0	0	0
To atmosphere	1.3	0	0	0	0	0	0
As supplements and crop residues	51	8	137	13	18	8	14

CHANGE IN POOLS (KG/HA/YR)	N	P	K	S	CA	MG	NA
Organic pool	-158.4	-1.7	0	-22.9	0	0	0
Standing plant material	-194	-21	-204	-11	-20.9	-13.9	-8.8
Inorganic mineral	0	1.6	-9.9	0	-7.5	-12.1	-14
Inorganic soil pool	149.8	-29.1	63.1	0	-8.7	12.1	4.9
Root and stover residuals	67.3	8.2	-31	6.2	-8.9	-2	1

Wairarapa Treatment 3 (Cochise) Block Nutrient Budget

LOSSES FROM ROOT ZONE

	TOTAL LOSS (KG/YR)	LOSS PER HA (KG/YR)
Nitrogen	39	5
Phosphorus	2	0.4

NUTRIENTS ADDED (KG/HA/YR)	N	P	K	S	CA	MG	NA
Effluent added	0	0	0	0	0	0	0
Fertiliser, lime and other	24	0	0	0	0	0	0
Irrigation	0	0	0	0	0	0	0
Supplements	0	0	0	0	0	0	0
Rain/clover fixation	2	0	2	4	2	4	18

NUTRIENTS REMOVED (KG/HA/YR)	N	P	K	S	CA	MG	NA
Leaching, runoff and direct losses	5	0.4	10	9.1	27	3	19.9
As product	111	35	38	8	4	10	1
Transfer	0	0	0	0	0	0	0
To atmosphere	1	0	0	0	0	0	0
As supplements and crop residues	53	8	143	14	19	8	15

CHANGE IN POOLS (KG/HA/YR)	N	P	K	S	CA	MG	NA
Organic pool	-159.4	-1.7	0	-23.1	0	0	0
Standing plant material	-194	-21	-204	-11	-20.9	-13.9	-8.8
Inorganic mineral	0	1.6	-10.8	0	-7.5	-12.1	-14
Inorganic soil pool	141	-31.8	54.8	0	-9.7	11.1	3.9
Root and stover residuals	68.4	8.2	-30	6.2	-8.7	-2	1

Wairarapa Treatment 4 (Cochise) Block Nutrient Budget

LOSSES FROM ROOT ZONE

	TOTAL LOSS (KG/YR)	LOSS PER HA (KG/YR)
Nitrogen	39	5
Phosphorus	2	0.4

NUTRIENTS ADDED (KG/HA/YR)	N	P	K	S	CA	MG	NA
Effluent added	0	0	0	0	0	0	0
Fertiliser, lime and other	104	0	0	0	0	0	0
Irrigation	0	0	0	0	0	0	0
Supplements	0	0	0	0	0	0	0
Rain/clover fixation	2	0	2	4	2	4	18

NUTRIENTS REMOVED (KG/HA/YR)	N	P	K	S	CA	MG	NA
Leaching, runoff and direct losses	5	0.4	10	8.3	27	3	19.9
As product	119	38	41	9	4	10	2
Transfer	0	0	0	0	0	0	0
To atmosphere	8.5	0	0	0	0	0	0
As supplements and crop residues	56	9	150	14	20	9	16

CHANGE IN POOLS (KG/HA/YR)	N	P	K	S	CA	MG	NA
Organic pool	-159.4	-1.8	0	-23.3	0	0	0
Standing plant material	-194	-21	-204	-11	-20.9	-13.9	-8.8
Inorganic mineral	0	1.6	-11.8	0	-7.5	-12.1	-14
Inorganic soil pool	202.4	-34.1	45.1	0	-11.7	10.1	2.9
Root and stover residuals	69.6	8.4	-29	6.2	-8	-2	1

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Appendix 4: Block Nutrient Budgets - Conquest

Wairarapa Treatment 1 (Conquest) Block Nutrient Budget

LOSSES FROM ROOT ZONE

	TOTAL LOSS (KG/YR)	LOSS PER HA (KG/YR)
Nitrogen	39	5
Phosphorus	2	0.4

NUTRIENTS ADDED (KG/HA/YR)	N	P	K	S	CA	MG	NA
Effluent added	0	0	0	0	0	0	0
Fertiliser, lime and other	0	0	0	0	0	0	0
Irrigation	0	0	0	0	0	0	0
Supplements	0	0	0	0	0	0	0
Rain/clover fixation	2	0	2	4	2	4	18

NUTRIENTS REMOVED (KG/HA/YR)	N	P	K	S	CA	MG	NA
Leaching, runoff and direct losses	5	0.4	10	14.5	27	3	19.9
As product	84	27	29	6	3	7	1
Transfer	0	0	0	0	0	0	0
To atmosphere	0	0	0	0	0	0	0
As supplements and crop residues	43	7	116	11	16	7	12

CHANGE IN POOLS (KG/HA/YR)	N	P	K	S	CA	MG	NA
Organic pool	-160.4	-1.7	0	-22.7	0	0	0
Standing plant material	-194	-21	-204	-11	-20.9	-13.9	-8.8
Inorganic mineral	0	1.6	-8.9	0	-7.5	-12.1	-14
Inorganic soil pool	159.1	-21	92.9	0	-5.7	15.1	7.9
Root and stover residuals	65.4	8.2	-34	5.2	-9	-3	0

Wairarapa Treatment 2 (Conquest) Block Nutrient Budget

LOSSES FROM ROOT ZONE

	TOTAL LOSS (KG/YR)	LOSS PER HA (KG/YR)
Nitrogen	39	5
Phosphorus	2	0.4

NUTRIENTS ADDED (KG/HA/YR)	N	P	K	S	CA	MG	NA
Effluent added	0	0	0	0	0	0	0
Fertiliser, lime and other	31	0	0	0	0	0	0
Irrigation	0	0	0	0	0	0	0
Supplements	0	0	0	0	0	0	0
Rain/clover fixation	2	0	2	4	2	4	18

NUTRIENTS REMOVED (KG/HA/YR)	N	P	K	S	CA	MG	NA
Leaching, runoff and direct losses	5	0.4	10	10	27	3	19.9
As product	104	33	36	8	3	9	1
Transfer	0	0	0	0	0	0	0
To atmosphere	2	0	0	0	0	0	0
As supplements and crop residues	51	8	137	13	18	8	14

CHANGE IN POOLS (KG/HA/YR)	N	P	K	S	CA	MG	NA
Organic pool	-157.5	-1.7	0	-22.9	0	0	0
Standing plant material	-194	-21	-204	-11	-20.9	-13.9	-8.8
Inorganic mineral	0	1.6	-9.9	0	-7.5	-12.1	-14
Inorganic soil pool	156.1	-29.1	63.1	0	-8.7	12.1	4.9
Root and stover residuals	67.3	8.2	-31	6.2	-8.9	-2	1

Wairarapa Treatment 3 (Conquest) Block Nutrient Budget

LOSSES FROM ROOT ZONE

	TOTAL LOSS (KG/YR)	LOSS PER HA (KG/YR)
Nitrogen	39	5
Phosphorus	2	0.4

NUTRIENTS ADDED (KG/HA/YR)	N	P	K	S	CA	MG	NA
Effluent added	0	0	0	0	0	0	0
Fertiliser, lime and other	31	0	0	0	0	0	0
Irrigation	0	0	0	0	0	0	0
Supplements	0	0	0	0	0	0	0
Rain/clover fixation	2	0	2	4	2	4	18

NUTRIENTS REMOVED (KG/HA/YR)	N	P	K	S	CA	MG	NA
Leaching, runoff and direct losses	5	0.4	10	9.1	27	3	19.9
As product	111	35	38	8	4	10	1
Transfer	0	0	0	0	0	0	0
To atmosphere	2	0	0	0	0	0	0
As supplements and crop residues	53	8	143	14	19	8	15

CHANGE IN POOLS (KG/HA/YR)	N	P	K	S	CA	MG	NA
Organic pool	-159.4	-1.7	0	-23.1	0	0	0
Standing plant material	-194	-21	-204	-11	-20.9	-13.9	-8.8
Inorganic mineral	0	1.6	-10.8	0	-7.5	-12.1	-14
Inorganic soil pool	147.8	-31.8	54.8	0	-9.7	11.1	3.9
Root and stover residuals	68.4	8.2	-30	6.2	-8.7	-2	1

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Wairarapa Treatment 4 (Conquest) Block Nutrient Budget

LOSSES FROM ROOT ZONE

	TOTAL LOSS (KG/YR)	LOSS PER HA (KG/YR)
Nitrogen	39	5
Phosphorus	2	0.4

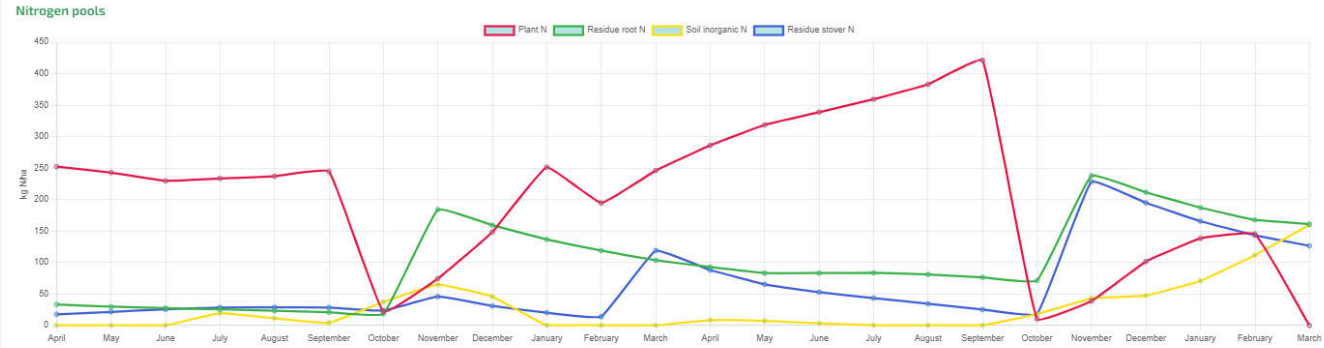
NUTRIENTS ADDED (KG/HA/YR)	N	P	K	S	CA	MG	NA
Effluent added	0	0	0	0	0	0	0
Fertiliser, lime and other	111	0	0	0	0	0	0
Irrigation	0	0	0	0	0	0	0
Supplements	0	0	0	0	0	0	0
Rain/clover fixation	2	0	2	4	2	4	18

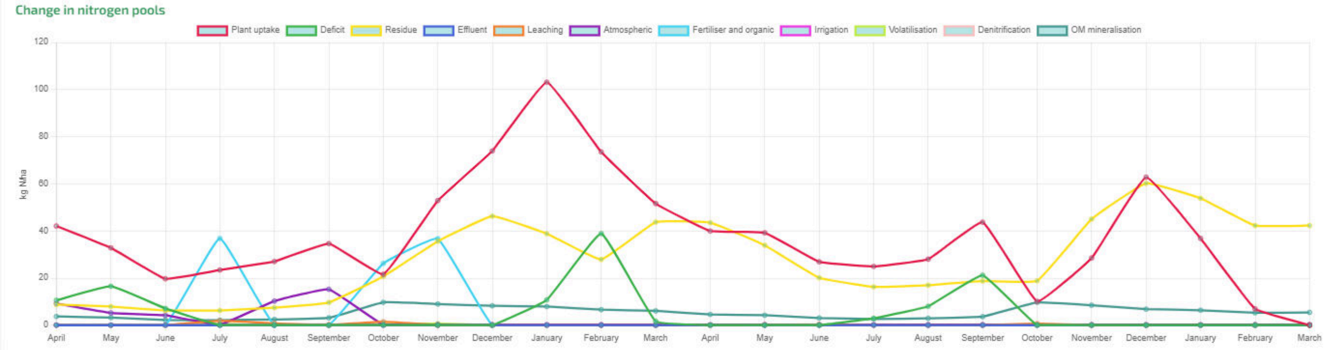
NUTRIENTS REMOVED (KG/HA/YR)	N	P	K	S	CA	MG	NA
Leaching, runoff and direct losses	5	0.4	10	8.3	27	3	19.9
As product	119	38	41	9	4	10	2
Transfer	0	0	0	0	0	0	0
To atmosphere	9.4	0	0	0	0	0	0
As supplements and crop residues	56	9	150	14	20	9	16

CHANGE IN POOLS (KG/HA/YR)	N	P	K	S	CA	MG	NA
Organic pool	-159.4	-2	0	-23.3	0	0	0
Standing plant material	-194	-21	-204	-11	-20.9	-13.9	-8.8
Inorganic mineral	0	1.6	-11.8	0	-7.5	-12.1	-14
Inorganic soil pool	208.4	-34.1	45.1	0	-11.7	10.1	2.9
Root and stover residuals	69.6	8.4	-29	6.2	-8	-2	1

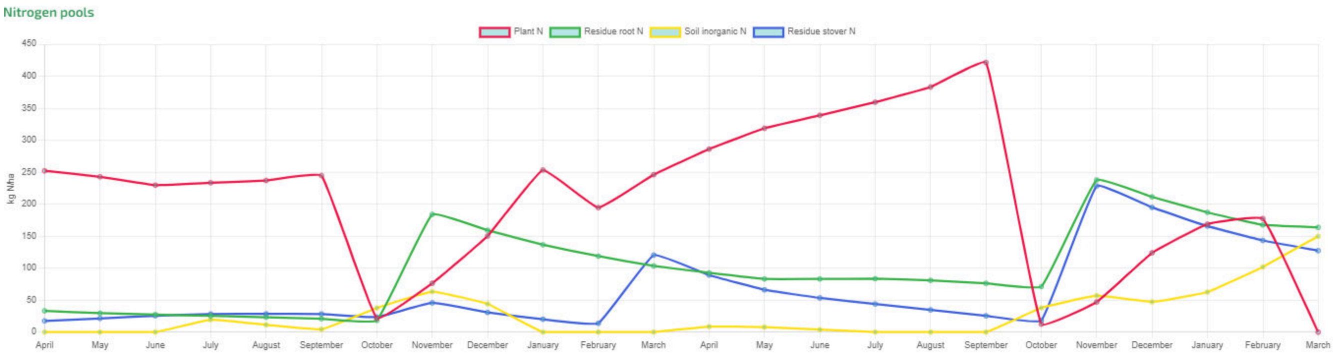
Appendix 5 - Nitrogen Pool Graphs Wairarapa – Cochise Treatments

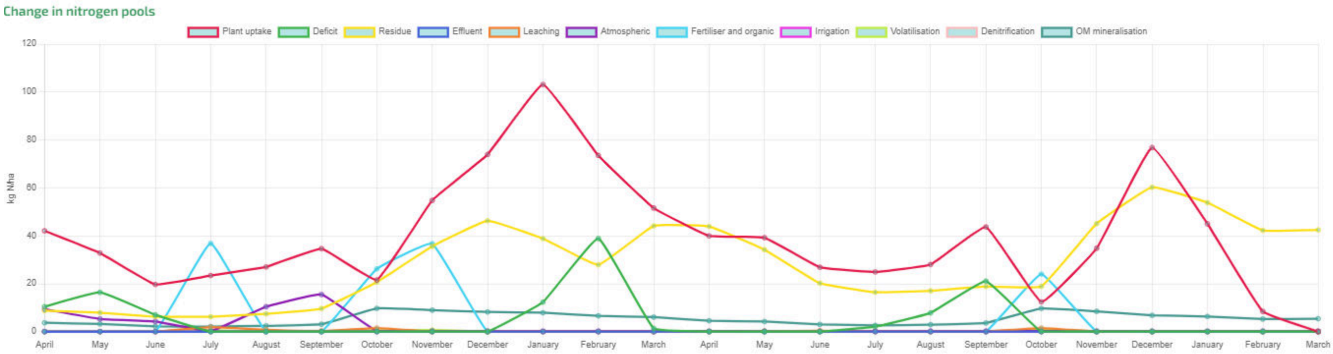
Wairarapa Treatment (Cochise) 1 Nitrogen Pool Graphs





Wairarapa Treatment (Cochise) 2 Nitrogen Pool Graphs





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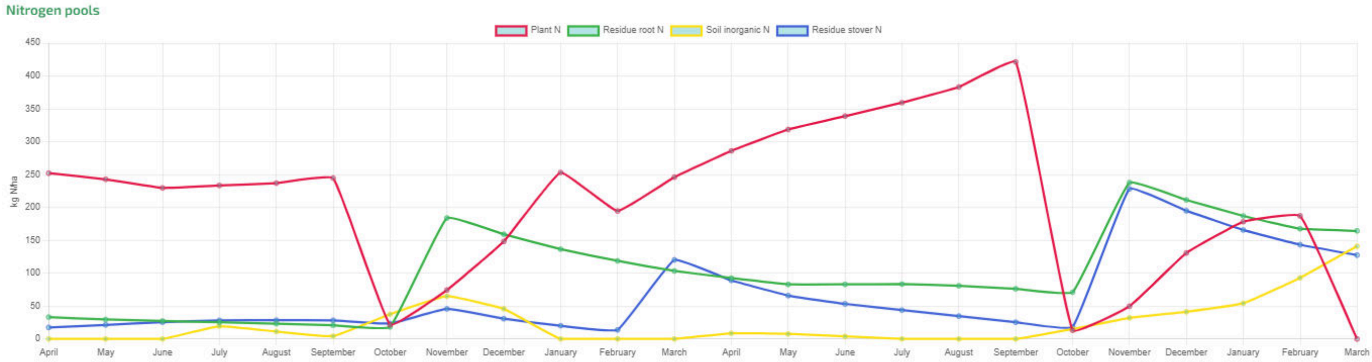
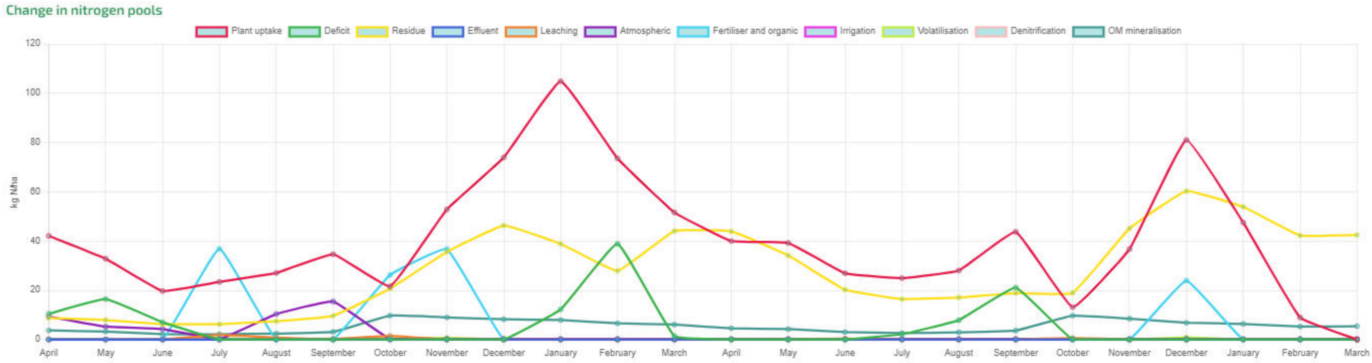
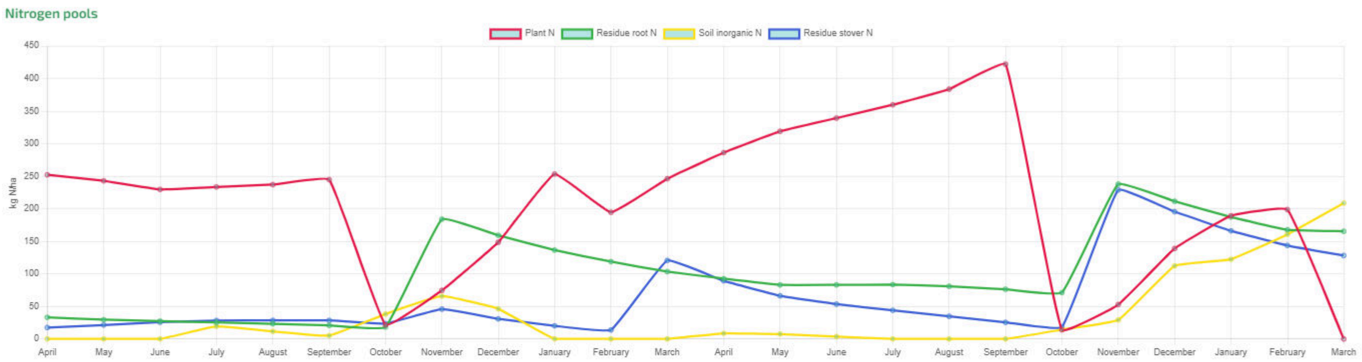
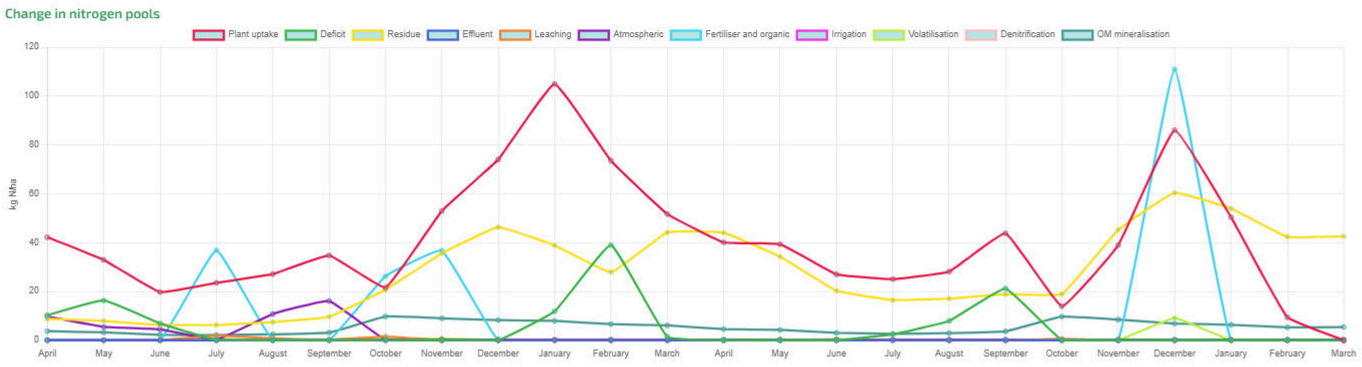
Wairarapa Treatment (Cochise) 3 Nitrogen Pool Graphs





Wairarapa Treatment (Cochise) 4 Nitrogen Pool Graphs





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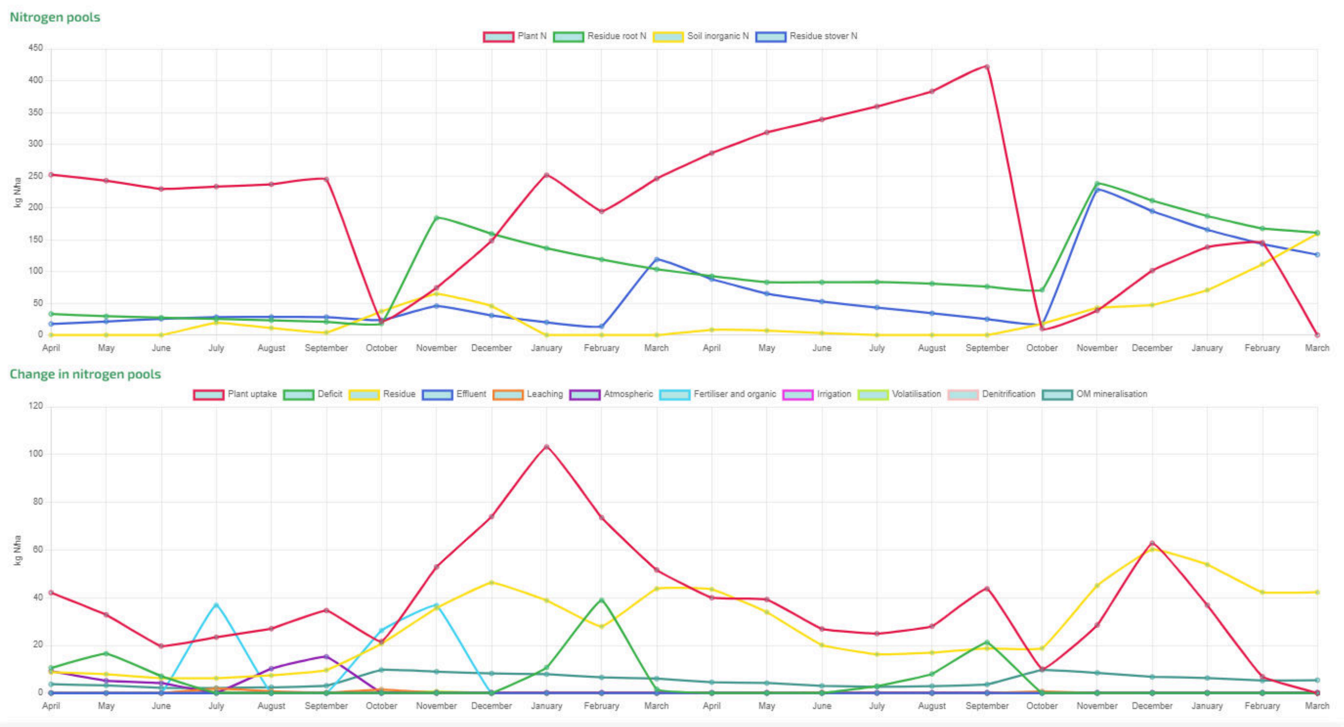
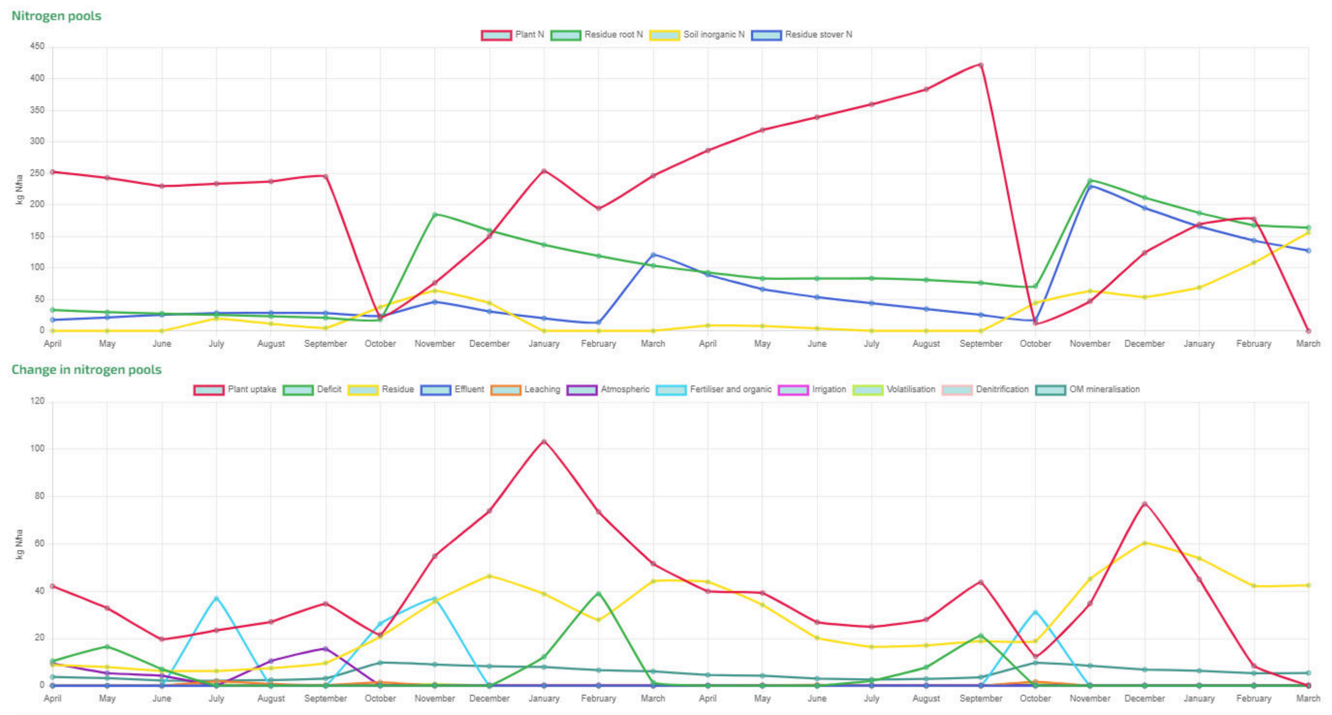
Appendix 6 Nitrogen Pool Graphs Wairarapa – Conquest Treatments

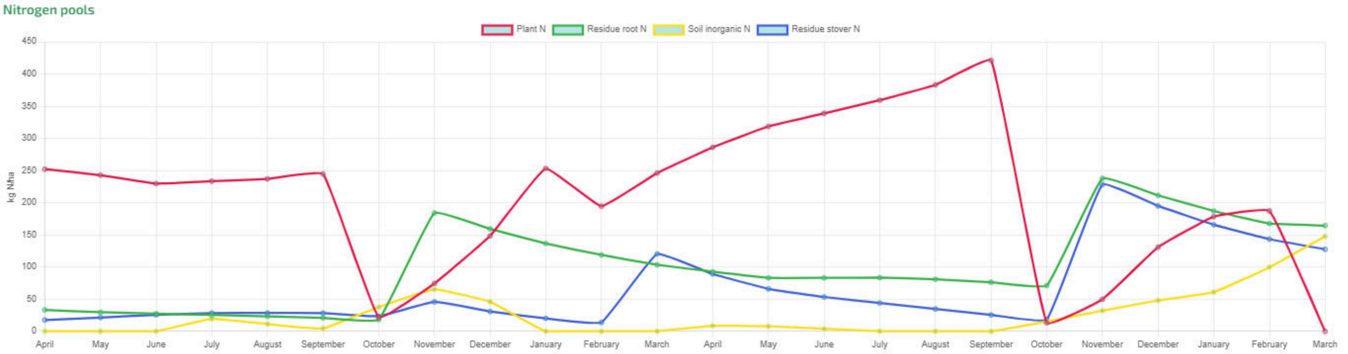
Wairarapa Treatment 1 (Conquest) Nitrogen Pool Graphs

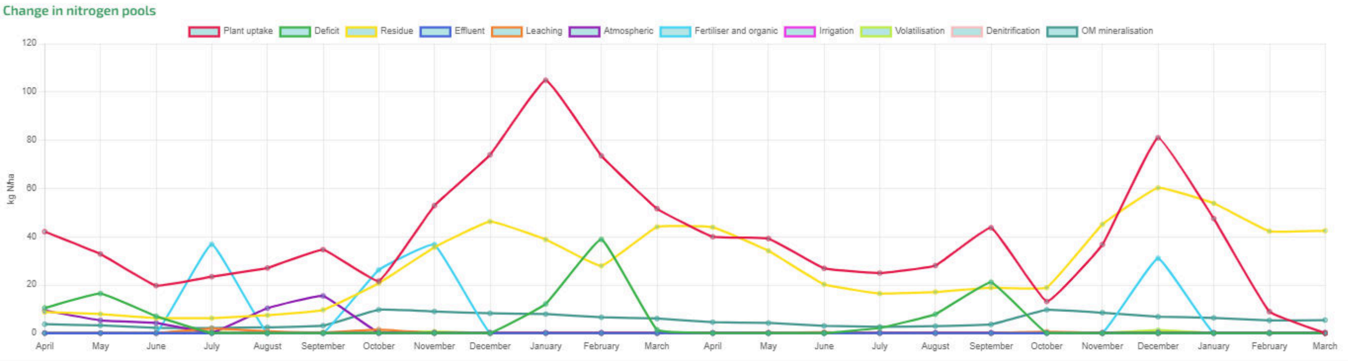


Wairarapa Treatment 2 (Conquest) Nitrogen Pool Graphs

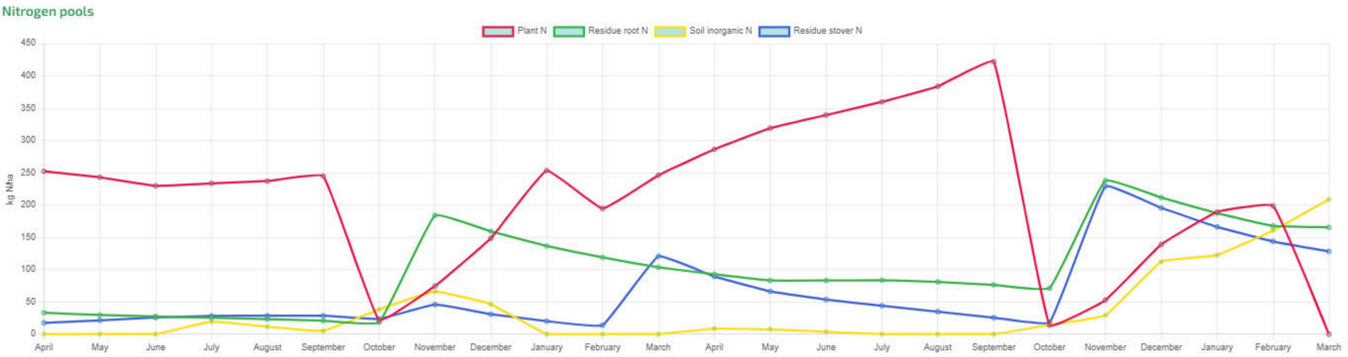


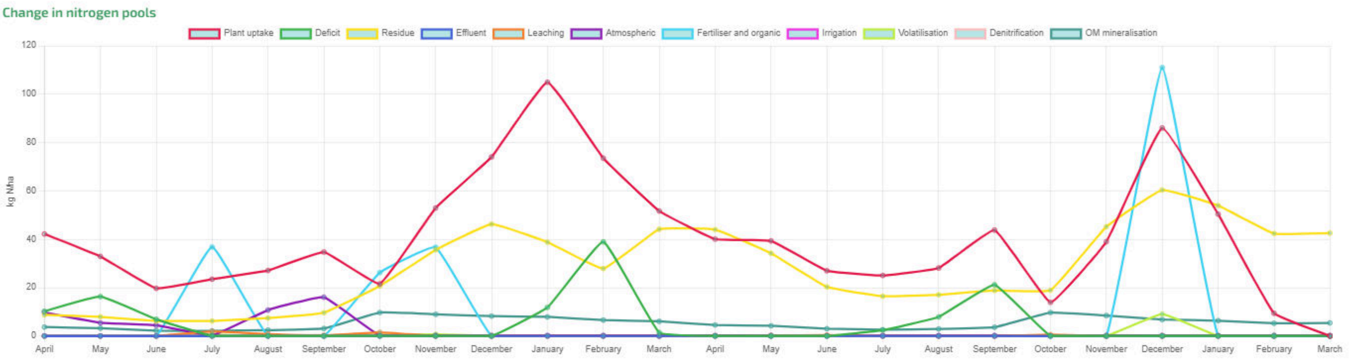
Wairarapa Treatment 3 (Conquest) Nitrogen Pool Graphs





Wairarapa Treatment 4 (Conquest) Nitrogen Pool Graphs





Appendix 7 Waikato Block Nutrient Budgets

Waikato Treatment 1 Block Nutrient Budget

LOSSES FROM ROOT ZONE

	TOTAL LOSS (KG/YR)	LOSS PER HA (KG/YR)
Nitrogen	839	54.1
Phosphorus	3	0.2

NUTRIENTS ADDED (KG/HA/YR)	N	P	K	S	CA	MG	NA
Effluent added	0	0	0	0	0	0	0
Fertiliser, lime and other	0	0	0	0	0	0	0
Irrigation	0	0	0	0	0	0	0
Supplements	0	0	0	0	0	0	0
Rain/clover fixation	41.4	0	1	3	1	3	8

NUTRIENTS REMOVED (KG/HA/YR)	N	P	K	S	CA	MG	NA
Leaching, runoff and direct losses	54.1	0.2	6.8	35.2	83.3	24.4	48.1
As product	174	49	56	12	14	12	5
Transfer	13.6	-1	12	-1	3	0	0
To atmosphere	68	0	0	0	0	0	0
As supplements and crop residues	59	9	159	15	21	9	17

CHANGE IN POOLS (KG/HA/YR)	N	P	K	S	CA	MG	NA
Organic pool	-554.3	-41.2	0	-65.2	0	0	0
Standing plant material	68.8	6.7	41.2	3	15.3	3.7	1
Inorganic mineral	0	3.1	-30.1	0	-4.2	-2.8	-11.9
Inorganic soil pool	160	-27	-240.3	0	-129.4	-43.7	-50.3
Root and stover residuals	-1.3	0	-3.6	3	-1.7	0	0.3

Waikato Treatment 2 Block Nutrient Budget

LOSSES FROM ROOT ZONE

	TOTAL LOSS (KG/YR)	LOSS PER HA (KG/YR)
Nitrogen	915	58.8
Phosphorus	3	0.2

NUTRIENTS ADDED (KG/HA/YR)	N	P	K	S	CA	MG	NA
Effluent added	0	0	0	0	0	0	0
Fertiliser, lime and other	24	0	0	0	0	0	0
Irrigation	0	0	0	0	0	0	0
Supplements	0	0	0	0	0	0	0
Rain/clover fixation	42	0	1	3	1	3	8

NUTRIENTS REMOVED (KG/HA/YR)	N	P	K	S	CA	MG	NA
Leaching, runoff and direct losses	58.8	0.2	6.8	35.2	87.5	24.4	48.1
As product	173.6	49	56	12	13.6	12	5
Transfer	13	-1	12	-1	3	0	0
To atmosphere	71.5	0	0	0	0	0	0
As supplements and crop residues	59	9	159	15	21	9	17

CHANGE IN POOLS (KG/HA/YR)	N	P	K	S	CA	MG	NA
Organic pool	-552.9	-41.2	0	-65.2	0	0	0
Standing plant material	68.8	6.7	41.2	3	15.3	3.7	1
Inorganic mineral	0	3.1	-30.1	0	-4.2	-2.8	-11.9
Inorganic soil pool	175.8	-27	-240	0	-133.6	-43.7	-50.3
Root and stover residuals	-1.9	0	-3.6	3	-1.7	0	0.3

Waikato Treatment 3 Block Nutrient Budget

	TOTAL LOSS (KG/YR)	LOSS PER HA (KG/YR)
Nitrogen	899	57.8
Phosphorus	3	0.2

NUTRIENTS ADDED (KG/HA/YR)	N	P	K	S	CA	MG	NA
Effluent added	0	0	0	0	0	0	0
Fertiliser, lime and other	24	0	0	0	0	0	0
Irrigation	0	0	0	0	0	0	0
Supplements	0	0	0	0	0	0	0
Rain/clover fixation	42	0	1	3	1	3	8

NUTRIENTS REMOVED (KG/HA/YR)	N	P	K	S	CA	MG	NA
Leaching, runoff and direct losses	57.8	0.2	6.8	35.2	86.9	24.4	48.1
As product	173.6	49	56	12	13.6	12	5
Transfer	13	-1	12	-1	3	0	0
To atmosphere	70.6	0	0	0	0	0	0
As supplements and crop residues	59	9	159	15	21	9	17

CHANGE IN POOLS (KG/HA/YR)	N	P	K	S	CA	MG	NA
Organic pool	-553.3	-41.2	0	-65.2	0	0	0
Standing plant material	68.8	6.7	41.2	3	15.3	3.7	1
Inorganic mineral	0	3.1	-30.1	0	-4.2	-2.8	-11.9
Inorganic soil pool	177.8	-27	-240	0	-132.9	-43.7	-50.3
Root and stover residuals	-1.9	0	-3.6	3	-1.7	0	0.3

Waikato Treatment 4 Block Nutrient Budget

LOSSES FROM ROOT ZONE

	TOTAL LOSS (KG/YR)	LOSS PER HA (KG/YR)
Nitrogen	1,077	69.3
Phosphorus	3	0.2

NUTRIENTS ADDED (KG/HA/YR)	N	P	K	S	CA	MG	NA
Effluent added	0	0	0	0	0	0	0
Fertiliser, lime and other	104	0	0	0	0	0	0
Irrigation	0	0	0	0	0	0	0
Supplements	0	0	0	0	0	0	0
Rain/clover fixation	43.4	0	1	3	1	3	8

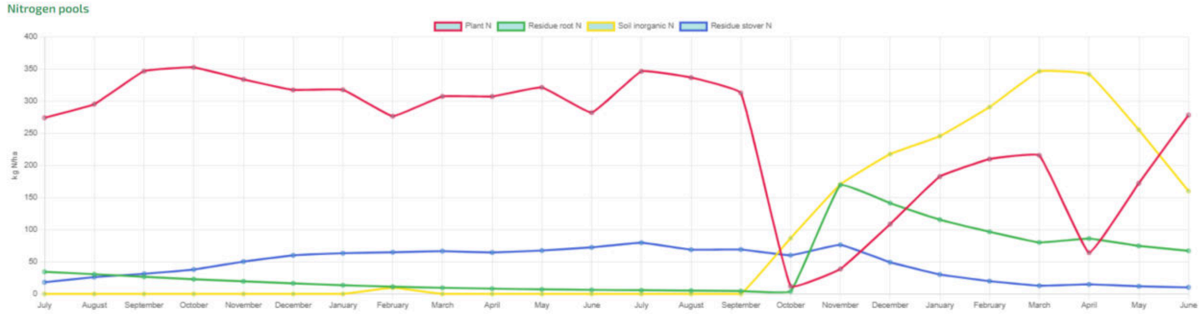
NUTRIENTS REMOVED (KG/HA/YR)	N	P	K	S	CA	MG	NA
Leaching, runoff and direct losses	69.3	0.2	6.8	35.2	95.7	24.4	48.1
As product	172.6	49	55	12	13	12	5
Transfer	13	-1	11	-1	3	0	0
To atmosphere	85.1	0	0	0	0	0	0
As supplements and crop residues	59	9	159	15	21	9	17

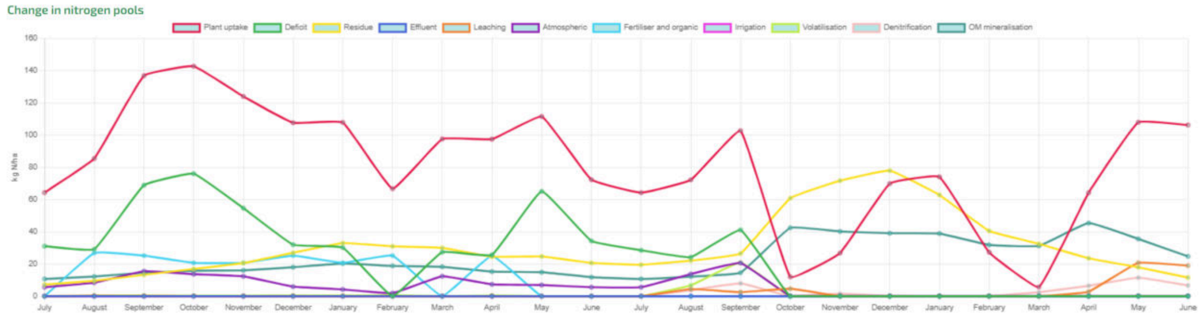
CHANGE IN POOLS (KG/HA/YR)	N	P	K	S	CA	MG	NA
Organic pool	-548.2	-41.2	0	-65.2	0	0	0
Standing plant material	68.8	6.7	41.2	3	15.3	3.7	1
Inorganic mineral	0	3.1	-30.1	0	-4.2	-2.8	-11.9
Inorganic soil pool	230.6	-27	-239	0	-140.9	-43.7	-50.3
Root and stover residuals	-2.2	0	-3.6	3	-1.7	0	0.3

Leftfield Innovation Limited

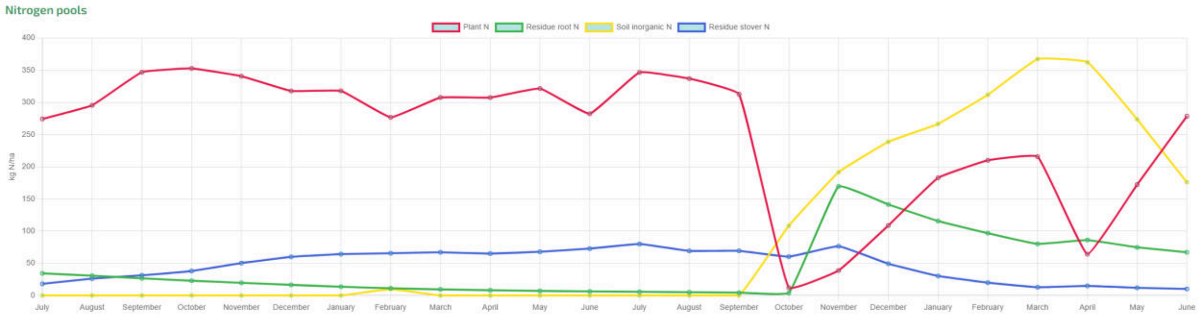
Appendix 8 Waikato Block Nitrogen Pool Graphs

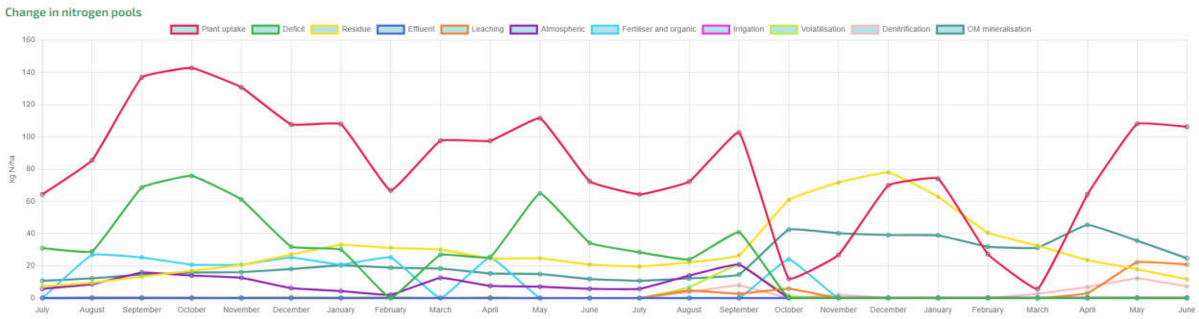
Waikato Treatment 1 Nitrogen Pool Graphs



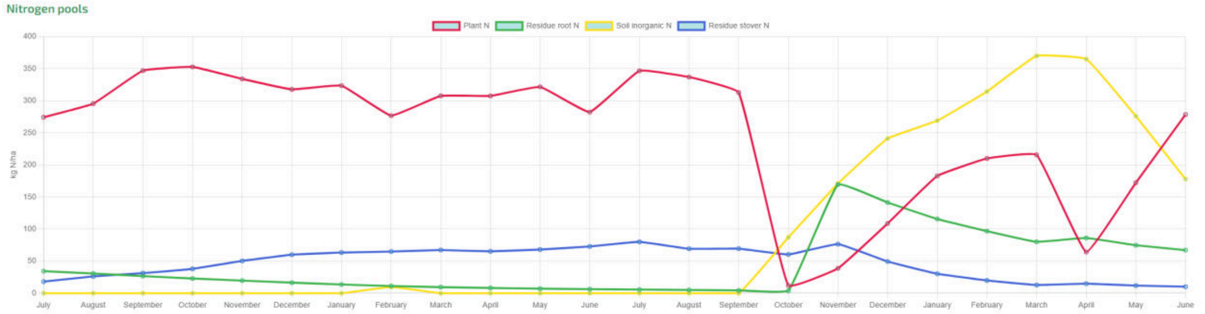


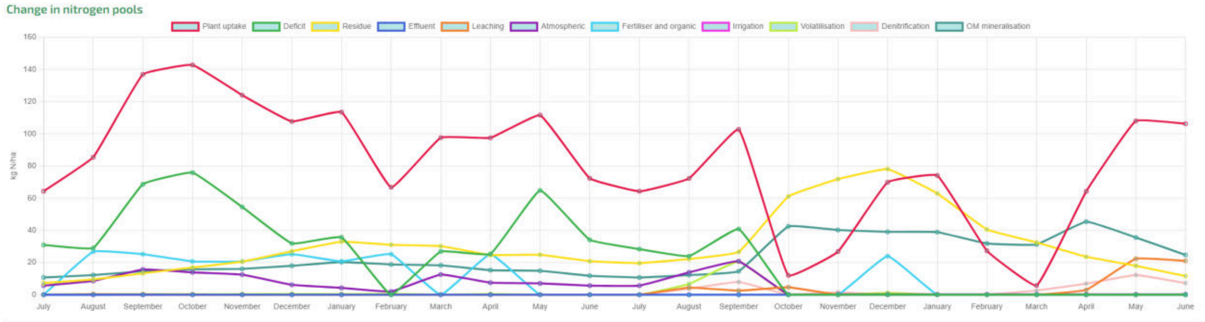
Waikato Treatment 2 Nitrogen Pool Graphs





Waikato Treatment 3 Nitrogen Pool Graphs





Waikato Treatment 4 Nitrogen Pool Graphs