SEPWA & RCSN – R & D Project

Investigation of nitrogen dynamics in controlled traffic farming systems.

GRDC ID : SEP 00013

Season 2014

Contents

Executive summary

This project undertook a relatively simple trial design to test the concept of variations in crop nitrogen dynamics in relation to soil compaction during the 2014 season. The trial design was replicated at 3 sites: high rainfall sandplain soils (Perks); medium rainfall mallee soil (Egan); and low rainfall mallee soil (Vermeersch). Each site showed a significant loss of crop biomass and grain yield due to the simulated compacted 'trafficked zone" as well as in the adjacent 'paddock zone' when compared to the zone of 'zero traffic' adjacent to the power pole. Given that this yield was achieved from the same nitrogen application as the adjacent plots this does demonstrate a greater nitrogen efficiency in the non compacted soil area.

While all sites did have increased grain yield without apparent protein dilution there was no consistent pattern in nitrogen dynamics detected from the N rich strips, biomass cuts, tissue tests or grain protein sampling. This is more than likely due to dry seasonal conditions in the mallee soil sites particularly in the July/August period. At the higher rainfall site some variation in N response was noted from the N rich strips, however it is difficult to be definitive from a single site and single season assessment. As a result the nitrogen efficiency advantages of lower levels of soil compaction were not able to be clearly defined.

From the yield increases demonstrated in this trial combined with anecdotal evidence it is more than likely nitrogen efficiency gains would be present in the less compacted soils of controlled traffic farming (CTF) systems along with yield gains. Feedback from SEPWA executive has indicated that this trial does show interesting results, yet they are not of a farm scale which would accurately display the overall economic benefits of CTF.

This project has clearly demonstrated the potential yield advantage of having no historical compaction of machinery on a soil. All sites had significant yield increases from not only the deliberately trafficked zone, but also the paddock area assessments immediately adjacent. While yield benefits of the zero traffic areas are stark, it needs to be remembered that the majority of a paddock has been trafficked with machinery at some stage of its history. As a result the possible 18% to 46% yield increases of the zero traffic zones over the paddock assessments are not necessarily obtainable in the near future.

This clearly indicates that sub soil compaction and subsequent loss in crop yield is a real factor of modern mechanised grain farming across multiple soil types and rainfall zones. Before we consider trying to ameliorate this soil damage caused from previous traffic, we must first confine machine tyres to tram lines to limit further damage. Once this is in place, then further investigation can commence on how we might de-compact historic damage and access the yield advantages highlighted here as well as possible fertilizer efficiency gains.

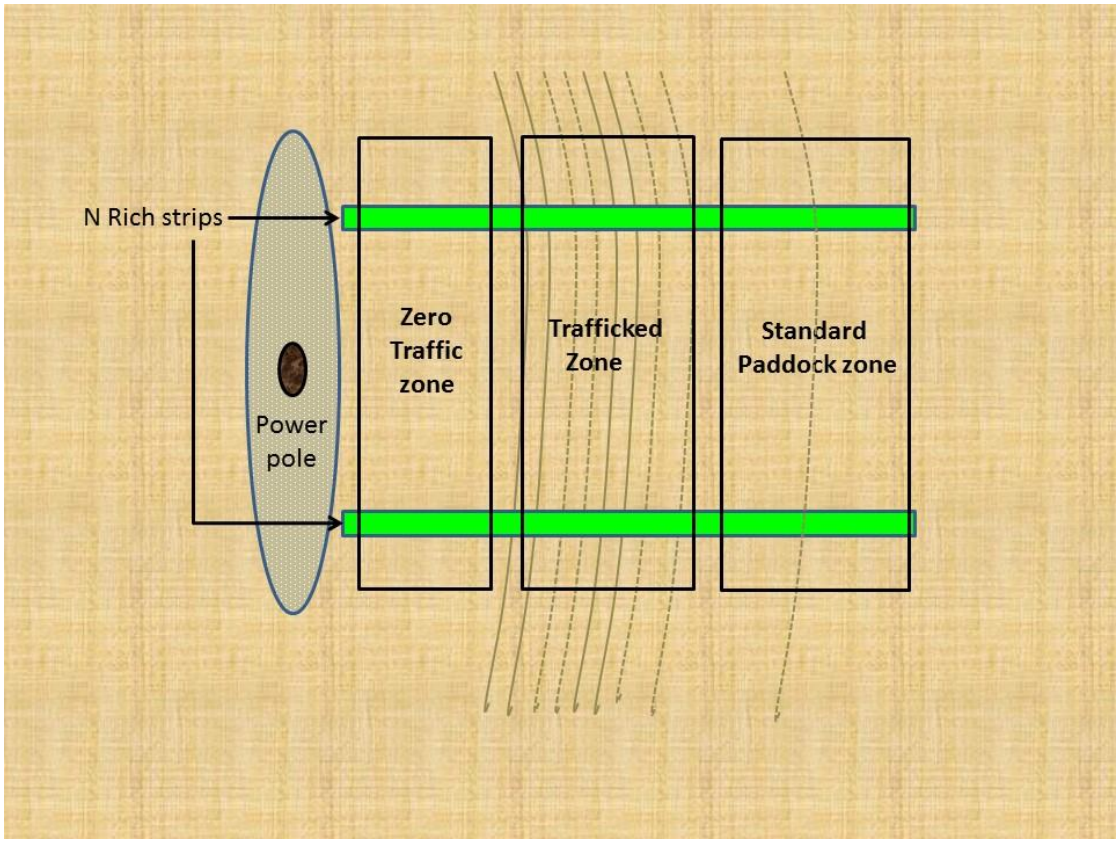
Background

This project has come from initial work by Quenten Knight (Precision Agronomics Australia (PAA), Esperance) which indicated that there may be efficiency gains in nitrogen utilisation due to less compaction in controlled traffic farming (CTF) systems. As per request from Grains Research and Development Corporation (GRDC), South East Premium Wheat Growers' Association (SEPWA) designed field trials that were aimed at better understanding the influence of CTF on nitrogen-cycling and soil compaction across soil types and rainfall zones in the Esperance Port Zone (EPZ).

This Project was funded by GRDC's Esperance region RCSN investment with additional funding for soil testing from the GRDC funded Controlled Traffic Farming research headed by Paul Blackwell DAFWA Geraldton.

Research Methodology

A simple trial design was developed which involved the selection of a place in the paddock which has had the traffic "controlled" by an immovable feature for a number of years. A power pole was chosen for this as it is a non-crop effecting obstacle compared to other objects such as a road or tree. The permanent nature of the power pole means that the passing traffic of machinery has been "controlled" by the need to go around the obstacle. This micro area of "zero traffic" soil was compared to soil immediately adjacent which was simulated for compaction or "trafficked" prior to seeding of the 2014 cereal crop. This was then compared to the standard part of the paddock beyond.



The CTF simulation trial design used by SEPWA during the 2014 season

There were 3 trial sites implemented during the 2014 growing season:

- High rainfall sandplain – Perks, Condingup
- Medium rainfall mallee – Egan, Mt Ridley
- Low rainfall mallee – Vermeersch, Cascade

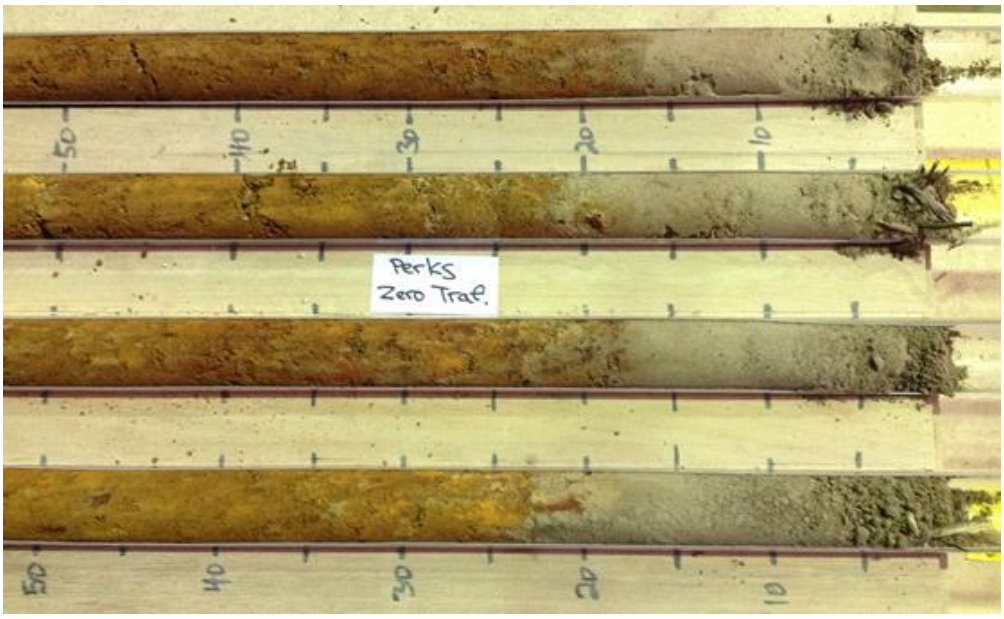
Base line soil testing

Prior to crop sowing, each site was deep cored and soil tested in the “zero traffic”, “trafficked” and “standard paddock” zones. The purpose of this base line soil testing was to test if there were any background soil anomalies in soil fertility between the zones within the trial area or each site. The sampling methodology was 4 soil cores per site with 2 cores being composited into 2 separate soil tests. The profiles were split into 3 sampling depths: 0 to 10cm, 10 to 30cm and 30 to 50 cm. Soil was cored after the simulated compaction in the “trafficked zone”. The following is a site by site assessment of the soil cores and test results.

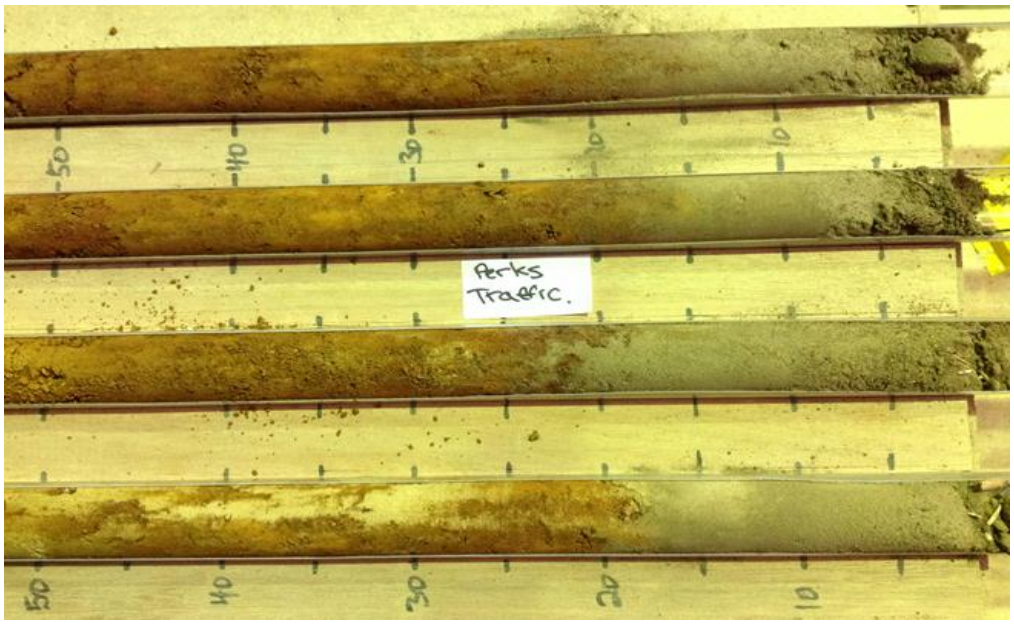
Perks Site – High Rainfall Sandplain

This site appears reasonably consistent across the 3 assessment areas. There is a lower level of phosphorus recorded in the paddock area (16 PPM) compared to that of the Zero traffic and trafficked area of 29.5 and 30 PPM. Although notably different, it is above 12 PPM which is considered a minimal threshold for P levels in HR sandplain soils.

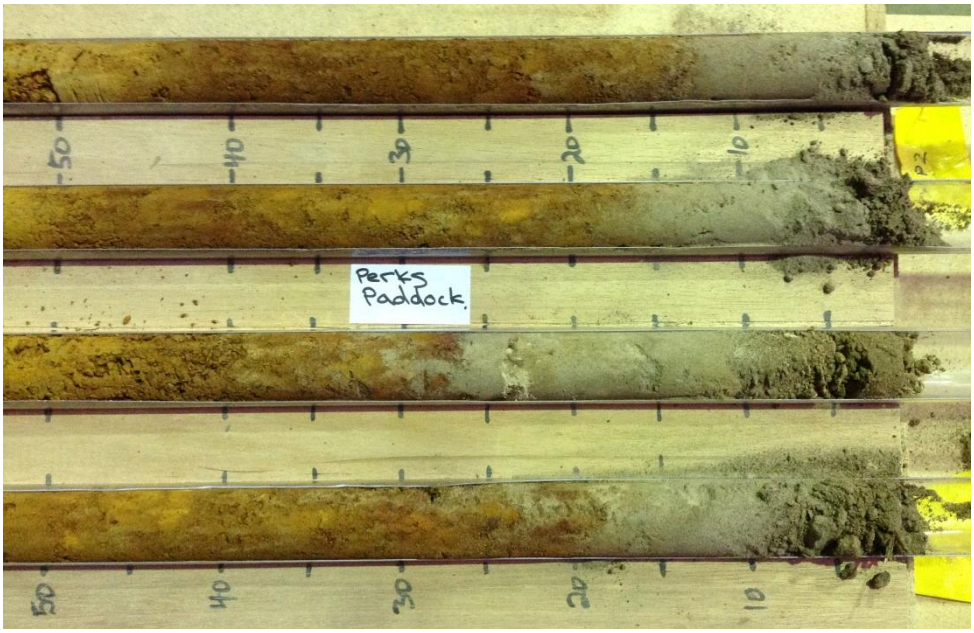
Perks - Soil core photos



Perks – Zero Traffic Zone



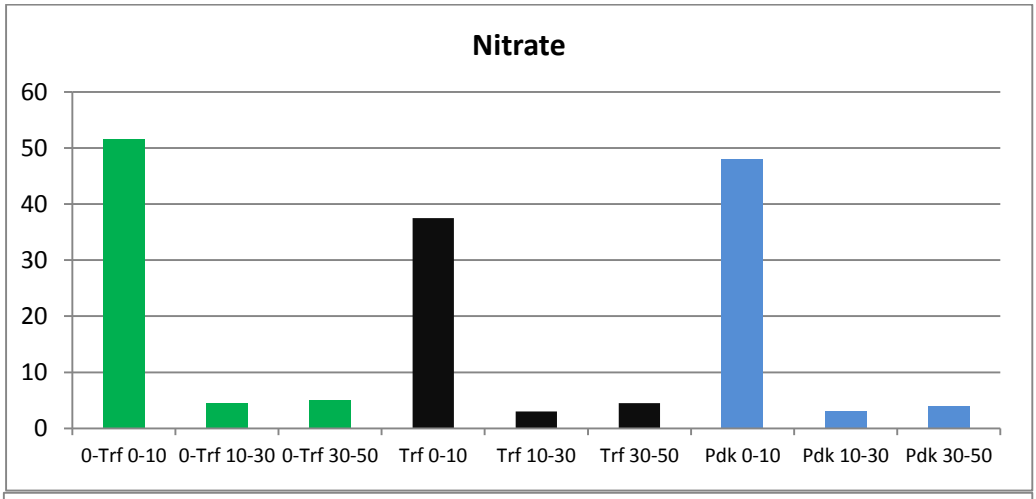
Perks – Trafficked Zone

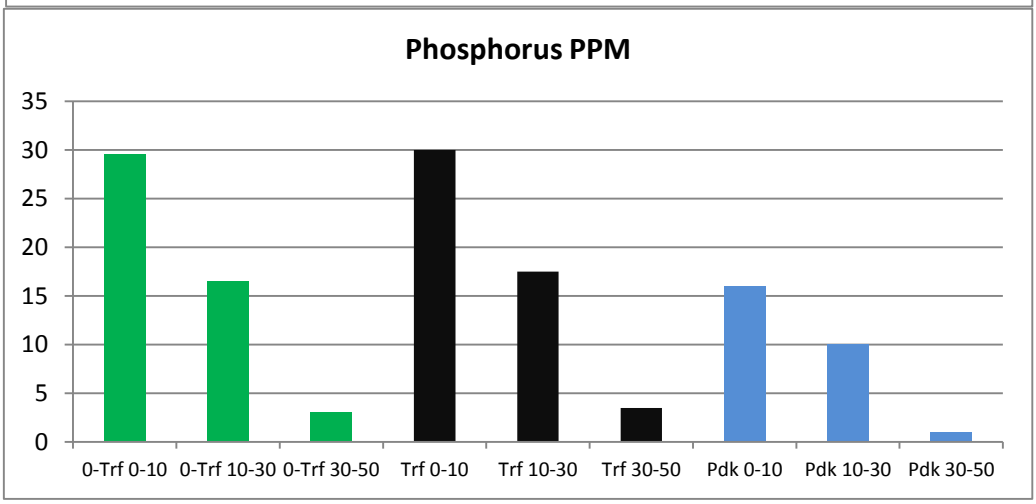


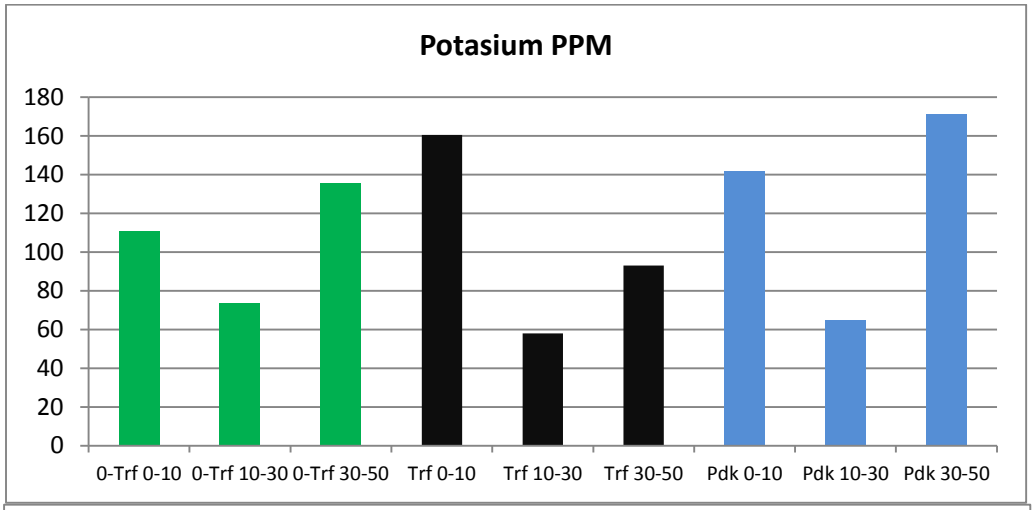
Perks – Paddock Zone

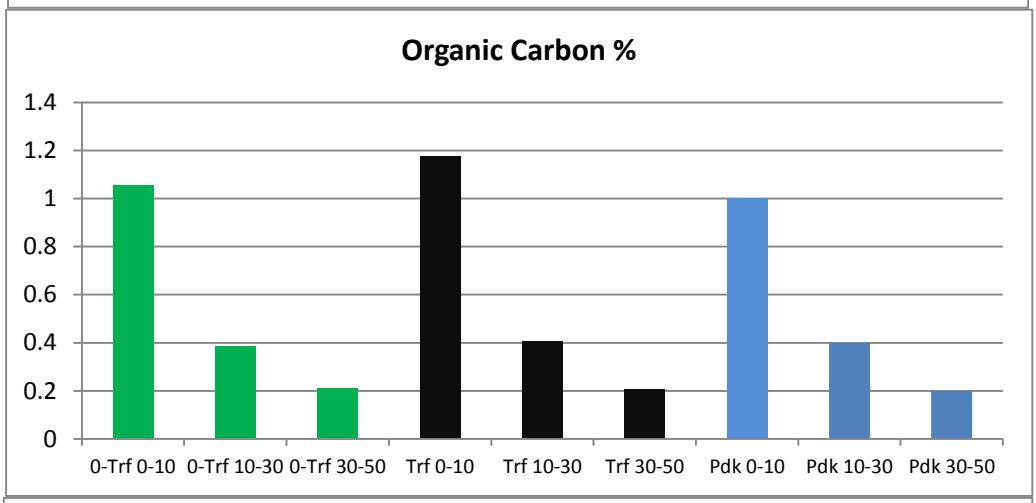
Perks Soil Chemistry results:

Green = Zero Traffic, **Black** = Trafficked and **Blue** = Paddock Zones






Potasium PPM
180
160
140
120
100
80
60
40
20
0
0-Trf 0-10
0-Trf 10-30
0-Trf 30-50
Trf 0-10
Trf 10-30
Trf 30-50
Pdk 0-10
Pdk 10-30
Pdk 30-50


Organic Carbon %
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0-Trf 0-10
0-Trf 10-30
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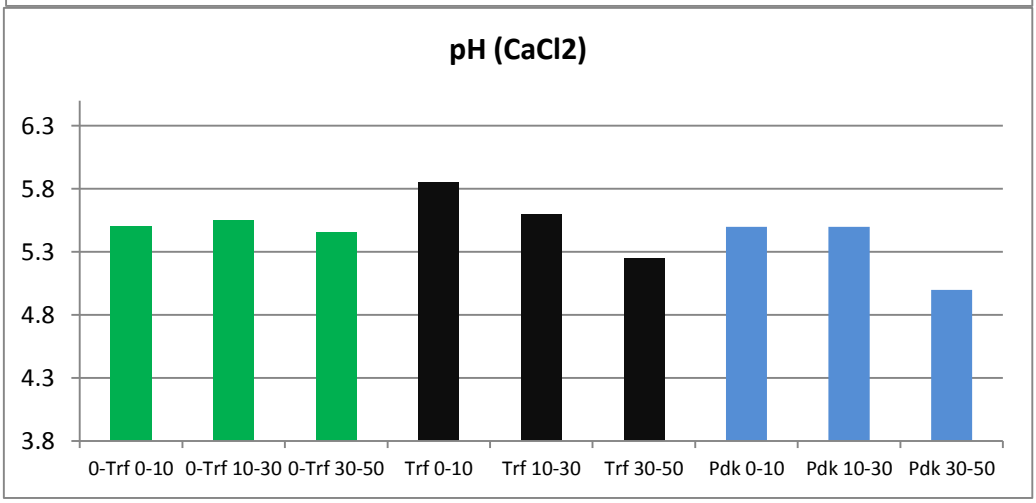
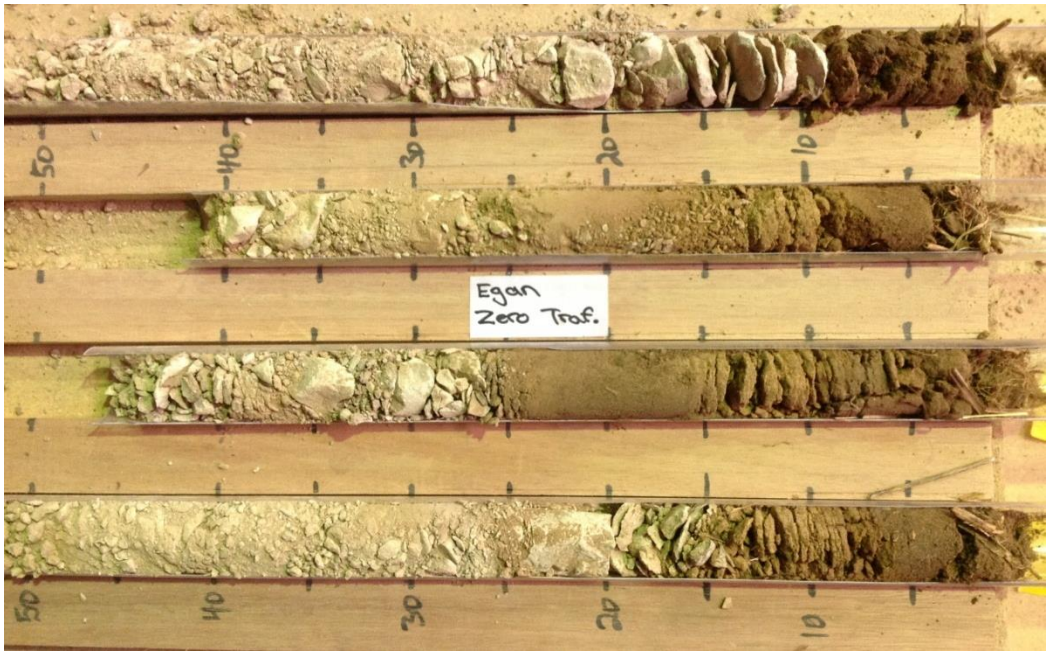
Trf 10-30
Trf 30-50
Pdk 0-10
Pdk 10-30
Pdk 30-50


pH (CaCl2)
6.3
5.8
5.3
4.8
4.3
3.8
0-Trf 0-10
0-Trf 10-30
0-Trf 30-50
Trf 0-10
Trf 10-30
Trf 30-50
Pdk 0-10
Pdk 10-30
Pdk 30-50

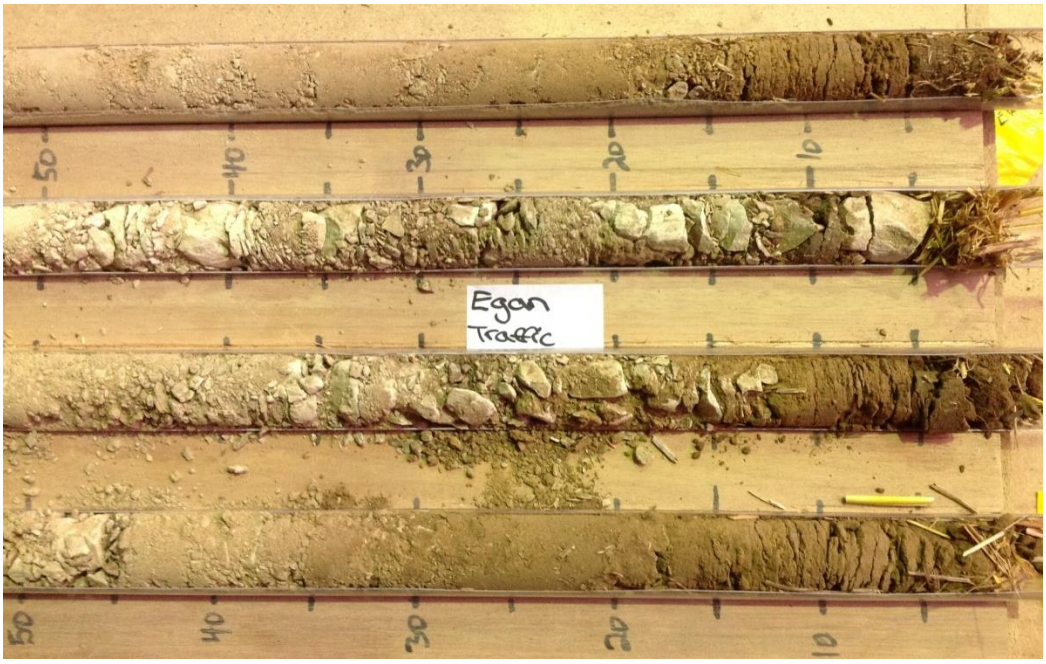
Egan Site – Medium Rainfall Mallee

This site has a moderate decrease in phosphorus levels as you move from Zero Traffic (56.5), to Trafficked (41.5) to the Paddock zone (42) in the 0 to 10cm depth range. Typical of Esperance mallee soils there is high levels of potassium and high pH levels down the profile across all zones. This site in particular increases in pH down the profile due to the evident calcareous subsoil in the soil core photos. Overall a very consistent site for the trial.

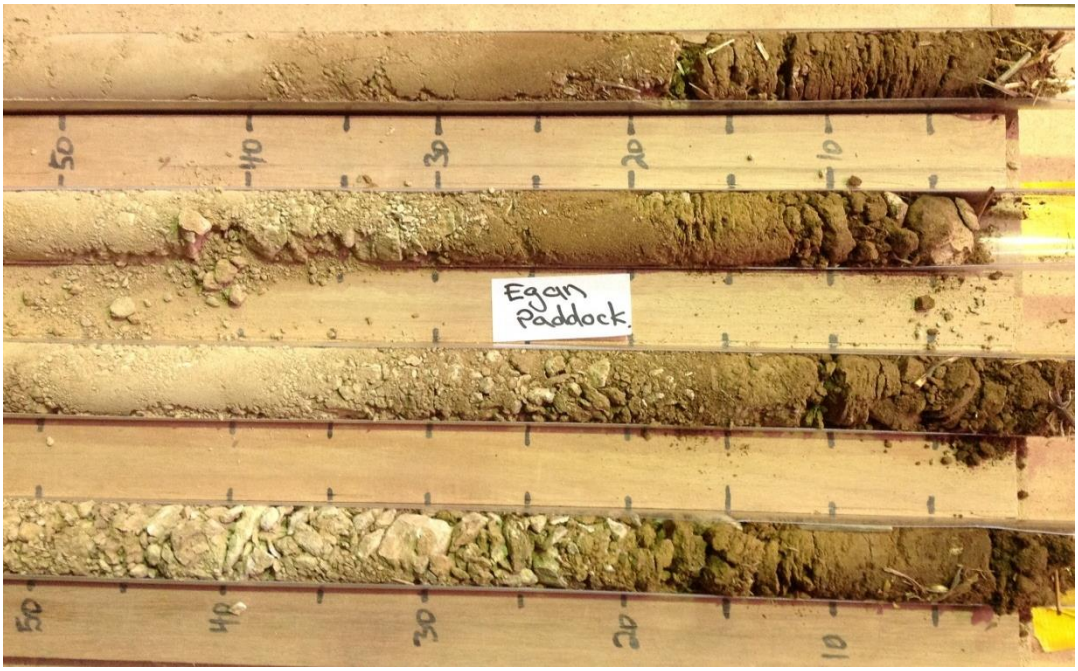
Egan - Soil core photos.



Egan – Zero Traffic Zone

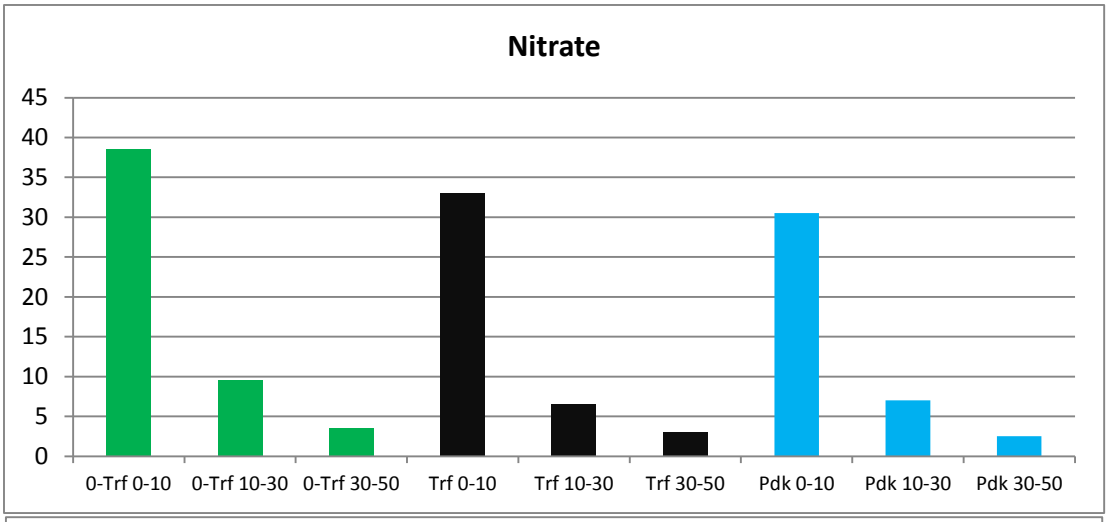


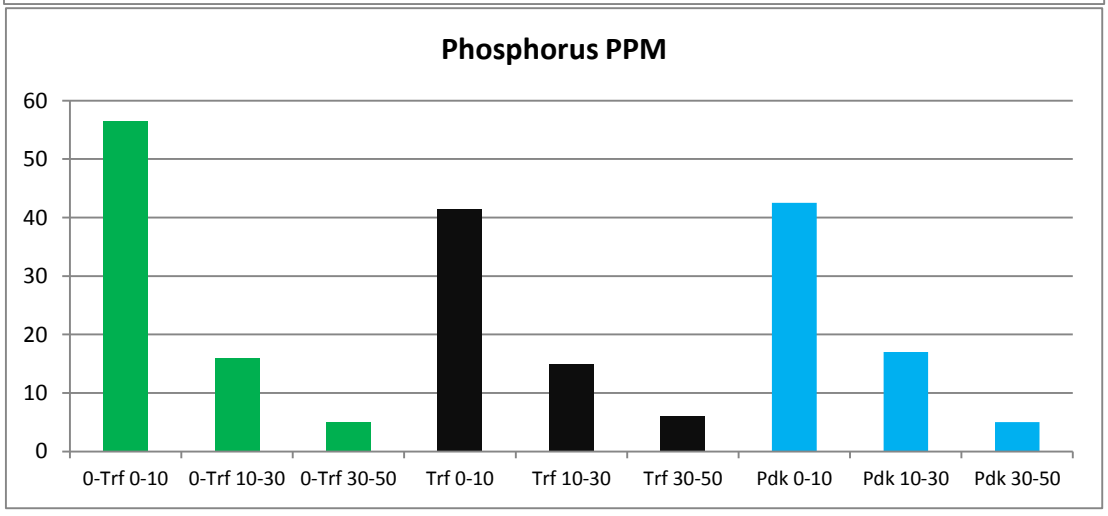
Egan – Trafficked Zone

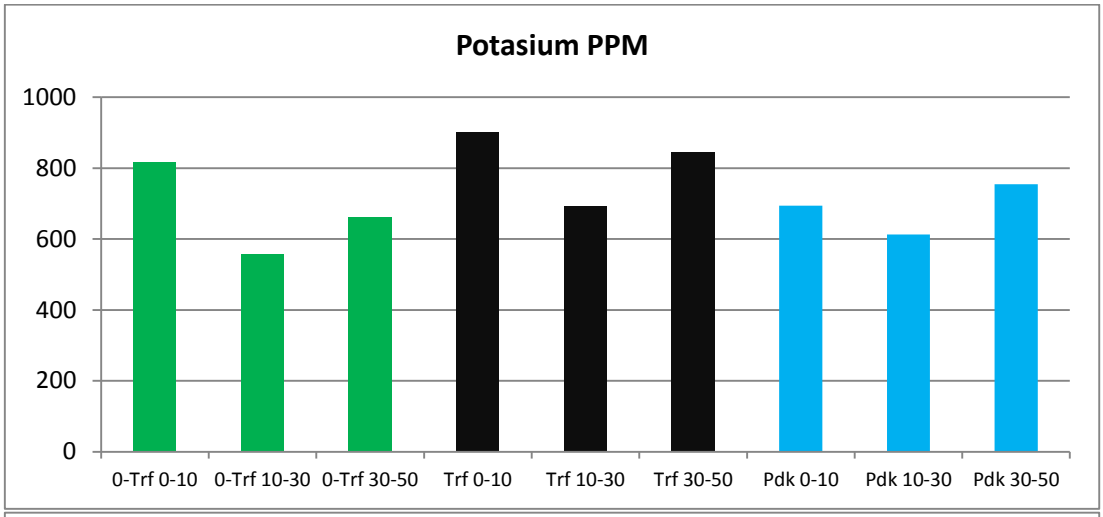


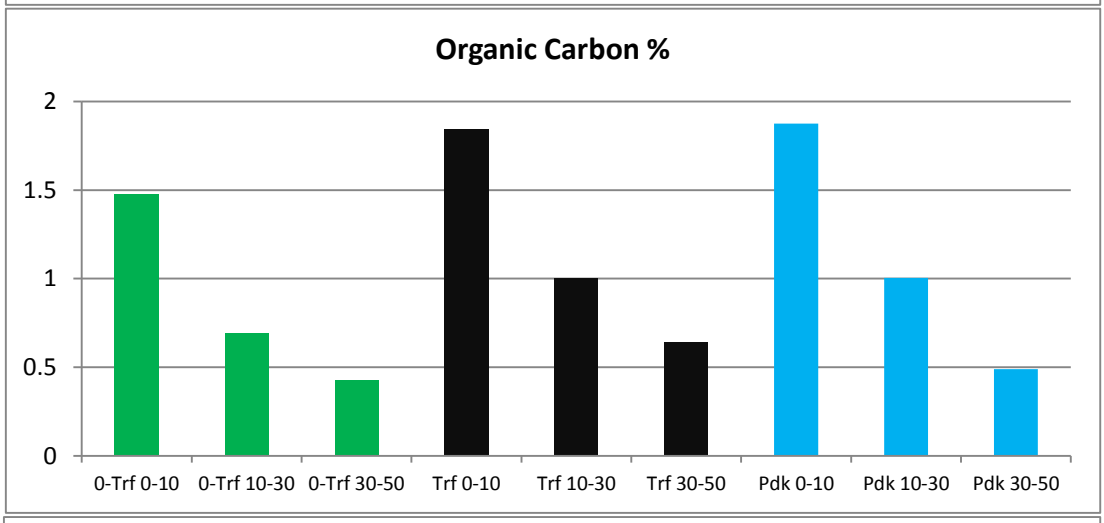
Egan – Paddock Zone

Egan Soil Chemistry results:
Green = Zero Traffic, **Black** = Trafficked and **Blue** = Paddock Zones






Potasium PPM
1000
800
600
400
200
0
0-Trf 0-10
0-Trf 10-30
0-Trf 30-50
Trf 0-10
Trf 10-30
Trf 30-50
Pdk 0-10
Pdk 10-30
Pdk 30-50


Organic Carbon %
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1.5
1
0.5
0
0-Trf 0-10
0-Trf 10-30
0-Trf 30-50
Trf 0-10
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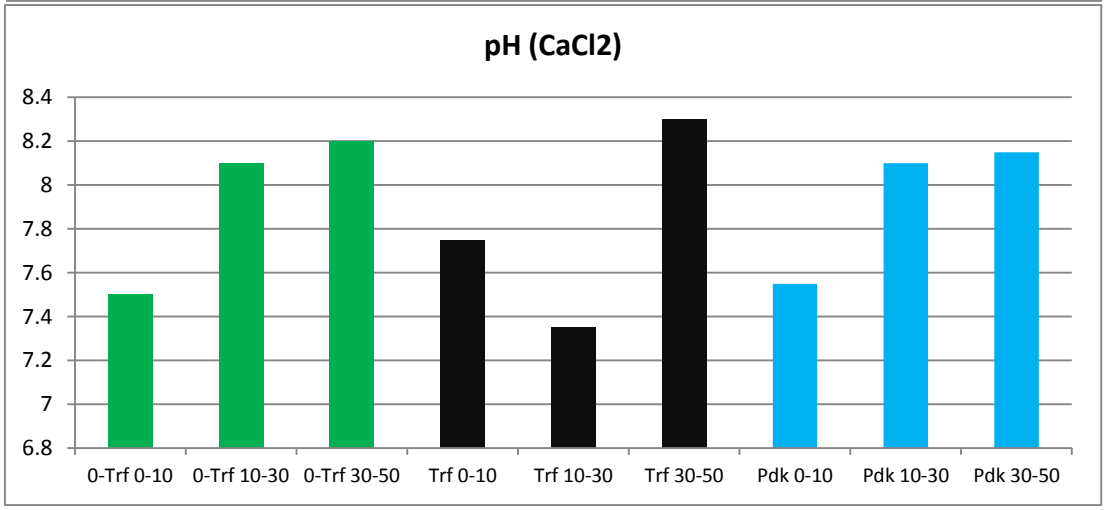
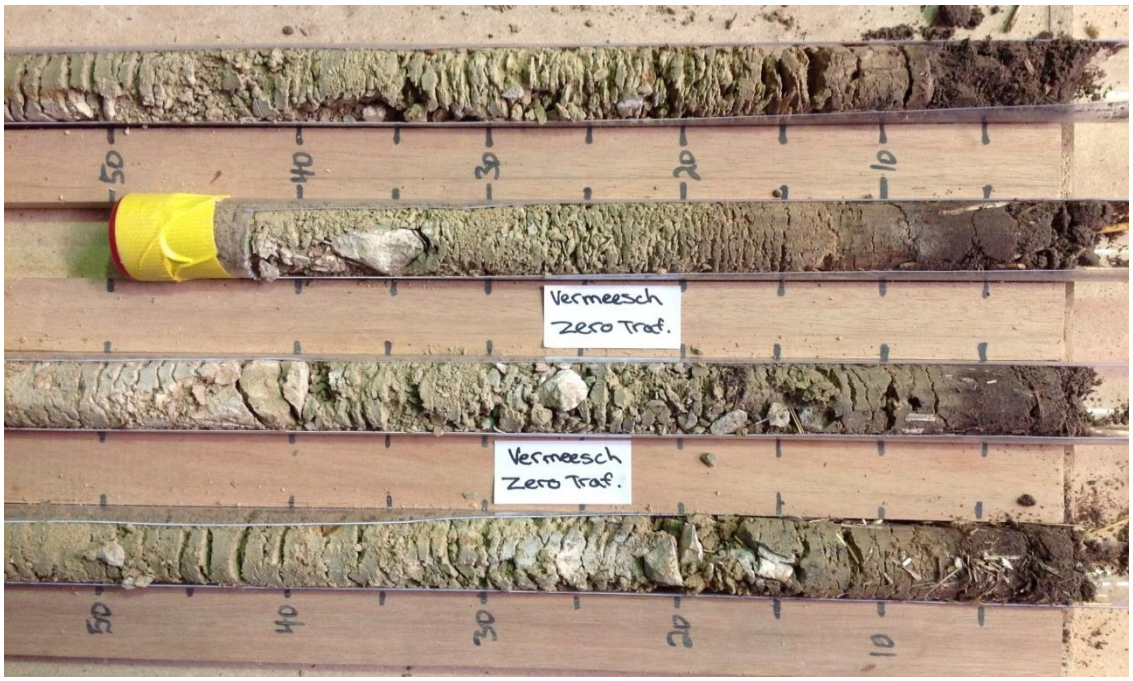
Trf 30-50
Pdk 0-10
Pdk 10-30
Pdk 30-50


pH (CaCl2)
8.4
8.2
8
7.8
7.6
7.4
7.2
7
6.8
0-Trf 0-10
0-Trf 10-30
0-Trf 30-50
Trf 0-10
Trf 10-30
Trf 30-50
Pdk 0-10
Pdk 10-30
Pdk 30-50

Vermeersch Site – Low Rainfall Mallee

This site has a moderate increase in phosphorus levels as you move from Zero Traffic (30), to Trafficked (37) to the Paddock zone (40) in the 0 to 10cm depth range. Agronomically, this would be unlikely to effect crop performance as it is above the 20 to 25 unit threshold considered for a phosphate response on this soil type. Typical of Esperance mallee soils there is high levels of potassium and very high pH levels down the profile across all zones. This site is notable by the negligible amount of nitrate across all of the sample zones. Overall a very consistent site for the trial.

Vermeersch - Soil core photos

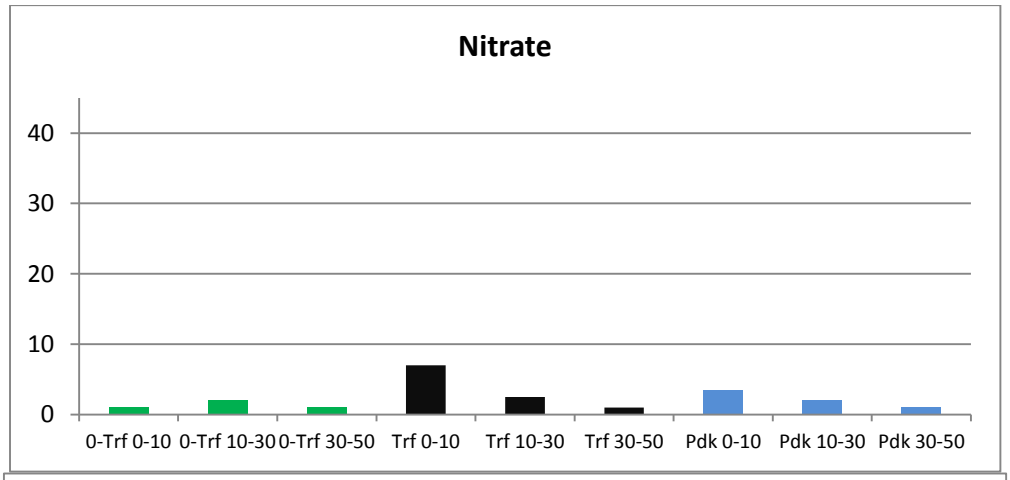


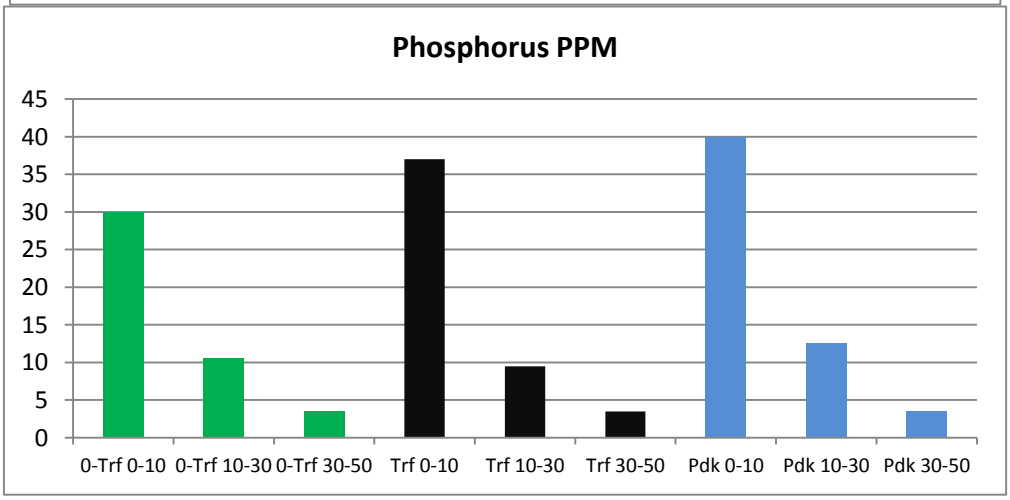
Vermeersch – Zero Traffic Zone

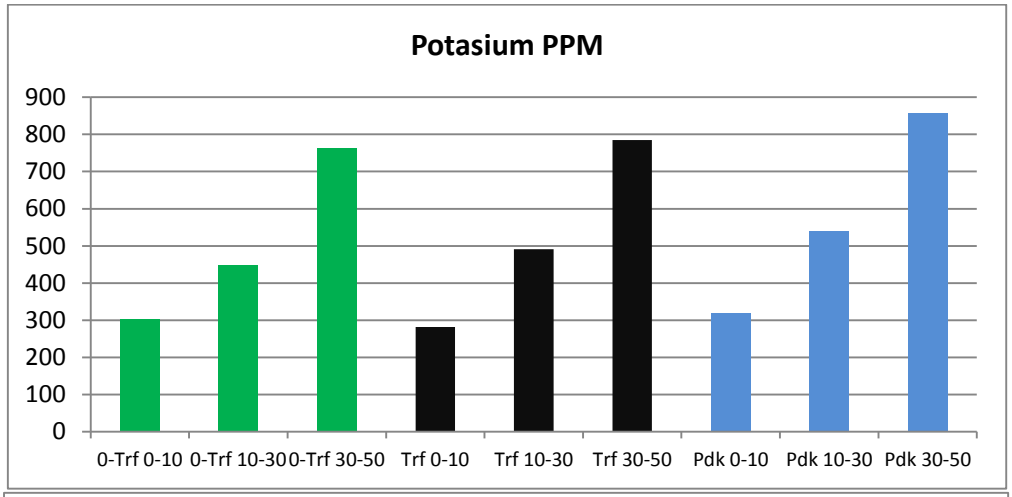
Vermeersch – Trafficked Zone

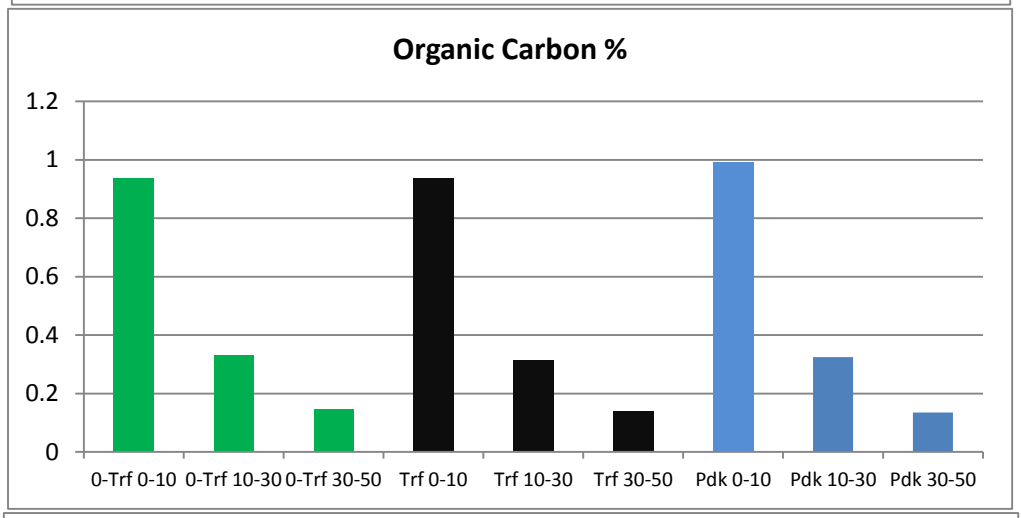
Vermeersch – Paddock Zone

Vermeersch Soil Chemistry results:
Green= Zero Traffic, **Black** =Trafficked and **Blue** = Paddock Zones






Potasium PPM
900
800
700
600
500
400
300
200
100
0
0-Trf 0-10
0-Trf 10-30
0-Trf 30-50
Trf 0-10
Trf 10-30
Trf 30-50
Pdk 0-10
Pdk 10-30
Pdk 30-50


Organic Carbon %
1.2
1
0.8
0.6
0.4
0.2
0
0-Trf 0-10
0-Trf 10-30
0-Trf 30-50
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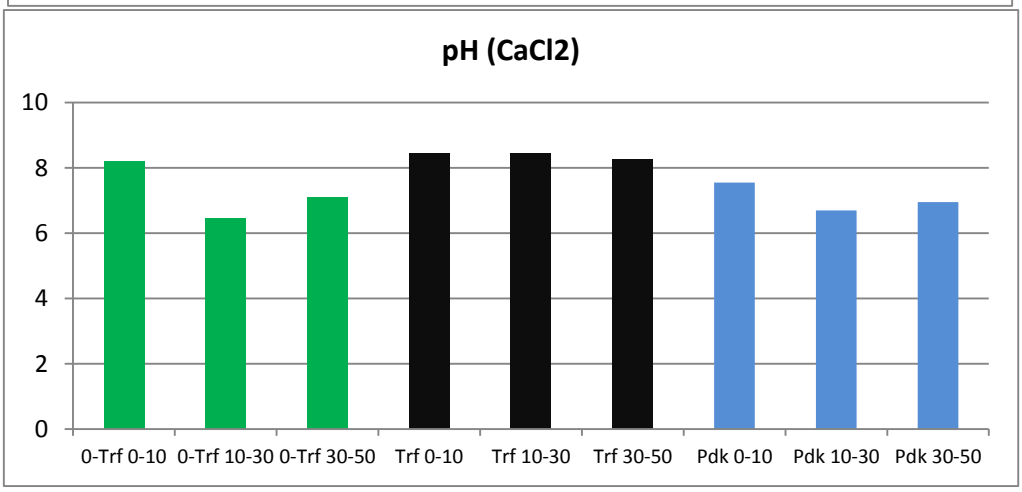
Pdk 0-10
Pdk 10-30
Pdk 30-50


pH (CaCl2)
10
8
6
4
2
0
0-Trf 0-10
0-Trf 10-30
0-Trf 30-50
Trf 0-10
Trf 10-30
Trf 30-50
Pdk 0-10
Pdk 10-30
Pdk 30-50

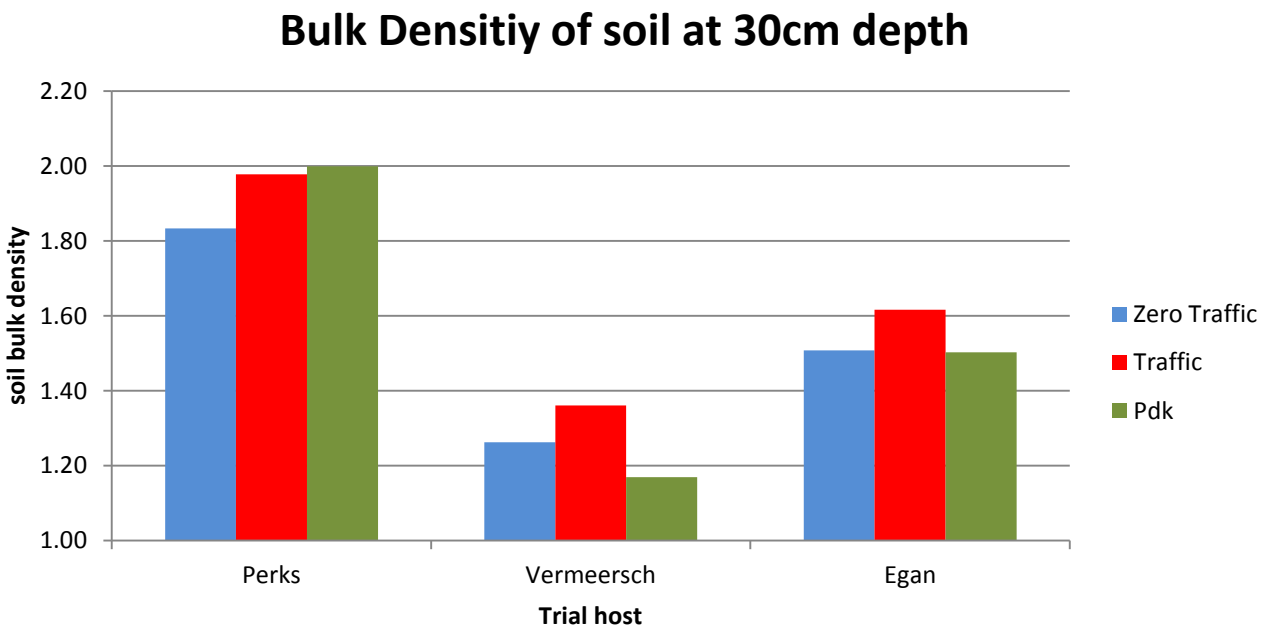
Compaction simulation.

At each site, the host farmer was asked to simulate compaction for the “Trafficked” zone.

At the Perks site this was with a Caterpillar track tractor with a clay karri grader full of soil. At the Egan site compaction simulation was from a self-propelled boom spray with around 3000 L of water on board. Finally at Vermeersch site it was single axle 4x4 water truck with approximately 5000L of water on board.

Off all the sites, the Vermeersch simulation compaction by the water truck was by far the most aggressive, followed by the Perks simulation. At the Egan site, a dry soil profile and relatively well floated machinery tyres appeared to have little to no compaction effect.

At all sites the simulated compaction did increase soil bulk density at a 30cm depth level above the zero traffic area. This is clearly demonstrated by the following graph of soil bulk densities of the sites following the simulated compaction.

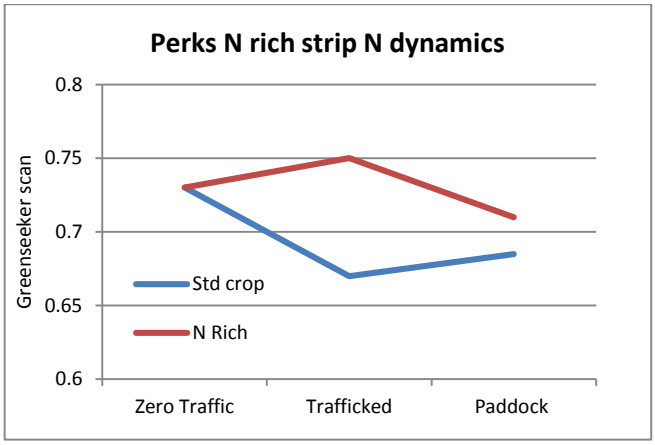


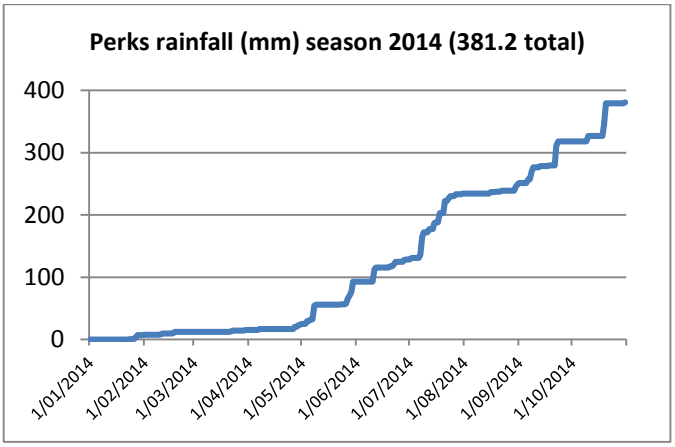
N Rich strip Results

All sites were seeded as per normal with the N rich strips being implemented at early tillering stage. The aim of implementing N rich strips was to compare the nitrogen responsiveness of the "N Rich" area in each of the traffic zones at each site. Variations between the N rich strips and adjacent paddock standard nitrogen application was compared between the zero traffic, trafficked and standard paddock zones via a hand held green seeker scanner in late August 2014.

Perks Site – N dynamics

Despite being dry during late July and into August, the Perks site provided some interesting insight into the possible nitrogen dynamics which sub soil compaction may induce.

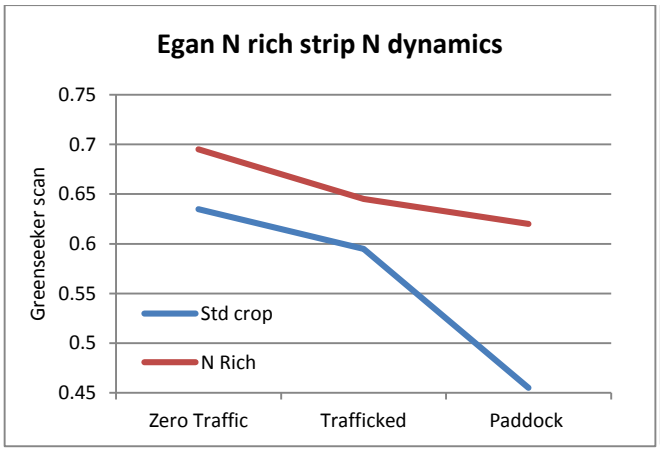


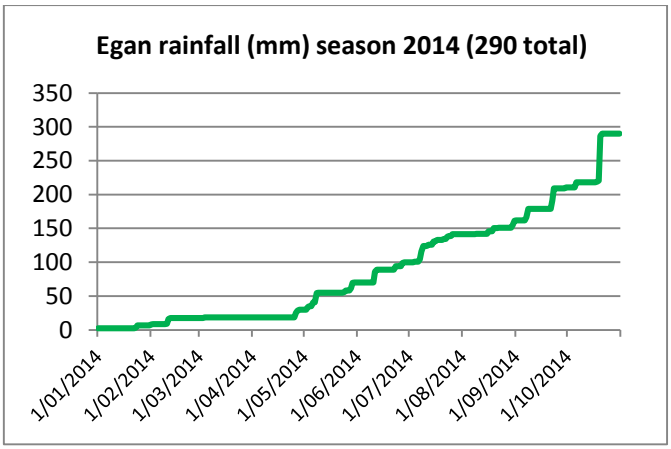


It can be noted here that compacted "Trafficked" zone varied significantly from the "Zero Traffic" and "Paddock" green seeker readings in the standard crop to the N rich strip. In the zero traffic zone there is virtually no difference between the N rich application and the farmer practice. Conversely in the trafficked zone, where it was compacted, there was a massive difference in the N rich scan compared to the standard crop. This observation strongly supports the hypothesis that soils which are less compacted would have greater nitrogen efficiency than those that are compacted. Unfortunately this is a single site and single season observation and further investigation in this concept is required.

Egan site – N dynamics

The very dry July and August conditions at the Egan site meant that any seasonal response to applied nitrogen was unlikely to provide meaningful results.

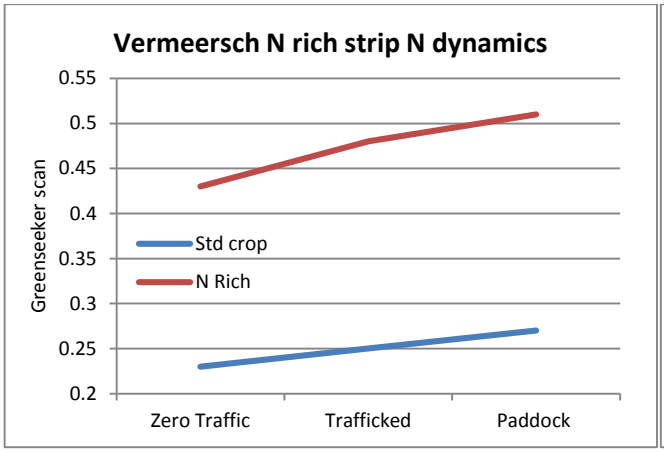


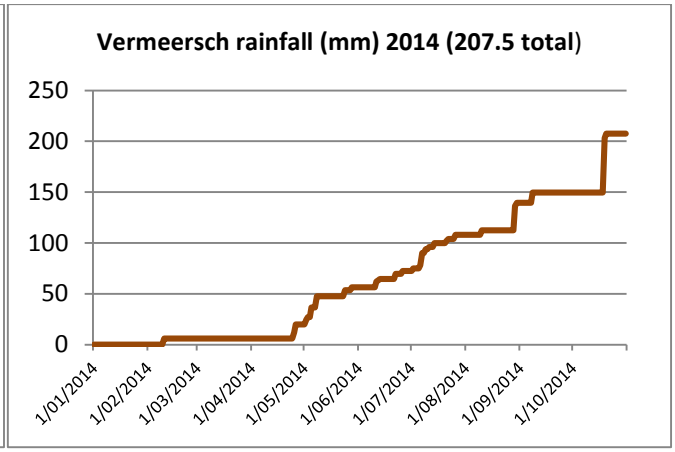


It can be noted that the Egan site did have some variation in responsiveness to the N rich strip however it showed no apparent correlation to the level of compaction present in the soil.

Vermeersch site – N dynamics

The 2014 season meant that the barley at the Vermeersch site was in a very moisture stressed condition in late August. The crops' ability to show any variation in nitrogen response was highly unlikely due to the very dry July and August months' rainfall.





It can be noted from the N rich strip dynamics graph that the variation in soil compaction level had no effect on the green seeker scan differences across the site.

Penetrometer assessments.

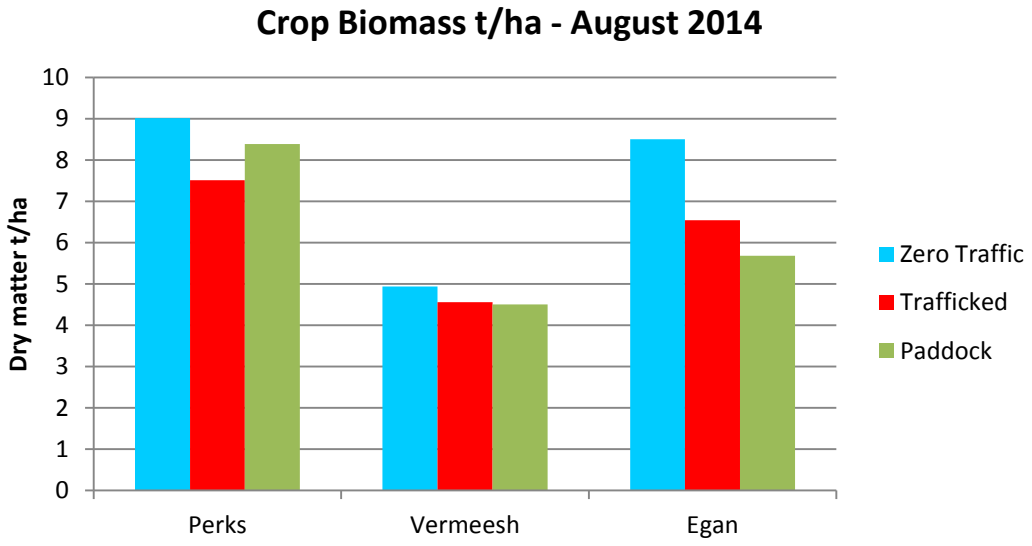
During the August assessment of the sites the dry seasonal conditions resulted in very high soil strength levels. Unfortunately this soil strength was beyond the capabilities of the penetrometer and we broke the device.

As a result we do not have a data set for the soil penetrometer assessments for this project.

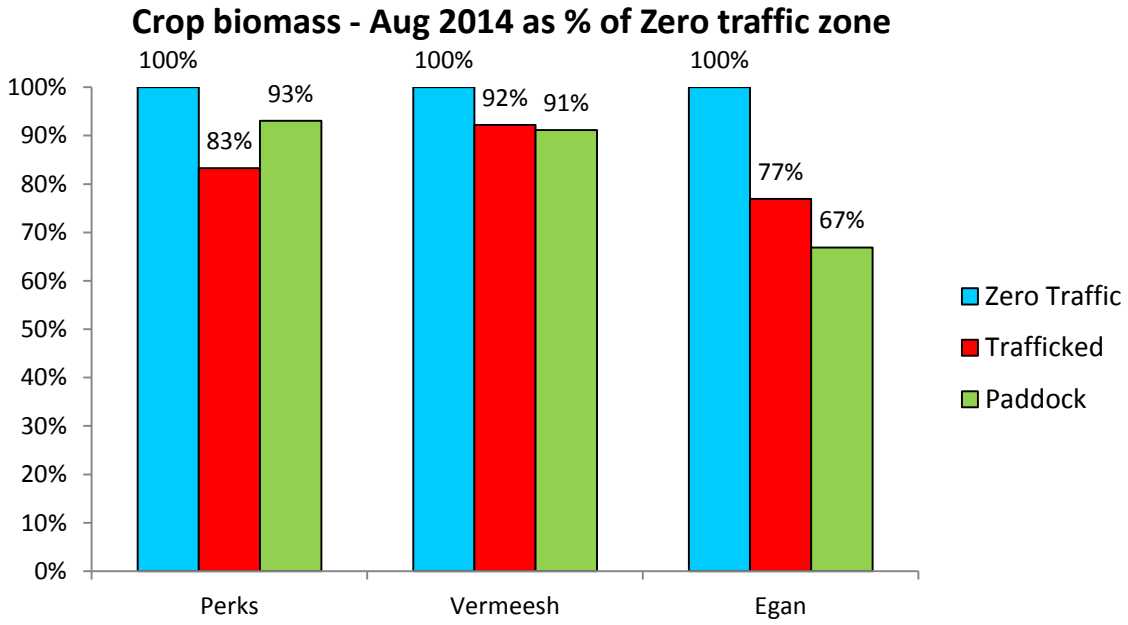
This has highlighted that in dry seasonal conditions the limitation of moisture not only restricts plant growth via plant moisture stress but would also have a compounding effect by increasing soil strength beyond crop root growth capabilities. This would then limit the available crop rooting depth or 'the size of the bucket". This factor combined with sub soil compaction adds great complexity to yield and nitrogen dynamic prediction models (such as Yield Prophet) which factor in plant rooting depth.

Biomass assessments

During the late August site assessment there were plant biomass cuts taken between each of the traffic zones. These plant biomass cuts were dried, weighed and analysed for nutrient content to assess the crops' uptake efficiency of N between treatments. There were atotal of 3 cuts taken from each zone combined to give the following results:



It can be noted that all sites decreased in crop biomass as it went from the Zero traffic zone to the trafficked and paddock zones. This is more clearly expressed as percentage of the zero traffic crop biomass.



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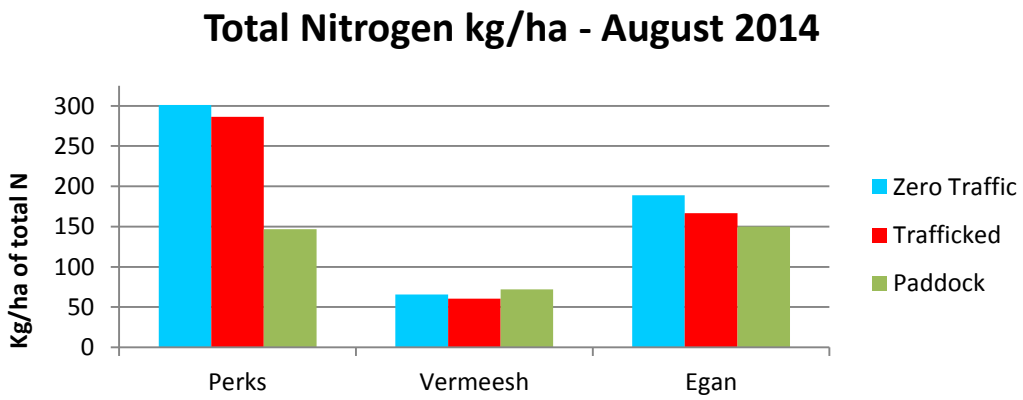
Plant tissue tests

At the August assessment of plant biomass cuts crop samples were also submitted for plant tissue tests.

Sample ID	B	Ca	Cl	Cu	Fe	Mg	Mn	Nitrate	P	K	Na	S	Total N	Zn
	mg/Kg	%	%	mg/Kg	mg/Kg	%	mg/Kg	mg/Kg	%	%	%	%	%	mg/Kg
PERKS ZERO TRAFFIC	4.65	0.33	0.85	3.42	77.83	0.16	48.49	142.56	0.32	2.88	0.02	0.26	3.34	19.41
PERKS TRAFFICKED	6.31	0.38	1.03	4.05	83.51	0.18	53.42	118.57	0.32	3.01	0.02	0.28	3.81	18.99
PERKS PDK	2.89	0.2	0.89	2.63	59.52	0.1	57.33	145.88	0.21	2.43	0.02	0.15	1.75	11.24
VERMEERSCH ZERO TRAFFIC	10.71	0.09	0.97	3.41	42.58	0.13	10.65	< 40.00	0.31	1.66	0.35	0.13	1.33	13.84
VERMEERSCH TRAFFICKED	13.55	0.1	1.08	3.54	41.16	0.14	11.01	< 40.00	0.29	1.76	0.45	0.14	1.33	13.85
VERMEERSCH PDK	18.63	0.08	1.33	5.28	44.92	0.15	11.81	< 40.00	0.36	1.88	0.56	0.17	1.6	17.49
EGAN ZERO TRAFFIC	5.71	0.2	1.16	5	42.42	0.11	19.76	42.53	0.36	2.91	0.2	0.19	2.22	21.4
EGAN TRAFFICKED	5.99	0.25	1.7	4.7	48.83	0.15	29.22	232.71	0.4	4.05	0.29	0.25	2.55	20.7
EGAN PDK	4.94	0.25	1.28	4.71	83.35	0.12	16.21	48.78	0.28	3.26	0.13	0.22	2.64	19.74

This plant tissue testing results were used to calculate the total Nitrogen uptake of the crop canopy between the sites.



At the Perks and Egan site the increase in biomass was still prevalent when factored by the tissue test results of total nitrogen content. At the Vermeersch site this correlation was not present and this is more than likely due to the very dry seasonal conditions experienced by the crop in the late August period. The increase of total nitrogen at 2 of the 3 sites does indicate that the zero traffic zones provided plants with better nitrogen uptake availability than the compacted soils of the trafficked and paddock zones.

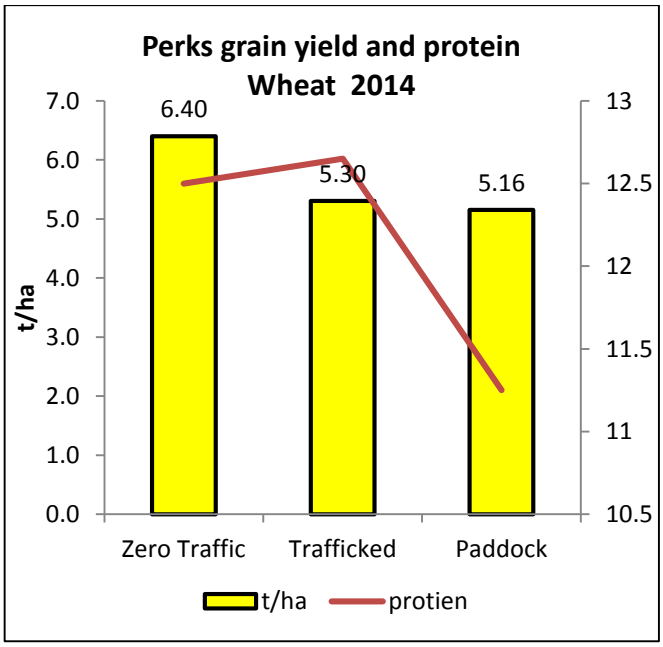
Harvest results

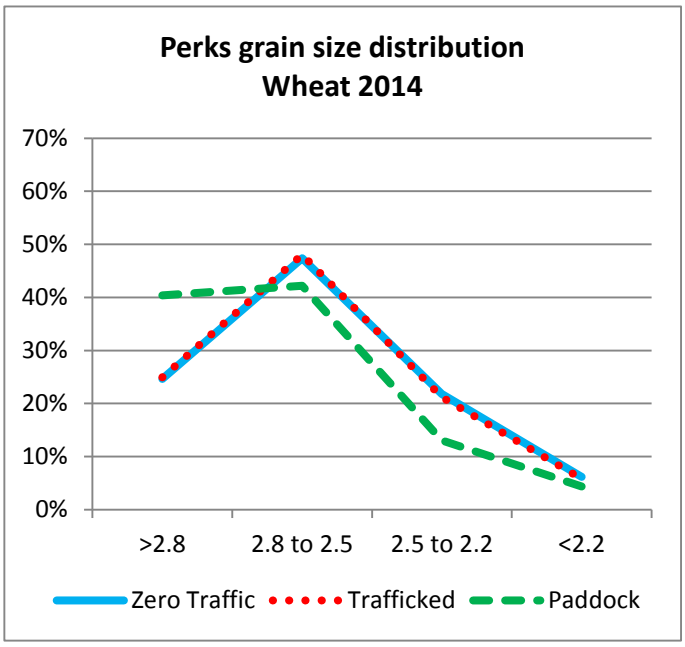
In early December the sites were hand harvested. Each treatment had 3 cuts taken which were mechanically threshed for grain separation. Following weighing for yield assessment an industry standard grain assessment was conducted via Infratect and screens.

	Yield	protein	Grain size distribution				1000 grain weight	HL weight
	t/ha	%	>2.8	2.8 to 2.5	2.5 to 2.2	<2.2	grm	grm
Vermeersch Zero Traffic	2.35	11.25	60%	35%	4%	1%	38.68	70.494
Vermeersch Trafficked	2.05	11.1	68%	28%	3%	1%	38.74	69.286
Vermeersch Paddock	1.99	12.2	37%	51%	9%	3%	34.85	69.934
Egan Zero Traffic	3.66	14.75	59%	36%	4%	1%	40.2	71.608
Egan Trafficked	1.61	16.3	16%	63%	15%	6%	32.77	68.454
Egan Paddock	2.50	14.95	59%	36%	4%	1%	40.21	70.174
Perks Zero Traffic	6.40	12.5	25%	47%	22%	6%	37.28	80.496
Perks Trafficked	5.30	12.65	25%	48%	21%	6%	37.89	79.284
Perks Paddock	5.16	11.25	40%	42%	13%	4%	39.2	82.122

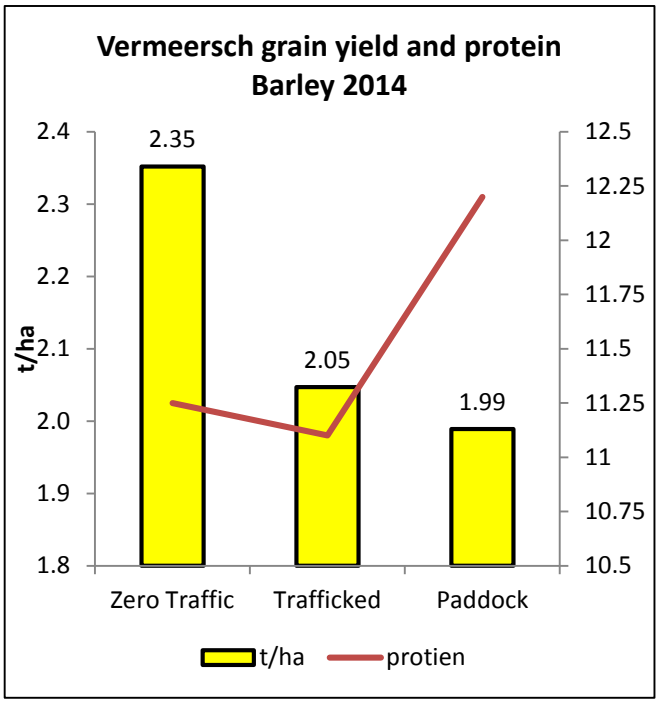
The individual site details are as follows:

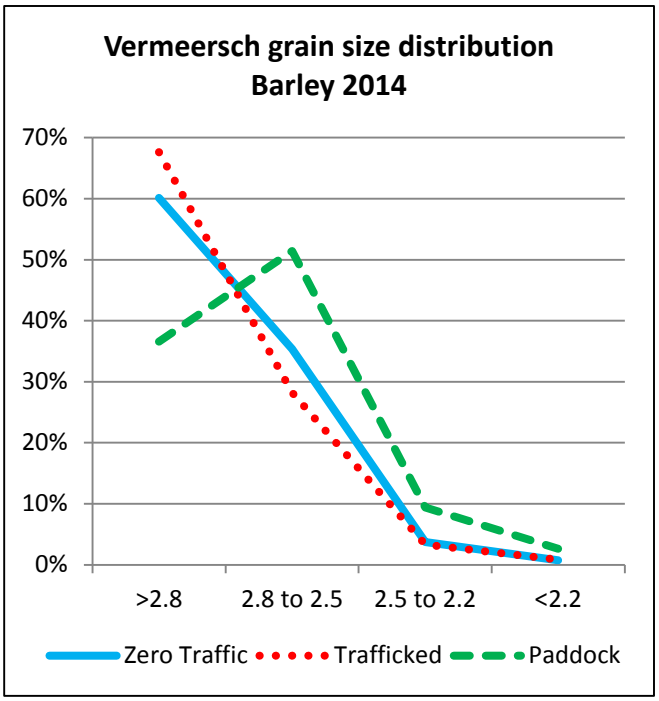
Perks site harvest results



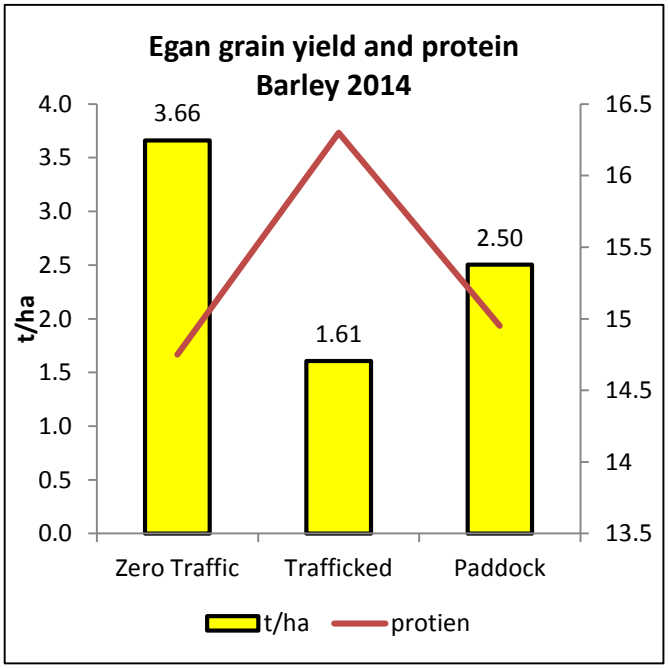


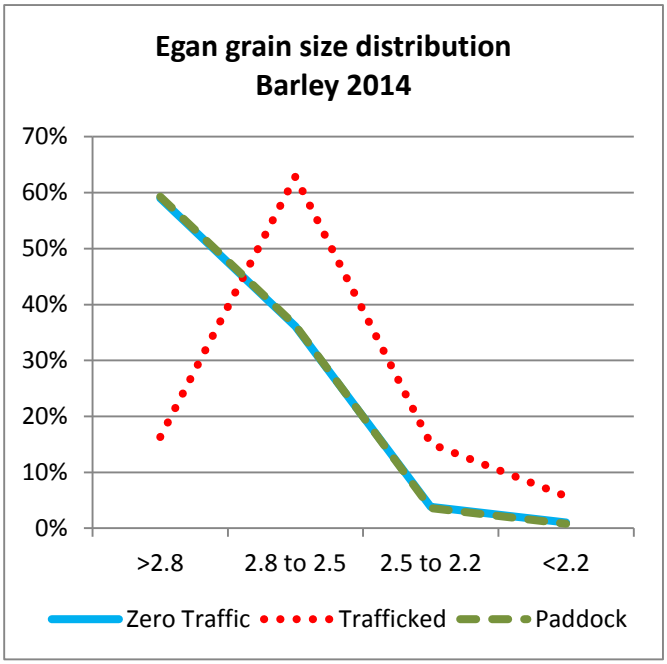
Vermeersch site harvest results





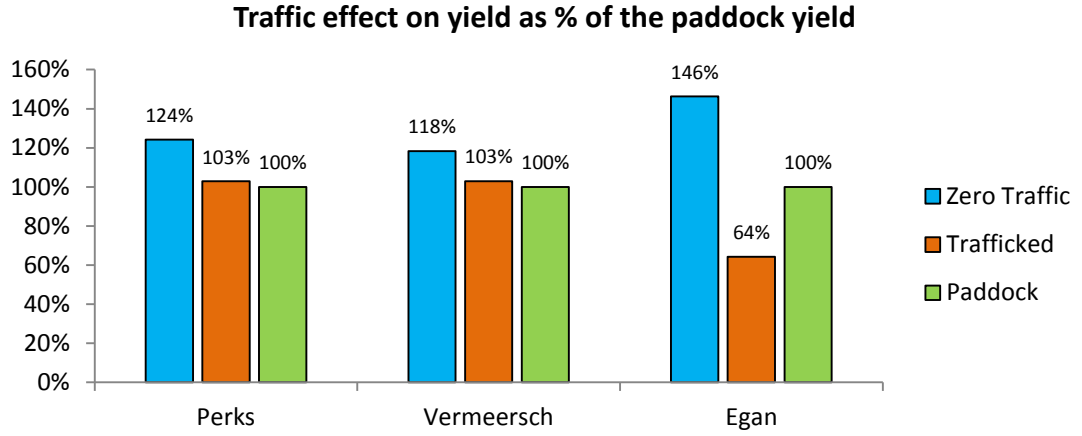
Egan site harvest results





Summary of harvest results and trial observations.

Corresponding to the biomass assessments, the compaction of the Trafficked zone had a notable effect on the crop performance. As a comparison of all sites there was an increase of grain yield of between 18 and 46% of the zero traffic area above the paddock assessments.



Each of the grain yield, protein and grain assessment factors were analysed via REML analysis using GenStat software. In this analysis the replication factor was the 3 individual sites which produced p values of <0.001 in all factors of measurement in the trials. While this shows that statically the impact of the traffic reduced overall grain size, reduced yield and increased protein the relatively small number of sites in this style of analysis does limit the validity of these supporting statistics.

From simple observation of the raw data the effect of compaction in the trafficked zone's has considerably decrease yield across all sites. What is interesting is that the paddock observation was also consistently reduced from the zero traffic zone. This data indicates that the legacy of machinery traffic across paddocks has impacted on the soil profile limiting crop growth. As a next progression from this observation it would seem obvious to investigate how soils might be de-compacted to recapture some of the yield potential noted from the zero traffic zone adjacent to the power pole.

Of the sites, the Egan data shows precisely the typical effect a compacted soil might have on crop performance. Grain yield has been decreased, grain protein has increased with an overall decrease of grain size and weights. These combination of factors suggest a limitation of root growth and hence plant available water at grain filling has been limited.

In terms of nitrogen efficiency, the 2014 season was not conducive to the expression of crop and soil nitrogen dynamics due to the extremely dry August period at all sites. For this reason there is only partial data to support the hypothesis that less compacted soils have greater nitrogen efficiencies that those of compacted soils. At the Perks site the N rich strip scans did show changes in responsiveness compared to the standard N application between the compacted and non compacted zones. This indicates that given seasonally responsive nitrogen conditions, the non compacted soil profile may be able to provide greater nitrogen efficiency than compacted soils. Further work would need to be conducted in this area to determine the reliability of this observation as well as the possible causes being from either greater rooting depth of the plant and hence increases of plant available water of other possible soil biological interactions.

As further support for the variation of nitrogen dynamics, 2 of the 3 sites maintained the concentration of nitrogen within the crop canopy measured by the total nitrogen per square meter. Given each zone had the same nitrogen application and similar base line soil testing results, this increase does indicate possible nitrogen fertilizer efficiency gains may be available in less compacted soils.