CASE STUDY

Using EM38 mapping to guide variable rate fertiliser strategies at Meringur in NW Victoria

FARMER NAME: Anthony Hunt

LOCATION: Meringur, NW Vic

RAINFALL: 270 mm

ENTERPRISES: Cropping 6200 ha in a cereal/legume rotation (wheat, barley, lentils, field peas and vetch) with some barley and vetch grown for hay, and 1,000 Merino ewes

DEMONSTRATION FOCUS: EM38 soil mapping, soil testing, variable rate fertiliser application

KEY MESSAGES

- This demonstration shows how electromagnetic (EM38) mapping was used on a Meringur farm in 2023 to map soils, guide soil testing, and set up variable rate fertiliser zones and test strips.
- EM38 mapping was confirmed to be an excellent approach to mapping soil moisture properties and a great starting point for VRT and cropping to soil type.
- Soil tests showed great variability in P levels and phosphorus buffering index (PBI) across the paddock and identified one zone where P could be yield limiting in some years. Results showed the importance of testing different soil types separately to avoid losing information on spatial variability.
- The variable rate fertiliser strategy used in 2023 did not appear to improve crop yields this year, since test strips of flat rate fertiliser did not yield differently to adjacent crop sown with the zoned rates, and a test strip of higher fertiliser in a low input zone also showed no yield difference. This may have been due to the unusual 2023 growing season (a wet June followed by a dry finish), with more vigorous crop areas potentially experiencing most moisture stress in spring. However, it is still likely the VRT strategy developed here will be of long-term value.
- The approach of mapping soils, testing soils within each zone and setting up test strips appears cost effective and relatively straightforward, particularly for producers with VRT capability on seeding equipment and yield monitoring on their header. Due to seasonal variation, results may not always be as expected but over the long term, the approach is likely to help to optimise fertiliser application and groundcover on any cropping farm.

INTRODUCTION

Anthony Hunt and his family run a mixed farming operation at Meringur in NW Victoria. The family runs some sheep – a Merino flock of 1000 ewes joined to crossbred rams – but the operation is heavily geared towards cropping wheat, barley, field peas and lentils across 6,200 ha. The Hunts also sow vetch pastures for sheep feed and to control weeds and fix nitrogen. Best practice methods that have been introduced and refined in recent years include early termination of some vetch/field pea crops to conserve moisture for cropping the following year, careful weed control in all annual crops and over the summer, no-till sowing, early sowing and a greater focus on maintaining groundcover on soils.

One of the challenges for farmers in the Millewa is dealing with highly variable soil. Most paddocks are a mix of sand hills, which are prone to wind erosion, more productive mid-slope soils, and heavier flats that are lower yielding in most years. Some Millewa growers are beginning to explore variable rate technology as a way to better match fertiliser inputs with yield potential across paddocks as well as boost groundcover on hills to reduce erosion.

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INTRODUCTION CONT...

In 2023, a demonstration site was set up on the Hunt's property to show how electromagnetic (EM38) mapping can be used to set paddocks up for variable rate technology (VRT), and to investigate whether varying fertiliser inputs impacts crop performance and groundcover.

DEMONSTRATION DETAILS

The demonstration site was a 120 ha paddock located off Meringur South Rd at Meringur (Figure 1), and included a mix of sandy rises, mid-slope soils and heavier flats. The site had been sown to vetch in 2021 and 2022, with the most recent vetch crop terminated in late August 2022.

In March 2023, the paddock was mapped using EM38 mapping. To relate EM38 information to key soil properties (moisture content, subsoil constraints, phosphorus (P) levels and phosphorus buffering index, PBI), soil samples were taken at three depths at four sites with differing EM38 results. Zones were then identified for VRT fertiliser application across the paddock, and test strips set up to see how different rates of mono-ammonium phosphate (MAP) sowing fertiliser impacted crop performance. The wheat variety Hammer CL Plus was sown on May 16, 2023, at 35 kg/ha.

Over the course of the 2023 growing season, the following agronomic data were collected:

- plant counts, assessed by counting plant numbers along 1 m row lengths at twenty locations across the paddock
- yield, assessed using header yield mapping at harvest
- total vegetation cover (green and non-photosynthetic) was assessed using the MODIS Fractional Cover Product developed by CSIRO with data provided by Agriculture Victoria.

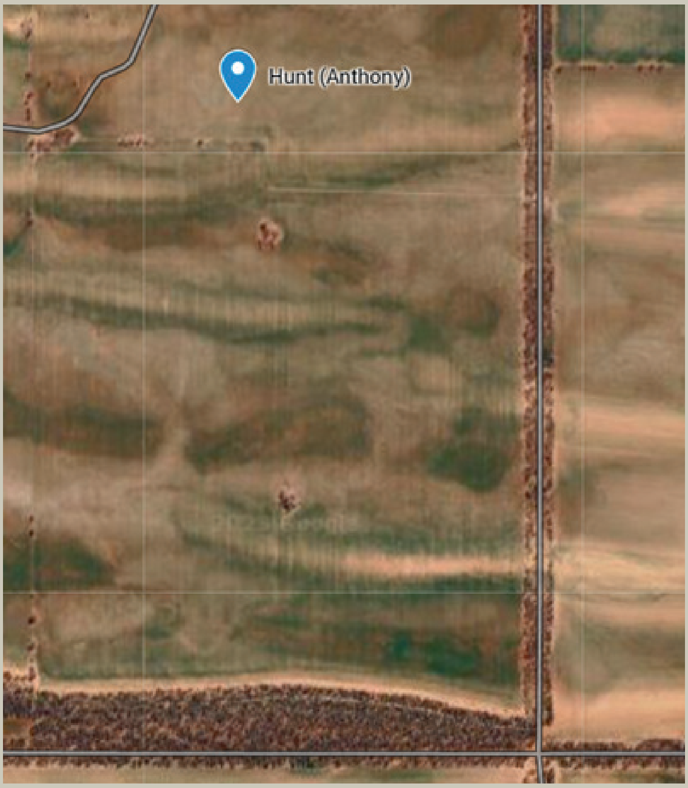

Figure 1. Hunt demonstration site, Meringur South Rd.

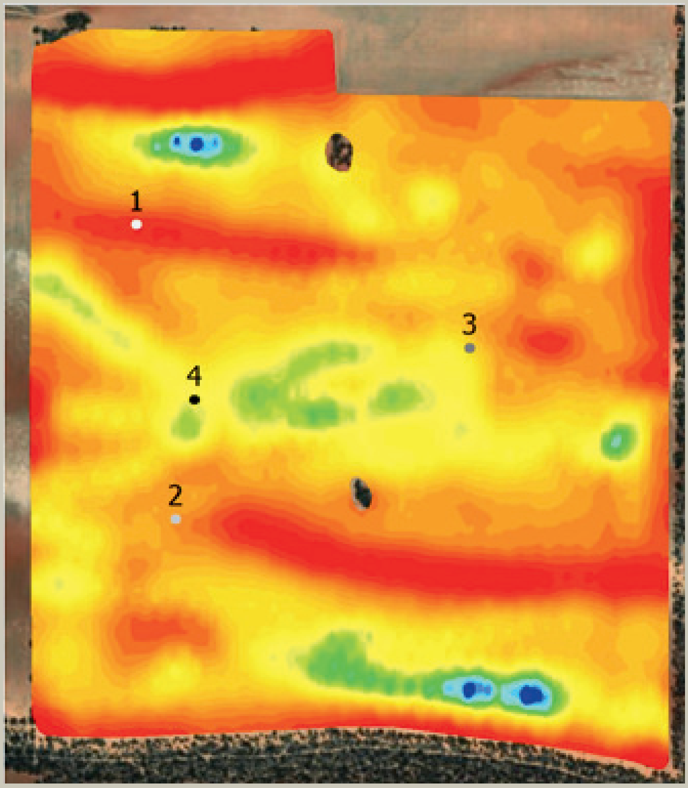

Figure 2. Hunt EM38 map

RESULTS

EM38 mapping showed that soils vary greatly across the paddock (Fig 2). Red areas indicate deeper sands, while the green and blue areas show heavier soils more likely to have subsoil constraints. Numbers indicate locations of soil tests.

Key soil test results are shown in Table 1. These were for topsoil, except for total N, which includes N to 60 cm. Full details of soil tests are included in Appendix A.

- There were high levels of variation in P and PBI across the paddock; P was sufficient at sites 1, 2 and 4, but deficient at site 3, a high PBI soil.
- Soil pH was in the expected range of 7-8.
- N levels ranged from 86 kg/ha on hilltops to about 140 kg/ha on other soils, enough for 2.2 t/ha wheat crops on hilltops and about 3.5 t/ha on the other soil types.
- Average values across all four soil types are also presented, to show what test results would have looked like if four sites were sampled and then pooled for testing.

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RESULTS CONT..

There was a strong relationship between EM38 results and moisture availability in each of the four soils (based on crop lower limit, the minimum amount of water in the soil that a crop can tolerate without experiencing water stress), confirming the suitability of EM38 mapping for zoning these soils (Figure 3).

Based on EM38 maps, crop lower limit values and soil tests, four zones were identified for VRT fertiliser application. Target fertiliser rates were set at 20, 30, 40 and 55 kg/ha of MAP (Figure 4).

To provide information on the impact of VRT fertiliser rates on crop performance, four test strips were also set up (see lettering in Figure 4):

A. 35 kg/ha of MAP (farmer standard practice) on two sandhills, for comparison with higher rates (40 and 55 kg/ha) prescribed by VRT.

B. 35 kg/ha MAP on a flat prescribed by VRT to receive 20 kg/ha, to see if cutting fertiliser on heavy soils reduced yield.

C. 55 kg/ha MAP in a strip of intermediate soil prescribed by VRT to receive 30 kg/ha, to see if boosting fertiliser rates in that soil increased yield.

The spring of 2022 was unusually wet, providing some subsoil moisture going into 2023. The 2023 growing season was also unusually wet in June (85 mm), but drier than average August to October, and rainfall across the year was average (273 mm). Plants established at an average density of 55 plants/m2, grew well early, but then experienced moisture and heat stress as crops matured in September and October.

Wheat yield data from the demonstration paddock are shown in Figure 5.

In the test strips on sandy soils (Figure 5 sites A):

- Hill tops zoned for 55 kg/ha achieved 1.34 t/ha when receiving the zoned rate, and 1.39 t/ha when receiving the farmer practice rate of 35 kg/ha
- Mid-slopes zoned for 40 kg/ha achieved 2.28 t/ha when fed the zoned rate, and 2.25 t/ha when receiving farmer practice rate of 35kg/ha

In the test strip on heavy soils (Figure 5 site B):

- Soils zoned to receive 20 kg/ha achieved 3.2 t/ha when given the zoned rate and 2.8 t/ha when receiving farmer practice 35 kg/ha. Similarly, nearby soils in the 30kg/ha zone achieved 2.3 t/ha when given that rate and2.33 kg/ha when receiving farmer practice 35 kg/ha.

Table 1. Key soil test results

Site	Colwell P	PBI	Target Colwell P*	Colwell P Balance	pH (CaCl)	Nitrogen (0-60cm)	Yield N Potential **
1	16	17	14	2	7.1	86	2.2
2	21	34	18	3	7.8	147	3.7
3	12	91	27	-15	7.7	138	3.5
4	20	57	23	3	7.7	134	3.4
Avg	17	50	21	-4	7.6	126	3.2

*Target Colwell P based on P response curves of P Moody (2007), but may underestimate what is needed for 90% of yield potential in modern farming systems (Sean Mason, pers. comm.)

** N potential calculation assumes 20 kg N/t grain and 50% nitrogen use efficiency (i.e. yield N potential = N (kg/ha)/40) and is based on N levels in 0-60 cm.

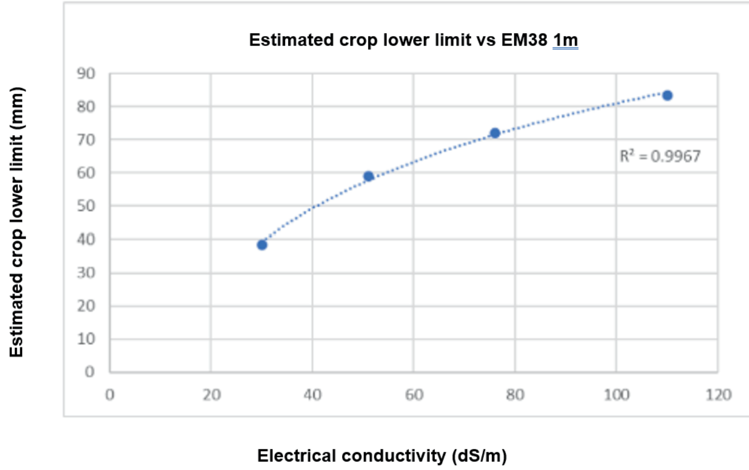

Figure 3. Relationship between EM38 results and crop lower limit – low EM38 values are associated with soils that 'give up' stored moisture to plants, while high EM38 values are associated with soils that hold on to moisture.

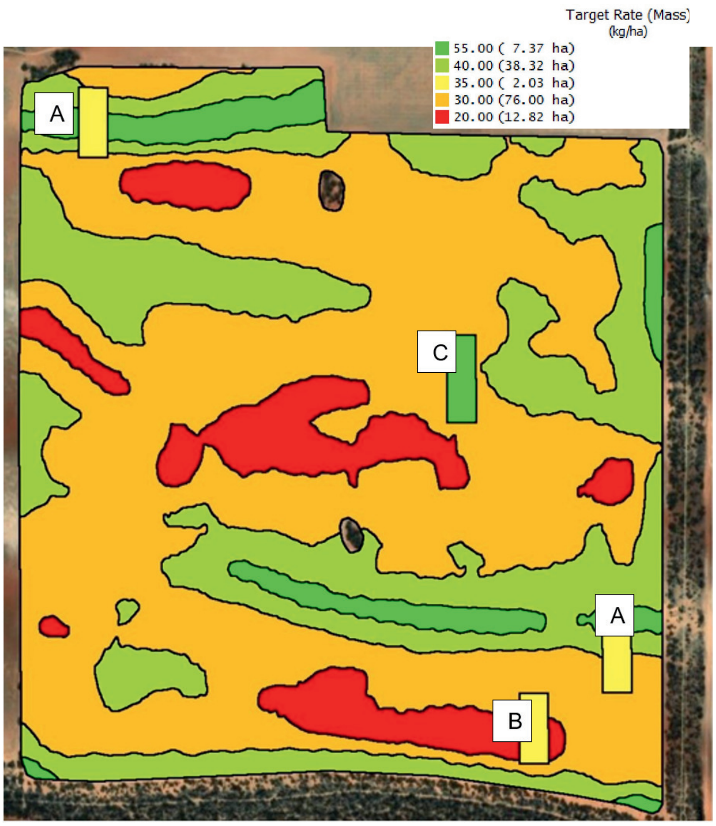

Figure 4. Vari-rate map for base fertiliser on the Hunt demonstration site, with rates ranging from 20kg/ha (red) on heavy soils to 55 kg/ha (green) on unstable sandhills. Test strips were also included at 35 kg/ha (farmer practice, coloured yellow) and 55 kg/ha (green areas).

RESULTS CONT..

In the test strip on intermediate soils (Figure 5 site C), providing extra fertiliser (55kg/ha) in an area zoned for 30 kg/ha did not improve yield compared to adjacent areas (2.3 and 2.35 t/ha respectively).

Taken together, these results suggest that increasing fertiliser on lighter soils, or increasing or reducing fertiliser levels on better or heavier soils, had minimal impact on yields in 2023. Overall yields averaged 2.1 t/ha.

Groundcover assessments made using satellite data showed a general trend towards more groundcover over the past 5 years. There was a strong rise during the 2023 growing season associated with crop growth, then a decrease as crops senesced and were harvested (Figure 6).

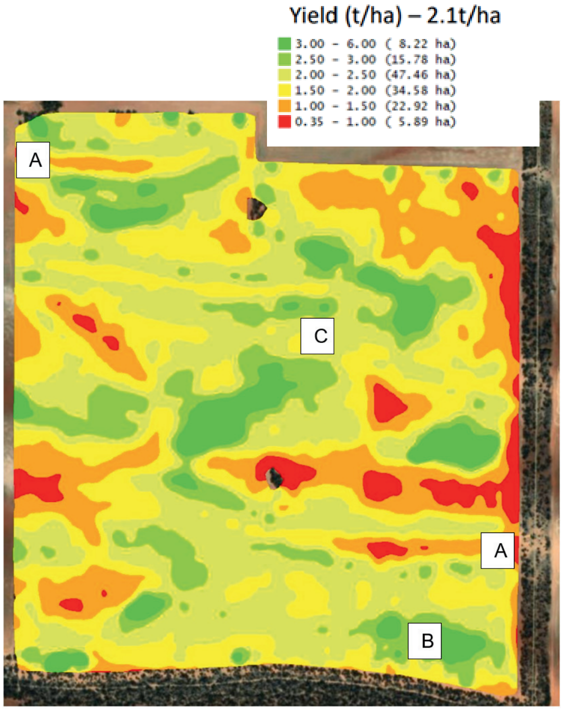

Figure 5. Yield maps from the Hunt VRT paddock.

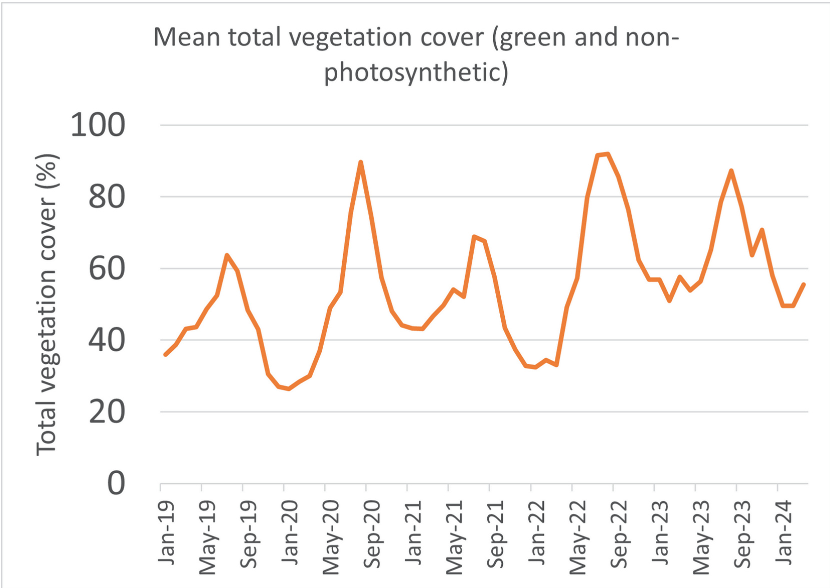

Figure 6. Historical groundcover data for the Hunt demonstration site.

DISCUSSION

EM38 results correlated well with crop lower limit and soil type in this study, confirming that EM38 provides a suitable approach for soil mapping in the Millewa. The cost of mapping, which is a one-off cost, was approx. $7/ha in 2023, and in many cases can be recovered through improved crop performance or fertiliser efficiencies in a single year.

Soil testing results showed excellent levels of N (80-140 kg/ha), which was not surprising given the paddock had been sown to vetch for the two previous years. Rates of N fixation of 50 to 150 kg/ha are typical during a vetch hay or green manure crop. Results also highlighted the importance of testing for PBI as well as P, since target P levels vary considerably with soil type. One site (the highest PBI site) did show P to be deficient, and this site should be monitored to ensure P levels do not decline further.

The average data in Table 1 provided an excellent illustration of the way information on spatial variation in soils is lost when different soil types are bulked - the average values from the paddock would have missed the N deficiency in soil type 1, underestimated P supply in soils 1, 2 and 4, and overestimated P supply in soil type 3.

At 2.1 t/ha, average wheat yields were slightly above average in 2023, which was a great result considering the dry finish to the year. This is a likely consequence of the subsoil moisture going into the season and the excellent rainfall that occurred in June, effectively 'filling the bucket' of plant available water for the crop. The absence of subsoil constraints in any of the tested soils indicates crops would have been able to extract water from deep in the profile across the paddock. Best practice approaches used at the site like careful weed control (in the previous vetch crops and over the previous summer), early sowing and good soil fertility would also have allowed the crop to yield well despite the dry finish.

DISCUSSION CONT...

The VRT fertiliser strategy tested at this site (extra fertiliser on lighter soils, less fertiliser on heavier soils) was based on the expectation that, in a dry environment such as the Mallee, soil type would be the main driver of yield variability. Lighter soils generally provide more moisture from low rainfall events, and have low inherent fertility, and thus generally respond to increased inputs. This strategy would, in time, lead to better yields and more biomass on lighter soils, and potentially allow reduced inputs on lower yielding parts of the paddock. The absence of a yield response to more or less fertiliser this year on different soils could be due to a number of factors including:

1. The high rainfall in June effectively 'filled the bucket' of plant available water for the wheat crops in both light and heavy soils. Once wetted, the heavier soils would have had more moisture to give back, compensating for the fact that heavy soils also retained more moisture.

2. Both N and P were present at relatively high levels across most soil types. Had more soils been deficient for N and P, higher and lower fertiliser rates would have been more likely to increase or decrease yields.

3. In the one soil type that was predicted to be P deficient (soil type 3), the wheat crop still did not yield more with higher fertiliser; this may have been because plants grew more vigorously with the higher fertiliser but then ran out of moisture earlier and could not fill grain.

Despite the lack of any clear responses to fertiliser rate in this demonstration, the VRT strategy presented here may still be the best approach given the likelihood that lighter soils will outyield heavier soils over the long term and thus need more nutrition to balance nutrient removal. Repeat testing, along with permanent trial strips, will be required to monitor trends in P in the different soil types.

Given fertiliser rates did not obviously impact yields, the VRT fertiliser strategy applied here probably did not impact groundcover levels this year. The fact that the Hunts did not graze the wheat stubble in this paddock due to erosion concerns would have helped retain cover across early 2024. Longer term data on total vegetation cover does show an increase in average ground cover over the past 5 years, likely due to recent good seasons as well as improvements in the Hunt's agronomic practices – which over the past 10 years have included early termination of pastures, summer weed control, no till seeding, earlier sowing and a greater focus on retaining groundcover. More data are needed over more seasons to confirm this trend.

Mapping soil variation, testing soils, setting up test strips and studying yield maps is relatively straightforward and cost effective for producers with VRT capability on seeding equipment and yield monitoring on their header. Due to seasonal variation, results will not always be as expected but, over the long term, the approach is likely to provide valuable information to optimise fertiliser strategies and groundcover on any cropping farm.

Australian Government Department of Agriculture, Fisheries and Forestry | Future Drought Fund | mallee catchment management authority | Mallee Sustainable Farming | ROBUST MALLEE FARMING SYSTEMS SUSTAINABLE, INNOVATIVE AND PROFITABLE

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REFERENCE

Moody PW (2007) Interpretation of a single-point P buffering index for adjusting critical levels of the Colwell soil P test. Australian Journal of Soil Research 45(1), 55-62.

Appendix A. Soil test results from four sites in the Hunt demonstration paddock.

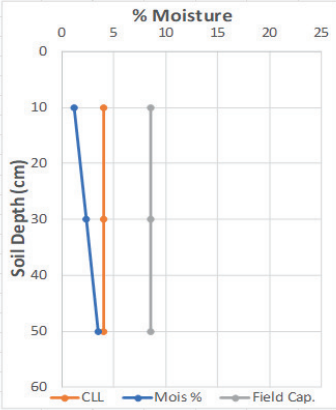
SITE	1	EM38 1m	30	EM38 0.5m	22

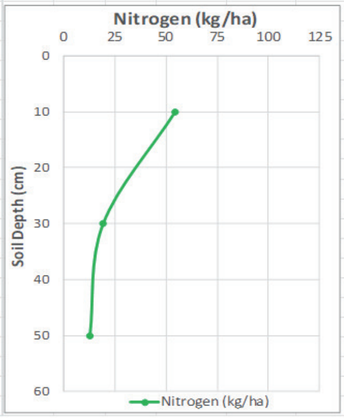
Topsoil Results			
Col. P	PBI	Col. K	Org. C%
16	17.3	208	0.39

Soil Depth	Soil Texture	Total Moisture (mm)	PAW Estimate	Nitrogen (kg)
0-20	LS	4	-9	54
20-40	LS	8	-5	19
40-60	LS	11	-2	13
	Totals	23	-16	86

Soil Depth	EC	pH (CaCl)	pH (H2O)	
	Chemical Constraints			
0-20	0.069	7.1	7.9	Boron
20-40	0.082	8.1	9.2	0.61
40-60	0.08	8.1	9.2	1.04

Subsoil Contraints - 40-60cm					
Ex. Ca.	Ex. K	Ex. Mg	Ex. Na	CEC	ESP
6.12	0.1	1.09	0.1	7.41	1.35





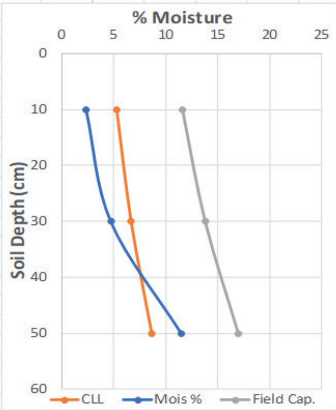
SITE	2	EM38 1m	51	EM38 0.5m	26

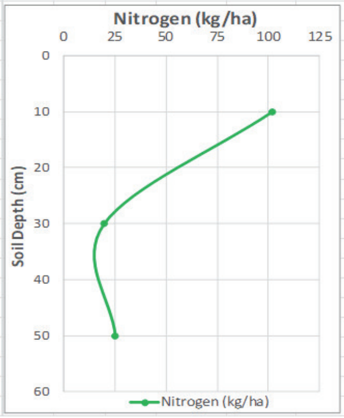
Topsoil Results			
Col. P	PBI	Col. K	Org. C%
21	34.2	229	0.49

Soil Depth	Soil Texture	Total Moisture (mm)	PAW Estimate	Nitrogen (kg)
0-20	SL	7	-9	102
20-40	LSCL	13	-5	20
40-60	SCL	32	8	25
	Totals	53	-6	147

Soil Depth	EC	pH (CaCl)	pH (H2O)	
	Chemical Constraints			
0-20	0.119	7.8	8.7	Boron
20-40	0.093	7.8	9	0.67
40-60	0.106	7.8	9.1	0.74

Subsoil Contraints - 40-60cm					
Ex. Ca.	Ex. K	Ex. Mg	Ex. Na	CEC	ESP
8.31	0.14	1.68	0.1	10.23	0.98





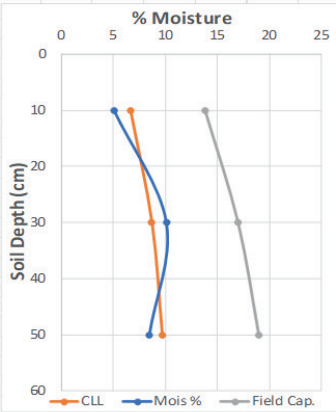
SITE	3	EM38 1m	76	EM38 0.5m	52

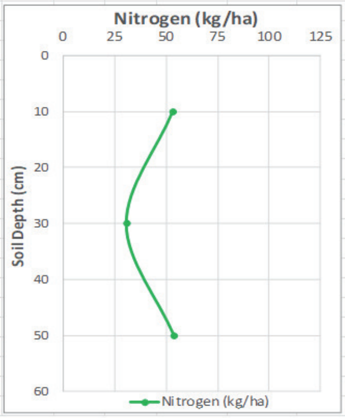
Topsoil Results			
Col. P	PBI	Col. K	Org. C%
12	91	248	0.69

Soil Depth	Soil Texture	Total Moisture (mm)	PAW Estimate	Nitrogen (kg)
0-20	LSCL	14	-5	53
20-40	SCL	28	4	31
40-60	CL	25	-4	54
	Totals	68	-4	138

Soil Depth	EC	pH (CaCl)	pH (H2O)	
	Chemical Constraints			
0-20	0.133	7.7	8.8	Boron
20-40	0.273	8.2	9.8	4.77
40-60	0.339	8.3	9.9	6.86

Subsoil Contraints - 40-60cm					
Ex. Ca.	Ex. K	Ex. Mg	Ex. Na	CEC	ESP
6.53	0.36	2.24	0.6	9.73	6.17





SITE	4	EM38 1m	110	EM38 0.5m	59

Topsoil Results			
Col. P	PBI	Col. K	Org. C%
20	56.9	400	0.53

Soil Depth	Soil Texture	Total Moisture (mm)	PAW Estimate	Nitrogen (kg)
0-20	SCL	11	-13	81
20-40	CL	24	-4	36
40-60	LC	26	-5	17
	Totals	62	-22	134

Soil Depth	EC	pH (CaCl)	pH (H2O)	
	Chemical Constraints			
0-20	0.13	7.7	8.6	Boron
20-40	0.119	7.9	8.9	1.3
40-60	0.309	8	9.9	2.63

Subsoil Contraints - 40-60cm					
Ex. Ca.	Ex. K	Ex. Mg	Ex. Na	CEC	ESP
6.62	0.24	2.99	0.84	10.69	7.86