CASE STUDY

Setting up for variable rate technology (VRT) - mapping soil variability in the Millewa

FARMER NAME: Nigel Charles

LOCATION: Bambill, Vic

PROPERTY SIZE: 2100 ha

RAINFALL: 250 mm

ENTERPRISES: Cropping wheat, barley, vetch and field peas in a cereal-legume rotation, and self-replacing Merino flock.

DEMONSTRATION FOCUS: The use of EM38 mapping and soil testing to characterise variable soils.

INTRODUCTION

Nigel Charles and family have a mixed farm at Bambill in NW Victoria, cropping wheat, barley, vetch and field peas in a cereal-legume rotation, and running a self-replacing Merino flock.

In recent years, the Charles' focus has been on summer weed control to conserve moisture, and sowing vetch pastures to allow better control of grassy weeds in winter and reduce reliance on nitrogen fertilisers. Weeds are now low enough in number to allow some crops to be sown dry.

There are several paddocks on the Charles' property where there is great variation in soils. Some lighter soils produce minimal biomass and are erosion-prone in dry years. This site was set up on the Charles' property to demonstrate how electromagnetic (EM38) can be used for soil mapping, and to investigate whether varying seed and fertiliser inputs improves crop performance and overall groundcover.

KEY MESSAGES

- This case study shows how electromagnetic (EM38) soil mapping can be used to map soils and guide soil testing on farms with variable soil types, and how test strips can be used to optimise seed and fertiliser inputs to improve crop performance and groundcover.
- EM38 mapping was confirmed to be an excellent approach to mapping soil moisture properties and subsoil constraints in the Millewa, 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.
- Within test strips, reducing seed inputs by 25% lowered yield by approximately 10%, and increasing seeding rates did not improve yield, confirming farmer practice seeding rates (40kg/ha) were appropriate in 2023.
- Varying base fertiliser levels did not obviously impact grain yield in test strips, but increased base fertiliser on higher yielding parts of the paddock may be required to prevent nutrient decline.
- A map for paddock scale VRT was set up with three zones, which can be used in future seasons.
- Double sowing sandhills, and not harvesting erosion prone hill tops, were useful approaches in boosting groundcover and reducing erosion risk.

DEMONSTRATION DETAILS

- In March 2023, a paddock on the Charles' property with particularly variable soils and historic erosion issues was selected for an EM38 soil survey. Variation in soils was mapped using electrical conductivity results.
- Soil samples were also taken at three depths (0-10 cm, 20-40 cm and 40-60 cm) at four sites with differing EM38 results, to relate EM38 information to key soil properties such as moisture content, subsoil constraints, phosphorus (P) levels, and PBI (the extent to which P is tied up in soils and unavailable to plants).
- To investigate how wheat performs with different input levels in the paddock, test strips were set up spanning a range of soil types as follows (see Fig 1):
  - 25% less seed (seeding rate 30kg/ha rather than standard 40kg/ha)
  - 25% more seed (seeding rate 50kg/ha rather than standard 40kg/ha)
  - 40% less fertiliser (base fertiliser at 30kg/ha rather than standard 50kg/ha)
  - 40% more fertiliser (base fertiliser at 70kg/ha rather than standard 50kg/ha)
  - double sowing along a sandhill (100kg/ha base fertiliser and 80kg/ha seeding rate).
- All other agronomic details were as per district 'best practice'.
- Over the course of the 2023 growing season, the following agronomic data were collected:
  - plant counts, assessed by counting plant numbers along twenty 1 m row lengths in each test strip
  - yield, assessed by harvesting each test strip and weighing grain
  - ground cover, assessed using a Levy point sampler to assess vegetation touch points at twenty random locations in each plot in summer and early autumn.

RESULTS

- EM38 mapping showed that soils vary greatly across the Charles' paddocks (Fig 1). Red areas indicate deeper sands, while the blue and purple areas show heavier soils more likely to have subsoil constraints. The numbers in Figure 1 show sites used for soil tests.
- Key results of soil tests (0-10cm) are shown in Table 1. Full details of soil tests are included in Appendix A.
- In brief:
  - There was great variation in P levels and PBI across the paddock. P was marginal at sites 3 and 1, where Colwell P is lower than target levels for that PBI class.
  - Soil pH was in the expected range, but was highest at site 3, where PBI was also highest, which is expected (high levels of $CaCO_3$ lead to alkalinity and P tie-up).
  - Nitrogen levels were fairly consistent across the paddock, enough for close to 2 t/ha, except at site 4 where subsoil constraints may have reduced N availability.

Table 1. Key soil test results (0-10cm) from the 4 sites on the Charles' property.

Site	Colwell P	PBI	Target Colwell P*	Colwell P Balance	pH (CaCl)	Nitrogen	Yield N Potential **
1	16	13	13	3	7.2	74	1.9
2	20	58	23	-3	7.6	90	2.3
3	15	74	25	-10	7.9	72	1.8
4	24	37	19	5	7.3	67***	1.7

*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 potential = N (kg/ha)/40].
*** At site 4, high sodicity, salinity and pH in the subsoil is likely preventing plant roots extracting moisture and nutrients from > 40cm (see Appendix A).

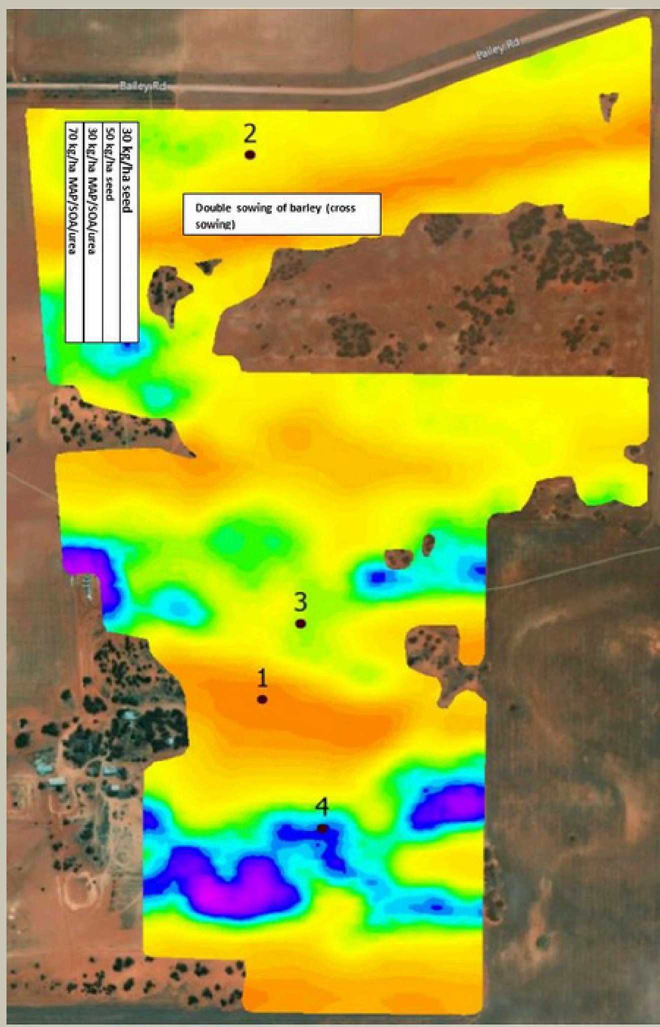


Figure 1. Deep EM38 map with soil test sites, and trial strips on the Charles' property. Red areas are deep sandy soils, generally on hills, blues and purples are the heavier soils, and greens and yellows are the intermediate 'mid-slope' soils.

RESULTS CONT..

- There was a strong relationship between EM38 and moisture availability (based on crop lower limit, the minimum amount of water in the soil that a crop can tolerate without experiencing water stress; Fig. 2), indicating EM38 mapping is highly suitable for zoning these soils.
- The 2023 growing season was uncharacteristically wet in May and June, then drier than average in August and September. Key agronomic results were as follows (Table 2):
  - Plant numbers were proportional to seeding rate, as expected.
  - Reducing sowing rates by 25% led to slightly lower grain yields (2.0 t/ha compared to 2.2-2.4 t/ha), but increasing seeding rates by 25% did not increase grain yields, and may have slightly lowered them (2.2 t/ha compared to 2.3 t/ha paddock average).
  - There was no obvious response to higher base fertliser across the test strips.
  - Higher seed and fertiliser rates led to slightly better levels of ground cover(more vegetation touch points, e.g., see Fig. 3) .
  - Double sowing on top of a sandhill did lead to obviously higher plant density and improved ground cover (Fig. 4) – this area was not harvested to protect against erosion.
- Based on EM38, soil testing and test strips, three zones were identified for potential VRT in the study paddock in future (Fig. 5).

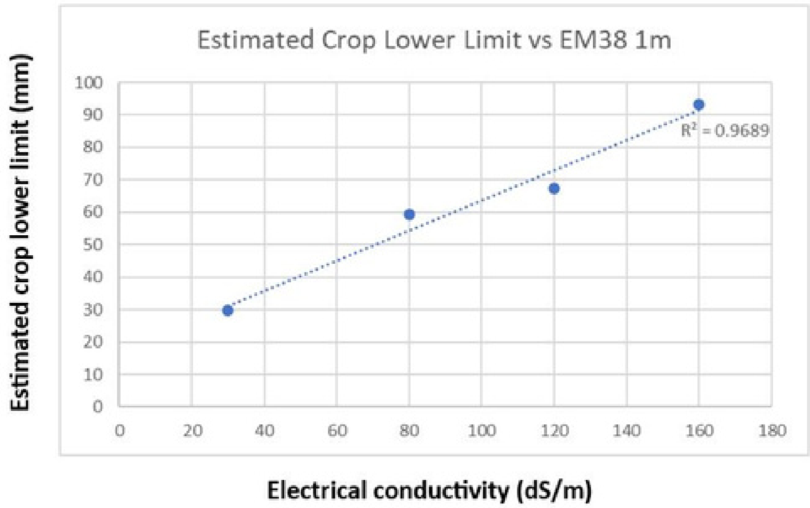


Figure 2. Relationship between EM38 and crop lower limit – low EM38 values are associated with soils that 'give up' stored moisture to plants, while high EM38 values are associated with soils that hold on to moisture.

Figure 4. Double sown barley on a sandhill at Bambill.

Table 2. Plant counts, grain yield and ground cover (as assessed using a Levy Point Sampler) **across the different test strips.**

Treatment	Plants/m2	Grain yield (t/ha)	Ground cover (touch points, Levy Point sampler), Dec 2023
30 kg/ha seed	40	2.02	4.6
50 kg/ha seed	62	2.18	5.0
30 kg/ha base fert	49	2.35	4.5
70 kg/ha based fert	49	2.34	5.0
Double sowing	83	-	5.5
Farmer practice (40 kg/ha seed, 50 kg/ha fert)	49	2.30	4.7

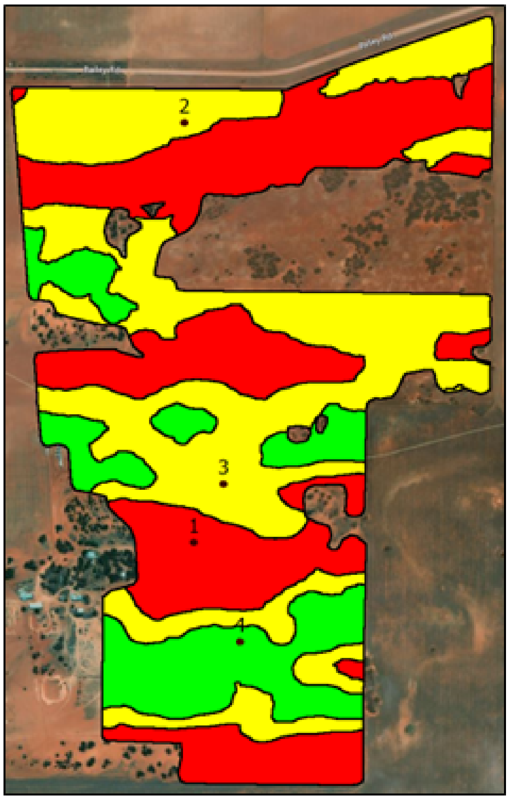


Figure 5. Potential zone map – three zones are shown, lighter sandhills (red), mid-slope (yellow), and heavier, more constrained soils (green).

Figure 3. Plots at the Charles' demonstration site at time of groundcover assessment, Dec 2023.

DISCUSSION AND NEXT STEPS

- EM38 results were confirmed to correlate well with crop lower limit and soil type, and therefore provide a great starting point for soil mapping and the testing of different soil types. 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 in a single year.

- Results highlighted the importance of considering PBI when interpreting soil P, since target P levels vary so much with PBI. Since some soil types were marginal for P, P levels should be monitored and increased if multiple good harvests are achieved.

- If VRT is adopted, more base fertiliser (e.g. 60 kg/ha) should be applied in the red and yellow areas of Figure 2 to replace likely nutrient removal from these non-constrained areas. It may also be profitable to increase P fertiliser levels on high PBI soils (e.g. site 3) that appear otherwise unconstrained, though this should be tested with trial strips targeting this soil type.

- Further test strips with more and less fertiliser, in other seasons, are required to understand the best way to manage soils such as in site 4, which have subsoil constraints (sodicity, salinity and high pH) – such areas may ultimately prove to be riskier to crop, in which case reducing inputs may be the best approach to reducing risk and increasing profitability.

- In future, it would be interesting to harvest test strips on the Charles' property using a harvester fitted with yield monitoring equipment, so that grain yield can be assessed at a finer scale in strips running across different soil types.

- An additional treatment that could be explored would be to vary levels of N fertiliser, with the expectation that sands and sandy loams may respond to higher N rates. It may also be worth exploring higher seeding rates on sandy soils – preliminary results from other sites in the Millewa in 2023 showed higher seeding rates did boost wheat yields on light soils.

- Though EM38 worked well in this study, there are other approaches to zoning that could be explored, including yield maps and satellite-based maps (e.g. NDVI, Google Earth). These would likely be less precise, but do offer a cheaper approach than EM38 that may suit some farms.

- Double sowing of sandhills was an effective way of building groundcover on erosion prone hills and is a simple practice that can be broadly recommended to reduce erosion risks in the Millewa.

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

This project is supported by the Mallee Catchment Management Authority, through funding from the Australian Government's Future Drought Fund.

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 Charles' paddock.

Appendix A. Soil test results from four sites in paddock.

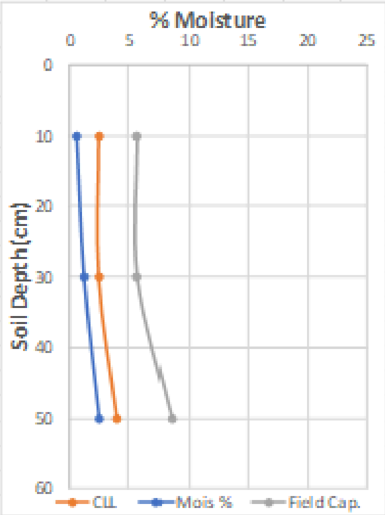
SITE	1	EM38 1m	30	EM38 0.5m	1

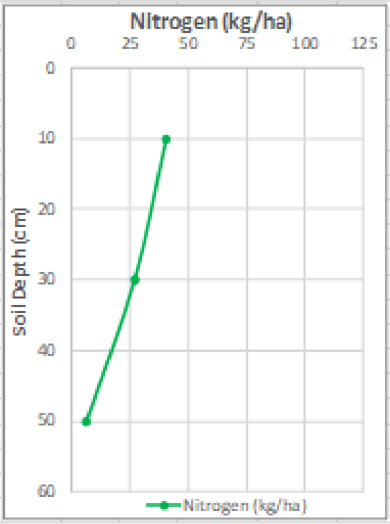
Topsoil Results			
Col. P	PBI	Col. K	Org. C%
16	13.4	186	0.2

Soil Depth	Soil Texture	Total Moisture (mm)	PAW Estimate	Nitrogen (kg)
0-20	S	2	-6	41
20-40	S	4	-4	27
40-60	LS	8	-5	6
	Totals	14	-15	74

Soil Depth	Chemical Constraints EC	pH (CaCl)	pH (H2O)	
0-20	0.101	7.2	8.7	Boron
20-40	0.065	7.8	9.1	0.39
40-60	0.069	8.2	9.3	0.4

Subsoil Contraints - 40-60cm					
Ex. Ca.	Ex. K	Ex. Mg	Ex. Na	CEC	ESP
4.24	0.16	0.45	0.1	4.95	2.02





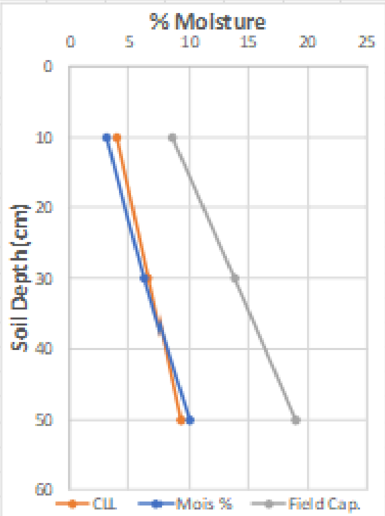
SITE	2	EM38 1m	80	EM38 0.5m	34

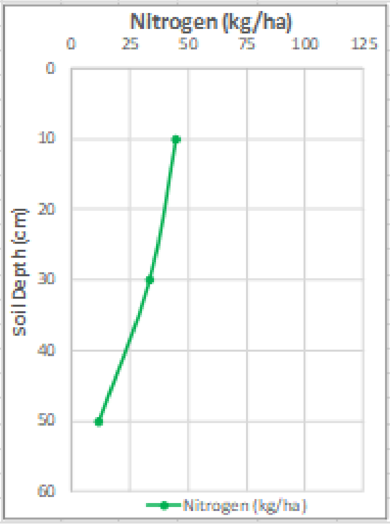
Topsoil Results			
Col. P	PBI	Col. K	Org. C%
20	58.2	429	0.3

Soil Depth	Soil Texture	Total Moisture (mm)	PAW Estimate	Nitrogen (kg)
0-20	LS	10	-3	45
20-40	LSCL	18	-1	34
40-60	CL	30	2	12
	Totals	58	-1	90

Soil Depth	Chemical Constraints EC	pH (CaCl)	pH (H2O)	
0-20	0.114	7.6	8.7	Boron
20-40	0.114	7.8	8.8	1.3
40-60	0.22	7.8	9.7	2.83

Subsoil Contraints - 40-60cm					
Ex. Ca.	Ex. K	Ex. Mg	Ex. Na	CEC	ESP
7.9	0.25	3.14	0.43	11.72	3.67





SITE	3	EM38 1m	120	EM38 0.5m	45

Topsoil Results			
Col. P	PBI	Col. K	Org. C%
15	73.9	405	0.5

Soil Depth	Soil Texture	Total Moisture (mm)	PAW Estimate	Nitrogen (kg)
0-20	LS	10	-3	32
20-40	SCL	18	-6	25
40-60	CL	26	-4	15
	Totals	54	-13	72

Soil Depth	Chemical Constraints EC	pH (CaCl)	pH (H2O)	
0-20	0.124	7.9	8.9	Boron
20-40	0.157	8	9.4	1.22
40-60	0.394	8.1	10.1	3.62

Subsoil Contraints - 40-60cm					
Ex. Ca.	Ex. K	Ex. Mg	Ex. Na	CEC	ESP
5.94	0.26	2.25	0.33	8.78	3.76