Improving land management decisions through a better understanding of factors limiting production

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Take Home Message

- EM38 surveys need to be calibrated through soil testing to identify areas with subsoil constraints.
- Simulated wheat yields using historical rainfall data demonstrated the effects of soil type and subsoil limitations on potential crop yields and recharge.
- Variable rate technology for fertiliser could optimise returns for paddocks with subsoil limitations.

Aims

1. Identify within paddock variability (subsoil limitations) and its effects on production and recharge.
2. Identify different paddock 'zones' and the effect of rainfall (amount and distribution) on production.

Introduction

Within paddock variability

Farmers are aware of soil type variability and its effects on yield in their paddocks. Paddocks managed as a whole result in some parts of the paddock being over supplied with inputs and other parts under supplied. The result is an averaging of income and input costs - not the optimum potential return from the paddock. With relatively cheap GPS and Precision Farming equipment we now have the technology to identify areas in a paddock which yield differently and to match crop needs to potential production.

Subsoil constraints – affecting the 'size of the bucket'

In the Birchip region paddock variability in yield is often due to subsoil limitations caused by high levels of EC (electrical conductivity - a measure of salts); Chlorides (the salt, sodium chloride); Boron (a toxic element in high concentrations); and sodicity (high sodium levels in relation to calcium and magnesium ions).

Colloquially these factors combined effect what is known as the size of the bucket. Plants growing in a soil with a large deep bucket (no constraints to root growth) have a higher yield potential compared to plants growing in a soil with a small shallow bucket (subsoil limitations that are affecting the rooting depth).

This effect is exacerbated in years with low spring rainfall. September and October are critical months for crops at the peak of their vegetative growth. Temperatures are rising resulting in high levels of transpiration and evaporation. In early October a wheat crop might use 5 to 7mm of moisture per day. If there is a dry period during this time and the soil cannot supply enough moisture the crops will wilt and yield is reduced.

Climate and Recharge risk

During winter (June, July, August) average monthly rainfall is high and rainfall variability is low but in the critical spring months of September and October rainfall variability is high.

Spring rain is often lacking and the crops are dependent on soil stored moisture to supply their water requirements. Subsoil limitations restrict root growth and water extraction by the plant. These soils cannot supply much water to the crop for production and they get saturated and leak rapidly in wet seasons which can contribute to elevated water tables and salinity.

Methods

In January 2004, two paddocks were randomly soil sampled with 30 cores taken at four depth increments (0-10, 10-40, 40-70, 70-100cm) to investigate soil water and chemical variability across the paddock. Paddocks were Sunnyside and Smith P9, located west of Birchip. Extensive soil sampling, soil water characteristics, EM38 survey, crop and root measurements were undertaken throughout the year.

The APSIM crop simulation model was characterised for each soil type and yield, runoff and recharge was simulated using historical rainfall information for each production zone. The model was run continuously over 100 years which allows for summer rainfall and different sowing soil water contents for each cropping season.

Results

(i) Results of intensive soil sampling

Each soil sample was analysed for soil pH, EC, soil nitrate and soil water. The 40-70cm layer was analysed for cations (Ca, Mg, K and Na) to determine ESP (Exchangeable Sodium Percentage) - a measurement of soil sodicity. This layer was analysed for ESP as generally subsoil constraints become apparent at this soil depth.

Soil Nitrate and Soil Water

Soil water and nitrate was measured in four soil layers. These are critical measures for determining yield potential, production risk and N fertiliser requirements. Many farmers measure soil water and nitrate before sowing but rarely know how many cores need to be sampled to provide an accurate representation of the paddock. 30 cores were taken across each paddock to determine variability in soil nitrate and soil water values. The number of sample points can be decided for different levels of accuracy (Table 1).

Table 1: Number of soil cores required for varying accuracy around the mean for soil nitrate and water.

Error (% of mean)	Number of soil cores required			
	0-100cm soil nitrate (ppm)		0-100cm soil water (gravimetric %)	
	Sunnyside	Smith	Sunnyside	Smith
5	>300	275	79	34
10	107	73	23	11
20	29	20	8	5
30	14	11	5	4
50	7	6	4	3
100	4	4	3	3

Mean nitrate: 6.5 and 3.4ppm; Mean soil water: 16.1 and 17.8% for Sunnyside and Smith respectively.

Example: to determine how many cores to take for soil nitrate at Sunnyside (mean soil nitrate 0-100cm is 6.5ppm) to be within 10% of the mean with 95% probability 107 soil cores would need to be sampled.

An error rate of around 20 to 30% of the mean will still give a valid interpretation of soil water and nitrate. If a 30% error is accepted then a more realistic number of cores needs to be taken (11 to 14 cores for soil nitrate; and 4 to 5 cores for soil water) (see shaded area on Table 1).

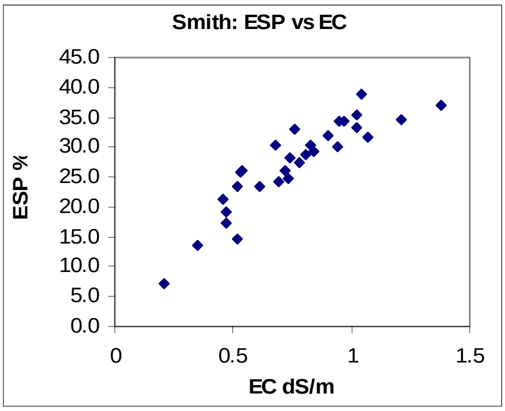
Subsoil constraints

Subsoil constraints assessed were EC (Electrical Conductivity- measure of salt) and sodicity (% of sodium (Na) to the other cations (Ca, Mg and K). EC values of greater than 0.68 dS/m and/or Sodicity over 15% are the critical values where root growth and water taken up by plants is starting to decrease.

Sunnyside and Smith EC ranges were 0.13 to 0.46 dS/m (0-10cm), to 0.19 to 1.44 dS/m (70-100cm)

At Sunnyside 48% and Smith 60% of samples were above EC critical value of 0.68dS/m at 40-70cm. Sodicity levels were high in 40 to 70cm samples at both sites. Sunnyside, 66% and Smith 90% were above 15% ESP.

There was a close relationship between EC and sodicity in the 40 to 70cm layer at both sites (see Figure 1) For southern Mallee soils with the same geological origin, the relationship between EC, sodicity, chloride and boron is closely correlated. To measure the extent of subsoil limitations on this soil type it is possible to just measure EC, (Note: this only applies to this soil type, on other soils in other regions, notably those with high gypsum, this relationship may not apply).



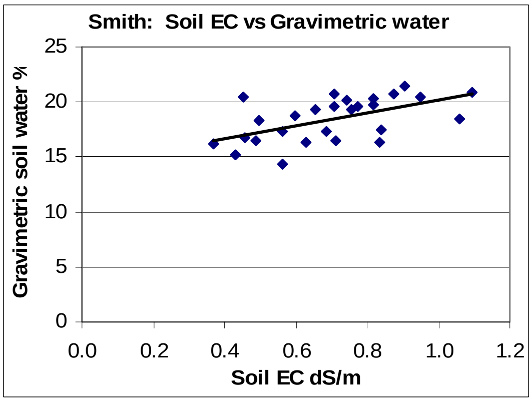


Figure 1: Smith correlations between EM survey vs EC (0-60cm) and EC (dS/m) vs Gravimetric soil water (%)

Subsoil constraints and soil water

Subsoil constraints reduce root development and uptake of water. Soils with high subsoil limitations are generally low production zones with wetter soil and therefore are more susceptible to deep drainage.

At both Sunnyside and Smith there was a correlation between subsoil constraints, as measured by soil EC, and soil water (Figure 1). Generally the higher the soil EC the higher the soil water content of the soil.

(ii) EM38 mapping and soil type differentiation

The two paddocks were EM38 surveyed on 6/5/2004. Conditions before and during the survey were very dry.

The EM technique measures the conductivity in the soil to a depth of 1.5m which is related to, EC of the soil (electrical conductivity as a measurement of salts), soil water and clay content of the soil.

A positive correlation between the EM survey and soil EC was found at Smith, but not at Sunnyside (Figure 2).

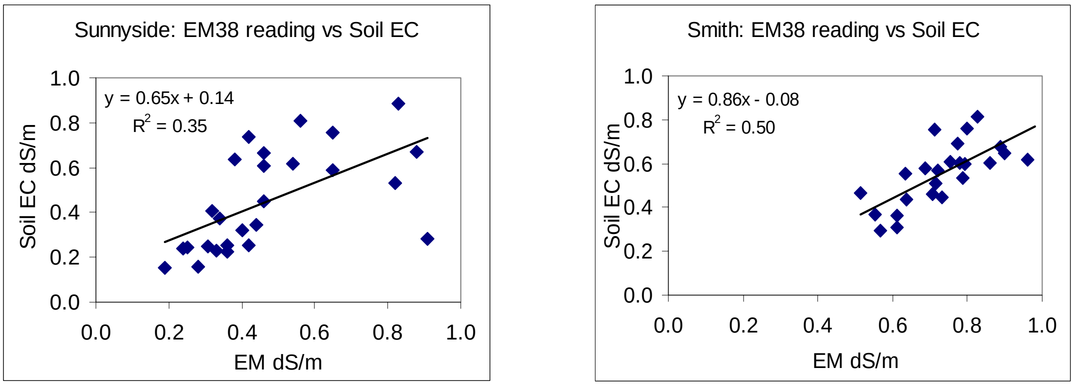


Figure 2: Correlation between EM survey and soil EC (0-60cm) at Sunnyside and Smith.

Soil type characteristics

Distinct soil types were identified across each paddock with differing soil properties critical for root development and crop growth. The most critical properties were texture (clay content) and soil EC.

The Smith paddock EM survey and intensive soil sampling identified three distinct soil types - Mallee Clay Loam, Mallee Sandy Clay Loam and Grey Clay. The Mallee Clay Loam soil type was further separated into two zones moderate and high subsoil limitations (Figure 3). The Grey Clay soil was only 5% of the paddock so this soil type is not presented in the results.

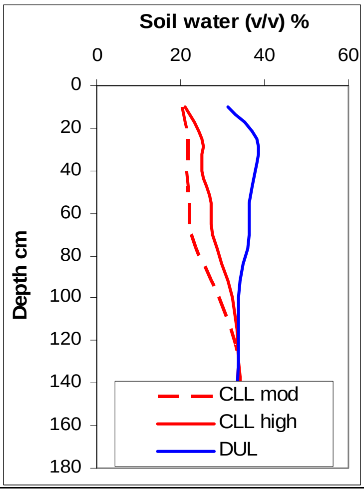
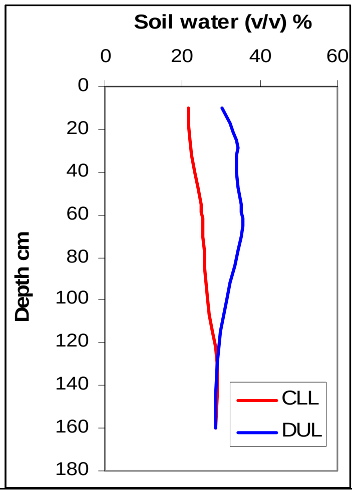
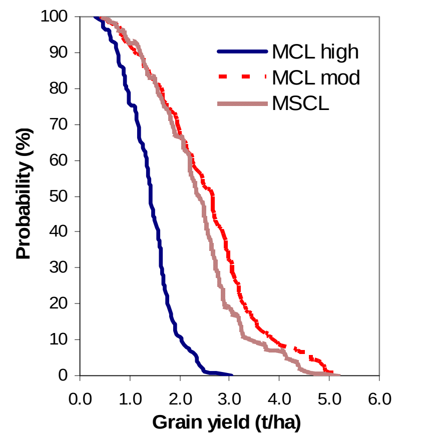
Mallee Clay Loam	Mallee Sandy Clay Loam	Smith
		
Two levels of subsoil constraints (i) moderate; and (ii) high. Total area in paddock: 55% (with approximately half in each zone with constraints) PAWC mod: 106mm PAWC high: 78mm Clay loam in the topsoil, with an increasing clay content down the soil profile	Area in paddock: 40% PAWC: 107mm Sandy clay loam in the topsoil, higher clay content in the deeper susbsoil, also more limestone in the subsoil.	

Figure 3: Description of soil types and 100 year simulation run for each main soil type in the Smith paddock. PAWC (Plant Available Waterholding Capacity) calculated for each soil type and extent of subsoil limitations.

(iii) Simulation of crop production over 100 years

Simulation runs for Smith paddock yield, using 100 years of historical local rainfall data, were done for each of the soil types (Figure 3). For the simulations the sowing date was set to 15mm of rain over a three day period from May to July; and N fertiliser was applied to be non-limiting.

There were large differences found in production between different soil types and subsoil limitations. The Mallee clay loam (MCL) with moderate constraints had an average yield of 2.5t/ha; the MCL with high constraints had an average yield of 1.4t/ha. The sandier soil (Mallee Sandy Clay Loam) had an average yield of 2.4t/ha. Although the sandier soil had low subsoil constraints, wheat yields were restricted because the soils hold less water and drain faster (lower Drained Upper Limit) than soils with higher clay contents.

Production in relation to rainfall in Spring

Spring rainfall is critical for production in the southern Mallee and 20% of years have low spring rainfall. The impact of a dry Spring after a dry or wet summer for each of the main soil types was simulated in both paddocks. Yields were simulated for each soil zone for years with less than 36mm of rain during spring (less than half of average September/October rainfall) Results of the Smith paddock are presented. (Table 2).

Table 2: Smith -average, minimum and maximum yield for three soil zones in years with a dry spring (<36mm Sept+Oct) following a wet or dry summer.

Crop Yield t/ha	**MCL Mod Constraints**		**MCL High Constraints**		**MSCL**	
	Wet summer	**Dry summer**	**Wet summer**	**Dry summer**	**Wet summer**	**Dry summer**
Average	1.72	1.39	0.92	0.86	1.39	1.32
Minimum	0.94	0.42	0.46	0.31	0.68	0.48
Maximum**	2.90	2.90	1.63	1.63	2.47	2.50

**year with a dry spring, but a wet winter from May to August

The 'size of the bucket' is clearly demonstrated in this example of the impact of a dry spring on production. Mallee Sandy Clay Loams cannot store much water following a wet summer and yields after a wet or dry summer were similar. Mallee Clay Loams with Moderate Constraints performed, on average, 0.4 t/ha better after a wet summer than after a dry summer – indicating that the soil bucket can store enough water for a dry spring. Mallee Clay Loams with High Constraints performed poorly regardless of whether the crop followed a dry or wet summer – indicating that the soil bucket cannot store enough water for a crop in a dry spring.
In years with a wet spring (> 98mm of rain in Sept+Oct) it made no difference if it followed a wet or dry summer. On Mallee Clay Loams with Moderate Constraints the average yield was 3.6t/ha; and with High Constraints the average yield was 1.8t/ha regardless of a dry or wet summer prior to cropping. The Mallee Sandy Clay Loam soil yielded on average 3.3 t/ha regardless of whether there had been a dry or wet summer.

Soil types and recharge
Water by-passing the rooting system of a crop, or recharge, is water lost to production and added to the water table. This can result in a salinity problem somewhere in the landscape The simulation model was run for 100 years of historical rainfall for a continuous wheat rotation without disease or weeds in the crop, or over the summer fallow period and with sufficient N fertiliser to approximate optimal production. We found large differences in recharge between the soil types in both paddocks. Smith results (Table 2).

Table 2: Smith - Simulated recharge on three soil types. * % years with more than 5mm per annum recharge

	MCL Mod Constraints	**MCL High Constraints**	**Mallee Sandy clay loam**
Avg. annual recharge mm	28	49	35
Frequency >5mm p.a.**	53%	76%	60%
Max recharge - mm (year)	129 (1909)	157 (1973)	140 (1909)

Discussion

EMI as a tool to differentiate soil conditions and limitations to production

The EM38 survey measures - soil electrical conductivity (EC), soil texture (clay content) and soil water (how much water is in the soil at the time of the survey. Because these three factors interact the EM survey must be calibrated against measured soil values for these three factors (EC, clay content and soil water) at the time the survey is carried out. It is not a stand alone technique to identify areas of poor production potential .

Subsoil constraints and long term yield and production risk

APSIM simulations demonstrated the large impact of subsoil constraints on production. At Smiths the high subsoil limitations reduced crop yield by 1.1 t/ha compared to the moderate subsoil limitations (yield of 1.4t/ha versus 2.5t/ha respectively). At Sunnyside subsoil constraints reduced median yield by 1.25t/ha. The reductions in yield resulted from the reduced size of ‘the bucket’.

The impact on production and recharge of the ‘size of the bucket’ (soil texture and subsoil limitations) was demonstrated with the dry spring and recharge simulations. The more severe the subsoil constraints, the greater the impact on the ‘size of the bucket’, resulting in severe limitations to yield if rainfall during these critical two months is limiting and a much higher risk of recharge occurring during wet periods.

Subsoil constraints and crop selection

Wheat and barley are more tolerant to subsoil constraints compared to canola, field peas and lentils. In the southern Mallee Lentils are the most sensitive crop to subsoil constraints.

Short lucerne phases (2 to 3 years) or medic pastures have the potential to dry out the deeper subsoils. At the BCG systems site, medics dried the soil down to levels lower than wheat and other crops, and it is possible that these types of pastures can assist in reducing the recharge potential.

Commercial Practice

- Calibration of the EM survey is necessary to assess the severity of subsoil constraints.
- Areas with high subsoil constraints are susceptible to low yield potential in dry springs.
- Variable rate technology for P and N fertiliser should be investigated to optimise income potential
- Pulses (lentils) are very sensitive to high subsoil constraints and should not be grown in these zones.
- Fallowing will not buffer the impact of low winter or spring rainfall if the ‘bucket is too small’ to effectively store enough water for crop growth in spring. Fallowing also increases recharge potential.
- Recharge potential is higher on soils with severe subsoil limitations than low subsoil limitations
- Lucerne and medic pastures may help to dry out the subsoil and reduce recharge potential.

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