

Detecting subsoil constraints on farms in the Murray Mallee

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Abstract

Mobile electromagnetic (EM) induction technology coupled with accurate global positioning system (GPS) equipment offers realistic economic opportunities to map out areas of farms that are affected by subsoil constraints since electrical conductivity is well correlated with high soil water and salt content. We examined the technical feasibility of using mobile EM38 with GPS to map out suspect subsoil constraints on four farms across the Murray Mallee (Balranald, Swan Reach, Waikerie and Walpeup). Different data loggers required different speed calibrations. Strong relationships between soil water ($R^2=0.61-0.93$; $RMSE=0.02 \text{ Mg/m}^3$), chloride ($R^2=0.71-0.95$; $RMSE=35-248 \text{ g/m}^3$) and to a lesser extent boron ($R^2=0.55-0.83$; $RMSE=1.2-3.1 \text{ g/m}^3$) were found with EM38 measurements and large areas of the fields at Balranald and Walpeup were discovered to have substantial subsoil constraints. At Swan Reach linear relationships between EM38 measurements and yield maps varied from year to year from poor (wheat in 2001, $R^2=0.08$) to moderate (barley in 1999, $R^2=0.25$ and Triticale in 2000, $R^2=0.31$). A stronger relationship occurred between barley in 1999 and triticale in 2000 with $R^2=0.52$. Analysed together, a collection of yield and EM38 maps and simulation models, this technology offers significant advances to help farmers identify and manage subsoil constraints on a spatial basis in individual fields.

Key Words

EC, high pH, precision agriculture, rooting depth

Introduction

Recent studies in the Mallee region of Australia have raised the question of how to identify and manage constraints to crop production that relate to factors in the soil limiting root growth, water use and grain yield. These constraints have been both physical (e.g. compaction) and chemical in nature with the chemical constraints typically associated with high pH. Those soils of the Mallee that have high pH typically exhibit high salt and boron and crops often do not extract all the apparent available water by harvest. The variable nature of subsoil constraints across farm fields has been long recognised but little progress has been made in identifying and managing this variation for profitable outcomes. One of the reasons for this is the very high cost of grid sampling the soil to test for possible constraints. However, strong correlations exist between the various subsoil constraints and this has led to single factors (e.g. ESP or salt) being used to measure spatial variation (1,2). This correlation is the basis for the use of electromagnetic (EM) induction technology in agricultural resource management (3). Such technology provides measurements of bulk soil electrical conductivity. Mobile EM38 coupled with accurate global positioning system (GPS) equipment offers more realistic economic opportunities to map out areas of farms that are affected by subsoil constraints that are related to high salt, since electrical conductivity is well correlated with soil water and salt content. This is particularly encouraging for regions like the Mallee where high salt and poor water use of crops is widespread. Those soils of the Mallee that have high pH typically exhibit high boron and salt and crops often do not extract all the apparent available water by harvest (2,4). We examined the technical feasibility of using mobile EM to map out suspect subsoil constraints on four fields across the Murray Mallee.

Methods

Experimental sites

We selected four farm fields (40-100 ha) that had a history of yield maps and the farmers had intentions of continuing to map crop yield for subsequent crops across the Mallee Sustainable Farming Project region of the Murray Mallee (2). These were located near Balranald (lat. S 34° 45', Long. E 143° 27', elev. 78 m), Swan Reach (lat. S 34° 32', Long. E 139° 45', elev. 50 m), Waikerie (lat. S 34° 17', Long. E 140° 2', elev. 62 m) and Walpeup (lat. S 35° 07', Long. E 141° 59', elev. 85 m).

Yield and EM38 mapping

Yield and position data were obtained from all farms from Case IH/AgLeader yield monitoring equipment. Geonics EM38 data (vertical and horizontal dipole) were collected after harvest (except at Walpeup) by a mobile data logging system supplied by contractors. One contractor used an OmniStar differential corrected Trimble GPS/TSC1 data logger whilst the other used an OmniStar differential corrected Fugro GPS/Fujitsu Stylistic 1200 Logging system. Transects were made at 10 m spacings and data collected at nominally 1 s intervals. Since the GPS antenna cannot be placed above the EM sensor, because of electrical interference to the EM signal, all data was position corrected for antenna offset (distance and velocity). The Geocentric Datum of Australia (GDA94) grid was used for all comparative map and statistical analyses. Position corrected EM38 data was kriged to a 5 x 5 m and 10 x 10 m grid with the Software Vesper V1.0c (5). We employed a punctual (point) spherical model with a local variogram using a minimum of 90 and maximum of 150 data points per grid estimate. The kriging interpolation provides estimates of the grid mean and variance. Crop yield data was kriged to a 10 x 10 m grid with the same model for EM38 but with 10 x 10 m block kriging procedure as this approximated the area supported by the yield measurements. The 10 x 10 m kriged grid was used for all statistical comparisons with other kriged data at these grid points while the 5 x 5 m grid EM38 data was used to print maps and locate points for further measurements of interest.

Soil analyses

Soil water, chloride and boron (hot CaCl₂) contents were determined together with soil EC (1:5 extract) and pH (water and CaCl₂) from selected positions determined from the EM38 map. The positions were selected to cover the full range of EM38 measurements. Individual or duplicate soil samples were taken with a 50 mm diameter core sampler at 20 cm intervals to 2 m at each site.

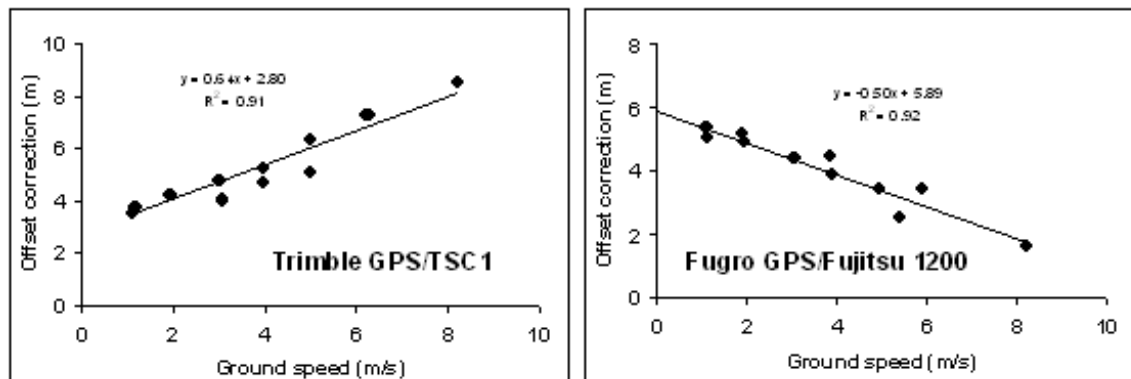


Figure 1: Antenna offset correction for two GPS-EM Logging systems.

Results

Mobile EM38 data acquisition

An essential requirement for mobile EM measurement was the need to correct for antenna offset. Figure 1 shows the offset correction needed for each data logger. The Trimble GPS/TSC1 data logger's acquisition time was 0.64 s and the zero speed offset was 2.8 m while the Fugro GPS/Fujitsu 1200 data

logger was -0.50 s and the zero speed offset was 5.89 m. The importance of individual speed calibration for each logging system is obvious.

EM38 Calibration against soil measurements

Calibration accuracy of EM38 measurement against, vertical and horizontal, weighted profile soil measurement varied from site to site, but high Coefficients of Determination (R^2) and low Root Mean Square Error of the residuals (RMSE) were achieved at all sites where high soil EC was measured (Table 1).

Table 1. Coefficient of Determination (R^2) and Root Mean Square Error of the residuals (RMSE) for calibration of EM38 in the vertical mode for soil EC, water, chloride and boron content at each site.

Site	EC(1:5) dS/m		Water (Mg/m ³)		Chloride (g/m ³)		Boron (g/m ³)	
	R^2	RMSE	R^2	RMSE	R^2	RMSE	R^2	RMSE
Balranald	0.96	0.15	0.93	0.02	0.95	248	0.67	3.1
Swan Reach	0.44	0.06	0.61	0.02	0.71	35	0.55	1.2
Waikerie	0.85	0.11	0.72	0.02	0.78	156	0.81	2.3
Walpeup	0.86	0.09	0.88	0.02	0.93	92	0.83	2.5

At Swan Reach where the poorest calibrations were obtained all soil measurements were very low. No significant relationship was observed with pH. Linear calibrations obtained highest R^2 for EC(1:5) and soil boron content whilst curvilinear calibrations achieved significant higher R^2 for soil water and chloride content with each inversely related. This is not unexpected since EM is related to both soil water and salt content, such that the relationship with soil EC is linear.

Locating the spatial extent of subsoil constraints

The strategy of measuring soil water and chloride after harvest in nominally dry conditions with EM38 helps identify spatially where subsoil constraints occur, provided the crops matured into a terminal drought. This is because the most common constraint in the Murray Mallee is salt and is associated with a high water content because of its osmotic potential. Thus where, EM38 readings are high (>0.6 dS/m, 4) the water content at this location will reflect both the matric (clay) and osmotic (salt) water potentials and should be a direct measure of the lower limit of extraction of the preceding crop. Where salt is not high the water content will represent the matric potential only.

Thus, using spatial maps of soil EC, chloride or boron together with soil water content we can identify potential areas of subsoil constraints in farm fields. Only one site (Balranald) had extensive areas above 0.6 dS/m with marginal areas identified at Walpeup and very little evidence of high salt at the Waikerie or Swan Reach sites (data not shown).

Relationships between EM38 and yield maps

Preliminary yield analyses at one site (Swan Reach) show that linear relationships between EM38 and yield maps varied from year to year from poor (wheat in 2001, $R^2=0.08$) to moderate (barley in 1999,

$R^2=0.25$ and Triticale in 2000, $R^2=0.31$) (Figure 2). A stronger relationship occurred between barley in 1999 and triticale in 2000 with $R^2=0.52$. Since no significant subsoil constraints were present at Swan Reach weak relationships are expected, as the key factors would be temporal in nature. Indeed, the poor relationship between EM38 and wheat yield in 2001 will be partly due to the low EM38 areas being treated differently. Here, the farmer added more fertiliser and seed to this area in an attempt to overcome the very low (near zero) yield seen in previous years (e.g. barley in 1999). We plan to complete our analysis of the remaining sites and include more sites where subsoil constraints are greater and utilise simulation models to help remove the temporal effects of weather and management.

Conclusion

Progress to date is encouraging, as it is now possible to spatially identify subsoil constraints that are correlated with EM38 measurements at a sub-paddock scale. It is important that correction for antenna offset for speed is made and calibration with soil properties is made for each field because of different soil and management history. By measuring EM38 at harvest, where crop maturity occurs under terminal drought, maps of soil water lower limit of extraction can be made. Such maps can provide soil water extraction limits for application of simulation models on a spatial basis where the temporal effects of weather and management may be considered.

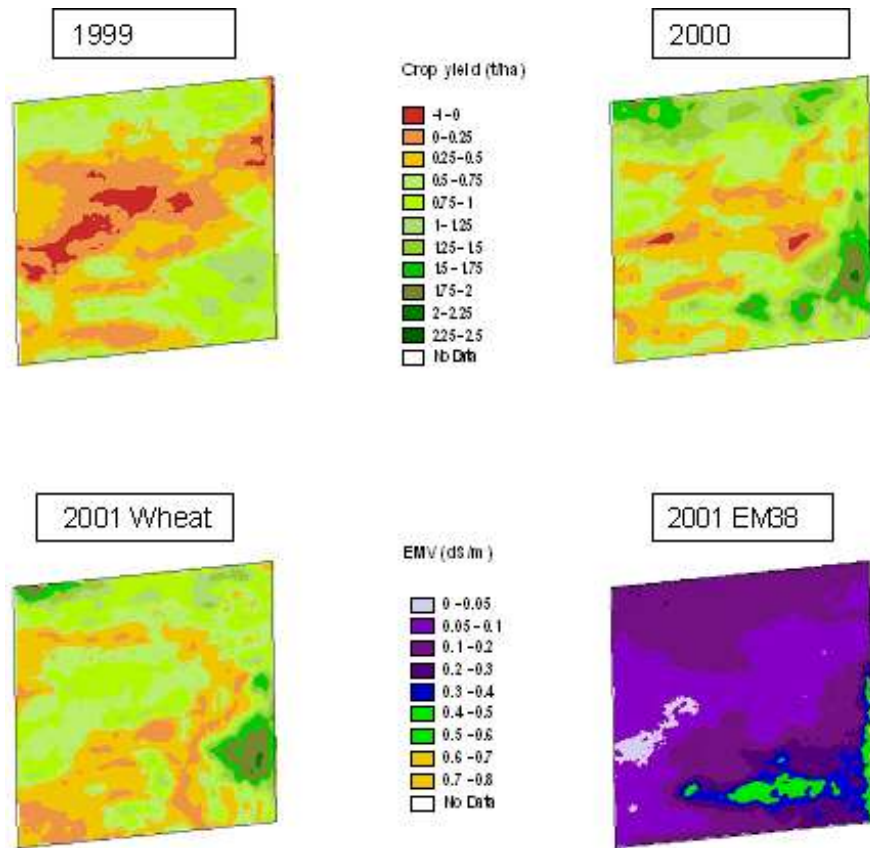


Figure 2. Yield and EM38 (vertical dipole) maps from the same 50ha field at Swan Reach showing areas of low and high yield between crops in relation to EM38 measurements.

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