Variable rate prescription mapping for lime inputs based on electromagnetic surveying and deep soil testing

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KEY MESSAGES

Soil acidity is recognised as a major limiting constraint to crop productivity in Western Australia (DAFWA, 2006). Electromagnetic induction (EM) surveying is starting to be recognised as a reliable tool for mapping soil changes within paddocks across the WA wheatbelt. Electromagnetic induction surveys measure apparent electroconductivity (ECa), which is primarily influenced by soil salinity, moisture and clay content (Lesch et al., 2005). A strong relationship between soil pH and ECa was observed and used to develop variable rate prescription maps for lime application.

AIMS

This study sought to identify whether electromagnetic data with ground-truthing at a density of 0.025 samples/ha could be used to determine changes in soil pH across the landscape with the aim of developing variable rate prescription maps for lime application.

METHOD

The study area (324ha) is located approximately 23km southeast of Tambellup (480mm annual rainfall) and is situated within a landscape predominantly consisting of middle and upper slopes and broad hillcrests. Soils consisting of grey shallow sandy and loamy duplexes, including soils with alkaline subsoils and grey deep sandy duplex soils. The lower parts of the survey area (i.e. <~260m ASL) are situated within a landscape consisting of minor drainage depressions dominated by generally shallow grey sandy duplex soils with outcrops of granite and dolerite and minor areas of red duplex soils (Stuart-Street and Marold, in press).

Geophysical data

Apparent electroconductivity was measured with a Geonics DUALEM38 instrument that integrated ECa measurements over 0-50cm (shallow) and 0-150cm (deep) depth intervals. These data were gathered at a sampling density of approximately 60 readings/ha. Interpolated surfaces were created by Precision Cropping Technologies using the Kriging method. Processed data were analysed using Viewpoint II, a Geographical Information Systems (GIS) software package designed for Precision Agriculture applications[1].

Soil data

Soil samples were collected from seven sites across the study area, representing the range of shallow ECa values (Figures 2). Soil samples were collected by a hydraulic soil corer of 50mm diameter, with subsamples for the 10-30cm depth interval prepared from 3 cores. Seven 0-10cm samples were collected from evenly arranged points around the perimeter of a circle of 35 cm diameter. Samples were analysed for field texture, pH (CaCl2) and gravel percentage by CSBP's soil laboratory.

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[1] See http://www.deltadatasystems.com/

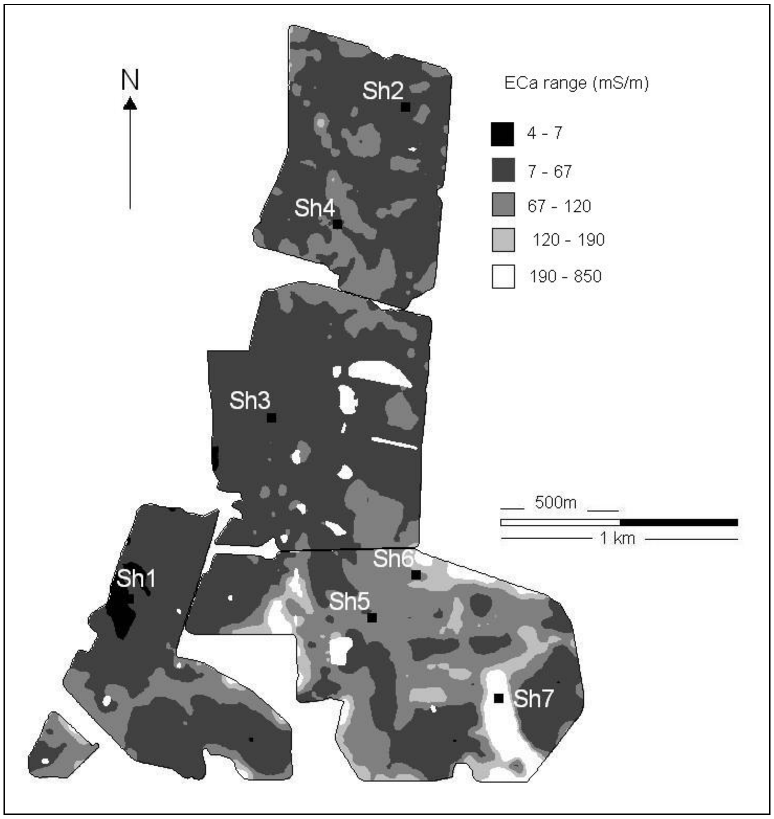

Figure 1 – Soil sample locations and ECa variability across the study area.

RESULTS

Table 1 shows the results of the soil analyses, recommended lime rates, exchangeable sodium percentage and the corresponding ECa values and elevation data for each site. Exponential regressions revealed a strong, negative relationship between ECa and elevation (Rsq = 0.75) and ECa; and a strong, positive correlation (R-sq = 0.89) between ECa and 10-30cm chloride levels. The relationships between ECa, pH and soil texture are explored in further detail in the following sections.

Table 1 Soil analyses results by sampling depth and site elevation and shallow ECa values.

Site	Field texture[2]	Gravel (%)	pH ($CaCl_2$)		Lime rate (t/ha)	Chloride (mg/kg)	Al ($CaCl_2$) mg/kg	Elevation (m ASL)	ECa (Shallow mS/m)
	0-30cm[3]	0-30cm	0-10cm	10-30cm		10-30cm	0-10cm		
SH1	1.5	25-30	5.1	5.5	1	19	0.7	267	6
SH2	1.5	5-10	4.8	5	1.5	34	0.6	265	30
SH3	2 – 2.5		4.9	6.1	1	34	1.4	267	41
SH4	2 - 3		5.9	7.1	0	57	3.3	263	68
SH5	2.5 - 3		6.7	8	0	92	3.5	259	76
SH6	2.5		6.5	8	0	597	4.5	258	114
SH7	2.5 - 3		7.7	8.2	0	7067	12.5	256	658

[2] 1.5 = Sandy Loam; 2 = Loam; 2.5 = Clay loam; 3 = Clay

[3] Weighted average of 0-10cm and 10-30cm depth intervals

Apparent electroconductivity and soil pH

There was a significant correlation (R-sq = 0.79, $p < 0.05$) between the 0-30cm weighted average of soil pH and shallow ECa at or below 114 mS/m (Figure 1), representing 89% of the survey area. Areas with an ECa over 114 mS/m were deemed to be limited more by salinity constraints than pH and thus excluded from the analysis (see Table 1). A 3rd order polynomial regression (R-sq = 0.96) was used to determine lime rates at the lower end of the ECa spectrum (i.e. < 80mS/m).

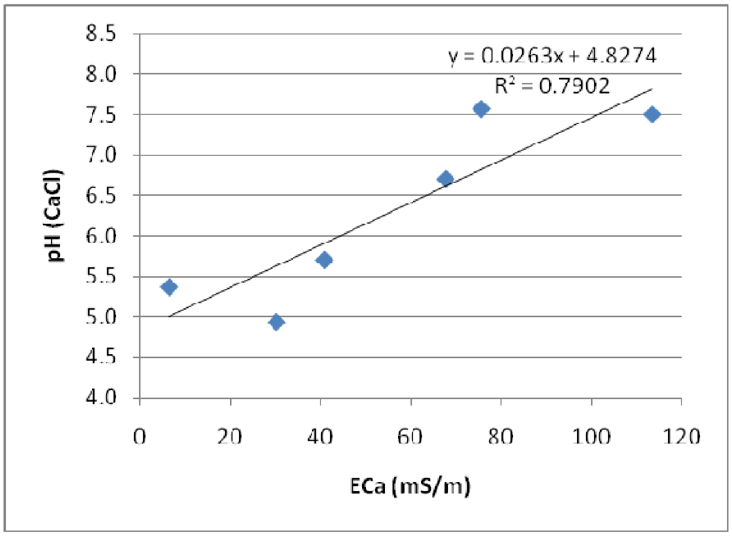

Figure 2 – Relationship between shallow (0-50cm) apparent electroconductivity (ECa) and weighted average pH of 0-10cm and 10-30cm sampling depths.

pH Buffering Capacity and Productivity

Apparent electroconductivity is influenced by soil moisture, clay and salt content; therefore several factors are likely to be influencing the indirect relationship between soil pH and ECa. The upper landscape is characterised by sandy loam topsoils (0-10cm) and midsoils (10-30cm) with a low ECa. Soil pH buffering capacity (pHBC) increases with clay content, therefore the relatively low clay content of the soils characterised by a low ECa indicates a lower pH buffering capacity compared to the heavier textured soils with a higher ECa. Organic carbon levels varied from 0.9% to 2.3%, with no clear relationship with ECa.

Visual analysis of a 2m contour map indicates that the most elevated areas in the survey area shed water and are less productive due to this localised topographical variation and the effect of higher gravel content in reducing plant-available water content. The midslope soils accumulate water, contain less gravel and are generally well drained, resulting in higher potential productivity. The low pH of the soils represented by sample site SH2 is most likely to be influenced by both product removal and relatively low clay content and consequent pHBC.

Soils lower in the landscape (represented by sites SH4 – SH6) have higher clay contents and therefore higher pHBC. The soil-landscape descriptions of Stuart-Street and Marold (in press) also suggest that these sections of the landscape have inherently alkaline soils, further increasing their pHBC.

Economic implications of pH variability

Normal famer practice for this property would be to spread 1t/ha of lime across the entire property every 5 years. As a result of this work, it was found that lime was not required, at this point in time, across 58% of the survey area. The savings from this are summarised in Table 2.

Table 2 Soil analysis results by sampling depth and site elevation and shallow ECa values.

Variable rate (t/ha)	Area (ha)	Tonnes	Traditional spreading @ 1t/ha	Savings = 164 tonne @ $50/ha spread	EM Survey and groundtruthing cost	Net saving
0	187	0				
1	90	90				
1.5	47	70				
Total	324	160	324t	$8200 ($25/ha)	$6062 ($19/ha)	$2138 ($6/ha)

Commercial rates for EM surveys with ground-truthing range from $17 to $20/ha, therefore the financial benefits of conducting a geophysical survey with ground-truthing are evident in the example provided. The surveying cost is a once-off; therefore future net benefits would be greater than those shown here. Ongoing monitoring of topsoil and midsoil pH is recommended to determine variable-rate effectiveness and appropriate rates of future lime applications.

CONCLUSION

An electromagnetic induction survey of the study area revealed a wide variation in apparent electroconductivity (ECa) and was used to guide soil sampling for a range of characteristics including topsoil and subsoil pH. A significant relationship between ECa and average top-midsoil pH was observed across the study area. Clay content, as determined by field texture, also appeared to be correlated with ECa. Based on the prior soil-landscape mapping knowledge and the influence of clay content on pHBC, it was concluded that variable rate application of lime would be used to ameliorate production-limiting pH levels in soils with lower ECa, with higher rates of lime in soils assessed as being at greatest risk of acidification through low buffering capacity and product removal. This led to considerable savings in lime application costs.

This work is in progress and further testing is required to confirm the application of electromagnetic induction surveys and site assessment as a means of determining acidification risk and lime requirements.

KEY WORDS

Electromagnetic induction, variable rate, lime, precision agriculture

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