Grid soil mapping to define the variability in multiple soil properties.

Kirsten Barlow[1], Sebastian Ie[2], Ben Fleay[2]

[1] Precision Agriculture, 113 Main Street, Rutherglen, Vic, 3685, www.precisionagriculture.com.au, k.barlow@precisionagriculture.com.au
[2] Precision Agriculture, PO Box 691, Ballarat, Vic 3353, www.precisionagriculture.com.au,

Abstract
Soil constraints such as acidity, sodicity and nutrient availability can cause significant losses in production, limit crop choice, and further reduce the health of our soil resources if untreated. Grid soil sampling is a proven strategy to identify and enable targeted amelioration of soil constraints across a paddock. This paper presents the results of grid soil mapping on 289 commercial paddocks, investigating the relationships between soil pH, CEC, ESP and soil test P observed in the grid mapped surface soil data. The results highlight the variability within individual paddocks for these soil characteristics. Whilst some soil characteristics (e.g., pH and CEC) were well correlated in some paddocks, for most other characteristics up to 75% of paddocks had no consistent trends between the soil test data with correlation coefficients of between -0.5 to 0.5. Grid soil sampling allows the different patterns of spatial variation to be determined for individual soil properties, and enables separate variable rate strategies to be developed.

Key Words
Grid soil sampling, surface soil, pH, Colwell P, Olsen P, Cation Exchange Capacity

Introduction

Soil constraints, such as acidity, sodicity and nutrient availability, are a significant challenge across all agricultural systems. Soil acidity affects 50% of Australia's agricultural land which will continue to acidify without intervention, while sodicity affects between 23-59% of agricultural land within different States (Rengasamy and Churchman, 1999). Amelioration of these constraints through the application of lime, gypsum and fertiliser account for a significant portion of annual on-farm expenditure. Increasingly, producers are seeking an evidence-base for these decisions and to optimise returns on investment.

Farmer knowledge, historic yield and satellite data can all provide a valuable insight into the variation observed within a paddock in relation to both crop and pasture production. However, this variation is driven by multiple factors including soil type, available water, available nutrients, the effects of soil constraints, previous yields and management. Grid soil sampling is a sampling strategy that identifies and enables targeted amelioration of soil constraints across a paddock. An alternative to grid mapping is to develop farm management zones using a range of different datasets (EM38, NDVI, yield, elevation, true-colour image etc.). Underlying this alternative approach is the assumption that the major constraints to production are consistent within the identified zones, and that the zones are correlated with any soil properties that are subsequently measured in each zone.

This paper presents the results of grid soil mapping on 289 commercial paddocks, investigating the relationships between soil pH, Cation Exchange Capacity (CEC), Exchangeable Sodium Percentage (ESP) and soil test phosphorus (both Olsen and Colwell P) observed in the grid mapped data.

Methods

The results presented in this paper were from commercial grid soil sampling conducted by Precision Agriculture Pty Ltd over a 12-month period. The grid soil sampling divides a paddock into small grids (generally a 2 ha grid is used but this does vary across industries). Within each grid, 0-10 cm soil cores were collected on a diagonal transect that zig-zagged through the paddock. Soil samples were sent to a commercial, accredited laboratory for analysis of soil pH_{Ca}, exchangeable cations and soil test P (either Colwell or Olsen, Rayment and Lyons, 2011).

Data analyses were restricted to paddocks with greater than five grid samples and a full set of pH, exchangeable cations and soil test P results, which equated to 289 paddocks with an average of 20 grid samples (range 5 to 102). Graphical and statistical analyses were conducted in both Excel and SPlus 6.2 for Windows (Insightful Corp. 2003) to derive correlation coefficients and linear regressions.

Results

All the soil tests (pH, CEC, ESP and soil test P) varied notably between and within each paddock (Figure 1) as shown by the spread in average soil test values and the Coefficients of Variation (CoV) which ranged from around 1% to over 100%. The CoV is a measure of the relative variability in a data set and represents the ratio of the standard deviation to the mean. Soil pH generally had the lowest CoV of the four soil tests, reflecting the log scale of the pH measurements. Soil pH had a mean CoV of 5.2% (range = 1-17%); this value corresponded with an average standard deviation of 0.28 pH units within a paddock. Colwell P and Olsen P were comparably variable with an average CoV of 28% and average standard deviation of 15 and 5.6 mg/kg for Colwell P and Olsen P respectively. CEC and ESP had the greatest spread in the variation observed with an average CoV of 25% and 36% respectively, corresponding to ranges of 5-92% for CEC and 6-119% for ESP. The ESP was the only attribute whereby a higher average soil test value was reflected in a higher CoV.

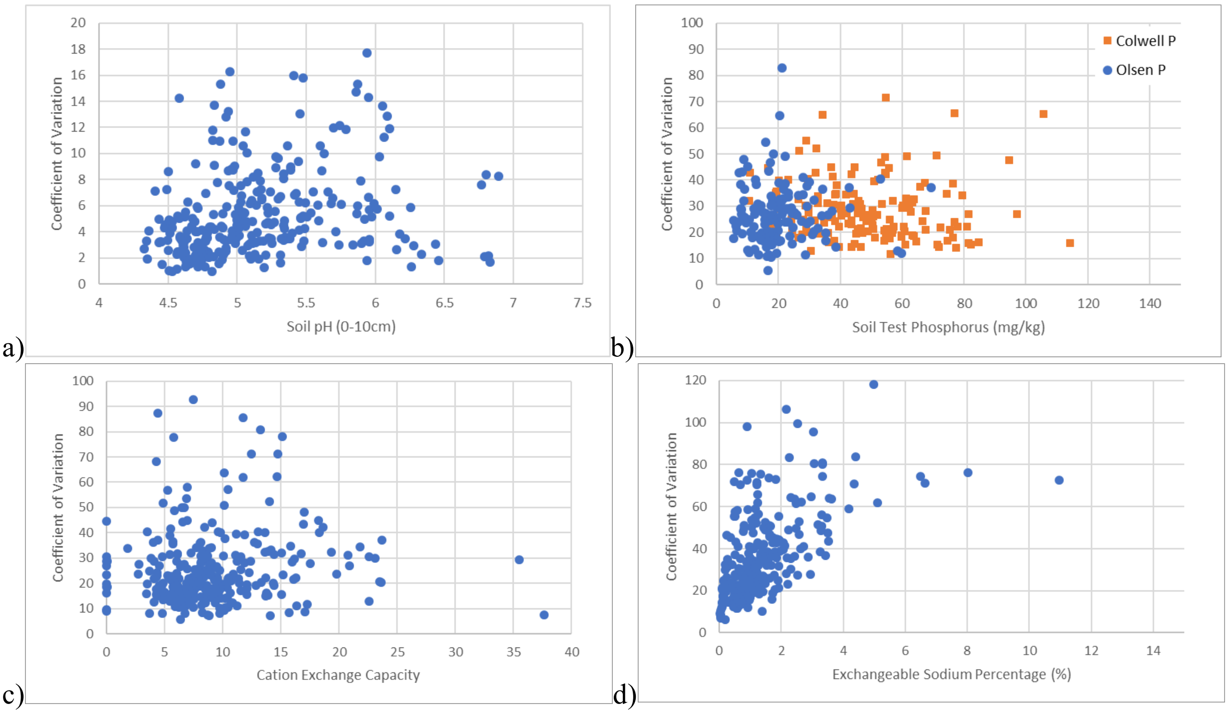

Figure 1. The grid soil sampling results from 289 paddocks showing the paddock average value and the coefficients of variation (%) for (a) pH_{Ca}, (b) soil test phosphorus both Colwell and Olsen P, (c) Cation Exchange Capacity and (d) Exchangeable Sodium Percentage.

To demonstrate the potential application of grid soil mapping, consider an example paddock selected for illustrative purposes (Figures 2a and 2b). The results show the variation in soil test values (pH and Colwell P) across the paddock. The average soil pH was 5.2 ranging from 4.5-5.9, with a standard deviation of 0.3 and a CoV of 5.9%. The average Colwell P was 62 mg/kg ranging from 5-119 mg/kg, with a standard deviation of 19 mg/kg and a CoV of 32%. There is no clear pattern between the two soil test values in this example (Figure 2c), where the pH and Colwell P values of the individual grid points have a correlation coefficient of 0.03. In this example paddock, the management zones for soil pH and Colwell P were different, with grid soil sampling allowing for the development of both variable rate lime and P strategies that accurately targeted each individual soil constraint.

Using the data from the 289 paddocks presented (Figure 1), we investigated the correlation coefficients between the different soil tests (Figure 3) as well as the R-squared values of linear regressions between the different soil tests (data not shown). The relationship between CEC and soil pH was the strongest within this data set (Figure 3a). The average correlation coefficient between pH and CEC (Figure 3a) was 0.54, with 46% of the paddocks having a strong correlation (> 0.7). This correlation reflects the role that CEC can play in buffering the pH of each soil, as well as the effect of soil pH on the variable charge exchange sites within the soil.

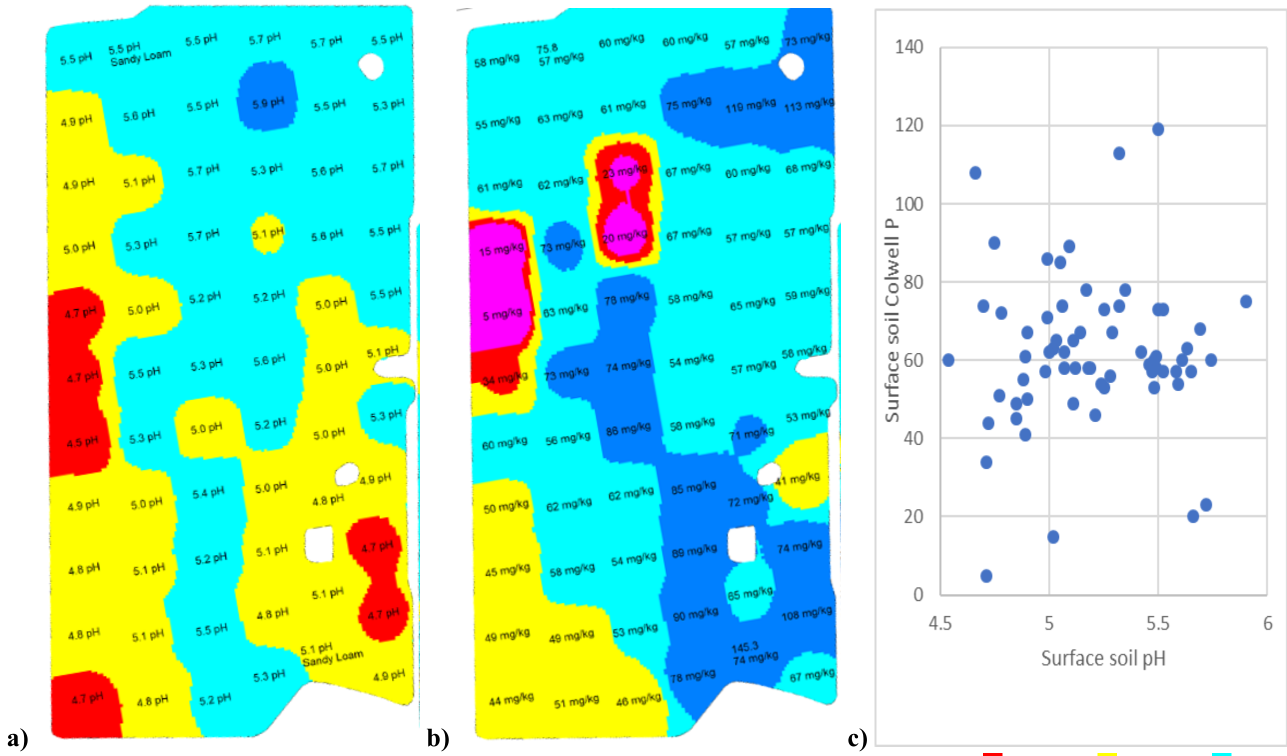

Figure 2. The grid soil sampling results from an example paddock showing (a) pH_{CaCl_2} 4.5-4.7, 4.8-5.1, 5.2-5.7, 5.8-6.5, (b) soil test phosphorus - Colwell 5-23mg/kg, 24-34mg/kg, 35-52mg/kg, 53-70mg/kg, 71-119mg/kg and (c) the individual grid results for pH and Colwell P.

In contrast, there was a very random distribution in the correlation coefficients observed for pH:soil P, soil P:CEC and CEC:ESP (Figure 3b-d). In each of these paddocks, the individual correlations ranged from a strong positive correlation (>0.7) to a strong negative correlation (<-0.7), with between 56-76% of the paddocks having a poor correlation of between -0.5 to 0.5. The results suggest that, while identifying zones with consistent trends in surface soil properties may work on some paddocks, up to 70% of the paddocks had very low correlations between the different soil tests. Zones would not adequately describe the variation in these paddocks. Similar results were observed in the fitting of linear regressions between the different soil test values.

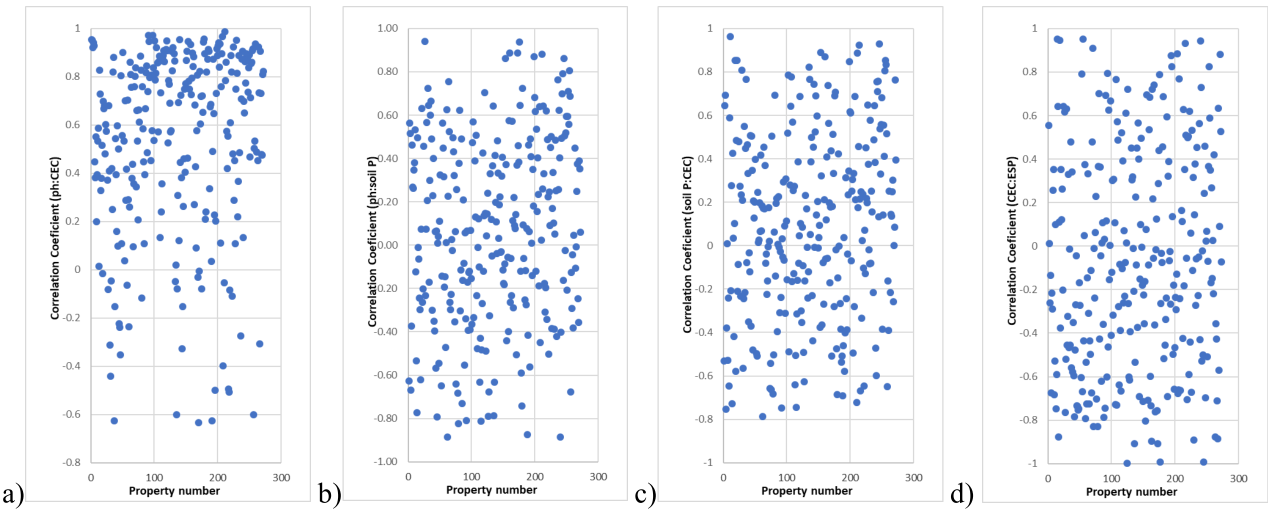

Figure 3. The correlation coefficients for the 289 properties comparing, (a) pH_{Ca} to cation exchange capacity, (b) pH_{Ca} to soil test phosphorus, (c) soil test phosphorus to cation exchange capacity and (d) cation exchange capacity and the exchangeable sodium percentage.

These results focus on the surface soil characteristics (0-10 cm) and the potential soil constraints based on standard surface soil testing. The potential for stratification within these surface soils, especially under no-till cropping systems, also needs to be considered in the interpretation of any soil test data. For example, while the surface soil pH measured on a 0-10 cm soil sample may suggest that soil pH is not a significant constraint to

www.agronomyaustralia.org/conference-proceedings

crop production, if the 7-10 cm depth is highly acidic (pH_{Ca}<4.2) this could severely constrain root development down through the soil profile and limit crop production. Furthermore, potential soil constraints at deeper depths in the soil profile may need to be considered.

Conclusion

Grid soil mapping results from surface soils across 289 commercial paddocks were investigated for correlations between a range of soil chemical properties. While there were some paddocks where different soil properties were highly correlated (>0.7), there was generally a poor correlation between the soil test values. This suggests that the development and sampling of management zones inferred from yield, satellite and NDVI data may be an inadequate method of targeting multiple soil properties in the majority of situations, and the only way this can be validated is by comparing zones with an unbiased dataset (such as a grid soil map). On-going analysis of the data will directly investigate the relationships between extensive grid soil sampling data and management zones developed from these other data sources including EM38, NDVI and yield data.

When addressing within-paddock variability the greatest return on investment is often achieved by addressing the key soil properties limiting crop performance. Soil acidity and sodicity are common constraints which can be addressed through variable rate applications of lime and gypsum. These results suggest that while CEC and pH are generally well correlated across a paddock, the ESP does not necessarily follow the same spatial patterns. Grid soil sampling allows the different patterns of spatial variation to be determined for individual soil properties, and enables separate variable rate strategies to be developed.

Grid soil mapping provides a comprehensive measure of the variation in soil properties across the paddock. Where multiple soil properties are measured, variable rate strategies can be developed for each soil constraint to ameliorate individual soil properties. For example, the development of individual variable rate lime and phosphorus strategies for the paddock in Figure 2.

References

Rayment GE and Lyons DJ (2011) Soil chemical methods – Australasia. CSIRO Publishing, Melbourne.

Rengasamy P and Churchman GJ (1999) Cation exchange capacity, exchangeable cations and sodicity. In Soil Analysis an interpretation manual. Eds KI Peverill, LA Sparrow, DJ Reuter. pp.147-159, CSIRO Publishing, Melbourne.