Effective soil sampling – high and low cost options to gain soil fertility information for management.

Jason Condon.

Graham Centre for Agricultural Innovation, Charles Sturt University and NSW Department of Primary Industries, Wagga Wagga, NSW.

Keywords

- soil sampling, variability, zonal management.

Take home messages

- Soil is inherently variable.
- Grid sampling can create high density information but perhaps is not necessary.
- No/low cost tools exist to enable zones to be identified for sampling and potential management.

Background

Efficient nutrient and soil management of agricultural land relies on soil testing to provide the analytical data to be used in decisions relating to fertiliser and soil amendment application. Soil testing is comprised of soil sampling, analysis and interpretation, which then allows an informed recommendation to be made. Of these, soil sampling provides possibly the greatest unrealised error.

There are different methods which can be utilised to sample a paddock. In the past, the recommended method was to take a multicore (25-30 cores), composite sample to be sent to an accredited laboratory for analysis. The locations of the sites to be cored could be completely random or situated along transects marked by features such as posts on fence lines or recorded global position system (GPS) locations. To decrease the time taken to obtain samples, cluster sampling has evolved. This involves taking five samples at each of five sites within the area to be sampled. With more thought, areas within the paddock could be identified as different zones to be managed. These zones may be identified by production (areas of good or bad growth) or soil properties (colour, texture, slope). Once identified, each zone can be multi-cored to produce separate composite samples for analysis, interpretation and fertiliser recommendation for each zone.

With the greater availability of GPS equipped machinery and variable rate technology, there has recently been more interest in obtaining greater spatial precision in soil sampling and creating site specific soil recommendations. Some businesses are now offering grid sampling, using composite multicores of multiple grid sites, or in-field 'on the go' or point sampling services which provide growers with variable rate recommendations for their paddocks at a fine scale (e.g. 10 points per hectare). However, these services come at a cost which currently exceeds traditional soil sampling costs leaving growers with questions relating to the cost/benefits of soil sampling methods. Some have answered these questions by creating maps of, for example, soil pH and variable lime rate recommendations based on grid sampling and then comparing these to a single rate lime application based on a soil test value created by multicore-composite sampling of the same area. Not surprisingly this makes the higher cost option of grid sampling seem beneficial in cases where it is not necessary to lime the whole area. However, it may be argued that 'adequate' or 'efficient' recommendations could be made utilising low or no cost information to identify zones to be sampled. In order to do this, knowledge of factors creating soil and production variability needs to be understood.

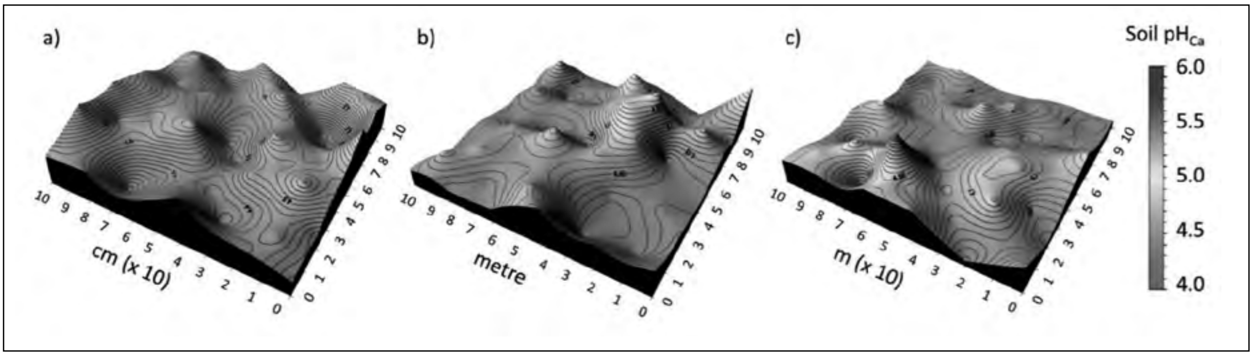

Figure 1. Soil pHCa from the 0cm - 5cm soil layer from a 10 x 10 grid within areas of 1m^2, 10m^2 and 100m2 *(Source: Moodie and Condon, unpublished).*

Soil variability

Spatial variability in soil physical and chemical (and therefore biological) properties exists horizontally and vertically. That is, soil properties can be expected to be different as we move across a paddock or as we dig down into soil. If we treat a paddock as one management unit and sample it as such, the variability is not realised in the information created by the analysis and inefficiencies are likely to occur in the fertiliser applications made.

The magnitude of variability of commonly measured soil properties has been reviewed (Rossel and McBratney 1998). Conyers and Davey (1990) demonstrated that in grazed pastures the magnitude soil pH variation that existed over a grid of 16m also existed in a 1m grid located within the larger area. This magnitude of spatial variability is visually represented in Figure 1 where soil from a visually uniform area was core sampled (20mm diameter cores) from the 0 - 5cm layer of soil from 10 x 10 point sample grids at scales of 10cm, 1m, 10m' i.e. 100 samples each from an area of 1m^2, 10m^2 and 100m^2, respectively (Moodie and Condon, unpublished).

To account for this level of variability in a measured soil sample in the field, multiple cores are taken to find the average pH of the area. Statistically, 25 to 30 subsamples provided a sample mean that represents the mean of the area. With the use of grid sampling and software that allows values from point samples to estimate unmeasured areas between the grid points (a process called kriging), maps can be made that report kriged values for management pixels. The density of sampling points required to give confident kriged values is determined by the variability of the measured property in the field. Based on values of variability reported in the literature, it has been estimated that to manage land at pixels of 20m x 20m scale using precision agriculture technologies, a sampling interval of 30m would be required for grid sampling (McBratney and Pringle 1999), making the process economically unviable if using traditional laboratory analysis (Rossel and McBratney 1998). As a response to this limitation, 'on the go' measurement technologies are being developed which lower the cost of gaining a data point which can then be used to formulate management recommendations. For example, commercial services for 'on the go' measurement of soil pH, clay and organic matter content and EM38 services are currently available. Another option is to create composite samples (e.g. 8- 12 cores) from each subsampled grid cell (e.g. 1-4 hectares). That is, create sampling grid cells that are multi-cored to enable more confidence that the composite sample from each grid better represents the soil in the field within that grid cell. Then use the grid to create maps and spatially variable fertiliser recommendations. An example of this is shown in Figure 2 where soil pH was measured from approximately 39 sampling grid cells.

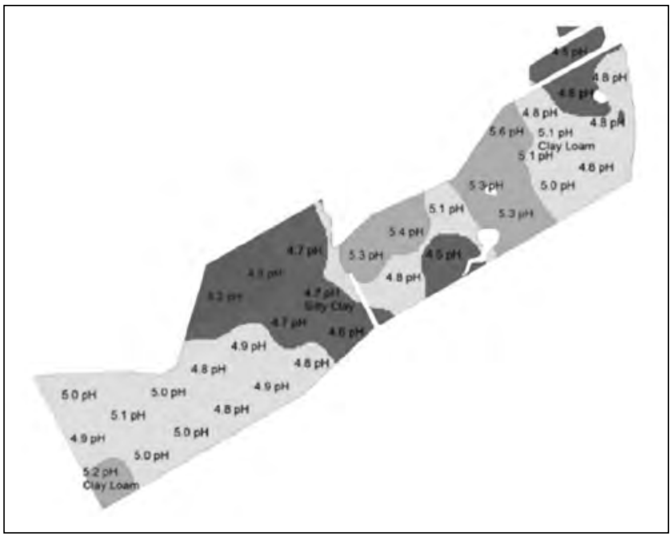

Figure 2. Soil pH map of a paddock. Data produced from 0-10cm multi-cored composite samples of 2 hectare grids.

The economic comparison of these methods is highly dependent on the cost of analysis, the actual variability in the field, and the factors that are influencing yield within the paddock. Some comparisons demonstrate theoretical savings compared to single rate applications of lime while experimentally, a lack of economic return can occur (Rossel et al. 2001, Bianchini and Mallarino 2002). Regardless, knowledge of why soil variability exists may enable low cost alternatives to high cost, data rich sampling strategies.

What causes spatial variability?

Variation in soil properties exist as a result of processes or factors that form and change the soil. The five main soil forming factors are climate, organisms, relief (topography), parent material and time (Jenny 1941). Understanding these soil-forming factors helps enable us to identify where differences in soils may exist.

At a paddock scale, climate can be discounted in our discussion to identify within paddock variability. Organisms can alter soil due to biochemical processes, but they are also tools which enable soil variability to be identified. For example, remanent vegetation species are often linked to the soil properties; pine trees are found on one soil type, eucalyptus trees on another, acid tolerant weed species can mark areas of low pH, and salt tolerant species may indicate locales of possible salinity.

Changes in parent material can influence soil colour, texture and nutrient status. It is possible to have parent material changes at a paddock scale and these are often also linked to relief (topography). For example, moving from a hill top to a gentle slope to an alluvial flat. Topography also influences soil depth and determines water movement through the landscape. When the land was initially cleared, changes in soil colour, texture and topography were the basis for setting paddock boundaries as it was understood that changes in these soil properties would create soils that require different management.

The final factor, time, in the context of soil formation, relates to geologic time but for identifying within paddock variation, is probably best represented as the effect of our management on soil over time. For example, clearing land and burning trees, the agricultural enterprise selection and fertiliser use can all influence soil chemical properties in each paddock; and there tends to be more variation of soil chemical properties in grazed pastures than in cultivated cropping fields (Conyers and Davey 1990). The use of precision placement of fertiliser in, under or beside the sowing row has now created a new (but perhaps predictable) source of variability of some measured properties, (e.g. soil pH), as fertilisers are placed in the same location each time crops are grown. Another source of management derived variation within paddocks is the removal of fences and consolidation of paddocks as the scale of machinery and area of land managed increases. This essentially brings soil of different management history within the same paddock and introduces another source of variation to the paddock.

Application of knowledge to create savings

Using the paddock demonstrated in Figure 2 as an example, the paddock was part of a recently acquired property, no yield data were available, topography was relatively flat, and only a small number of one species of remanent trees existed. The most recent, free imagery available (Figure 3a)

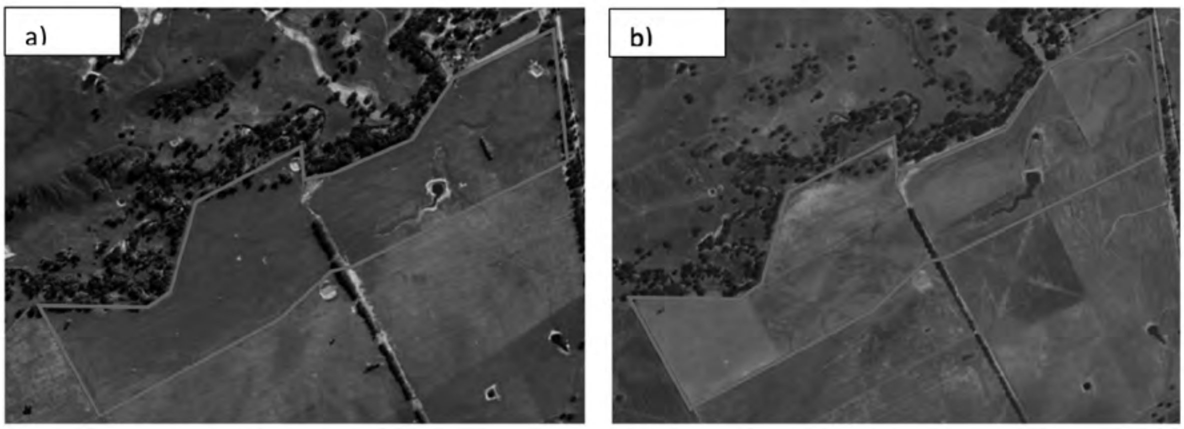

Figure 3. Imagery taken in (a) 2018 of a recently acquired paddock under management and (b) the same area in 2010.

showed some variability in plant growth around the dams and slight drainage line. However, utilising historic free imagery (Figure 3b) from 2010, it could be seen that the current paddock is a composite of seven prior paddocks. These prior paddocks (Figure 3b) could easily be designated separate zones for sampling (i.e. to produce seven multi-cored-composite samples). Within each of the prior paddocks, areas of visual difference are apparent and could be used to create additional zones for sampling. Using this method 11 zones could be identified (Figure 4) which could be multi-cored-composite sampled at low cost with only 11 samples sent for analysis. This strategy would greatly decrease the cost of data acquisition to enable utilisation of variable rate lime application.

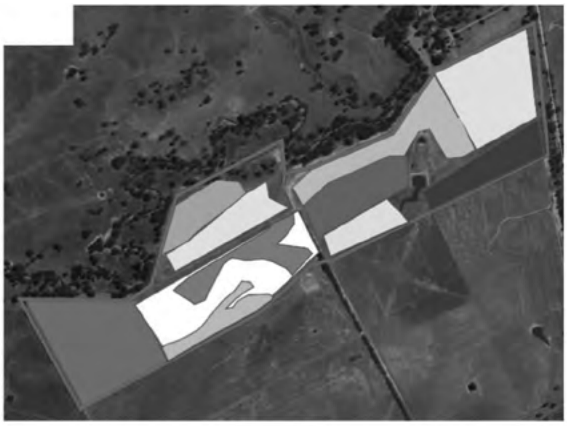

Figure 4. Zone designation based on prior fences and differences in vegetation colour evident in Figure 3b.

The use of free normalised difference vegetation index (NDVI) images and yield maps are also useful in the process of identifying zones of different plant production which may be the result of variations in soil properties. In addition to these plant-based spatial variability identifiers, the low-cost tools available to growers to identify different zones based on soil formation knowledge are collated in Table 1. The information created by grid sampling is highly valuable to the identification of zones or implementation of site specific management, however that information comes at significant cost.

The informed identification of sampling (and potential management) zones using the tools listed in Table 1 would appear to be the lowest cost method of gaining information to utilise variable rate technology. Utilisation of other forms of spatial data (EM38) or other examples of 'on-the-go' sampling further contributes to the information gained but the cost of acquisition then becomes a factor in the economic benefit of the process. The example provided here (Figure 4) was able to pick the areas of pH extremes that were evident in Figure 2. Though not all zones would require different management, the lower number of samples sent for analysis, compared to grid sampling, allows financial resources to be repurposed for the analysis of greater numbers of depth increments, e.g. 5cm intervals for A horizons (soil before the clay begins) in duplex soils, providing more information on the soil profile rather than just 0cm-10cm soil fertility. For example, if the analysis of a sample cost $100, the 39 samples of the grid would cost $3900 for analysis alone. Sampling from 11 zones in the 0-5cm, 5-10cm, 10-20cm layers (or 0-10cm, 10-20cm, 20-30cm) would cost $3300. The process of sampling would also allow the opportunity to experience soil variability in soil physical properties during sampling (e.g. hard pans, structural changes, etc). At the very least, 0-10cm sampling of the 11 zones would come at cost of $1100 representing lower cost information acquisition than grid sampling.

It should be acknowledged that the information obtained from soil testing is used to formulate fertiliser recommendations based on relationships between soil test values and plant production (calibration curves) that are not perfect and that exhibit their own variability. Therefore, precision in sampling does not necessarily ensure improved outcomes from fertiliser recommendations.

Table 1. Identifying factors and no or low-cost tools available to designate zones of potentially different soil fertility.

Source of variability	Identifying factor	No/low cost tool	Confirmation by yield map	Management
Soil type change	Soil colour Soil texture Remanent vegetation	Free digital imagery, coring, observation	Yes	Zonal
Topography	slope	Elevation from RTK GPS, DEM	Yes	zonal
Paddock consolidation (fence removal)	Presence of strainer posts or gate posts	Historic records, Free digital imagery through time	Yes	zonal
Grazing animals	Vegetation (urine/dung patches)	In field observation	No	Cannot be zoned or managed
Fertiliser rows	None	On row coring	No	Row zoning

Conclusion

The sampling strategies mentioned here aim to decrease errors in sampling. Spatial differences in soil properties are only one source of variation in agricultural productivity from a paddock. However, identifying areas of different input requirement and managing them separately can be a method of increasing production efficiency. Ultimately the grower may choose to employ whatever sampling services at their disposal and of their interest, but in terms of resource optimisation, the implementation of soil knowledge with low cost or free information can allow for adequate zonal management decisions to be made.

Useful resources

www.grdc.com.au/GRDC-FS-SoilTestingS

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Acknowledgements

The image presented as Figure 2 was provided by an undisclosed third party. Digital images presented in Figures 3, 4 were obtained from Google Earth.

Contact details

Jason Condon
Graham Centre for Agricultural Innovation,
Locked Bag 588, Charles Sturt University,
Wagga Wagga
02 6933 2278
jcondon@csu.edu.au

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