Mapping soil constraints at a farm scale

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WE conducted a research project that mapped soil properties over 2000 hectares of grey clay soil at a similar resolution to yield maps so we could better understand the drivers of yield variability at the site. The large amount of data produced allowed us to identify areas of a paddock that were affected by different yield limiting factors, such as:

- High exchangeable sodium percentage (ESP);
- High salinity; or,
- Closed depressions (holes deeper than 2.5 cm).

Mapping these properties spatially allowed us to calculate the potential yield increase if the limitation was removed. Using this information, a farm manager can determine if investment in remediation is likely to provide a return and, if a return is likely, the best areas to trial remediation can be easily identified.

We found from these mapped soil properties that cotton yield was lower in the areas with shallow depth to 10 per cent (ESP), closed depressions, and in a small area of saline soil. At this site, the depth to pH of 8 was not correlated with cotton yield.

Cotton yield was highest in areas where soil had low salinity and ESP to the full 140 cm depth. Yield was modelled to decline by 0.5 bales per hectare as the depth to 10 per cent ESP rose from 140 cm to 30 cm.

Generating digital soil maps

This project aimed to test improvements in the availability of data and in the statistical techniques used to generate digital soil maps over the past 20 years. The data improvements have included relatively widespread availability of measures of landscape variation, such as satellite images and digital elevation models, and on-farm measures of variation in the form of electromagnetic induction (EM) and yield variation from yield maps.

Conducting the ground-based survey.

The statistical techniques have progressed from regression models through regression plus a spatial component to machine learning plus residuals. These models can be used to make 3D predictions of soil properties. To date, digital soil maps have been produced predominantly by researchers and government agencies.

The process of generating digital soil maps involves three general steps.

Step 1

The first step is to collate covariate data. Covariates are measurements at known locations that are correlated with soil properties. We conducted ground-based surveys with sensors for EM, radiometrics and RTK elevation.

- EM had the benefit that the four sensor pairs respond to soil electrical conductivity at different depths from the surface to between 0.4 metre and 2.5 metres. At this site, two crop-free years before the EM survey meant that there were no differences in soil moisture due to variation in crop growth.
- Radiometrics measures natural radiation emitted by minerals in the soil and changes with topsoil parent material.
- RTK elevation is a precise measure of land surface shape.

The field measurements were supplemented by satellite measure of bare soil colour, and cut and fill estimated from a surface survey conducted before land forming.

Step 2

The second step was to collect soil samples at selected sites. The covariate data was input to a statistical package which identified 71 sample sites to best sample the range of covariates across the whole of the area surveyed.

Three cores were pulled from the centre of rowcrop hills at each of the 71 sample sites. These cores were split into depth layers of 0 to 30, 30 to 60, 60 to 100 and 100 to 140 cm. Cations of calcium, magnesium, potassium and sodium, particle size of sand, silt and clay, pH, salinity, chloride, sulphate and nitrate were measured in all samples. Phosphorus, zinc, copper, iron and manganese were measured in the 0 to 30 cm samples only.

Step 3

The third step is to generate maps of individual soil properties at each depth. The process used was to model the relationship between the covariates and each measured soil property using a machine learning process that also calculated the error in the model. This model was then applied to the whole covariate data set to calculate soil properties for each depth across the whole soil survey area.

Selecting relevant soil properties

This process produced 48 maps of soil properties, which seemed like a case of too much data and not enough information. So, we selected the soil properties most relevant to

FIGURE 1: Map of depth to 10 per cent ESP and boxplot of the correlation between depth to ESP and cotton yield

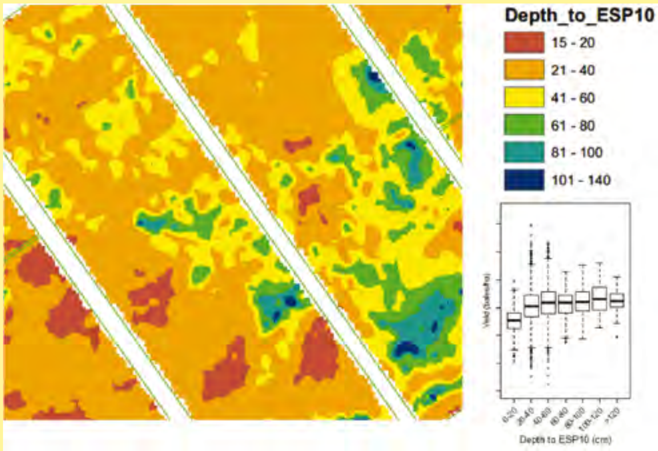
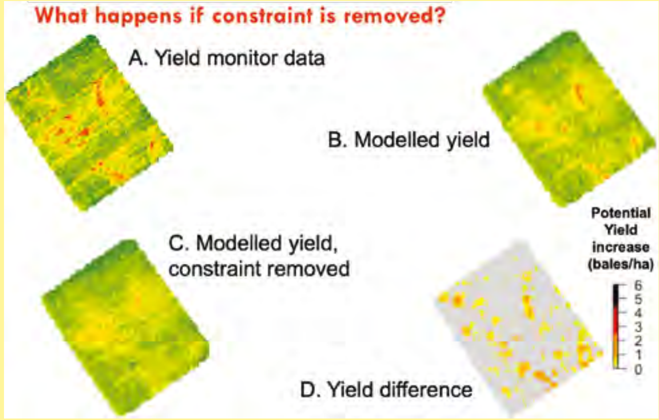


FIGURE 2: Conceptual model of process to quantify the potential yield benefit of removing yield constraint of closed depressions



crop growth in an objective way using a two-stage process. The first stage was to calculate the depth to critical values for selected soil properties of:

- ESP (Figure 1);
- Salinity measured as exchangeable conductivity of the saturated extract (ECe); and,
- pH.

At this stage we also calculated the location of closed depressions from the RTK elevation data.

The second stage was to examine the correlation between the critical values calculated above and measures of cotton growth and yield over five seasons (Figure 2). This process predicted that cotton yield was restricted by ESP in 28 per cent of the area surveyed, by closed depressions (holes) in 11 per cent of the area, and by salinity in one per cent of the area. We did not find a correlation between alkaline pH and cotton yield at this site.

Mapping other areas

We have repeated the soil mapping process on 900 hectares of grazing land in central NSW and on a 700 hectare mixed irrigation aggregation in the Murrumbidgee Irrigation Area. In both cases the maps created were able to differentiate between areas with soil properties that limit crop type from areas where soil properties can be amended to improve productivity. This information reinforced knowledge that was gained over decades of expensive trial and error.

What we have learnt

This project demonstrates that while digital soil maps are not an end in themselves, they can be used in association with yield maps to quantify the yield cost of soil constraints. The effect of soil properties on yield is easier to identify if there is substantial variation in the property, and substantial areas with values that are both lower and higher than the critical value.

This occurred most notably with ESP at this site, while the variation in pH and ECe had a smaller impact on yield variability. A major benefit of this approach was the investigation of soil properties to depth as we also found that high levels of salinity and ESP observed past one metre depth continued to have an effect on yield that could not be observed if only the topsoil was investigated.

Finally, some lessons learnt from this project include that it is essential to collect at least one covariate at the same resolution as the soil map or finer. As we have not yet found universal relationships between covariates and soil properties, so soil samples are currently required for each survey project.

We also found that the combination of covariates that is most useful in predicting soil properties varies between survey projects. Better understanding of which covariates are useful in which regions will allow the cost of the mapping exercise to be reduced over time.

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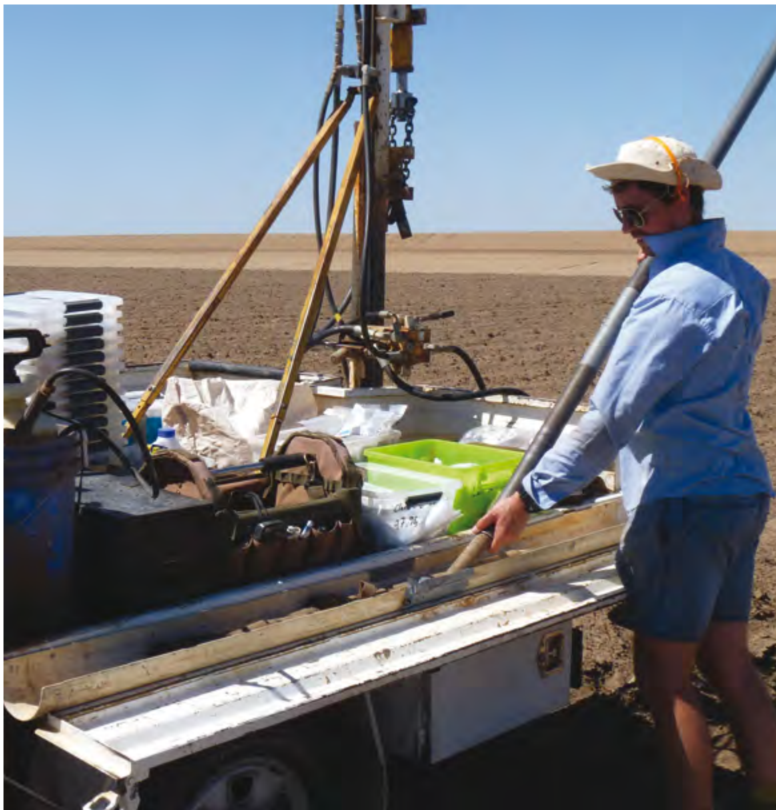

Soil cores were pulled from the centre of rowcrop hills at each site.