Digital soil maps are being created that correlate yield losses to specific soil constraints.

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Improved tools lead to enhanced maps

Written for SPAA by Rebecca Thyer

USING spatial data, machine learning and guided soil testing, digital soil maps are pinpointing soil constraints and their specific impact on yield.

Ed Jones from the University of Sydney has been researching how well digital soil maps can calculate paddock needs. Tested on three Australian farms, the work is proving positive, with the maps able to indicate differences in yield attributable to certain soil constraints.

Digital soil maps

As the spatial data required for soil mapping has rapidly developed over the past 20 years, it was an opportune time for researchers to revisit on-farm digital soil mapping.

Ed, a Research Fellow at the university's Sydney Institute of Agriculture, says this data includes landscape variation data, such as satellite images and digital elevation models, and on-farm variation data, including electromagnetic induction (EMI) surveys and yield data.

These data layers can be used as 'covariates' to assist in predicting patterns in soil properties. "Collecting spatial data has become cheaper, more widely available and much more accurate over time."

Ed explains that digital soil mapping incorporates three aspects:

- Covariate maps, such as elevation, EMI survey, gamma radiometrics and satellite imagery;
- Site investigation; and,\
- The construction of soil attribute maps, for properties such as texture, pH, and sodicity.

They are doing more than scratching the surface by looking at the landscape and soil profile. He says digital soil maps are valuable because of their capacity to investigate relationships with yield.

Working with soil specialist (and uncle) Dr Pat Hulme, from Sustainable Soils Management in Warren, NSW, Ed tested this approach on three farms. The aim was to identify which soil properties drove yield variation and decide on management options to ameliorate those constraints.

Project 1

The first project covered 2000 hectares at Cubbie Station, a 93,000 hectare cotton farm in south western Queensland.

The data used on this project included a proximal sensing survey of soil EMI, gamma radiometric and elevation data, which is collected with other paddock operations when RTK guidance is used. These were analysed with records of cut and fill from paddock levelling operations, and a bare soil redness index, used as an indicator of topsoil variability, from the Sentinel satellite.

This data was combined to create a covariate database, which was used to determine soil sampling locations for ground truthing. At four depths – 0–30 cm, 30–60 cm, 60–100 cm and 100–140 cm – 70 soil cores were taken and analysed for pH, exchangeable cations, EC and texture (sand, silt, clay).

Ed says that by investigating the

relationships between the laboratory measured soil properties and the covariate dataset, they were able to produce a continuous map of the 2000 hectares.

"Using this technique, we do produce a massive amount of information. But what we are essentially aiming for are digital maps that show what areas are affected by constraints. In this instance, the constraints were sodicity, salinity and water logging. And then we quantify what those constraints mean for yield."

To understand each constraint's yield impact, machine learning is used. It allows for a constraint to be artificially removed, which in turn, provides an indication of the yield loss attributable to that constraint.

The maps produced for Cubbie at first reflected what farm managers knew, that there was not much variation in the upper soil layers. But at depths of 50–140 cm, within the crop's root zone, there was variation in sodicity.

"We were able to identify some paddocks with this constraint and determine its impact on yield. Those soil properties can help explain what farm managers see year after year in their yield maps."

Another unexpected result was finding that water was ponding in some areas, a discovery made with high resolution elevation data.

Irrigated cotton runs are designed to fall at a certain gradient. But they found that some runs had small discrepancies in fall causing water to pond. This correlated to yield loss. "With these results, farm managers could calculate the costs of relevelling paddocks compared to the yield loss and decide whether to invest or not." (Figure 1).

In the maps produced, each pixel represents an area of 20 by 20 metres. "The great thing about this approach is that we can pinpoint each area where a constraint is having a yield impact.

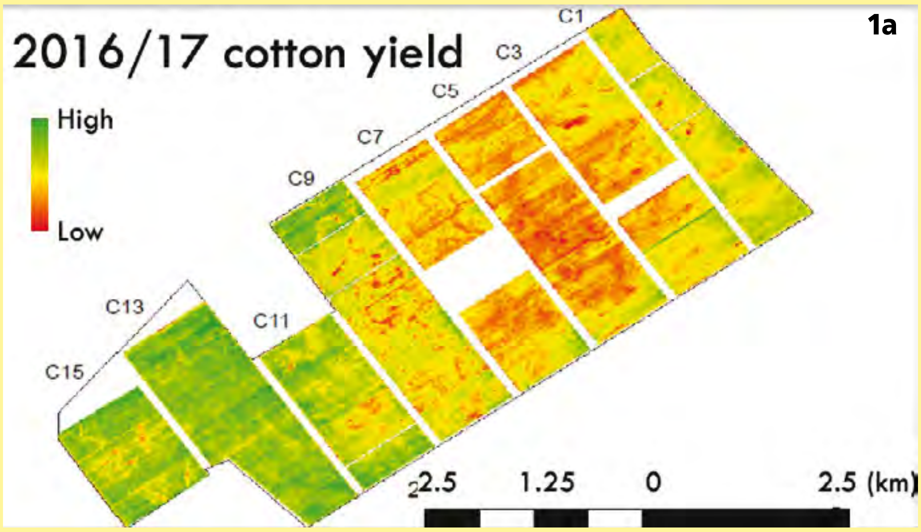
"It can show yield costs and how certain soil constraints influence that yield. Then it is over to the farmer to decide if the yield loss is at a stage where amelioration is worthwhile or not."

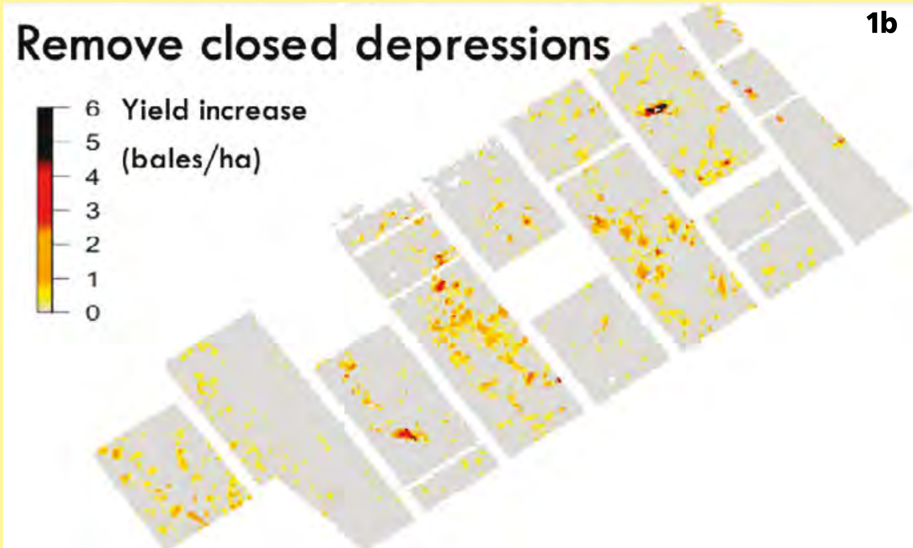
Other examples

To test the work further, Ed and Pat have digitally mapped two other properties – a grazing enterprise and a mixed, irrigated farm.

On 900 hectares in the undulating

FIGURE 1





These maps show how digital mapping techniques can assess the value of soil remediation.

FIGURE 1a: The 2016–17 cotton yield on selected paddocks at Cubbie Station. Green indicates higher yielding areas and red lower yielding areas.

FIGURE 1b: Using clever calculations, this map shows the potential yield benefits (in bales per hectare) from levelling cotton runs to reduce water logging, which has proved to be a yield constraint in some paddocks.

Depressions, where water collects, were identified and quantified when collecting high-resolution elevation data.

Using machine learning, Ed can artificially remove a yield limiting factor, like depressions, showing the potential benefits of amelioration.

In this example, there is some value in remediation, as seen in the red to black colours: More cotton bales are possible if water logging is addressed.

Pinpointing where the depressions are could also help target certain areas for renovation, instead of re-levelling entire paddocks. Likewise, it could also help to manage input applications in those areas.

landscape between Narromine and Dubbo, they set out to investigate why grazing was proving unprofitable for one enterprise.

"That farmer was keen to map the farm's soils and with that improve pastures, working out, for example, the best location for fodder crops," Ed says.

Combining satellite data, elevation and on-farm collected EMI and gamma surveys with 25 strategically located soil cores to ground truth the proximal data, they created a digital map.

Pat knew the land being surveyed, had acidic soils. "But we were able to differentiate areas where just the topsoil was acidic, so liming would be beneficial, from areas where the whole profile was acidic."

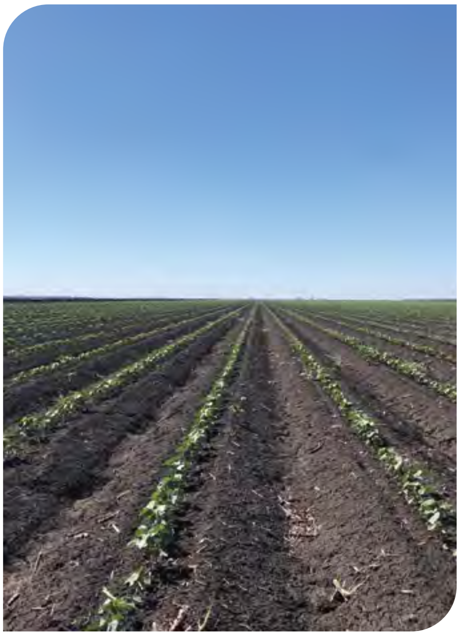
The third test site, 700 hectares of irrigated land at Yanco in NSW, was important for both Ed and Pat to investigate. The farm is owned by Pat and is where Ed spent some of his younger years. It meant they had a fairly good idea about the soils and what crops worked best.

Again, multiple data layers were used with 25 soil cores to create a digital map.

Pat says it was hard to admit that they did not know everything about the soil at Yanco after farming it for more than 40 years. But lessons were learnt.

"The soil is less saline and sodic, but more variable than soil further downstream on the alluvial floodplain.

"This mapping reinforced that different areas of this farm are best suited to different cropping systems," Pat says.



"By artificially removing a constraint, we have an indication of the yield loss attributable to that constraint"

Ed says the great thing about the mapping was being able to produce a result in six weeks, compared to needing decades of farming experience.

Soil tests

Although much of the work is completed using digital spatial data, it still requires a certain number of soil cores to be taken for ground truthing.

The number of soil cores taken needs to be statistically significant, plus cost effective. Ed says that number depends on the land surveyed. "We use a statistical approach that investigates variation in the covariate data to determine how many soil cores are required to capture a sufficient proportion of the variability at each site, while maintaining a minimum of 25 cores."

Ed says that at up to $500 per soil core, soil testing can be expensive. But via a Grains Research and Development Corporation-funded project he is also working on ways to use various soil sensors, such as visible, near-infrared spectroscopy and X-ray fluorescence spectroscopy to test soil cores.

"We want to see if we can avoid the step of sending samples to the lab." The sensors being evaluated would potentially be used to scan the soil for texture, water holding capacity, sodicity and pH in the field, instead of in the laboratory.

The first step is building a soil spectral library against which samples can be compared and equipment can be calibrated. Ed has scanned more than 8,000 soil samples , from a stockpile of soil cores held by the University of Sydney. Each sample's unique response helps to build models and estimate new scanned samples' properties. That work will be completed in October.

For the time being, Ed is enthusiastic about what digital soil mapping could bring. "Digital soil maps are important. They can show us how variation in soil is related to variation in yield, which we can already see on yield maps. By taking the next step and removing constraints, we can work out yield penalties and make amelioration decisions.

"I think our work has shown that you can improve on-farm productivity with the soils that are there. The end game is to maximise productivity for a certain soil within the bounds of that soil's own inherent qualities."

Edward Jones is a Research Fellow in the Sydney Institute of Agriculture with a specialisation in soil spectroscopy.

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