Performance through collaboration

RESEARCH FINDINGS
FACT SHEET

DIAGNOSIS FRAMEWORKS FOR MULTIPLE AND COMPLEX SOIL CONSTRAINTS

Project 4.3.005

From left to right: Kate Coffey (Riverine Plains), farmer Nathan Lawless, Soil CRC researchers Yunru (Chloe) Lai and Suman Gajurel (University of Southern Queensland) at the Riverine Plains workshop.

KEY POINTS

- Soil constraints can be diagnosed using data that growers already collect, in combination with publicly available soil information, reducing reliance on intensive soil sampling and laboratory testing.
- This project developed a framework that predicted plant available water capacity with reasonable accuracy across Australia's grain growing regions and performed better than some conventional estimation methods.
- The framework demonstrated potential for predicting key chemical constraints including acidity, alkalinity, salinity, sodicity, fertility, and aluminium and boron toxicity. Results were stronger where larger and more diverse soil datasets were available.
- Workshops with growers confirmed that the data required to run the models already exists on many farms, although it is often held in varied and inconsistent formats. The workshops also identified the requirements for a practical soil constraints diagnosis tool, providing a foundation for decision support systems to help manage soil constraints.

THE CHALLENGE

Soil constraints such as acidity, sodicity and compaction limit the productivity of around 77% of Australia's agricultural soils, costing the grains industry billions of dollars in lost production potential each year. Constraints often occur together and can vary in severity both across a field and down the soil profile. This makes accurate diagnoses difficult without intensive soil sampling and laboratory testing, which is expensive, slow, and labour intensive.

As a result, many growers do not collect the information needed to accurately identify soil constraints. Without a clear diagnosis, it is difficult to target amelioration effectively and potential productivity gains may be missed.

OUR RESEARCH

The project developed and tested a framework for diagnosing multiple soil constraints using publicly available data and farmers' own data.

To diagnose physical constraints, the project focused on plant available water capacity (PAWC), which measures how much water a soil can store for crop use and is a useful indicator of physical limitations to root growth. PAWC was estimated using the Agricultural Production Systems sIMulator (APSIM) with an inverse modelling approach. Rather than predicting crop performance from known soil properties, the model worked backwards from crop performance to estimate the PAWC most consistent with observed yields. The model combined information from the Soil and Landscape Grid of Australia, Scientific Information for Land Owners (SILO) climate data, and multi-year farm management and yield records. The framework was tested across Australia's grain growing regions.

For chemical constraints, the project developed machine learning models to predict the soil properties associated with common constraints, including pH (acidity and alkalinity), electrical conductivity (salinity), exchangeable sodium percentage (ESP, sodicity), cation exchange capacity (nutrient holding capacity), and exchangeable aluminium and boron (toxicity).

The models were trained using existing soil datasets together with soil, environmental and crop information. Their accuracy was assessed using cross validation and independently collected soil data. Several machine learning methods, including Cubist and Random Forest, were compared to identify the best approach for each soil property. Where local soil data were limited, national datasets were used to improve model performance.

From left to right: Kelly Angel (Birchip Cropping Group) with Soil CRC researchers Yunru (Chloe) Lai and Suman Gajurel (University of Southern Queensland) at the Birchip Cropping Group workshop.

Workshops

Alongside the modelling, the project held workshops with grower group partners to identify the farm and public data that growers can realistically access and use. The workshops also examined how these data are stored and managed across different platforms. This ensured the framework was built around the information growers already have available, rather than data that are difficult or impractical to obtain.

RESEARCH FINDINGS

Physical constraints

The inverse modelling framework predicted PAWC with reasonable accuracy across Australia's grain-growing regions (R^2 = 0.75). This substantially outperformed conventional approaches. Estimates taken directly from the Soil and Landscape Grid of Australia consistently underpredicted PAWC, and the framework substantially outperformed pedotransfer functions based on soil texture (R^2 = 0.27).

Performance held up across a wide range of soils and climates, and the framework was not biased toward any region or soil type, indicating it can be applied across diverse cropping environments.

Prediction accuracy depended on the quality of the input data. The best results were achieved using the Soil and Landscape Grid of Australia together with SILO climate data for model initialisation. Accuracy declined when lower resolution international datasets were used.

Chemical constraints

Using soil test data that growers routinely collect, Cubist machine learning models predicted several key soil properties with reasonable to high accuracy: cation exchange capacity (R^2 = 0.90), pH (R^2 = 0.81) and electrical conductivity (R^2 = 0.81).

Predictions for ESP and chloride were less accurate because fewer data were available to train the models.

To improve these predictions and extend the approach to aluminium and boron toxicity, the project tested additional machine learning methods using larger national soil datasets. Random Forest models gave the best overall performance, improving predictions for ESP, chloride, aluminium and boron.

Workshops

The workshops confirmed that most of the data needed to support a soil constraint diagnosis tool usually already exists on farm or is publicly available. However, these data are often stored in different formats, spread across multiple platforms and managed inconsistently. In most cases, the information would require manual entry into the modelling framework.

The workshops also identified the features a diagnosis tool would need for growers to adopt it. Because soil amelioration is an infrequent activity, the tool would need to be simple and intuitive to use without requiring users to relearn it each season. Growers said the tool should accept a range of data formats, connect with existing farm platforms and continue to work where internet access is limited. It should provide recommendations that fit existing farm practices and support both blanket and variable rate amelioration.

Local validation of recommendations and clear information about how farm data would be used were also considered essential for building trust.

SIGNIFICANCE OF THE FINDINGS

This project demonstrated that multiple, interacting soil constraints can be diagnosed using data that growers already collect, together with publicly available soil information. This reduces the need for intensive soil sampling and laboratory testing, lowering one of the main barriers to diagnosing soil constraints and targeting amelioration.

The project also advanced two complementary modelling approaches. Inverse modelling provided a practical way to estimate PAWC which is otherwise difficult and expensive to measure. Machine learning models enabled spatial prediction of key soil chemical properties across Australia's grain growing regions. Together, these approaches showed that combining biophysical modelling with machine learning can improve soil constraint diagnosis beyond what either method can achieve alone.

These methods provide the foundation for decision support tools that can help growers diagnose soil constraints and identify suitable amelioration options.

Project team

- Keith Pembleton, Chloe Lai, Suman Gajurel, Craig Lobsey (University of Southern Queensland)
- Nathan Craig (West Midlands Group, now at Innovation Squared)
- Rob Milla (Burdekin Productivity Services)
- Clair Browne (Birchip Cropping Group)
- Jane McInnes (Riverine Plains)

NEXT STEPS

The next priority is to incorporate these approaches into decision support tools for soil constraint amelioration. The aim is to combine the diagnosis methods developed in this project with models that predict how soils and crops respond to different amelioration options, supported by economic analysis so growers can compare the likely costs and benefits of each intervention.

The workshops showed that any tool will need to fit the way growers already work by supporting existing data formats, integrating with farm software where possible, and remaining simple to use. A new soil constraint decision support tool is the focus of the Soil CRC's **'Next generation tools for higher performing soils'** project (4.3.007).

This fact sheet and related publications are available on the Soil CRC Knowledge Hub (soilcrc.com.au/resources).