

Demonstrating the value of soil testing to support Australian farmers' local soil knowledge through a digital tool and action learning

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Abstract

The level of soil testing required to understand soil change is not widely practiced by Australian farmers; to a large extent, they rely on tacit knowledge. To support farmers' local understanding of soil performance and improve the value of soil testing, soil scientists and local agronomists engaged in a series of action-learning workshops throughout New South Wales to demonstrate how an online remote sensing tool can be used to strategically soil sample. Once the farmers identified soil testing locations, the researchers conducted soil sampling at those sites in consultation with the farmers. In the follow-up workshop, where soil test results were presented to the farmers, nearly all agreed that the results aligned with their local knowledge of their paddock. However, only half of the farmers said they would use the digital tool in future soil sampling, but they would also consider soil testing more frequently.

Introduction

Currently, there is a low level of farmer awareness of how soil testing can be used to understand spatial yield variation within paddocks and improve crop management. This is especially true when soil samples tend to be taken from the surface 10 cm and bulked to obtain 'average' paddock results. Farmers often use soil testing in an ad hoc manner to determine crop nutrient availability and then to guide fertilizer use (Lobry de Bruyn & Andrews, 2016). Hence, there is a limited grasp of how soil testing to greater depth combined with paired sampling of high/low yielding areas can be used to understand soil constraints affecting yields and to develop spatially tailored soil management.

The financial investment required to conduct soil testing can also lead to hesitancy among farmers who believe the economic benefits of detailed soil data have not been sufficiently demonstrated, and there is limited guidance on interpreting soil tests to guide decision-making. The project addressed these concerns by supporting farmers' understanding of how soil testing can be used to improve farm management and profitability. This approach represents a significant shift from traditional forms of soil testing, which tend to rely on the use of sampling grids or random sampling approaches

to collect soil across a paddock with minimal involvement by the farmer. We demonstrated a digital tool (ConstraintID) and instructed farmers on how to use the tool in action-learning workshops so that they could identify soil sampling locations in paddocks of interest. ConstraintID uses archived satellite imagery to illustrate seasonal and spatial yield variability and to identify locations for targeted soil testing.

This approach aims to reduce the expense of obtaining spatially relevant soil data and should increase farmers' confidence in where and why to sample. The demonstration of inexpensive onsite soil analysis complementary to standard laboratory testing was used to assist farmers in understanding the links between soil conditions and yield variability without the need for large financial investments. The aim is to see if this will increase farmers' confidence in the usefulness of soil testing and investment in further soil testing over time, and alter management practices.

Material and methods

In consultation with local agronomists, local land services, and land-care staff, we identified seven farmer groups of ~8 participants across New South Wales (NSW) (northern, central, and southern NSW) in Mungindi, Walgett, Yarrie Lake, Forbes, Wagga Wagga, Temora, and Grong Grong. Human ethics clearance (HE22-014) was obtained for farmer surveys at each workshop. Actively seeking farmer feedback to develop and improve extension material and ConstraintID was also sought to increase its relevance and use. The 1st survey (n = 60) characterized participants' interest in the project and documented their experience with soil testing. The second survey (n = 31) sought to understand the impact of the use of a digital tool and soil test results on farmers' soil management, and future interest in soil testing. The survey instruments for each farmer workshop were developed in Qualtrix and were completed online or in hard copy. We also planned to link the responses from the two surveys to understand the individual impact of the project on a farmer's learning and how their local soil knowledge and use of a digital tool (ConstraintID) aligned with the soil test results.

The first workshop (late July to early October 2022, n = 51 people) was conducted in a local community hall or by Zoom if participants were unable to attend in person and were designed to: a) demonstrate ConstraintID and how it can be used to examine yield variability and select sampling locations (high, low, and moderately performing zones); and b) discuss how soil testing can be used to explain paddock performance and hence yield variability. ConstraintID is a recently developed web-based tool that processes 20 years of remote-sensing data from LANDSAT satellites to enable farmers to identify spatial variations in crop yield rapidly and affordably and to use these to select soil testing locations. The combination of ConstraintID and farmers' local experience of paddock performance represents an integrated approach that assists a farmer not only in choosing where and how to soil test but also in interpreting soil analyses to understand yield variation against their local knowledge. This approach conforms to the definition of on-farm experimentation as espoused in Lacoste et al. (2022).

For each paddock, three soil cores up to a 90 cm depth were taken from each of the performance zones (January–April 2023) and processed at both a commercial soil testing laboratory and, for soil physical properties, by the researchers. Hence, each paddock had nine complete cores that were soil-tested at five depths per core and analyzed for a range of soil properties. Soil samples were compatible with national soil monitoring program databases, such as the Soil and Landscape Grid of Australia. The soils were classified according to the Australian Soil Classification System, and lodged with eSPADE (New South Wales soil and landscape data portal).

Following soil testing, all original participants were invited to a second workshop (July to August 2023, n = 39 people attended) to discuss soil test results, the potential reasons for yield variation, and to develop an action plan for future management. For the second

workshop, an interactive presentation was developed that allowed farmers to delve into the areas of concern, and compare their soil test results against common thresholds. A typical soil profile pit was excavated for each workshop to examine the soil in situ, help farmers interpret soil data, and identify potential management options (Fig. 1). This level of scaffolded support is currently lacking in commercial soil-testing environments.

These workshops were designed to engage individual farmers with data from their properties, which we could also assess as a technique to increase farmers' understanding and engagement in soil knowledge. As the second workshop was delayed due to flooding and delays in soil sampling, the immediate necessity of obtaining soil test results had passed. Hence, the return rate to the second workshop was only 50% of the original participants, and some questions in the second survey were only answered by two-thirds of the participants. Therefore, feedback was predisposed toward those who attended as well as those who chose to answer the survey fully. Following workshop participation, farmers were again asked for feedback on their understanding of yield variability in their selected paddocks, and how targeted soil sampling and testing would affect their future soil management strategies.

Our initial intention to link the two surveys to gauge individual learning and correlate soil testing experience with other question responses was not possible, as those returning to the second workshop were not able to recall the anonymous linking password they used in the first survey. In the future, an easily remembered word, such as your first pet's name, will be suggested to the participants.



Fig. 1: In the field with participants examining a soil profile as part of the second action learning workshop

Results

Characteristics of participants

Most of the participants were farmers (63%) or had a mixed role between farming and supplying agronomic advice (17%), and a similar portion were solely agronomists (20%). About a third of the participants were under 30 years of age and would be considered digital natives, while another 46% were between 30 and 50 years of age, and 23% were over 50 years of age (who would be unlikely to have grown up with the internet). Only a small proportion of women participated (18%), and this was usually part of a family-operated farm or agronomist. There was a range of property sizes, and agronomists covered large areas, as they had multiple clients. In response to local experience in the area, an average of 17 ± 12 years was spent in the area.

Those who were attracted to the project either nominated 'I want to learn more about soil testing' (71%) or 'I am generally interested in soils' (61%). On average, people have

more than one reason to attend. Participants also exhibited a mix of confidence in the knowledge of their soils and how to manage them productively, with 43% stating they were 'confident' and 52% saying they were 'unsure'. Likewise, most participants were fairly confident that they understood their soil test results (59%), but only 29% interpreted the soil test results on their own.

Of interest to this project was the prior experience of soil testing, and the largest proportion of participants were 'regular users' who soil sampled every 2–3 years (40%); however, 34% were either soil sampling every 4 to 5 years (17%) or soil sampling greater than every 5 years (17%). A similar percentage of participants (18%) were 'frequent users' and were undertaking soil sampling as part of their agronomic work. Only a small proportion of the participants had undertaken no soil testing (7%). This meant that the participants covered a wide range of soil testing experiences, from infrequent users to 'regular users.' In previous soil testing experience, the number of samples taken ranged from a few to 30 per paddock, with only 35% detailing a range of soil tests, which were generally soil chemical properties. In most cases, the soil testing was focused on soil pH, nitrogen, and phosphorus, and only 3 of 52 participants mentioned measuring carbon. Soil structure was only mentioned specifically by two participants.

Overwhelmingly, farmers relied on their agronomists to interpret their soil test results (55%) or themselves (29%), while a small proportion undertook the activity jointly with their agronomists (9%). It also seems that farmers trusted the person or their judgment when interpreting the soil test and would 'follow most of the advice' (70%). The advice was usually about fertilizer rates or soil amendments (lime and gypsum), with the proviso that it was dependent on cost.

Triangulating local soil knowledge, ConstraintID, and soil test results

The paddock of interest for soil testing was identified by the farmer, and then ConstraintID was used to identify three locations in each of the performance zones for soil coring. Farmers' normal practice is to hire an agronomist to grid samples anywhere between 3 and 30 samples, and only to a shallow depth of 0–20 cm, at best. Congruence with local knowledge of the paddock for those participants who did attend was high, with 97% answering the question 'Did the soil test results support what you knew about your paddock?' in the affirmative. Most elaboration on the response seemed to indicate that the soil test results revealed no surprises to the landholder or agronomist: 'It identified and reinforced my thoughts,' 'The results explained some of my assumptions,' 'The information roughly matched real-world harvest results within the paddock,' and 'confirmed the soil constraints.'

The follow-up question focused on the use of ConstraintID on performance variability in conjunction with soil testing, and all participants agreed they now appreciate what is affecting paddock-level performance from the soil test: 'It highlighted possible subsoil constraints,' 'easy tool to show where potential problems are,' and 'highlighted the constraints on water use and moisture retention.' Some reservations were expressed: 'Probably have to see with trials and experience.'

The participants were asked what new insight or understanding they gained from participating in this project. Three recurrent themes were how to manage soils better, appreciating that they are highly variable, and knowing the soil type to depth also affects soil productivity and yields.

Impact of ConstraintID on soil testing and practice change

The action learning workshops were held almost a year apart; therefore, the delivery of the soil test results arrived 'too late' for the farmer to make use of the results for the current cropping season. There was an indication that for those 'already employed'

practices (variable fertilizer application, and the application of lime and gypsum), there would be further modification and enhancement because of the soil test results gathered through ConstraintID. Also, the three practices that participants would consider using, based on their soil test results, were deep banding of phosphorus (56%), applying organic manure (70%), and undertaking deep ripping (43%), with few participants considering the option of 'taking land out of production' because of their soil test results (15%).

In terms of how farmers responded to the use of the digital tool, there seemed to be some interest in ConstraintID outside the first workshop, with 48% exploring their farm and other areas, 21% only in preparation for soil sampling in the project, and 31% 'no further use' after the first workshop. Most participants (95%) at the second workshop agreed that ConstraintID helped identify where to soil test in the paddock despite less interest in engaging with the tool outside the introductory workshop. The qualitative responses to this question highlighted how the tool for those prepared to engage with it would alter their normal practices.

Fourteen out of 20 people (64% of attendees responded to this question) said that using ConstraintID to strategically locate soil testing locations would assist them in soil testing more often and over larger areas. However, these people were also the ones prepared to use ConstraintID outside the workshop setting, either before the project soil sampling (43%) or to explore a wider area (57%). Hence, those who expressed interest in the digital tool were already primed to use it, either through their roles and interests or because of their higher level of digital capability. Interestingly, those who would not soil test more frequently had all used Constraint ID outside the workshop setting to explore a wider area, which may indicate that they were already sampling soil frequently. Also, the feedback survey gained formative feedback for designers, and one suggestion was a clear link to key resources and a 'learnings' page.

Discussion

The project was funded to improve farmer's appreciation for soil variability and to highlight through the use of a digital tool how they could strategically soil test in zones of plant performance to examine the constraints to production and sustainable farming. The responses of those involved were generally positive, but the reflections of the staff involved in conducting the project revealed that there was a high transaction cost in 1) attracting participants to the project and 2) organizing and conducting the workshops, and follow-up soil sampling on the participant's land.

At its core, this project was proposed to be farmer-centric, focusing on their learning needs, and engaging with them, and was heavily reliant on their involvement and use of the digital tool for locating soil sampling sites. However, despite their involvement over more than 12 months, they were not actively involved in project design, data acquisition, or analysis. Unfortunately, to obtain funding for the proposal, it is expected to articulate a fully designed project with clear outcomes and deliverables. To be genuine on-farm experimentation, landholders would need to be engaged sooner in the development phase of the digital tool and not test its validity after it was developed, as it was in this project.

The larger lesson from this project was that the value of soil testing is not an easy proposition to convince people of, especially those who are a) mostly delegating responsibility to an agronomist or b) not convinced of the value of soil testing in the first place. The pivotal relationship that needs to be understood better and supported is between farmers and their agronomic advisors as well as ensuring that local soil knowledge, held by farmers, is included when soil testing. Also, having assurance that agronomic advisors are up to date in their soil knowledge, especially of soils' physical properties, such as dispersion, and its effects on plant growth.

We propose that the two groups work more closely together, assisted by a tool such as ConstraintID, to decide where soil will be sampled and why. However, as it is a fee-for-service relationship, it requires tangible outcomes that, in the case of soil improvements, are not immediately discernable. However, farmers would likely continue a relationship if plant production or profitability improved, and for an agronomist, this would mean continuity in an investment.

Conclusion

The value proposition to encourage more farmers to undertake soil testing, thus leading to more-detailed soil information and possibly greater knowledge of soil behavior and its effects on plant production was partly realized, with indications that soil testing data was of some value to the participating farmers. Most returning participants found the digital tool –ConstraintID – useful for identifying soil sampling locations. However, the use of a digital tool is more suited to the digitally literate and to farmers who work closely with an agronomist, which was commonly reported by the participating farmers for interpreting soil test results.

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