From Constraints to Solutions: Evaluating Sandy Soil Management with an Interactive Web App.

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Abstract

There are more than five million ha of cropping sands in the southern cropping region of south-eastern Australia. Many sands are underperforming due to poor crop establishment and a lack of crop access to nutrients and water. A recent six-year Sandy Soils project provided growers with an understanding of key sandy soil constraints, management options and yield and profit outcomes for these management strategies. Although sandy soils are challenging, growers are enthusiastic about facing their production challenges and in recent years, ameliorating sandy soils has gained popularity. Understanding the key soil constraints, the yield response to amelioration techniques as well as knowing how best to implement these practices are important considerations that can help growers adopt these practices. This paper examines an interactive web application that allows growers, consultants, and researchers to interrogate and visualise sandy soil project trial yield results alongside site climate and soil constraint information. The App draws on trial data from 26 sites across the GRDCS Southern region, representing 138 trials. Users can compare trial data with their on-farm experience to help decide if the management strategies are suitable for their farm. The paper will use a case study example of how the App can add evidence to decisions about sandy soil management.

Keywords

Sandy soils, deep tillage, decision support, web application, trial results.

Introduction

In southern Australia, more than five million ha of cropping land are sandy (McBeath et al. 2023). Typical constraints to crop productivity include a range of chemical and biological parameters impacting the soil supply and retention of nutrients, sandy soil may exhibit properties such as low organic matter and cation exchange content, water repellence, acidity, generalised lack of nutrients, and low biological activity, as well as physical constraints such as high soil strength (da Silva et al. 2024, Huang et al. 2020, Unkovich et al. 2023). Opportunities exist to increase crop yields on sandy soils through mitigation and amelioration of constraints to production. Many sandy soils have multiple constraints, and identifying the primary constraint along with its magnitude will help guide management. Mitigation strategies include improving crop establishment and soil water retention, using polymers and wetters, residue management, and sowing on or near the previous crop row. Amelioration techniques include soil inversion, mixing, and/or shattering with or without the addition of amendments.

This paper reports on a project aimed at lifting yields in underperforming sandy soils by improving the diagnosis and management of constraints. It involved collaboration with growers to implement research trials on commercial farms. Data sharing is becoming an expected practice for industry-funded projects, as there is a push for greater returns from research funding (Walters et al, 2018). It is now commonplace for trial results to be published alongside traditional outputs. The project's data has been published in several formats, including the ‘Data Access Portal’ (https://data.csiro.au/) a certified repository that provides access to CSIRO’s research data, enabling reusability, and ensures long-term preservation and persistence. It is also published in an R Shiny app called ‘Sandy soil App – Sandbox’ (https://shiny.csiro.au/soil-sandbox/) which displays project data in a format that supports farm decision-making. Although farmer decision-making on adopting innovations, is inherently complex (Walters et al 2018), and it can never be assumed that access to relevant data and information will lead to action, there is optimism that data availability and information can assist in farming decisions (Evans et al. 2017). This paper examines ‘Sandbox’, a purpose-built easy-to-use, interactive web application that aims to connect growers and advisers to soil mitigation and amelioration research outputs including factsheets, decision matrices and a database of trial results. The App engages with users to help them better understand sandy soil constraints, guiding users through diagnosing constraints and exploring management options with possible yield responses. Further we explore how a hypothetical farmer might use the App to support the management of sandy soils.

Methods

The Sandbox App collated data from 26 sites totaling 138 unique amelioration and mitigation treatments. The experiments ran between the 2014 -2022 growing seasons in the low to medium rainfall Southern cropping region. The suite of trials run at the various sites did not include all possible amelioration options, only 17% of the trials were annual mitigation strategies, the most common was the addition of fertiliser, and animal manures, while more than 80% of the trials were amelioration techniques. As the main purpose of the database is to act as a repository, the database contains more variables and raw data (including replicates) than the App. The inclusion of both raw trial data and metadata is guided by FAIR principles (Wilkinson et al. 2016), which suggests data that is findable, accessible, interoperable, and reusable will extract the maximum benefit. Yield response data was collected at all sites, and is the focal point of the App. Along with the yield, the App also includes the site's soil constraints, geographical location and climate data which helps with the interpretation of the results. The soil constraints were ranked according to criteria outlined in factsheets that have been embedded in the App (Azeem et al. 2024). The trial results presented in the App have been summarised and statistically analysed, it is a bridge between the raw data stored on the DAP and traditional formats. The App also contains linkage to key project factsheets outlining how to identify constraints and how to optimise machinery set-up. It guides users by helping to identify the primary constraint to crop production and it's relative impact. It collates treatment options relevant to the primary constraint and reports the trial results in which these treatment options were tested. The trial results in the App are presented on a site-by-site basis and are selected by a drop-down menu. Firstly 'cumulative yields' are plotted, as a response by treatment (including the control), this is displayed as a stacked bar graph which is made up of the years the trial was run. The same results are also displayed as a table along with the results of a one-way ANOVA analysis and multiple comparisons of treatments by means of LSD and a grouping of treatments. The final table presents the results as a 'yield gain' expressed as tonnes per hectare relative to the control treatment per site and year. This table also reports the crop grown and the decile season, which can assist in the interpretation of the results.

Results and Discussion

At the core of the App is the project framework, which guides users in thinking about sandy soil management. It describes regionally specific sandy soil constraints along with methods for diagnosing and rating. Constraints included are repellency, nutrients, acidity, and soil strength, and their relative impact is categorised into three classes: no issue, moderate or severe. Information on the constraints and its testing is supported with links to GRDC factsheets, encouraging users to gain a better understanding. A 2022 survey of growers and consultants who attended the 'Sandy Soil Roadshow' (n=77) revealed that many key learnings mirror the projects frameworks; comments suggest growers are starting to normalise parts of the decision-making process, by defining the problem, identifying the cause and developing a plan.

The App also lists the trial sites and their soil constraints' severity rating, tested using the described methods in the App. Physical constraint was the most common constraint (96%), with half of the sites rating the problem as severe, lack of nutrients was also a common constraint (46% rated it severe). Repellence was identified in just over half of the sites; however, it was more commonly reported as a moderate problem. Finally, acidity was less common with only 15% of sites rating this as moderate or severe. Many sites had multiple soil constraints, with half of the sites identifying three of the four major constraints evaluated. Furthermore, 42% of sites had two or more constraints that were severe. Identifying the primary constraint is challenging when multiple soil constraints exist, furthermore, when two constraints are both rated severe it is difficult for the farmer to know which one to focus on. However, using the App to explore and assess mitigation and amelioration options for a given set of constraints can be helpful. With this information, trial outcomes for a specific site and management option can be evaluated.

Using the hypothetical farm near Karoonda, we consider how the App could be used to support decisions. The soil constraints at the hypothetical farm include severe soil strength, severe fertility, and moderate water repellence. These severity ratings are then used to filter the list of sites in the App, which identified Bute and Lowaldie as sites with similar constraints. Although Karoonda and Bute are 200 km apart they have some similar soil characteristics and trials run at Bute may elicit a similar yield response. By taking this approach a farmer at Karoonda could evaluate the trials run at Bute and Lowaldie to support future management decisions on their own farm. Knowledge of the soil constraints can be used to identify the most suitable

treatment options using a matrix table in the App. Along with the table the App describes management options based on soil's constraints providing detailed information and links to GRDC fact sheets.

Using the soil constraints identified at our hypothetical farm we can use the matrix table to identify management options. The matrix table puts forward three different deep tillage options to address high soil strength, including ripping, mixing or inversion, with added amendments. Looking at the management options for low fertility we can see that there is some overlap, and we can narrow down our options to ripping with added amendments or soil mixing with added amendments. The final step is to review trial results for sites with similar constraints evaluating the success of management options identified in the matrix table. The choice of mitigation or amelioration strategies represents a shift in how sandy soils have been historically managed. According to the 'Sandy Soil Roadshows' survey over the last five years, non-mechanical treatments have been more popular than mechanical ones, however, more than half of growers managing sandy soils anticipate using mechanical methods in the future

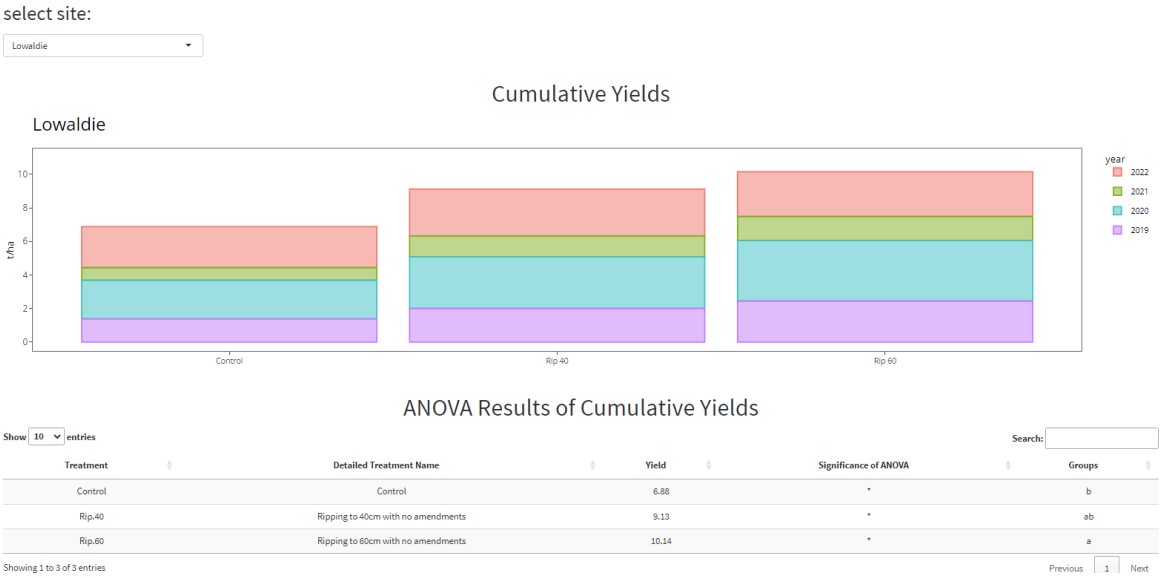

Figure 1. Cumulative yield results for Lowaldie site.

Returning to the hypothetical farm, and the project framework we have identified similar sites (Bute and Lowaldie) and some management options (ripping or mixing with added amendments) we can now review the yield responses for the proposed management options. At the two Lowaldie sites, ripping trials with no amendments were explored at depths of 40 and 60cm over four seasons, in wheat and barley crops. The cumulative yield for ripping at 60cm was significantly higher than the control at both Lowaldie sites and at the 'deep sand' site both ripping treatments produced significant yield gains. These results suggest that ripping to 60cm with no amendments is likely to improve yields for multiple years. However, these trials only address high soil strength and do not treat poor nutrition, therefore it is likely that a yield gap still exists. At Bute site, 24 management strategies were explored, over seven seasons, in wheat, barley and lentil crops. 12 treatments explored ripping to a depth of 50cm, with and without the addition of amendments (chicken litter, fertiliser or clay) while the remaining treatment applied amendments to the soil surface. The highest yield gain was for treatments that had both soil modification with amendments, while treatments with only amendment applied to the surface were not statistically different to the control, and finally, treatments with only soil modification had a small yield gain. At this site management options that address both soil strength and nutrition are most beneficial, while strategies that address only one constraint, either nutrition or soil strength produce smaller yield gains. The trial results at both sites reinforce the importance of correctly identifying and ranking soil constraints, as well as the challenges in ranking one soil constraint over another. The range of trial results at these sites also highlights the complexity associated with choosing the most effective management strategies. Furthermore, the cost of the management choice varies considerably, which could also play into the grower's decision process. In variable risky climates, there may be merit in gaining a better understanding of the limiting constraint by trialing less costly strategies before adopting more costly solutions.

Conclusion

Through a case study example of a hypothetical farm, we have demonstrated how a purpose-built interactive web application can support growers in understanding their sandy soil constraints and guide them through the difficult choice between management options. At the core of the App is the project framework which guides users in thinking about their sandy soil, by identifying the constraints, and assessing the best option. It aims to bridge the gaps between raw trial results and published journal papers, presenting a range of project data and supporting documents that communicate a clear, accessible message about the identification and management of sandy soil constraints. It is designed to be useful for both farmers and their advisers as they work through decisions about sandy soil management.

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