SOIL CRC

Performance through collaboration

YEAR IN REVIEW

2023

CRC FOR HIGH PERFORMANCE SOILS LIMITED

MAJOR PARTNERS

PARTNERS

ASSOCIATES

Contents

About the Soil CRC

The Cooperative Research Centre for High Performance Soils (the Soil CRC) was established in 2017 to give farmers the knowledge and tools they need to make decisions on extremely complex soil management issues.

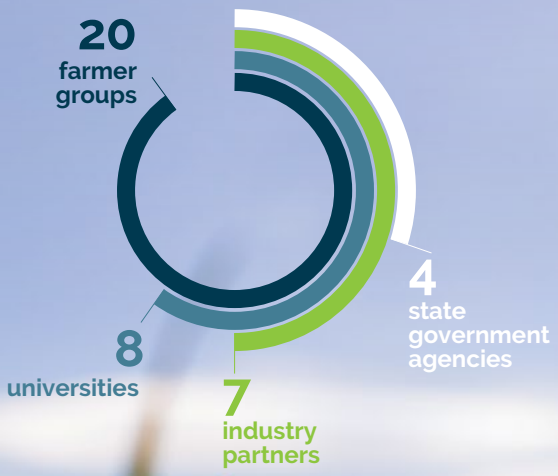
Through our soil research and innovation program, we are developing new solutions that are unlocking the potential of Australia's agriculture sector.

Our practical, real-world outputs allow farmers to optimise their productivity, yield and profitability, and ensure the long-term sustainability of their farming businesses.

The Soil CRC is the largest collaborative soil research effort in Australia's history, bringing together eight universities, four state government agencies, seven industry partners and 20 farmer groups.

Our multi-disciplinary research efforts are helping Australian agriculture to reach its target for farm gate output of $100 billion per year by 2030.

Participants



2023 in review

10 Years' funding

$39.5 million Commonwealth investment

$133 million cash and in-kind industry support

7 new projects approved
10 completed

8 PhD students commenced

Vision

Australian farmers using best practice soil management to underpin a dynamic, sustainable and profitable agriculture sector.

Mission

To contribute new knowledge, tools and practices to help Australia's farmers better manage their soils in order to improve the profitability, sustainability, resilience and well-being of the agriculture sector.

Values

Collaborative

The Soil CRC is a collaborative and inclusive research and adoption organisation, passionate about soil and bold in its approach to delivering outcomes.

End user-driven and focused

The Soil CRC is end user-driven in all things it does. Through farmers and other groups, industry are genuine partners in the CRC, helping to set priorities, develop proposals, undertake research, interpret results and communicate new knowledge.

Multidisciplinary

The Soil CRC employs the necessary disciplines and expertise to deliver change during the life of the CRC, while being aspirational in its long-term goals to ensure a continuing legacy.

Research excellence

The Soil CRC is committed to research excellence — in science practice, capacity building, governance, management, integrity and ethics. The CRC is committed to being a national collaborative leader, recognised as an integral part of Australia's agricultural innovation system.

38 PhD students currently studying

4 programs

$2.7 million committed to new projects

38 active Soil CRC projects

4 new registered trade marks

Message from the Chair and Chief Executive Officer

As the Soil CRC wraps up its sixth year of its 10-year funded life, we are at the peak of our activity and investment. Projects are being undertaken in all states of Australia, bringing our participants together in productive and collaborative partnerships.

We have completed 28 projects and 38 Commonwealth milestones — all delivering practical solutions for Australia's underperforming soils, helping farmers to improve their productivity and profitability.

The work of the Soil CRC continues to contribute to the three goals of the National Soil Strategy — prioritise soil health, empower soil innovation and stewards, and strengthen soil knowledge and capability. We are a key supporter of the National Soil Action Plan, which outlines priority actions for the next five years to improve Australia's soil health and long-term security.

As we move into our final four years, we increase our focus on soil knowledge transfer and research extension and adoption. Our Board approved the creation of a new role to help facilitate this shift, and in May 2023, we welcomed our first Soil Knowledge Broker, Felicity Harrop. Felicity is working with our grower groups and other delivery partners, including the Regional Soil Coordinators, to ensure our research outputs are made available where they can best be used.

In August 2022, the Board commissioned an external review of the Soil CRC to help inform the Soil CRC's 2023–27 Strategic Plan, utilising the expertise of Prof. Leigh Sullivan, soil scientist and university administrator, and Ms Caroline Welsh, farmer, extension officer and grower group chair. The process included an extensive document review and interviews with 50 key stakeholders in the Soil CRC, including board members, staff, program leaders, university and farmer group representatives, researchers and PhD students.

The review found that overall, the Soil CRC is in very good shape and meeting the expectations of many of its participants and stakeholders. However, it did include six recommendations to help improve the effectiveness of the CRC in its remaining four years. These recommendations were considered during the Soil CRC's strategic planning process in the first half of 2023 and informed the development of our Strategic Plan for 2023–27.

In April 2023, the Soil CRC announced funding for six new research projects, with a cash investment of $2.7 million and $6.2 million of in-kind contributions from participants. This investment brings the total spending on projects to more than $33 million since the CRC commenced in 2017. This has been supplemented by a number of externally funded projects, providing an additional $6 million in funding to date.

Eight new PhD students joined our 38-strong PhD cohort in 2022–23. With one student completing their PhD this financial year, it brings the total number of completions to four. Situated in 12 universities across Australia and representing a wide range of disciplines, our students are a key part of the contribution that the Soil CRC is making to Australia's future capacity in soil research.

In 2022–23, we were finally able to see our stakeholders face-to-face for a number of important events, including our 2022 Soil CRC Participants Conference. Over 150 delegates joined us in Adelaide to hear about the Soil CRC's work, and to network and collaborate. It was wonderful to welcome both our Soil CRC participants, and external stakeholders with an interest in our research.

In June 2023, over 20 Soil CRC researchers and students travelled to Darwin to present their research to more than 300 delegates at the Soil Science Australia Conference. It was a great opportunity to shine a spotlight on the Soil CRC, highlighting the breadth of our work to the national soil science community.

We celebrated World Soil Day at Old Parliament House in November 2022 with the Parliamentary Friends of Soil. The event was hosted by co-chairs the Hon. Michael McCormack MP and Ms Meryl Swanson MP, with the Hon. Murray Watt, Minister for Agriculture, Fisheries and Forestry, and Ms Penny Wensley AC, National Soils Advocate and Soil CRC Patron, both speaking at the event. It was pleasing to see political leadership and recognition being shown on this issue.

On a sad note, our friend and colleague, Julie Moulton, passed away in April 2023 after a battle with cancer. As our Research Administration Officer, Julie had a lot of contact with researchers and contract administration staff in our participant organisations and was a friend to everyone she had contact with. Vale Julie.

We thank the members of the Board, management and staff of the Soil CRC for their continued contribution to the organisation's operation. We extend our gratitude to all Soil CRC participants, researchers and students who are working together to deliver the outcomes of the Soil CRC.

We look forward to the final four years of the Soil CRC where we will focus on ensuring that the Soil CRC leaves a legacy that will be recognised for years to come.

Dr Paul Greenfield AO
Chair, Soil CRC

Dr Michael Crawford
CEO, Soil CRC

Vale: Julie Moulton

The story so far...

29 projects completed

Over $33 million cash committed to projects

4 PhD student completions

50 PhD student commencements

$6 million additional investments

5 registered trade marks

Highlights and achievements

The Soil CRC approved funding for six new research projects with a cash investment of $2.7 million and a further $6.2 million of in-kind contributions from participants. This brings the total spending on projects to more than $33 million since the CRC commenced in 2017.

We welcomed eight new PhD students in 2022–23 and saw one student complete their PhD, taking the total number of active students to 38 and the total number of completions to four.

Our new Soil Knowledge Broker commenced in May 2023, strengthening our focus on soil knowledge transfer and research adoption as the Soil CRC enters its final four years.

The Soil CRC registered four new trade marks — three for our Nurtured Lands® brand and one for the BILBY® (a below-ground wireless data node). This will enable commercialisation of products and services generated by our projects.

The Soil CRC was a Silver Sponsor of the 2023 Soil Science Australia Conference, held in Darwin in June, where our CEO Dr Michael Crawford delivered a keynote address. More than 20 Soil CRC researchers and PhD students presented their Soil CRC-funded work, in both oral and poster presentations.

We continued to support implementation of the National Soil Strategy with contributions to steering and working groups, and to research which supports its three goals — prioritise soil health, empower soil innovation and stewards, and strengthen soil knowledge and capability.

Soil CRC PhD student Bhavya Mod (University of Newcastle) was selected as a finalist in Cooperative Research Australia's Early Career Researcher competition. This is the second year in a row that Soil CRC researchers have been finalists in this competition.

Soil CRC Board Member, Robbie Sefton, was made a Member (AM) in the General Division of the Order of Australia for Services to Agriculture.

Soil CRC research scientist, Professor Richard Bell (Murdoch University) was awarded the prestigious JA Prescott Medal by Soil Science Australia for making an outstanding contribution to soil science.

Soil CRC Program 4 Leader, Dr Lukas Van Zwieten (NSW Department of Primary Industries), became the inaugural inductee to the Biochar Hall of Fame at the Australian New Zealand Biochar Industry Group's Biochar Roadmap Summit in Adelaide.

The Soil CRC, National Soils Advocate, Soil Science Australia and Soils for Life co-hosted a World Soil Day breakfast with the Parliamentary Friends of Soil to highlight the important contribution that soil makes to our economy, environment and society. Speakers included the Hon. Murray Watt, Minister for Agriculture, Fisheries and Forestry, and Parliamentary Friends of Soil co-chairs the Hon. Michael McCormack MP and Ms Meryl Swanson MP, as well as the National Soils Advocate and Soil CRC Patron, Ms Penny Wensley AC.

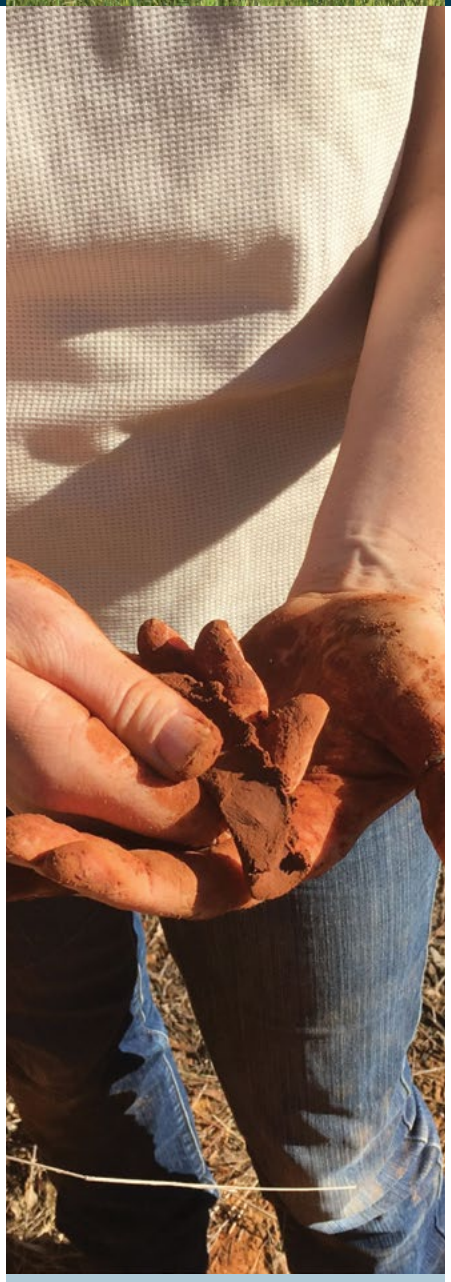
The Soil CRC collaborated with Meat and Livestock Australia (MLA) to deliver two scoping studies related to livestock grazing systems — Soil Management in Livestock Grazing Systems and Soil Indicators for Livestock Grazing Systems Performance. The project was delivered by Federation University, the NSW Department of Primary Industries and the SA Department of Primary Industries and Regions in 2022–23.


FINALIST

Program 1

Investing in high performance soils

Program Leader:
Professor Catherine Allan
Charles Sturt University



Program 1 uses economics, marketing and social science research to help farmers achieve their soil stewardship and profitability goals. Researchers and participants from 11 grower groups, seven universities and five industry partners, along with six PhD students, are supporting farmers to maintain the long-term integrity and fertility of soils for future generations.

Australian farmers are often encouraged — or even forced — by markets, policy settings or shifting social norms to make management decisions that have the potential to damage soils, farm profitability and public good. Program 1 encourages practice change by finding ways to shape markets and assist grower groups.

Program 1 will deliver a 'public good package' of information and capacity-building activities for researchers, farmer groups and Soil CRC partners. The three related outputs in the package will support and enable opportunities to accelerate change and build adaptive capacity.

The first output involves using markets to reward farmers for improved soil stewardship. A three-year project focused on consumer markets found there is potential and willingness for some consumers, and others in the value chain, to reward soil stewards by paying more for agricultural goods.

In the past year, a follow-on project built on these positive results by investigating financial market rewards. Sending signals to consumer and financial markets requires some form of verification or certification, and a project on this topic made good progress in 2022–23, complemented by a law-focused PhD study.

The second output relates to acceptance and use of approaches to soil stewardship among farmers. Understanding today's farmers is essential for supporting change, and in 2022–23 the first round of six comprehensive social benchmarking surveys was completed with the administration and analysis of surveys in Tasmania and the Victorian Wimmera. A new project to re-survey north central Victoria, central west New South Wales and the wheatbelt in Western Australia was also approved.

Other activities in this output area include a farmer group-focused

project, which builds on prior Soil CRC research on 'adoption' to critically evaluate modes of farmer engagement and knowledge sharing. Four PhD research projects are associated with this area of social research, examining understanding of soil management norms and intuition in decision-making, the role of gender, as well as knowledge sharing of regenerative farming.

The third output relates to innovative and effective ways of operating and collaborating in complex and uncertain situations. In 2022–23 we gained new knowledge through four projects focused on innovation, and on-farm economics and risks. One project is guiding five farmer groups in building their adaptive and entrepreneurial capacities. Another is developing a tool for farmer groups to use to help them decide which innovations to support and promote.

Other projects are seeking to move beyond simplistic (and therefore deceptive) economic analysis of practices, to better reflect the reality of making decisions within complex social and ecological systems. This includes economic considerations related to regenerative agriculture and organic fertilisers created from waste. One PhD student's work is complementing this output with research into the economics of soil amelioration.

There are linkages between projects across the program. For example, data from the social benchmarking survey informs the market-focused research. Over the next three to four years more data will be shared among projects in Program 1, fostering the emergence of new ideas and enabling the development of integrated information on the social and economic aspects of improved soil stewardship.

Case study 1

Knowledge-sharing for good soil stewardship

Knowledge sharing: the key to enhancing research adoption

Hundreds of millions of dollars are invested each year in agricultural science and technology, but adoption rates for many technologies remain quite low. Effective knowledge sharing processes between farmers, scientists and key knowledge brokers is essential for enhancing research adoption and good soil stewardship.

Dr Hanabeth Luke of Southern Cross University is leading the Soil CRC's research effort to address the challenges and opportunities associated with sharing soil knowledge, with the aim of increasing farmer uptake of new research outputs.

This project will guide engagement, collaboration and knowledge-sharing efforts by the Soil CRC and its participants, towards maximum effectiveness and impact on soil health, fertility and performance.

Collaborating for success

Southern Cross University is driving this research project, which involves four other universities and grower groups from four case study regions in Victoria, Western Australia, New South Wales and South Australia.

"I'm working with Dr Penny Cooke from Southern Cross University and a multi-organisational team to understand how knowledge is shared, to increase farmer confidence to invest in new soil management approaches, practices and technologies," Hanabeth explained.

"The project is super-charging the knowledge-sharing and extension efforts of the grower groups as we work as a team to co-develop and trial a range of knowledge-sharing modes and strategies across the different case study regions."

These range from digital strategies to new ways to run field days, drawing on the skills of a cross-institutional, cross-disciplinary research team to test and assess the effectiveness of these modes over time.

Keeping it local

Embedded in this project is an understanding that knowledge-sharing processes need to be locally relevant and related to key challenges identified by farmers.

"We've empowered the grower groups—AIR EP in South Australia, West Midlands Group in Western Australia, Central West Farming Systems in New South Wales and Birchip Cropping Group in Victoria—to take the wheel and help steer the research course," Hanabeth said.

Of course, these are people who really value research, so the strategic priorities of each group within this project was based on data from the Soil CRC's social benchmarking surveys and our research in their regions.

"The enthusiasm of the grower groups has been key to the success of this project so far. Our project team is still meeting monthly to discuss their engagement priorities and approaches, having powerful discussions about what is working and what could be improved."

Simon Kruger from West Midlands Group said he values the opportunity to have lots of conversations with other project participants.

"What's working for them can also work for me, or maybe I could tweak it a bit to work for our group and our farmers," he said.

Even when some regions were hit with severe flooding last year, grower groups found ways to adjust and carry on with the research effort, such as holding an 'Unbog Yourself' field day in the wake of the floods. Idea sharing has been an integral element of this project.

Data-driven

This research builds on the findings of previous Soil CRC projects to deliver robust and useful data.

Data is collected using three key methods:

- A standardised evaluation form distributed at farming events — this uses high level questions to help assess the effectiveness of engagement strategies and likely investment/adoption that might arise from events.
- Process diaries completed by project team members when carrying out an engagement activity — the details are entered into the diary, including who was involved, what was done, who is engaging with different approaches and an analysis of the strengths, weaknesses, opportunities and threats.
- Regular project participant meetings — these are used to discuss what the grower groups are trialling, to share ideas and capture reflections.

Hanabeth said the data is showing farmers require multiple 'touch points' to aid knowledge sharing and adoption.

"A farmer might hear about a new practice or technology once in the newspaper or online, but that doesn't automatically prompt action. They then need to start talking about it with other farmers and hear other opinions.

"There is a process of knowledge-sharing and demonstration that needs to happen before farmers will develop the confidence to try something new," she said.

"This links to the findings coming out of the Soil CRC's survey projects, which shows how our decisions are impacted by the opinions and experiences of others."

Sharing the knowledge

This two-year project will wrap up in late 2023 and is expected to deliver a range of research outputs, including:

- a knowledge sharing guide with tips for engaging people, which includes a section on digital engagement
- recommendations for a training program
- short 'how to' videos from our partner grower groups
- a journal paper on project design.

Simon said he is excited about the knowledge sharing guide that will come out of this project, noting it will benefit both grower groups and researchers.

"If we want good outcomes from the research that we're doing, we really need to think about the farmers and end-users at the start of the project," he said.

Program 2

Soil performance metrics

Program Leader: Associate Professor Richard Doyle
University of Tasmania

Program 2 seeks to better understand indicators of soil performance and how these can be used to enhance soil productivity. Twenty grower groups, six universities, two government research partners and 11 PhD students are developing tools linked to soil management products that will help farmers better manage their soils for increased productivity and profitability.

Program 2 researchers are developing a range of technologies that will enable farmers to cost-effectively collect data for monitoring soil performance. In the past year, their efforts have focused on finalising the development of the Bilby® (an underground communication node), the Bandicoot™ (an advanced penetrometer) and the QUOLL™ e-Nose (a soil electronic nose for smelling soil). Efforts are now ramping up to commercialise these products, with the Soil CRC securing a registered trademark for the BILBY™ in 2022-23.

Work continued on the development of the Soil CRC's Lab-on-a-Chip technology, which integrates a 3D printed micro-fluidic device with a smartphone app to measure soil nutrients. Our project team has produced prototypes for soil nitrate and soil pH, with efforts now focused on the detection of soluble phosphorus.

The next funded phase of the project will focus on commercialisation pathways for these devices. Researchers are also looking at options to advance the Lab-on-a-Chip technology to measure organic carbon and biological properties.

The second phase of the Visualising Australasia's Soils (VAS) is well underway and involves working with farmer groups on data storage, access and sharing, along with linking the display of available paddock and farm scale soil moisture maps and point data. Engagement with farmer groups, managing staff changes and clarifying the use-cases and purpose of VAS is ongoing. Refining the use-cases will strengthen the value proposition of sound soil data storage, sharing and management.

We are also advancing our understanding of data management across the Soil CRC and highlighting the need for improved training and understanding of what metadata should be reported with the various soil data sets we generate.

Program 2 is increasing our understanding of farmers' use and comprehension of the value of various soil performance indicators. Further work is needed on relating this to various farming systems and key soil types.

Finally, we are working on gaining a better understanding of soil biological indicators and their use and effectiveness in soil health assessment.

The PhD students in Program 2 are at various stages of their candidature. Their research work covers many areas, from improving our understanding of soil biological health, to the use of various types of remote sensing to better sense and resolve soil properties, along with advancing knowledge of spatial variations. Our students are involved in advancing the Lab-on-a-Chip technology and using machine learning for better soil moisture monitoring.

Program 3

New products for soil fertility and function

Program Leader: Professor Megharaj Mallavarapu
University of Newcastle

Program 3 aims to develop new fertiliser formulations, pesticide delivery systems, soil enhancements, microbial carrier products and improved mechanisms for delivering these solutions to farmers. These pursuits collectively aim to enhance soil performance and productivity for agricultural practitioners.

This program brings together seven grower groups, six universities, and three industry partners. There are 12 active projects and four completed projects, with eight current PhD students and two PhD completions.

Substantial progress has been made in Program 3, with 15 out of 21 Commonwealth milestones accomplished successfully. The remaining Commonwealth milestones are actively being pursued through ongoing projects, including those started this year.

Our researchers have made significant contributions to the field, with the successful synthesis of micro-lime and micro-gypsum products, along with the creation of innovative biochars and microbial carrier products.

One project has demonstrated the positive impact of biosolid application on soil health, which carries implications for sustainable agricultural practices and environmental conservation.

Another project conducted meta-data analysis and mapping studies to provide insights into organic and clay amendments, resulting in improvements to sandy soils. This achievement has positive implications for enhancing soil fertility.

Few studies are dedicated to extracting high-grade fertilisers, particularly phosphorous (P), from waste streams. The successful synthesis of novel biochar from the waste streams underscores the program's commitment to resource recovery from waste for potential application as fertiliser, to reduce the reliance on chemical fertilisers.

Other key achievements in 2022-23 include:

- **Biochar-clay innovations:** the synthesis of biochar-nanocomposites with remarkable P absorption capacity. These formulations hold promise as potent P fertilisers for agricultural crops.
- **Plant growth and manure studies:** ongoing experiments involving glasshouse and field trials to explore the value of manures as phosphorous fertilisers for plant growth and productivity. This research also investigates the influence of raw versus treated manures on both plant growth and organic matter degradation.
- **Enhancing soil structure:** progressing the development of new amendments aimed at enhancing soil structure. Nano-structured lime and gypsum prototype products have been synthesised, and their superior reactivity, dissolution rates, and mobility into subsoil have been established.
- **Nano-lime and nano-gypsum application:** surface application of nano-lime and nano-gypsum has demonstrated substantial potential for addressing subsoil acidity and sodicity respectively, with higher use efficiency and a reduction in application rate of up to 25%.
- **Microbial carrier products:** innovations extend to moisture retention and microbial carrier products designed for rhizobia. These advancements hold the promise of enhancing the efficacy of beneficial microbes in the soil, thereby contributing to nitrogen fixation, root disease protection, and symbiotic interactions with plants.

Program 4

Integrated soil management solutions

Program Leader:
Dr Lukas Van Zwieten
NSW Department of Primary Industries

Program 4 aims to develop cost-effective and sustainable solutions, driven by innovation, to build more productive and resilient soil. This will underpin a dynamic, sustainable and profitable Australian agriculture sector.

Projects within Program 4 foster collaboration between 15 grower groups, seven universities, three government research partners and nine PhD students. Together, they are delivering innovative soil management techniques and products, data and models using 16 field trials.

Grower groups and research teams around Australia run our field trials, with some gaining additional co-investment from the Grains Research Development Corporation and the Department of Primary Industries and Regional Development in Western Australia. In the past year, these field trials supported nine field days and farm walks to help raise awareness of our research and demonstrate best soil management practices to growers.

While there is much interest in maintaining year-round ground cover in cropping systems, the impact of these practices for in-crop water availability and crop yield remain poorly understood in Australia. Broad interest in cover cropping, mixed-species cropping and intercropping has stemmed from the knowledge that ground cover has multiple benefits, including maximising carbon inputs into soil, through sustaining the soil biological community and contributing to soil physical properties, and protecting the soil from erosion.

Field trials in far north Queensland are demonstrating improved resilience of sugarcane soils to compaction stresses where mixed species cover crops were used instead of bare fallow. In soils in New South Wales and Victoria, cover cropping has improved physical and biological characteristics of soil, including water infiltration.

Our researchers have installed an extensive array of soil monitoring probes at a winter rainfall field site to quantify and model changes to water storage and drainage, and investigate the water dynamics in rotations with cover crops. This work is further supported by a PhD student who continues to refine models for water use in summer rainfall cover cropping scenarios. Cover crops have so far demonstrated benefits to the

infiltration of water into soil, likely through improvements to soil physical structure such as aggregation and soil surface properties.

Finding economically viable solutions for multiple complex soil constraints is challenging. Laboratory, glasshouse and field trial sites show that these constraints need to be carefully diagnosed before successful amelioration can be achieved.

Field trial sites on highly calcareous soils on the upper Eyre Peninsula in South Australia have shown that a package of higher seeding rates, increased fertiliser inputs and a fungicidal seed dressing produced the best growth and highest grain yields. A bespoke carbon-coated mineral fertiliser that delivered slow-release phosphorus also provided significant benefits to crop production. In contrasting soils in the south east of South Australia, foliar application of iron minerals to address root uptake deficiency significantly improved legume production, while also addressing challenging weed issues.

Field trials in New South Wales and far north Queensland are assessing a range of technologies for enhancing the structure of sodic subsoils to improve root access to water and nutrients. These include the subsoil placement of stoichiometrically balanced organic amendments, gypsum and bespoke carbon-coated minerals. Soil water sensors are being used to detail the water dynamics at these sites.

One of our PhD students is developing new amendments for addressing non-wetting sands and improving our understanding of mechanisms of action. Field trial sites in Western Australia are evaluating soil management techniques, including organic amendments, deep ripping, application of clay, use of perennial legumes and crop sequences, to increase soil carbon content and crop access to water.

Another PhD student has been developing a reverse modelling framework of APSIM (Agricultural Production Systems Simulator) that can predict the plant available water capacity (PAWC) of a soil with moderate accuracy using only crop yield and management information. The predicted PAWC in combination with other soil and crop data is being used to train a machine learning model to predict physical and chemical constraints. The team has mapped the availability and accessibility of on-farm data that could be used as inputs for the next generation of decision support platforms focused on diagnosing and ameliorating soil constraints.

Work continues on a computer-based approach to learn from Soil CRC data and public datasets to find the best ways to manage multiple soil constraints. Data from Soil CRC field trials will be standardised for modelling purposes and to ensure that it is findable, accessible, interoperable and reusable.

Case study 2

Plant-based solutions to improve soil performance

Looking at crop diversity through a local lens

Diversity in farming systems is known to provide multiple benefits including resilience, weed and disease suppression and improved soil health. But crop diversity in major cropping systems in Australia is limited. A recently completed Soil CRC project set out to change this by uncovering how soil performance is affected by increased crop diversity.

Increasing the diversity of plants in farming systems provides a diversity of carbon inputs into the soil, leading to an increased diversity in soil biology and a more resilient soil.

Project Leader Professor Terry Rose from Southern Cross University explained, "the key challenge is finding economically viable ways to increase plant diversity in the farming system, given that crops grown in the existing rotations are generally the most profitable and low-risk options."

The 'Plant-based solutions to improve soil performance' project investigated how soil performance and profitability are affected by increased crop diversity in rotational systems, in both broadacre grains and sugarcane industries.

It also looked at the potential for plant-based solutions to improve soil performance through rhizosphere modification — altering the conditions in the zone of soil surrounding the plant root, where the biology and chemistry of the soil are influenced by the root.

From the lab to the field

Laboratory, glasshouse and small plot trials were conducted in the first phase of the research to develop a mechanistic understanding of the processes underlying potential improvements in soil function and productivity under new practices.

The project then established five long-term field sites across Australia to investigate the impact of different management practices on soil function and crop yields within local cropping systems.

The management practices and systems assessed were:

- Summer cover cropping in Australian southern cropping systems
- Temporary cereal-legume intercropping in southern cropping systems
- Oilseed-legume intercropping in southern cropping systems
- Use of perennial legumes in Western Australian cropping systems
- Use of cover crops during the plough-out phase of sugarcane farming systems in the wet tropics.

Guided by grower groups

The field sites were established in conjunction with our participant grower groups — Hart Field Site Group in Southern Australia, Facey Group in Western Australia, Central West Farming Systems in New South Wales, Riverine Plains in Victoria and Herbert Cane Productivity Services in Queensland.

"These grower groups provided ongoing feedback to ensure the research addressed their needs," Terry said.

"Growers were also able to observe the trials in their local regions, increasing their confidence in the research outcomes."

The grower groups worked with researchers and staff from Southern Cross University, Murdoch University, Charles Sturt University and NSW Department of Primary Industries.

Promising results improve decision-making

The project identified cover cropping in tropical sugarcane farming systems and temporary cereal-legume intercropping in southern Australian grain cropping systems as promising options for increasing plant diversity and maintaining productivity.

"Importantly, temporary cereal-legume intercropping shows potential for integrating legumes into the farming system with little need to change other farming practices, meaning it is easy to adopt," Terry said.

Summer cover crops were found to have potential to be used tactically in southern Australian cropping systems (for example, in wet seasons, or where fallow groundcover is low), but may not be suitable every season because their water use can affect subsequent winter crop yields.

Terry explained that the results provide an evidence base from which farmers can make management decisions around summer cover cropping, where previous decisions were made based on anecdotes or information from wetter temperate environments in the northern hemisphere.

And finally, oilseed-legume intercropping did not improve productivity over individual monoculture legume or canola crops in the seasons tested. The project team recommended subsequent studies should focus on reducing inputs in intercropping systems.

Extending field trials to increase knowledge

Temporary cereal-legume intercropping, oilseed-legume intercropping, and summer cover cropping will be investigated further in subsequent years at two of the long-term trial sites to examine longer-term impacts on soil performance and system productivity.

A new Soil CRC project commenced in January 2023 and the three management practices will be further investigated until January 2026.

Research project updates

Rewarding soil stewardship

Project number: 1.1.004

Project leader: Dr Nicholas Pawsey, Charles Sturt University

Participating organisations:

- Charles Sturt University
- Federation University Australia
- University of Southern Queensland
- Birchip Cropping Group
- Riverine Plains
- Western Australian No-Tillage Farmers Association

Duration: 2022–2025

Summary

A previous Soil CRC project, 'Collaborative approaches to innovation', identified that many finance stakeholders and growers accept the importance of good soil stewardship and are interested in how it might be encouraged and rewarded.

The current project is focused on activating financial markets to reward soil stewardship and unlock investment in soils. The research aims to demonstrate a stronger link between good soil stewardship and financial profitability. This involves improving connections between researchers, growers and financial markets, and translating soil science for the finance sector.

A three-stage approach involving grower groups and the finance sector will secure outcomes that best reflect industry expectations.

A range of potential mechanisms and pathways have been identified including sustainability-linked loan schemes, risk assessment and other financial decision tools, government programs and policies, and insurance products.

Activities

The research team published an Australian Accountancy Standards Board (AASB) working paper on opportunities to promote soil reporting by corporate agribusinesses, to support agri-investors and other stakeholders to understand the significance of soil stewardship.

Titled 'Improving the Visibility of Soil Health in Corporate Reporting', the paper drew on the perspectives from across a broad range of agribusinesses and investors. The study aimed to contribute to the development of the International Sustainability Standards Board's draft requirements for disclosure of sustainability-related financial information.

During 2023, we also:

- Interviewed a range of growers from Birchip Cropping Group, Riverine Plains and WANTFA to understand their perspectives on the financial costs and benefits of soil stewardship, and alternative modes of rewarding their investments in soil health.
- Completed a broad ranging literature review of the empirical literature concerning the financial returns of soil stewardship practices in dryland, broadacre cropping contexts.

Results and findings

Our work on promoting soil reporting found:

- Significant opportunities to enhance the corporate disclosures on soil management and risks given that such disclosures are relatively sparse in comparison to reporting on other sustainability-related matters (such as water and emissions).
- While many agribusiness investors presently lack a detailed appreciation of the nature of soil health, there is growing recognition of the importance of soil in investment decisions.
- There is strong support for enhanced soil reporting by agribusinesses, noting soil-related information should be simple, concise, communicated in terms investors understand, and focused on data that is already captured by agribusinesses for management purposes.

Next steps

Our efforts to understand grower perspectives on alternative modes of rewarding soil stewardship and to quantify the financial implications of soil-related risks and opportunities will provide the foundations for future pilot activities. These activities will focus on trialling novel approaches of rewarding soil stewardship through financial markets.

What drives farmer decisions?

Project number: 1.2.005

Project leader: Dr Hanabeth Luke, Southern Cross University

Participating organisations:

- Southern Cross University
- Charles Sturt University
- Soils for Life
- Wimmera CMA
- Southern Farming Systems

Duration: 2021–2023

Summary

Improved understanding of farmer decision-making can help to increase long-term soil health and productivity, inform strategic planning and build innovation capacity. This project surveyed land management practices in Tasmania and the Wimmera region of Victoria to complete the Soil CRC's social benchmarking of rural landholders across Australia. Previous studies were undertaken in North Central Victoria, South Australia, Western Australia and New South Wales as part of the Soil CRC's 'Surveying farm practices' project.

The social benchmarking method has been developed and adapted from well-established research techniques in rural sociology, to explore the complex factors driving the management of soils and landscapes.

Improved understanding of farmers and their practices will help the Soil CRC, farmer groups and NRM organisations to better target their innovations and communications, as well as contributing to their strategic planning.

Activities

- Tasmanian social benchmarking survey implemented mid-2022.
- Four-page summary released to local partners in November 2022.
- Development of the Wimmera study priorities and survey pre-test undertaken in mid-2022.
- Data analysis completed and draft Tasmanian social benchmarking report supplied to partners, March 2023.
- Wimmera social benchmarking survey implemented February–April 2023.
- Project team members presented at the Wimmera Machinery Field Day, March 2023.
- Data analysis completed and draft Wimmera social benchmarking report supplied to partners, June 2023.

Results and findings

- Passing on a healthy and sustainable farm for future generations was the most commonly held value for farmers across all six regions.
- Looking after family and their needs, preventing pollution, protecting natural resources, and creating wealth and striving for a financially profitable business were other important values.
- Including family in decision-making has emerged as an important element of farm management that is more likely to result in the implementation of resilience-building practices, from whole-farm planning and maintenance of ground cover to succession planning.
- Just under half of the full-time farmers surveyed saw themselves as early adopters. About 15% of farmers across regions see no reason to change their practices and are happy even if their farm may not be 'the best farm around'.
- Soil erosion due to wind or water, low biological activity in soils and the declining nutrient status of soils are important property-wide issues across the survey regions.
- Beliefs around climate change varied across the regions surveyed but is a key emerging issue, alongside succession planning.

Next steps

A new Soil CRC project will deliver follow-up social benchmarking surveys between 2024 and 2026, to discern changing practices, values, beliefs and attitudes over time and across Australian farming regions. These follow-up surveys will also provide a means to evaluate the impact of the Soil CRC and its partner organisations over time.

Building farmer innovation capability — Phase two

Project number: 1.4.003

Project leader: Professor David Falepau, Charles Sturt University

Participating organisations:

- Charles Sturt University
- Southern Farming Systems
- Holbrook Landcare Group
- Facey Group
- Birchip Cropping Group
- Soils for Life

Duration: 2022–2023

Summary

Farmer-led innovation provides an alternative to historical approaches to research, development and adoption of technologies and practices to improve soil management.

Following on from the Soil CRC project 'Building farmer innovation capability' which worked with five farmer groups to build their innovation systems, capability and culture, phase two is establishing similar partnerships with another five farmer groups.

These groups are working with a partner, such as an agribusiness or research and development provider, who supports them towards the accelerated development and commercialisation of an innovation targeted at improving soil stewardship.

An innovation manager is being trained within each farmer group in conjunction with their partner, to design and implement an innovation system including all stages from ideation through to commercialisation and adoption.

Activities

- Innovation managers came together to run their ideas on services and technologies to improve soil stewardship through our 'innovation incubator boot camp' at Charles Sturt University's Agritech Hub.
- Building on their hands-on experience in innovation, a similar 'boot camp' brought the innovation managers and their farmer group executives together to build out their farmer group innovation strategies.

Results and findings

Consistent with the previous project, the current project is building innovation capability, systems and culture within participating farmer groups.

Next steps

Through this and the previous project, participating farmer groups are well equipped to work with the wider CRC research portfolio to realise innovation and adoption of practices and technologies for improved soil stewardship.

Smelling soil: eNose development

Project number: 2.1.005

Project leader: Dr Shane Powell, University of Tasmania

Participating organisation:

- University of Tasmania

Duration: 2022–2024

Summary

Previous Soil CRC project, 'Smelling soil', proved it was possible to build a low-cost electronic smell sensor — or 'eNose' — for measuring soil gas emissions and detecting changes in soil conditions.

This project continues development of the eNose, aiming to build a useful and useable device that can help growers understand what is happening in their soil. The eNose will detect the 'aroma' of soil as a rapid test of activity in soil, helping growers make informed decisions about how to best manage their soil to be more productive and resilient to environmental change.

The project focuses on two areas: building a robust device suitable for field use and investigating the relationship between eNose data and significant changes in soil biological activity.

Activities

The project team is engaging in a range of development and pre-commercialisation activities to develop a product fit for commercialisation and adoption by Australian farmers:

- Refining the sensor selection and device design.
- Designing the database and user interface that will enable users to access and analyse data.
- Testing and re-design of device housing.
- Lodging a trademark application with IP Australia for the QUOLL™ eNose.
- Engaging in early discussions with interested industry partners.

Results and findings

- Field tests demonstrated that the housing of the device is important, to enable robust and reliable results.
- Pot trials under controlled conditions have demonstrated that the device reliably distinguishes between soil mixes with different organic matter content and detects responses to soil wetting events.

Next steps

In the next stage of the project, we will further test the abilities of the QUOLL™ eNose in both the laboratory and field, and will further develop the user interface.

Measuring soil microbes

Project number: 2.1.008

Project Leader: Dr Michael Rose, NSW Department of Primary Industries

Participating organisations:

- NSW Department of Primary Industries
- Wheatbelt NRM
- Birchip Cropping Group
- Central West Farming Systems
- Northern Grower Alliance
- Primary Industries and Regions South Australia
- Southern Cross University
- Griffith University

Duration: 2022–2025

Summary

This project aims to increase our understanding of the soil microbial indicators that drive agronomic decision-making, to improve soil biological performance, ecosystem services and agricultural productivity.

The project is evaluating a broad suite of microbial indicators and assessing their relevance to agronomic or environmental outcomes, such as crop yield, soil structure, and nutrient availability.

Samples are being taken across broad spatial and temporal scales to determine whether relationships between indicators and functions can be generalised, or whether they are site or seasonally specific.

Activities

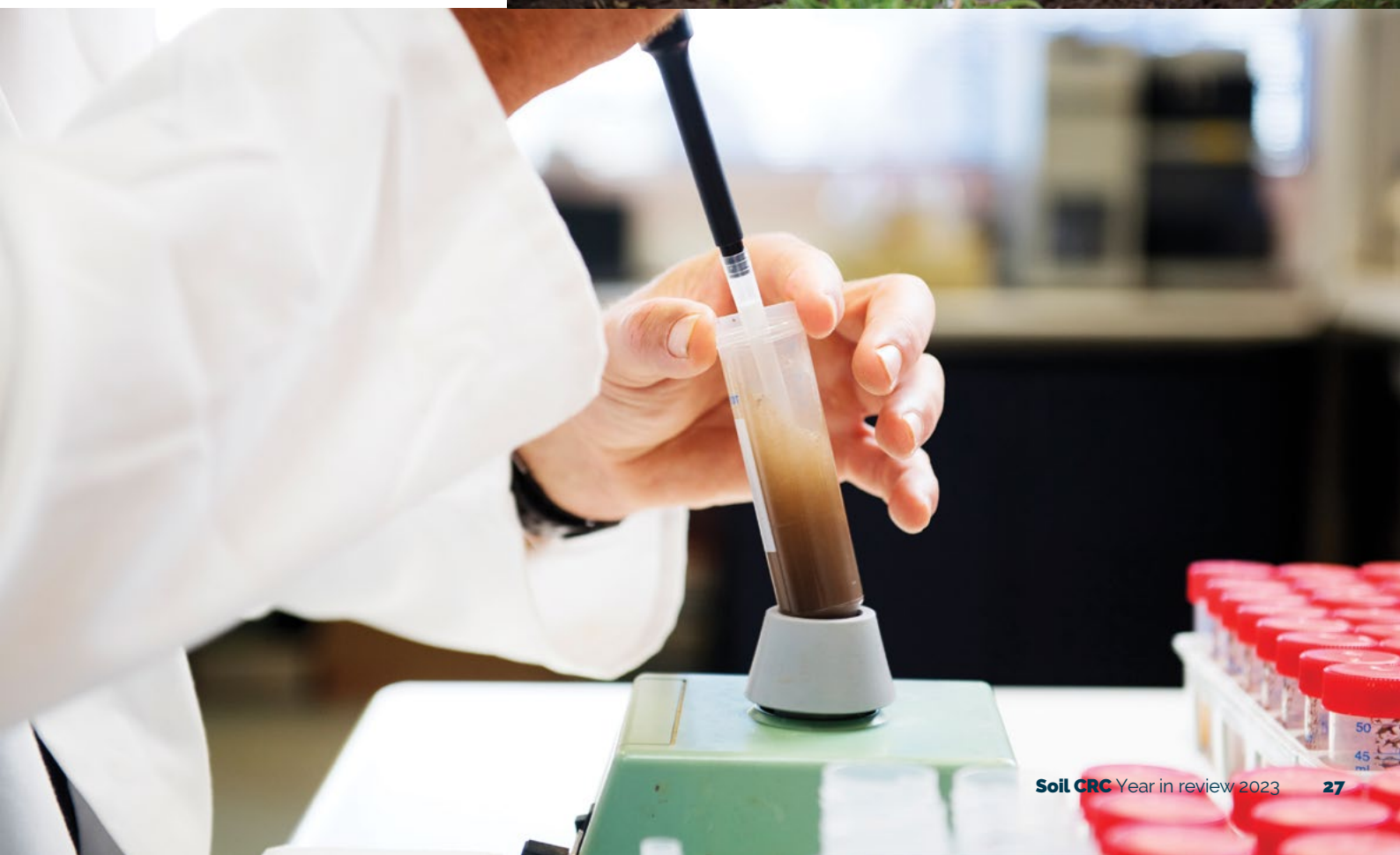
- Soil samples from the entire first season of trials (including pre-sowing, in-crop and harvest) have now been analysed for four of the five original sites. One site (NGA) in northern NSW was inundated by floodwater and the site, treatments and crop were destroyed. Data are currently being analysed on a site-by-site basis and will be compiled and analysed together soon.
- An article based on results from the Eyre Peninsula site in South Australia (addressing calcareous soil constraints) was published in the Eyre Peninsula Farming Systems summary. This demonstrated the power of quantitative PCR (qPCR) to detect management practice effects within one season.
- Pre-sowing sampling for the second season was undertaken from experimental field sites in April-May 2023 and analysis of these samples is ongoing.
- An oral presentation was delivered in late June at the Soil Science Australia National Conference in Darwin, entitled 'Making sense of microbial indicators for soil and crop health'. There was significant interest in standardisation of promising candidate biological indicators — further discussions with other Soil CRC participants are planned to progress this avenue of research translation.

Results and findings

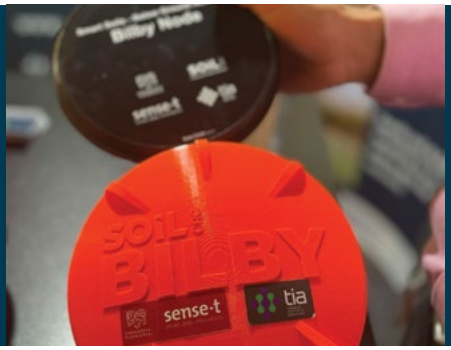
- Protocols for measuring each microbial indicator have now been validated, and the precision for each method has been characterised by analysing replicate samples of the baseline soils from each of the five sites.
- Strong relationships across sites and treatments have been identified between different soil carbon fractions, soil microbial biomass and certain soil enzyme activities. In particular, strong correlations between labile soil carbon, soil protein, mineralisable nitrogen and chitinase activity have been observed at each site.
- To date, DNA-based microbial indicators (e.g. the qPCR of different pathogens, nematodes and mycorrhizal fungal groups) have been more sensitive than other physiological or biochemical measures to changes in management practices. For example, we were able to detect changes in specific pathogen loads or mycorrhizal groups after fungicide application or different crop rotations. In certain cases, these changes were correlated to differences in crop growth and yield — but these varied on a site-specific basis. This suggests that it may be difficult to identify microbial indicators that can be used as measures of soil health across different cropping systems and soil types.

Next steps

The project will continue to monitor sites around Australia to better understand the spatial and temporal dynamics of the different indicators, and their relationships to crop health and other soil functions. At the end of the project, recommendations will be made on which microbial indicators, if any, should be included as routine monitoring tools for increased agricultural productivity and resilience to environmental stresses such as drought.



‘Smart’ soil sensors



Project number: 2.2.002

Project leader: Dr Marcus Hardie, University of Tasmania

Participating organisations:

- University of Tasmania
- University of Southern Queensland
- Federation University Australia

Duration: 2019–2023

Summary

The aim of this project was to build and develop usable technologies and next generation field-based sensors to measure, map, interpret, and communicate data in new ways, that meet growers’ needs.

Based on grower feedback, product refinement and PhD student input, the project team has created three new technologies:

- **The Penetrometer or Bandicoot™** is a mobile mapping tool that simultaneously measures soil moisture, penetration resistance (soil compaction), and salinity while being mechanically driven into the soil by a farmer or advisor. The device allows for quick and accurate investigation as to the depth and potential cause of poor soil or crop performance.
- **The BILBY®** is a below ground wireless communication node for sending soil moisture data to an above ground gateway. The BILBY® enables growers to install soil moisture sensors in any location within a paddock — out of harm’s way from stock, machinery or pests. The BILBY® can transmit data 300m to 3,000m, depending on burial depth and soil moisture. It has a battery life of five years when measuring and sending data hourly.
- **HydroLogicAI** is the brainchild of Soil CRC PhD student Chenting Jiang. It is a machine learning system for determining the Soil Water Retention Function (SWRF) from changes in daily soil moisture.

Activities

- Consultation with other Soil CRC participant organisations.
- Testing and calibration of technology.
- Exploration and development of HydroLogicAI.
- Product refinement and naming.
- Investigating commercialisation avenues.

Results and findings

- A new project, ‘Commercialising the BILBY®’ has been funded to further develop the BILBY® and attract an industry partner to manufacture and commercialise it.
- Trials of the BILBY® have commenced with a potential industry partner to evaluate the compatibility of the BILBY® with their existing soil moisture monitoring hardware and data services.
- Trials are continuing to refine the enclosure, hardware and operational software of the BILBY®, as well as expand the existing field trials to better understand its performance in different soils and environments.
- The first working Bandicoot™ is nearing completion. Further tests are required to optimise the sensor tip design: however all of the mechanical and electrical components of the device have been finalised.
- HydroLogicAI has shown initial success in being able to accurately match measured and modelled soil moisture in complex multi-layer soil, however new approaches will be required to further refine the inverse estimation of the soil water retention properties.

Affordable rapid field-based soil tests

Project numbers: 2.2.004, 2.1.007

Project leader: Dr Liang Wang, University of Newcastle

Participating organisations:

- University of Newcastle
- University of Tasmania
- Burdekin Productivity Services
- Herbert Cane Productivity Services

Duration: Phase one 2019–2023, phase two 2022–2026

Summary

The aim for phase one of this project is to develop a tool kit for rapid in-field measurement of soil chemical properties, including soil pH and macronutrients nitrogen, phosphorus and potassium. Currently, analysis of soil nutrients requires laboratory-based testing, which can be time-consuming and costly. The project scope includes both hardware — a 3D-printed microfluidic chip — and software, an app for smartphones.

Phase two of the project aims to extend the functionality of the tool kit, to rapidly determine soluble soil organic matter and key biological functions.

This new technology will benefit farmers by providing simple, quick and affordable in-field tests, the results of which can support decision-making.

Activities

- Enhancement and fine-tuning of both the microfluidic device and smartphone application prototypes.
- Redesigning the colourimetric reagents to ensure longer shelf life and compatibility with lab-on-chip operations.
- Integration of self-calibration features within the lab-on-chip mechanism.
- Showcasing the product prototype to potential end-users, gathering valuable insights and assessing real-world applications.

Results and findings

- Successful conceptualisation and development of a prototype for a lab-on-chip (microfluidic) device that incorporates self-calibration functions, through the infusion of chemical standards in various microfluidic pathways.
- Employing colourimetry for soil analyses, specifically assessing nitrate (N), phosphate (P), and pH levels.
- Successfully addressing the long-term storage challenge associated with the lab-on-chip device. The product can now be stored at room temperature for over six months.
- A novel colour interpretation methodology has been introduced, allowing for more accurate prediction of the analytes' concentrations based on colour outputs from the holistic microfluidic device.
- Development of the prototype smartphone Soil Colour App, which uses device camera/s to capture the results from the colourimetric measurement, automatically interpreting the colour values into a quantitative prediction of the targeted soil chemicals using calibration models, considering all interfering factors.

Next steps

- Promising results show the project is on the right path. Further studies, process refinement and material customisation provide opportunities for improvement.
- The next phase of the project involves enhancing the smartphone application to incorporate newly developed colourimetric techniques that automatically interpret the colour information from our lab-on-chip device.
- Efforts will be made to refine the composition of the N, P, and pH reagents to ensure better field applications.
- Initiatives are underway to design lab-on-chip detections for both soil active carbon and ammonia.
- Advancing lab-on-chip mechanisms to detect soil enzyme activities.

The project aims to refine the current prototype based on various farming management usage patterns, including extensive field validation against existing key soil test results. The team will also conduct commercialisation and market studies for the device's anticipated design and assess the total cost of the entire kit.

Improved soil data management

Project number: 2.2.005

Project leader: Dr Nathan Robinson, Federation University Australia

Participating organisations:

- Federation University Australia
- Charles Sturt University
- Manaaki Whenua Landcare Research New Zealand
- NSW Department of Primary Industries
- University of Tasmania

Duration: 2021–2023

Summary

Across its four programs, the Soil CRC is producing a large amount of new data. This project aims to ensure data generated by Soil CRC projects is reliably stored, shared, analysed and visualised.

Through co-design and trial with Soil CRC projects, the project is developing guidelines, processes and policies that support discovery and the re-use of research data. This will make it easy for researchers, farmer groups, growers and advisors to contribute soil data including sensor data streams into automated and FAIR (Findable, Accessible, Interoperable, Reusable) systems.

Research will explore how near real-time in-field sensor and other soil data could be used with Soil CRC related data analytics, modelling, decision support and visualisation dashboards.

Soil data that is both spatially and temporally explicit will help researchers use the data for foresight and allow multiple outcomes from data. This becomes important for farmers, as being able to use soil data for decision-making is critical to them optimising their soil productivity.

Activities

- The research team have collected insights from current project partners about their soil data management practices to inform the research.
- Surveys and focus groups have been employed with researchers, project partners and postgraduate students to understand their soil data management practices and needs, with specific application to Soil CRC projects.
- Tools currently in development include data management plan guidelines and template, a glossary of data management terms and training videos/webinars.

Results and findings

Results to date have shown that as a community, soil researchers are not as progressed in data management as might been expected. There is a lack of a common, shared understanding of what data management is, and participants do not often share data. There has been high interest for training and education in data privacy, security, storage, standards, documentation, licencing, sharing and retention. Participants also reported finding it difficult to calculate the cost of good data management.

Next steps

The project will map current research data management practices, develop tools to assist researchers to better manage their research data and improve the visibility (and thereby opportunity for reuse) of current soil data, incorporating data from new technologies for soils, improving accessibility of soils data in the future.

Visualising Australasia's Soils: extending the soil data federation

Project number: 2.3.002

Project leader: Associate Professor Peter Dahlhaus, Federation University Australia

Participating organisations:

- Federation University Australia
- Manaaki Whenua Landcare Research New Zealand
- Southern Cross University
- University of Newcastle
- Agricultural Innovation and Research Eyre Peninsula
- Birchip Cropping Group
- Burdekin Productivity Services
- Central West Farming Systems
- Corrigin Farm Improvement Group
- Facey Group
- FarmLink Research
- The Gillamii Centre
- Hart Field Site Group
- Herbert Cane Productivity Services
- Holbrook Landcare Network
- Liebe Group
- MacKillop Farm Management Group
- Mallee Sustainable Farming
- North Central CMA
- Riverine Plains
- Southern Farming Systems
- Western Australian No-Tillage Farmers Association
- West Midlands Group
- Wheatbelt NRM
- Wimmera Catchment Management Authority

Duration: Phrase one 2019–2021, phase two 2021–2024

Summary

This project aims to provide Soil CRC researchers, and the agriculture industry more broadly, with access to data, information and knowledge on Australasian soils. Phase one, completed in 2021, saw the launch of the Visualising Australasia's Soils (VAS) spatial data portal. The VAS portal provides an online place to discover and share soils information, activities and research from Australia and New Zealand.

Phase two, currently in progress, aims to create an independent and enduring soil research data federation of public and private sector data. Key objectives are motivating soil data custodians to make their data 'Findable, Accessible, Interoperable and Reusable' (FAIR) and aligning with other initiatives to maximise discovery and reuse.

Activities

Activities conducted so far in phase two of the project include:

- Impact research to inform future development.
- In-depth semi structured interviews, to establish a baseline of VAS portal use and achievement.
- Finalising sub-contracts with project partners.
- Substantial updates to the VAS portal, including improved capability for delivering comprehensive soil profile data for contributors and regions.
- Extensive work on the website and the system build.
- Adding new data to the portal and improving data visibility.

Results and findings

- VAS portal usage is mixed, with limited or little use of the system — but interviewees are optimistic about potential.
- Data sharing and interrogation through VAS is widely anticipated, but the portal is currently mostly used for data management and storage.
- Data sharing faces a range of barriers including technical features and practicability.

Next steps

- Promoting and increasing the use of the VAS portal.
- Building the value proposition of VAS.
- Increasing the availability of project partner data via the portal.
- Developing guidelines for the use and application of data in the portal.

Increasing nutrient efficiency with new organic amendments

Project number: 3.1.005

Project leader: Professor Terry Rose, Southern Cross University

Participating organisations:

- Southern Cross University
- NSW Department of Primary Industries
- FarmLink
- NSW Environment Protection Agency

Duration: 2021–2025

Summary

Many farmers have access to manures or other organic amendments. But transport and spreading costs, along with uncertainty over crop responses and longer-term impacts on soils, limit their use.

The aim of this project is to develop recommendations for the use of animal manures and new organic amendment products, to give growers confidence to replace or partially replace mineral fertiliser inputs with organic amendment products.

The project will determine the fertiliser value of animal manures, including how new organic amendment products affect nutrient use efficiency in the field compared to traditional fertiliser inputs. It will resolve the mechanisms that drive nutrient use efficiency, using a combination of field and controlled-environment studies with locally available manure and treated (composted or thermally treated) manure sources.

Activities

- The project team completed a meta-analysis of 19 published studies with 84 data points, where synthetic phosphorus fertilisers were compared to animal manures as a phosphorus source.
- PhD student Maryam Barati carried out pot studies using cattle, pig and chicken manure as a phosphorus source compared to Monoammonium phosphate.
- Field trials examining phosphorus fertiliser value of manures commenced at FarmLink and NSW Department of Primary Industries sites.
- The nutrient use efficiency trial at Temora in NSW was re-established at Ardlethan.

Results and findings

- No data were obtained from the Temora nutrient use efficiency trial from 2021–22, due to prolonged waterlogging. The trial site was deemed to be compromised and re-established at Ardlethan.
- Preliminary results from pot trials and a meta-analysis of published literature suggest the phosphorus fertiliser value of manures may be similar to that of synthetic phosphorus fertiliser, when the duration of crop growth is more than four months.
- A research paper was published in 2022, examining the amount of phosphorus available in waste products in Australia, including animal manures, compared to the amount of phosphorus exported from fields in harvested grains. Around 136,000 tonnes of phosphorus is removed from fields in harvested grains each year in Australia, and only 27,000 tonnes is available in captured animal manure — hence, animal manures alone can't sustain soil phosphorus fertility in cropping soils.

Next steps

- Pot and field trials comparing phosphorus fertiliser value of manures to synthetic phosphorus fertiliser will be harvested and the data analysed.
- Results of the project will be presented in late 2023 at the FarmLink Spring field walks.
- In-crop and post-crop soil sampling will be done for the nutrient use efficiency trial.

New organic amendments for retaining soil moisture

Project number: 3.3.004

Project leader: Professor Chengrong Chen, Griffith University

Participating organisations:

- Griffith University
- University of Newcastle
- Australian Organics Recycling Association
- Western Australian No-Tillage Farmers Association
- Herbert Cane Productivity Services
- Queensland Farmers Federation
- Grassdale Fertilisers

Duration: 2021–2024

Summary

Commercially available water retention materials include surfactants, which help to reduce soil water repellence and improve soil wetting processes. However, the effectiveness and environmental risk of some of these materials is unknown.

This project aims to develop cost-effective, environmentally friendly moisture retention materials that will enable farmers to increase their soil's productivity and profitability.

The project team is developing a range of innovative products by evaluating, modifying and activating naturally occurring, locally available organic- and clay-based materials. These new products are expected to enhance soil moisture capture and retention, and improve seed germination, crop establishment and farming activity under dry conditions.

Activities

- Having collected various clay- and organic-based materials from locations across Australia and tested their water retention capacity, the project team are starting to identify locally available water retention materials for farmers to use on their soils.
- The team are writing a scientific paper characterising the physicochemical properties of several locally available commercial clay- and organic-based materials, which will provide a reference for agricultural activities in drought-affected regions of Australia.
- A series of novel efficient water retention materials have been successfully prepared by chemically modifying some selected clay- and organic-based materials using highly hydrophilic components. The team are writing a scientific paper on material modification.
- The project team has successfully prepared effective cellulose-based materials from nine organic waste materials and tested their water retention capacity.
- The team has examined moisture retention and release characteristics of selected clay- and organic-based moisture retention materials in different soil types across Australia.

Results and findings

- The water retention performance of the prepared modified materials is significantly enhanced compared to the unmodified materials. This indicates that it is an effective technique for improving water retention in clay- and organic-based materials.
- The prepared cellulose-based materials from different raw materials have similar thermal stability and the water holding capacity of most of them was significantly improved compared to their raw materials.
- Through testing with different types of soil, the modified clay-based and organic-based materials showed superior moisture retention capacity and release characteristics compared with the control group and the two commercial products. This indicates that the modification we used is an effective technique for improving water retention in clay- and organic-based materials.

Next steps

Pot trials will be used to evaluate the performance of the key moisture retention products in enhancing seed germination and crop establishment in different types of soils and with key crops.

New farming methods to sequester soil carbon

Project number: 4.1.006

Project leader: Dr David Minkey, Western Australian No-Tillage Farmers Association

Participating organisations:

- Western Australian No-Tillage Farmers Association
- Murdoch University
- Facey Group
- Corrigin Farm Improvement Group
- West Midlands Group
- The Liebe Group

Co-funder: WA Department of Primary Industries and Regional Development

Duration: 2022–2025

Summary

This project aims to trial, measure and demonstrate crop sequencing and new technologies that can sequester organic carbon, mitigate greenhouse gas emissions and improve soil fertility in crop production systems that have traditionally struggled to accumulate carbon.

Four large-scale field trials will be used to assess soil management and amelioration technologies, and various crop sequence approaches will be utilised to build soil carbon and improve soil health. The project seeks to determine if these new soil management practices can enable growers to participate in carbon trading schemes.

Activities

Four long-term sites across Western Australia were established in 2022 to investigate new soil and farm management opportunities. These sites continue to be monitored, including yield, soil carbon and soil health.

- **Bullaring** — Established as a randomised block with seven crop treatments including soil disturbance, clay amelioration, mixed cropping with inter-row legumes and a perennial legume.
- **Kweda** — Two trials were established including a large on-farm experiment with a complementary small plot trial to evaluate a range of organic and inorganic amendments and deep ripping (using a Bednar ripper).
- **Coorow** — bentonite clay and chicken manure amendments were applied in 2022 with a crop sown in 2023.
- **Wathingarra** — an existing long-term site was utilised with additional treatments applied in 2022. These include a combination of amendments (biochar, frass, or biochar and frass) which were incorporated using mouldboard ploughing, rotary spading or shallow tillage, compared to an untreated control. Serradella was sown across the site in 2023 to give the site a break from cereals.

Results and findings

- The Bullaring field experiment has revealed that potential plant productivity improvements could be achieved on unfertile sands using perennial legumes and soil amelioration approaches; however, observed trends are based on one crop cycle only.
- The paddock-scale experiment at Kweda showed improvement between the unripped (control) and the ripping treatments; gypsum was recognised as the most beneficial amendment; no significant differences were shown for plant establishment and plant health. The small plot trial investigated a series of novel amendments and variable rates, all incorporated by a Bednar ripper — no significant differences were found for plant establishment and grain yield.
- The dry conditions experienced at the Coorow site meant the site was unable to establish a cover crop in 2023. A cover crop will be sown when adequate rainfall occurs.
- Combining various amendments and amelioration did not increase grain yield at the Wathingarra site; the compost or rotary spading applied in 2021 significantly increased grain yield in 2022 compared to their respective treatments, but biochar and/or frass did not; in the absence of mouldboard ploughing or rotary spading, there was a trend of increased crop growth and grain yield with the application of biochar and/or frass.

Next steps

The participant grower groups will continue to manage and monitor the trials over four years and data will be collected and collated into a database annually.

Addressing complex soil constraints

Project number: 4.2.002

Project leader: Dr Jason Condon, Charles Sturt University

Participating organisations:

- Charles Sturt University
- Birchip Cropping Group
- Agriculture Victoria
- Facey Group
- FarmLink
- Hart Field Site Group
- NSW Department of Primary Industries
- Riverine Plains
- Central West Farming Systems

Duration: 2019—2022

Summary

Soils often exhibit multiple constraints that limit their productivity. Addressing these limitations requires complex solutions rather than treating each constraint in isolation. This project set out to identify amendments that can overcome multiple constraints, to increase plant productivity. The project team used glasshouse and incubation studies to determine if, and how, soil amendments act to overcome constraints.

Project findings will inform site and amendment selection for future Soil CRC field studies, and project data will inform economic modelling, construction and refinement of decision support systems to be used in soil management. The findings will also help growers understand how, and by how much, amendments improve soil and in what circumstances.

Activities

Six grower groups were involved in a consultative process to identify 'problem' soils in their areas that appeared to have multiple constraints to production.

The magnitude of the constraints on plant performance was quantified in soil column studies by application of best practice amendments relative to an untreated control.

Concurrent lab incubation studies tested the response of various rates of multiple potential amendments on chemical and physical properties of soil, from each layer of selected soil profiles. These studies were used to select promising amendment types and rates to apply to soil to overcome identified constraints. The plant response to these amendments were then tested in a final series of column studies.

Results and findings

- Problem soils contain multiple constraints, often in different layers of the soil profile.
- Organic amendments can improve soil structure and provide additional nutritional benefits. However, they can also produce a salinity hazard depending on the initial salinity of the soil, the rate of application and the salt content of the amendment.
- The addition of organic material to subsoils was beneficial where surface soils provided adequate aeration to lower layers. If surface soils were not structurally stable, organic matter addition was harmful to root growth.
- The addition of nutrients was able to overcome the impact of soil constraints on plant performance in the column studies conducted.

Next steps

The project found that plant performance in soils with multiple constraints can be improved with additional nutrition to the subsoil. This means that improved plant performance can be achieved with fertilisers that can be effectively placed in the subsoil, or fertilisers can be developed that can move to the layer required by plants. Matching the required amendment to the specific soil constraints present requires further study in the field.

Overcoming soil constraints in highly calcareous soils

Project number: 4.2.003

Project leader: Dr Nigel Wilhelm, Primary Industries and Regions South Australia

Participating organisations:

- Primary Industries and Regions South Australia
- NSW Department of Primary Industries
- MacKillop Farm Management Group
- Agricultural Innovation and Research Eyre Peninsula

Co-funder: Grains Research and Development Corporation (GRDC)

Duration: 2020–2023

Summary

The goal of this project was to identify and overcome soil constraints in order to lift crop production and improve profitability of crop production on highly calcareous soils (high in calcium carbonate). It investigated the impact of subsoil and topsoil amelioration strategies on crop growth, health, nutrient supply and productivity. The knowledge generated by this project will lead to the development of management strategies, which improve soil condition, increase nutrient and water use efficiency of crops and increase farm profitability. It will also improve our understanding of the impact of high carbonate on crop performance.

Activities

- Field experiments were conducted from 2020 to 2022 on three sites on the upper Eyre Peninsula at Minnipa, Poochera, and Port Kenny in South Australia.
- At each site in 2021 and 2022, two replicated field trials were established to investigate amelioration strategies which have potential to overcome soil constraints on poor performing highly calcareous soils, and improve early crop vigour, health, biomass, and grain yield.
- Three of the six trials were set up to investigate long-term subsoil strategies by placing different amendments (pelleted chicken manure, carbon-coated minerals, trace elements, granular and fluid fertilisers) at 20 and 40 cm depths.
- The other three trials investigated short-term topsoil strategies (pre-seeding nitrogen, granular and fluid phosphorus, trace elements, carbon-coated minerals, fungicide, soil wetter and sweep cultivation).
- Field trials were also conducted in the south-east of South Australia. This is a high rainfall zone and an area where broad beans suffer from severe yellowing during winter and spring when grown on highly calcareous soil. These trials investigated applications of iron and manganese to correct the yellowing.

Results and findings

- Crops growing on a mildly calcareous soil were less responsive to the strategies investigated than those grown on highly calcareous soils.
- Short-term topsoil strategies resulted in better gains in crop biomass and yield when compared to longer-term subsoil strategies.
- Higher seeding rates and nutrition at sowing is effective at achieving high plant densities, crop biomass and grain yield.
- Carbon-coated minerals in the topsoil improved crop vigour, biomass, and grain yield.
- High soil strength is an issue in calcareous soils but positive responses to deep ripping are not common and are usually limited by the hostile subsoil.
- Severe yellowing in broad beans was overcome with multiple applications of an iron chelate (Fe-EDDHA) and resulted in large grain yield increases. Applications of manganese did not improve bean production.

Next steps

- Further investigations are needed to determine optimum application rates for carbon-coated minerals and to fully define the residual benefits. This product is not commercially available.
- Further investigations are required to test the effectiveness of reduced rates of Fe-EDDHA at correcting iron deficiency in pulses, to develop more effective application strategies for Fe-EDDHA or to find alternative (and cheaper) sources of iron.

Diagnosis frameworks for multiple and complex soil constraints

Project number: 4.3.005

Project leader: Associate Professor Keith Pembleton, University of Southern Queensland

Participating organisations:

- University of Southern Queensland
- West Midlands Group
- Burdekin Productivity Services
- Birchip Cropping Group
- Riverine Plains

Duration: 2021–2024

Summary

The purpose of this project is to diagnose and prioritise multiple and interacting soil constraints at the sub-field level using farmer generated and publicly available data. The project is developing underpinning data-centric methods as a software code framework that future decision support tools will use to diagnose soil constraints.

The goal of this research is to reduce the cost barrier (the need for detailed soil sampling at depth) to farmers diagnosing complex and multiple soil constraints in their fields. It is achieving this by developing a hybrid modelling and diagnostic approach that brings together biophysical models, artificial intelligence (AI) and statistical approaches to analysing farmer and publicly available data to identify and diagnose soil constraints at a sub-field level.

Activities

- Meetings with grower group partners around the farm data landscape.
- Employed an inverse modelling approach to develop a universal approach to predicting soil plant available water holding capacity across Australia.
- Employed AI approaches to predict soil chemical and physical constraints from standard soils test information and crop yield history.

Results and findings

We can successfully predict plant available water holding capacity for any location within the Australian wheat belt from just a few years of crop yield and management information.

Early results of the AI models show we can accurately predict soil physical and chemical constraints from existing basic data.

Next steps

- We are refining the AI algorithms to improve accuracy and their application.
- Our next focus will be determining the most limiting constraint (i.e. the priority constraint for amelioration).

PhD student program

The Soil CRC's PhD student program underpins our four research programs to build capability in the future of Australia's soil research. In 2022–23 we welcomed eight new PhD students and saw one student complete their PhD, taking the total number of currently active students to 38 and the total number of completions to four.

With one more student ready to commence by the end of 2023 and four more open PhD positions, the Soil CRC is well on the way to reaching its target of 40 PhD completions by the end of the CRC.

Highlights

- Our expanding PhD cohort is now situated in **12 universities** across Australia, is aged between **24 and 60+ years**, covers all stages of candidature, and includes students from a wide range of disciplines and cultural backgrounds. As such, it brings together a huge wealth of knowledge, experiences, professional networks, and capabilities for our students to engage with and learn from.
- **Sepide Abbasi** from University of Newcastle completed her PhD.
- **Rahat Shabir** from Griffith University submitted his thesis and received excellent examiner comments (Rahat went on to complete his PhD in the second half of 2023).
- **Bhavya Mod** from University of Newcastle was a finalist in Cooperative Research Australia's annual Early Career Researcher competition.
- **Eighteen students published their research**, with students authoring 41% of the Soil CRC's 66 publications.
- The annual **Soil CRC PhD Workshop Day** took place in conjunction with the 2022 Soil CRC Participants Conference in Adelaide — 30 students from nine universities attended the workshop and six students presented in the conference.
- We held **four PhD workshops** throughout the year.
- We continued to **profile students** and share their successes in our monthly newsletter, website and social media channels, highlighting how their research will benefit farmers.

In their words

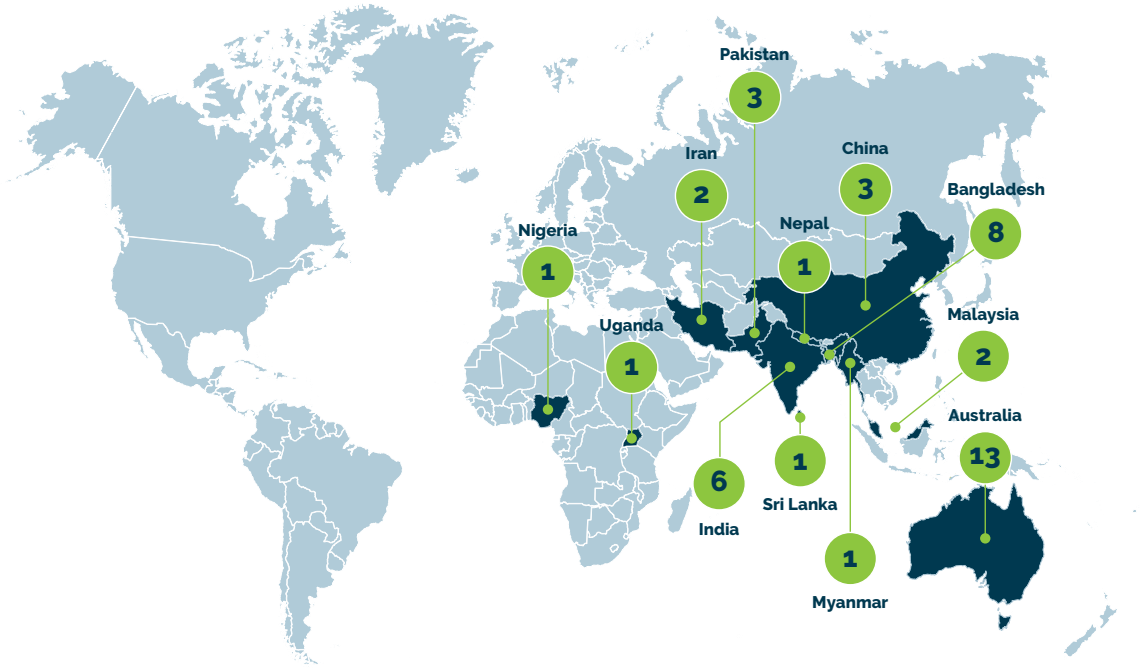
"Finding out I was a finalist in Cooperative Research Australia's 2023 Early Career Researchers Competition was a highlight. I feel very privileged to have made the final cut alongside three other inspiring PhD students, which enabled me to present my research at the prestigious Collaborate Innovate conference. I'm really thankful to the Soil CRC for encouraging and supporting PhD students to participate in different conferences and events."

Bhavya Mod, University of Newcastle

"I love the opportunity to contribute to the growing body of research about soil science and social norms. I am grateful as I am being mentored and supported by incredible supervisors. I love that my PhD has enabled me to work closely with farmers, policy makers, soil officers and soil scientists."

Melissa Wales, Charles Sturt University

Country of origin

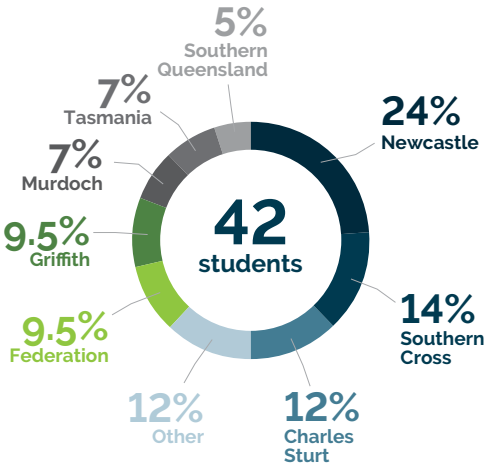


Gender

43% female

57% male

Students by university



Our PhD students

Student	University	Project title	Program
Completed			
Sepide Abbasi	University of Newcastle	Phosphorus release and labile phosphorus from iron phosphate and biochar in rhizosphere induced by root exudates	3
Md. Zahangir Hossain	University of Newcastle	Biochar and nutrient interactions	3
Xiangyu Liu	Griffith University	Developing sensitive soil health indicator of Australia agricultural land	4
Md. Aminur Rahman	University of Newcastle	Biochar modification for the generation of high quality phosphorus fertiliser products	3
Active 2022–23			
Mathew Alexanderson	Southern Cross University	Regenerative agriculture: exploring the boundaries of an alternative agricultural system	1
Adnan Al Moshi	Federation University Australia	Next generation below ground sensor communication using seismic waves for smart soil applications	2
Vijay Aralappanavar	University of South Australia	Diffusive Gradient in Thin-films methodology for assessing bioavailability of soil herbicide residues	4
Maryam Barati	Southern Cross University	Improving phosphorus acquisition in grain crops with organic amendments	3
Cameron Copeland	Southern Cross University	Understanding the mechanisms of soil microbial function and their role in cropping systems	4
Dristi Datta	Charles Sturt University	Developing a hyperspectral imagery-based decision support system for soil assessment using vegetation pattern	2
Suman Gajurel	University of Southern Queensland	Modelling and diagnosis of multiple soil constraints across Australian farming systems	4
Daven Gopalan	Southern Cross University	Redox in the rhizosphere and its concept in phosphorus acquisition in plants	4
Louise Hunt	Southern Cross University	Negotiating the complexities of farming in the 21st century	1
Sepideh Jalayer	University of Newcastle	Toward digital mapping of soil moisture	2
Chenting Jiang	University of Tasmania	Machine learning the soil water function	2
Harleen Kaur	University of Newcastle	Biochar functionalisation to derive as P enriched fertilizer	3
Phillip Kay	University of Tasmania	Microbial changes associated with improved or reduced soil health	2
Salini Khuraijam	University of Newcastle	Exploring economic aspects of adopting soil amendments for ameliorating soil constraints in Australia	1
Stephen Lang	University of Adelaide	Impacts of soil modification on roots and the rhizosphere	4
Henry Luutu	Southern Cross University	Optimisation of hydrothermal carbonisation-treated wastes for use as novel soil amendments	3
Reuben Mah	University of Tasmania	3D printed devices for in-field soil measurements	2
Naveeda Majid	University of Newcastle	Non-wetting soils: the cause, mechanism of non-wetting and remediation	4

Student	University	Project title	Program
Bhavya Mod	University of Newcastle	Carbon storage in soil using agro industry biowaste	3
Tania Monir	Murdoch University	Stability of soil carbon under different amendments in sandy soils	3
Kamrun Nahar	Griffith University	Enhancing soil resilience to alkaline sodicity and acidity constraints to improve soil productivity	4
Sadia Sabrin Nodi	Charles Sturt University	Development of a grower focused mobile app for estimating, analysing and recording soil properties	2
James O'Connor	University of Western Australia	Food waste valorisation products as a nutrient source and carbon amendments	3
Oluwadunsin Oyetunji	RMIT University	Value of compost-blended fertilizer products to boost nutrient-use efficiency and productivity in broadacre farming systems	3
Vibin Perumalsamy	University of Newcastle	Reconciling carbon sequestration with fertiliser value of biowastes in farming systems through nanostabilisation of biowastes	3
Win Win Pyone	Murdoch University	Managing phytotoxicity of soil borne herbicide residues in grain cropping systems	4
Mohammad Arifur Rahman	Federation University Australia	A robust data-driven method to develop digital mapping of soil organic carbon	2
Sundus Saeed Qureshi	Griffith University	Developing novel cellulose-based moisture-retaining materials to mitigate drought in the soil system	3
James Sargeant	Federation University Australia	An effective decision support system for soil health assessment and monitoring by integrating IoT technology and drone imaging	2
Rahat Shabir	Griffith University	Developing effective biochar and biopolymer material as an alternative microbial carrier	3
Prasanthi Sooriyakumar	University of Western Australia	Managing soil carbon to increase soil productivity	3
Maria Then	Murdoch University	Proximal sensing in soil water repellency management	2
Mohd Arish Usman	University of Newcastle	Design and development of advanced biochar-clay composite	3
Melissa Wales	Charles Sturt University	Social norms of soil management	1
Peter Weir	Federation University Australia	In-paddock variability of plant available water	2
Christopher Wilmot	Charles Sturt University	Policy and legislative changes for activating markets to better incentivise soil stewardship practices	1
Linda Wirf	Charles Sturt University	Beyond adoption: gendered knowledges in agricultural practice change in Australia	1
Hanlu Zhang	University of Southern Queensland	Soil-moisture profile dynamics affected by cover crop: Effect of changes in soil biology and structure	4

Our people

The Soil CRC is governed by a skills-based Board of Directors with an independent Chair, four independent members and four non-independent members. The Board provides oversight of the Soil CRC activities, performance and strategic direction.

Soil CRC Board

- **Dr Paul Greenfield AO FTSE** — Chair
- **Professor Andrea Bishop** — Non-independent Director
- **Malcolm Buckby** — Non-independent Director
- **Ralph Hardy** — Independent Director
- **Kate Lorimer-Ward** — Non-independent Director
- **Dr David Minkey** — Non-independent Director
- **Robbie Sefton AM** — Independent Director
- **Dr Simon Speirs** — Independent Director
- **Professor Roger Swift FTSE** — Independent Director

The Board has five committees that govern research, finance and risk, nominations, remuneration, and intellectual property and commercialisation.

ABOVE L–R: Andrea Bishop, Ralph Hardy, Simon Speirs, David Minkey, Roger Swift, Paul Greenfield and Robbie Sefton. Absent: Malcolm Buckby and Kate Lorimer-Ward.

Soil CRC staff

- **Dr Michael Crawford** — Chief Executive Officer
- **Heather Apps** — Research Contracts Officer (from October 2022)
- **Mark Flick** — Chief Financial Officer
- **Dr Rhona Hammond** — Intellectual Property Officer
- **Felicity Harrop** — Soil Knowledge Broker (from May 2023)
- **Olivia Louis** — Communications Manager (from April 2023)
- **Lisa Mahoney** — Research Administration Assistant (until October 2022)
- **Jodi McLean** — Chief Operating Officer
- **Julie Moulton** — Research Administration Officer (until January 2023)
- **Katherine Seddon** — Communications Manager (until October 2022)
- **Sandy Slater** — Finance Officer (from August 2022)
- **Kathy Stokes** — Executive Assistant to the CEO
- **Dr Cassandra Wardle** — PhD Program Manager
- **Dr Lucy Weaver** — Research Administration Officer (from April 2023)

Program Leaders

Our four program leaders oversee and implement the research direction of the Soil CRC.

- **Professor Catherine Allan** — Program 1 Leader, Charles Sturt University
- **Associate Professor Richard Doyle** — Program 2 Leader, University of Tasmania
- **Professor Megharaj Mallavarapu** — Program 3 Leader, University of Newcastle
- **Dr Lukas Van Zwieten** — Program 4 Leader, NSW Department of Primary Industries

Soil CRC Patron

The Honourable Penelope Wensley AC is the patron of the Soil CRC. She is also the patron of Soil Science Australia and works closely with both organisations to help promote Australia's strengths and capabilities in soil science and related disciplines, both nationally and internationally.

Financial summary

As extracted from the annual audited Financial Statements for the year ended 30 June 2023.

Profit or Loss

For the Year Ended 30 June 2023

	2023 $	2022 $
Revenue	22,938,739	22,763,165
Other income	349,654	58,317
Consultant fees	(82,063)	(73,032)
Employee benefits expense	(672,741)	(594,469)
Finance expenses	(763)	(769)
IT expenses	(98,991)	(66,235)
Legal expenses	(21,988)	(16,885)
Other expenses	(517,376)	(300,470)
Research expenditure — cash	(7,105,639)	(7,949,242)
Research expenditure — in kind	(14,728,241)	(13,787,337)
Travel expenses	(60,591)	(33,043)
Surplus before income tax	**-**	**-**
Income tax expense	-	-
Surplus for the year	**-**	**-**
Other comprehensive income for the year	-	-
Total comprehensive income for the year	**-**	**-**

Participants' Contributions (Cash basis ex GST)

For the Year Ended 30 June 2023

	2023 $	2022 $	Cumulative to 2021 $	Total $
Agricultural Innovation and Research - Eyre Peninsula				
Cash contributions	0	0	20,000	20,000
In-kind contributions				
- Staff	40,000	16,750	115,250	172,000
- Other	21,750	23,380	74,890	120,020
Total	**61,750**	**40,130**	**210,140**	**312,020**
Australian Organics Recycling Association Limited				
Cash contributions	0	0	0	0
In-kind contributions				
- Staff	45,000	21,250	115,000	181,250
- Other	0	0	2,000	2,000
Total	**45,000**	**21,250**	**117,000**	**183,250**
Birchip Cropping Group Inc				
Cash contributions	5,000	3,750	20,000	28,750
In-kind contributions				
- Staff	62,500	41,250	295,750	399,500
- Other	64,475	34,403	90,425	189,303
Total	**131,975**	**79,403**	**406,175**	**617,553**
Burdekin Productivity Services Limited				
Cash contributions	0	0	0	0
In-kind contributions				
- Staff	65,000	63,125	143,750	271,875
- Other	24,790	14,050	11,500	50,340
Total	**89,790**	**77,175**	**155,250**	**322,215**
Central West Farming Systems Inc				
Cash contributions	0	0	0	0
In-kind contributions				
- Staff	100,000	132,525	343,000	575,525
- Other	104,506	141,789	220,473	466,768
Total	**204,506**	**274,314**	**563,473**	**1,042,293**

Participants' Contributions
(Cash basis ex GST) *cont.*

	2023 $	2022 $	Cumulative to 2021 $	Total $
Charles Sturt University				
Cash contributions	200,000	200,000	800,000	1,200,000
In-kind contributions				
- Staff	1,110,000	698,250	2,070,000	3,878,250
- Other	549,532	425,174	904,418	1,879,124
Total	**1,859,532**	**1,323,424**	**3,774,418**	**6,957,374**
Corrigin Farm Improvement Group				
Cash contributions	0	0	0	0
In-kind contributions				
- Staff	42,500	0	30,000	72,500
- Other	56,900	0	1,398	58,298
Total	**99,400**	**0**	**31,398**	**130,798**
Department of Jobs, Precincts and Regions (VIC)				
Cash contributions	0	0	0	0
In-kind contributions				
- Staff	37,500	103,750	1,022,500	1,163,750
- Other	20,950	67,544	440,093	528,587
Total	**58,450**	**171,294**	**1,462,593**	**1,692,337**
Department of Regional NSW				
Cash contributions	0	0	525,000	525,000
In-kind contributions				
- Staff	992,500	1,069,250	2,558,750	4,620,500
- Other	469,250	1,100,146	936,812	2,506,208
Total	**1,461,750**	**2,169,396**	**4,020,562**	**7,651,708**
Department of Primary Industries and Regions (SA)				
Cash contributions	100,000	100,000	400,000	600,000
In-kind contributions				
- Staff	120,000	200,575	465,750	786,325
- Other	146,522	352,971	582,460	1,081,953
Total	**366,522**	**653,546**	**1,448,210**	**2,468,278**

	2023 $	2022 $	Cumulative to 2021 $	Total $
Facey Group Inc				
Cash contributions	3,750	5,000	20,000	28,750
In-kind contributions				
- Staff	75,000	6,225	727,500	808,725
- Other	45,250	0	16,500	61,750
Total	**124,000**	**11,225**	**764,000**	**899,225**
Farmlink Research Limited				
Cash contributions	0	0	0	0
In-kind contributions				
- Staff	20,000	18,450	58,750	97,200
- Other	15,140	5,236	22,173	42,549
Total	**35,140**	**23,686**	**80,923**	**139,749**
Federation University Australia				
Cash contributions	100,000	100,000	400,000	600,000
In-kind contributions				
- Staff	855,000	544,050	1,668,750	3,067,800
- Other	471,271	393,963	659,648	1,524,882
Total	**1,426,271**	**1,038,013**	**2,728,398**	**5,192,682**
Griffith University				
Cash contributions	125,000	100,000	375,000	600,000
In-kind contributions				
- Staff	332,500	359,500	1,498,750	2,190,750
- Other	535,388	304,500	847,395	1,687,283
Total	**992,888**	**764,000**	**2,721,145**	**4,478,033**
Hart Field Site Group Incorporated				
Cash contributions	0	0	0	0
In-kind contributions				
- Staff	20,000	20,200	81,250	121,450
- Other	25,500	48,692	111,650	185,842
Total	**45,500**	**68,892**	**192,900**	**307,292**

Participants' Contributions
(Cash basis ex GST) *cont.*

	2023 $	2022 $	Cumulative to 2021 $	Total $
Herbert Cane Productivity Services Limited				
Cash contributions	0	0	0	0
In-kind contributions				
- Staff	102,500	133,250	163,750	399,500
- Other	27,840	61,665	93,858	183,363
Total	**130,340**	**194,915**	**257,608**	**582,863**
Holbrook Landcare Group				
Cash contributions	0	0	0	0
In-kind contributions				
- Staff	70,000	24,750	54,250	149,000
- Other	2,063	150	2,548	4,761
Total	**72,063**	**24,900**	**56,798**	**153,761**
Manaaki Whenua Landcare Research (New Zealand)				
Cash contributions	0	134,000	1,068,000	1,202,000
In-kind contributions				
- Staff	85,000	35,250	281,250	401,500
- Other	1,224	84,638	16,002	101,864
Total	**86,224**	**253,888**	**1,365,252**	**1,705,364**
MacKillop Farm Management Group Inc				
Cash contributions	0	0	0	0
In-kind contributions				
- Staff	5,000	5,000	25,000	35,000
- Other	1,000	3,500	2,333	6,833
Total	**6,000**	**8,500**	**27,333**	**41,833**
Mallee Sustainable Farming Inc				
Cash contributions	0	0	0	0
In-kind contributions				
- Staff	22,500	12,500	22,500	57,500
- Other	0	0	250	250
Total	**22,500**	**12,500**	**22,750**	**57,750**

	2023 $	2022 $	Cumulative to 2021 $	Total $
Murdoch University				
Cash contributions	187,500	112,500	600,500	900,500
In-kind contributions				
- Staff	457,500	452,000	797,500	1,707,000
- Other	323,383	335,528	585,658	1,244,569
Total	**968,383**	**900,028**	**1,983,658**	**3,852,069**
North Central Catchment Management Authority				
Cash contributions	0	0	15,000	15,000
In-kind contributions				
- Staff	0	45,000	187,500	232,500
- Other	27,400	4,000	14,500	45,900
Total	**27,400**	**49,000**	**217,000**	**293,400**
NSW Environment Protection Authority				
Cash contributions	30,000	50,000	50,000	130,000
In-kind contributions				
- Staff	2,500	6,250	5,000	13,750
- Other	0	0	0	0
Total	**32,500**	**56,250**	**55,000**	**143,750**
Nutrien Ag Solutions				
Cash contributions	0	0	0	0
In-kind contributions				
- Staff	210,000	85,750	655,750	951,500
- Other	0	1,600	82,450	84,050
Total	**210,000**	**87,350**	**738,200**	**1,035,550**
Riverine Plains Incorporated				
Cash contributions	0	0	0	0
In-kind contributions				
- Staff	42,500	28,750	76,700	147,950
- Other	27,051	29,625	67,833	124,509
Total	**69,551**	**58,375**	**144,533**	**272,459**

Participants' Contributions
(Cash basis ex GST) *cont.*

	2023 $	2022 $	Cumulative to 2021 $	Total $
South Australian Grain Industry Trust Fund				
Cash contributions	150,000	150,000	600,000	900,000
In-kind contributions				
- Staff	22,500	38,550	56,250	117,300
- Other	35,000	0	7,500	42,500
Total	**207,500**	**188,550**	**663,750**	**1,059,800**
South East Water Corporation				
Cash contributions	30,000	30,000	120,000	180,000
In-kind contributions				
- Staff	25,000	24,125	387,500	436,625
- Other	1,000	2,125	161,500	164,625
Total	**56,000**	**56,250**	**669,000**	**781,250**
Southern Cross University				
Cash contributions	200,000	200,000	800,000	1,200,000
In-kind contributions				
- Staff	962,500	620,750	3,062,500	4,645,750
- Other	813,406	782,373	1,761,069	3,356,848
Total	**1,975,906**	**1,603,123**	**5,623,569**	**9,202,598**
Southern Farming Systems Limited				
Cash contributions	0	0	0	0
In-kind contributions				
- Staff	25,000	31,450	58,000	114,450
- Other	12,500	12,000	38,293	62,793
Total	**37,500**	**43,450**	**96,293**	**177,243**
Society of Precision Agriculture Australia (SPAA)				
Cash contributions	0	0	0	0
In-kind contributions				
- Staff	10,000	0	68,750	78,750
- Other	260	1,200	500	1,960
Total	**10,260**	**1,200**	**69,250**	**80,710**

	2023 $	2022 $	Cumulative to 2021 $	Total $
The Gillamii Centre				
Cash contributions	0	0	0	0
In-kind contributions				
- Staff	0	0	2,500	2,500
- Other	0	0	0	0
Total	**0**	**0**	**2,500**	**2,500**
The Liebe Group Inc				
Cash contributions	0	0	0	0
In-kind contributions				
- Staff	37,500	0	27,750	65,250
- Other	32,750	0	0	32,750
Total	**70,250**	**0**	**27,750**	**98,000**
The Trustee for Soils for Life Trust				
Cash contributions	20,000	20,000	80,000	120,000
In-kind contributions				
- Staff	220,000	189,025	303,750	712,775
- Other	44,793	29,481	50,659	124,933
Total	**284,793**	**238,506**	**434,409**	**957,708**
The University of Newcastle				
Cash contributions	300,000	300,000	1,200,000	1,800,000
In-kind contributions				
- Staff	867,500	646,075	3,325,643	4,839,218
- Other	754,613	773,260	2,359,098	3,886,971
Total	**1,922,113**	**1,719,335**	**6,884,741**	**10,526,189**
University of Southern Queensland				
Cash contributions	150,000	150,000	600,000	900,000
In-kind contributions				
- Staff	440,000	492,650	1,415,000	2,347,650
- Other	438,103	285,206	739,381	1,462,690
Total	**1,028,103**	**927,856**	**2,754,381**	**4,710,340**

Participants' Contributions
(Cash basis ex GST) *cont.*

	2023 $	2022 $	Cumulative to 2021 $	Total $
University of Tasmania				
Cash contributions	150,000	112,500	600,500	863,000
In-kind contributions				
- Staff	495,000	931,250	2,473,750	3,900,000
- Other	743,611	862,321	1,599,506	3,205,438
Total	**1,388,611**	**1,906,071**	**4,673,756**	**7,968,438**
Western Australian No-Tillage Farmers Association				
Cash contributions	10,000	10,000	40,000	60,000
In-kind contributions				
- Staff	160,000	83,750	315,000	558,750
- Other	36,375	4,203	64,598	105,176
Total	**206,375**	**97,953**	**419,598**	**723,926**
West Midlands Group Incorporated				
Cash contributions	0	0	10,000	10,000
In-kind contributions				
- Staff	115,000	66,875	50,000	231,875
- Other	92,916	20,750	49,000	162,666
Total	**207,916**	**87,625**	**109,000**	**404,541**
Wheatbelt Natural Resource Management Incorporated				
Cash contributions	0	0	0	0
In-kind contributions				
- Staff	62,500	73,375	198,750	334,625
- Other	17,000	58,084	99,229	174,313
Total	**79,500**	**131,459**	**297,979**	**508,938**
Wimmera Catchment Authority				
Cash contributions	0	0	0	0
In-kind contributions				
- Staff	130,000	110,625	412,300	652,925
- Other	7,840	9,382	60,675	77,897
Total	**137,840**	**120,007**	**472,975**	**730,822**

	2023 $	2022 $	Cumulative to 2021 $	Total $
Other third party				
Cash contributions	600,183	846,477	980,000	2,426,660
In-kind contributions				
- Staff	197,500	71,250	0	268,750
- Other	51,889	11,000	0	62,889
Total	**849,572**	**928,727**	**980,000**	**2,758,299**
Total Participant Contribution				
Cash contributions	2,361,433	2,624,227	9,324,000	14,309,660
In-kind contributions				
- Staff	8,685,000	7,503,400	25,621,393	41,809,793
- Other	6,043,241	6,283,939	12,778,273	25,105,451
Total	**17,089,674**	**16,411,564**	**47,723,666**	**81,224,904**
Total Commonwealth Contribution				
Cash contributions	4,708,000	4,742,000	18,188,750	27,638,750
Total	**4,708,000**	**4,742,000**	**18,188,750**	**27,638,750**
Total Contributions				
Cash contributions	7,069,433	7,366,227	27,512,750	41,948,410
In-kind contributions				
- Staff	8,685,000	7,503,400	25,621,393	41,809,793
- Other	6,043,241	6,283,937	12,776,273	25,103,451
Total	**21,797,674**	**21,153,564**	**65,910,416**	**108,861,654**

Publications

Formal research publications

Books

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Book chapters

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End-user publications and reports

Conference papers — other, non-refereed

Baumgartl, T., Reeves, J., Kilham, S., Godfrey, S., Diack, J., Culas, R., Behrendt, K. & Nordblom, T. (2022) Concept of a framework to define economic and social costs and benefits of regenerative farming systems. 22nd World Congress of Soil Science, 31 July–5 August, Glasgow, Scotland.

Bell, R., Yeap, S. & Pradeep, K. (2023) Using zeolite and compost to increase water retention and decrease nutrient leaching from sand. National Soil Science Australia Conference, 25–30 June, Darwin, Northern Territory.

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Morrison, M., Greig, J., Mackenzie, K., Grimmer, L., Hatton MacDonald, D., Nayeem, T. & Tocock, M. (2023) Activating the Consumer Market for Soil Stewardship Practices. Heartland Environmental and Resource Economics Workshop, 17–18 April, Champaign, Illinois.

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