SOIL CRC

Performance through collaboration

YEAR IN REVIEW

2022

CRC FOR HIGH PERFORMANCE SOILS LIMITED

MAJOR PARTNERS

- The University of Newcastle Australia
- Charles Sturt University
- NSW Government Department of Primary Industries
- Federation University Australia
- Griffith University
- Manaaki Whenua Landcare Research
- Murdoch University
- SAGIT
- Southern Cross University
- University of Southern Queensland
- University of Tasmania

PARTNERS

- Agriculture Victoria
- aora australian organics recycling association
- BCG Shared Solutions
- Facey Group Shaping the Future
- North Central Catchment Management Authority Connecting Rivers, Landscapes, People
- nsw epa
- Government of South Australia Primary Industries and Regions SA
- SoilsforLife
- South East Water
- wantfa Pioneers and Leaders in Conservation Agriculture
- Wimmera CMA

ASSOCIATES

- AIR EP Ag Innovation & Research Eyre Peninsula
- Burdekin Productivity Services
- Corrigin Farm Improvement Group
- CWFS Central West Farming Systems
- FarmLink change • adapt • prosper
- Gillamii Centre Sustainable Agriculture in Practice
- HART
- HCPSL Herbert Cane Productivity Services Ltd.
- Holbrook Landcare Network
- Liebe Group Working together in Agriculture
- Mallee Sustainable Farming
- MFMG www.mackillopgroup.com.au
- Nutrien Ag Solutions
- RiverinePlains
- SPAA Society of Precision Agriculture Australia
- SFS Southern Farming Systems
- West Midlands Group our knowledge hub
- wheatbelt natural resource management

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About the Soil CRC

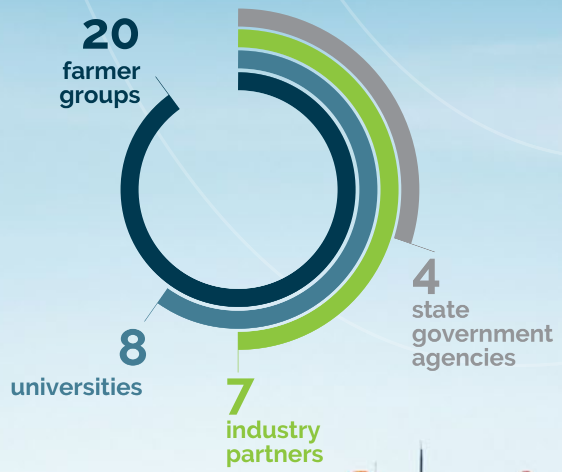
The Cooperative Research Centre for High Performance Soils (the Soil CRC) was established in 2017 to give farmers the knowledge and tools they need to make decisions on extremely complex soil management issues.

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

The Soil CRC bridges the gap between soil science and farm management, bringing together scientists, industry and farmers to find practical solutions for improving the performance and productivity of Australia's soil. This enables 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.

Participants



2022 in review

10 Years' funding

$39.5 million Commonwealth investment

$127 million cash and in-kind industry support

7 new projects approved 7 completed

13 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.

34 PhD students currently studying

31 Milestones achieved to date

4 programs

$3.4 million committed to new projects

45 current Soil CRC projects

Message from the Chair and Chief Executive Officer

As the Soil CRC completes its fifth year, we reach the halfway mark of our ten-year funding term from the Commonwealth and our 39 participant organisations. This milestone gives us the opportunity to reflect upon how far we have come since our commencement in 2017, and what is still to be achieved.

The external environment in which we operate is one in which the challenges of climate change are now being recognised and addressed at all levels. The implications for agriculture, and importantly, for soil management, are now very high on the agenda for both government and industry.

The National Soil Strategy, released in May 2021, provides an overarching framework for the Soil CRC's activities. We make a significant contribution to its three goals — prioritise soil health, empower soil innovation and stewards, and strengthen soil knowledge and capability.

The Soil CRC has rightly established itself nationally as a key provider of research and development, as well as skills and expertise in research translation and adoption. We have an extensive portfolio of projects aimed at giving farmers the tools and knowledge they need to better manage their soils, and improve their farm's productivity and profitability in a changing climate.

In the past year, the challenges of the COVID-19 pandemic once again impacted the way we delivered our projects. And once again, we were prevented from coming together physically to network and connect in our Participants Conference. However, we instead held an online Soil CRC Update and Forum which was attended by over 100 Soil CRC participants. This provided an opportunity to hear from researchers, students and farmer groups involved in the CRC.

Some of us were able to gather for a week in Cairns in early July 2021 for the National Soils Conference. Not everyone was able to make it in person. However, for those that did, it was a great opportunity to shine a spotlight on the Soil CRC. The breadth of work that was presented at this conference generated much interest among the national soil science community.

Later, we celebrated World Soil Day at Old Parliament House in December 2021 with the Parliamentary Friends of Soil. The event was attended by co-Chairs the Hon. Michael McCormack MP and the Hon. Linda Burney MP, along with the Minister for Agriculture, the Hon. David Littleproud MP, and the Minister for Energy and Emissions Reduction, the Hon. Angus Taylor MP. The event highlighted the commitment to soil health by many stakeholders across Australia.

In April 2022, the Soil CRC announced funding for seven new research projects, with a cash investment of $4 million, and $8 million of in-kind contributions from participants. The investment brings the number of active Soil CRC projects to 45, and spending on projects to more than $30 million since the Soil CRC launched in 2017.

Our Soil CRC PhD cohort continued to expand, adding another 13 students, for a total active cohort of 34. We also saw our first graduates, with three students completing their PhDs in 2021–22. Enrolled in participant universities across Australia, the PhD students make an important contribution to the Soil CRC, and are part of the contribution that the Soil CRC is making to Australia's future capacity in soil research.

We said goodbye to retiring Board Member Dr Steve Carr, and welcomed a new Board Member, Dr David Minkey. At the Program Leader level, Prof Nanthi Bolan left the University of Newcastle, and was succeeded by Prof Megh Mallavarapu as the leader of Program 3. We thank both Steve and Nanthi for their contributions, and welcome David and Megh to the governance and management of the CRC.

We would like to extend our gratitude and thanks to the members of the Board for their valuable contributions again this year. We extend that gratitude to the management and staff of the Soil CRC for their unwavering contribution to the organisation's operation through turbulent times.

We look forward to 2022–23 and beyond, when we will build upon the foundation laid in the first five years of the Soil CRC.

Dr Paul Greenfield AO
Chair, Soil CRC

Dr Michael Crawford
CEO, Soil CRC

Case study 1: *Building Farmer Innovation Capability*

Partnership approach builds culture of innovation for farmer groups

How can farmers overcome barriers to adopt new agricultural technologies and practices?

The Soil CRC's *Building Farmer Innovation Capability* project is bringing farmers into the initiation and development stages of innovations, by collaborating with farmer groups.

Soil CRC farmer group members nominate or hire a representative to receive training on designing and implementing innovations.

Project Leader, Professor David Falepau from Charles Sturt University, describes it as "a model that positions farmers as the drivers of innovation."

Creating a low-risk environment for new approaches

The project gives Soil CRC farmer groups the opportunity to experience the benefits of such a role while splitting costs — creating a low-risk environment.

"Innovation doesn't happen serendipitously," says David, "you have to make an investment."

Groups can choose to continue funding the role themselves once their time in the project ends.

To effectively adopt new innovations, farmer groups need some capabilities which the project helps to build. This includes creating a system for managing new ideas and concepts, deciding what innovations should be progressed (to gathering investment, creating prototypes or even going to market) as well as individual capability for embracing innovations. This creates a culture that is conducive to innovation.

David explains it as "removing the fear of trying something new."

"We want people coming up with ideas, and not being afraid to share them. The more that come through, the more likely you are to find something truly innovative."

That means embracing risk taking and learning to reward failure as much as success.

Groups develop and document an innovation strategy and take one idea through the entire innovation process.

Naomi Scholz, Executive Officer for Agricultural Innovation & Research Eyre Peninsula, says "having an innovation manager through the project enabled us to develop innovative projects that we wouldn't have otherwise, and target funding opportunities for developing them."

Keeping it local with a customisable approach

The project allows groups to target area's most relevant to them in terms of adopting innovations.

Naomi says that for her farmer group "the innovation was in the form of extending delivery methodology to ensure we were engaging with local advisors. That's what drives projects and attracts local audiences — creating opportunities for discussion rather than a one-way delivery."

The project has seen many innovations explored.

"We quickly learned that farmer groups are not homogenous" says David.

Initially, there was a focus on big data, with some groups gathering data from different sources to combine, analyse and derive benefits for farmers.

Some groups focus on research, utilising findings from other projects to see if an innovation can be explored.

Some groups are already investing in an innovation-specific role, often forming part of leadership duties. For these, the project is about increasing their capabilities, rather than developing systems and strategies from scratch.

Other groups employed someone specifically for the role when they began the project.

In the current round of participating groups, a designated innovation manager is developing an innovation strategy in tandem with leadership. This approach embeds the principles of the project at different organisational levels.

A two-way street between researchers and farmers

Working on the project made David realise that sharing findings with farmers is more than mere research extension.

"The perception has been that it's a one-way interaction, but it actually goes both ways in terms of communicating, with a real opportunity for farmers to relay their experiences on the ground back to research bodies."

The project has highlighted the opportunity to create an alternative process, with farmer groups acting as an intermediary.

Jane McInnes from Riverine Plains describes the project as an opportunity to "hear exactly what our farmers want and focus our research efforts into those areas."

"The process of developing an innovation strategy was beneficial — it made us proactive instead of reactive when seeking project funding. And brought a high-level strategic way of operating, that means we can better serve our members."

An opportunity to be a world leader

David sees the project as a step towards Australia becoming a world leader in farming research and innovation.

"We're a developed economy with the resources to invest in research and development. Plus, we have a diversity of climatic zones and farming systems. All the ingredients are there for our farmers to be not only driving innovations, but also selling those to other nations."

With prime development and testing grounds for innovation, creating a sustainable system within Australia could soon be creating benefits for other nations — a knowledge economy for agriculture.

Watch Project Leader David Falepau explain the project.

Case study 2: *New Amendments for Sandy Soils*

Novel approaches could be the answer to improving the productivity of sandy soils

Sandy soils account for 16 million hectares of agricultural lands in southern Australia. These soil types make it harder for crops to absorb water and thus nutrients. Traditionally less productive than other soils, research has shown they can be significantly improved – but little is understood about the mechanisms for success.

The Soil CRC's *New Amendments for Sandy Soils* project has set about changing this.

The ability of crops to absorb water and nutrients is dependent on the organic matter and clay content present in soils. This means that sandy soil productivity is generally lower than loam or clay. The project looks to explore novel ways of improving sandy soil productivity, by setting up a long term, field-based experiment.

The project is a collaboration between Murdoch University, Federation University, South Australia Research and Development Institute, West Midlands Group and the Australian Organics Recycling Association.

Project Leader, Professor Richard Bell from Murdoch University, explains the project is about using new amendments to create "soil that better retains water, nutrients and carbon."

Sandy soils — more dominant than we knew

An unanticipated outcome for the project was uncovering just how dominant sandy soils are.

Previous estimates were around 10.5 million hectares of sandy soils in Australia. Working with Dr Nathan Robinson from Federation University, the project undertook new mapping and found there were 16 million hectares of sandy soils present.

With such an expansive area of sandy soils in Australia, the potential for the project to improve yields for Australian farmers is huge.

Bringing large-scale research to soil composition

The concept of amending sandy soils to improve their productivity has been around for a long time. Farmers have been attempting to improve the yield of these soils by digging up clay from subsoils to mix with topsoils — increasing the reactive surface by reducing the presence of sandy soil as a component.

Richard says, “we've been working on trying to improve sands for decades, if not centuries.”

Part of the project was setting up a large experiment north of Perth, with the West Midlands Group. This area is predominantly sandy soils and is used for mixed agriculture — beef cattle and cropping. With reasonable rainfall, it's a perfect testing ground for studying novel approaches in the field.

With different types of additives tested over multiple seasons, the outcomes of the experiment will provide insights as to which soil additives are effective, and at what quantities. From there, further research can be initiated on how to make options that are commercially viable and affordable for growers.

Novel products could be the key to unlocking sandy soil productivity

Several novel products have shown initial promise when mixed with sandy soils.

Gypsum, rich in iron and magnesium oxide, improves the ability of sand to bind to carbon. Compost materials, with added clay, have the potential to improve soils for the long-term, by building carbon and thus the capacity for soil to hold onto nutrients.

The experiment will also test zeolite, and a synthetic compound hydrotalcite. With a negative charge, this compound could potentially allow soil to hold onto both carbon and water more effectively.

Richard explains that a big part of the project has been connecting with farmers, hearing what they are looking for and what they've tried. Farmers and researchers working together is more likely to improve outcomes.

“As university researchers, we're not out in the regions as often as we need to be. Working with grower groups provides us with a connection to farmers. We get to share our findings, but also hear what farmers are looking for — what would make the research most helpful, and even identify growers that might want to work with us.”

With sandy soils varying across Australia, and the project aiming to be applicable to different production systems, this direct contact is essential.

Collaboration brings new perspectives

A large partnership, the project is leveraging different areas of expertise. Support from the Soil CRC has brought an international eye, too. While the project has been actively training a new generation of Australian researchers with its doctorate program, a post-doctoral fellow from Brazil has recently joined.

“That's an international contact we would never have made without the Soil CRC's involvement,” says Richard.

Working across public and private sectors has been fruitful too.

“We have different strengths, and together we can achieve more relevant outcomes from the research.”

Ultimately, it's about the growers.

Richard explains “this project is the first step in creating a suite of practices for growers, and giving them options to work with these soils in different regions and for different crops, that are economically accessible,”

“If we want long-term improvements to soil, experimenting with amendments and ways to incorporate them is the best way to do it.”

The story so far... at the halfway mark

19 projects completed

$30 million cash committed to projects

3 PhD student completions

42 PhD student commencements

$4 million additional investments

Highlights and achievements

Seven new research projects were approved by the Board, with a total lifetime investment of $4 million. This brings the total number of approved Soil CRC projects to over 60, 45 of which were active at the end of 2021–22. The CRC has now allocated over $30 million of its cash resources to research projects.

The Soil CRC welcomed 13 new PhD students in 2021–22, bringing the total number of commencements to 42, with 34 of these students currently active. This year saw the first completions, with three students completing their studies and submitting theses for examination.

The Soil CRC secured $600,000 from the WA Government for a research project investigating practices to increase soil organic carbon. This project will involve Murdoch University and five of the WA grower groups who are participants in the Soil CRC.

The Soil CRC was a Silver Sponsor of the 2021 Joint Conference of Soil Science Australia and the New Zealand Society of Soil Science in Cairns in July 2021 and convened a session presenting an overview of the Soil CRC's research. In addition, a number of Soil CRC researchers presented their Soil CRC-funded work, in both oral and poster presentations.

In May 2022, the Board recommenced in-person Board meetings. The Board visited Charles Sturt University in Wagga Wagga (NSW), where they heard from Charles Sturt and NSW Department of Primary Industries researchers, and visited a field site at Lockhart.

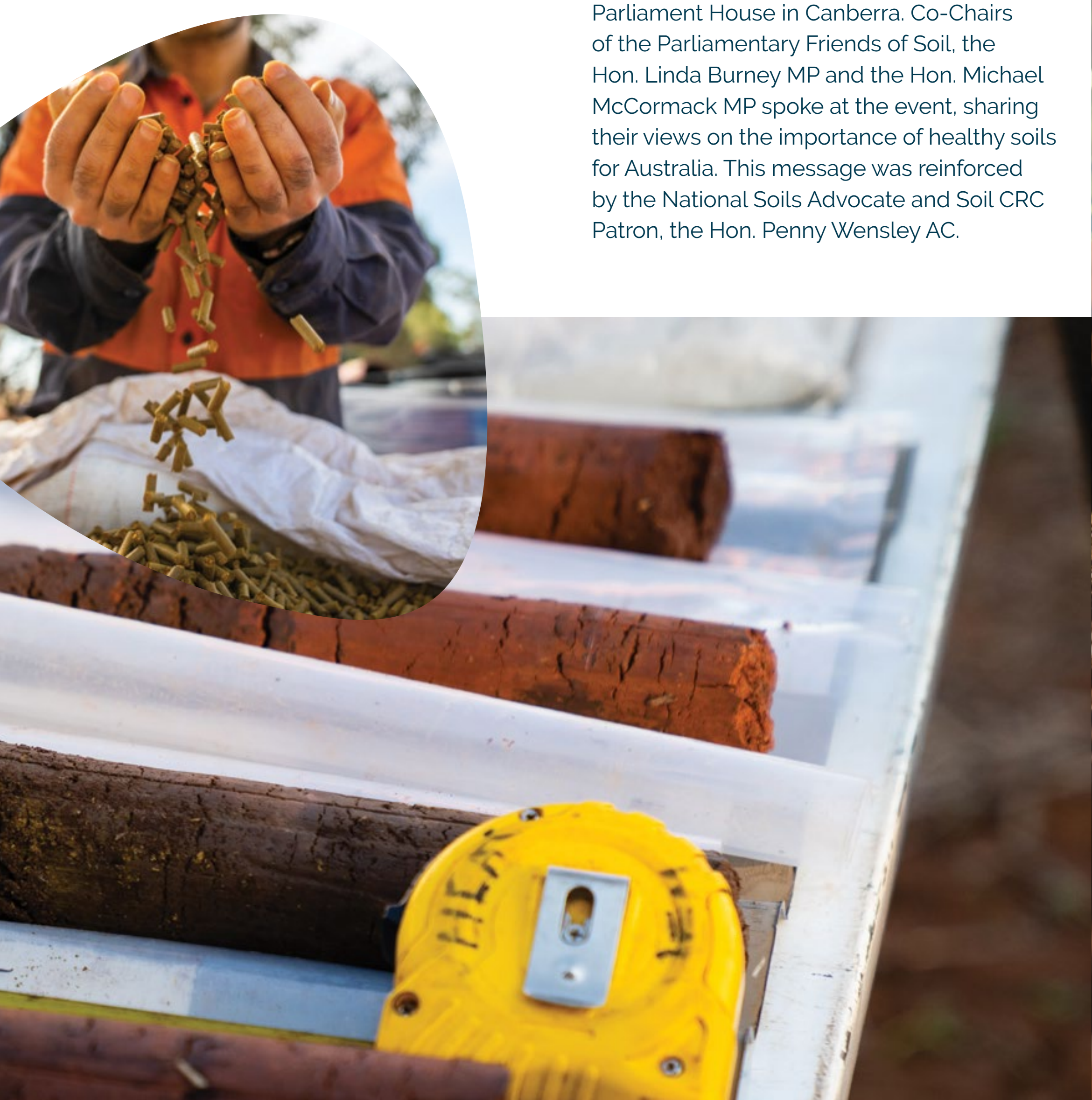
The Soil CRC continued to support implementation of the National Soil Strategy. We did so through our contributions to steering groups and working groups, and to research which supports its three goals — prioritise soil health, empower soil innovation and stewards, and strengthen soil knowledge and capability.

In support of the Australian Government's Future Drought Fund and its Science to Practice Forum in June 2022, the Soil CRC released two fact sheets and a supporting technical report explaining how farmers should manage soils after a drought, in both cropping and grazing systems.

The Soil CRC supported two of its researchers, Dr Yanju Liu (University of Newcastle) and Dr Penny Cooke (University of Tasmania), to undertake and complete the veski inspiring women STEM sidebyside program. The program was designed to empower women at different career stages with the skills, networks and mindset to develop and achieve their career goals.

Two Soil CRC researchers, Dr Chloe Lai (University of Southern Queensland) and Mathew Alexanderson (Southern Cross University) were selected as finalists in Cooperative Research Australia's Early Career Researcher competition. The achievement was even more remarkable considering the competition was open to all Australian universities and CRCs, and the Soil CRC filled two of the four finalists positions.

To celebrate World Soil Day (December 2021), the Soil CRC collaborated with the National Soils Advocate, Soil Science Australia and Soils for Life to host a breakfast for the Parliamentary Friends of Soil and other stakeholders at Old Parliament House in Canberra. Co-Chairs of the Parliamentary Friends of Soil, the Hon. Linda Burney MP and the Hon. Michael McCormack MP spoke at the event, sharing their views on the importance of healthy soils for Australia. This message was reinforced by the National Soils Advocate and Soil CRC Patron, the Hon. Penny Wensley AC.



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 assist farmers to achieve their soil stewardship and profitability goals by investing in high performance soils. This program involves 11 grower groups, seven universities, five industry partners and six PhD students. There are 11 active projects in this program, with nine now complete.

Researchers in Program 1 aim to provide a comprehensive and nuanced understanding of issues related to managing agricultural soils well, even as the world and its climate changes. They are also providing practical tools and approaches that assist soil researchers, farming groups, farmers and policy-makers to make better decisions about managing agricultural soils. The ultimate output for Program 1 will be a 'public good package' of information and capacity-building activities for researchers, farmer groups and Soil CRC partners. This will support and enable opportunities to accelerate change and build adaptive capacity. The program has three related portfolios, with contributions from various projects.

The first portfolio relates to market mechanisms for soil stewardship. This year, a three year project focused on how different actors in the consumer market value chain understand the role of soil in agricultural production was completed. A follow-on project commenced in 2022, examining the potential for certification and verification of soil management practices. A policy and law focused PhD study has commenced to complement work in this area.

The second portfolio relates to acceptance and use of approaches to soil stewardship among farmers. In this portfolio, a social benchmarking survey is providing robust, spatially-referenced information about farmers' practices, values, beliefs and intentions. In 2021–22, a survey was developed for Tasmania, which will add to survey data already collected from New South Wales, South Australia, Western Australia and Victoria. The information gathered can support numerous other projects, such as one aimed at increasing our understanding of 'adopting' and 'adoption' as part of a knowledge system. Four PhD research projects are associated with this portfolio, examining understandings of soil management norms and intuition in decision-making, the role of gender, as well as knowledge sharing regarding aspects of regenerative farming.

The third portfolio relates to innovative and effective ways of operating and collaborating in complex and uncertain situations. A new project, building on past work and commencing in 2022, seeks to enhance adaptive and entrepreneurial capacities among collaborating farmer groups. 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, farmer-driven research, and organic fertilisers created from wastes. One PhD student's work is complementing this portfolio.

There are linkages between projects across the program. For example, data from the social benchmarking survey informs the market-focused research. Also, work on building the capacity of farmer groups is encouraging new collaborations and approaches to knowledge-sharing. Program 1 projects also link with research in other programs in the Soil CRC, helping farmers to better capture the benefits of investing in high performance soils.

Program 2

Soil performance metrics

Program Leader:
Associate Professor Richard Doyle
University of Tasmania

Program 2 aims to better understand indicators of soil performance, and how these can be used to enhance soil productivity. This includes developing new ways of sensing, field testing, visualising, and using soil performance data. This will provide Australia's farmers with greater decision-making powers to ensure their farms are increasingly profitable, while retaining or enhancing soil performance.

The activities within Program 2 involve 20 grower groups, six universities, two government research partners and 12 PhD students. The program includes 12 active projects and four completed projects.

There is not a universally accepted suite of indicators of soil performance. However, there are subsets of key indicators for unique landscapes and their specific farming systems. Our research teams are working jointly with Program 1 to match important indicators to specific farming systems, to better determine the soil health indicators that matter most.

Program 2 researchers are developing a wide range of novel soil sensors to assist farmers with collecting sub-paddock-scale, cost-effective data for monitoring soil performance. One research team is working on a soil fork (probe) which can measure soil moisture and strength simultaneously. The tip can be used in a range of handheld mobile mapping configurations, or mounted on autonomous mobile platforms to provide data for soil management decisions. Our researchers are also assessing soil nutrients by developing electro-chemical sensors that can provide in-field fertility status. This allows more real-time understanding of soil nutrient fluxes within the soil profile, helping farmers to better manage their fertiliser applications, and how these relate to soil moisture changes.

Our research teams are finalising a working prototype of our lab-on-a-chip technology, which uses innovative 3D printed micro-fluidic devices and smart phone cameras to measure soil nutrients. With the help of farmer groups, field testing and design adjustment has begun. This exciting project has received further funding to refine it for potential commercialisation. Our researchers have also been able to assess biological functions in the soil using an electronic nose (eNose). This work will now turn to refining how the eNose can help farmers better assess biological health and functions in their soils under different management systems. In addition, several PhD candidates are trialling hyperspectral image data sets from drones and space to help assess soil condition.

Program 2 researchers are also working to enable easier and safer communication of data from within and under crops and pastures. The Bilby™ is an underground communication node. It can send signals from deep within the soil to above ground networks, making it safe from potential damage by livestock and machinery. It can be linked to a range of soil sensors, such as soil moisture and salinity probes, and soil temperature sensors.

Our researchers are also looking at new ways of measuring the beneficial functions of soil microbes. This will enhance our understanding of soil biological health, assisting farmers and scientists to determine the most applicable and measurable indicators of soil biological health. Our PhD candidates are helping us better understand soil microbes, and how enzyme activity is affected by various stress factors in soils.

In addition, we are helping farmers to better understand water repellence in Western Australia's sandy soils, along with better mapping and resolutions for this problem. The aim is to help farmers better manage soil water retention, and reduce losses to run-off and evaporation.

Work is being undertaken to help Soil CRC participants develop guidelines, processes and policies that support discovery and re-use of soil data. This will make it easier for researchers, farmer groups, growers and advisors to contribute soil data, particularly through sensor data streams into automated systems. This is important for farmers, because better-informed decision-making is critical for optimising resource use, productivity and sustainability.

Visualising Australasia's Soils (VAS) is a soil data sharing system that can help farmers better store and use their data, along with state government and industry soil data.

It uses FAIR principles (findable, accessible, interoperable and reusable). The first phase of the project has produced a working internet portal that supports 16 farmer group participants with their data needs. The second phase, Visualising Australasia's soils: extending the data federation, is expanding this work to all Soil CRC farmer groups, and including enhanced data analytical capability and visualisation.

The next five years will provide exciting opportunities to map out the pathway to successful manufacture and distribution of these technologies, commercialise them, and tell the stories of their use.

Program 3

New products for soil fertility and function

Program Leader:
Professor Megharaj Mallavarapu
University of Newcastle

Program 3 research aims to develop new fertiliser products, pesticide delivery systems, soil amendments, microbial carrier products and delivery mechanisms for farmers to enhance the performance of soils.

Projects within Program 3 involve collaboration between seven grower groups, six universities and three industry partners. There are 13 active projects and three completed projects, with nine current PhD students and two PhD completions.

Program 3 has made significant progress in synthesising micro-lime and micro-gypsum products, and novel microbial carrier products, demonstrating the value of biosolid application on soil health, and synthesising meta data and mapping studies involving organic and clay amendments to improve sandy soils. Researchers are also developing pesticide delivery mechanisms that are more targeted and less wasteful. This will help to reduce the negative impacts of pesticides on cropping systems and the broader environment.

Having demonstrated that biosolid application can improve soil health, research is now focusing on the most cost-effective ways to use nutrients from solid and liquid wastes to create new fertiliser products, which have a growing market in Australia. For example, a novel biochar has been synthesised from waste streams, with researchers also examining recovering high grade fertilisers — in particular phosphorus — from waste. Two PhD students have submitted their theses as part of this research. More work is being done on engineering biochar to enhance nutrient use efficiency and crop productivity, and reduce nutrient loss to the environment. Researchers are designing and evaluating surface clay-based nanocomposites with tunable functional groups and surface porous properties.

There is progress on developing soil amendments to address constraints such as soil acidity, sodicity, and poor soil structure without physically disturbing soil. Researchers have synthesised meta-data and mapping studies involving organic and clay amendments to improve sandy soils and synthesised micro-lime and micro-gypsum products which are now being trialled in experiments.

Researchers are developing delivery systems for moisture retention and microbial carrier products. These seed coatings could help increase the effectiveness of desirable, beneficial microbes in the soil, which help to fix nitrogen, protect against root diseases, and act as symbionts with plants. Researchers have been examining the best formulation of rhizobial carrier.

Over 100 potential individual carrier materials and their combinations were assessed, with the best four alternative carrier formulations identified. These all have higher rhizobial survival rates, nodulation, and drought resistance than peat inoculants under laboratory conditions. A follow-on project will further test these formulations in glasshouse and field trials.

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 involve collaboration between 15 grower groups, eight universities, three government research partners, one international research provider and nine PhD students. Program 4 is delivering data and results from 18 field trials run by grower groups around Australia and partnering with the Grains Research Development Corporation. One student has completed their PhD on the role of soil carbon in developing microbial functional resilience to compaction and drying.

Projects are identifying plant-based and biological solutions to develop high-performing, more resilient soils. Researchers are field-evaluating cover cropping, mixed-species cropping and intercropping to improve soil. Data shows improvements in physical and biological characteristics of soil, including water infiltration. There is much interest from farmers in maintaining year-round ground cover to minimise water and wind erosion, maximise carbon inputs into soil, and maximise soil biological functions and diversity. However, the impacts of these practices on in-crop water availability and crop yield remain poorly understood in Australia.

Preliminary data suggests cover cropping can lower the availability of soil moisture for winter crops in southern zones. However this effect appears reduced in northern cropping systems, which have more consistent rainfall throughout the year. A PhD student project is looking to further refine water use in cover cropping scenarios. The project has assessed and modelled changes in soil organic carbon in cover cropping systems, and the potential benefits to soil water holding capacity. Another PhD project is assessing whether the microbiome from a high performing soil can be transferred to poorer soils. Early results suggest the soil physicochemical properties tend to drive the microbial community and its functions, rather than the microbiome that was transferred between soils.

Fixing complex multiple constraints is challenging. This has been highlighted in mechanistic studies showing interactions between amendments can be rate responsive, and yield response can vary from a yield penalty through to a 300% increase. Field sites are being used to assess novel amelioration and management strategies to address surface and subsurface constraints including dispersion, high pH, declining soil organic carbon content and chemical toxicities.

The site established at Lockhart (NSW) in 2022 featured in a Soil CRC promotional video. The site showcases surface and subsurface amendments to address these constraints. Early data suggests improved root exploration of the subsoil, increasing access to resources such as water and nutrients.

Highly alkaline soils affect over eight million hectares Australia-wide, limiting crop productivity. Early crop vigour can be poor in these soils, and crop production continues to be limited by low water use efficiency. Constraints include low phosphorous status, low water-holding capacity, high burden of rhizoctonia, low nitrogen availability, severe fertiliser toxicity during germination, and at depth, extreme pH, sodicity and salinity. Eight field trials on highly calcareous soils on the upper Eyre Peninsula and in south-east South Australia are in their second season. These are testing a range of strategies and novel amendments, and the 2021 season has shown statistically significant results. A range of strategies, including carbon-coated mineral fertilisers, have increased yield by 30% compared with current best farmer practice. Positive residual effects of these amendments have been shown beyond the first year of application.

Five models have been updated within APSIM (Agricultural Production Systems Simulator), FallowARM (Agricultural Risk Management Tools) and Gypsy (a gypsum application model). These are now available and used by industry to better manage soil. Work continues to train artificial intelligence algorithms using private and publicly accessible data, as well as data originating from Soil CRC field trials, to determine whether they can correctly identify soil constraints. In future, these will be used to develop tools to optimise amelioration strategies for multiple, complex soils constraints.


Site: Lockhart
Plot: 6
Treatment: 10
Application rate: 15 and 1.5 t/ha

Research project updates

Understanding and promoting good soil stewardship

Completed: December 2021

Project Number: 1.1.003

Project Leader: Professor Mark Morrison, Charles Sturt University

Participating organisations:

- Charles Sturt University
- University of Tasmania

Duration: 2018–2021

Team members

- Mark Morrison, Charles Sturt University
- Anthony Saliba, Charles Sturt University
- Tahmid Nayeem, Charles Sturt University
- Felicity Small, Charles Sturt University
- Sosheel Godfrey, Charles Sturt University
- Eddie Oczkowski, Charles Sturt University
- Darla Hatton MacDonald, University of Tasmania
- Dugald Tinch, University of Tasmania
- Louise Grimmer, University of Tasmania
- Kirsty McKenzie, Charles Sturt University
- Jenni Grieg, Charles Sturt University
- Rachel Nichols, Charles Sturt University

Summary

This project investigated how much knowledge Australians have of soil stewardship, including how it is used in agricultural value chains. Research aimed to unpack consumer notions of environmentally friendly production, to identify avenues for increasing information sharing about these practices. The goal of the project was to assess the likelihood of food consumers being willing to pay for better soil management, which would lead to higher farm-gate prices for farmers implementing these soil stewardship practices. The project also sought to engage value chain stakeholders, to see if there was interest in sharing project results with this group. Findings from this project will help to inform subsequent quantitative projects on this topic.

Activities

- Focus groups with consumers.
- Development of communication materials for activating the consumer market.
- Archival analysis and literature review.
- Interviews with value chain members.

Results and findings

Most consumers have limited knowledge of soil and soil stewardship practices, but a niche market is already emerging, and certain consumers are willing to pay more for this feature. Our research showed consumer education will increase interest in soil stewardship and may impact on the willingness of consumers to pay for soil stewardship practices. Value chain stakeholders do not believe consumers would be willing to pay for these practices. Some of these stakeholders are already supporting soil stewardship, but they are not willing to increase farm-gate prices.

Next steps

- Large scale quantitative online survey.
- Research on developing a certification and verification solution to assist in activating the consumer market.
- Research on developing government legislation and policy to facilitate the activation of the consumer market.

Surveying farm practices

Completed: August 2021

Project Number: 1.2.004

Project Leader: Dr Hanabeth Luke, Southern Cross University

Participating organisations:

- Southern Cross University
- Charles Sturt University
- North Central CMA
- NSW Department of Primary Industries
- Primary Industries and Regions South Australia
- Western Australian No-Tillage Farmers Association
- Agricultural Innovation and Research Eyre Peninsula
- West Midlands Group
- Eyre Peninsula Natural Resources Management Group (Third Party)

Duration: 2019–2021

Team members

- Hanabeth Luke, Southern Cross University
- Catherine Allan, Charles Sturt University
- Simon McDonald, Charles Sturt University
- Warren Lake, Southern Cross University

Summary

Improved understanding of farmer decision-making can help to improve long-term soil health and productivity, inform strategic planning and build innovation capacity. This project used high-quality rural sociology research techniques to explore the complex factors driving the management of soils and landscapes. The objective was to gain a thorough understanding of the drivers of on-farm decision making across Australian farming systems.

Activities

The survey approach and instrument built on previous work by Professor Allan Curtis of Charles Sturt University, with an added emphasis on soils. Questionnaires were physically mailed to landholdings over ten hectares in chosen regions, to either a random selection or everyone, depending on the region's population. Our survey focused on three regions: the Western Australian Wheatbelt, the Eyre Peninsula of South Australia and North Central Victoria.

Results and findings

- Passing on a healthy and sustainable farm for future generations was the most commonly held value for farmers across all three 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.
- Just under half of the full-times farmers surveyed saw themselves as 'early adopters'.
- 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 all three regions.
- Beliefs around climate change varied across the three regions.
- All regions reported changing weather patterns as the most important challenge for Australian farming systems, followed by public support or opposition for agricultural practices.

Next steps

The snapshot will help to inform Soil CRC researchers and extension agents, enabling them to develop improved ways of engaging with farmers and targeting what is important to them. Farming practices and social issues will change over time, thus repeating these surveys later in the Soil CRC research program will provide valuable longitudinal data.

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 will apply a range of soil biology metrics (composition of the microbial population, its performance functions and microbial food source) that have been proposed both in Australia and internationally as indicators of soil health, and assess their relevance to agronomic or environmental outcomes, such as crop yield, soil structure, or nutrient availability. Samples will be taken across broad spatial and temporal scales to determine whether relationships between indicators and functions can be generalised, or whether they are only site or seasonally specific.

Activities

- Field experiments in NSW, Victoria, SA and WA testing various management practices designed to overcome locally relevant soil constraints, including the effect of fertiliser, cover crops, herbicide residues, soil amendments, and regenerative farming systems.
- Annual baseline sample collection from each site in March and April to validate and standardise experimental protocols for measuring different microbial indicators.
- Pre-sowing sample collection from every plot of each field experiment in May and June to analyse for the suite of microbial indicators.

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.
- Nearly all methods showed a coefficient of variation of <20%, which is regarded as suitable for the analysis of biological processes.
- Although only a limited number of samples have been analysed to date, 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 and chitinase activity have been observed at each site.

Next steps

- Crop-sampling in 2022 with additional in-field measurements of crop growth and health, and in-field hydraulic conductivity.
- Soil sample analysis for microbial indicators.
- A similar sampling scheme in 2023 to provide two years of sequential data and information about the robustness, dynamics and interpretability of the proposed microbial indicators.

Smart soil sensors

Project Number: 2.2.002

Project Leader:
Dr Marcus Hardie, University of Tasmania

Participating organisation:
University of Tasmania

Duration: 2019–2022

Summary

This project aims to develop the next generation of 'smart' soil sensors. The goal is to create sensors that overcome issues the technology has faced — such as transmitting data effectively over large areas and improving automatic interpretation of data — to provide farmers with actionable insights. This project will develop the next generation of field-based sensors that can measure, map, interpret, and communicate sensor data using new approaches that meet growers' needs for information in order to make on-farm decisions. The project aims to create proof of concept, or prototypes, for three types of sensors:

- **Smart fork:** A fork that can measure soil resistance, soil moisture and salinity, and transmit data for visualisation on smart phones while in the paddock.
- **Below-ground antenna:** Send sensor data wirelessly through deep-rooted crops in compact soils, so that sensors can be fully buried without risk of damage from stock, pests or machinery.
- **Soil moisture:** Develop algorithms that use existing soil moisture sensors to learn the soil properties needed for use with models such as APSIM and Yield Prophet, and enable growers to relate moisture content to crop stress.

Activities

- Consultation with other Soil CRC participant organisations.
- Development of prototypes and software.
- Calibration and testing.
- Evaluation by growers.

Results and findings

The program initially sought to create different tools — a smart shovel, below ground sensor and self-learning moisture sensors. But the team pivoted based on feedback from growers. A range of promising technology was also unearthed by PhD candidates working with the project team.

Next steps

The team hope to continue their progress with commercialisation of the developed technology, along with further exploration of technologies put forward by PhD candidates.

Affordable rapid field-based soil tests

Project Number: 2.2.004

Project Leader: Dr Liang Wang, University of Newcastle

Participating organisations:

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

Duration: 2019–2022

Summary

This project aims to develop a tool kit for rapid in-field measurement of soil chemical properties. Current analysis option of soil nutrients requires laboratory-based testing. While reliable, this type of testing is also time-consuming and costly. Development is focused on measuring soil pH and macronutrients such as nitrogen, phosphorus and potassium. Project scope includes both hardware — a 3D-printed microfluidic chip — and software, an app for smartphones.

Activities

- Selection, evaluation and mix-optimisation of chemicals to be used for construction of the chip.
- Testing of reaction time, temperature, light intensity, soil colour and pH.
- Design and development of multiple device and app prototypes.

Results and findings

A number of technical findings are helping to improve development of the physical test kit and smartphone app. For example, low temperatures were found to hinder colour formation in the test kit, low light can make colour samples harder to process accurately, and unbalanced soil samples can interfere with test calibration — introducing errors to the testing process.

Visualising Australasia's soils

Phase One completed: 2021

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
- 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

Team members

- Chris Sounness, Birchip Cropping Group
- Rob Milla, Burdekin Productivity Services
- Di Parsons and Diana Fear, Central West Farming Systems
- Karina Bateman, Gillamii Centre
- Rod Nielson and Mike Sefton, Herbert Cane Productivity Services
- Dale Stringer, Holbrook Landcare Network
- Shane Phillips, Nutrien Ag
- Rebecca McGregor, Liebe Group
- Danielle England, MacKillop Farm Management Group
- David Bone, Mallee Sustainable Farming
- Phil Dyson, North Central Catchment Management Authority
- Cassandra Schefe, Riverine Plains
- Jon Midwood, Southern Farming Systems
- David Minkey, Western Australia No-Tillage Farmers Association
- Joel Boyd, Wimmera Catchment Management Authority

Summary

This project provides the agriculture industry with access to data, information and knowledge on Australasian soils. It has leveraged established technologies, developed by the lead researchers, to combine data from different public and private sources to make agriculture data more findable and accessible. The project also developed a data stewardship and governance model that provides guidance for custodians on who has access to their data. A key differentiator from other soil data initiatives is that data custodians have been empowered with the skills, knowledge and tools for their soil and agriculture data to be seamlessly integrated with other agricultural data sources in next generation data models and knowledge products. This enhances decision making in the sector, generating new insights into the profitability and resilience of Australian agriculture.

Activities

- Research with farming group partners.
- Design of system architecture (based on usability).
- Creation of a data supply model.
- Samples and soil observations.
- Training programs for data stewards.

Results and findings

The most significant result of this research to date is demonstration that Australasian soils data, sourced largely from the private sector, can be made available and accessible while respecting the rights of data custodians. The project has successfully implemented a central soil data system, accessible via a portal, that includes both public and private sector soil data.

Next steps

In the second phase of the project, educational materials for data stewards will continue to be developed and delivered, including online educational modules for farmers and researchers. Data input will continue, from the Soil CRC's own archives and projects. A data-sharing system with user control will be created, and legacy data will be explored for possible adding.

Recovering nutrients from organic waste streams

Project Number: 3.1.003

Project Leader:
Professor Ajayan Vinu, University of Newcastle

Participating organisations:

- University of Newcastle
- Griffith University
- Southern Cross University
- Central West Farming Systems
- Primary Industries and Regions South Australia
- Australian Organics Recycling Association
- South East Water
- Herbert Cane Productivity Services
- Manaaki Whenua — Landcare Research New Zealand

Duration: 2018–2022

Summary

This project aims to produce a novel nano-sized phosphorus fertiliser using essential nutrients recovered from waste streams, harnessing innovative and energy-efficient technologies. The fertiliser will then be tested across a range of farming systems and soil types. The aim is to reduce the potential environmental hazards of excess phosphorus in wastewater, while producing a cost-effective phosphorus fertiliser. It is expected the novel fertiliser will increase Australian crop productivity, contributing to more efficient and sustainable nutrient use.

Activities

- Sample collection.
- Reviews conducted and published.
- Chemical testing.
- Conducted incubation and glasshouse testing.
- Identified phosphorus recovery technique.
- Synthesised and tested chemicals.

Results and findings

Effluents from livestock farms are sustainable and cost-effective sources of phosphorus. A novel chemical compound has been identified which shows promise as a means of capturing phosphorus from effluent, for use as a fertiliser. When this compound is used, the resulting fertiliser releases phosphorous over a longer period of time than commercial fertilisers.

Next steps

Further work is needed to translate initial experimental findings into producing a commercially available fertiliser with real-world use. A cost-benefit analysis must be done to determine the commercial viability of producing fertiliser in this manner. A variety of materials must also be tested for suitability in reducing production costs. Field trials are required to test the efficiency and suitability of the fertiliser in various real-world settings.

Unlocking soil nutrients with organic amendments

Project Number: 3.1.006

Project Leader:
Dr Balaji Seshadri, University of Newcastle

Participating organisations:

- University of Newcastle
- University of Southern Queensland
- Central West Farming Systems
- South East Water
- Department of Primary Industries and Regions, South Australia
- Australian Organics Recycling Association
- Herbert Cane Productivity Services
- Manaaki Whenua — Landcare Research New Zealand

Duration: 2020–2024

Summary

This project aims to explore how using organic amendments (specifically, organic wastes such as composts, manures and biosolids) impacts nutrient release in selected soil and cropping systems, under different soil management practices. It is exploring how the use of these amendments can unlock tightly bound soil nutrients, enhance nutrient use efficiency, and reduce reliance on often-depleted natural materials such as phosphate rock and water. The project will also examine innovative approaches to applying organic amendments in agricultural soils, and methods for making nutrients available for plants through moisture retention and nutrient mobilisation.

Activities

- Farm visits.
- Consultations with farmers.
- Field sample collection.

Results and findings

Activities to date have provided insights into the challenges and requirements associated with the proposed use of organic amendments in this manner.

Next steps

In future, bulk soil samples will be used for plant growth experiments in the glasshouse, using various amendments. Samples of amended and non-amended soils already collected may be further analysed to inform future field trials.

New fertilisers to overcome nutrient stratification in soil

Project Number: 3.1.007

Project Leader:
Professor Ajayan Vinu, University of Newcastle

Participating organisations:

- University of Newcastle
- NSW Department of Primary Industries
- Murdoch University
- Western Australian No-Tillage Farmers Association
- Andromeda Metals
- Minotaur Exploration

Duration: 2021–2024

Summary

This project focuses on developing a biochar-humic-clay composite-based nanofertiliser loaded with phosphorus and zinc. It also explores how such a nanofertiliser can be used to study constraints for these nutrients at different soil stratification (i.e. layers). To design nanofertiliser products, the project team combines advanced materials technologies with soil chemistry and agronomic techniques. This allows them to measure nutrient releases, bioavailability and plant uptake. This project aims to improve nutrient use efficiency, hindered by soil layers in the grain-growing areas of Australia.

Activities

- Selection of project team.
- Confirmation of project plan.
- Drafting literature review about fertiliser management strategies for nutrient stratification.
- Synthesis and characterisation of a series of clay-biochar composites at GICAN laboratories.

Next steps

- Submit a review article on fertiliser management strategies for the nutrient stratification issue.
- Characterise biochar-clay composite materials for their various physico-chemical properties.
- Modify the clay-biochar composites with humic material to develop a clay-humic-biochar material to further be loaded with phosphorous and zinc to develop a nanofertiliser.
- Evaluate the prepared fertiliser product for its efficacy in the soil and plant growth.

New products for subsoil constraints

Project Number: 3.3.002

Project Leader:
Dr Ehsan Tavakkoli, NSW Department of Primary Industries

Participating organisations:

- NSW Department of Primary Industries
- University of Newcastle
- University of Southern Queensland

Duration: 2019–2023

Summary

Many Australian agricultural soils contain one or more subsoil physicochemical constraints that can limit effective root growth. This limits water and nutrient use by crops. As a result, crop yields are significantly less than their water-limited potential. Gypsum and lime are widely used as the main soil amendments to address soil sodicity and acidity. However, these salts are sparingly soluble, which means they barely dissolve in most conditions on Australian farms. This reduces their effectiveness to ameliorate subsoil constraints. Therefore, more effective amendment formulations are needed to address these subsoil constraints including acidity, sodicity and transient salinity. In this project, the research team will harness recent advances in chemical engineering techniques and development of innovative organic-based amendments. They aim to better address subsoil constraints and improve the understanding of the interactions of these novel products with different soil types and crops. This project will also address zone-specific placement of amendments by using advanced formulations and application machinery.

Activities

- Engineering and characterisation of functionalised submicron organic-based gypsum and lime to ameliorate multiple subsoil constraints.
- Investigation of the potential of submicron organic-based amendments to boost the agronomic efficiency.
- Pot trials to assess the agronomic efficiency of submicron organic-based amendments, using advanced soil chemistry and plant physiology techniques.
- Evaluation of potential effects of submicron organic-based amendments such as nitrification, microbial respiration and root elongation.
- Small-scale field studies to verify the effective placement of submicron organic-based amendments and mineral-enhanced organic matter.
- Verification of various placement strategies of submicron organic-based amendments using field based micro-plot studies.

Results and findings

- The nano-structured lime products showed significant differences in their particle size and specific surface area compared with the current commercially available products.
- Reduced particle size was linked with a significant increase in specific area and enhanced rate of dissolution.
- The nano-structured gypsum developed using nano-ball milling process dissolved better compared to conventional products.
- Nano-structured lime applied to a depth of up to 25 cm moved through the soil better, increased the pH level more and reduced exchangeable aluminium more than conventional products.
- Surface application of AgLime had no impact below 10 cm.
- 24% less lime was needed when applying 'NanoLime' compared to AgLime to achieve the same changes in soil pH.
- Nano-structured lime products changed subsoil pH and exchangeable aluminium which improved wheat shoot and root biomass in glasshouse studies.

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

This project aims to identify and assess the capacity of naturally occurring organic- and clay-based materials in moisture capture, retention and storage. It also aims to design and synthesise novel moisture-retaining organic- and clay-based products and evaluate their effectiveness in reducing impacts of water repellence and compaction, increasing soil available water and improving soil physical structure and fertility, thereby enhancing seed germination and accelerating the crop establishment and growth under dry conditions. The findings of this project will provide farmers with practical solutions to help mitigate drought issues and improve farming activity and productivity under dry conditions.

Activities

- Testing of over 40 types of organic- and clay-based materials, collected from various places in Australia for water holding capacity and water release.

Results and findings

- Among organic-based materials, water holding capacity of bagasse, rye hay, oaten hay, sphagnum, brewery fruit waste and banana waste is significantly higher than that of other materials.
- Among clay-based materials, water holding capacity of sodium bentonite is significantly higher than that of other materials.
- In terms of water releasing, most clay- and organic-based materials lose significant amounts of water by evaporation within the first three days. In contrast, the water releasing rates of oaten hay, brewery fruit waste, calcium bentonite and sodium bentonite were significantly slower.
- Overall, oaten hay, brewery fruit waste and sodium bentonite showed excellent water retention performance without further modification.

Next steps

- Data collection of the chemical and physical properties of the key highly efficient clay- and organic-based moisture retention materials.
- Synthesis of novel, high moisture-retaining clay-based and organic-based materials.
- Development of highly effective novel cellulose-based moisture retaining materials.
- Glasshouse evaluation of selected novel efficient moisture retention materials for improving farming under dry condition.
- Completion of data analysis and effective novel moisture retention materials evaluation.
- Completion of soil resilience protocols.

Evaluating alternative rhizobial carriers

Project Number: 3.4.001

Project Leader:
Professsor Chengrong Chen, Griffith University

Participating organisations:

- Griffith University
- University of Newcastle
- Murdoch University
- Central West Farming Systems
- Western Australian No Tillage Farmers Association
- Herbert Cane Productivity Services
- Burdekin Productivity Services
- Australian Organics Recycling Association

Duration: 2018–2022

Summary

This project is evaluating the characteristics and potential of different materials to capture and retain moisture as well as supporting the growth of rhizobia, which are bacteria that establish inside the root nodules of legume and fix nitrogen from the atmosphere. The materials studied include locally available organic and inorganic materials, biochars, and new and emerging polymers. The project is also evaluating the potential of these materials for developing novel formulation of inoculants for effectively delivering rhizobia to improve soil productivity.

Activities

- Collection of more than 100 types of potential carrier materials.
- Characterisation of the physicochemical properties of the materials. Tools used to complete these characterisations include scanning electron microscope (SEM), X-ray Powder Diffraction (XRD), transmission electron microscopy (TEM) for structure analysis, Fourier-transform infrared spectroscopy (FTIR), X-ray photoelectron spectroscopy (XPS) for functional group analysis, pressure plate extractor for water retention test, inductively coupled plasma (ICP) spectroscopy for element test and more.
- Culture of rhizobial strains (CB1809, CC1192 and RRI 128) at laboratory scale. These were used to test the carrier potential of various carrier materials.
- Testing of the best carrier inoculants to assess performance on soybean plants' growth at green house using pot trial.

Results and findings

- The physicochemical characterisation of carrier materials showed that almost all carrier materials have potential to be used as carrier inoculant. However, some materials e.g. biochars pyrolyzed at lower temperatures (400°C), mulch hay, cow manure, chicken manure, mill mud, diatomite, coir and bagasse showed excellent performance regarding the availability of nutrients and morphological structures.
- Shelf-life study of individual carrier materials are comparable to peat. However, mixing of different materials using different ratios showed significant increase in shelf life as compared to peat. For instance mill mud, biochar, diatomite and cow manure-based formulations outperformed the peat regarding determination of shelf life up to 120 days.
- Pot trial results of some tested carrier materials showed that these materials have a good potential to be used as an alternative rhizobial carrier. For instance, pine wood biochar pyrolyzed at 400°C and mixing of biochar with some biopolymers (xanthan gum) showed excellent results on soybean root nodulation and growth.

Next steps

- Critically analyse and review existing literature (research papers and reports) in methodology and protocol for manufacturing of the rhizobial inoculant.
- Collaborate with rhizobium inoculation industry to develop the specific protocols for production of novel rhizobium inoculants (cow manure-based, diatomite-based, biochar-based and mill-mud based) for glasshouse and field trials.
- Assess the effectiveness and performance of the novel inoculants (cow manure-based, diatomite-based, biochar-based and mill-mud based) in nodulation, nitrogen fixation, and biomass production in different types of soils and under different moisture conditions in glasshouse.
- Measure the potential ecological impacts of these inoculants on soil.
- Evaluate the effectiveness of selected novel inoculants in enhancing nodule formation, nitrogen fixation and crop yield (field pea, chickpea, soybean and lentil) in four field sites across Australia.
- To develop cost-effective delivery of rhizobia under different agro-ecological conditions to improve grain legume and pasture legume production in Australia.

Plant based solutions to improve soil performance

Project Number: 4.1.002

Project Leader: Associate Professor Terry Rose, Southern Cross University

Participating organisations:

- Southern Cross University
- Central West Farming Systems
- NSW Department of Primary Industries
- Murdoch University
- Charles Sturt University
- Facey Group
- Herbert Cane Productivity Services
- Hart Field Site Group
- Riverine Plains

Duration: 2019–2022

Summary

The project is investigating how planting more plant species in rotational systems impacts soil performance and farm profitability in broadacre grains and sugarcane industries.

Activities

- Five long-term field sites have been established in Queensland, South Australia, Victoria, Western Australia and New South Wales.
- Laboratory experiment, glasshouse trials and small-plot field trials have been conducted near Lismore NSW and Wagga Wagga NSW to provide mechanistic data to support results from long-term field sites.
- The project team has delivered information to growers at two field days and through four newsletter articles.
- Three journal papers have been published.

Results and findings

From the long-term trial sites in Victoria (run by Riverine Plains) and NSW (run by Central West Farming Systems)

- Indications that summer cover crops are depleting soil moisture prior to winter crop sowing, but in seasons to date this has not significantly impacted on winter crop yields.
- Companion sowing wheat crops with a legume then terminating legumes after 8–10 weeks has found limited impacts on soil function and no impact on wheat yields.
- Minor changes in soil properties from the increased plant diversity may not impact on crop growth in the short term, so continual evaluation over the medium term is necessary.

From the long-term trial site in South Australia (run by Hart Group)

- Intercropping trials indicate small changes in soil function during the growing season, but contrary to much of the literature, have not increased the Land Equivalent Ratio (LER) compared to monoculture treatments.

From the long-term trial sites in Queensland (run by Herbert Cane Productivity Services)

- Multi-species cover crops were among the top performers in terms of biomass production and weed suppression, and did not cause any yield loss in subsequent cane crops.
- The impact on soil function, nematodes and arbuscular mycorrhiza (AM) fungal colonisation of cane is still being assessed.

From the long-term trial site in Western Australia (run by Facey Group)

- Perennial legumes emerged this season after drought caused failure in previous seasons, and measurements are ongoing.

Evaluating ecosystems' role in increasing soil carbon and soil resilience

Completed: July 2021

Project Number: 4.1.003

Project Leader: Dr Mehran Rezaei Rashti, Griffith University

Participating organisations:

- Griffith University
- NSW Department of Primary Industries
- Central West Farming Systems
- Herbert Cane Productivity Services
- Soils For Life
- Facey Group
- Primary Industries and Regions South Australia
- Australian Organics Recycling Association

Duration: 2019–2021

Team members

- Mehran Rezaei Rashti, Griffith University
- Chengrong Chen, Griffith University
- Lukas Van Zwieten, NSW Department of Primary Industries
- Chris Brown, Griffith University
- Josh Rust, NSW Department of Primary Industries
- Xiangyu Liu, Griffith University
- Lawrence Di Bella, Herbert Cane Productivity Services
- Sarah Hyde, Facey Group
- Chloe Turner, Facey Group
- Megan Zamhel, Herbert Cane Productivity Services
- Sue Boyd, Griffith University

Summary

This project aimed to help Soil CRC partners and farming groups adopt best management practices for re-engineering stressed soils for higher crop productivity and farm profitability. It focused on understanding factors that impact soils' responses to compaction and drought stresses. It used a soil resistance and resilience approach to assess soils' microbial functional response, as well as a soil biological functions to assess soil resistance and resilience. It also assessed the effect of soil properties and management history on the response of different soils.

Results and findings

- In low stress condition, soil microbial activity and respiration rate are mainly governed by the bioavailability of soil carbon and nitrogen pools.
- Under stressed condition soil texture, soil water-filled pore space and the applied stress levels (rather than soil organic matter content) regulate the resistance and resilience of soil microbial functions to compaction and drought stresses.
- Soils with fine texture have higher resistance of microbial carbon use efficiency.
- Soils with coarse texture have higher resilience of microbial carbon use efficiency to compaction and drought stresses.
- Response pattern of soil microbial community to environmental disturbance is highly related to soil texture and the applied stress levels, rather than the history of field management practices.
- However, improved field management practices (e.g. minimum tillage, cover cropping, crop rotation, legume fallow, organic residue amendment) can increase soil organic matter content, labile carbon and nitrogen pools and soil microbial diversity, which lead to a significant increase in soil microbial functional resistance and resilience to compaction and drought stresses.

Next steps

- Assess the effect of ecosystem processes on improvement of soil carbon stocks (quality and quantity) and soil functional resilience to environmental stresses.
- Quantify the changes in soil microbial functional resistance and resilience to key environmental stresses (e.g. drought, compaction, chemical residues of fungicides and carbon decline) as induced by the ecosystem-based management practices.
- Provide recommendations and decision support tools for better quantification of the benefits of ecosystem-based land management practices on soil carbon stocks and resilience in different farming systems.
- Assess the limitations in the adoption of farming practices that may result in more resilient soils and make recommendations on when these systems would be most likely to deliver positive outcomes for farmers.

Regenerative farming systems

Completed: June 2022

Project Number: 4.1.004

Project Leader: Dr Gwen Grelet, Manaaki Whenua Landcare Research New Zealand

Participating organisations:

- Manaaki Whenua Landcare Research New Zealand
- Primary Industries and Regions South Australia
- Soils for Life
- Wheatbelt NRM

Duration: 2019–2022

Summary

This project piloted a co-innovation approach to soil carbon research. Regenerative agriculture is proposed as a solution to reverse climate change, biodiversity loss, declining water quality and health of freshwater ecosystems, wellbeing crisis in rural and farming communities and food system dysfunctions. In Australia, where soil carbon is low, an increase in soil carbon would also improve agricultural productivity and soil resilience to heat, drought and flood.

Activities

- Developed a small-scale social study with a range of farmers, researchers, consultants and relevant agencies:
  - — formulated key research questions and hypotheses.
  - — designed a relevant field-based experiment.
  - — selected metrics to indicate sought-after functions.
- Implemented a one-off sampling campaign to capture in-field data and collect samples for subsequent lab analyses.
- Tested experimental approach with analysis of data and consultation with social study team.

Results and findings

Nine 'research' themes were identified to bridge knowledge gaps about soil carbon functionality and understanding of regenerative agriculture.

- The 100 variables assessed spoke to seven of the research themes identified in the small-scale social study.
- A large between-site variability was observed in the data — for some variables, large within-site variability also occurred.
- Significant differences between regenerative and standard management were observed mostly for variables describing aspects of soil biology (community, activity). Overall, this small dataset suggests that bacterial-driven processes are less prominent under regenerative management. Additionally, regeneratively managed soils had a greater number of pathogenic nematodes typically associated with cereals, regardless of land use — this was due to the incorporation of cereals in most regenerative systems regardless of production type, and was also accompanied by an increase in free-living and/or plant-associated beneficial nematodes, suggesting soils' capacity to suppress but not eliminate harmful nematodes.
- On average, greater soil carbon stocks were measured in the regenerative properties but the difference between regenerative and standard management was site specific and was not statistically significant.

Next steps

- It is difficult to confidently determine the impact of regenerative management on soil carbon unless a larger number of sites are sampled. We recommend also undertaking sampling at multiple time points.
- Our data suggest that soil biological processes and plant-soil interactions are key to understanding how regenerative systems work, and the extent to which they differ from systems managed under current regional best practice.
- We encountered substantial challenges associated with site selection, including, but not exclusively, challenges linked to the definition of 'regenerative' management.
- Studies seeking to understand functions at scales larger than a single field would be more informative (but likely more costly).
- We recommend including some indicators of economic and human behavioural outcomes to any subsequent studies on the topic of regenerative agriculture.

Improved management of herbicide residues in soil

Completed: June 2022

Project Number: 4.2.001

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

Participating organisations:

- NSW Department of Primary Industries
- Murdoch University
- Southern Cross University
- Western Australian No-Tillage Farmers Association
- Agricultural Innovation and Research Eyre Peninsula
- Birchip Cropping Group

Duration: 2019–2022

Team members

- Michael Rose, NSW Department of Primary Industries
- Lukas Van Zwieten, NSW Department of Primary Industries
- Josh Rust, NSW Department of Primary Industries
- Scott Petty, NSW Department of Primary Industries
- Richard Bell, Murdoch University
- Gavan McGrath, Murdoch University
- Win Win Pyone, Murdoch University
- Simon Yeap, Murdoch University
- Terry Rose, Southern Cross University
- Lee Kearney, Southern Cross University
- Amanda Cook, Department of Primary Industries and Regions South Australia
- Naomi Scholz, Ag Innovation and Research Eyre Peninsula
- Mark Stanley, Ag Innovation and Research Eyre Peninsula
- Kelly Angel, Birchip Cropping Group
- David Minkey, Western Australian No-Tillage Farmers Association

Summary

Herbicides are widely used in Australian agricultural systems for weed control. Some herbicides can persist in soil long enough to pose a risk of injuring the following crop. There is currently a lack of information, tools and services available to farmers to help determine if herbicide residues are causing yield losses. The primary objective of this research project was to identify improved methods of minimising crop damage from herbicide carryover in soil, thereby improving yield and soil productivity.

Activities

- Testing of herbicide toxicity bioassays in glasshouse. The six herbicides investigated were diuron, clopyralid, imazapyr, pyroxasulfone, trifluralin and propyzamide.
- Soil sampling to measure sorption of diuron, imazapyr and clopyralid in contrasting soils across Victoria, South Australia and Western Australia.
- Sorption and plant toxicity data were used to interpret the results of over 30 field surveys and designed experiments to measure the fate and effects of herbicide residues in soil.
- Development of new pedotransfer functions to predict sorption of the three priority herbicides in soil, based on sorption experiments.
- Development of a new model predicting herbicide persistence in soil.

Results and findings

This research has produced a new model predicting herbicide persistence in soil and new pedotransfer functions based on MIR spectroscopy to predict sorption of herbicides across a range of soil types. Key findings of this research regarding identification of crop damage from herbicide carryover in soil for improving management of herbicide residues are:

- Herbicide toxicity thresholds for the effect of soilborne residues on seedling shoot biomass were identified for six different herbicides in sand and soil, for eight different crops. Crop tolerance rankings were determined for each of these herbicides.
- Critical damage thresholds for herbicide in plant leaf tissue were defined for six different herbicides, which will enable leaf testing under field conditions to diagnose which herbicides are causing crop injury.
- Monitoring data of imazapyr, clopyralid, diuron and pyroxasulfone showed that herbicide persistence was strongly related to rainfall, where less than 100 mm of rainfall in the 180 days after herbicide application led to greater persistence of herbicides in soil and higher risk to following crops.
- Results from field experiments of the effect of herbicide residues on soil health with control treatments at three different sites highlight the site-specific nature of herbicide benefits and potential costs. It reinforces the need for greater tools and knowledge to help avoid potential crop injury caused by herbicides.

Next steps

Feedback from growers and agronomists suggests that information generated in this project would build confidence in decision making to avoid herbicide residue damage, by better diagnosing when, where and how herbicides are persisting in soil and causing crop damage. More research and translation are required to validate findings from this project under a wider range of conditions and establish a testing service for herbicide residues in soil and plant samples.

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 is to improve profitability of crop production on highly calcareous (i.e. with high levels of calcium carbonate, also known as containing lime or being chalky) soils by reducing the impact of soil constraints. It aims to quantify such soils' water holding characteristics. It is also striving to identify the benefits of organic matter, extra nutrient inputs and/or amelioration practices on microbial activity and crop nutrient supply and growth. The impacts of a range of amendments on subsoil properties and plant growth are being assessed, and management packages for more profitable crop production will be developed.

Activities

- Established eight field trials in two regions of South Australia (across three sites in the upper Eyre Peninsula and one site in the South-East).
- Controlled environment experiments to develop innovative approaches to overcoming hostile chemical conditions in highly calcareous soils. Led by the NSW Department of Primary Industries, the team is investigating a range of materials (e.g. biochar) that might stabilise organic carbon in these soils and hence improve nutrient cycling and availability.
- Investigations into the water relations of highly calcareous soils, microbial activity and function in these extreme soils and nutrient cycling and availability. This is being conducted by the CSIRO as part of a linked project funded by GRDC.

Integrated solutions for accessing soil moisture

Project Number: 4.2.004

Project Leader: Dr Ehsan Tavakkoli, NSW Department of Primary Industries

Participating organisations:

- NSW Department of Primary Industries
- Agriculture Victoria
- Murdoch University
- Burdekin Productivity Services
- Charles Sturt University

Duration: 2020–2024

Summary

The project will quantify the multi-year soil and crop responses to management practices on key soils in four cropping regions — Victoria, New South Wales, Queensland and Western Australia, to address the subsoil constraints. Quantifying how subsoil constraints affect a crop's ability to use soil water is important for productivity and water-use efficiency, because yield is linked to transpiration. It will improve our understanding of the interactions of these strategies with how plants use soil water in different soil types and farming systems.

Activities

- Field trials including specific treatments designed to ameliorate multiple soil constraints.
- Each trial consists of approximately five treatments and four replicates in a randomised block design.
- Measurement of soil water content using a combination of gravimetric and water sensing equipment.
- Measurement of soil moisture availability and plant water use in the WA trial using the Electrical Resistivity Tomography.
- Measurement of changes in soil water content at a plot scale using electromagnetic induction procedure.

Next steps

Four trial sites will continue over five years, aiming to be long term experiments to assess how amelioration strategies will improve crop rooting depth, water use and productivity by re-engineering soils with multiple constraints. Economic assessments of amelioration strategies will be developed to guide the adoption of better soil management strategies by farmers.

Watch more about this project.

Improving decision support decisions

Completed: January 2022

Project Number: 4.3.002

Project Leader: Dr Keith Pembleton, University of Southern Queensland

Participating organisations:

- University of Southern Queensland
- Federation University Australia
- University of Tasmania
- NSW Department of Primary Industries
- Burdekin Productivity Services
- Birchip Cropping Group
- West Midlands Group
- Riverine Plains

Duration: 2019–2022

Team members

- Chloe Lai, University of Southern Queensland
- Keith Pembleton, University of Southern Queensland
- Roy Anderson, University of Southern Queensland
- John Bennett, University of Southern Queensland
- Nathan Robinson, Federation University Australia
- Simon Clarendon, NSW Department of Primary Industries
- Lukas Van Zwieten, NSW Department of Primary Industries
- Claire Browne, Birchip Cropping Group
- James Murray, Birchip Cropping Group
- Rob Milla, Burdekin Productivity Services
- Nathan Craig, West Midlands Group
- Cassandra Schefe, Riverine Plains
- Brian Horton, University of Tasmania
- Peter Dahlhaus, Federation University Australia
- Caroline Mohammed, University of Tasmania

Summary

This project built on and improved the representation of different soil constrains in existing Decision Support Systems (DSS) and models based on knowledge gathered through the 'Soil models, tools and data: Current state of play, future directions and setting up for longevity and a legacy from the CRC for High Performance Soils' project.

Activities

- Development of an inverse-modelling approach empirically linking lab-measured soil fractions to the conceptual pool of plant-available phosphorus in the Agricultural Production Systems Simulator (APSIM) for major cereal cropping soil of Australia.
- Development of a pH yield-constraining function by examining data from a wide range of field trials.
- A meta-analysis on the effects of different soil amendments on yield responses of plant grown under sodic conditions.
- Enhancement of sodicity amelioration tool Gypsy's functionalities including enabling field-based variable-rate gypsum recommendation and optimised zonal management based on available budget.
- Performance of extensive simulations to understand the impact of weed management during fallow on soil water and dynamics.

Results and findings

- This project enhanced the representation of different soil constraints in existing DSS and provided a solid foundation to build a diagnostic modelling framework for multiple complex soil constraints.
- The sodicity amelioration tool Gypsy has been improved from a Windows-based program to an online tool with enhanced functionalities.
- Successfully developed weed management during fallow decision-support tool.
- Successfully developed decision support tool for initialising phosphorous in APSIM. This will likely enhance the ability of such models to inform P management and to improve nutrient use efficiency.

Next steps

Future research will include the integration of Soil CRC field experiment outputs in a diagnostic framework for prioritising amelioration of multiple soil constraints to further our understanding of the concomitant effects of different soil intervention strategies.

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 — 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.

The CEO reports to the Board on management of the Soil CRC. The CEO leads a team that operate the Soil CRC.

Soil CRC staff

- Dr Michael Crawford — Chief Executive Officer
- Mark Flick — Finance Manager
- Dr Rhona Hammond — Intellectual Property Officer
- Lisa Mahoney — Research Administration Assistant
- Jodi McLean — Chief Operating Officer
- Julie Moulton — Research Administration Officer
- Katherine Seddon — Communications Manager
- Kathy Stokes — Executive Assistant to the CEO
- Dr Cassandra Wardle — PhD Program Manager
- Jessie Xu — Finance Officer (until Nov 21)

Soil CRC Patron

The Patron of the Soil CRC is the National Soils Advocate, the Honourable Penelope Wensley AC. She is also 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.

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

PhD student program

The Soil CRC welcomed 13 new PhD students during 2021–22. Alongside three students completing their PhDs, this took the total number of currently active students to 34.

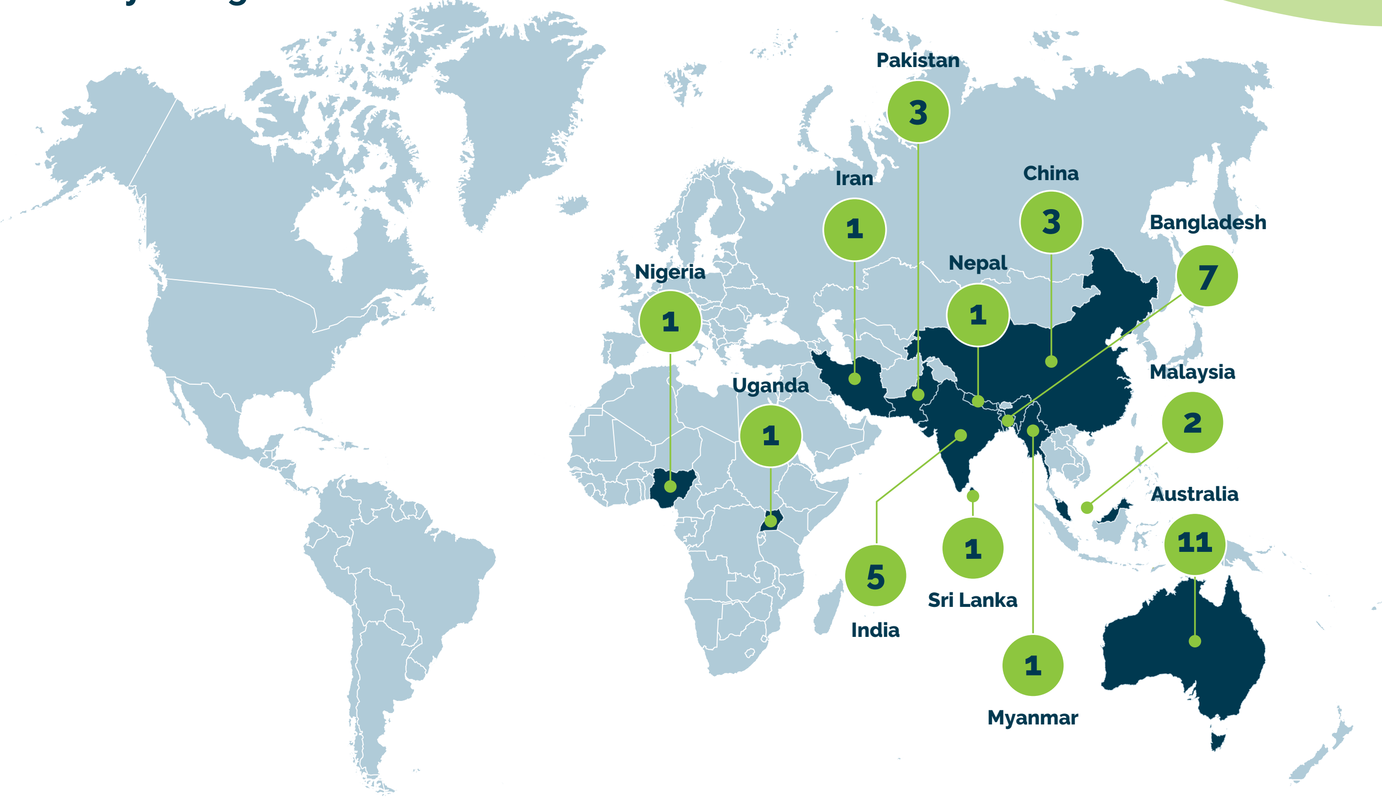
With another five students ready to commence by the end of 2022, and eight more open PhD positions available, the Soil CRC is well on the way to reaching its target of 40 PhD completions by the end of the CRC.

The Soil CRC PhD student program is building capability in the future of Australia's soil research. A PhD through the Soil CRC provides a rewarding opportunity to contribute to the health, sustainability and profitability of soils in Australia, and the communities that depend upon them. Students in the Soil CRC PhD program are part of a cohort that are supported with training, information, resources and networking opportunities.

Highlights

- Three students completed their PhDs:
  - Md. Zahangir Hossain is now employed by Soil CRC participant West Midlands Group as Cropping Systems Officer.
  - Xiangyu Liu is continuing his research at Soil CRC participant Griffith University as a Research Fellow.
  - Md. Aminur Rahman returned to his home country of Bangladesh, where he is working for the Bangladeshi Government as a Senior Chemist.
- Our expanding PhD cohort is distributed across nine universities, is aged between 23 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 draw on.
- The Soil CRC had two (out of four) finalists in Cooperative Research Australia's annual Early Career Researcher competition in October 2021: Dr Chloe Lai from the University of Southern Queensland, and PhD student Mathew Alexanderson from Southern Cross University.
- A large effort was made in supporting the Soil CRC PhD cohort. Students attended the Soil CRC program inductions in October 2021, the Soil CRC Update and Forum in March 2022, six other online PhD workshops, fortnightly Soil CRC Webinars during 2021, and three virtual PhD writing sessions spread throughout the year.
- A student profile section was added to the Soil CRC website to highlight our PhD students, the fantastic research they are doing, and how their work will help make a difference for farmers.

country of origin

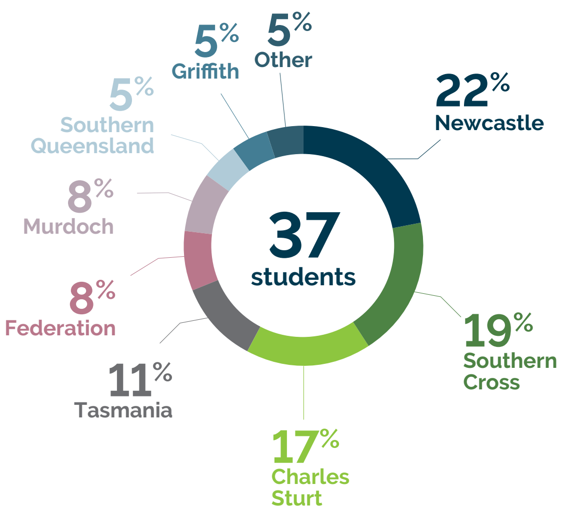


female:male

38% female

62% male

% students at each university



Financial summary

As extracted from the annual audited Financial Statements for the year ended 30 June 2022.

Financial summary

Profit or Loss

For the Year Ended 30 June 2022

	2022 $	2021 $
Revenue	22,763,165	20,179,132
Other income	58,317	60,730
Consultant fees	(73,032)	(62,455)
Employee benefits expenses	(594,469)	(532,186)
Finance expenses	(769)	(1,015)
IT expenses	(66,235)	(103,711)
Legal expenses	(16,885)	(5,820)
Other expenses	(300,470)	(370,834)
Research expenditure — cash	(7,949,242)	(5,454,098)
Research expenditure — in-kind	(13,787,337)	(13,689,801)
Travel expenses	(33,043)	(19,942)
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 2022

	2022 $	2021 $	2020 $	Cumulative to 2019 $	Total $
(a) Agricultural Innovation and Research — Eyre Peninsula					
Cash contributions	-	20,000	-	-	20,000
In-kind contributions					
— Staff	16,750	35,750	42,000	37,500	132,000
— Other	23,380	34,102	38,788	2,000	98,270
Total	40,130	89,852	80,788	39,500	250,270
(b) Australian Organics Recycling Association Limited					
Cash contributions	-	-	-	-	-
In-kind contributions					
— Staff	21,250	7,500	12,500	95,000	136,250
— Other	-	-	-	2,000	2,000
Total	21,250	7,500	12,500	97,000	138,250
(c) Birchip Cropping Group Inc					
Cash contributions	3,750	5,000	5,000	10,000	23,750
In-kind contributions					
— Staff	41,250	28,250	62,500	205,000	337,000
— Other	34,403	36,099	42,676	11,650	124,828
Total	79,403	69,349	110,176	226,650	485,578
(d) Burdekin Productivity Services Limited					
Cash contributions	-	-	-	-	-
In-kind contributions					
— Staff	63,125	51,250	50,000	42,500	206,875
— Other	14,050	3,750	6,750	1,000	25,550
Total	77,175	55,000	56,750	43,500	232,425
(e) Central West Farming Systems Inc					
Cash contributions	-	-	-	-	-
In-kind contributions					
— Staff	132,525	95,500	62,500	185,000	475,525
— Other	141,789	117,783	69,155	33,535	362,262
Total	274,314	213,283	131,655	218,535	837,787

	2022 $	2021 $	2020 $	Cumulative to 2019 $	Total $
(f) Charles Sturt University					
Cash contributions	200,000	200,000	200,000	400,000	1,000,000
In-kind contributions					
— Staff	698,250	562,500	682,500	825,000	2,768,250
— Other	425,174	533,292	359,526	11,600	1,329,592
Total	1,323,424	1,295,792	1,242,026	1,236,600	5,097,842
(g) Corrigin Farm Improvement Group					
Cash contributions	-	-	-	-	-
In-kind contributions					
— Staff	-	25,000	-	5,000	30,000
— Other	-	1,398	-	-	1,398
Total	-	26,398	-	5,000	31,398
(h) Department of Jobs, Precincts and Regions (VIC)					
Cash contributions	-	-	-	-	-
In-kind contributions					
— Staff	103,750	100,000	100,000	822,500	1,126,250
— Other	67,544	147,367	88,726	204,000	507,637
Total	171,294	247,367	188,726	1,026,500	1,633,887
(i) Department of Regional NSW					
Cash contributions	-	-	-	525,000	525,000
In-kind contributions					
— Staff	1,069,250	988,750	540,000	1,030,000	3,628,000
— Other	1,100,146	523,842	390,662	22,308	2,036,958
Total	2,169,396	1,512,592	930,662	1,577,308	6,189,958
(j) Department of Primary Industries and Regions (SA)					
Cash contributions	100,000	100,000	100,000	200,000	500,000
In-kind contributions					
- Staff	200,575	200,750	137,500	127,500	666,325
- Other	352,971	333,847	239,808	8,805	935,431
Total	653,546	634,597	477,308	336,305	2,101,756

Participants' contributions (Cash basis ex GST) cont.

For the Year Ended 30 June 2022

	2022 $	2021 $	2020 $	Cumulative to 2019 $	Total $
(k) Facey Group Inc					
Cash contributions	5,000	5,000	5,000	10,000	25,000
In-kind contributions					
— Staff	6,225	80,000	147,500	500,000	733,725
— Other	-	-	5,000	11,500	16,500
Total	11,225	85,000	157,500	521,500	775,225
(l) Farmlink Research Limited					
Cash contributions	-	-	-	-	-
In-kind contributions					
— Staff	18,450	6,250	2,500	50,000	77,200
— Other	5,236	8,700	4,473	9,000	27,409
Total	23,686	14,950	6,973	59,000	104,609
(m) Federation University Australia					
Cash contributions	100,000	100,000	100,000	200,000	500,000
In-kind contributions					
— Staff	544,050	428,750	240,000	1,000,000	2,212,800
— Other	393,963	329,959	169,689	160,000	1,053,611
Total	1,038,013	858,709	509,689	1,360,000	3,766,411
(n) Griffith University					
Cash contributions	100,000	75,000	100,000	200,000	475,000
In-kind contributions					
— Staff	359,500	393,750	640,000	465,000	1,858,250
— Other	304,500	273,722	449,870	123,803	1,151,895
Total	764,000	742,472	1,189,870	788,803	3,485,145
(o) Hart Field Site Group Incorporated					
Cash contributions	-	-	-	-	-
In-kind contributions					
— Staff	20,200	28,750	25,000	27,500	101,450
— Other	48,692	69,650	42,000	-	160,342
Total	68,892	98,400	67,000	27,500	261,792

	2022 $	2021 $	2020 $	Cumulative to 2019 $	Total $
(p) Herbert Cane Productivity Services Limited					
Cash contributions	-	-	-	-	-
In-kind contributions					
— Staff	133,250	41,250	65,000	57,500	297,000
— Other	61,665	35,750	54,108	4,000	155,523
Total	194,915	77,000	119,108	61,500	452,523
(q) Holbrook Landcare Group					
Cash contributions	-	-	-	-	-
In-kind contributions					
— Staff	24,750	19,250	10,000	25,000	79,000
— Other	150	-	85	2,463	2,698
Total	24,900	19,250	10,085	27,463	81,698
(r) Manaaki Whenua — Landcare Research (New Zealand)					
Cash contributions	134,000	267,000	267,000	534,000	1,202,000
In-kind contributions					
— Staff	35,250	26,250	35,000	220,000	316,500
— Other	84,638	6,425	1,800	7,777	100,640
Total	253,888	299,675	303,800	761,777	1,619,140
(s) MacKillop Farm Management Group Inc					
Cash contributions	-	-	-	-	-
In-kind contributions					
— Staff	5,000	10,000	2,500	12,500	30,000
— Other	3,500	1,333	1,000	-	5,833
Total	8,500	11,333	3,500	12,500	35,833
(t) Mallee Sustainable Farming Inc					
Cash contributions	-	-	-	-	-
In-kind contributions					
— Staff	12,500	-	-	22,500	35,000
— Other	-	-	-	250	250
Total	12,500	-	-	22,750	35,250

Participants' contributions (Cash basis ex GST) cont.

For the Year Ended 30 June 2022

	2022 $	2021 $	2020 $	Cumulative to 2019 $	Total $
(u) Murdoch University					
Cash contributions	112,500	187,500	150,000	263,000	713,000
In-kind contributions					
— Staff	452,000	252,500	340,000	205,000	1,249,500
— Other	335,528	234,490	344,918	6,250	921,186
Total	900,028	674,490	834,918	474,250	2,883,686
(v) North Central Catchment Management Authority					
Cash contributions	-	-	15,000	-	15,000
In-kind contributions					
— Staff	45,000	22,500	17,500	147,500	232,500
— Other	4,000	2,500	7,000	5,000	18,500
Total	49,000	25,000	39,500	152,500	266,000
(w) NSW Environment Protection Authority					
Cash contributions	50,000	-	-	50,000	100,000
In-kind contributions					
— Staff	6,250	5,000	-	-	11,250
— Other	-	-	-	-	-
Total	56,250	5,000	-	50,000	111,250
(x) Nutrien Ag Solutions					
Cash contributions	-	-	-	-	-
In-kind contributions					
— Staff	85,750	145,750	90,000	420,000	741,500
— Other	1,600	21,900	52,300	8,250	84,050
Total	87,350	167,650	142,300	428,250	825,550
(y) Riverine Plains Incorporated					
Cash contributions	-	-	-	-	-
In-kind contributions					
— Staff	28,750	25,500	30,000	21,200	105,450
— Other	29,625	42,833	25,000	-	97,458
Total	58,375	68,333	55,000	21,200	202,908

	2022 $	2021 $	2020 $	Cumulative to 2019 $	Total $
(z) South Australian Grain Industry Trust Fund					
Cash contributions	150,000	150,000	150,000	300,000	750,000
In-kind contributions					
— Staff	38,550	16,250	17,500	22,500	94,800
— Other	-	-	7,500	-	7,500
Total	188,550	166,250	175,000	322,500	852,300
(aa) South East Water Corporation					
Cash contributions	30,000	30,000	30,000	60,000	150,000
In-kind contributions					
— Staff	24,125	97,500	125,000	165,000	411,625
— Other	2,125	5,500	-	156,000	163,625
Total	56,250	133,000	155,000	381,000	725,250
(ab) Southern Cross University					
Cash contributions	200,000	200,000	200,000	400,000	1,000,000
In-kind contributions					
— Staff	620,750	885,000	840,000	1,337,500	3,683,250
— Other	782,373	987,237	601,269	172,563	2,543,442
Total	1,603,123	2,072,237	1,641,269	1,910,063	7,226,692
(ac) Southern Farming Systems Limited					
Cash contributions	-	-	-	-	-
In-kind contributions					
— Staff	31,450	23,000	7,500	27,500	89,450
— Other	12,000	11,337	10,118	16,838	50,293
Total	43,450	34,337	17,618	44,338	139,743
(ad) Society of Precision Agriculture Australia (SPAA)					
Cash contributions	-	-	-	-	-
In-kind contributions					
— Staff	-	1,250	5,000	62,500	68,750
— Other	1,200	-	500	-	1,700
Total	1,200	1,250	5,500	62,500	70,450

Participants' contributions (Cash basis ex GST) cont.

For the Year Ended 30 June 2022

	2022 $	2021 $	2020 $	Cumulative to 2019 $	Total $
(ae) The Gillamii Centre					
Cash contributions	-	-	-	-	-
In-kind contributions					
— Staff	-	-	-	2,500	2,500
— Other	-	-	-	-	-
Total	-	-	-	2,500	2,500
(af) The Liebe Group Inc					
Cash contributions	-	-	-	-	-
In-kind contributions					
— Staff	-	2,750	-	25,000	27,750
— Other	-	-	-	-	-
Total	-	2,750	-	25,000	27,750
(ag) The Trustee for Soils for Life Trust					
Cash contributions	20,000	20,000	20,000	40,000	100,000
In-kind contributions					
— Staff	189,025	143,750	85,000	75,000	492,775
— Other	29,481	25,700	18,250	6,709	80,140
Total	238,506	189,450	123,250	121,709	672,915
(ah) The University of Newcastle					
Cash contributions	300,000	300,000	300,000	600,000	1,500,000
In-kind contributions					
— Staff	646,075	1,000,000	765,000	1,560,643	3,971,718
— Other	773,260	1,155,478	935,620	268,000	3,132,358
Total	1,719,335	2,455,478	2,000,620	2,428,643	8,604,076
(ai) University of Southern Queensland					
Cash contributions	150,000	150,000	150,000	300,000	750,000
In-kind contributions					
— Staff	492,650	390,000	390,000	635,000	1,907,650
— Other	285,206	381,575	314,211	43,595	1,024,587
Total	927,856	921,575	854,211	978,595	3,682,237

	2022 $	2021 $	2020 $	Cumulative to 2019 $	Total $
(aj) University of Tasmania					
Cash contributions	112,500	150,000	187,500	263,000	713,000
In-kind contributions					
— Staff	931,250	983,750	735,000	755,000	3,405,000
— Other	862,321	945,027	609,479	45,000	2,461,827
Total	1,906,071	2,078,777	1,531,979	1,063,000	6,579,827
(ak) Western Australian No-Tillage Farmers Association					
Cash contributions	10,000	10,000	10,000	20,000	50,000
In-kind contributions					
— Staff	83,750	55,000	50,000	210,000	398,750
— Other	4,203	36,261	28,337	-	68,801
Total	97,953	101,261	88,337	230,000	517,551
(al) West Midlands Group Incorporated					
Cash contributions	-	10,000	-	-	10,000
In-kind contributions					
— Staff	66,875	30,000	12,500	7,500	116,875
— Other	20,750	45,000	4,000	-	69,750
Total	87,625	85,000	16,500	7,500	196,625
(am) Wheatbelt Natural Resource Management Incorporated					
Cash contributions	-	-	-	-	-
In-kind contributions					
— Staff	73,375	36,250	52,500	110,000	272,125
— Other	58,084	33,018	42,211	24,000	157,313
Total	131,459	69,268	94,711	134,000	429,438
(an) Wimmera Catchment Authority					
Cash contributions	-	-	-	-	-
In-kind contributions					
— Staff	110,625	55,000	92,500	264,800	522,925
— Other	9,382	4,678	17,816	38,181	70,057
Total	120,007	59,678	110,316	302,981	592,982

Participants' contributions (Cash basis ex GST) cont.

For the Year Ended 30 June 2022

	2022 $	2021 $	2020 $	Cumulative to 2019 $	Total $
(ao) Other third party					
Cash contributions	846,477	500,000	-	480,000	1,826,477
In-kind contributions					
— Staff	71,250	-	-	-	71,250
— Other	11,000	-	-	-	11,000
Total	928,727	500,000	-	480,000	1,908,727
(ap) Total Participant Contribution					
Cash contributions	2,624,227	2,479,500	1,989,500	4,805,000	11,898,227
In-kind contributions					
— Staff	7,503,400	7,300,250	6,512,500	11,809,143	33,125,293
— Other	6,283,937	6,389,551	4,982,714	1,406,077	19,062,279
Total	16,411,564	16,169,301	13,484,714	18,020,220	64,085,799
(aq) Total Commonwealth Contribution					
Cash contributions	4,742,000	7,128,000	4,062,750	6,998,000	22,930,750
Total	4,742,000	7,128,000	4,062,750	6,998,000	22,930,750
(ar) Total Contributions					
Cash contributions	7,366,227	9,607,500	6,052,250	11,803,000	34,828,977
In-kind contributions					
— Staff	7,503,400	7,300,250	6,512,500	11,809,143	33,125,293
— Other	6,283,937	6,389,551	4,982,714	1,404,077	19,060,279
Total	21,153,564	23,297,301	17,547,464	25,016,220	87,014,549

Appendices

Appendix A: PhD students

Student	University	Project Title	Program
Sepide Abbasi	University of Newcastle	Phosphorus release and labile phosphorus from iron phosphate and biochar in rhizosphere induced by root exudates	3
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
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
Kanva Goyal	Southern Cross University	Soil organic matter (nitrogen and carbon) storage in deep soils	2
Md. Zahangir Hossain	University of Newcastle	Biochar and nutrient interactions	3
Louise Hunt	Southern Cross University	Negotiating the complexities of farming in the 21st century	1
Chenting Jaing	University of Tasmania	Machine learning the soil water function	2
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
Xiangyu Liu	Griffith University	Developing sensitive soil health indicator of Australia agricultural land	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
Arnab Mitra	University of Tasmania	Mobile soil water extraction for biological and chemical analysis	2
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
Sadia Sabrin Nodi	Charles Sturt University	Development of a grower focused mobile app for estimating, analysing and recording soil properties	2

Student	University	Project Title	Program
James O'Connor	University of Western Australia	Food waste valorisation products as a nutrient source and carbon amendments	3
Oluwadunsin Oyetunji	University of Newcastle	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	Drone-based multimodal imaging for effective soil health assessment, monitoring, and decision support systems	2
Md. Aminur Rahman	University of Newcastle	Biochar modification for the generation of high quality phosphorus fertiliser products	3
Mudassir Rehman	Charles Sturt University	Farmer-friendly tools for assessment of soil biological activity	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	Evaluation of gamma radiometrics as a tool to manage soil water repellency in cropping soils	2
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

Appendix B: Publications

Book Chapter

Cheng, Y., Mah, R., Yang, H., Alejandro, F.A., Li, F., Balavandy, S.K., Wang, L., Breadmore, M., Doyle, R., & Naidu, R. (2021) Current applications of colourimetric microfluidic devices (smart phone based) for soil nutraient determination. Book: Smartphone-Based Detection Devices (1st Edition), Elsevier. https:/doi/org:10.1016/B978-0-12-823696-3.00010-6

Refereed Journal Papers

Bolan, N. Hoang, S.A., Beiyuan, J., Gupta, S., Hou, D., Karakoti, A., Joseph, S., Jung, S., Kim, K.H., Kirkham, M.B., Kua, H.W., Kumar, M., Kwon, E.E., Ok, Y.S., Perera, V., Rinklebe, J., Shaheen, S.M, Sarkar, B., Sarmah, A.K., Singh, B.P., Singh, G., Tsang, D.C.W., Vikrant, K., Vithanage, M., Vinu, A., Wang, H., Wijesekara, H., Yan, Y., Younis, S.A. & Van Zwieten, L. (2022) Multifunctional applications of biochar beyond carbon storage. International Materials Reviews 67(2) 150–200. https://doi.org/10.1080/09506608.2021.1922047

Di Bella, L., Zahmel, M., Van Zwieten, L. & Rose, T.J. (2021) Weed Suppression, Biomass and Nitrogen Accumulation in Mixed-Species and Single-Species Cover Crops in a Tropical Sugarcane Fallow. Agriculture 11(7) 640. https://doi.org/10.3390/agriculture11070640

Fang, Y., Tavakkoli, E., Weng, Z., Collins, D., Harvey, D., Karimian, N., Luo, Y., Mehra, P., Rose, M.T., Wilhelm, N. & Van Zwieten, L. (2022) Disentangling carbon stabilization in a Calcisol subsoil amended with iron oxyhydroxides: a dual-13C isotope approach. Soil Biology and Biochemistry 170 108711. https://doi.org/10.1016/j.soilbio.2022.108711

Hossain, M.Z., Bahar, M.M., Sarkar, B., Donne, S.W., Wade, P. & Bolan, N. (2021) Assessment of the fertilizer potential of biochars produced from slow pyrolysis of biosolid and animal manures. Journal of Analytical and Applied Pyrolysis 155 105043. https://doi.org/10.1016/j.jaap.2021.105043

O'Connor, J., Hoang, S.A., Bradney, L., Dutta, S., Xiong, X., Tsang, D.C.W., Ramadass, K., Vinu, A., Kirkham, M.B. & Bolan, N.S. (2021) A review on the valorisation of food waste as a nutrient source and soil amendment. Environmental Pollution 272 115985. https://doi.org/10.1016/j.envpol.2020.115985

O'Connor, J., Mickan, B.S., Siddique, K.H.M., Rinklebe, J., Kirkham, M.B. & Bolan, N.S. (2022) Physical, chemical, and microbial contaminants in food waste management for soil application: A review. Environmental Pollution 300 118860 https://doi.org/10.1016/j.envpol.2022.118860

Oyetunji, O., Bolan, N. & Hancock, G. (2022) A comprehensive review on enhancing nutrient use efficiency and productivity of broadacre (arable) crops with the combined utilization of compost and fertilizers. Journal of Environmental Management 317 115395. https://doi.org/10.1016/j.jenvman.2022.115395

Rahman, M.A., Lamb, D., Rahman, M.M., Bahar, M.M., Sanderson, P., Abbasi, S., Bari, A.S.M.F. & Naidu, R. (2021). Removal of arsenate from contaminated waters by novel zirconium and zirconium-iron modified biochar. Journal of Hazardous Materials 409 124488. https://doi.org/10.1016/j.jhazmat.2020.124488

Rahman, M.A., Rahman, M.M., Bahar, M.M., Sanderson, P. & Lamb, D. (2021). Antimonate sequestration from aqueous solution using zirconium, iron and zirconium-iron modified biochars. Scientific Reports 11 8113. https://doi.org/10.1038/s41598-021-86978-6

Rahman, M.A., Rahman, M.M., Bahar, M., Sanderson, P. & Lamb, D. (2021) Transformation of antimonate at the biochar-solution interface. ACS EST Water 1(9) 2029–2036. https://doi.org/10.1021/acsestwater.1c00115

Rahman, M.A., Lamb, D., Kunhikrishnan, A. & Rahman, M.M. (2021) Kinetics, isotherms and adsorption-desorption behavior of phosphorus from aqueous solution using zirconium-iron and iron modified biosolid biochars. Water 13(23) 3320. https://doi.org/10.3390/w13233320

Rahman, M.A., Lamb, D., Rahman, M.M., Bahar, M.M. & Sanderson, P. (2022) Adsorption-desorption behavior of arsenate using single and binary iron modified biochars: thermodynamics and redox transformation. ACS Omega 7(1) 101–117. https://doi.org/10.1021/acsomega.1c04129

Rose, M.T., Zhang, P., Rose, T.J., Scanlan, C., McGrath, G. & Van Zwieten, L. (2022) Herbicide residues in Australian grain cropping soils at sowing and their relevance to crop growth. Science of The Total Environment 833 155105. https://doi.org/10.1016/j.scitotenv.2022.155105

Rose, T.J., Parvin, S., Han, E., Condon, J., Flohr, B.M., Schefe, C., Rose, M.T. & Kirkegaard, J.A. (2022) Prospects for summer cover crops in southern Australian semi-arid cropping systems. Agricultural Systems 200 103415. https://doi.org/10.1016/j.agsy.2022.103415

Rose, T.J., Thompson-Brewster, E. & Cornish, P.S. (2022) Phosphorus constraints to potential land area cropped under organic and regenerative systems in Australia. Crop and Pasture Science 73(3) 263–272. https://doi.org/10.1071/CP21578

Singh, G., Ramadass, K., Sooriyakumar, P., Hettithanthri, O., Vithange, M., Bolan, N., Tavakkoli, E., Van Zwieten, L. & Vinu. A. (2022) Nanoporous materials for pesticide formulation and delivery in the agricultural sector. Journal of Controlled Release 343 187–206. https://doi.org/10.1016/j.jconrel.2022.01.036

Conference Publications

Kay, P., Glen, M. & Hardie. M. (2021) Soil health indicators and soil microbiomes. *Australian Plant Pathology Society Conference*. Online event. https://appsconference.com.au/2021-home

Penrose, B., Hernandez, A.D. & Hardy, R. (2021) I love the smell of nodules in the morning: Using a cheap electronic nose to smell clover-rhizobia communication. A*ustralian Society of Plant Scientists Conference*. Online event. https://www.asps.org.au/asps21

Surapaneni, A. (2021) Liquid injection of biosolids — alternative treatment process for pathogen reduction at a wastewater treatment lagoon plant. *Ozwater Conference 2021,* Adelaide Convention Centre, 4–6 May 2021. https://awa.sharefile.com/share/view/sd59da8e8590e457a9221ea066c5bd8e5/fo899954-e78e-4116-8276-12fb96a78d99

Surapaneni, A., Hampton, J., Short, G., Uren, P. & Seshadri. B. (2021) Soil injection of liquid biosolids: successful implementation of research development & demonstration (RD&D) pathway project. *Oz Water Conference 2021,* Adelaide Convention Centre, 4–6 May 2021 https://businessevents.australia.com/en/resources/case-studies/ozwater21-the-worlds-biggest-water-conference-in-2021.html

Zhang, H., Ghahramani, A., McLean-Bennett, J. & Erbacher, A. (2021) Effect of cover cropping on soil water dynamic in dryland farming system. *Soil Science Australia & The New Zealand Society of Soil Science Joint Conference,* 27 Jun — 2 Jul 2021, Cairns QLD Australia. https://www.soilscienceaustralia.org.au/2021-joint-conference/

Other Publications

Angel, K., Rose, M.T., Rose, T.J. & Van Zwieten, L. (2021) Herbicide Residues — measuring herbicide carryover. BCG Field Day. BCG Research Results Compendium 2020.

Condon, J. (2022) Trial report for Riverine Plains. Riverine Plains Inc 2022 Trial Book article.

Crawford, M. (2022) Groundbreaking science underpins health soils. Australia's Nobel Laureates III State of Our Innovation Nation 2021 and Beyond, 542–543. https://issuu.com/bpts/docs/nobel_iii-digital-book/542

Dahlhaus P., MacLeod A., Medyckyj-Scott D., Simons B., Bahlo C., Sexton A., Thompson H., Wong M., Robinson N., Milne R., Neyland A., Gillett H. & Ollerenshaw A. (2021) Visualising Australasia's Soils: A Soil CRC Interoperable Spatial Knowledge System. Phase 1 (2019–2021). Project 2.3.001 Final Report. Soil CRC.

Di Bella, L., Rose, M., Zahmel, M., Van Zwieten, L. & Rose, T. (2021). Cover crops for tropical cane systems. Article in the 'The Cane Stalk' December 2021 Newsletter pp. 10–12. Herbert Cane Productivity Services Ltd (HCPSL).

Dzoma, B. (2022) Findings from the first season of the Calcareous soils project. Agricultural Innovation & Research Eyre Peninsula (AIR EP) Newsletter.

Dzoma, B., Wilhelm, N., Cook, A., Richter, I. & Standley, C. (2022) Summary of EP field trial findings. Article in EP Farming Systems Summary 2021.

Dzoma, B., Wilhelm, N., Cook, A., Richter, I. & Standley, C. (2022) More profitable crops on highly calcareous soils by improving early vigour and overcoming soil constraints. Article for EPFS Annual Report 2022.

Higgins, V., Allan, C., Bryant, M., Leith, P., Cockfield, G. & Cooke, P. (2021) Understanding Adoptability of Techniques and Practices for Improved Soil Management. Final Technical Report, Project 1.2.002, Soil CRC, Newcastle.

Higgins, V., Leith, P., & Allan, C. (2021) A framework for assessing adoptability of practices and technologies by farmers to improve soil performance. Milestone Report to the Soil CRC.

Lai, Y., Ojeda, J., Wang, E., Clarendon, S., McLean-Bennett, J., Van Zwieten, L. & Pembleton, K. (2021) Better Quantification of bioavailable phosphorous in the landscape through inverse-modelling. Brian Chambers ECR Award. Poster presentation. https://fertiliser-society.org/brian-chambers-international-award/

Lai, Y., Pembleton, K., Robinson, N., Clarendon, S., Ojeda, J. & Horton, B. (2022) Improving the representation of soil productivity constraints in existing decision support systems and modelling platforms. Soil CRC Final Report 4.2.003.

Luke, H. & Baker, C. (2021) Soil CRC Social-Benchmarking Survey Cross-Regional Summary 2021. Article in 2021 Eyre Peninsula Farming Systems Summary Report.

Luke, H., Allan, C., Curtis, A., McDonald, S., Lake, W., Baker, C., Jenkins, A., Davenport, D., Craig, N., Sholtz, N., Hogan, R., Minkey, D., Stanley, M., Venticinque, K., Gilbert, F., Alexanderson, M., Lloyd, D., Hunt, L., Fear, D. & Wirf, L. (2021) Surveying on-farm practices: drivers of farmer decision-making. Final report for Project 1.2.004. Soil CRC.

Luke, H., Baker, C., Allan, C., McDonald, S. & Alexanderson, M. (2021) Agriculture in the northern wheatbelt: Rural landholder social benchmarking report 2021. Southern Cross University. https://soilcrc.com.au/wp-content/uploads/2021/05/Northern-Wheatbelt-Social-Benchmarking-Report_16_05.pdf

McMillan, H., Parvin, S. Condon, J., Rose, M. & Rose, T. (2021) Increasing plant species diversity in Central West cropping systems. Central West Farming Systems trial summary report 2021.

Morrison, M., Greig, J., Mackenzie, K., Small, F., Hatton-Macdonald, D., Grimmer, L. & Nayeem, T. (2022) Consumer demand, the value chain, and communication strategies for promoting soil stewardship. Final report for Project 1.1.003. Soil CRC.

Appendix B: Publications *cont.*

Pannell, D. & Crawford, M. (2022) Challenges in making soil-carbon sequestration a worthwhile policy. Farm Policy Journal 19 24–30. https://www.farminstitute.org.au/product/fpj1901-pannell-d-crawford-m-2022-challenges-in-making-soil-carbon-sequestration-a-worthwhile-policy/

Pawsey, N., Wills, B., Ascui, F., Allan, C., Colliver, R., Cockfield, G., Cook, S., Frost, M., Lynch, J. & Wong, A. (2021) Principles of Collaboration in Soil Research. Milestone Report for the Soil CRC.

Powell, S. (2021) The Sweet Smell of Soil. Handout at Wine Tasmania field day. https://winetasmania.com.au/vin%C3%B8-looking-after-the-land

Powell, S. & Clarry, S. (2021) Smelling soil article provided. FarmLink Annual Research Report.

Powell, S.M., Hardy, R., Hardie, M., Mohammed, C., Corkrey, R., Kay, P., Glen. M., Bowman, J.P. & Evans, K. (2021) Smelling soil. Final report for Project 2.1.004. Soil CRC.

Rezaei Rashti, M., Chen, C. & Liu, X. (2021) Evaluating soil functional resilience to compaction and drought stresses for developing higher performance soils. Final report for Project: 4_1.003. Soil CRC.

Rose, M.T., Van Zwieten, L., Rose, T.J., Kearney, L. & Cook, A. (2021) Developing knowledge and tools to better manage herbicide residues in soil. Lower Eyre Peninsula Field Day, Lower EP Ag Expo 2021 Booklet, AIR EP.

Rose, M.T., Van Zwieten, L., Ruttledge, A., Rose, T.J., Angel, K., Cook, A., Minkey, D., Pyone, W.W., Bell, R. & Widderick, M. (2022) Soil and plant tissue testing for herbicide residues — how can it help? GRDC Research Updates. GRDC Research Update Paper. https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2022/02/soil-and-plant-tissue-testing-for-herbicide-residues-how-can-it-help

Rose, M.T., Van Zwieten, L., Ruttledge, A., Rose, T., Angel, K., Cook, A. & Widderick, M. (2021) Residue Watch: How do I know if herbicide residues are breaking down before sowing? GRDC Research Updates. GRDC Research Update Paper. https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2021/07/residue-watch-how-do-i-know-if-herbicide-residues-are-breaking-down-before-sowing.

Rose, M.T., Van Zwieten, L., Rose, T.J., Kearney, L. & Cook, A. (2021) Pre-sowing testing for herbicide residues in soil. Minnipa Agricultural Centre Field Day. Minnipa Agricultural Centre Trial Booklet. Trial book article 2021.

Rose, M.T., Van Zwieten, L. & Cook, A. (2021) Persistence of the herbicide clopyralid in Eyre Peninsula soils. Eyre Peninsula Farming System Summary 2021, Primary Industries and Regions, South Australia, pp. 59–61. https://pir.sa.gov.au/__data/assets/pdf_file/0020/421229/epfs_summary_2021.pdf

Rose, T.J. & McInnes, J. (2022) Increasing plant species diversity in cropping systems. Riverine Plains Inc Trial Book article 2022.

Schapel, A., Bell, R. & Davenport, D. (2021) Sandy Soils: Organic and clay amendments to improve the productivity of sandy soils (Output Report). Literature Review. Milestone Report for the Soil CRC.

Weir, P. (2022) In-paddock soil moisture spatial variability for dryland cropping. Soil physics workshop, Soil Science Australia, Riverina and NSW Joint Branch Workshop, Wagga Wagga NSW.

Wilhelm, N., Fraser, M. & Pearce, A. (2022) Improved management of iron and manganese deficiency in broad beans at Lake Hawdon. Article for Mackillop Farm Management Group (MFMG) Report 2022.

Wilhelm, N. (2021) Lake Hawden field trial summary. Handout for Mackillop Farm Management Group (MFMG) Crop Walk, Robe, SA

Wilhelm, N. (2021) Nutrition on calcareous soils, Hyperyielding Project. Field Day Handout, Millicent, SA

Wilhelm, N., Fraser, M. & Pearce, A. (2022) Summary of SE field trial findings. Mackillop Farm Management Group (MFMG) Harvest Report, 2021.

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