



Beyond Soil Carbon

**Research in building healthy, functional and resilient soils
and why carbon is only part of the story**

Project Snapshot

Soil CRC Projects	New farming methods to sequester soil carbon (4.1.006)
	Building soil resilience and carbon through plant diversity (4.1.007)
Project Dates	2022 - 2026
Themes	Soil resilience Soil carbon Soil amendments / amelioration Plant diversity Crop rotations

Contents

<i>Challenge & Opportunity</i>	2
<i>Research Approach</i>	3
<i>Key Findings</i>	4
<i>Next Steps</i>	5
<i>Practical Implications</i>	6
<i>Decision Framework</i>	7
<i>Acknowledgements</i>	8

Key Messages

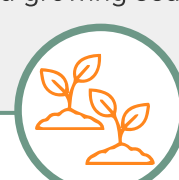
Building measurable soil carbon is slow, so judge implemented practices by improvements in soil function and short-term carbon change.



No single treatment consistently improved soil carbon, soil health and crop productivity. Responses depend on soil constraint, treatment and season.



Increasing plant diversity may support overall soil resilience, but significant improvements were not detected in soil carbon by the third growing season.



Who should care?

The findings are relevant to Wheatbelt grain growers and advisers managing low-fertility sandy soils. This research helps identify practices that can improve water and nutrient use now while creating conditions that may support long-term soil carbon and resilience.

The Challenge

Wheatbelt soil constraints

Many Western Australian sandy soils contain little organic carbon and have low water-holding capacity and poor nutrient retention. These constraints may limit crop productivity and make measurable soil carbon gains difficult.

Carbon takes time

Carbon also changes slowly. Short trials can show improvements in fertility, biomass or water use before they show clear changes in total soil carbon. This makes it important to separate immediate soil-function benefits from longer-term carbon outcomes.

More plant diversity does not automatically mean more carbon

Increasing plant diversity can provide more varied organic inputs, but carbon gains depend on whether the system actually produces additional biomass and how that material is stabilised in the soil. In 4.1.007, cover crops and temporary intercropping had not produced enough additional biomass by the third growing season to improve soil health or carbon, highlighting the challenge of turning greater diversity into measurable soil change.



Clay amelioration at Bullaring WA in 2022, testing whether clay could improve water and nutrient retention, crop growth and soil health in deep sandy soils. Source: Soil CRC.

Rarely only one constraint

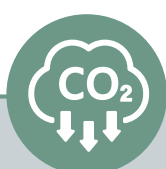
Many Western Australian soils have multiple constraints operating at the same time, including non-wetting, acidity, compaction, low fertility and subsoil constraints. Treating one limitation may not address the others, so combinations of physical amelioration and soil amendments were trialled rather than testing each approach in isolation.

The Opportunity



Improve constrained soils while supporting carbon gains

Soil amelioration and amendments can improve water holding, nutrient retention and fertility, creating better conditions for crop growth and longer-term soil carbon accumulation.



Use farming practices to increase carbon inputs

Crop sequencing, legumes, intercrops, cover crops and pasture phases provide opportunities to increase and diversify plant-derived inputs to soil.



Get productivity and soil-function benefits before carbon changes are measurable

Growers do not necessarily have to wait for measurable increases in soil carbon to gain value from these practices.

Research Approach

Long-term field trials investigated practical ways to improve soil carbon, soil function and resilience. Project 4.1.006 established four WA Wheatbelt trials at Bullaring, Kweda, Wathingarra and Coorow, testing combinations of soil amelioration, amendments and farming practices across different constrained soils.

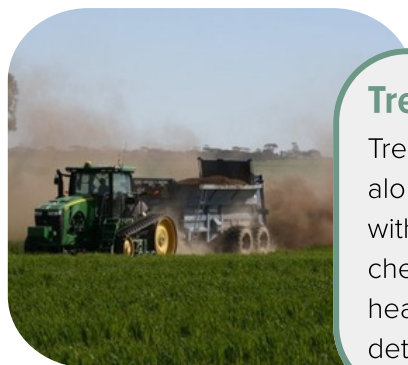
Project 4.1.007 used established trials across Victoria, NSW and Queensland to test crop rotations, intercropping, pasture phases and cover crops. Together, the projects examined how improving the soil environment and increasing plant inputs can influence soil carbon and resilience over time.



*The Wathingarra trial site
Source: West Midlands Group.*

WA field trials

Long-term field trials at Bullaring, Kweda, Wathingarra and Coorow compared practices for increasing soil carbon, soil health and crop productivity under Wheatbelt conditions. Each site represented different soil constraints and tested locally relevant combinations of cropping systems, soil amelioration and amendments. The trials were designed to assess these practices individually and in combination over multiple growing seasons.



Spreading compost

Treatments and measures

Treatments included deep ripping, rotary spading and mouldboard ploughing, alongside amendments such as clay, compost, gypsum, manure, biochar and frass, with treatments varying between sites. Researchers measured changes in soil chemistry and nutrients, soil water, soil carbon, crop establishment, biomass, plant health, weeds and yield. Measurements at different soil depths were also used to determine whether treatments redistributed or increased carbon below the surface.



Intercrop at the New South Wales site. Source: Soil CRC

Plant diversity

Long-term field trials across Victoria, NSW and Queensland investigated whether increasing plant diversity could improve soil resilience and carbon. The project trialled crop rotations, intercropping, temporary intercropping, pasture phases and cover cropping. Researchers examined how additional and more diverse plant inputs influence soil carbon and resilience, including the stabilisation of plant material and its contribution to soil aggregation.

Key Findings



Combination of practices is key

Combinations of crop sequencing, physical amelioration and amendments showed the strongest potential for longer-term gains.



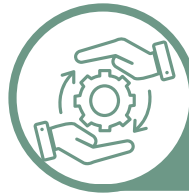
Treat the soil to improve function

Water-holding capacity and nutrient retention increased, helping crops use rainfall and fertiliser more effectively.



Treatment effectiveness varied by soil type

No single treatment performed best across all sites, with outcomes depending on soil type, constraints and management approach.



Plant diversity not yet conclusive for soil carbon

Plant diversity had not increased soil carbon after three seasons, but had not caused significant yield penalties.

Significance of Findings

For Wheatbelt growers, the practical value is that soil improvement can occur before a large carbon increase is measurable. Better water holding, nutrient retention, biomass production and reduced subsoil constraints can strengthen the productive base of sandy soils while supporting the longer-term pathway to carbon accumulation.

The research also cautions against treating plant diversity or organic amendments as stand-alone carbon solutions. Additional biomass and organic inputs matter, but whether they become stable soil carbon depends on the soil environment, seasonal conditions, management and time.



A tractor performing soil amelioration to address soil constraints and improve growing conditions.



What we know with confidence

- Carbon gains were small and variable.
- Soil fertility benefits were strongest when amendments were combined with physical amelioration.
- Building soil carbon in low-clay sandy soils is a slow process.
- Plant-diversity treatments had not caused significant yield penalties by the third growing season.

What is still uncertain

- The size and persistence of long-term soil carbon gains remain uncertain.
- Improvements in soil health and carbon had not yet been detected.
- Seasonal variation can strongly influence outcomes.
- Carbon gains depend partly on producing sufficient additional biomass.



Next Steps

Long-term monitoring is essential. Six trial sites are continuing to June 2028 through a Soil CRC project evaluating novel approaches for drought resilience (6.4.002), allowing carbon, soil water, soil health and crop performance to be assessed across more seasons. This project receives funding through the Australian Government's Future Drought Fund under the Long-Term Trials Program. The plant diversity trials will include assessment of resilience indicators including disease loads, soil aggregation, infiltration and nitrogen fixation.



CFIG's Executive Officer Joy Valle (centre) stands in the canola crop at the Kweda field site in WA with Soil CRC and Murdoch University researchers, Prof Richard Bell (left) and Dr Hassan Sardar. Source: CFIG.

Practical Implications

Looking for advice? The below table can help you weigh the pros and cons of implementing the practice considerations mentioned in this Fact Sheet on your own land.

 Practice Consideration	 Potential Benefits	 Potential Trade-offs
Use physical amelioration on constrained soils	Better root access, biomass and soil function.	Benefits can vary by soil, season and time.
Combine amelioration with organic amendments	Improved fertility, water holding and nutrient retention.	Benefits may decline over time or require reapplication.
Include legumes and intercrops	More diverse plant residues and nutrient cycling.	Competition for water may limit biomass gains.
Consider biochar and frass	Improved nutrient uptake and longer-term fertility.	Carbon gains may be slow or uncertain.
Increase plant diversity strategically	More diverse organic inputs and potential resilience benefits.	More diversity does not guarantee more biomass or carbon.



Pea-canola cover crop.
Source: Soil CRC



Soil that's been ameliorated



Biochar added to soil

Decision Support Framework

A more detailed guide for implementing the practices in this Fact Sheet, the Decision Support Framework will help you identify what may be limiting your system, the ecosystem processes to focus on, the management approaches that can help, and the risks & rewards worth considering. These tools have been created as a starting point, and are generic in their advice. Seek out additional information specific to your unique situation from trusted professionals.

Identify limitation What is currently limiting performance or resilience in your system?	Select ecosystem process Focus on the processes that addresses the limitation	Consider management options Choose practices that support these processes	Assess risks/trade-offs What should you consider before making changes?	Potential resilience outcomes What can you expect over time if processes improve?
Deep sandy soil has poor water and nutrient holding capacity, limiting crop growth.	Increase the soil's capacity to retain water and nutrients within the root zone.	Incorporate clay where low clay content is a major constraint, with higher rates producing the clearest crop response.	Clay is a high-input intervention and responses depend on application rate, soil type and seasonal rainfall.	Improved water and nutrient retention can increase crop performance and provide more biomass for longer-term carbon inputs.
Compaction or other physical constraints are restricting root access to water and nutrients.	Improve soil structure, infiltration and rooting depth so crops can access a greater soil volume.	Use deep ripping or other appropriate mechanical amelioration where a physical constraint has been identified.	Benefits vary by soil and season, and disturbance alone may not address low fertility or produce sustained carbon gains.	Better root exploration and water access can improve crop growth and resilience when seasonal conditions become limiting.
Low soil organic matter and fertility are limiting nutrient supply and biological activity.	Increase organic inputs and nutrient cycling within the soil.	Apply organic amendments such as compost, manure or biochar/frass where nutrients or organic matter are limiting.	Benefits can decline over time, and compost may increase weed pressure.	Organic inputs can improve nutrient availability, biomass and soil function.
Organic amendments are not producing a strong response on constrained sandy soils.	Improve incorporation, water availability and contact between organic material, soil and microbial communities.	Combine organic amendments with physical amelioration where both physical and fertility constraints occur.	Stacked treatments added benefits, but extra inputs and costs did not always deliver greater returns.	Addressing physical and fertility constraints together can create better conditions for organic matter cycling and carbon retention.
Low plant diversity and biomass are limiting the amount and variety of carbon entering the soil.	Increase living roots, plant-derived carbon inputs and nutrient cycling through a more diverse plant system.	Introduce suitable legumes, intercrops or more diverse crop sequences.	Companion crops can compete for limited moisture; the best-performing crop combination varied between seasons.	Diverse plant inputs can support nutrient cycling, soil cover and long-term soil resilience.

Acknowledgements



4.1.006 - New farming methods to sequester soil carbon

Project Lead Dr David Minkey, Western Australian No-Tillage Farmers Association (WANTFA)

Project Team Murdoch University, Liebe Group, West Midlands Group, Facey Group and Corrigin Farm Improvement Group

Sources

- <https://soilcra.com.au/projects/new-farming-methods-to-sequester-soil-carbon/>
- [Coorow experimental report \(2022-24\).pdf](#)
- [Wathingarra experimental report \(2022-25\).pdf](#)
- [Bullaring experimental report \(2022-25\).pdf](#)
- [Kweda Site Report \(2022-23\).pdf](#)



Scan to visit sources

4.1.007 – Building soil resilience and carbon through plant diversity

Project Lead Professor Terry Rose, Southern Cross University

Project Team NSW Department of Primary Industries and Regional Development, Central West Farming Systems, Riverine Plains, Birchip Cropping Group and Herbert Cane Productivity Services

Sources

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Wheatbelt Natural Resource Management (WNRN)

is a not for profit organisation leading positive change in the management of the Wheatbelt region's natural resources. We work with individuals and groups to protect the land, flora and fauna of the Wheatbelt while working with landholders to help develop sustainable agricultural systems.



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