

SOIL MICROBIAL INDICATORS: WHAT DO THEY MEAN AND HOW CAN THEY BE USED?

Project 2.1.008



Dr Zahangir Hossain from Wheatbelt NRM taking post-harvest samples at Newdegate, WA.

KEY POINTS

- Soil protein (ACE) is a low-cost test that correlated with total carbon, microbial biomass and several enzyme activities, making it the most promising practical indicator of soil biological condition.
- DNA-based indicators were better than most other soil microbial indicators at detecting the effects of farming practices and worked across different Australian cropping systems.
- Tests that count specific organisms, such as crop diseases, beneficial mycorrhizal fungi and nematodes, were more useful for management decisions than tests that only measure the total amount or broad variety of soil life.
- Site and season influenced most microbial indicators more than management. Results need to be judged against what is normal for that soil and district, not against a single national benchmark.
- Soil microbial indicators are most useful when interpreted alongside soil chemistry, soil physics and crop performance.

THE CHALLENGE

Well-functioning soil biology is central to soil health, crop performance and resilience. A wide range of soil tests can measure the diversity, abundance and function of soil microbes, but growers and advisers lack clear guidance on which microbial tests (indicators) are most useful for practical on-farm monitoring and decision-making.

Some soil microbial indicators only reflect general biological activity and are too high-level to guide specific management actions to improve soil function or crop productivity. Others are too specific to be widely applied, and many shift with the season and recent rainfall, so a single sample taken at the wrong time can give a misleading picture.

Clear guidance on selecting appropriate indicators and sampling strategies would help growers, advisers and researchers diagnose soil constraints, track how the soil responds to management, and have greater confidence in soil biological testing. This would support more targeted decisions around soil amendments, rotations, regenerative practices and chemical inputs, and create a pathway to practical soil biology tools that are scientifically robust and relevant to Australian farming systems.

OUR RESEARCH

This project evaluated how different land management practices affect soil biology, how those changes link to soil function and crop health, and which soil tests are practical and cost-effective for farmers and advisers to use in monitoring soil biology.

The project drew on five existing Soil CRC field experiments that covered a range of soil management issues including regenerative versus conventional systems, calcareous soils, herbicide use, plant-based solutions to improve soil performance and crop history effects (Figure 1).

Over 400 soil samples were collected from the five sites, over a range of seasons and management treatments. Researchers analysed 89 soil properties, from standard chemical and physical tests to a range of soil biology indicators including:

- Enzyme activity – a marker of biological activity.
- Autoclaved-citrate extractable (ACE) soil protein – measures the pool of organic nitrogen in soil organic matter.
- Phospholipid fatty acids (PLFA)-based microbial biomass – measures the total living microbial biomass and the balance between broad groups such as fungi and bacteria.
- Quantitative real-time PCR (qPCR) assays – the abundance of the organisms tested.
- DNA metabarcoding – shows which organisms are present and in what proportions.

The project assessed each indicator's sensitivity to management, its relationship with soil function, and its suitability for routine use.

RESEARCH FINDINGS

Soil type, climate and season had a bigger influence on soil biology than management. As a result, the large differences between sites and farming systems were easy to detect, while the more subtle effects of individual treatments within a single site were harder to discern, and varied from site to site depending on local soil and seasonal conditions.

DNA-based indicators were the most sensitive to management change, especially qPCR. qPCR measures of pathogens, arbuscular mycorrhizal fungi (AMF) and free-living nematodes responded to liming, crop rotation, regenerative versus conventional systems, pesticide use and some soil amendments, although the size and direction of the response differed from site to site. However, DNA-based tests are expensive and are not always practical for farmers.

Indicators that measure biological activity (e.g. enzyme-based indicators) responded clearly to liming but were less sensitive to other management practices.

Soil protein (ACE protein) emerged as a promising all-round proxy for soil biological condition. It correlated with total carbon, microbial biomass and key enzymes involved in nitrogen and phosphorus cycling.

Labile carbon, the easiest form of carbon for microbes to use, was also strongly linked to more diverse microbial communities.

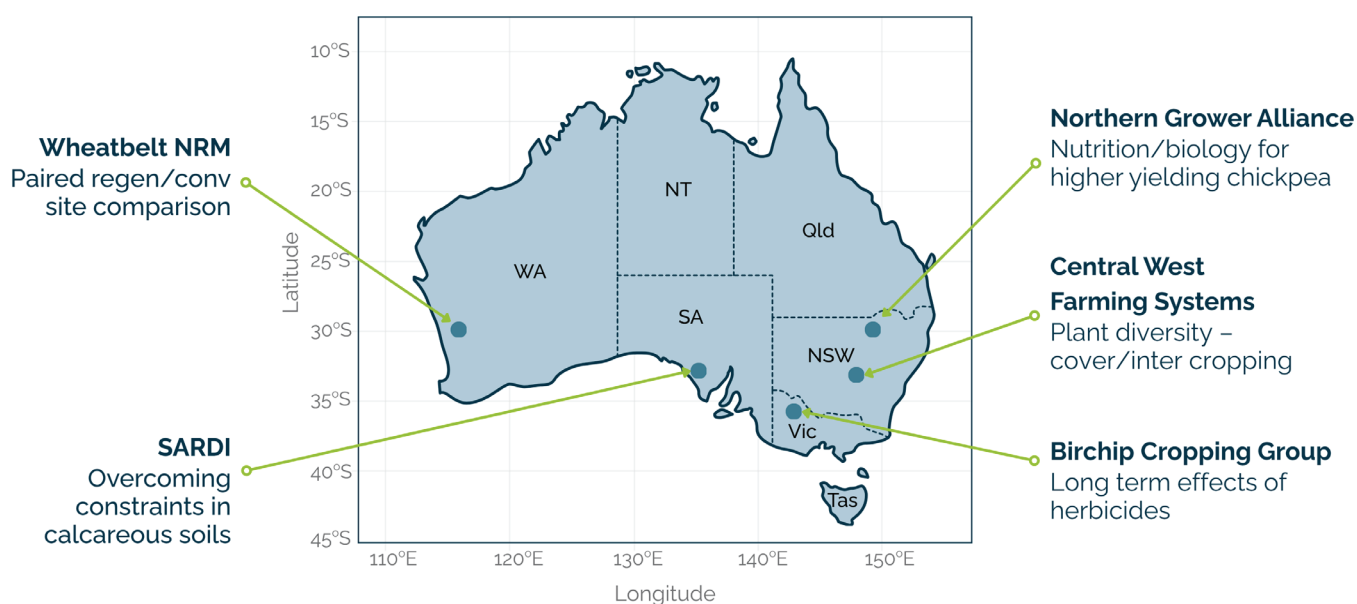


Figure 1. Project field experiment locations.

PLFA-based measures of total microbial biomass and the fungal-to-bacterial ratio responded weakly and inconsistently to the management practices tested. For example, at the Wheatbelt NRM paired paddocks in Western Australia, PLFA results differed more between locations than between conventional and regenerative management.

Nematodes were reliable indicators of broad system differences, such as regenerative versus conventional farming, and responded to pesticide use, in particular fungicides. At the Wheatbelt NRM sites, regenerative paddocks held more omnivorous and predatory nematodes, which points to a more structured soil food web, though site effects and management history masked many other apparent differences.

Overall, the findings suggest there is no single test or “soil health score” that captures soil biological condition. Instead, a small panel of indicators read alongside soil chemical and physical data gives a more reliable picture. The exact panel of tests should align to the outcomes desired by the landholder and agronomist. Additional fact sheets on soil microbial indicators are available on the Soil CRC Knowledge Hub.

Soil microbial indicators need to be matched to the soil constraints in question, such as known disease risk, poor nutrient cycling or acidity. Soil should be sampled at the same time each season, and compared against benchmarks from similar local soils rather than fixed national thresholds.

SIGNIFICANCE OF THE FINDINGS

These findings help to move soil biology from broad interest to practical application. The project shows that microbial indicators can add value to soil tests, but only when the right indicator is matched to the right question. A qPCR pathogen test, for instance, can tell a grower which disease-causing organisms are in a paddock and at what level, while a broad measure of total microbial biomass or diversity cannot.

The work also shows that interpretation is critical. Because site and seasonal effects were often stronger than management effects, biological results should not be treated like simple universal thresholds. Instead, they are most valuable when used alongside soil chemistry, soil physics, crop performance and local knowledge.

The project gives a firmer evidence base for building soil health frameworks, improving commercial testing services and giving growers clearer advice. Together these form a foundation for the practical testing services and decision-support tools that growers and advisers will use in future.



The project linked soil microbial indicators to plant productivity measures such as root health.



Project leader Associate Professor Mick Rose shared research highlights at a Birchip Cropping Group field walk in August 2026.

Project team

- Mick Rose, Terry Rose, Jay Anderson - Southern Cross University
- Katherine Weigh, Justine Cox, Lukas Van Zwieten - NSW Department of Primary Industries and Regional Development
- Felicity Gilbert (now WA DPIRD), Dimity Boggs - Wheatbelt NRM
- Kelly Angel, Yolanda Plowman - Birchip Cropping Group
- Diana Fear - Central West Farming Systems
- Lawrie Price - Northern Grower Alliance
- Amanda Cook, Alan McKay, Katherine Linsell - SARDI / PIRSA
- Mehran Rezaei Rashti, Chengrong Chen - Griffith University

NEXT STEPS

The next step is to refine a smaller set of priority microbial indicators for different end uses, such as disease risk, nutrient cycling, soil function and response to management. These indicators need to be validated across more sites, seasons and farming systems, so that thresholds and interpretation frameworks can be developed with greater confidence.

There is also scope to link these biological indicators more directly to agronomic performance, risk management and economic value for growers. Further work should test how well the most promising indicators predict crop response, resilience and soil function under seasonal stress, and should resolve open questions around standardisation, affordability, sampling timing, and how best to combine biological, chemical and physical indicators into decision-ready soil health tools.



This fact sheet and related publications are available on the Soil CRC Knowledge Hub (soilcra.com.au/resources).

The CRC for High Performance Soils (Soil CRC) brings together scientists, industry and farmers to find practical solutions for Australia's underperforming soils. Our aim is to enable farmers to increase their productivity and profitability by providing them with knowledge and tools to improve the performance of their soils. The Soil CRC is the largest collaborative soil research effort in Australia's history, with funding until 2027. We have attracted more than \$167 million in cash and in-kind resources over 10 years from our 39 participants and the Australian Government.