Plant-Soil Relationships

Emerita Professor Lynette Abbott
UWA School of Agriculture and Environment
& UWA Institute of Agriculture
The University of Western Australia

Email: Lynette.Abbott@uwa.edu.au

SW WA Landcare Tour

July/August 2023

Multispecies & Perennial Pastures for Building Resilience, Productivity & Profitability

Summary

- **Principles** of soil biological fertility
- **Plant-microbe interactions**
- **Microbial diversity and function**
  - Plant species diversity
  - Carbon based soil amendments
  - Plant species diversity and soil carbon
  - Grazing impacts on soil biological fertility

Acknowledgements

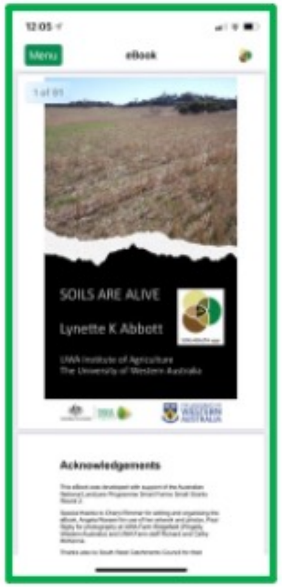
Dr Sasha Jenkins
Dr Mark Farrell
Dr Bede Mickan
Dr Zakaria Solaiman
Ian Waite
Prof Michael Huston
Prof Alan Robson

Bugs and Biology Grower Group

Soil Health app

Australian Government | National Landcare Program | The University of Western Australia

Soil Health



Lifetime of knowledge distilled in new SOILHEALTH app

L to R

Lyn Abbott (UWA)

Cheryl Rimmer (UWA)

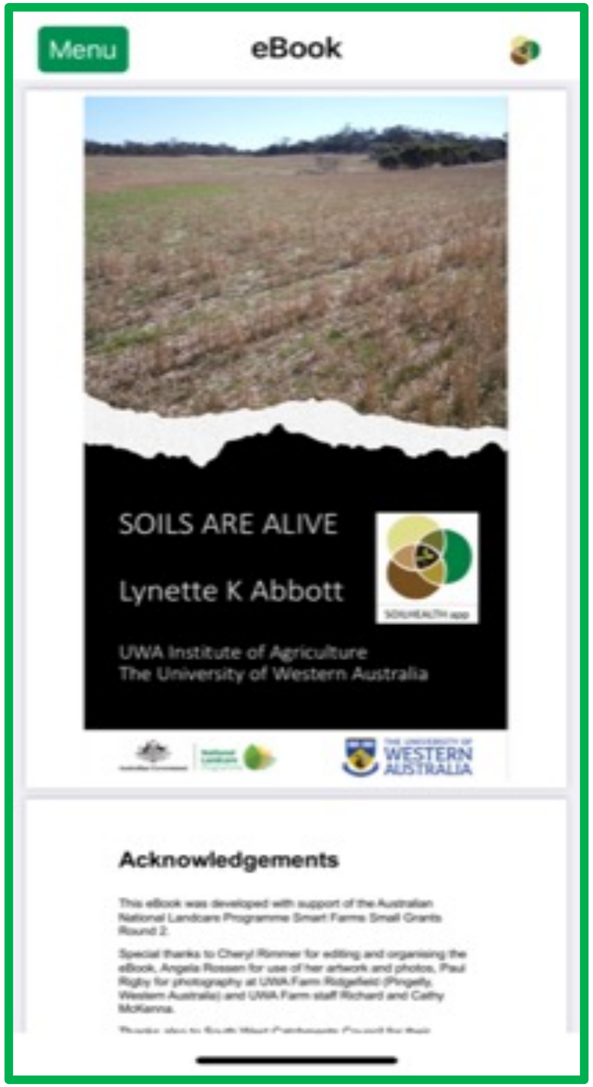
Alex Lush (Lush Digital)

Soil Health app

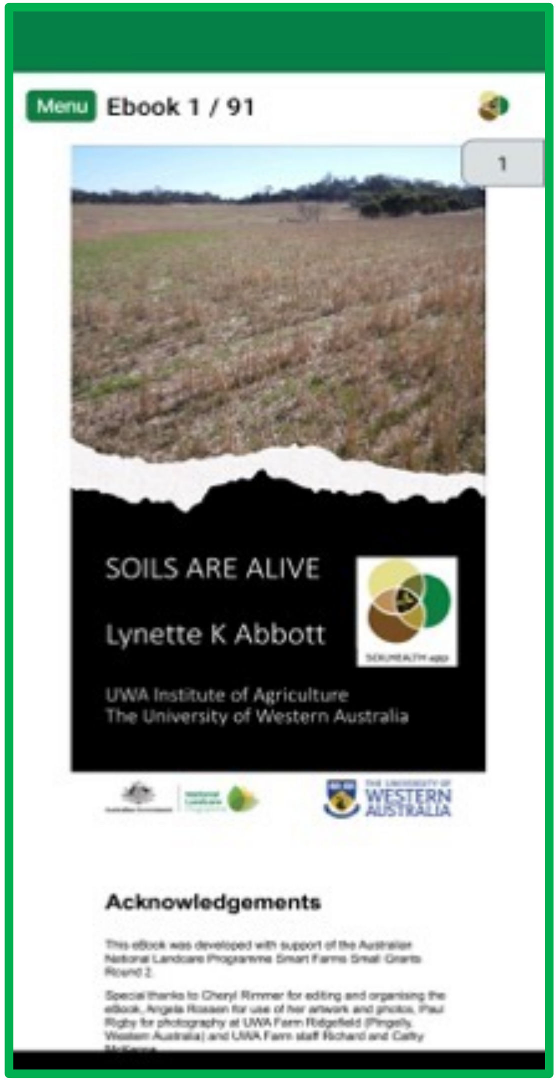
Table of contents-eBook


Table of Contents – *Soils are Alive*

IOS app



Android app



Soil Health app

e Book (90 pages)

Australian Government | National Landcare Program | The University of Western Australia

A. Introduction to Soil Biological Fertility

Soil biological fertility

- builds over time
- contributes to nutrient replacement
- replaces nutrients slowly
- leads to changes in plant physiology
- leads to changes in product quality
- can reduce input costs
- can increase profitability over time

Soils are Alive 26

B. The Soil Environment

The very diverse community of soil organisms is dynamic and both *interacts with and influences* the physical and chemical components of the soil habitat.

The habitats in soil are changed by land management practices and these changes influence whether organisms are active or inactive at a particular time.

Soils are Alive 29

B. The Soil Environment

Smaller soil animals such as springtails and mites are key components of the food web and have important roles in nutrient cycling.

Nematodes are diverse and include groups involved in nutrient cycling as well as plant disease.

Soils are Alive 31

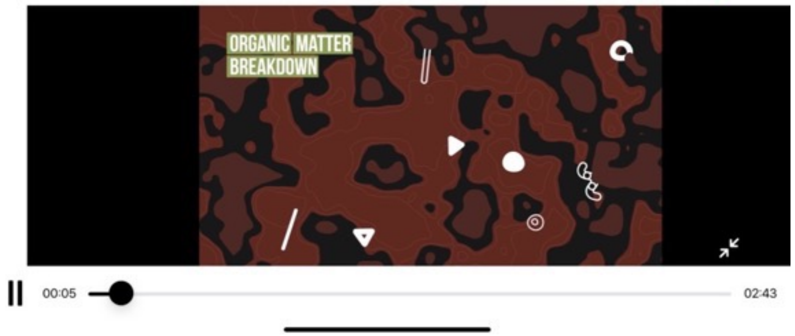
Soil Health app

ANIMATED VIDEOS

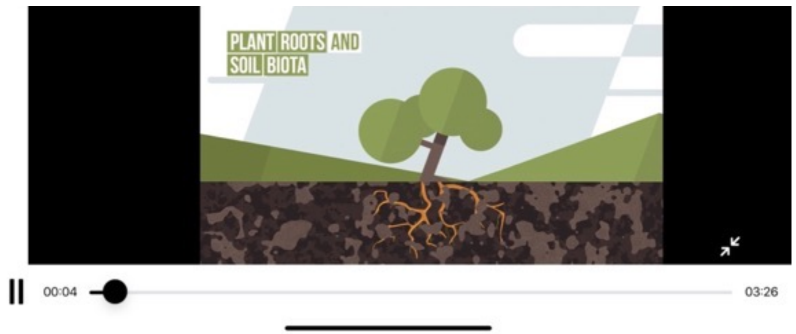
Australian Government | National Landcare Program | THE UNIVERSITY OF WESTERN AUSTRALIA

What is in soil and what does it do?

Organic matter breakdown

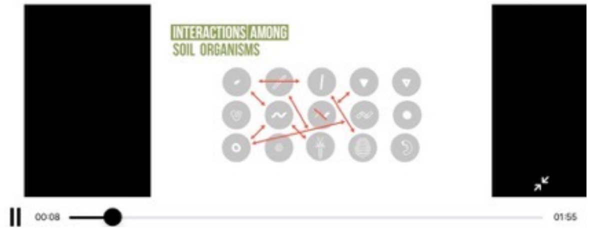


Plant roots and soil biota



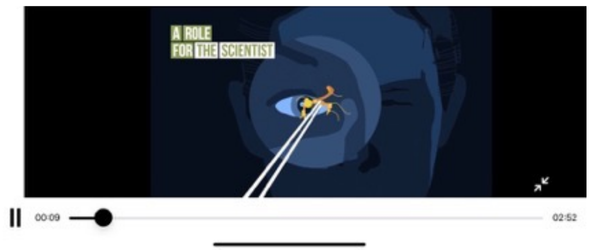
Types of soil disturbance

Interactions among soil organisms



Options for managing soil organisms

How is knowledge of soil organisms relevant?



Soil Health app

PODCASTS

1. Introduction to soil health
2. Introduction to soil biological fertility
3. Components of soil fertility
4. Soil as a habitat for living organisms
5. Mineralisation and Immobilisation
6. Nutrient cycling – Nitrogen
7. Other nutrient transformations
8. Biodegradation
9. Soil organisms and soil structure
10. Interactions with plants - the rhizosphere
11. Interactions with plants - nitrogen fixation
12. Interactions with plants - mycorrhizas
13. Interactions with plants – disease
14. Soil disturbance - soil biodiversity
15. Soil disturbance - soil biological processes
16. Interactions among soil organisms
17. Managing naturally occurring soil organisms
18. Managing with introduced organisms
19. Economic implications - mycorrhiza case study
20. Guidelines for managing soil biological fertility
21. Indicators of soil health - soil tests
22. On-farm trials / role of the scientist

Soil Fertility

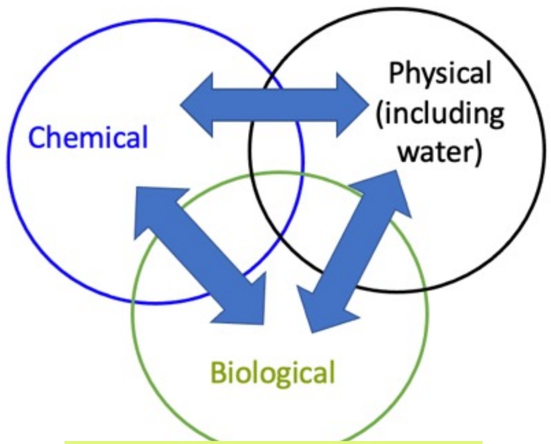
A. Introduction to Soil Biological Fertility

Soil fertility

Soil fertility is a combination of the physical, chemical, biological and hydrological characteristics of the soil.

'Optimal' measurements of components of soil fertility differ between soil types.

The physical, chemical and biological components of soil fertility interconnect and influence each other.



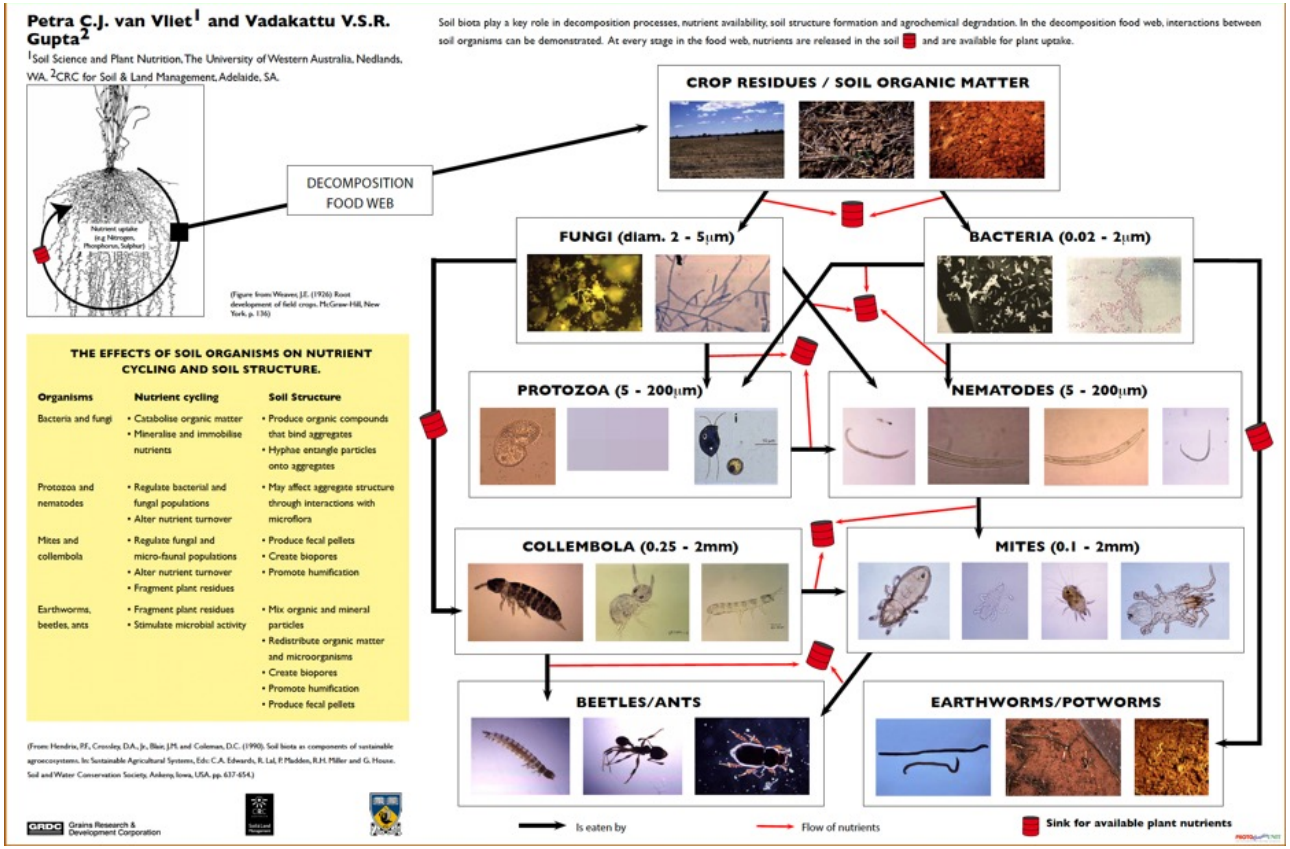
SOILHEALTH app

17

Soil biological processes contribute to soil fertility

Petra van Vliet PCJ, Gupta VVSR

Soil Biota and Crop Growth (or who eats what in soil)



Multifunctional contributions of soil microbial processes

Soil biological fertility

- time → Biological processes establish gradually
- nutrient replacement → Nutrients lost need to be replaced
- scheduling of nutrient supply → Nutrients will be supplied gradually

Multifunctional contributions of soil microbial processes

THE UNIVERSITY OF WESTERN AUSTRALIA

Soil biological fertility…

- time → Biological processes establish gradually
- nutrient replacement → Nutrients lost need to be replaced
- scheduling of nutrient supply → Nutrients will be supplied gradually

Implications for…

- plant physiology → How does slow nutrient release influence the plant? productivity?
- product quality
  - grain
  - forage

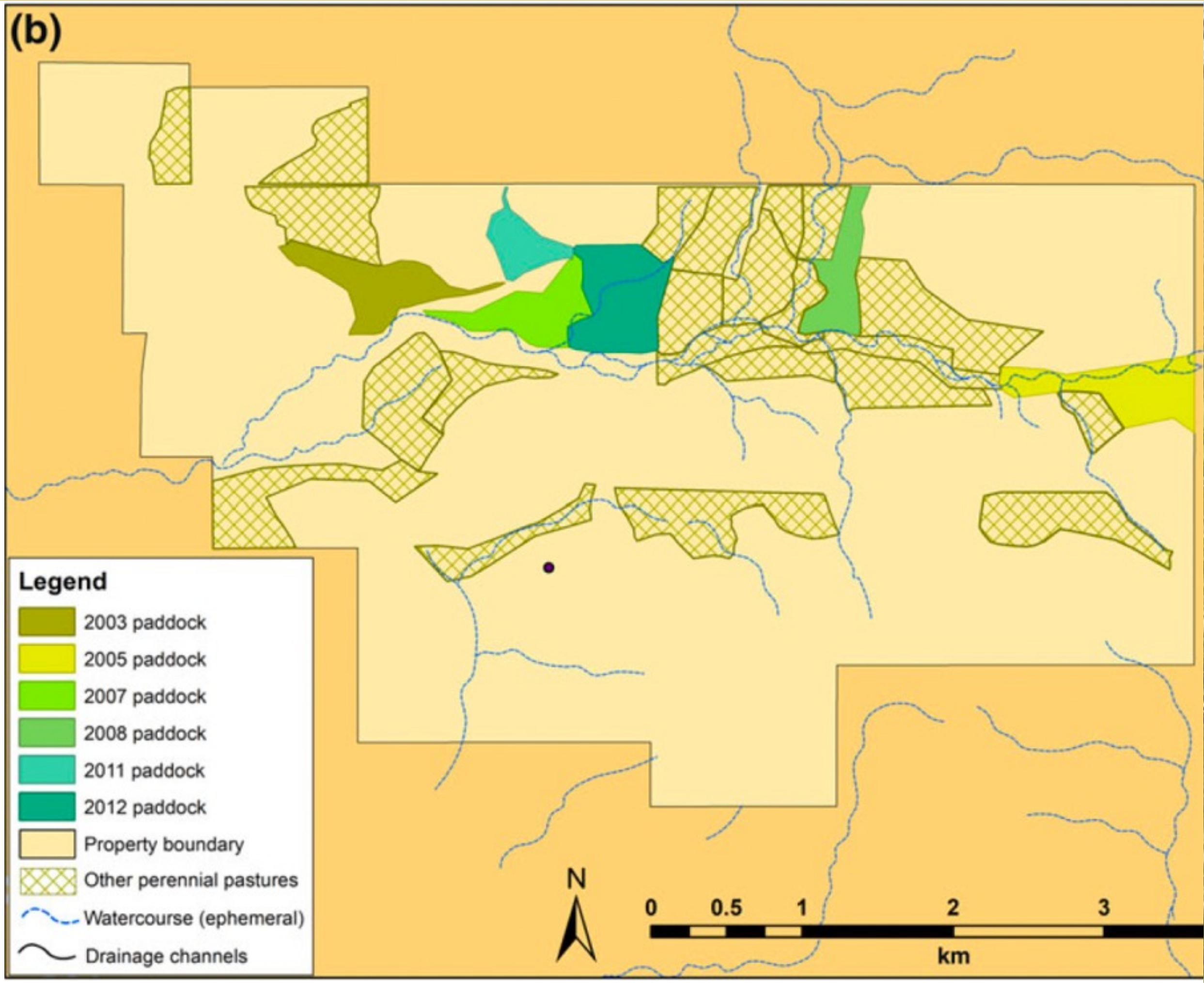
  → Does slow nutrient release influence grain or forage quality?
- costs / profitability → Is cost reduced? Is profitability increased?

Soil biological fertility is complex

Soil biological fertility builds resilience

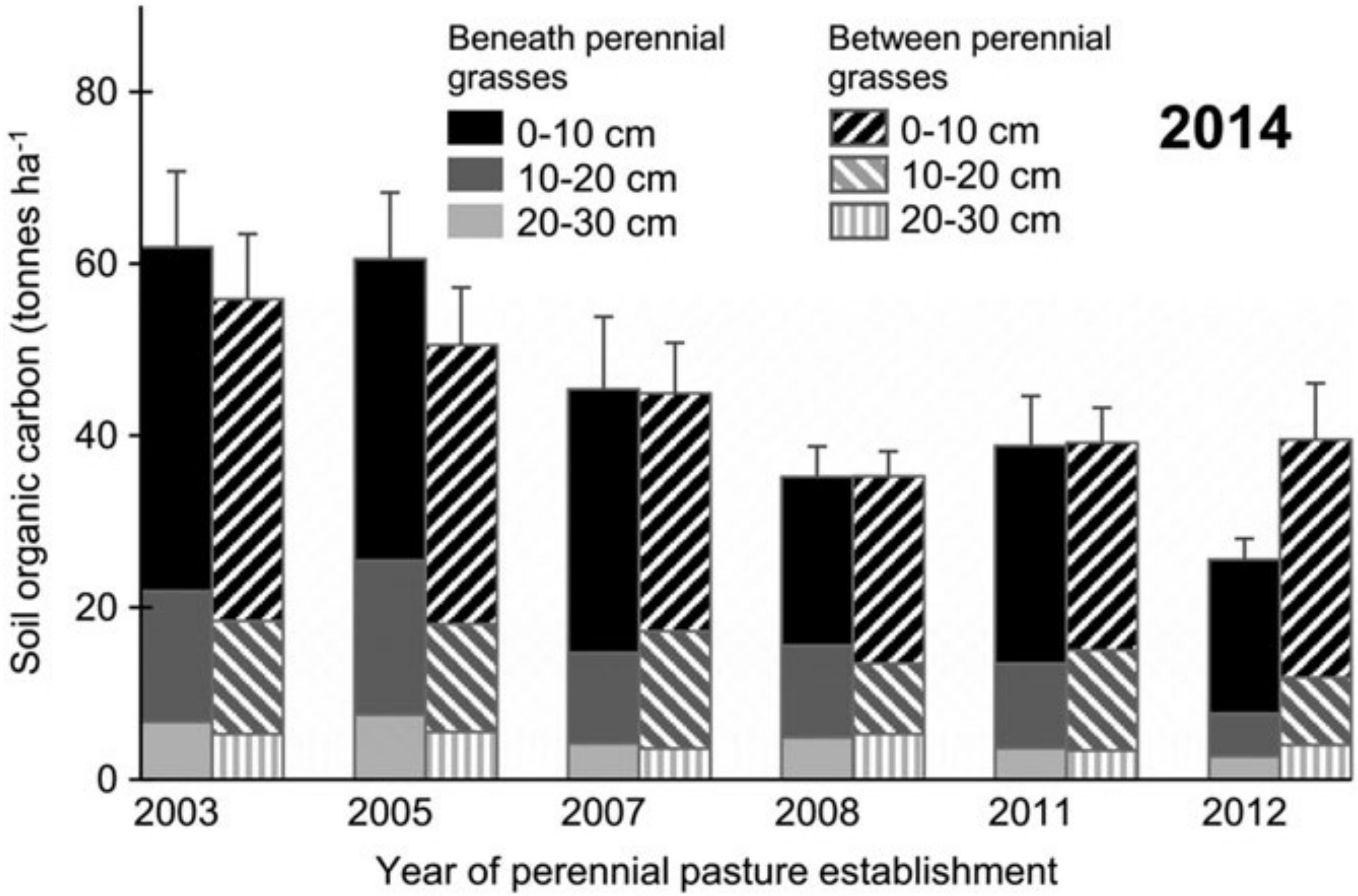
Soil carbon and mixed perennial/annual pastures – Wagin WA (Rob and Caroline Rex)

THE UNIVERSITY OF WESTERN AUSTRALIA



Pauli N, Abbott LK, Rex R, Rex C, Solaiman ZM. A farmer–scientist investigation of soil carbon sequestration potential in a chronosequence of perennial pastures.
Land Degradation and Development 2018;1–12. https://doi.org/10.1002/ldr.3184

Soil carbon and mixed perennial/annual pastures – Wagin WA (Rob and Caroline Rex)



Pauli N, Abbott LK, Rex R, Rex C, Solaiman ZM. A farmer–scientist investigation of soil carbon sequestration potential in a chronosequence of perennial pastures.
Land Degradation and Development 2018;1–12. https://doi.org/10.1002/ldr.3184

Interconnectedness of plant & microbial diversity and ecosystem multifunctionality

THE UNIVERSITY OF WESTERN AUSTRALIA

Key factors influence microbial diversity and ecosystem functionality globally to different extents include

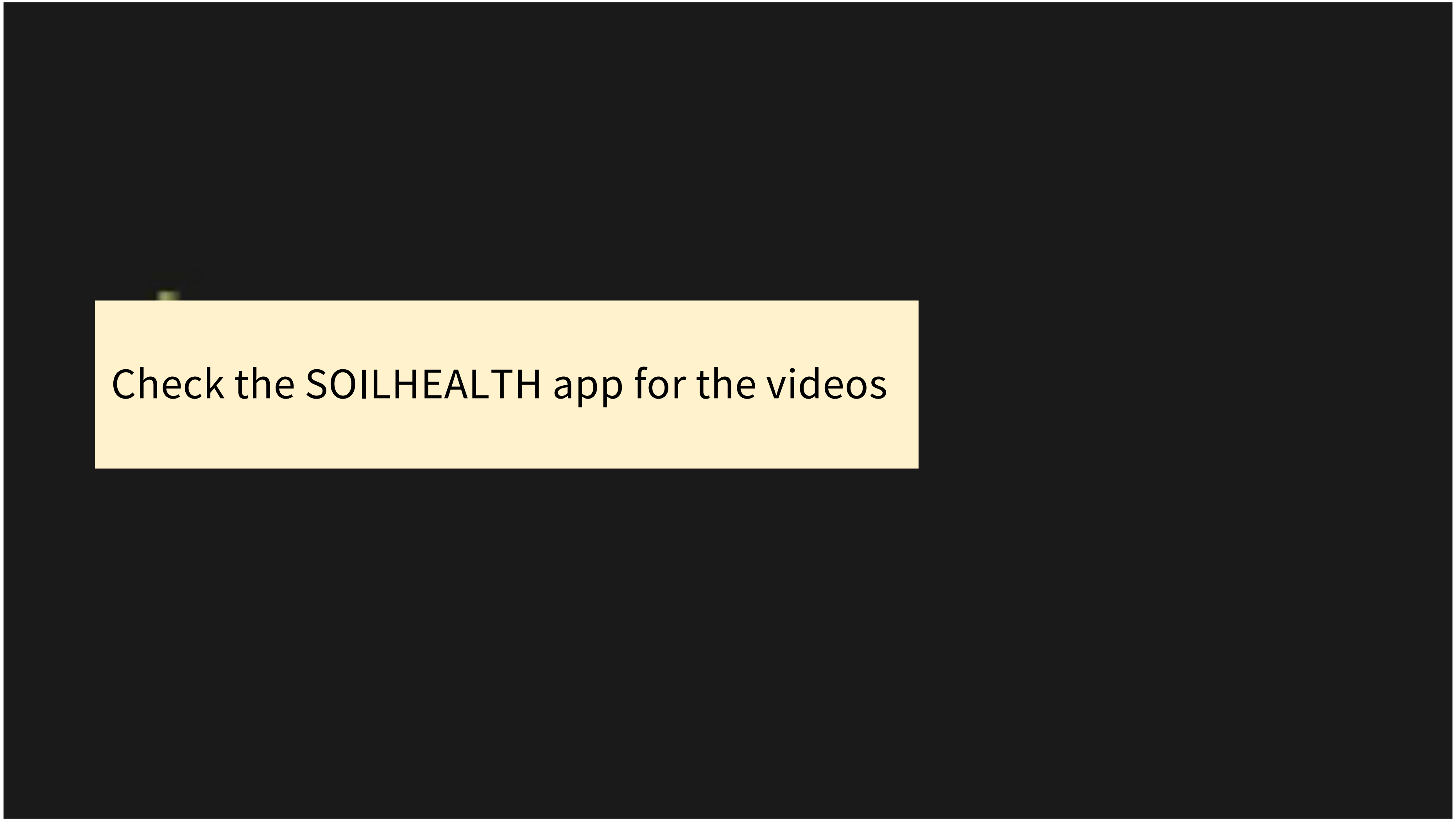
- temperature
- rainfall
- soil pH
- plant richness
- distance from equator
- altitude

Delgado-Baquerizo et al. (2023) Microbial diversity drives multifunctionality in terrestrial ecosystems. Nature Communications DOI: 10.1038/ncomms10541

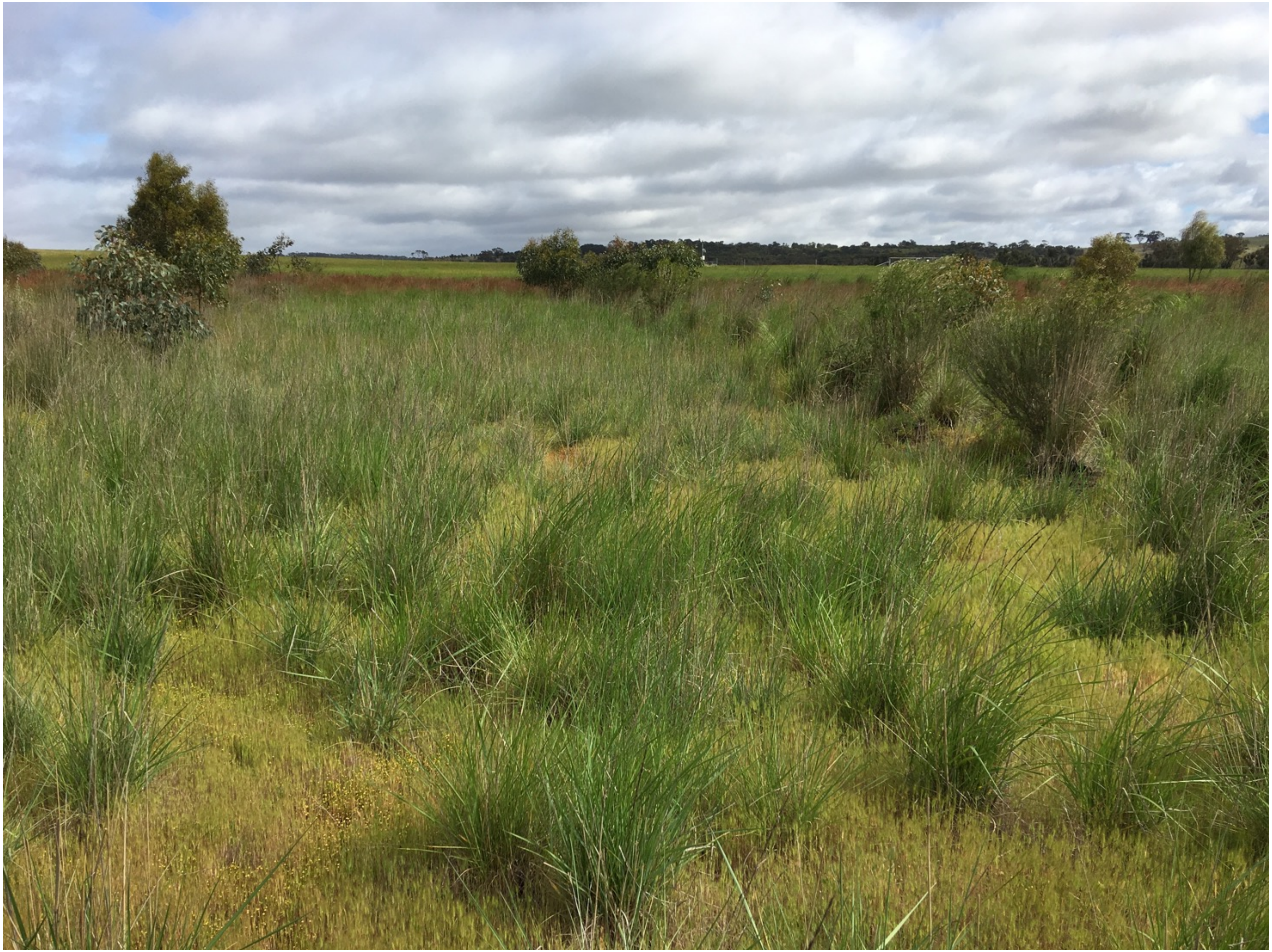
Plant roots and soil biota

- Soil Health Animation 3

SOILHEALTH app



Check the SOILHEALTH app for the videos



The Rhizosphere

THE UNIVERSITY OF WESTERN AUSTRALIA

Root exudates

Many carbon-rich substances are released from roots into soil.

These exudates provide energy for organisms that live in and around roots.

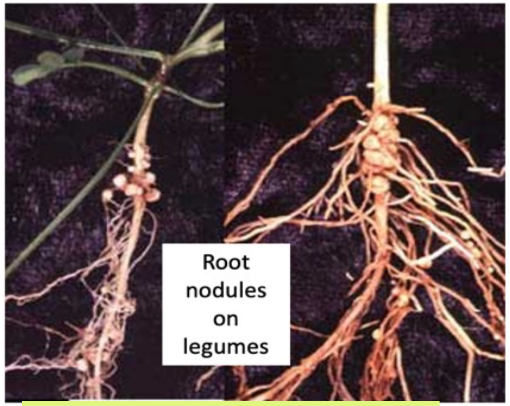
As a consequence, the rhizosphere (region around roots) is very microbially active compared with the bulk soil.

SOILHEALTH app

Beneficial associations with roots

Some microorganisms form beneficial associations with roots, and this includes symbiotic mycorrhizal fungi and rhizobia.

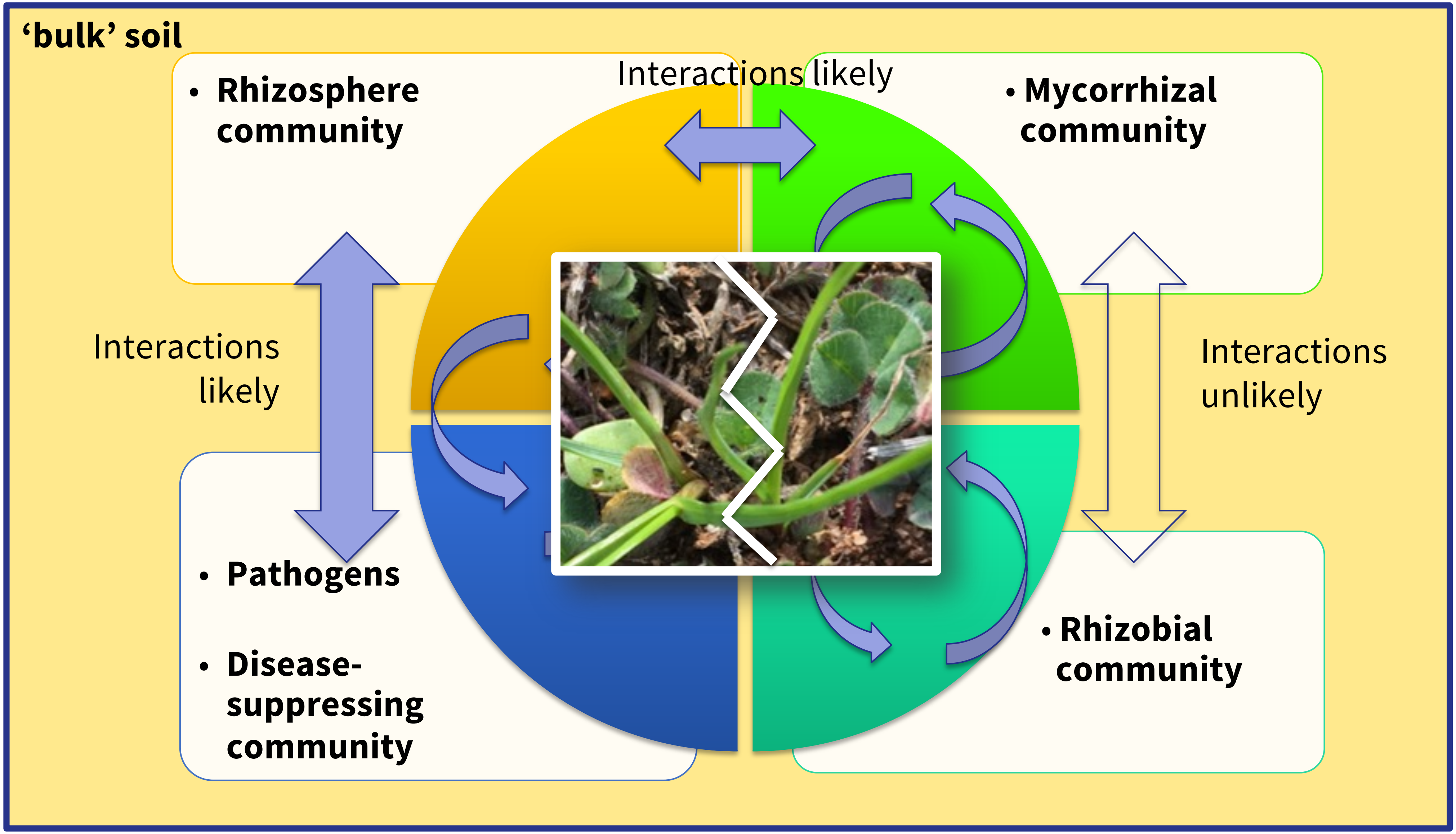
Other microorganisms which interact with roots include pathogenic fungi, bacteria and nematodes which cause plant disease when conditions are favourable for them to multiply in large numbers.



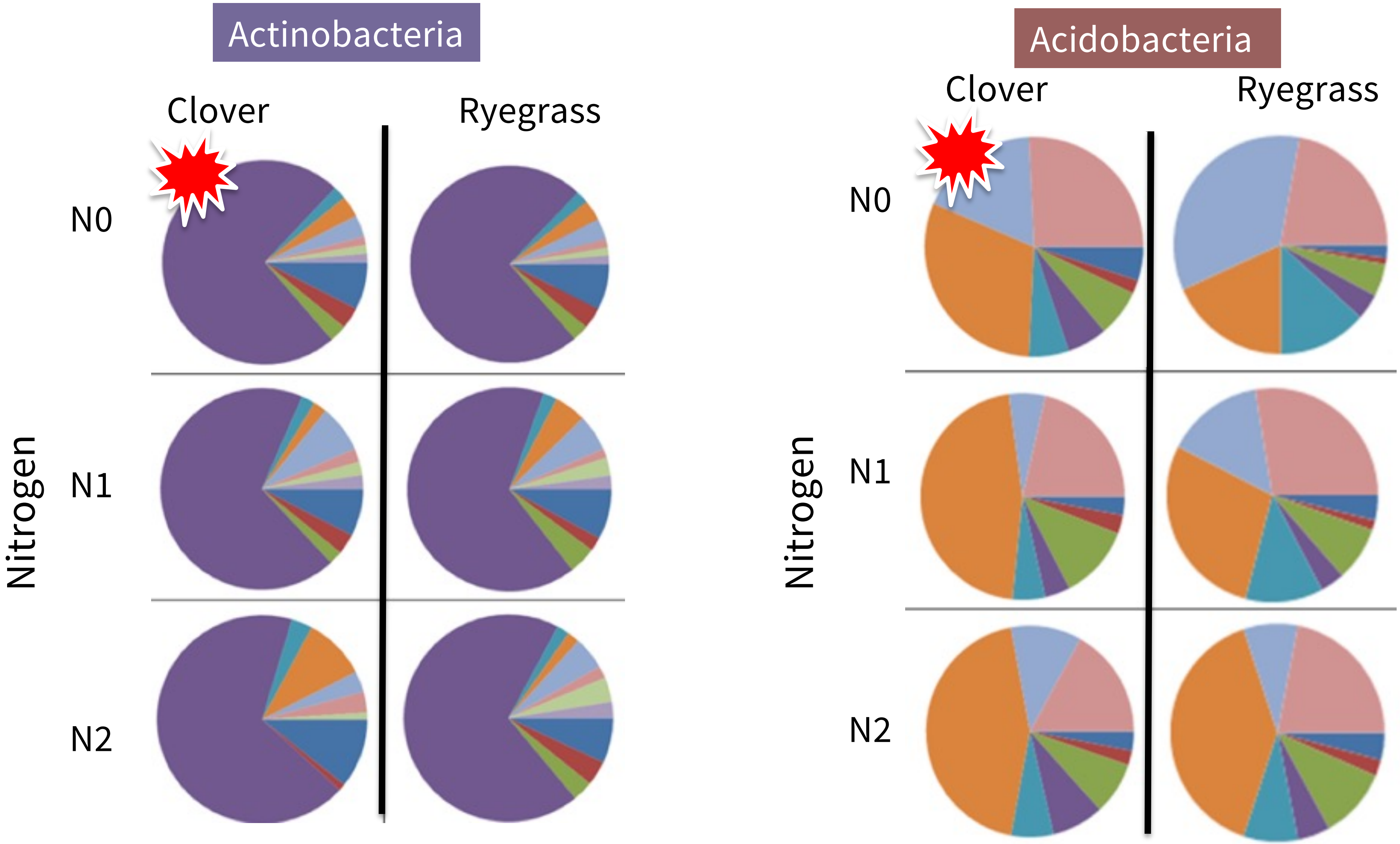
SOILHEALTH app

The Rhizosphere

THE UNIVERSITY OF WESTERN AUSTRALIA



Soil bacterial diversity – plant and N effects



Svatos KBW, Abbott LK (2019) Dairy soil bacterial responses to nitrogen application in simulated Italian ryegrass and while clover pasture. Journal of Dairy Science 102: 9495-9594

Arbuscular mycorrhizas

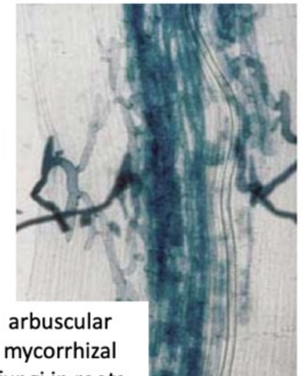
A. Introduction to Soil Biological Fertility

Arbuscular mycorrhizal fungi

Arbuscular mycorrhizal (AM) fungi are common soil fungi which form associations with roots of most plants used in agriculture.

They obtain carbon from roots and transfer nutrients to plants, especially phosphorus in phosphorus-deficient soils.

Hyphae of AM fungi can help aggregate soil particles and improve soil structure.

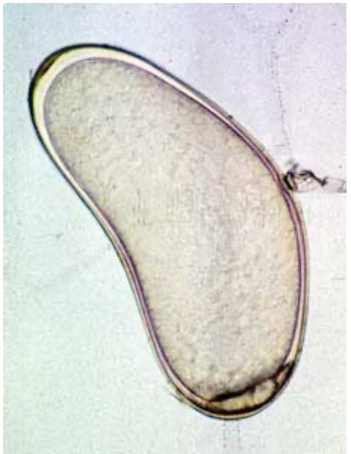


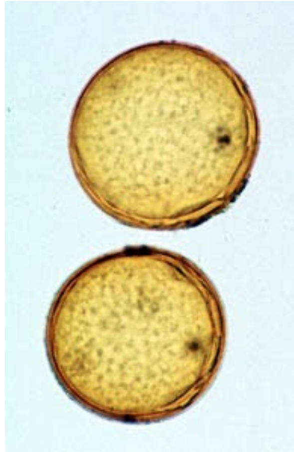
arbuscular mycorrhizal fungi in roots

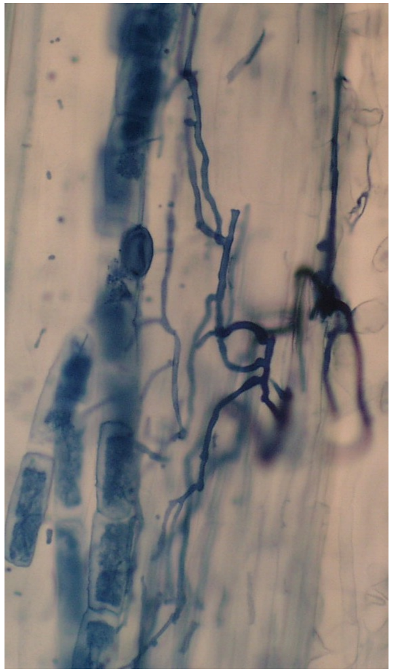
arbuscular mycorrhizal fungi soil

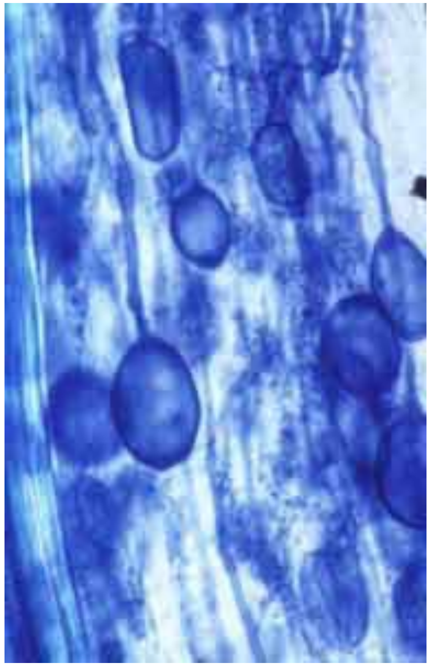
SOILHEALTH app

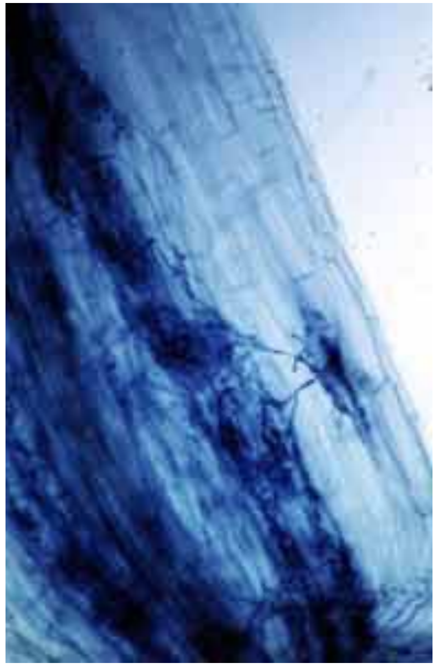
13



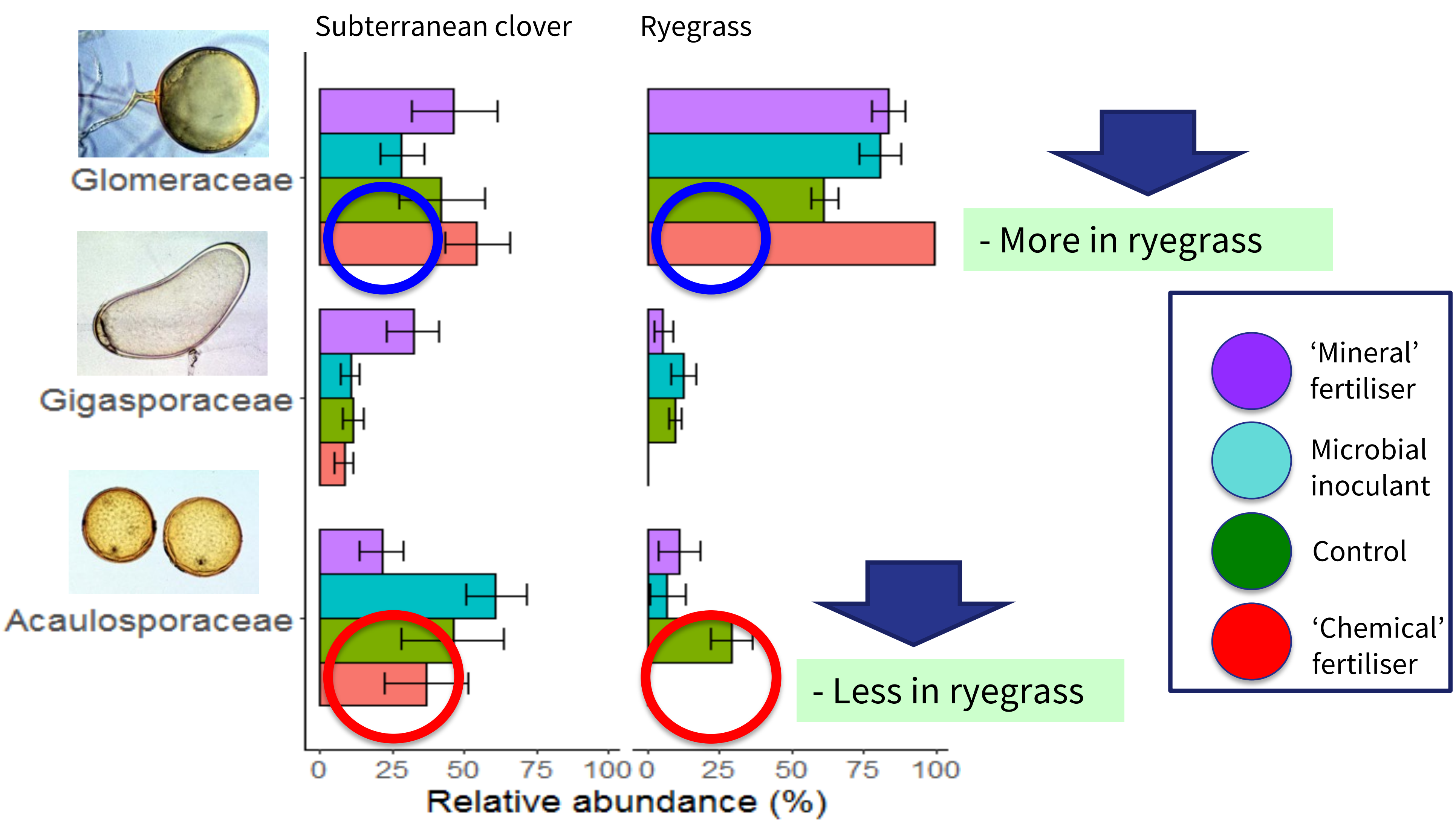






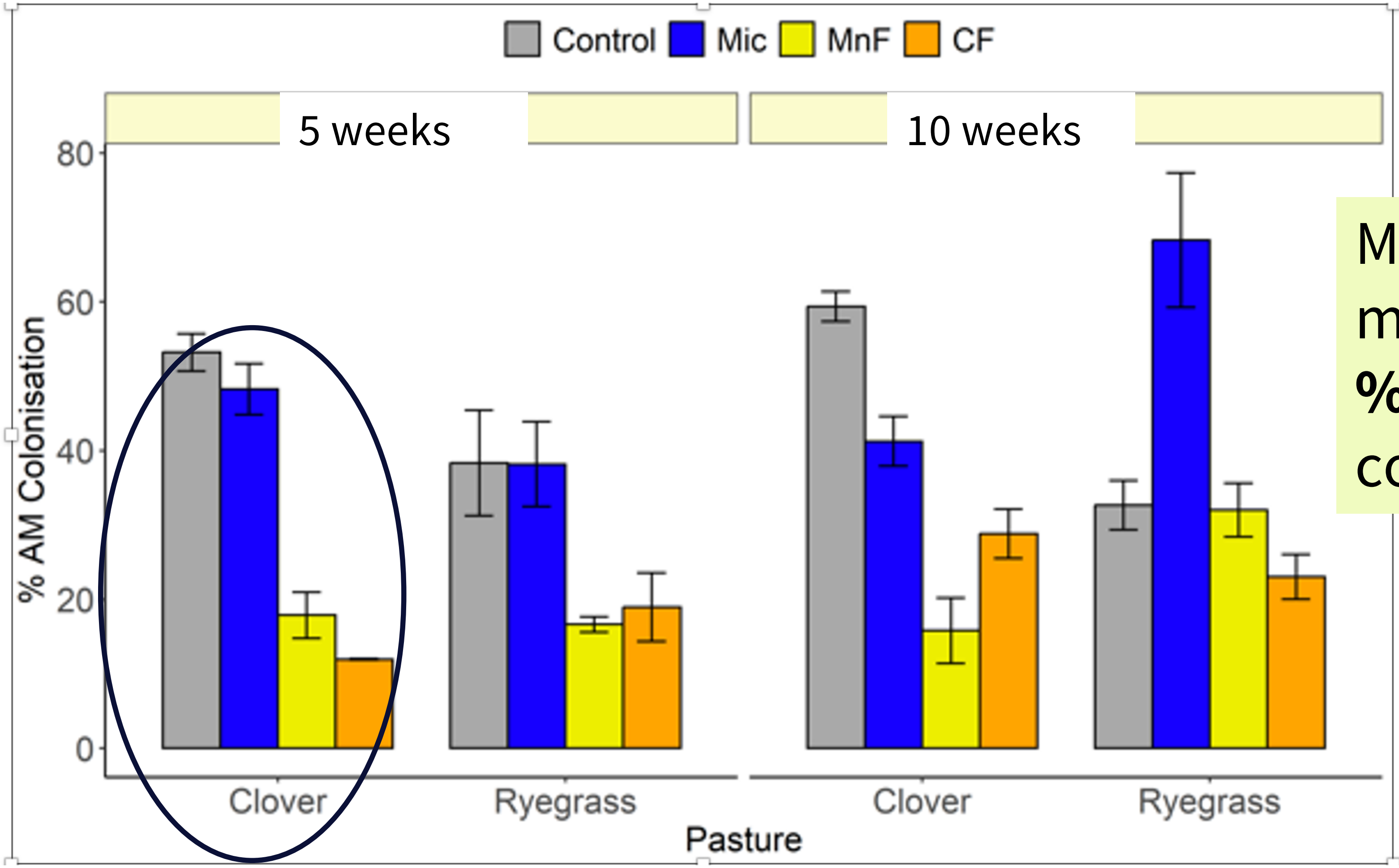


Mycorrhizas in different plants – responses to soil amendments



Alsharmani AR. Solaiman ZM, Leopold, M, Abbott LK, Mickan BS (2023) Impacts of rock mineral and traditional phosphate fertilizers on mycorrhizal communities in pasture plants. Microorganisms 11(4), 1051

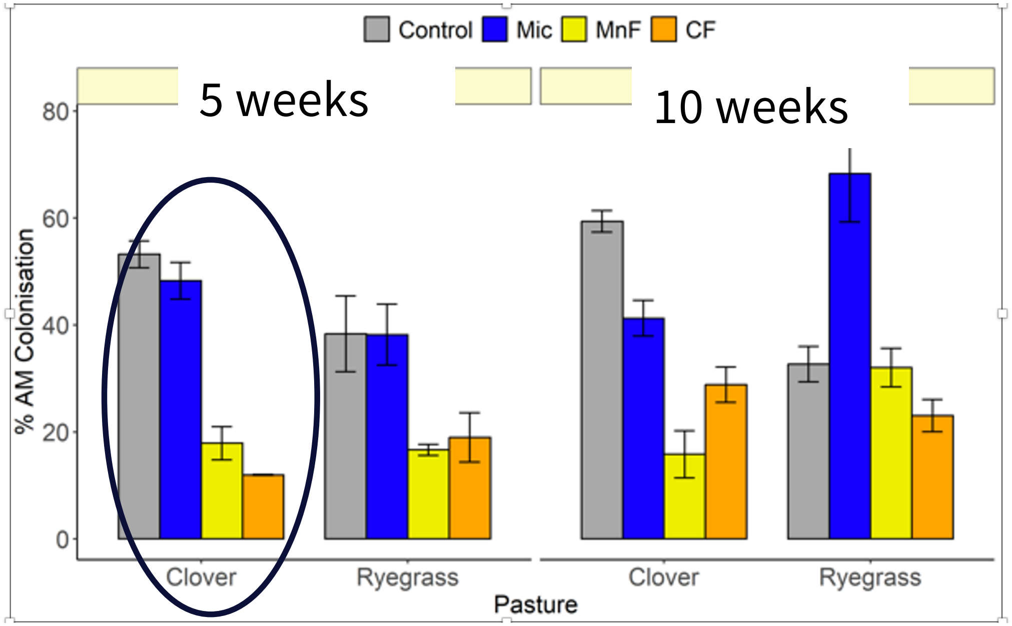
Mycorrhizas in different plants – responses to soil amendments

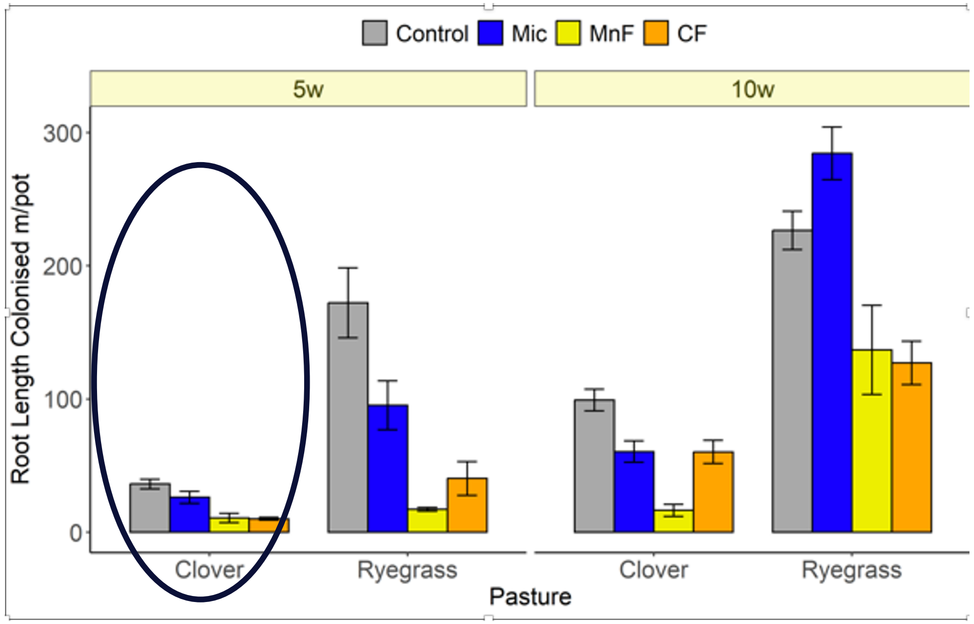


Mycorrhizas measured as **%** root length colonised

Alsharmani AR. Solaiman ZM, Leopold, M, Abbott LK, Mickan BS (2023) Impacts of rock mineral and traditional phosphate fertilizers on mycorrhizal communities in pasture plants. Microorganisms 11(4), 1051

Mycorrhizas in different plants – responses to soil amendments





Mycorrhizas measured as **%** root length colonised

Mycorrhizas measured as **length** of root colonised

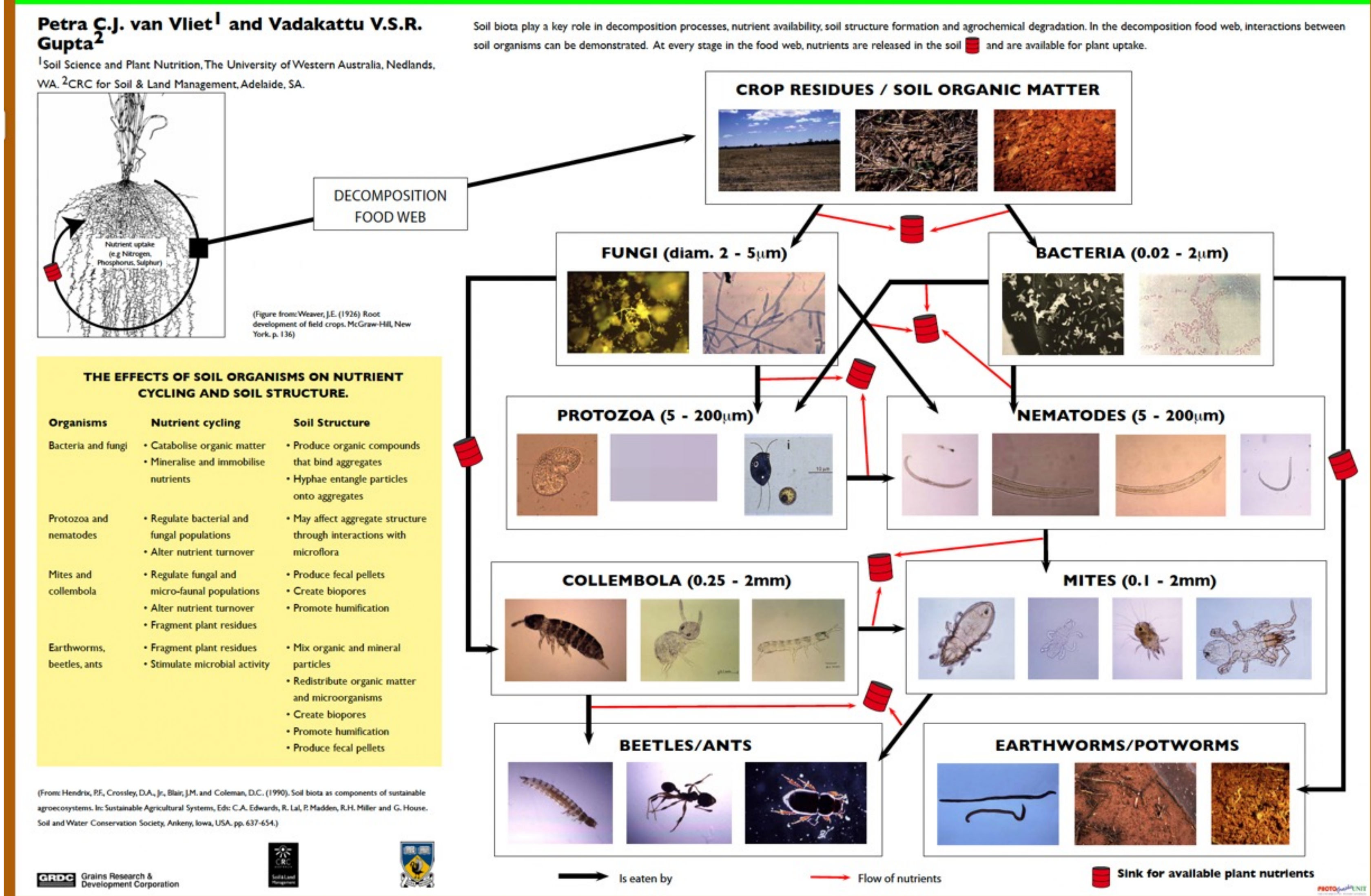
Alsharmani AR. Solaiman ZM, Leopold, M, Abbott LK, Mickan BS (2023) Impacts of rock mineral and traditional phosphate fertilizers on mycorrhizal communities in pasture plants. Microorganisms 11(4), 1051

Impacts of plant residues on soil fauna

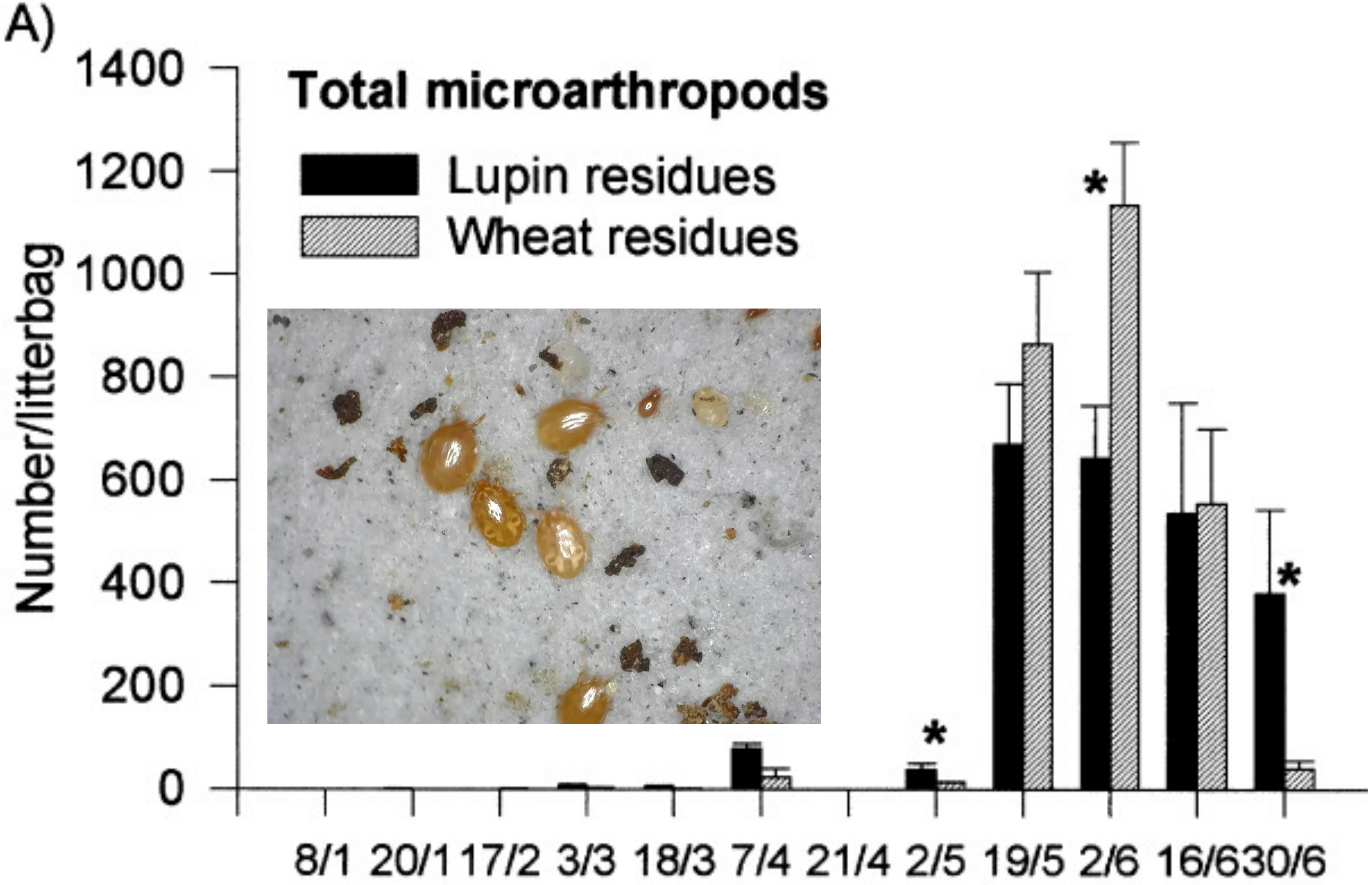
Petra van Vliet PCJ, Gupta VVSR

THE UNIVERSITY OF WESTERN AUSTRALIA

Soil Biota and Crop Growth (or who eats what in soil)



Impacts of plant residues on soil fauna



van Vliet PCJ, Gupta VVSR and Abbott LK (2000) Soil biota and stubble decomposition during summer and autumn in south-western Australia. Applied Soil Ecology 14: 111-124

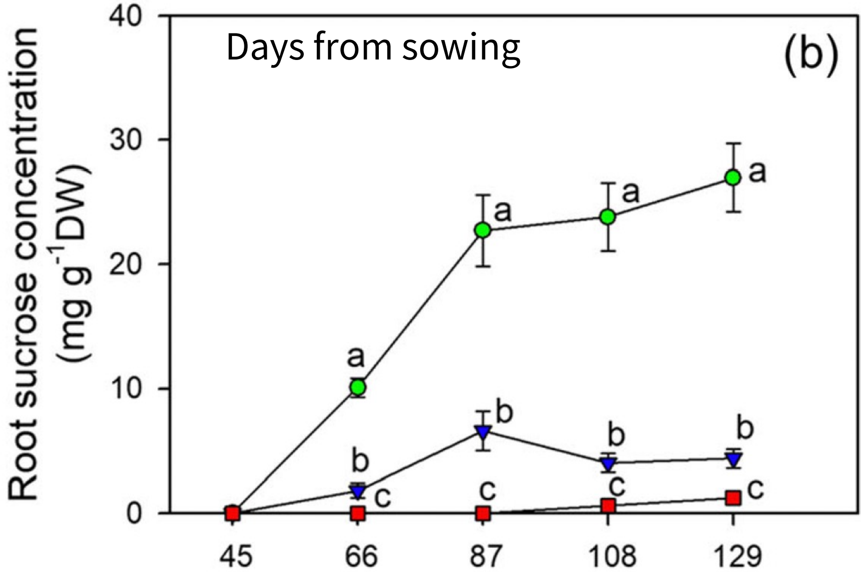
Grazing impacts on plant-microbial interactions

F. Agricultural Practices

Crop residues and grazing

While crop residues are important sources of carbon for soil organisms, roots also make a significant contribution to soil carbon.

Overgrazing reduces the potential for pastures to contribute to soil fertility in the longer-term by reducing carbon input from roots.



No grazing

Heavy grazing

SOILHEALTH app

65

Fan et al. (2019) Sequential defoliation impacts on colonization of roots of Lolium rigidum by arbuscular mycorrhizal fungi were primarily determined by root responses. Biology and Fertility of Soils 55: 789-800

Use of soil biological amendments*

* Extensive variation within amendment categories

Biological amendments
Humates / biochar etc
Manures / composts
Compost teas / biological extracts
Microbial inoculants

GRDC Project
Understanding Biological Farming Inputs

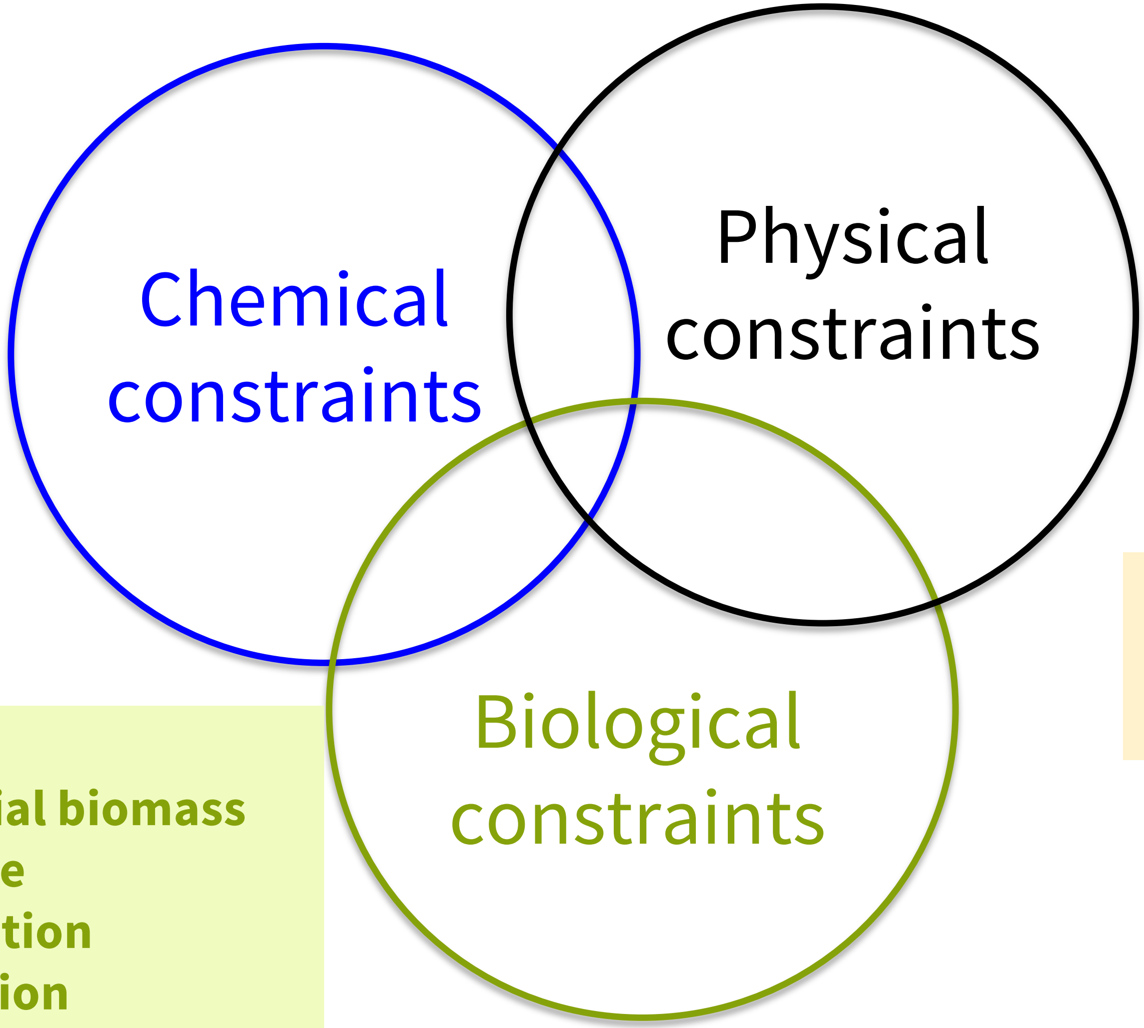
Mark Farrell (CSIRO)
Sasha Jenkins (UWA)

Lynne Macdonald (CSIRO)
Mike Webb (CSIRO)
Mike Wong (CSIRO, now Murdoch)

Abbott LK, Macdonald LM, Wong MTF, Webb MJ, Jenkins SN, Farrell M (2018) Potential roles of biological amendments for profitable grain production – A review. Agriculture, Ecosystems and Environment 256: 34-50

Impacts of soil biological amendments on soil constraints

- Salinity
- Low C
- Low N
- Low pH
- High pH
- Low CEC



- Erosion
- Water retention
- Water infiltration
- Soil aggregation
- Compaction

PLANT:
- Drought (seasonal)
- Frost

SOIL:
- Low microbial biomass
- Plant disease
- Poor nodulation
- Low N_2 fixation
- Low levels of AM fungi

* Multiple impacts also likely

Review:
Abbott et al. 2018

Impacts of soil biological amendments on soil constraints

The mechanisms underpinning benefits of soil amendments include:

1. Changes to nutrient supply to plants
2. Changes to plant physiology
3. Changes to soil structure and water movement in soil
4. Chemical interactions (such as changes in soil pH)
5. Biological impacts including
   - Nutrient cycling
   - Disease suppression

See GRDC website for

"Biological amendments for the Australian grains industry: summary review and framework"
Macdonald et al. 2018

https://publications.csiro.au/rpr/pub?pid=csiro:EP184635

Abbott LK, Macdonald LM, Wong MTF, Webb MJ, Jenkins SN, Farrell M (2018) Potential roles of biological amendments for profitable grain production – A review. Agriculture, Ecosystems and Environment 256: 34-50

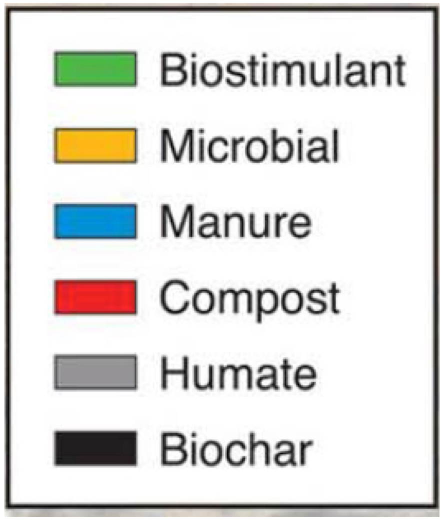
Impacts of soil biological amendments on soil constraints

Soil biological amendments differ in

(i) the extent of their influence

AND

(ii) the duration of their influence



For example,

biochar may have a small influence on soil biological processes but it may last over several years

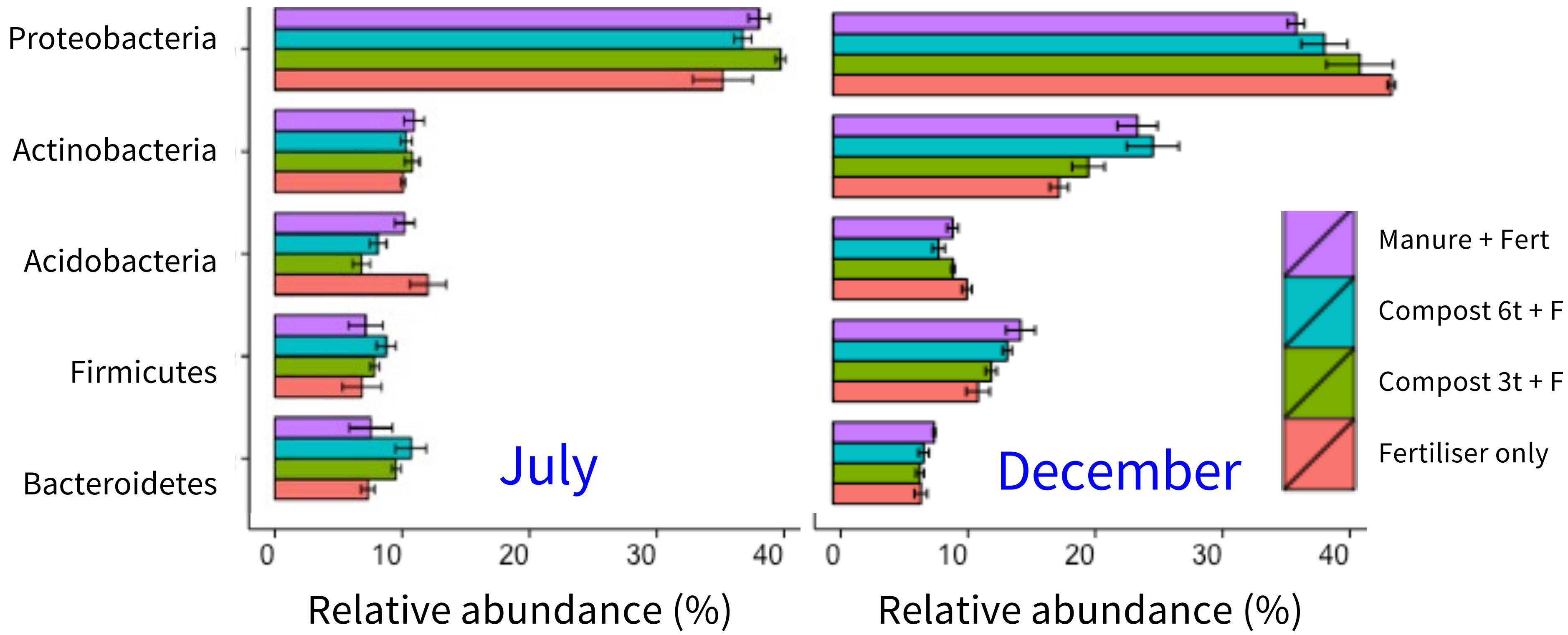
manure may have a large influence on nutrients in the soil, but this may be short-lived.

Review:
Abbott et al. 2018

Effects of soil amendments on bacteria

THE UNIVERSITY OF WESTERN AUSTRALIA

Dominant bacteria were associated with C & N cycling



16S ribosomal RNA genes amplified

SWCC south west catchments council

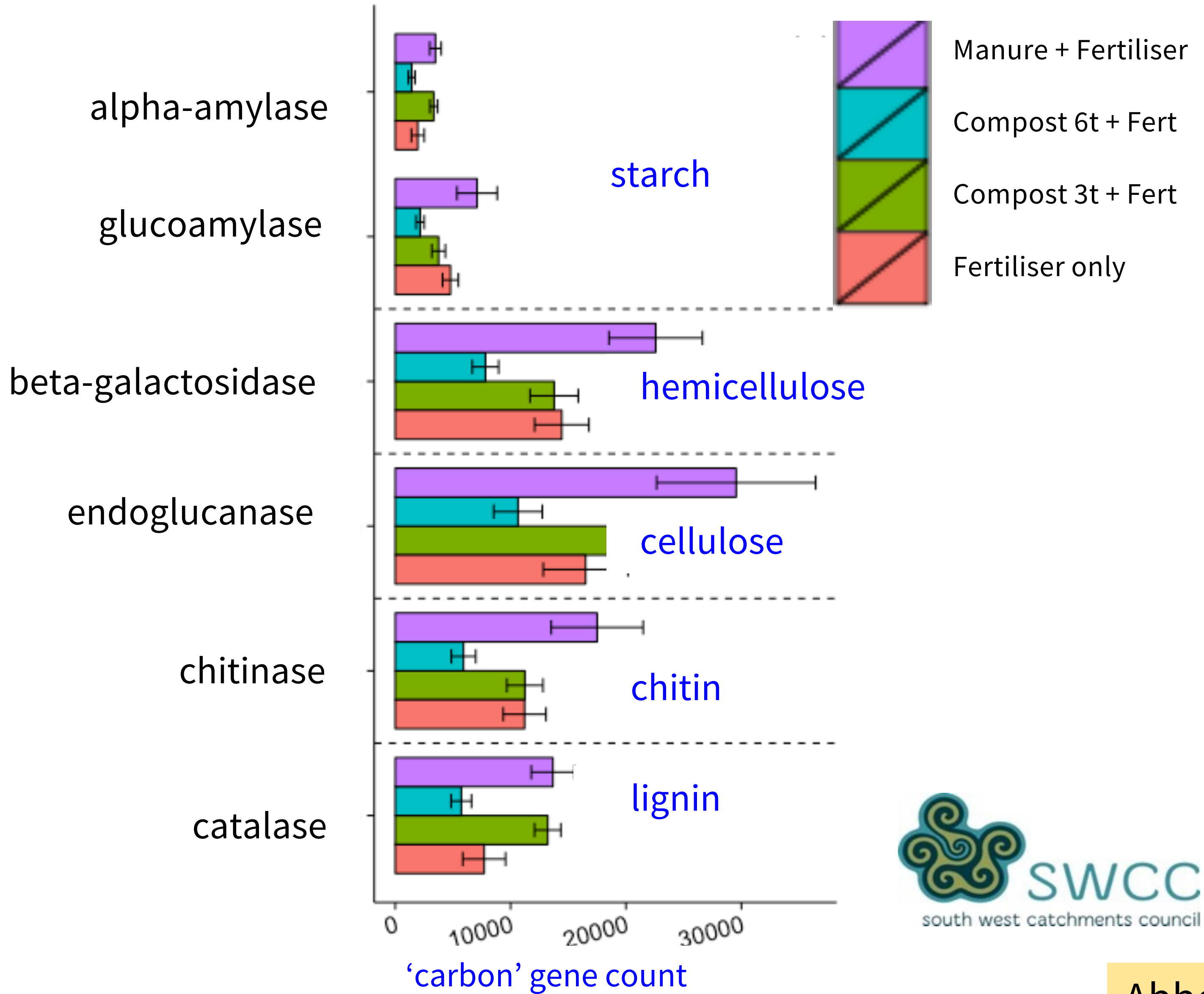
Australian Government

National Landcare Programme

Abbott et al. (in preparation)

Effects of soil amendments on bacteria
Soil carbon degradation enzymes involved

THE UNIVERSITY OF WESTERN AUSTRALIA



July soil samples

Predicted C enzyme activity:

- Manure
  high 'activity'
- Compost
  'activity' of 3t/ha greater than 'activity' of 6t/ha

SWCC south west catchments council

Australian Government | National Landcare Programme

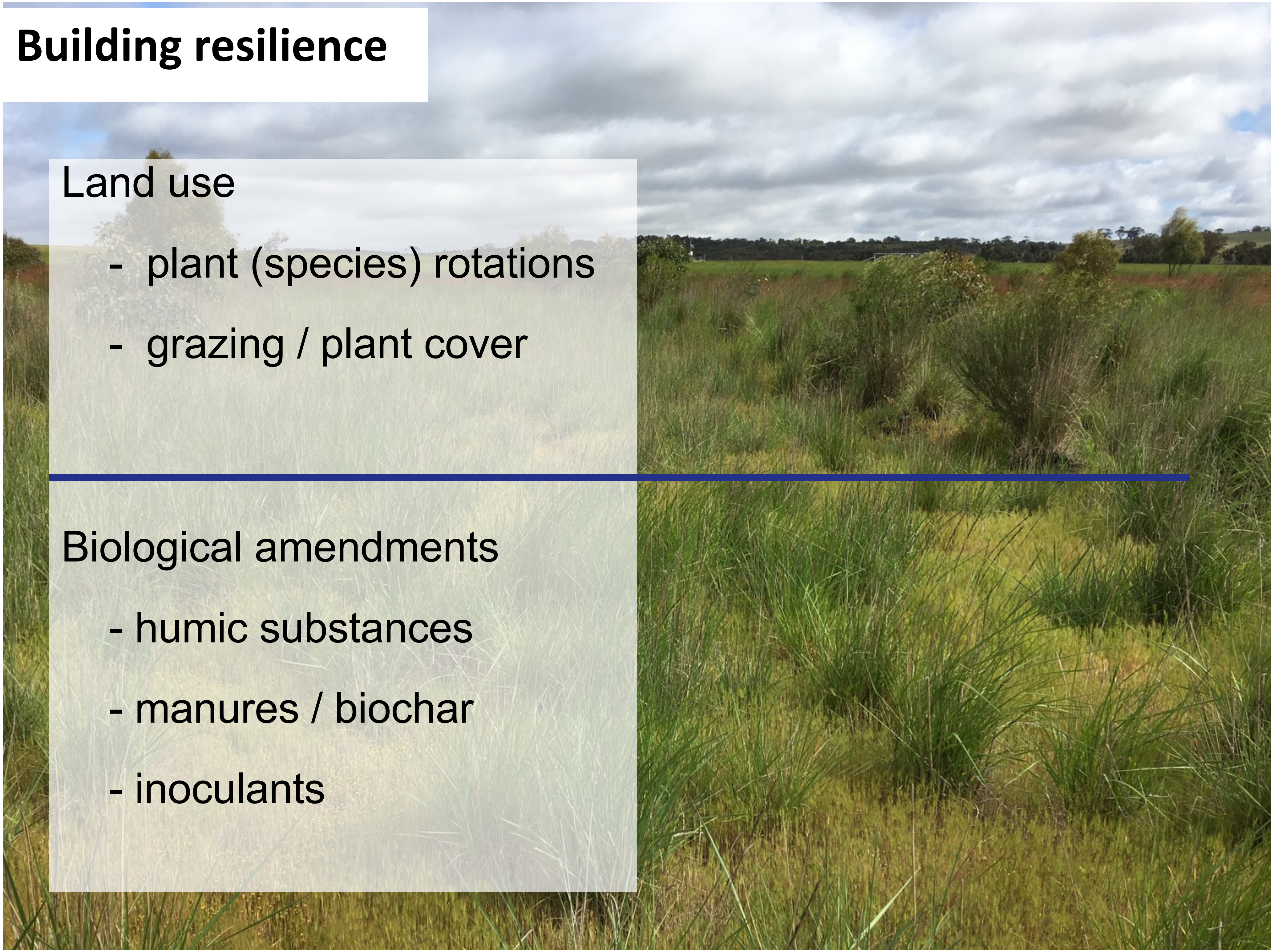
Abbott et al. (in preparation)

Effects of soil amendments on bacteria
Soil carbon degradation enzymes involved

Observations may change with time of year

(e.g. data are not the same when sampled in summer vs winter)

Building resilience

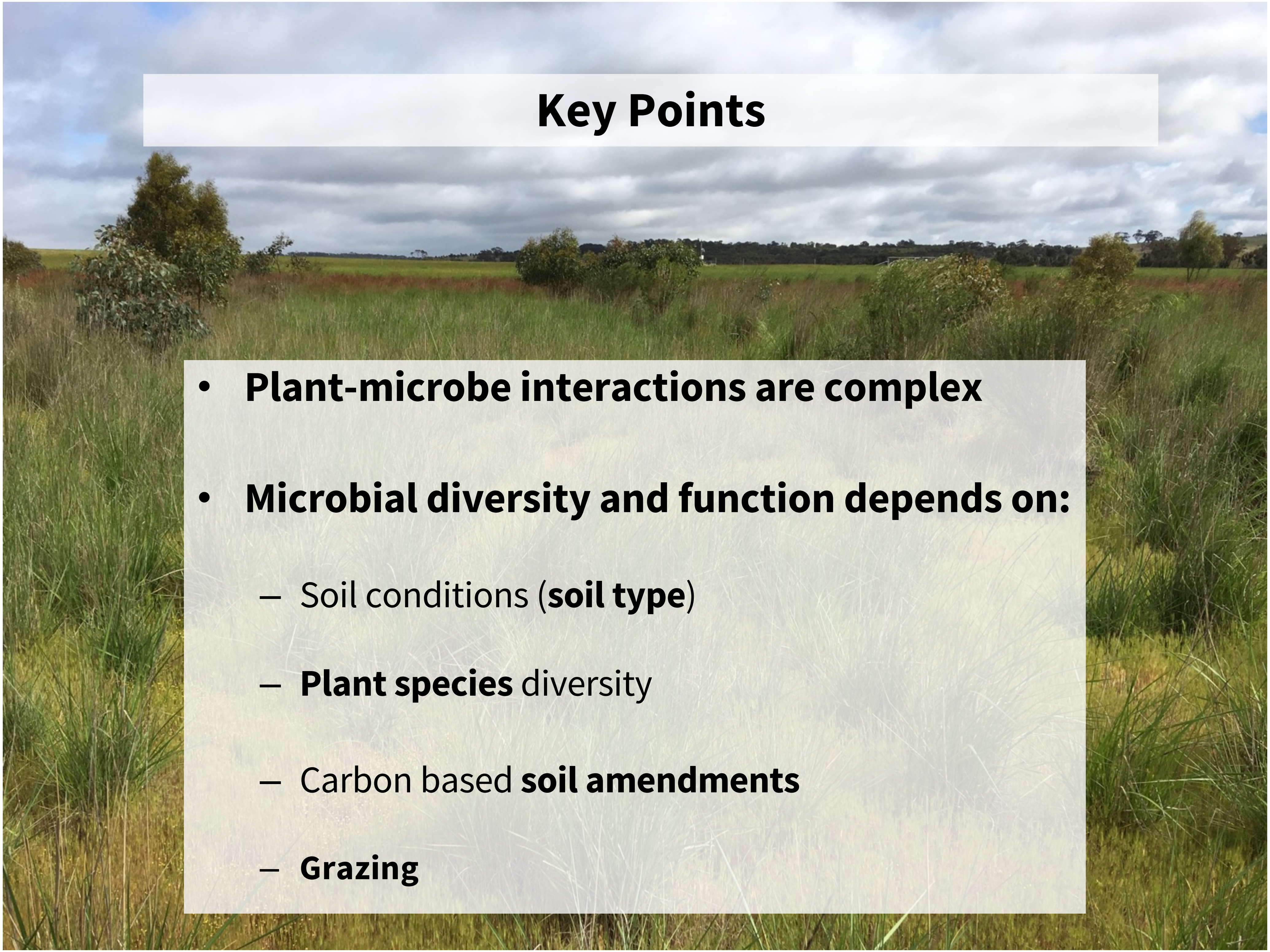


Land use

- plant (species) rotations
- grazing / plant cover

Biological amendments

- humic substances
- manures / biochar
- inoculants


Key Points
• Plant-microbe interactions are complex
• Microbial diversity and function depends on:
– Soil conditions (soil type)
– Plant species diversity
– Carbon based soil amendments
– Grazing