What’s happening in soil science and what does it mean for humanity?

Emerita Professor Lynette Abbott
UWA School of Agriculture and Environment
UWA Institute of Agriculture

EMAIL: Lynette.Abbott@uwa.edu.au
Soil security and food security
Dead OM
Roots
Soil Biota

Soil mineral and organic fractions

'Mineral fraction'

'Organic fraction'

Fungi, bacteria and animals
Soil biodiversity underpins biological processes

Amoeba

Fungal hyphae

Bacterial colonies

Photos: Karl Ritz
Recent advances in knowledge of soil

**Soil carbon** – modelling to predict soil carbon sequestration

**Soil health** – roles of soil organisms / biodiversity

**Biostimulants** – application of organic resources

**Soil structure** – soil pore matrix, aggregation

**Land capability assessment** – understanding links between soil type and land use
Recent advances relevant to soil biological fertility

Soil Biological Fertility
– the contribution of soil biological processes

Soil carbon – modelling to predict soil carbon sequestration

Soil health – roles of soil organisms

Assessment of molecular diversity of soil communities

Biostimulants – soil application of organic resources

Regenerative agriculture – revisiting fertiliser use and other management practices
Greater awareness of the roles of soil biology
Greater awareness of the roles of soil biology

- ‘bulk’ soil
  - Rhizosphere community
  - Mycorrhizal community
  - Rhizobial community
  - Disease-suppressing community
  - Pathogens

Interactions likely

Interactions unlikely
Soil bacterial diversity based on DNA tests
Soil bacterial diversity based on DNA tests

Influence of plant type and nitrogen

Actinobacteria

Clover

Ryegrass

Nitrogen

N0

N1

N2

Acidobacteria

Clover

Ryegrass

Nitrogen

N0

N1

N2

Svatos and Abbott (2019) in press
Bio-physical and bio-chemical interactions

Symbiotic nitrogen fixation

Mycorrhizal symbioses

Disease suppression
Important microbial interactions occur in soil pores

Organic matter breaks down here and releases nutrients

Cycles of wetting & drying

30μm

0.6μm

Organic matter input

Organic matter is protected here

Anaerobic/aerobic interface

Strong et al. (1989) Aust J Soil Research 36: 855-72
History of use of soil biological amendments

Pre-industrial fertilisers

Industrial fertilisers

Microbial inoculant industry (legumes)

‘Integrated’ practices + ‘biological’ practices + ‘organic’ practices

Today’s marketplace

A financial opportunity - good or bad?

• Historical emphasis on soil biological fertility
• ‘Modern’ emphasis on chemical fertility
• Today’s marketplace: ‘purchased’ soil biology?
Typical soil and plant constraints

**Chemical constraints**
- Salinity
- Low C
- Low N
- Low pH
- High pH
- Low CEC

**Physical constraints**
- Erosion
- Water retention
- Water infiltration
- Soil aggregation
- Compaction

**Biological constraints**
- Low microbial biomass
- Plant disease
- Poor nodulation
- Low $N_2$ fixation
- Low levels of AM fungi

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

**PLANT:**
- Drought (seasonal)
- Frost

Biological amendments to overcome constraints

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

Mainly organic amendments

Mainly organic amendments

Some ‘biostimulants’

Some ‘biostimulants’

Both organic amendments and ‘biostimulants’

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

- Drought (seasonal)
- Frost

- Low microbial biomass
- Plant disease
- Poor nodulation
- Low N₂ fixation
- Low levels of AM fungi

Use of biological amendments to enhance soil fertility

- Low microbial biomass
- Plant disease
- Low levels of AM fungi
- Poor nodulation
- Low N$_2$ fixation

- Manure
- Compost
- Humates
- Seaweed etc

X

√
Use of biological amendments to enhance soil fertility

- Low microbial biomass
- Plant disease
- Low levels of AM fungi
- Poor nodulation
- Low N\textsubscript{2} fixation

Manure
Compost
Humates
Seaweed etc

Is purchased microbial inoculation necessary?

Other forms of microbial inoculation
e.g. ‘compost teas’

## Quality control of soil biological amendments

<table>
<thead>
<tr>
<th>Biological amendments</th>
<th>Quality control / regulation</th>
<th>Importance of regulation?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manures</td>
<td>No (on farm use) Yes (for gardens)</td>
<td>? Yes (labels on bags)</td>
</tr>
<tr>
<td>Composts</td>
<td>Yes (good regulation)</td>
<td>Yes</td>
</tr>
<tr>
<td>Micobial inoculants</td>
<td>Yes (good regulation)</td>
<td>Yes</td>
</tr>
<tr>
<td>- rhizobia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- mycorrhizal fungi</td>
<td></td>
<td></td>
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<tr>
<td>- general microbial mixes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- humates</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- biochar</td>
<td></td>
<td></td>
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<tr>
<td>- seaweed</td>
<td></td>
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<tr>
<td>- compost teas</td>
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<tr>
<td>- Biodynamic preparations</td>
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</table>
Examples of effects of manure inputs on soil microbial communities

Modelling approaches predict:
- increases in soil carbon
- larger bacterial and fungal communities
- greater functional diversity and resilience to stress

Sasha Jenkins, UWA
Example of impact of compost and manure on soil bacteria

Field experiment
1 ha plots, 3 reps (+3 dairy farms) near Bunbury, WA

Experimental design (one farm)
- Manure 2t/ha (+ fertiliser)
- Compost 3t/ha (+ fertiliser)
- Compost 6t/ha (+ fertiliser)
- Control (+ fertiliser)

May          July         December
Manure and compost added to field soil

Abbott et al. (submitted)
Dominant bacteria in July and December

16S ribosomal RNA genes amplified
Dominant bacteria were associated with C & N cycling

Proteobacteria
Actinobacteria
Acidobacteria
Firmicutes
Bacteroidetes

July

December

Relative abundance (%)}

Abbott et al. (submitted)
Bacterial community vs soil Nitrate and Ammonium

Canonical analysis

**July:**
- NH$_4$ dominant
- Actinobacteria
- Firmicutes
- Chloroflexi

**December:**
- NO$_3$ dominant
- Proteobacteria
- Acidobacteria
- Bacteroidetes

Abbott et al. (submitted)
Soil carbon degradation – enzymes involved

Based on PICRUSt – predicted gene counts

July soil samples

Predicted C enzyme activity:

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

Abbott et al. (submitted)
Implications for compost use

Soil amended with 6t/ha compost had lower predicted functional gene counts than soil amended with 3t/ha compost

IMPLICATION:
C in compost applied at a higher level may degrade more slowly than C in lower level of compost
Soil amended with 6t/ha compost had lower predicted functional gene counts than soil amended with 3t/ha compost.

**IMPLICATION:**
C in compost applied at a higher level may degrade more slowly than C in lower level of compost.

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Relevant changes in bacterial activity can occur without measurable changes in soil carbon (%).

**IMPLICATIONS:**
1. Soil biological processes that involve N and C cycling can occur in soil without a change in soil chemical tests.

2. There is potential for predicting longer-term effects of compost on retention of carbon within the soil matrix.
Soil biological fertility

- time
- nutrient replacement
- scheduling of nutrient supply

Principles involved

- Biological processes establish gradually
- Nutrients lost need to be replaced
- Nutrients will be supplied gradually

Is a soil biology approach relevant?
Is a soil biology approach relevant?

Soil biological fertility...
- time
- nutrient replacement
- scheduling of nutrient supply

Implications for...
- plant physiology
- product quality
- costs / profitability

Principles involved
- Biological processes establish gradually
- Nutrients lost need to be replaced
- Nutrients will be supplied gradually

Questions arising
- How does slow nutrient release influence the plant? Productivity?
- Does slow nutrient release influence grain or forage quality?
- Is cost reduced?
- Is profitability increased?
Complementary biological strategies for fertiliser use

**Manage Phosphorus**

P / (C)

- Maintain presence of mycorrhizas in roots

**Manage Nitrogen**

N / C

- Build level of soil carbon

greater resilience / more sustainable
## Carrots

<table>
<thead>
<tr>
<th>Soil compost history</th>
<th>Carrot fresh wt (g/plant)</th>
<th>Carrot shoot wt (g/plant)</th>
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<tbody>
<tr>
<td>No compost</td>
<td>95.5 (+/- 8.9)</td>
<td>18.1 (+/- 8.9)</td>
</tr>
<tr>
<td>Recent compost</td>
<td>119.5 (+/- 8.7)</td>
<td>19.1 (+/- 1.2)</td>
</tr>
<tr>
<td>Past compost</td>
<td>131.7 (+/- 6.9)</td>
<td>21.6 (+/- 1.2)</td>
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Addo et al. (unpublished)
Complementary biological strategies for fertiliser use

Long-term use of compost in sandy horticultural soil

Carrots and mycorrhiza bioassay of soil

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<tr>
<th>Soil compost history</th>
<th>% mycorrhizal root length</th>
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<tr>
<td></td>
<td>Clover (5 weeks)</td>
</tr>
<tr>
<td>No compost</td>
<td>21 (+/- 0.8)</td>
</tr>
<tr>
<td>Recent compost</td>
<td>29 (+/- 0.8)</td>
</tr>
<tr>
<td>Past compost</td>
<td>36 (+/- 0.9)</td>
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Mycorrhizal fungi in carrot roots

Addo et al. (unpublished)
Biological strategies for complementing fertiliser use

When fertilisers are managed effectively + carbon retention

✓ Nutrient inputs would be CAPPED
✓ Soil biological processes would be SUPPORTED
When fertilisers are managed effectively + carbon retention

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✓ Soil biological processes would be SUPPORTED

YIELD WILL BE CAPPED AT A ‘SUSTAINABLE’ LEVEL

Is this a threat to food security?
When fertilisers are managed effectively + carbon retention

- Nutrient inputs would be CAPPED
- Soil biological processes would be SUPPORTED

YIELD WILL BE CAPPED AT A ‘SUSTAINABLE’ LEVEL

Is this a threat to food security?

When fertiliser inputs are NOT capped

X some biological processes can be overridden

X high yields correspond with high chemical fertility based on an imbalance in components of soil fertility
Advances in land capability assessment

Technical Report (October 2018) Assessment of land capability in Melbourne’s Green Wedge and Peri-urban areas. **Agriculture Victoria**

Soil security

Policy interface with soil science

Future soil management implications:
- use of biostimulants biofertilisers

Adoption of regenerative horticultural practices?
1. Soil is a complex ecosystem – its assessment is not straightforward

2. Horticultural practices change the dominance of organisms present in soil and their function

3. Some soil amendments can enhance beneficial contributions from soil organisms

4. Caution in use of microbial inoculation is required

5. A focus on soil carbon is important for the future

6. Advanced technologies for land capability assessments are key to preserving land for horticulture (with policy implications)