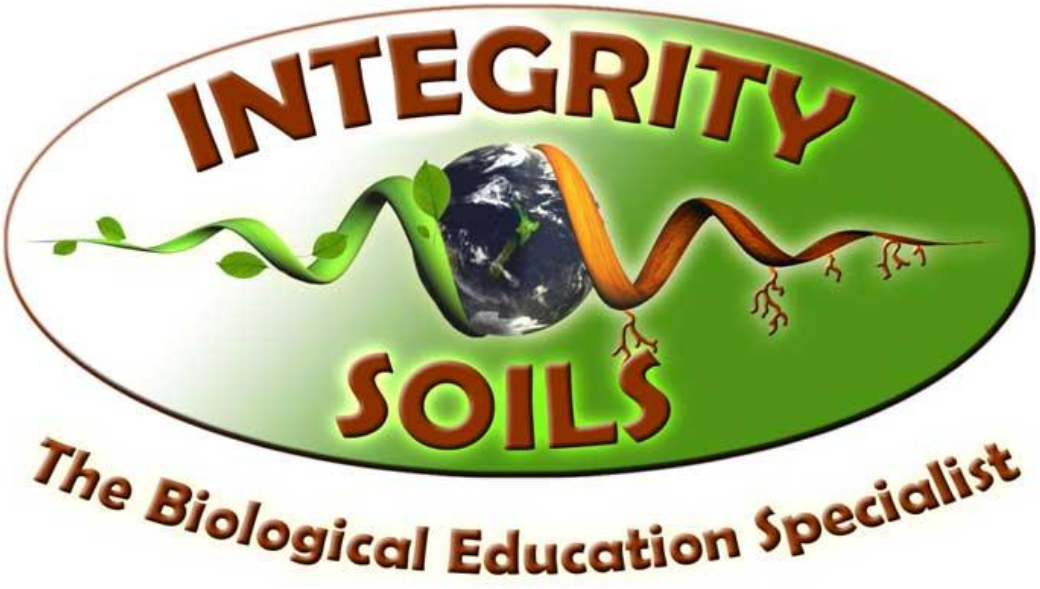
Teaming with microbes!

With Nicole Masters



Introducing Nicole Masters Agroecologist

- BSc Ecology, major soil science 1999
- CAT (teaching certificate)
- Commercial worm farmer 2002-2006
- Chair/spokesperson for the Association of Biological Farmers since 2009
- Finalist 2012: “Rural Businesswoman of the Year”

Topsoil loss in excess of topsoil formation *has been* the defining characteristic of agriculture.

- Estimates of past losses of Carbon from terrestrial stocks:
  - 66-90 Gigatons (Rattan Lal, Ohio State U.)
  - ~200 GT (Charles Rice, University of Kansas)

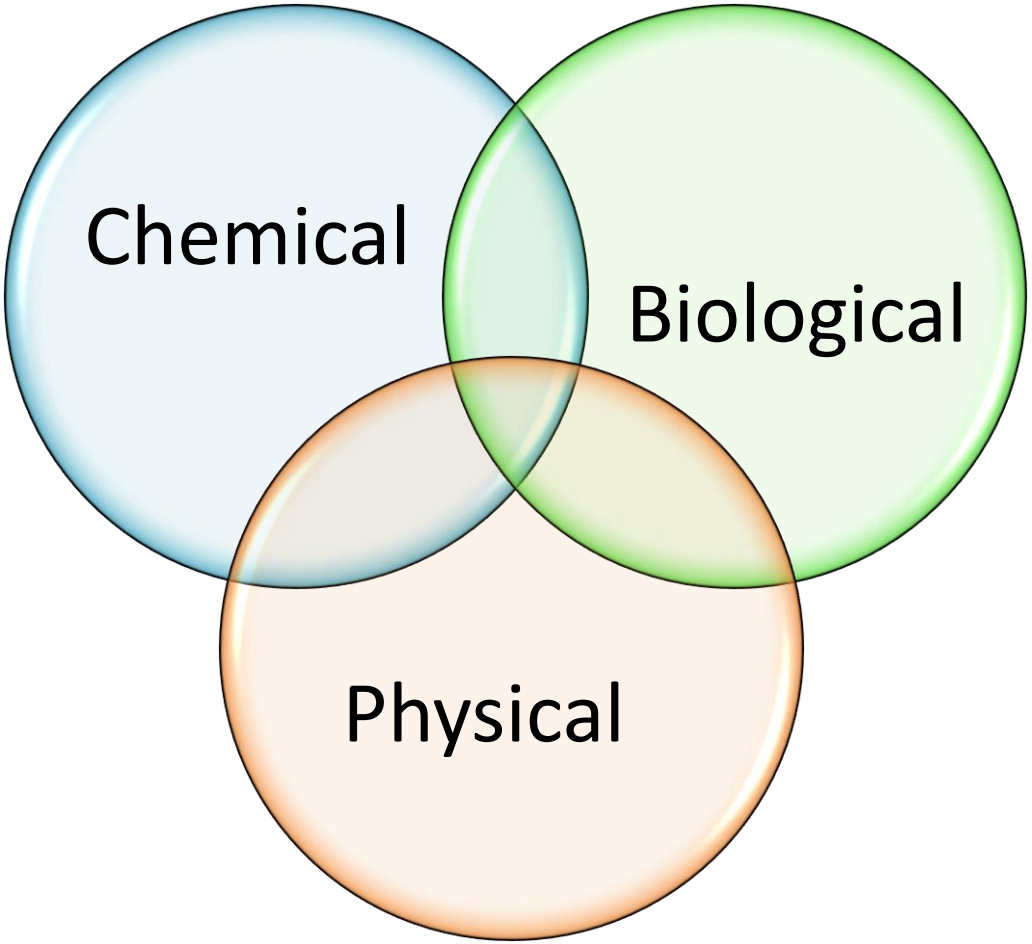
Topsoil

- Biological farmers are creating topsoil at unprecedented rates
- The measure of a sustainable ranching system is humus = stable carbon sequestration

Are you building or losing soil?

- Slaking test shows stability of soil aggregates (crumbs), erosion potential and how well soil can maintain its structure when it is rapidly wetted.
- Glues and microbe by-products protect and form soil crumbs

Soils require equal attention in these 3 areas:



Microbes are essential for:

- Nutrient immobilization
- Nutrient availability
- Increasing water holding capacity
- (Re) Building soil structure
- Disease protection
- Decomposition and detoxification

Benefits contd…

- Buffer to changable climate

- Secondary metabolites, plant growth hormones and enzymes

= mineralised nutrient dense FOOD

It’s the simple things which count the most…

“What are your yield limiting factors?”

It’s the simple things which count… Soil structure, carbon and growth

- –Air Management → Aerify
- Water Management
  - –Decay Management
    - »Nutrient Management

Two neighbouring orchards

Biological system

Compost application,
pasture in rows, no irrigation,

→ 3.8 kg C/m^2 (top 0.1 m)

Integrated system

No compost application,
herbicided rows, irrigation,

→ 2.6 kg C/m^2 (top 0.1 m)

Significant soil improvements in the biological block.

Macro-pores enhance the mixing of nutrients and contaminants.

= better buffering of nutrients and filtering of contaminants

Plant & Food RESEARCH
RANGAHAU AHUMĀRA KAI

The key players…

- Bacteria
- Archaea
- Fungi
- Flagellates
- Amoebae
- Ciliates
- Nematodes
- Algae

} Collectively called Protozoa

Soil life?

- Typical soil has 5000 species
- Good soil has 25,000 species
  - Must feed the microorganisms
    - Balanced mineralization
    - Bio-foods – sugars, fish, seaweed, humic acid, fulvic acid, organic materials, O_2, H_2O
  - Must inoculate – many species have been killed and must be reintroduced

Bacteria and archaea

Bacteria multiplying and consuming organic matter

- Oldest, simplest, most numerous organisms
- Involved in: disease suppression, nutrient retention, form soil microaggregates
- Important in the nitrogen cycle
- Decomposers, consume simple sugars
- Make alkaline secretions

  pH > 7

Carbon:Nitrogen ratios

Bacteria
C:N
6:1

Protozoa
C:N
10:1

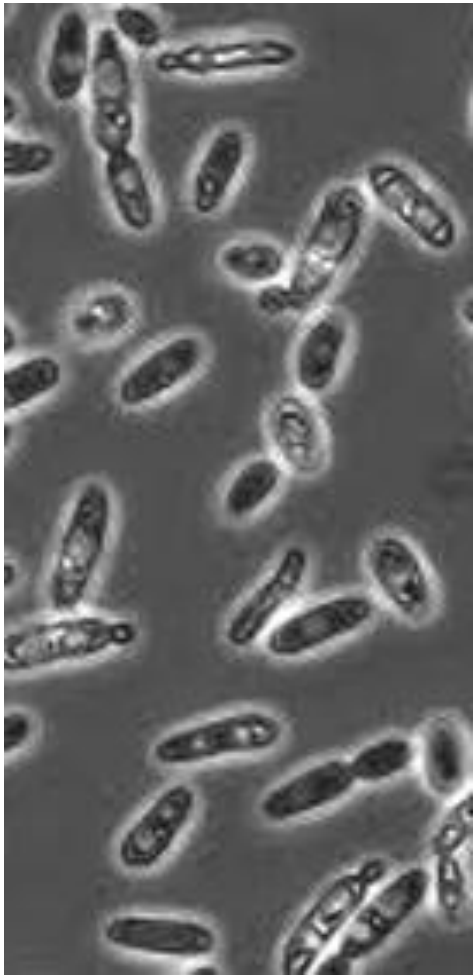
Nematodes
C:N
30:1

Actinomycetes

- The healthy smell of soil
- Antibiotics- eg *Streptomyces*
- Vital in nitrogen cycle
- Decompose difficult carbon forms
- Build humus

Yeasts

- Biofertilisers: nitrifiers, oxidisers, plant growth hormones
- Mediators for many beneficial plant compounds.
- Enhance root growth
- Affect soil texture and aggregates
- Yeast application to sugar beet showed growth and 43% increase in sugar content (Agamy et al, 2013)



Fungi

- Contain long strands of various lengths = hyphae
- Disease suppression
- Retain nutrients (esp Ca)
- Form crumb structure
- Decomposers
- Make organic acids to digest complex CHO (e.g. lignin, cellulose) pH < 7

Erosion and water holding

- Soil microbes and humus help to build soil structure & increase resilience to erosion

Fungi and Soil Structure

Soil microbes and humus help to build soil structure & increase resilience to erosion

- Fungal hyphae (threads) help hold soil granules together
- Fungal exudates (goo) help cement soil particles together

<u>Active Fungi Present</u> – Soil structure is maintained when immersed in water

<u>Fungi absent</u> - Soil structure is not maintained when immersed in water

Hendrikus Schraven, Soil Dynamics Water Trial

Placed a ram under one end to tilt the table once loaded with soil

One table loaded with soil combined with ‘Essential Soil’ mix (compost and compost tea)

One table loaded with same soil without the special mix – Bare Soil - Control

Hendrikus Schraven, Soil Dynamics Water Trial

Rain Events Applied: Collection devices to collect sediment and water

.

3 x 10 year storm events applied. Ie

5mm /hour for 30 minutes
40mm/hour for 40 minutes
5mm /hour for 30 minutes

At the end of this they applied a 50 year storm event.

5mm/hour for 30 minutes
50mm/hour for 30 minutes
5mm/hour for 30 minutes.

Hendrikus Schraven, Soil Dynamics Water Trial

- **Soil Loss from the Treated Table (1) was 98% less than Bare Soil Table 2.**

- **Treated Table (1) had 32% less water run-off than Bare Soil Table 2.**

- **Side issue: Water Run-off water of better quality than the initial water source used for the trial.**

Check out for more detail; http://www.hendrikus.com

- With thanks to Dr Christine Jones for term “liquid Carbon Pathway”

Mycorrhizal mycelium

With thanks to Dr Christine Jones for term “liquid Carbon Pathway”

Who gets the sugar??

Shoots	30 - 50%
Roots	30 - 50%
Microbes	40 - 0%

Decomposition pathway

ends in CO_2

.....

Sequestration pathway

produces HUMUS

“Soils first, livestock second”

SOIL CARBON is the key driver for the nutritional status of plants – and therefore the mineral density in animals and people

SOIL CARBON is the key driver for soil moisture holding capacity

Soil carbon is the key driver for farm **profit**

What kind of carbon????

Carbon

- Building block of Life
- Bio-active forms are key
- Carbohydrates; CHO
- Organic Acids
- Humus
    - Water holding capacity
    - CEC
    - Bio-food sources
    - Soil structure/aeration

Two major carbon cycles

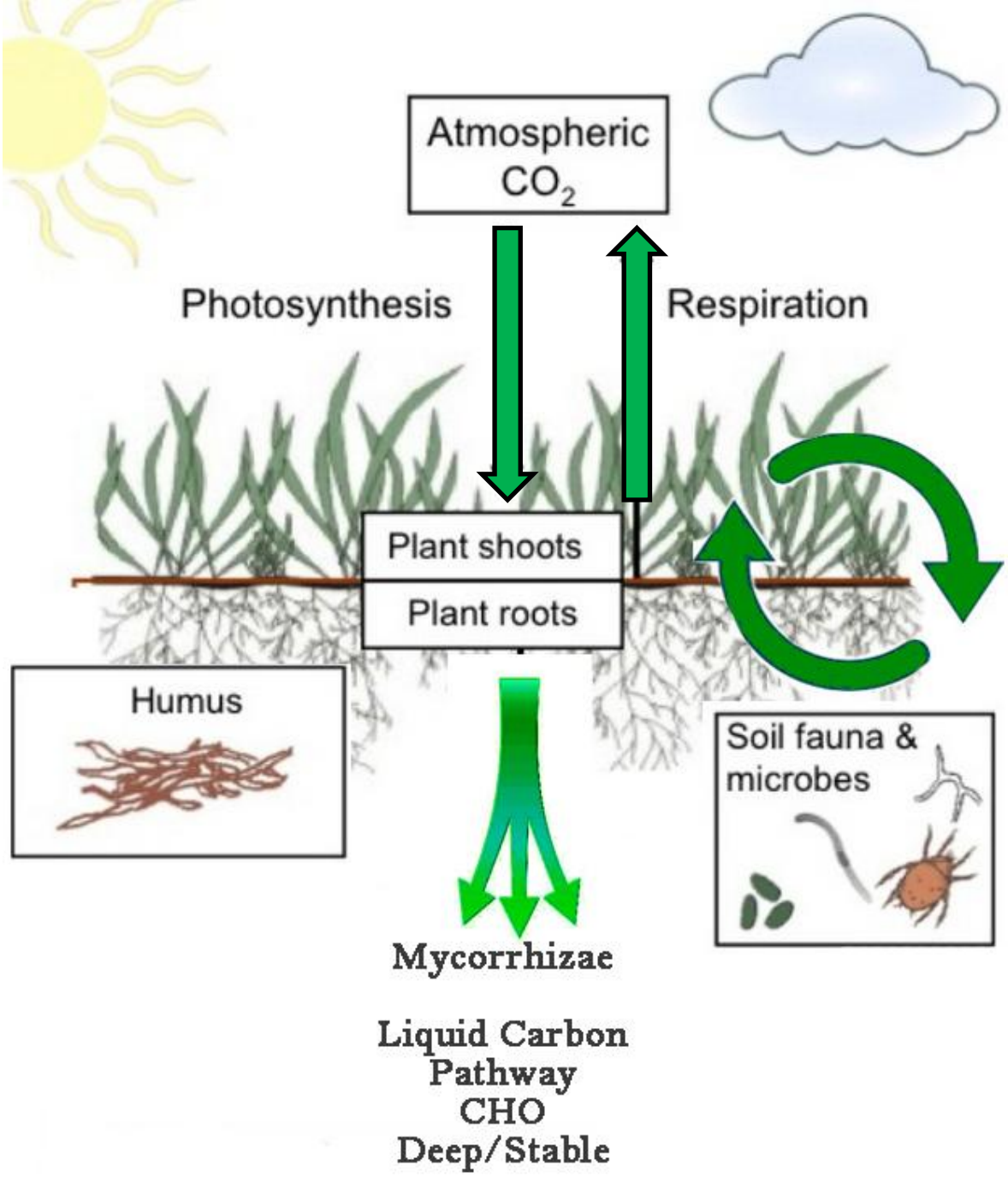
Decomposition pathway

ends in CO_2

.....

Sequestration pathway

produces HUMUS


Atmospheric
CO_2
Photosynthesis
Respiration
Plant shoots
Plant roots
Humus
Soil fauna &
microbes
Mycorrhizae
Liquid Carbon
Pathway
CHO
Deep/Stable

Plant and biological succession

- In response to disturbance events

Protozoa

- Smallest single-celled animals
- 3 main groups
  - Ciliates
  - Amoeba
  - Flagellates
- Vital - nutrient and nitrogen cycling
- Food source for higher organisms

Ciliates

- High numbers can indicate low oxygen levels or soil compaction

Protozoa Tea

- Soak GOOD lucerne hay or sweet meadow hay in water for 3 days
- Apply 50 litres/ha
- Release 60% of N and P held by bacteria

Nematodes

- Non-segmented worms
- 95% are beneficial
- “Root body guards”

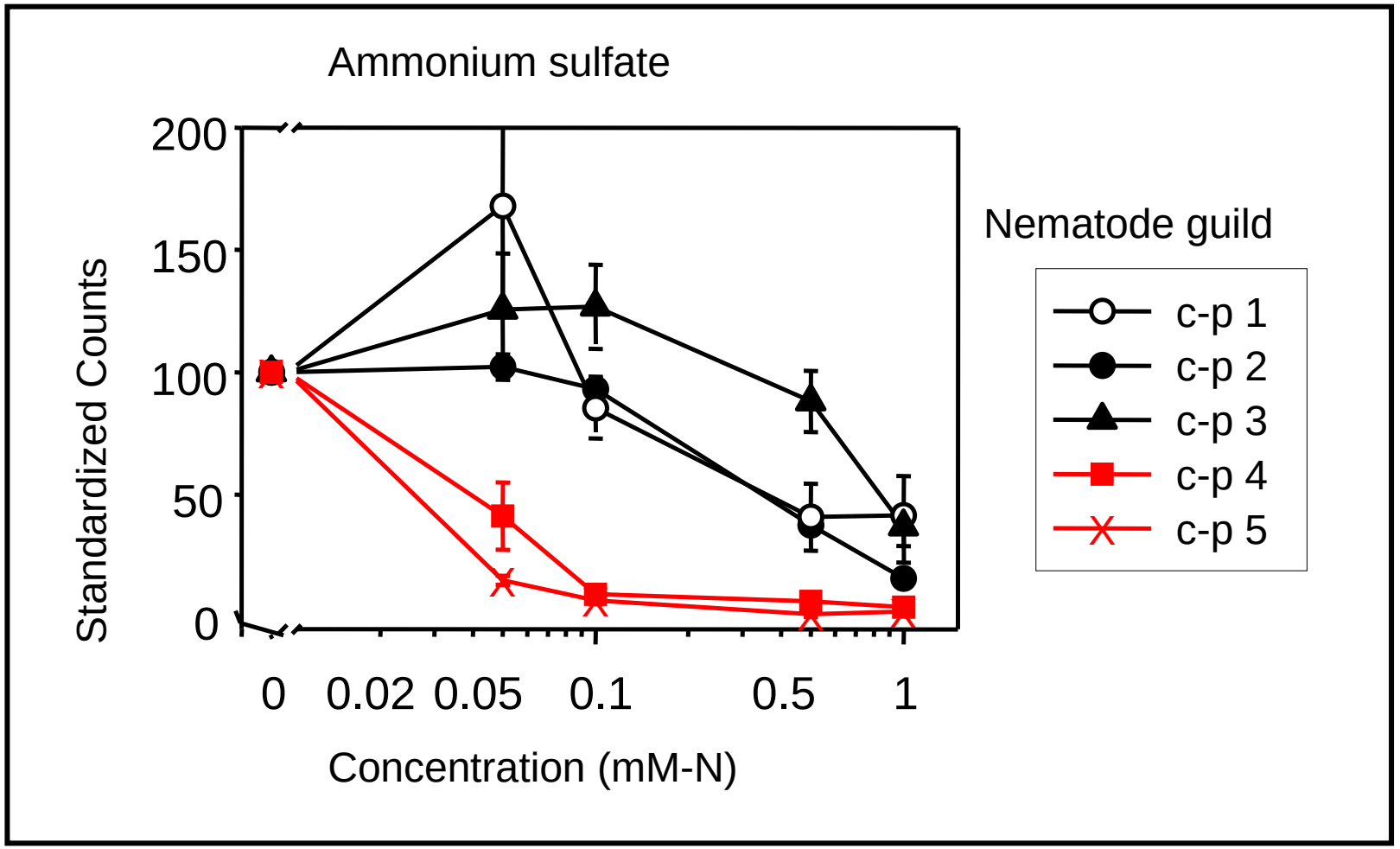
Could be 1000 nematodes in a teaspoon of low fertility soils

Up to 1,000,000 in healthy soils!

Nematodes contd

- Vital in nutrient mobilisation
- Feed on the primary decomposers (bacteria, fungi, actinomycetes) plus algae and eachother
- Central in maintaining F:B ratios
- Release nutrients (N, S, P) contained in microbes bodies
- Vulnerable to disturbance;
  - Salt fert, soil structure loss

Nematode Sensitivity – Mineral Fertilizers



= < 74ppm NH4So4

Tenuta and Ferris (2004)

Soil foodweb

Bacteria, algae and fungi form the base of the food web triangle next come the micro-invertebrates, tardigrades and the earthworms

- Nutrient cycling
- Shredders
- Predators
- Build passages & soil structure

Earthworms

- Feed on soil microbes
- 20 worms per spade process 45 T of castings/yr
- Soil health indicators

  < 5 worms – not good!

Feed the soil

- Bacteria and fungi require different foods:

- Typically **bacteria** thrive on more **simple carbon** sources “green materials”; molasses, sugar, fruit juice, milk, fish emulsion.

Fungal Foods

Fungi require more **complex carbons**; cellulose, cutins, lignins, “brown materials” e.g. humates, wood chip, fish oils.

Feeding the critters:

- **Protozoa** – consume bacteria. Protozoa inocula are compost, protozoa teas, and packaged products.
- **Nematodes** – consume bacteria, fungi and each other. Inoculate using packaged products or compost and vermicast.

How can we feed microbes?

Return crop residues

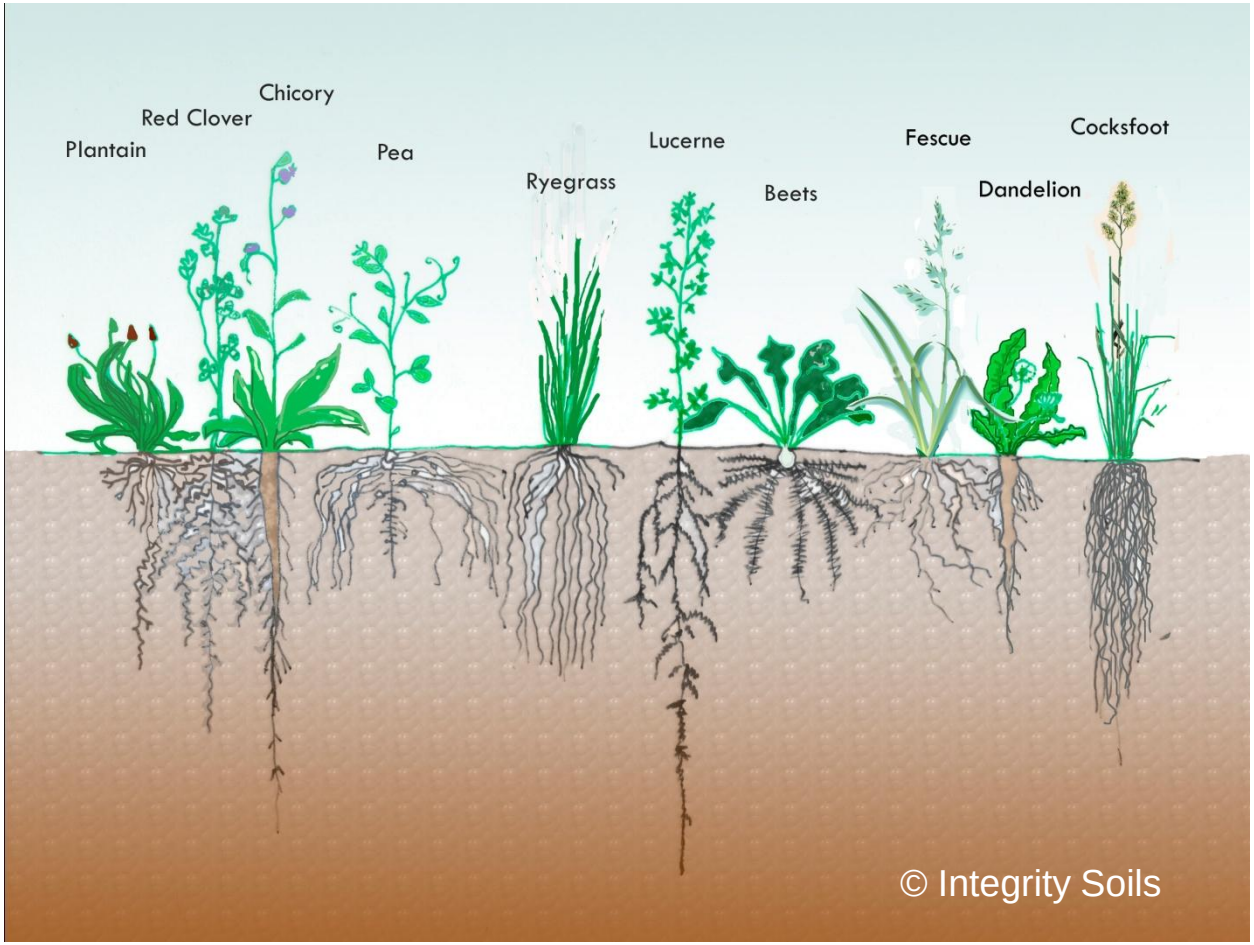
Cover crops

Diversify crop rotations & pasture species (Perennials)

Planned grazing

Add carbon materials, broad spectrum fertilisers and lime

Diversity is key



Fostering diversity provides multitude of benefits…

Beneficial insects, weed competition, mycorrhizal guilds, access to water, soil microbes, nutrient exchange, niche & edge effects, humus development……etc etc etc

Diverse Pasture Benefits: Soil

- greater root biomass and rooting depth
- Improve soil structure, aeration
- Build humus
- Filter water
- Build resilience
- Extend grazing season

Benefits to production

- 11spp mix -40% more annual production (Daly 1996, sanderson et al 2004)
- Less prone to insect attack, grass staggers and animal health problems than ryegrass based pastures.
- Improve overall feed value and ME
- Animal health

Clifton Park soil building recipe:

- 2 kg each white clover, orchard grass, perennial red clover, kidney vetch, and lucerne
- 5 kg each of cocksfoot and tall fescue
- 7 kg of meadow fescue
- 4 kg of timothy
- 3 kg of chicory
- 8 kg of burnet
- 1 kg of sheep's parsley
- and 1/2 kg of yarrow & oats

All the biology must be present

Which is “the most important?”

- Holistic system, can’t forget any part
- No retention without bacteria and fungi
- No return to plant available forms without protozoa, beneficial nematodes and microarthropods

What can we do to reduce microbial services?

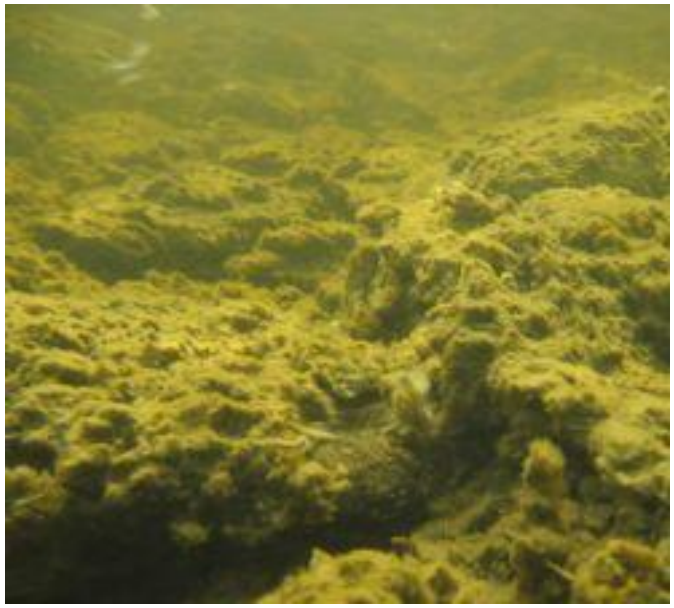
Summary…

- Disturbance pushes the environment towards more primitive forms
- Oxygen, Water, Food, Comfort
- Environment determines diversity
- Nutrition determines which microorganisms dominate

Some take home thoughts

- We are inextricably linked in with natures cycles
- Working with biology builds efficient whole systems
  - That are profitable
  - Productive
  - And fun!

If we don’t foster our underground workforce, then the services they provide are paid for by the wider environment, and own our back pockets.



Microbial quiz

Protozoa:

A: are small worms

B: “healthy” soil smell

C: the smallest animals

D: all of the above

Nematodes

A: root body guards

B: release nutrients

C: maintain F:B ratio

D:all of the above

Microbial quiz

Bacteria:

A: Eat complex sugars

B: make acids

C: Form micro-aggregates

D: long branching chains

Fungi the essential organism for retaining which nutrient?

A: Phosphorus

B: Sodium

C:Calcium

D: Magnesium

Microbial quiz

Bacteria:

A: Eat complex sugars

B: make acids

C: Form micro-aggregates

D: long branching chains

Fungi the essential organism for retaining which nutrient?

A: Phosphorus

B: Sodium

C:Calcium

D: Magnesium

Other thoughts to digest

- Many agricultural scientists deny that there is any link between human health and what happens on-farm, however…

  <u>Minerals in food are declining:</u>

  30 to 60% decline in mineral values since 1940 across the developed world: Se, Zn, Mn, Mg, Ca, and vitamins (WHO data)

Where has all the nutrition gone?

- Comparison of 19,000 feed samples, 298 biological farms had:
  - 6% ↑ Crude Protein
  - 47% ↑ Calcium
  - 16% ↑ Phosphorus
  - 11% ↑ Potassium
  - 29% ↑ Sulphur

- US Data, Dairyland Laboratories

Nutrients

- 16 nutrients for healthy plants
- 60 nutrients for healthy animals and humans
- How many of these nutrients are rotuniely applied in conventional fert applications?