Webinar: Soil organic matter, biology and mineralisation

The challenges & complexity of estimating mineralisation rates

13 May 2021

Ian Packer (Soilpack Services)

Marc Hinderager (AHR)

Integrated Crop Protection
PROTECTING CROPS

Soil Wealth
NURTURING CROPS

ahr applied horticultural research

Soil Wealth NURTURING CROPS

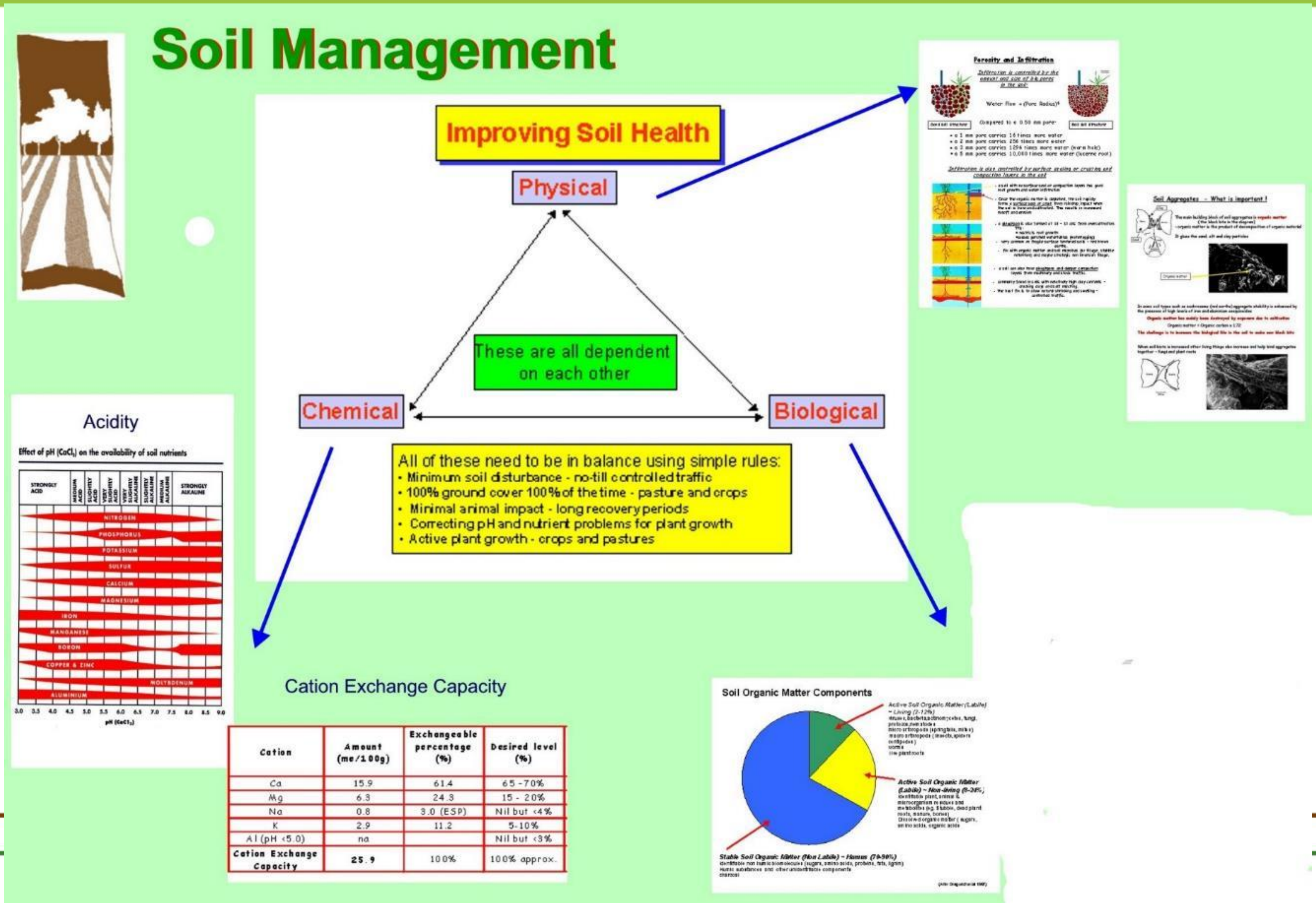
Integrated Crop Protection PROTECTING CROPS

RMCG

Hort Innovation Strategic levy investment

VEGETABLE FUND

Improving Soil Health



Cation	Amount (me/100g)	Exchangeable percentage (%)	Desired level (%)
Ca	15.9	61.4	65-70%
Mg	6.3	24.3	15 - 20%
Na	0.8	3.0 (ESP)	Nil but <4%
K	2.9	11.2	5-10%
Al (pH <5.0)	na		Nil but <3%
Cation Exchange Capacity	25.9	100%	100% approx.

Tracking & Measuring Soil Health

Integrated Crop Protection
PROTECTING CROPS
Soil Wealth
NURTURING CROPS

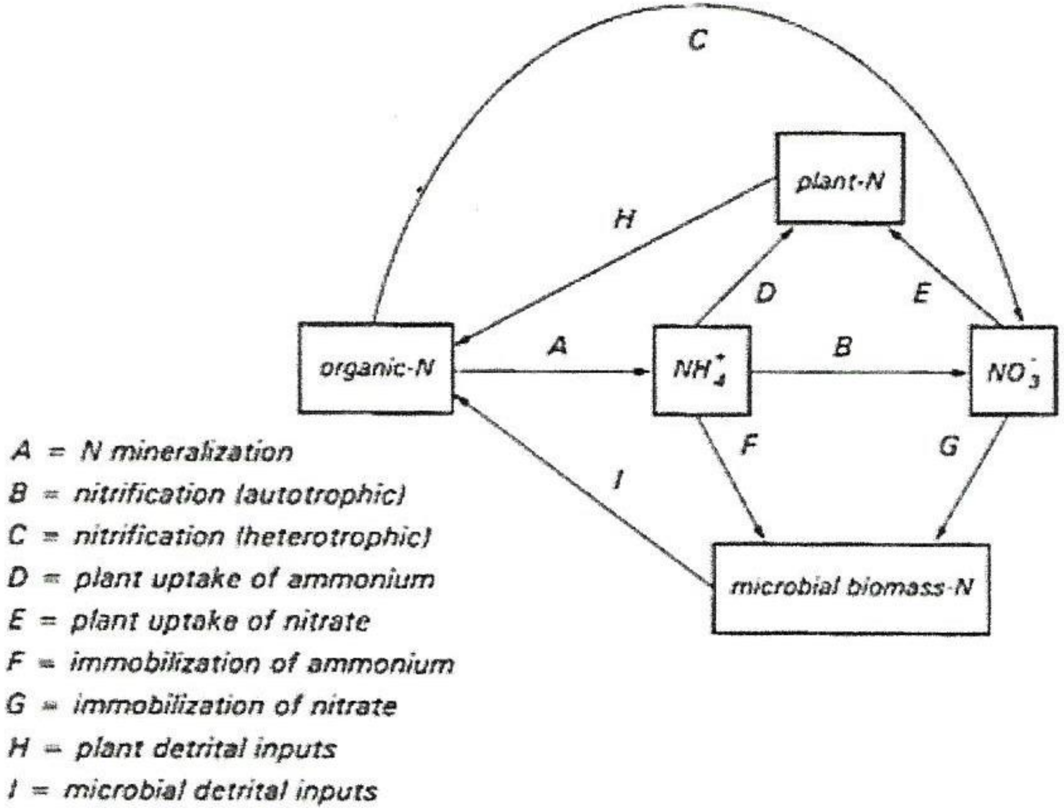
Relatively **easy** & accurate (chemical & physical)

- Water extractable carbon (O.M.)
- Soil respiration (critical)
- Bulk density, compaction (penetrometer)
- Water Aggregate Stability
- C:N ratio
- Organic N
- pH, minerals, Inorganic N

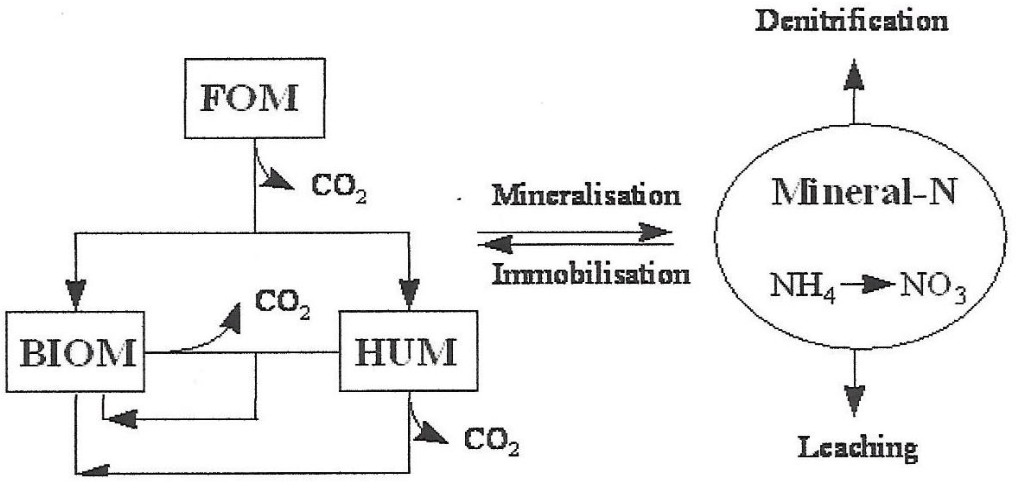
Relatively **difficult** & dynamic (biological)

- Total Fungi (functional groups)
- Total Bacteria (functional groups)
- Protozoa
- Predator:Prey ratios
- Macrofauna – earthworms, ants, etc.

Mineralisation - What is it?



or



- FOM – Fresh Organic Matter (stubble, compost)
- BIOM - Labile Fraction
- HUM – humus
- Note the evolution of CO_2 when decomposing fresh OM and labile OM to humus.
- Balance act of N additions and losses

Some Mineralisation Facts

- Mineralisation is the main process where soil organic matter is converted by microorganisms into plant available N forms.
- It is a continual process (dynamic, constantly changing) and dependent on
  - Soil temperature (warm vs cold soils)
  - Water content
  - Soil type & physical properties: eg compaction, waterlogging
  - The amount of organic matter and residues (Total N content)
  - pH – mineralisation is slower in acidic soil (below 5.5 CaCl)
- Peak plant N demand often does not match peak mineralisation periods.
- In mid spring mineralisation in a loam soil is about 1 kg/ha/day in a soil with 1% OM. **For many Australian soils, between 50 and 150 kg N is mineralised annually from organic matter & crop residues.**

Testing & Timing – *the fundamentals*

- Mineral Soil tests
  - Best if done within a few weeks before planting the crop
  - Know stubble (residues) amounts & condition *(net immobilisation vs net mineralisation)*
  - 1% organic carbon vs 2% organic carbon?

- Biological Activity tests
  - Calico method
  - Respiration method

Inputs of organic N

- Cover Crops (legumes vs non-legumes vs mixed)
- Compost, organic fertilisers
- Tillage

Cover Crops (or significant crop residues)

- Estimate or calculate dry matter per hectare.
- Mixed species need dried & weighed separately to find % of biomass.
- Test for N % & Carbon (C:N ratio)

Carbon to Nitrogen (C:N) of crop residues

Integrated Crop Protection
PROTECTING CROPS
Soil Wealth
NURTURING CROPS

Organic matter material	C:N ratio	Decomposition Rate
Ryecorn straw (grain harvested)	80:1	SLOWER
Corn stalks (no cobs)	60:1	
Ryecorn cover crop (anthesis)	40:1	
Pea straw (peas harvested)	30:1	
Ryecorn cover crop (early jointing)	26:1	
Lucerne hay - old (stems)	25:1	
IDEAL Microbial Diet	**24:1**	
Rotted feedlot manure	20:1	
Legume hay	17:1	
Cow manure	17:1	
Lucerne hay - young (leaves)	13:1	
Vetch cover crop	11:1	
Soil microbes (average)	8:1	FASTER

- Release of N from cover crop residues is a function of C:N ratios (+ environment)
- Plant Available N is a % of Total N
- Increasing soil carbon
  - High C:N ratio stubble will immobilise soil N which reduces total soil N, therefore more nitrogen is required!
  - Low C:N ratio stubble have lower immobilisation rates, therefore less N requirement.

Integrated Crop Protection
PROTECTING CROPS

N budget following ryegrass cover crop

Soil Wealth
NURTURING CROPS

- Ryegrass 2.5 t/ha dry matter X 4% N (mid jointing stage) C:N ~ 20:1
- Vegetable crop planted 15 days post termination of cover crop using strip till
- Cowra NSW: Oct Nov Dec … Overhead irrigation – 200 mm
- Crop Removal (75 day crop 45 t/ha x 3.3 kg N per tonne) 150 kg N
- Harvest Index (nitrogen) = 90% **170 kg N**
- Bulk density = 1.1 O.C. = 1% pH = 5.5 CEC = 7
- Soil test N post CC: 0 – 15 cm = 10 mg/kg 15 – 30 cm = 5 mg/kg 25 Kg N

- N budget ?

RYEGRASS

C:N = 20:1

N budget following ryegrass cover crop

- Total N requirement — 170 kg N/ha
- Soil test (rooting depth of crop) — 25 kg N/ha
- **Mineralisation estimate (0.5 kg/day X 70 days) — 35 kg N/ha**
  Ryegrass recycled N (2500 kg X 4% X 0.6) — 60 kg N/ha

- N budget **170** – 25 – 35 - 60 = **50 kg N/ha** (inorganic N = NO3 / NH4)

  Apply early - - - **50 - 60 kg N/ha**

Residual soil nitrogen should be less than 50 kg/ha following vegetable crops

Estimating mineralisation

Integrated Crop Protection
PROTECTING CROPS
Soil Wealth
NURTURING CROPS

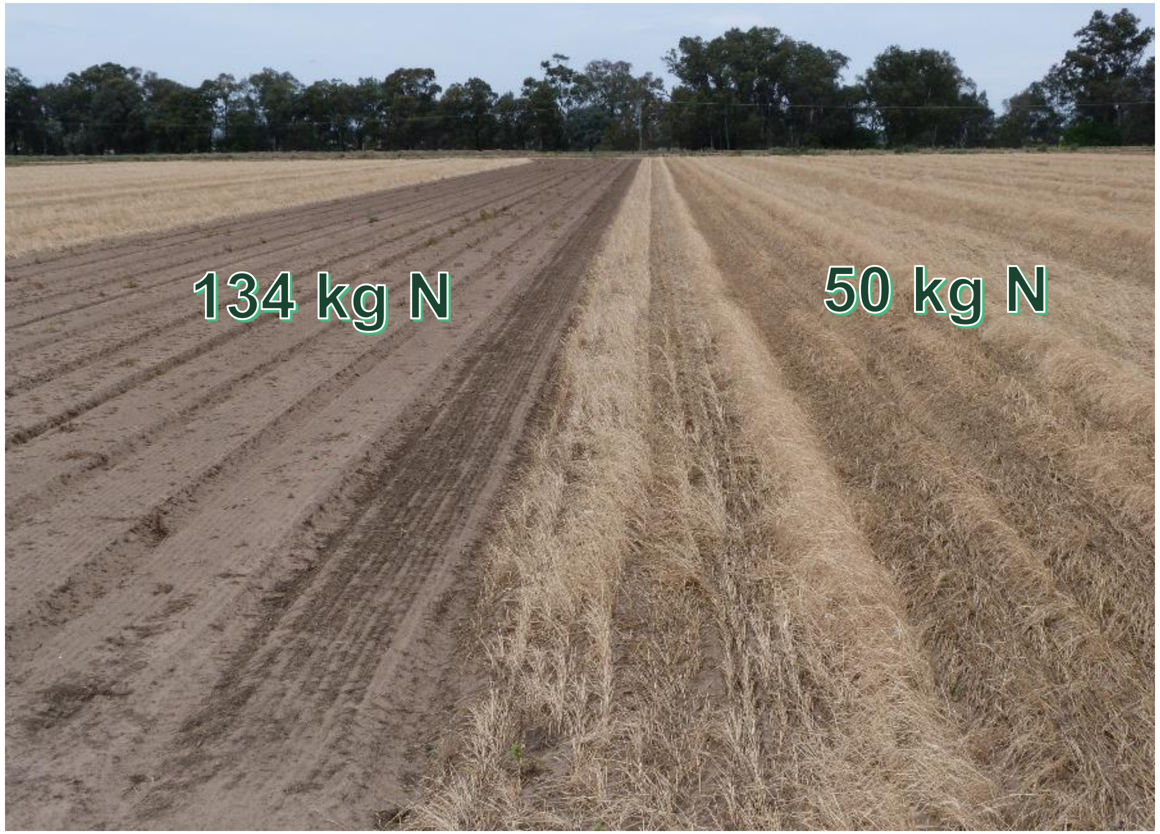
- Ideal pH, soil temperatures, soil moisture, soil texture reflect our 0.5 kg (average) for 70 days *estimate*.

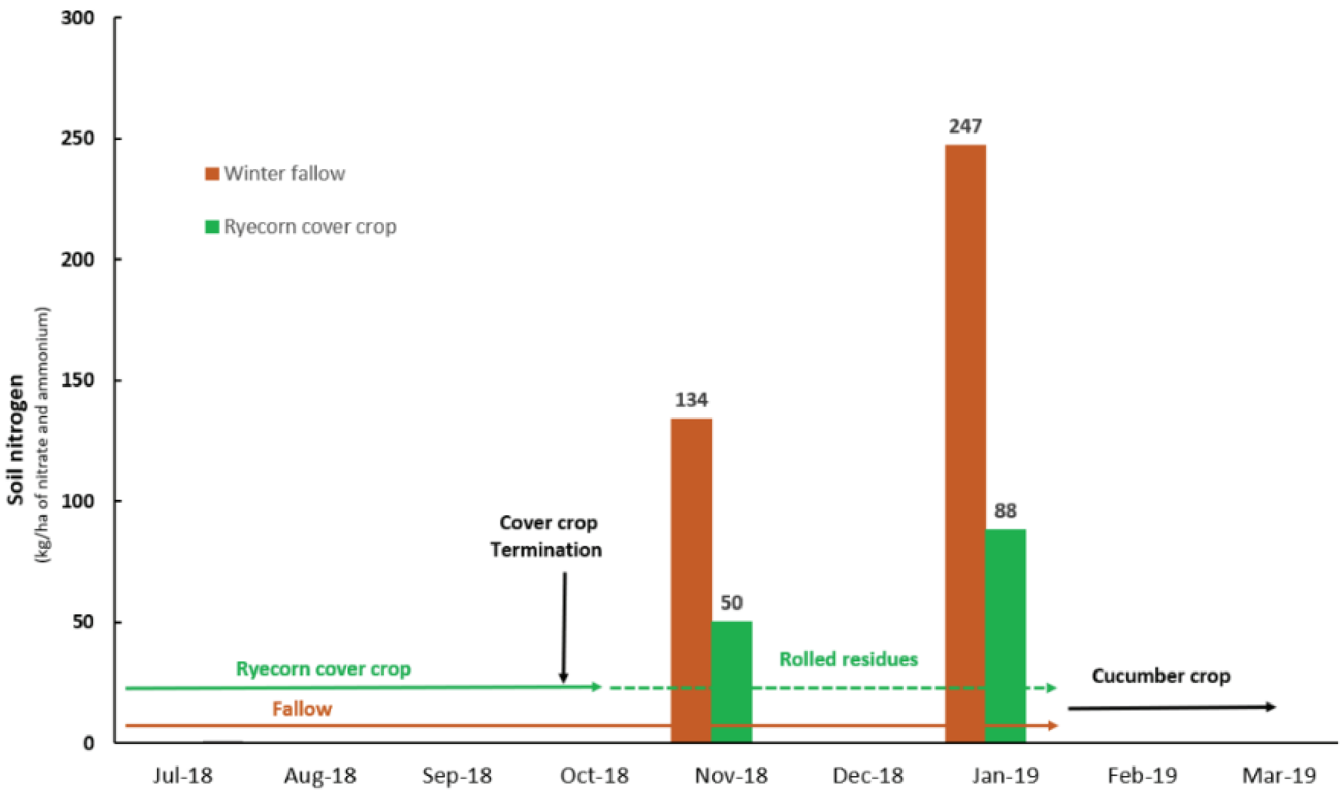
- Ryegrass net mineralisation *estimate:*

  2500 x 0.04 = 100 kg N x 0.6 = 60 kg N

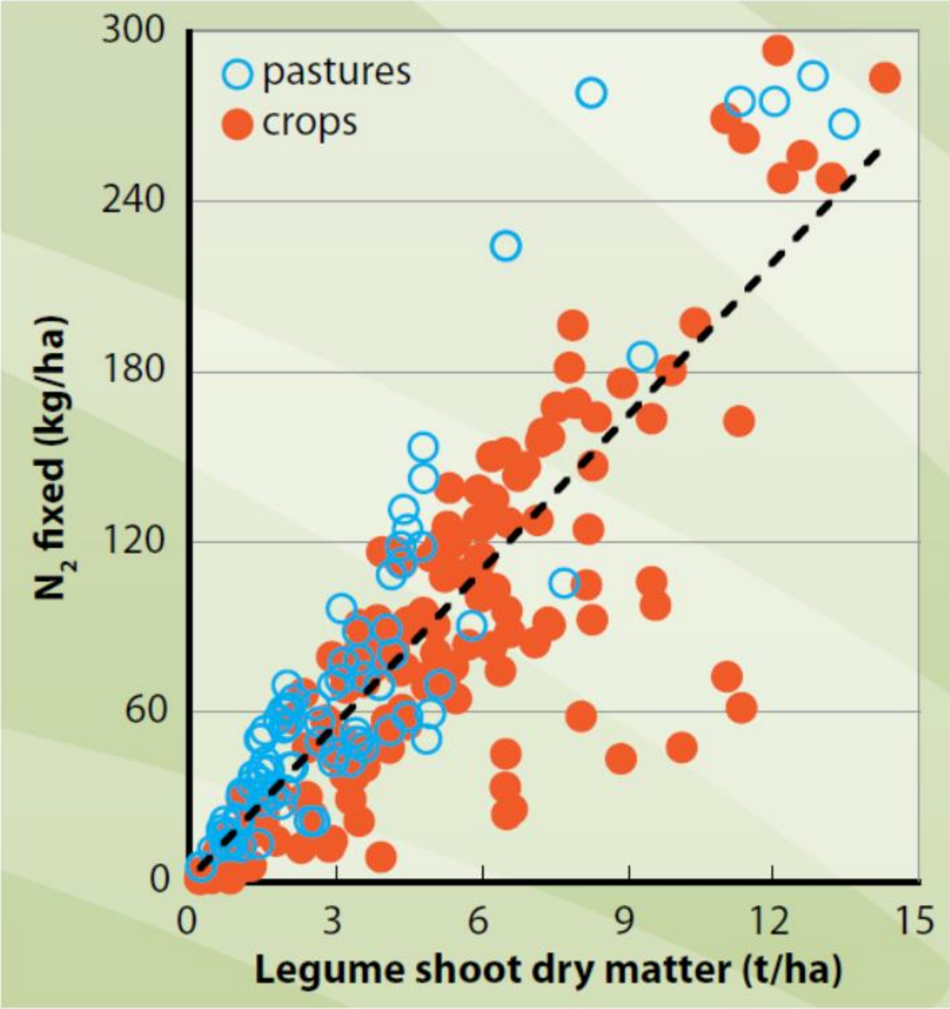
  D.M x N% = organic N x PAN% = Net N from CC

Timely soil tests!!



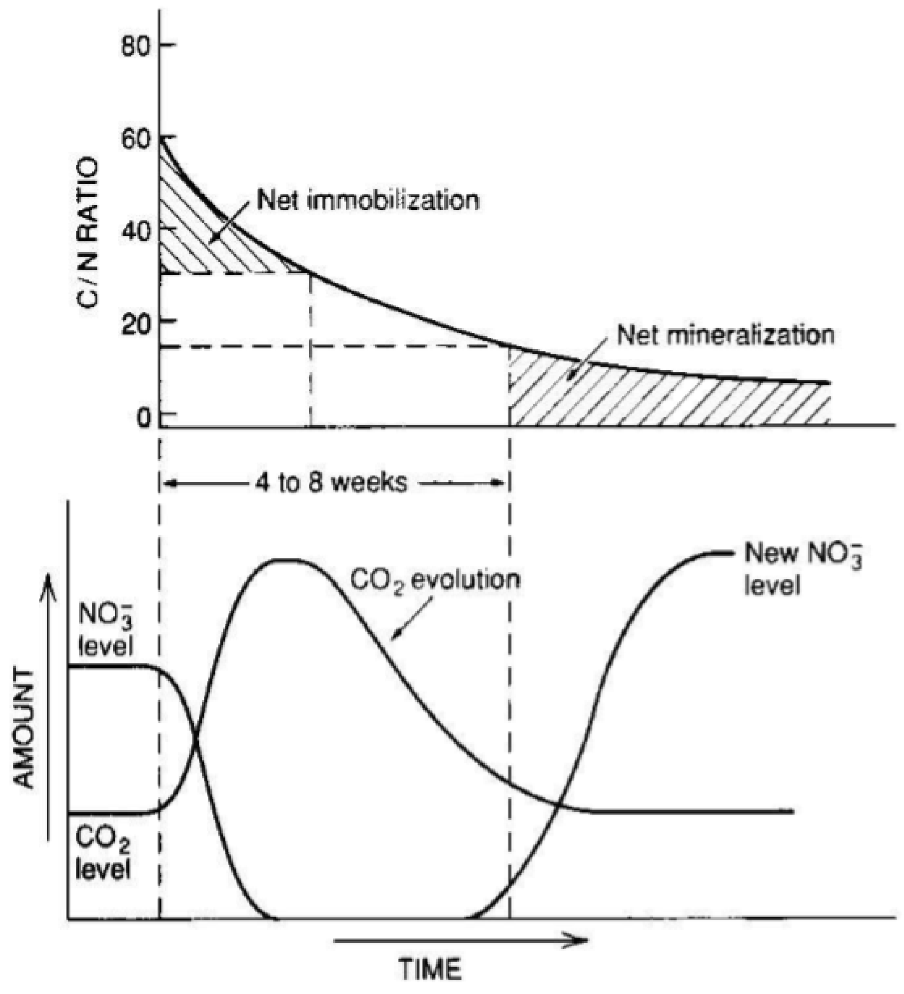


Legumes = net mineralisation (except lucerne)



- *Roughly* 20 kg of N is fixed per tonne of dry matter (a large portion is in roots – approx. 30 – 60%)
- A slow release of N compared to inorganic fertiliser
- Legume species, Soil pH, Rhizobia, soil N status all effect actual result!

Mineralisation of organic matter



- C:N ratio @ 60 will initially be net IMMOBILISATION
- C:N ratio @ 25, immobilisation is less, and time period for mineralisation is less
- CO2 evolution (soil respiration) is microbial activity and mineralisation of soil organic matter

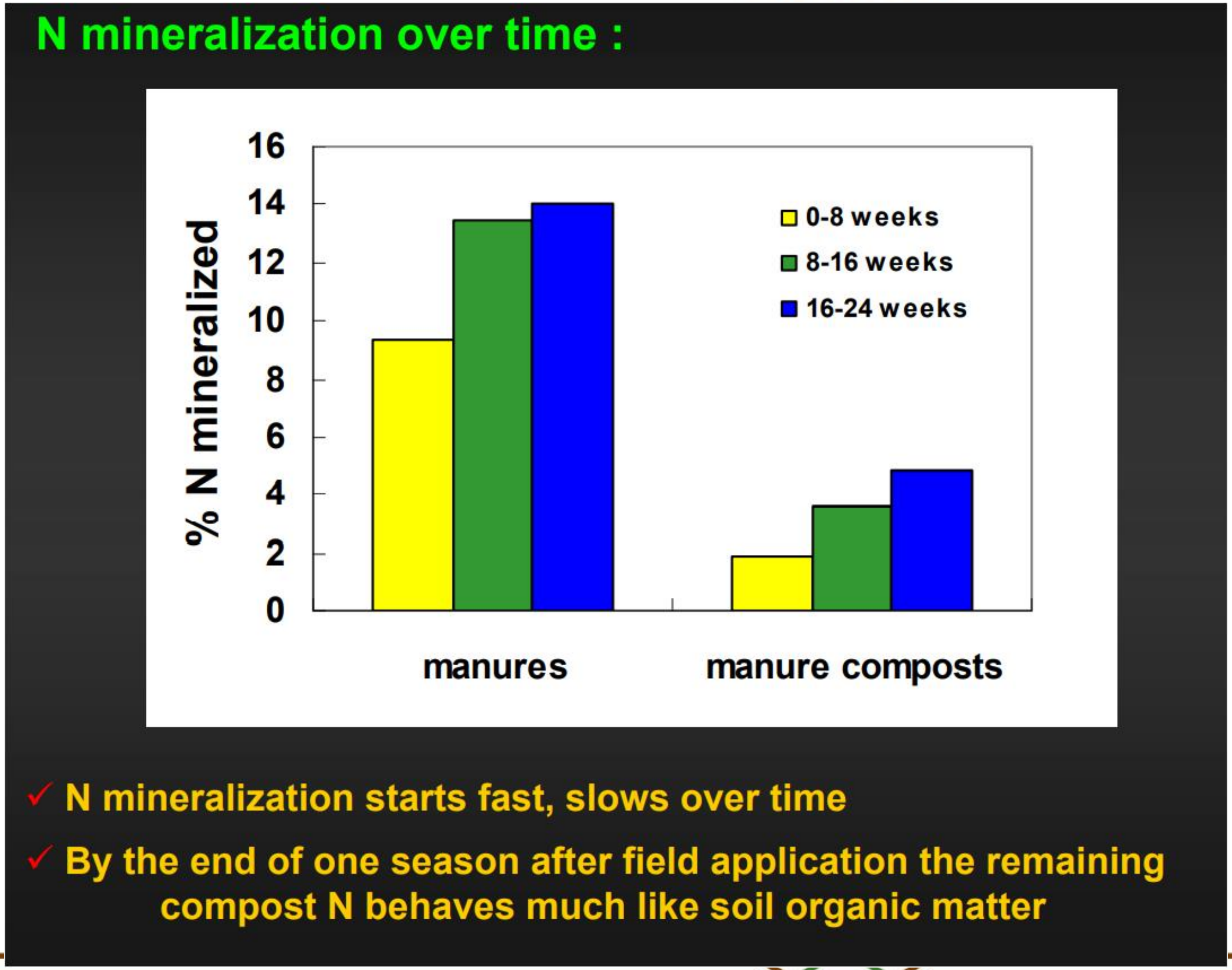
Compost – understand what you've applied

Compost			Wet weight	Dry weight
			10 t/ha	5 t/ha
Nitrogen %	1.5			**75 kg Total N**
Carbon:Nitrogen (C:N)	**15**			
Organic Matter %	45			
Total Organic Carbon%	25			
Labile Carbon %	5.6			
Moisture %	50			
Nitrate-N mg/kg	400			2 kg Nitrate
Ammonium-N mg/kg	35			.2 kg Ammonium

Net mineralisation ~ 7 – 10 kg N

Compost mineralisation

- Compost N mineralisation starts fast, then slows over time.
- After 6 – 12 months, the remaining compost N behaves much like soil organic matter.



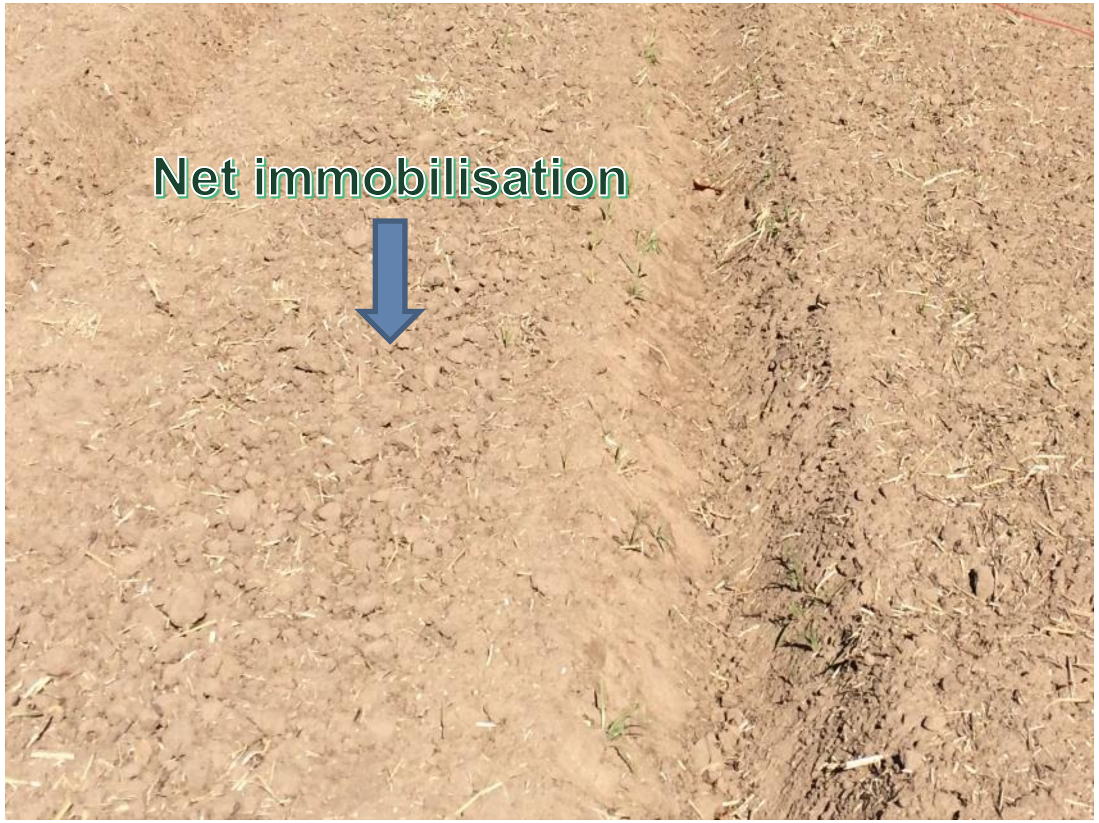
Benefits of Compost

- Fairly balanced nutrition, mostly slow release.
- Buffers soil acidity (& alkalinity)
- Improve soil structure (density, aggregates, infiltration, whc)
- Increased organic matter reduces plant pest & disease pressure
- Good source of microbes

Tillage

Tillage reduces soil organic matter

Tillage



One Final Comment

- It is impossible to observe a system in its natural condition because the mode of observation alters the systems state to some degree – Werner Heisenberg's Uncertainty Principle
- **There is no method for assessing soil N transformations to provide an unequivocal estimate.**
- This is despite the many methods (Process Based Models) available for estimating/measuring N transformations and availability (APSIM, CROPSYST, DAISY, FASSET, HERMES and STICS).
- **Don't despair it will occur and can be maximised with**
  - Good soil health – high soil OM
  - Optimum soil moisture, temperature and aeration
  - Good soil microbial activity
  - Provision of good low C:N compost or cover crops as food source

Source - N Mineralization, Immobilization and Nitrification – S. Hart, J. Stark, E. Davidson and M. Firestone - Methods of Soil Analysis Part 2 Microbiological and Biochemical Properties – SSSA Book Series no.5, 1994

Discussion:
Questions & Answers

Nitrogen = the most dangerous mineral

- EXCESS N causes lower antioxidants.
- EXCESS N causes thin cell walls, lush canopy - blocks air & light (disease).
- EXCESS N delays maturity, increases days to harvest (exposure).
- EXCESS N depresses benefits of other minerals.
- EXCESS N with low K & Zn increases sucking insects.

Keep nutrients in balance: N:K   N:Ca   N:P

Beware of toxicities and deficiencies

Soil Organic Matter Fractions

- **Soil Organic Matter** is organic material produced by the decomposition of plant and other forms of organic material (largely particulate) by the action of soil biota and microbes
- **Four soil organic matter pools:**
  - **Fresh organic substances** – plant residues, organic fertiliser, compost
  - **Fast decomposable** - particulate organic matter – labile fraction
  - **Slow decomposable** – humus – stable fraction and major N source

– **Inert** – unavailable SOM eg. Charcoal, calcium carbonate concretions/nodules or as diffuse carbonate. Also mafic parent materials (limestones, basalts) and dolomite or magnesium carbonate.

Soil Organic Matter (Carbon) Facts

Integrated Crop Protection
PROTECTING CROPS
Soil Wealth
NURTURING CROPS

- SOM is made up of carbon, oxygen, hydrogen and the nutrients such as nitrogen, phosphorus, sulfur, potassium, calcium. and magnesium. (Carbon averages about 58% of this mass).
- **Soil organic carbon is the carbon component of soil organic matter -** measuring organic carbon in soils is relatively easy and effective.

Soil organic matter is about 58% carbon, - SOM = SOC *1.72

(Specifically C% can range from 40 to 58%, (1.72 to 2.5) depending on the source and age of the OM.)

- Organic Matter N - 10000 P- 833 K - 200 S - 143 ratio for organic C

Measuring Soil Organic Carbon

- Soil organic carbon - mineral fraction the less than 2.0 mm - organic materials in the soil, such as large pieces of root, leaves and stubble, are NOT included in the measurement of soil organic carbon
- Measuring Soil Carbon
  - *Soil Organic Carbon Concentration -* grams of organic carbon per 100 grams of oven dry soil – usually bulk sample from 0 -10 cm. An indicator if C going up or down
  - *Soil Organic Carbon Stocks -* tonnes of organic carbon per hectare measured over 30cm with bulk density. Tradable carbon but costly and complex process to determine
  - *Soil Inorganic Carbon -* not included in the determination of the soil organic carbon levels

How Much C can we Sequester?

Integrated Crop Protection
PROTECTING CROPS
Soil Wealth
NURTURING CROPS

Table 20.3 Estimated rates of soil carbon sequestration under a range of land management changes

***Expected in early years of adoption before SOC reaches equilibrium levels**

Source	Land management change	Depth (m)	Rates of change in soil carbon stocks t C ha^{-1} yr^{-1}*
Chan et al. (2011)	Crop to crop/pasture rotation (33% pasture)	0–0.3	+0.22
	Crop to crop/pasture rotation (50% pasture)	0–0.3	+0.25
	Crop to crop/pasture rotation (67% pasture)	0–0.3	+0.40
	Pasture to crop	0–0.3	-0.28
	Pasture to improved pasture	0–0.3	+0.76
Sandeman et al. (2010)	Crop rotation (crop/pasture rotation)	0–0.15	+0.20
	Stubble retention	0–0.15	+0.19
	Reduced tillage	0–0.15	+0.34
	Crop to pasture	0–0.15	+0.30–0.60
Read et al. (2012)	Rehabilitation of scalded lands using water ponding	0–0.3	+>1.0
Freibauera et al. 2004	Zero tillage/no-till	0–0.3	+0.3, +0.4
	Perennial grass	0–0.3	+0.6
	Composting	0–0.3	+0.4
	Crop residue	0–0.3	+0.7
	Arable to woodland	0–0.3	+0.3–0.6
	Arable to grassland	0–0.3	+1.2–1.7
Stockmann et al. 2013	South Africa – CT to NT	0–0.3	zero
	Brazil CT to NT crop rotation with legume	0–0.3	0.04–0.88
	Canada CT to NT	0–0.3	0–0.16
	Canada wheat fallow to NT	0–0.3	0.20–0.30
	Canada annuals to perennials	0–0.3	0.45–0.77

- This is change in soil C stocks not carbon concentration often reported e.g. % OC or SOM % on soil test
- Over many land management systems in a range of soils and climate sequestering C on average is approximately 0.44 t C per ha per year
- Obviously going from crop to pasture and pasture to improved pasture is the best means of sequestering C but implementing conservation cropping techniques is also a positive management practice – less soil disturbance.
- Compost addition

Chapter 20 – Soil Carbon Sequestration as an Elusive Climate Mitigation Tool – Brian Murphy

Can I increase Soil Organic matter by 1% per Year?

(Lots of assumptions such as the high Harvest Index for a crop and the conversion of plant C to soil C).

- Wheat crop yield 5 t/ha (25 bags per acre) - Using a harvest index of 0.55 = **9.1 t/ha of biomass.**
- Assuming roots are 20% of this amount we end up with - 1.82 t/ha + 9.1 = **10.92 t/ha of biomass or 10,920 kg/ha**
- Assuming the **C content of material is 40% this is 4368 kg/ha of C**
- Assuming a conversion factor 10 to 20 % of plant matter to soil carbon - **436 – 872 kg C/ha carbon fed into soi**l.

- On the other side we have an assumption that **10 cm of soil is 1,323,000 kg/ha** – (bulk density of 1.32)
- So feeding **436 – 872 kg C** into soil represents an increase of **0.03 to 0.06 %** in soil carbon.

- **How much carbon is in 1% soil organic matter?**
- 1% organic matter of 1,323,000 Kg is **13,323 kg**
- Of this 58% is carbon = **7720 kg C/ha**
- Therefore **1% organic matter in 10 cm soil 10 cm = 7720 kgs C** a far cry from what you can feed back

Soil Microbiology

- Populations of soil ***bacteria*** change rapidly depending on moisture, time of year, type of crop & hosts (weeds, stubble, organic matter).
- The activity is greater in neutral rather than acid soils.
- Application of high rate of trace elements can be toxic an inhibit mineralisation
- Mineralisation is more rapid in sandy soils compared to loam or clay loam soils – clay minerals absorb organic compounds
- Soil macrofauna accelerate N mineralisation as they provide excreta, increase the surface area of litter and redistribute litter in the soil
- HEALTHY populations of soil bacteria AND fungi are encouraged by REDUCED TILLAGE, GROUND COVER & ORGANIC MATTER

Biological - Fungi : Bacteria ratio

- Bacteria tend to dominate in systems with fewer organic inputs (cover crops, crop residues, compost) leading to lower C:N ratios.
- Bacteria are more prominent in cooler seasons
- Bacteria are important in the soil ecosystem, but **fungi** are desired and more often considered indicators of good soil health.
- Fungi are more tolerant of acid conditions than bacteria. Fungi (saphrophytes) are mainly responsible for initial breakdown of organic matter, then bacteria required to make humus.

Soil Biology – (Pauline Mele - Australian Work}

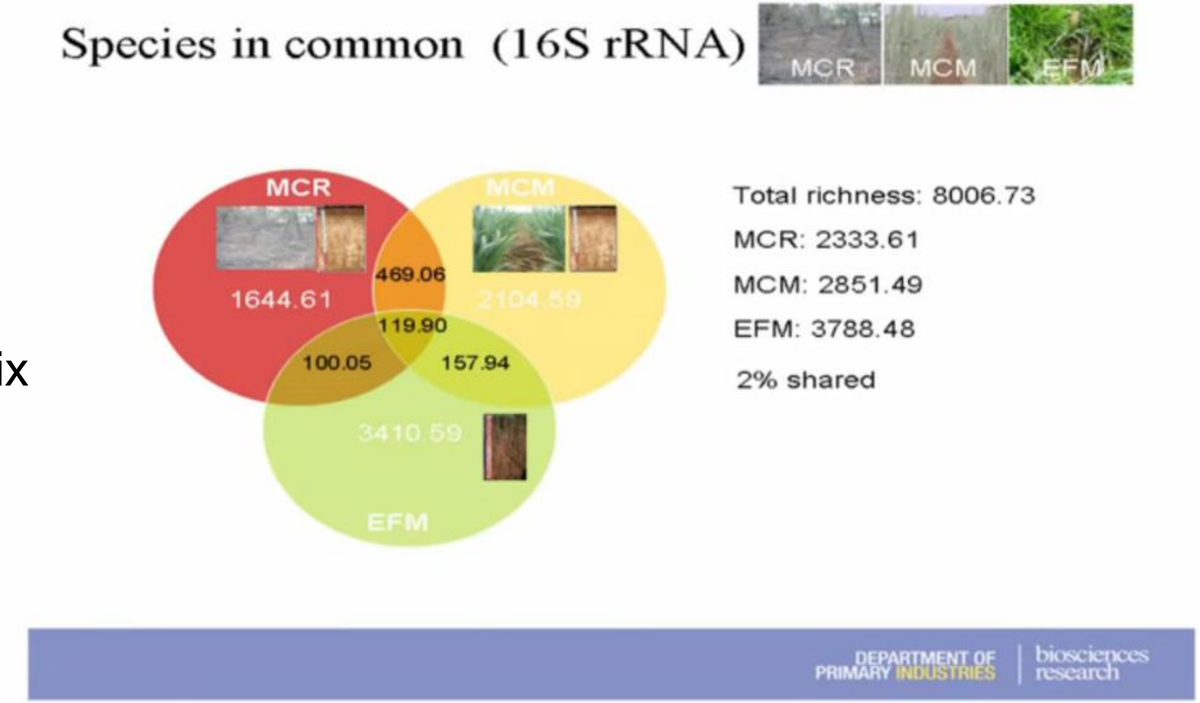
Just to give you an idea of the complexity and rigour involved in understanding soil biology

Metagenomics Comparison of:

- MCM – Agricultural Land
- MCR – Undisturbed Native vegetation next door
- EFM – improved pasture in another area

Wouldn't it be great if we could dial up a specific biological mix to target soil processes in different climates in different soils using a range of management practices

We are not there yet - Watch this Space




Banding P+K @ 7 cm
Banding N @ 15 cm
Rip @ 20 cm @ 10 kph

Net immobilisation … Net mineralisation

Integrated Crop Protection
PROTECTING CROPS
SoilWealth
NURTURING CROPS

- COMPOST

Best mineralisation scenario?

- warm soil (30C)

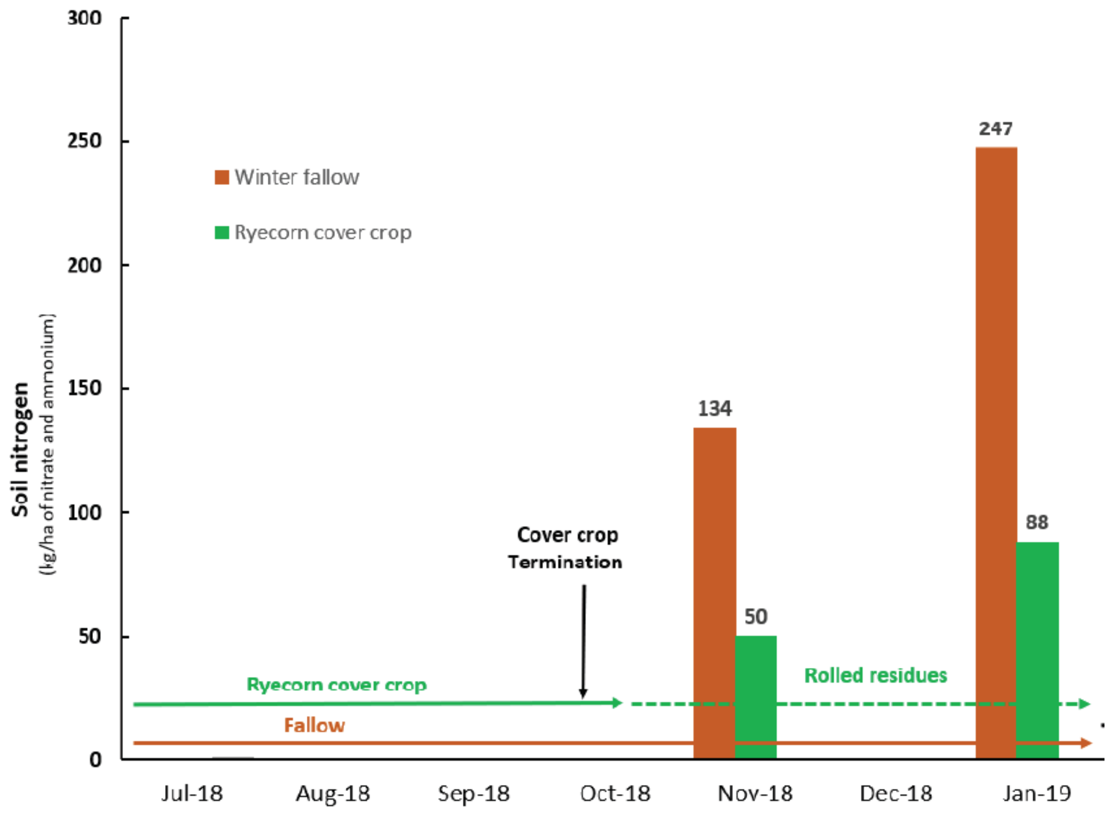
- moist soil

- pH = 6.5

Most compost rates need to be at least 10 t/ha

Application Rates of manures and composts to supply 150 kg/ha N		
Treatment	**Tons per acre**	**Tons per hectare**
Fresh Poultry Manure	11.4	28.2
Aged Poultry Manure	10.7	26.4
Standard Poultry Manure	15.6	38.5
Amended Poultry Compost	10.7	26.4
Fresh Dairy Manure	17.9	44.2
Aged Dairy Manure	18.1	44.7
Standard Dairy Compost	23.5	58.1
Amended Dairy Compost	26.4	65.2

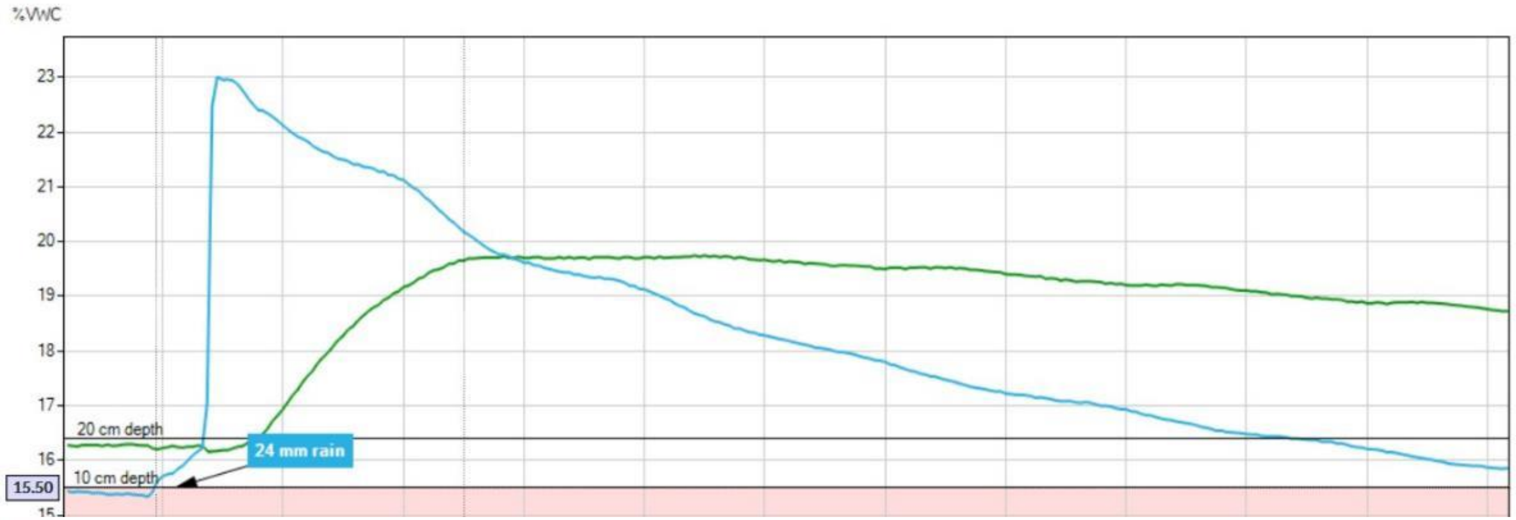
Integrated Crop Protection
PROTECTING CROPS
SoilWealth
NURTURING CROPS



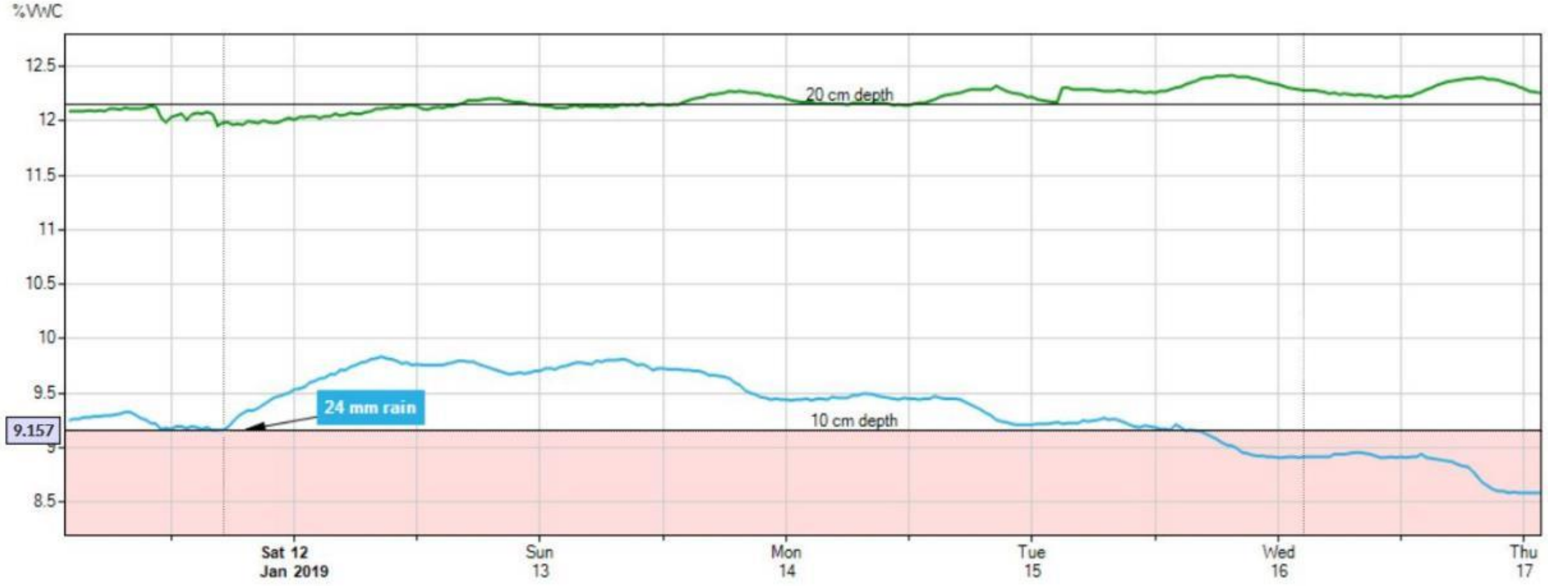
- Long fallow mineralised @ 1 kg N / day
- Rolled cover crop on surface mineralised @ .5 kg N / day

INFILTRATION: Cover Crop + Strip Till = Ground Cover

Integrated Crop Protection
PROTECTING CROPS
Soil Wealth
NURTURING CROPS

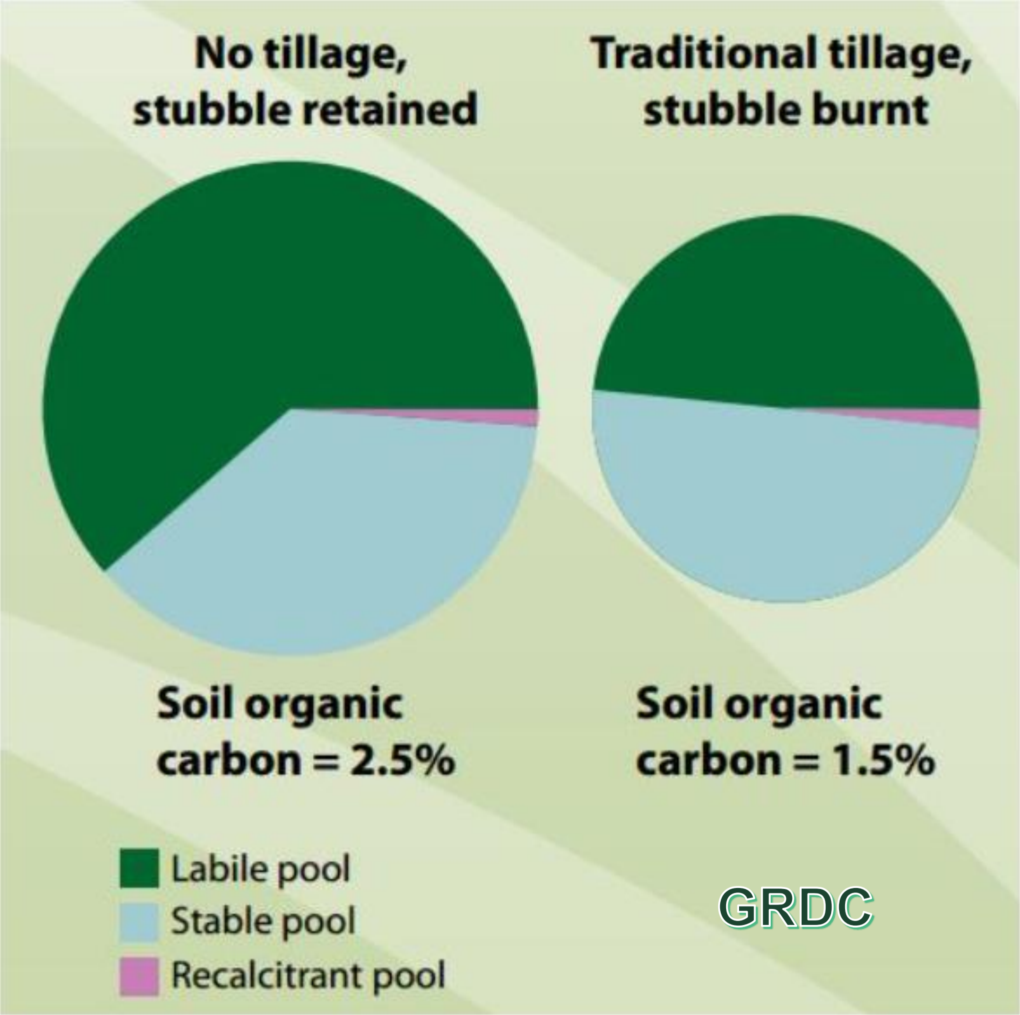


- Ryecorn Cover crop
- Rapid infiltration to 20 cm after 24 mm rain



- NO cover crop - bare soil
- No infiltration after rain
- Loss by runoff and evaporation at surface

"Turmoil of Tillage"



- Reduced tillage will slow the decline in soil organic matter.