

# Soil health: the chemical, the physical and the biological – effects of organic manures

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Dr. Patrick J. Forrestal ITLUS Winter  
Meeting 2018, Kildare



# Soil health isn't a conventional vs organic issue

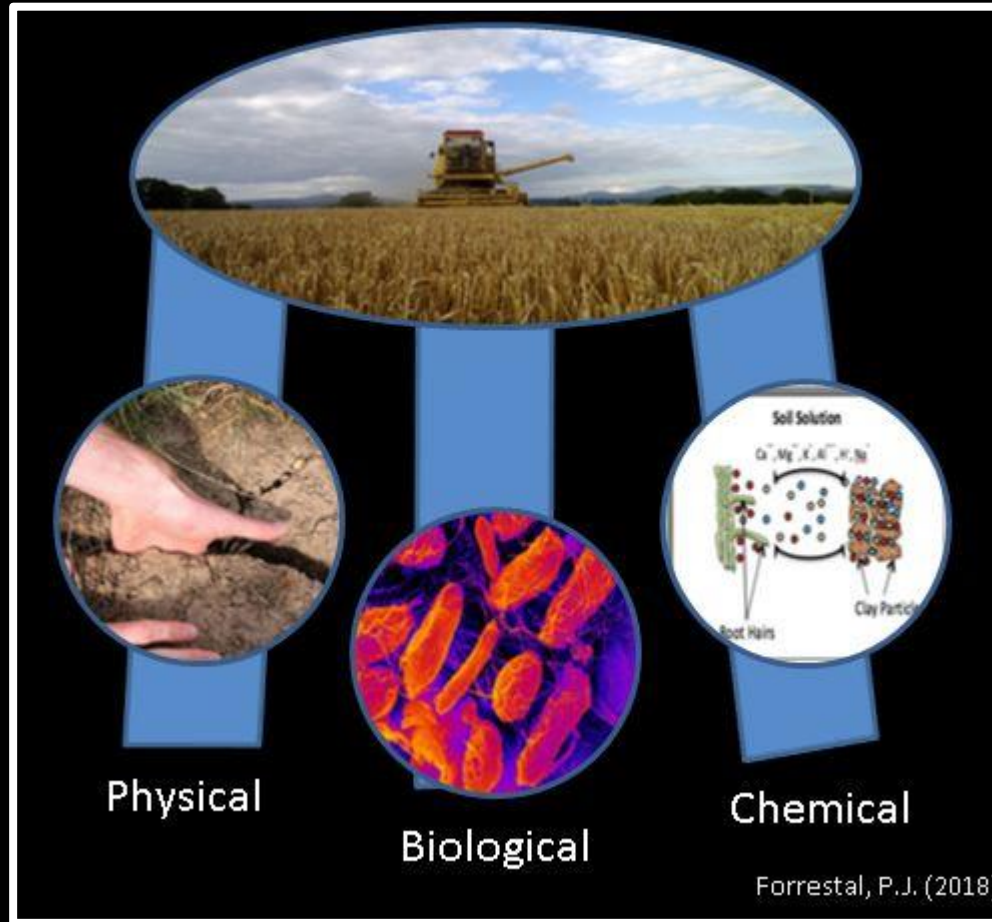


c. 1930



# Three pillars of soil health

Soil is only at its best productivity with focus on all three  
Any pillar can only partially compensate for neglecting another

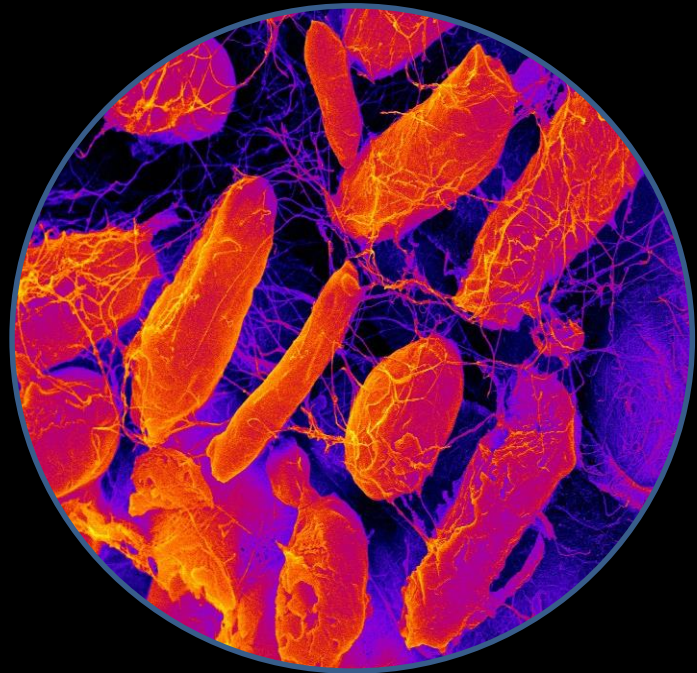


# The biological, Who is there?

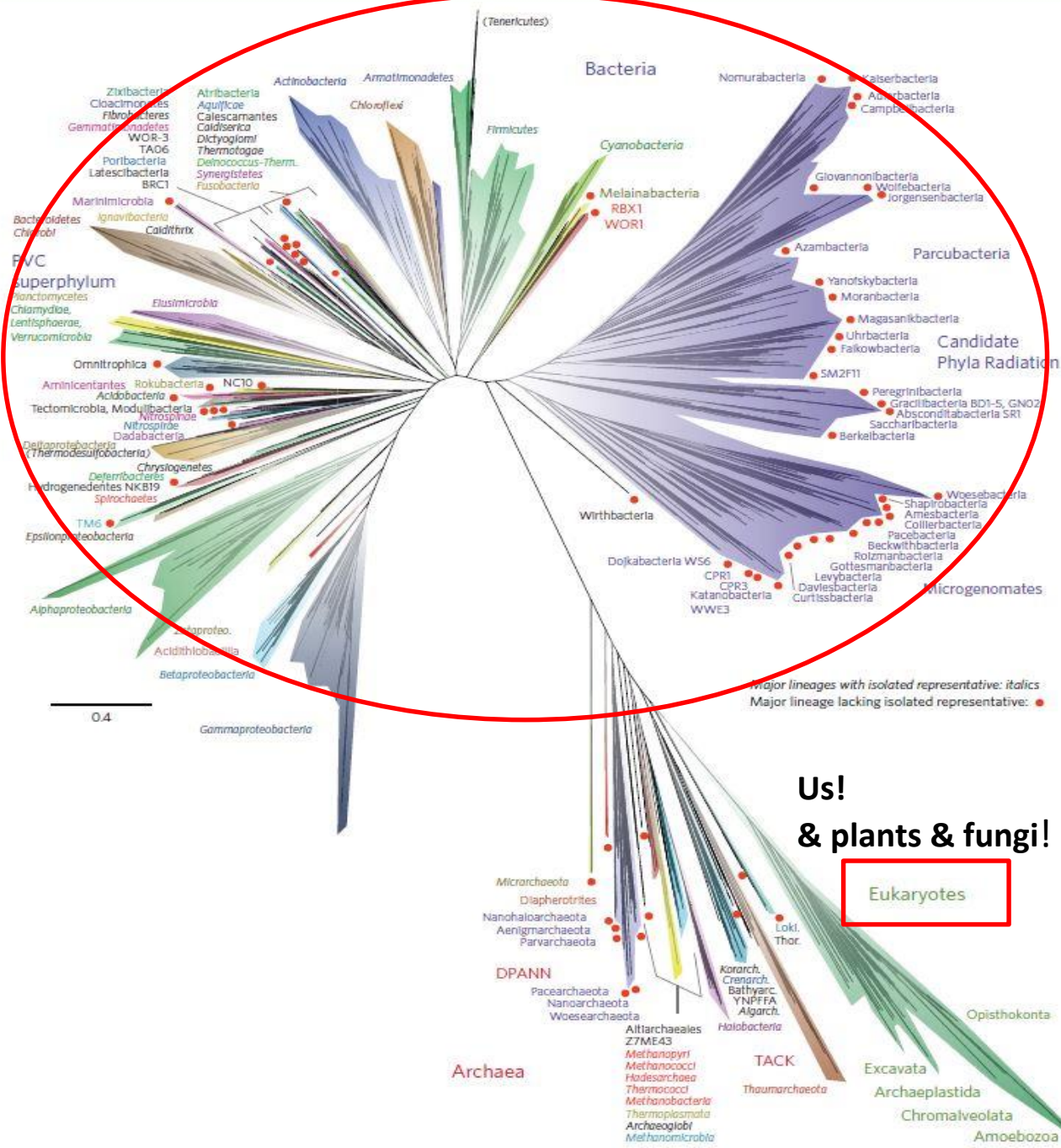
**The macro**



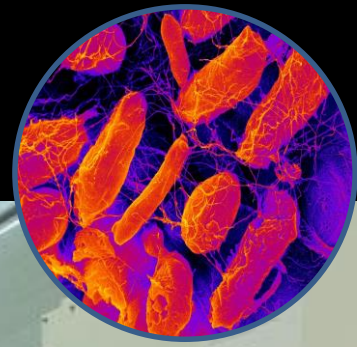
**The micro**







# Who is there?



KRISTIN VEUM, P.H.D.

USDA-ARS SOIL MICROBIOLOGIST

6.5 years of non-stop  
counting





# How do they obtain their energy i.e. ATP?

- Organic or Inorganic compounds

Chemotroph

- Light

Phototroph



# The chemotrophs – source of reducing equivalents

From organic compounds

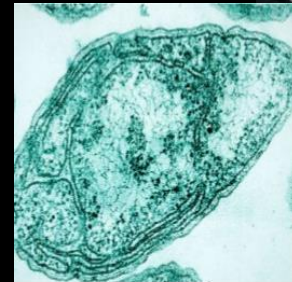
Organotrophs



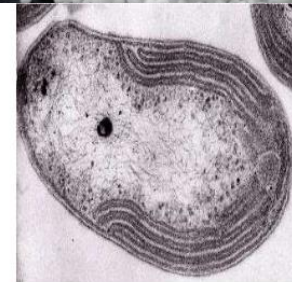
From inorganic compounds

Lithotrophs

e.g. nitrifying bacteria



Nitrosomonas



Nitrobacter



Source of **carbon** the building block for growth?

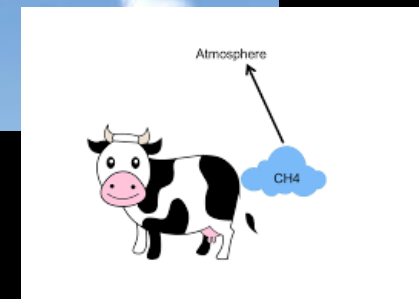
“Dismantling” energy-rich organic compounds

**Heterotroph** – most common

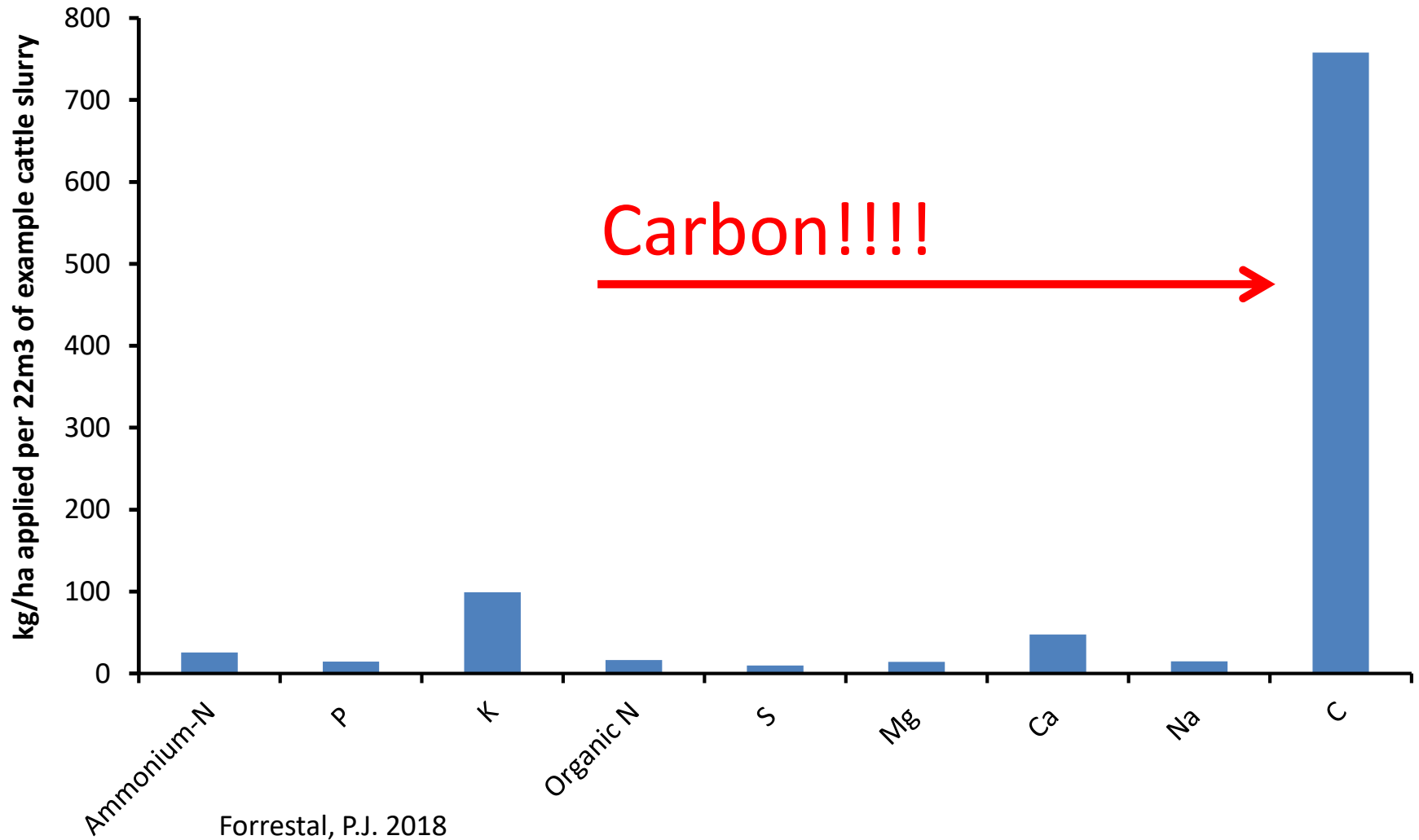
Fix from  $\text{CO}_2$   $\text{CH}_4$  e.t.c.

**Autotrophs**

e.g. algae



# What's in manure? Example Cattle Slurry



# Nutrient variability?

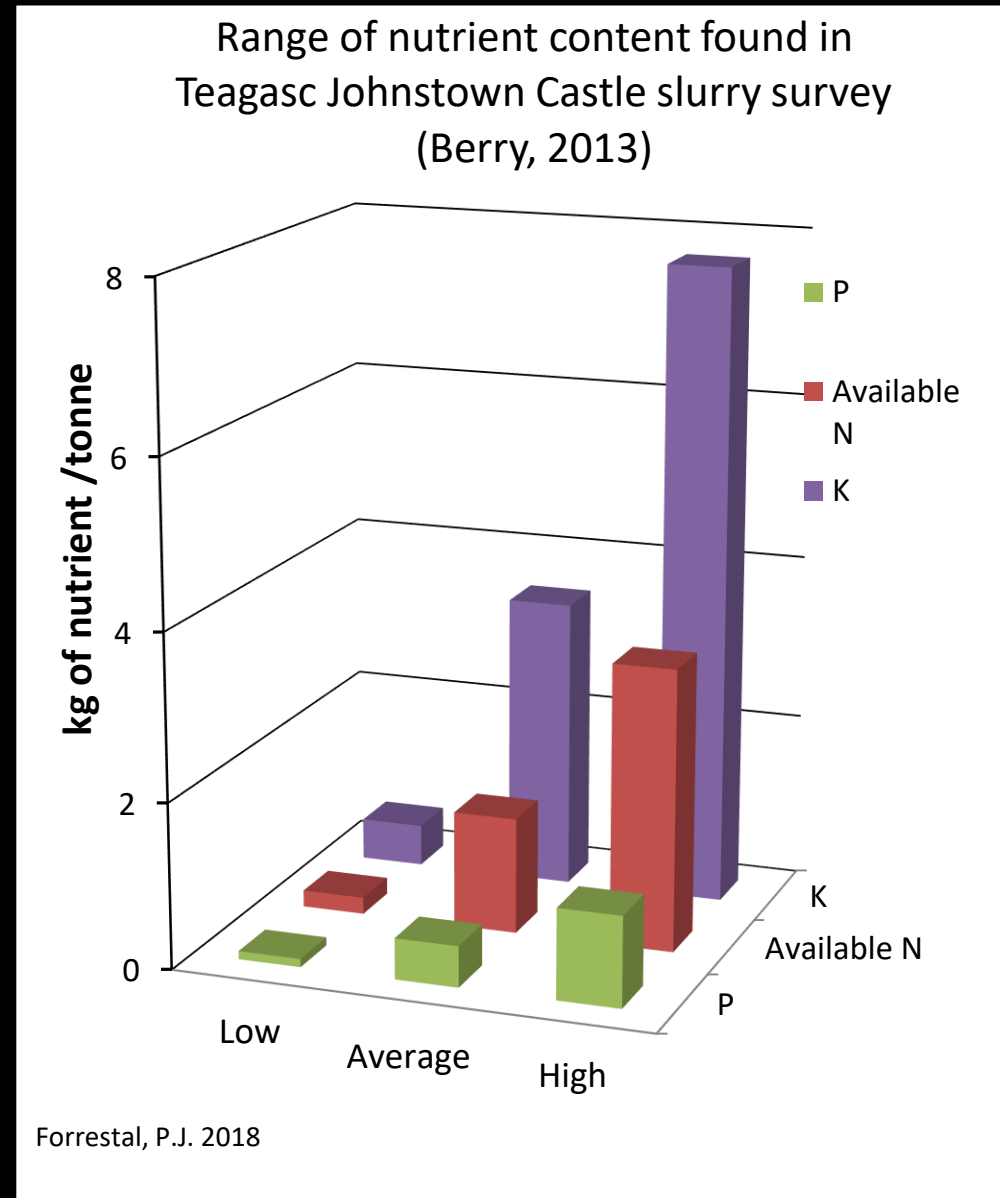
Large variability between farms

Between high and low:

**NH<sub>4</sub>:** 17 fold difference

**P:** 11 fold difference

**K:** 15 fold difference





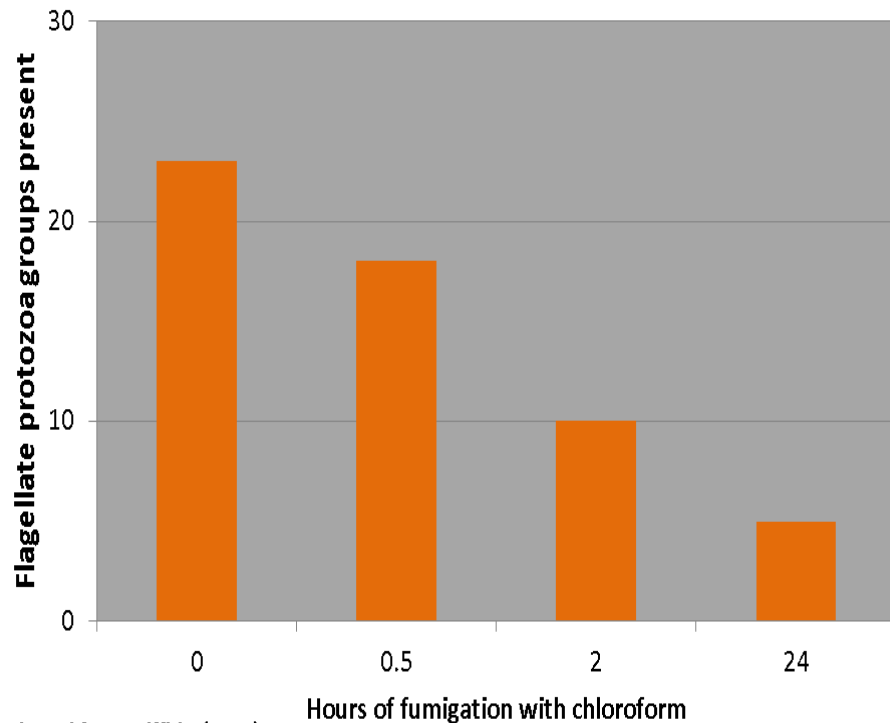
# Long-term Manure addition experiment, AFBI, Hillsborough



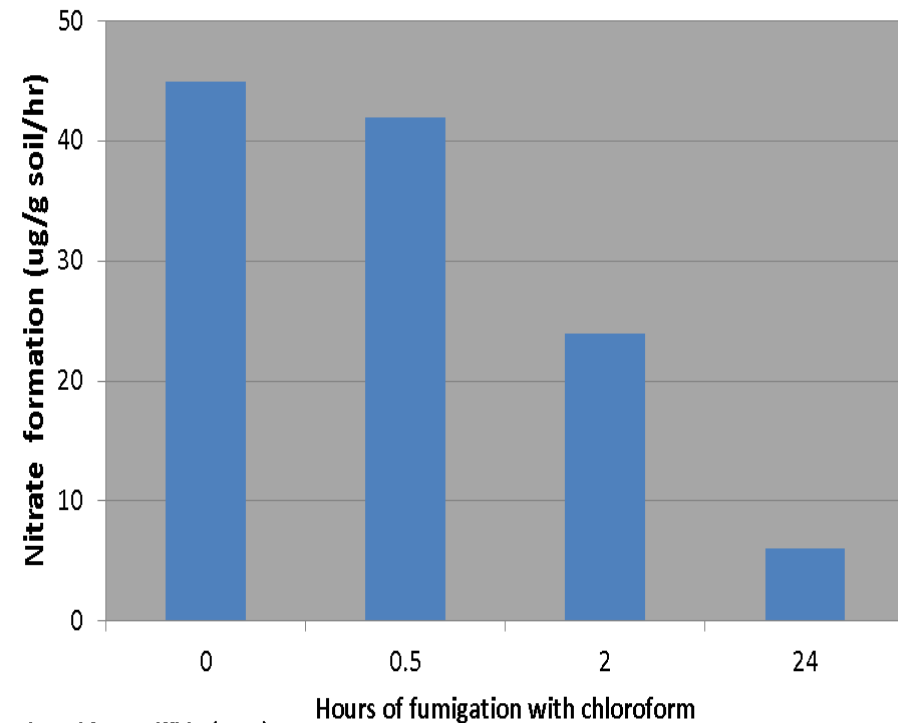
06/12/2018

Dr. Patrick J. Forrester ITLUS Winter  
Meeting 2018, Kildare

# Do we really need the biology?



Adapted from Griffiths (2000)



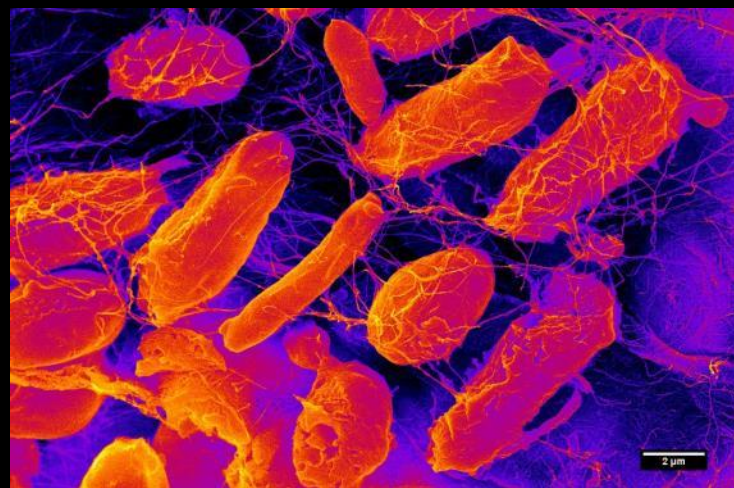
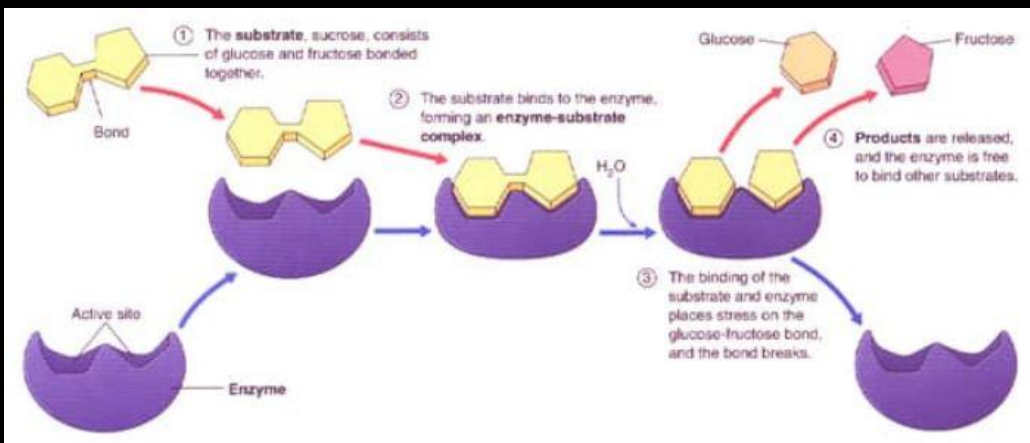
Adapted from Griffiths (2000)



The “jaws” of the microbiota are the chemical enzymes they secrete which breakdown the substances around them

## What are enzymes?

These are compounds which advance the rate of chemical reduction-oxidation reactions:



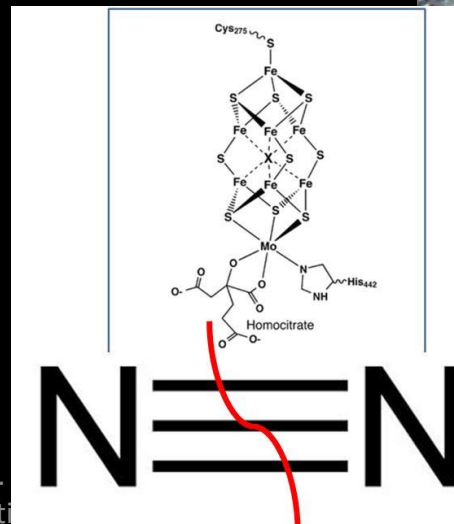


# Enzyme applications you might know?

## Legumes

- Nitrogenase

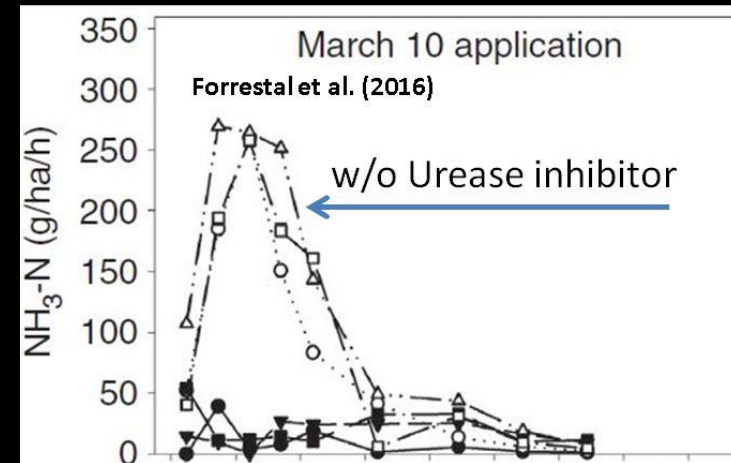
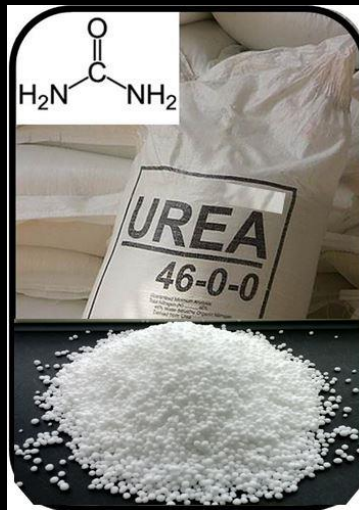
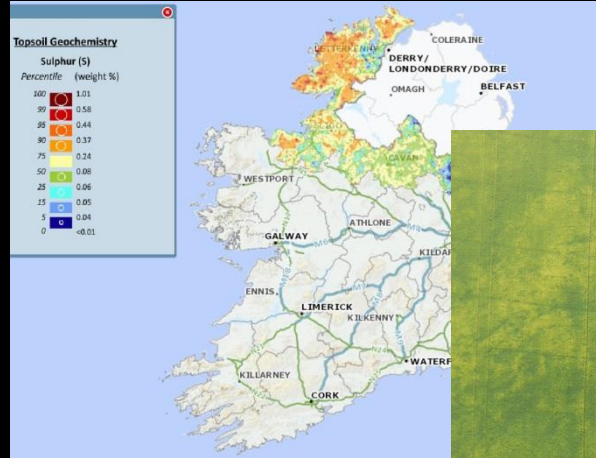
Carbon trading  
between the  
bacteria producing  
**nitrogenase** and the  
plants capturing  
carbon using  
**photosynthesis**



# Other Enzyme applications you might know?

e.g.

- Sulphatase
- Urease





# Green manure: effect on soil respiration – microbial life



**“Tillage Radish”**



**Vetch**



**Rye**

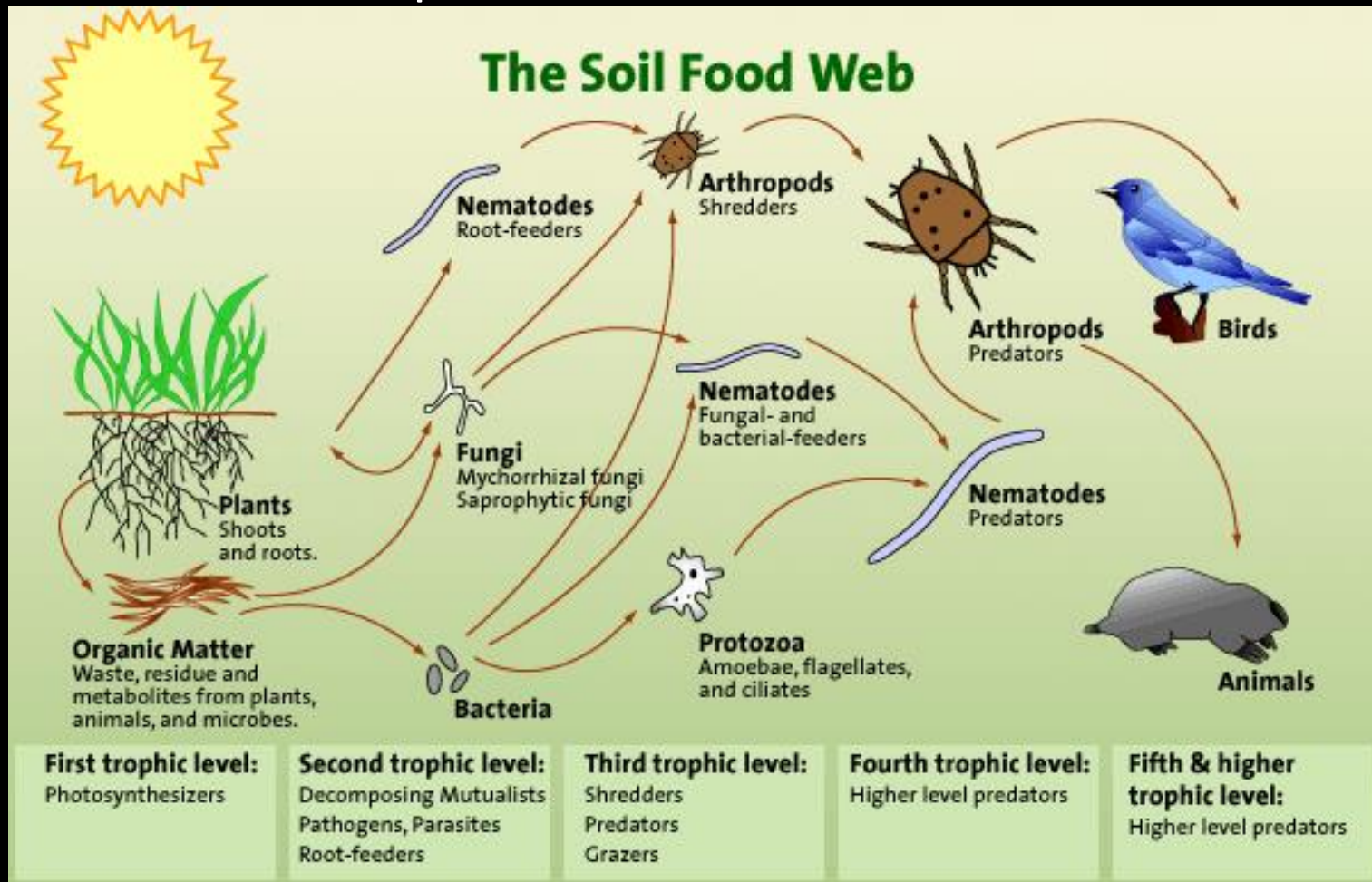


**No cover crop**





Any practice, input or weather effect that influences soil will advantage one group over another causing population shifts  
BUT we need diversity to be able to adapt – manure addition helps to feed the communities

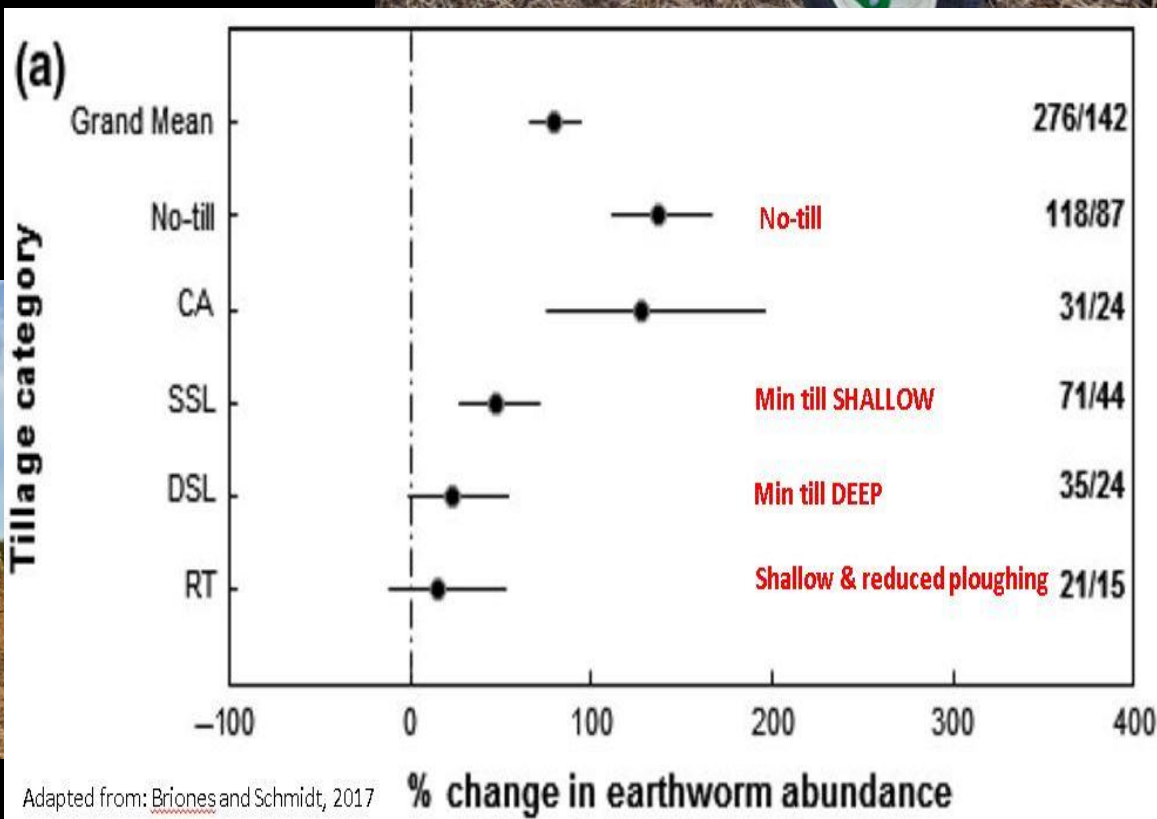




# Earthworms as an example of the macro



- Release 50 to 190 kg/ha/yr mineral N from soil (Schmidt and Curry, 2001)....this is worth €45-175/ha/yr
- Sensitive to ploughing and tillage





# Worm casting or middings

(plough, till, sow grass reseed)





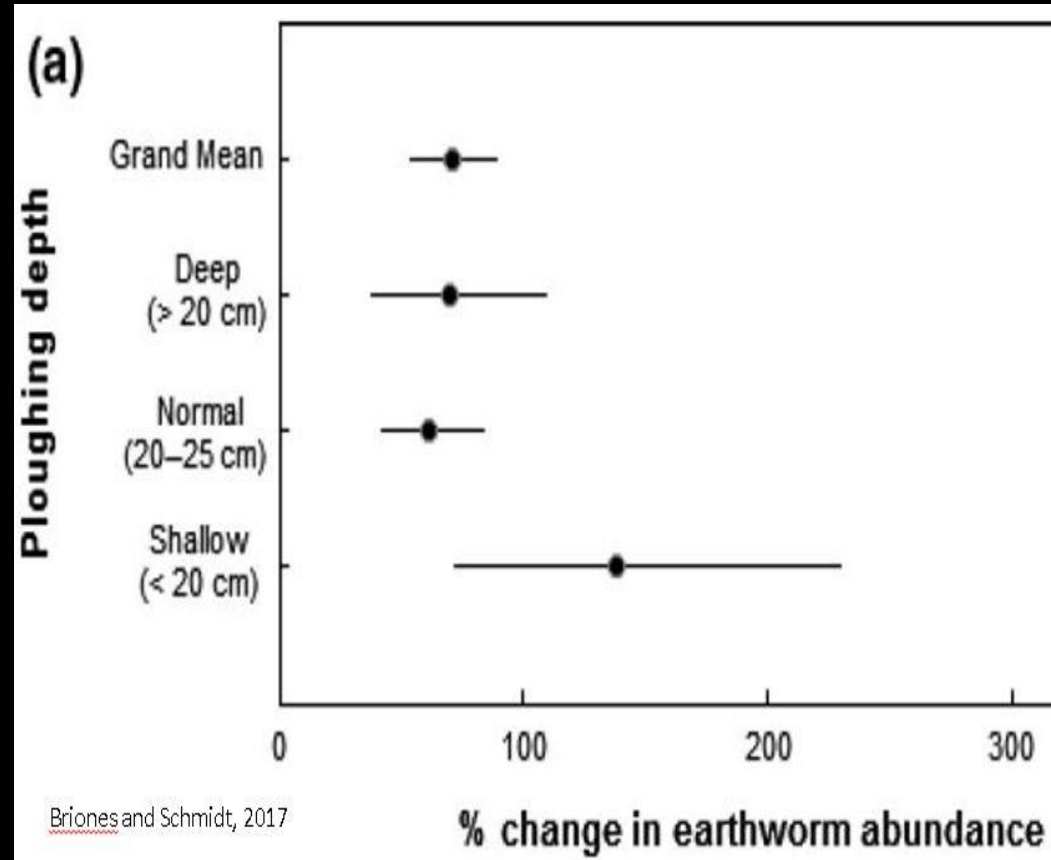
# How can you help earthworms under tillage on your farm?

## Practical tip – reduce ploughing depth & frequency

- **Ploughing Depth**



- Down to the makers name?

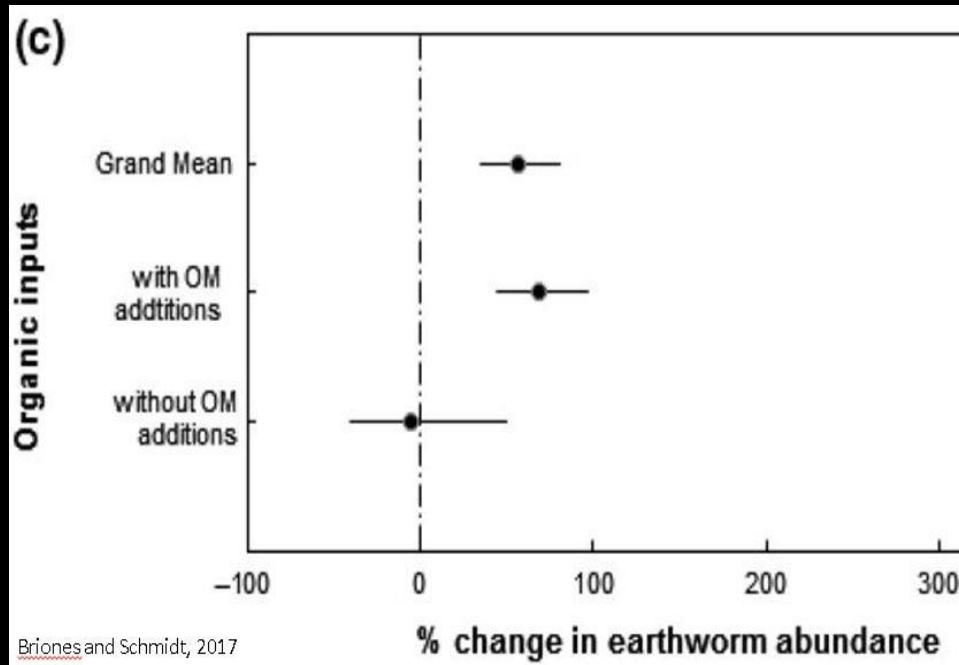
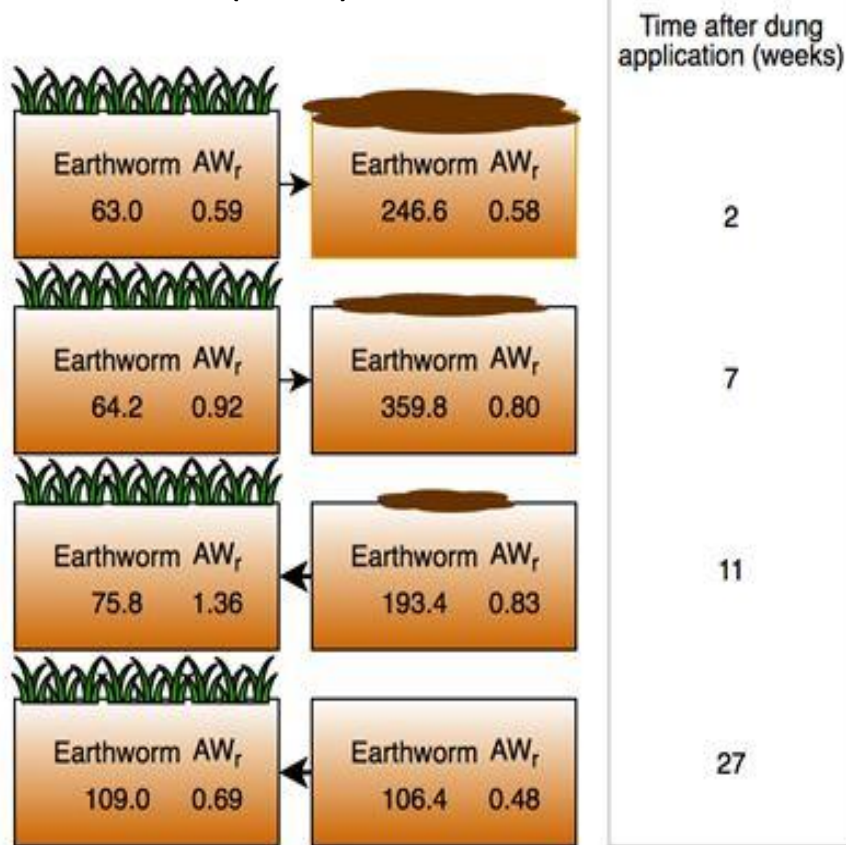


# How can you help earthworms under tillage on your farm?

Practical tips – add Organic Manures

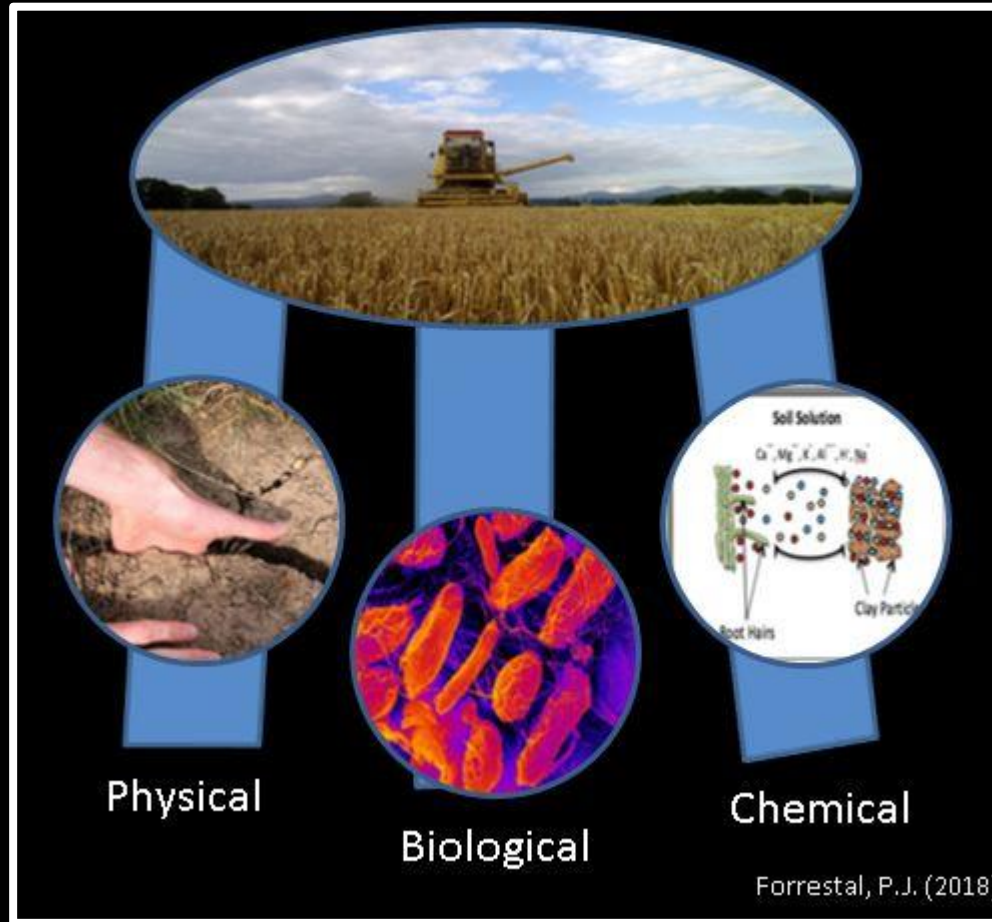


Bacher (2018)



# Three pillars of soil health

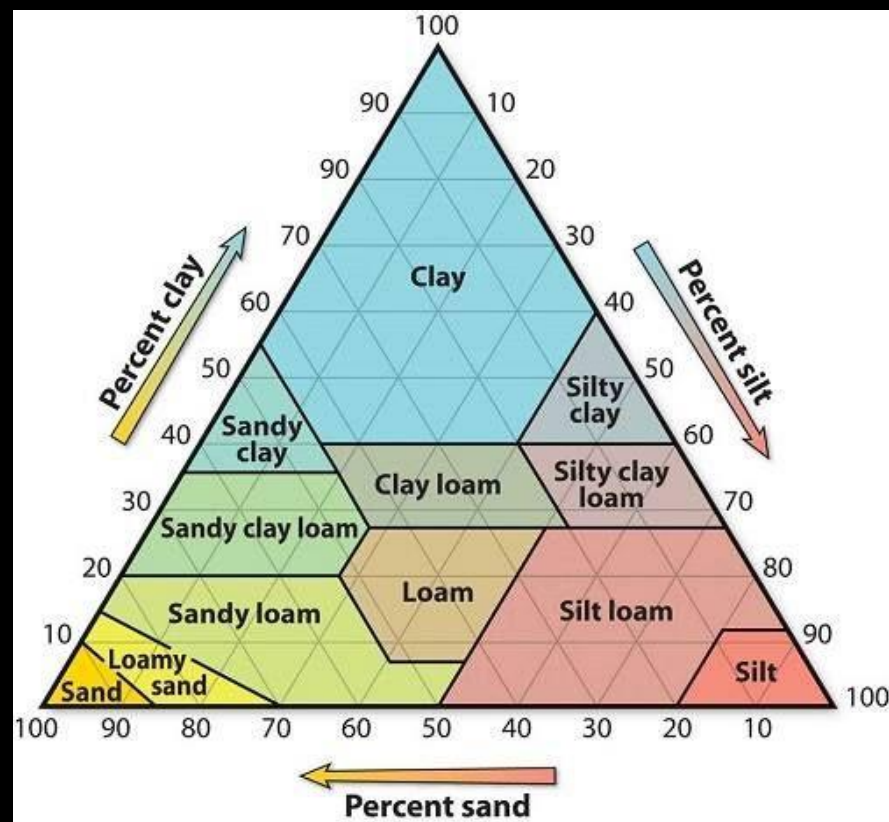
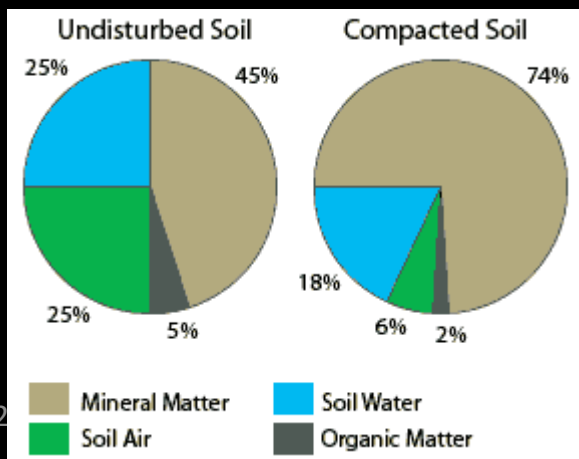
Soil is only at its best productivity with focus on all three  
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# The physical

Texture, structure, aggregation,



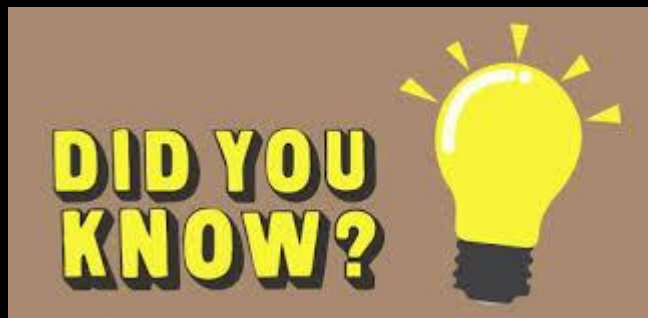


# Generalised properties/influences of separate particles

Property/ behaviour	Sand	Silt	Clay
Organic matter de-composition	Rapid	Moderate	Slow
Spring warm up	Rapid	Moderate	Slow
Nutrient store & resistance to pH change	Poor & Low	Medium	High
Shrink-swell potential	Very low	Low	Moderate to very high

Adapted from Weil and Brady exceptions due to soil structure and clay mineralogy occur

# The power of the clay fraction



More clay – more surface area  
A spoonful of clay can have the  
surface area of a football  
field!

Huge management implications:  
Compaction & recovery, warm up,  
tillage

So did you see cracking in your fields  
this summer?



# Did you see cracking in your fields this summer? What can we learn from it?





# The natural cracking and micro scale fissuring due to dry conditions is more beneficial than mechanical interventions



## Deep Loosening Effective?

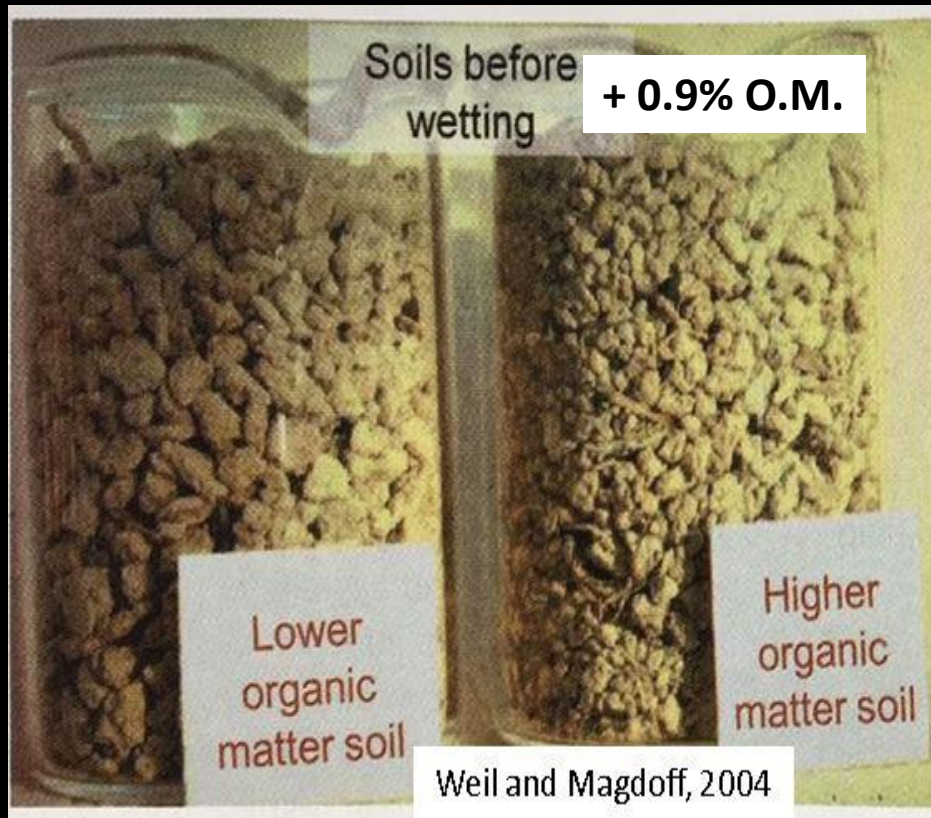
- ◆ Prevention is better than cure
  - ▶ Avoid the need for deep loosening
- ◆ Research not clear-cut
  - ▶ Re-compaction risk is real
  - ▶ May shift problem down the profile
- ◆ Loosened soils
  - ▶ Loose to depth of subsoiler
  - ▶ More moisture through profile



Credit:  
Dermot Forristal

**Prone to Re-Compaction and to depth !**

# Role of Organic Matter in soil physical health and compaction resistance



- O.M. => energy for biological activity => organic polymers – decaying O.M.
- Silts and clays become coated
- Compounds orient clay into packets binding soil into water stable aggregates



# How can you increase soil organic matter? Practical tips

Add more carbon to the soil – but how?

- Organic manures

Retention coefficient of 14% in long-term trials (Fornara et al., 2016)

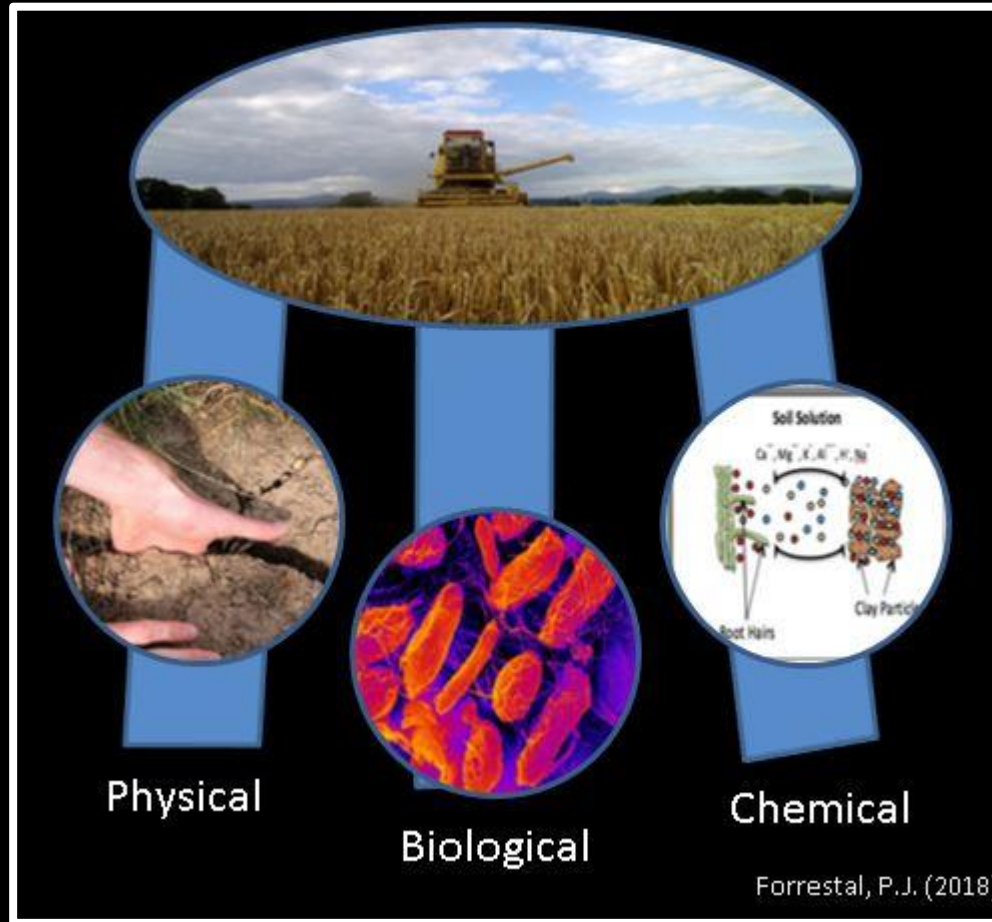
- Photosynthesis – green manures



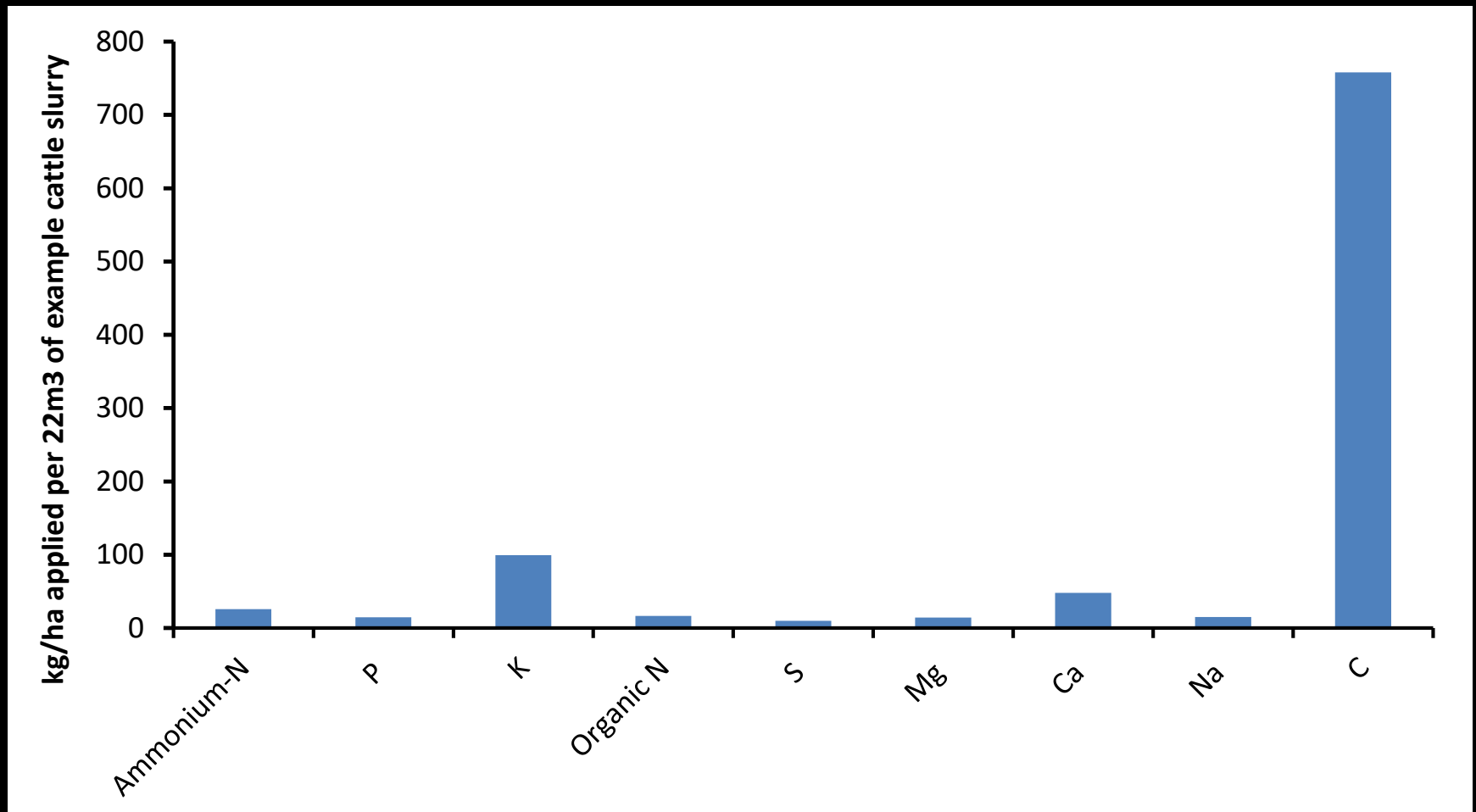


# Three pillars of soil health

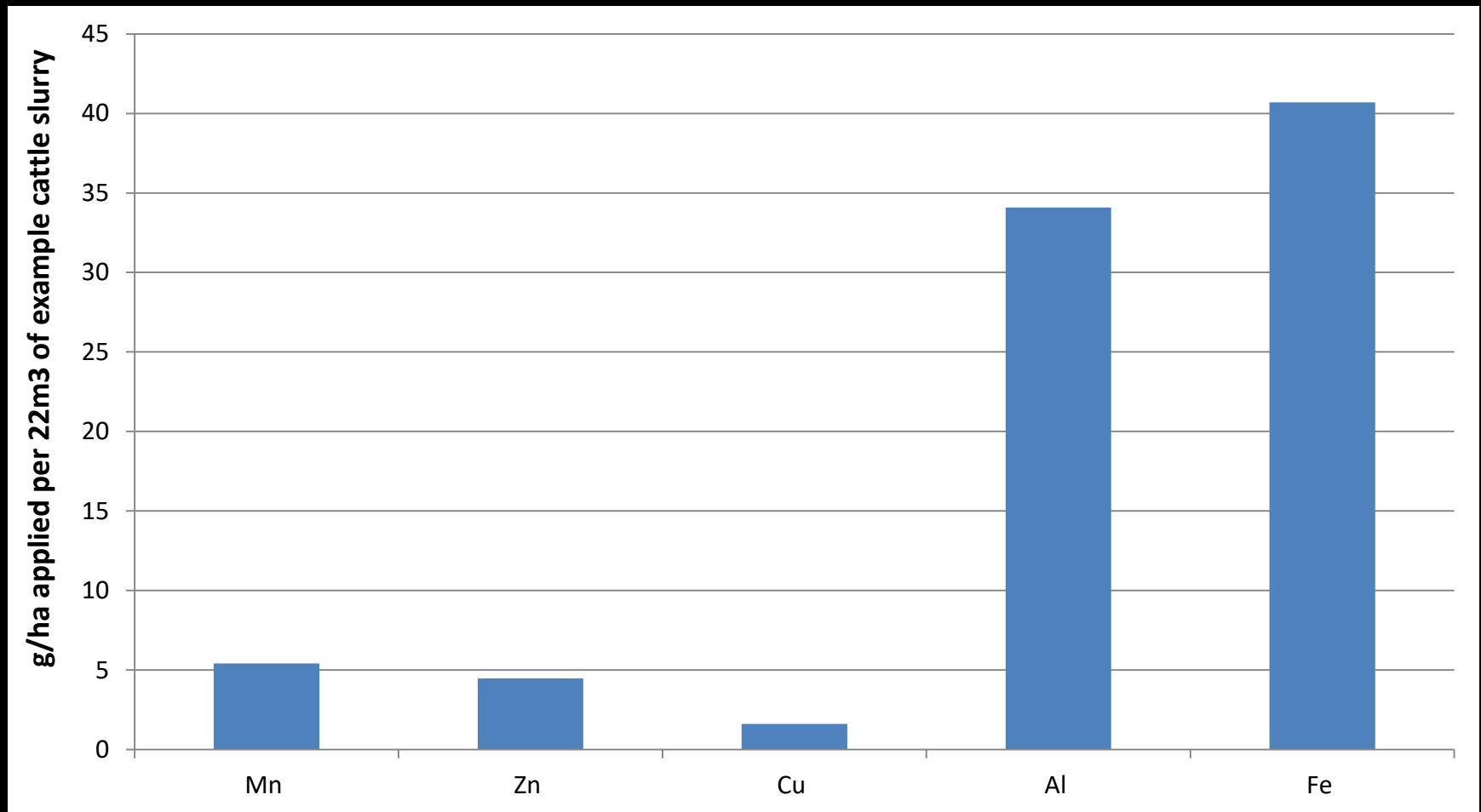
Soil is only at its best productivity with focus on all three  
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# An example of what is in cattle slurry beyond the available N: P: K



# An example of what is in cattle slurry beyond the available N: P: K





# First year mineral fertiliser N replacement value

Forrestal P.J., Bourke, M, Plunkett, M



## Methods

Randomised complete block experimental design with 4 replications

Sandy loam soil

Ploughed, pressed, basal P, K, S, Mg, Ca dressing to all plots



Manure  
88% D.M.  
3.8% N



Manure rates  
90, 135, 180  
270, 360 kg N/ha



Calcium ammonium  
Nitrate Rates (CAN)  
50, 100, 150,  
200, 250 kg N/ha



Manure & 50 kg  
N/ha CAN tilled  
in during sowing

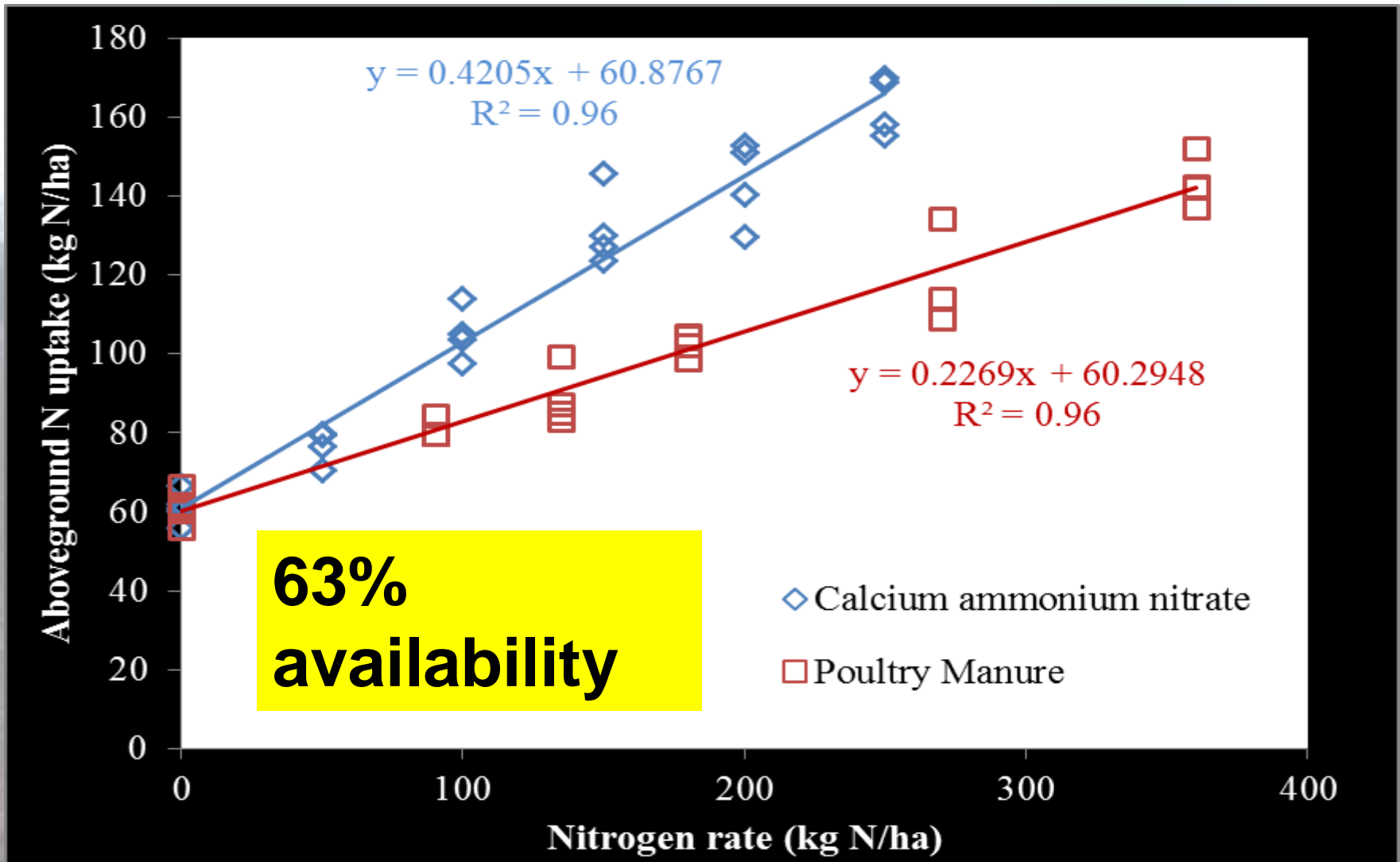


Harvest &  
aboveground  
biomass

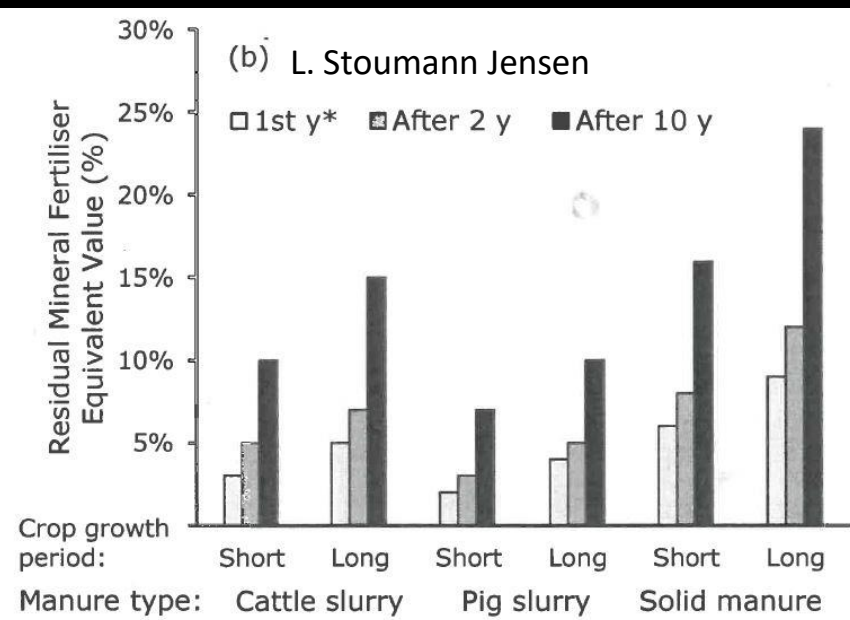
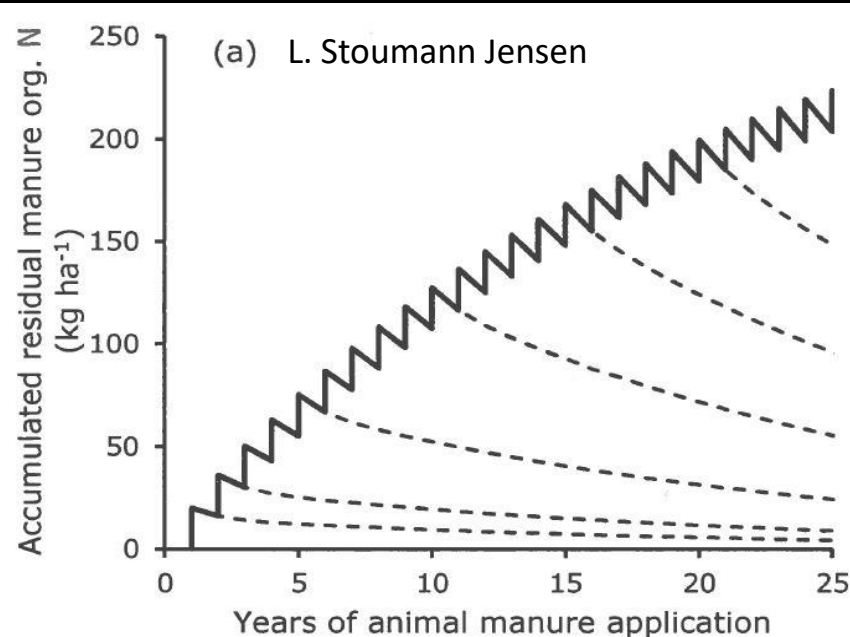


Nitrogen  
content  
analysis

# First year N availability compared to CAN



# Organic N – long-term



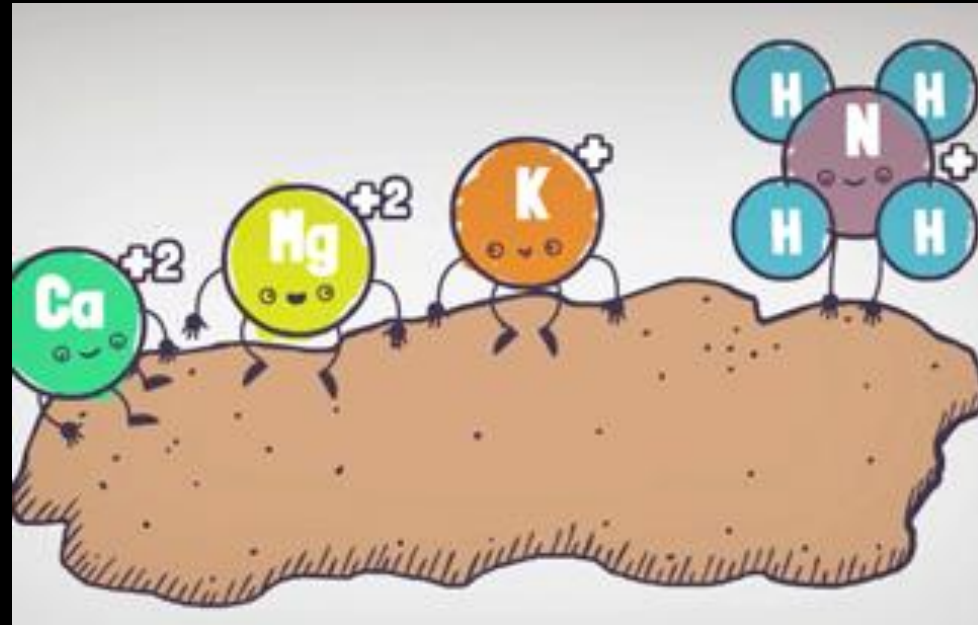
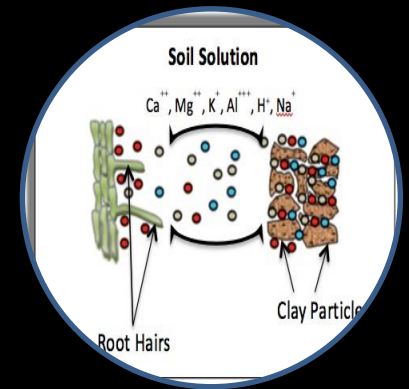


# The chemical health

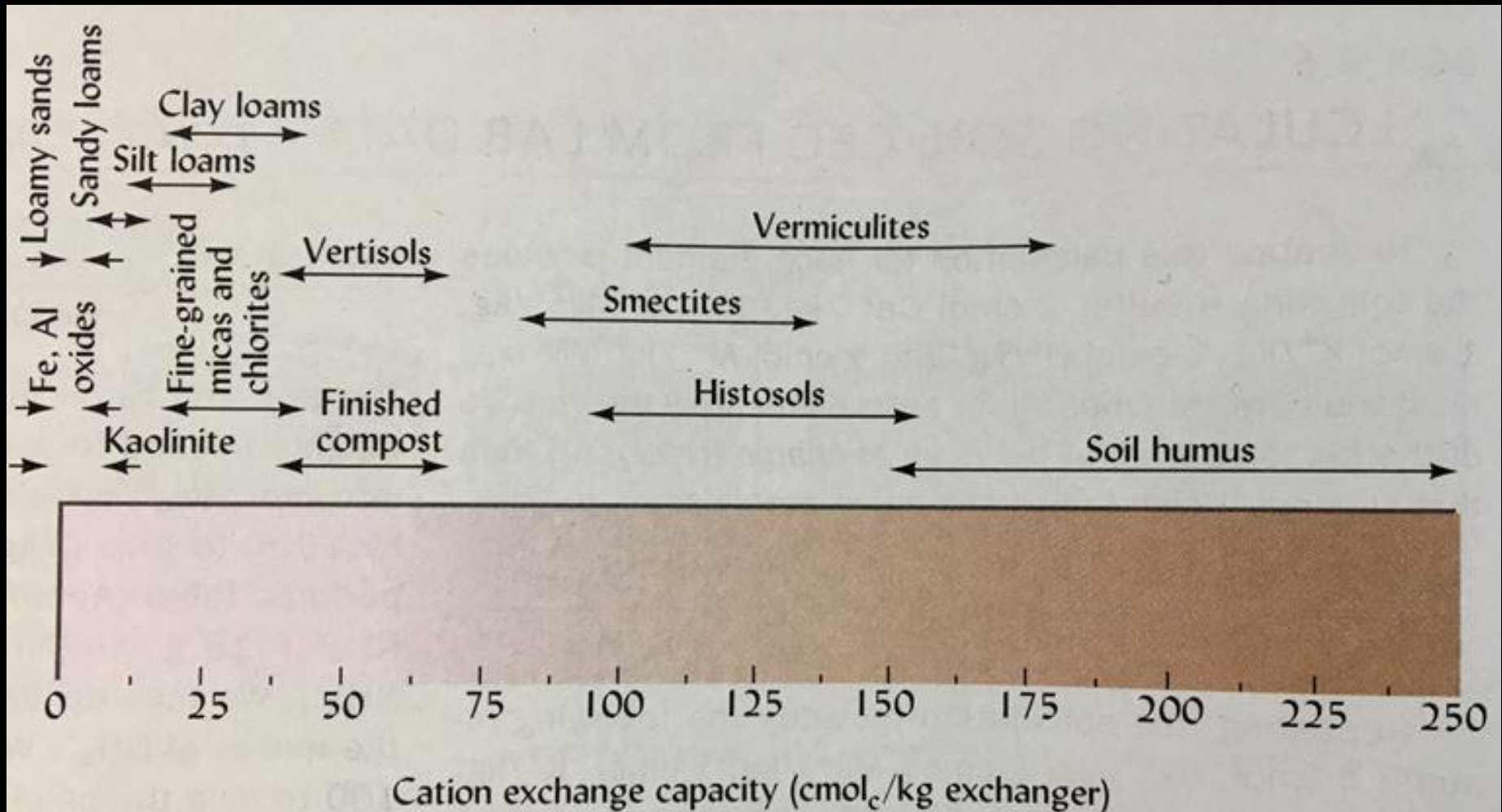
Heavily influenced by  
**cation exchange capacity** of a soil

Sum of all exchangeable  
cation charges that a  
soil can hold

- Ability to store and supply nutrients
- Resist pH change

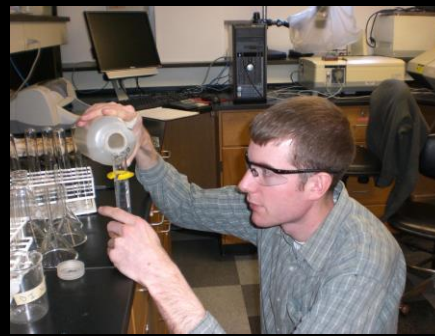


# CEC of various soil fractions

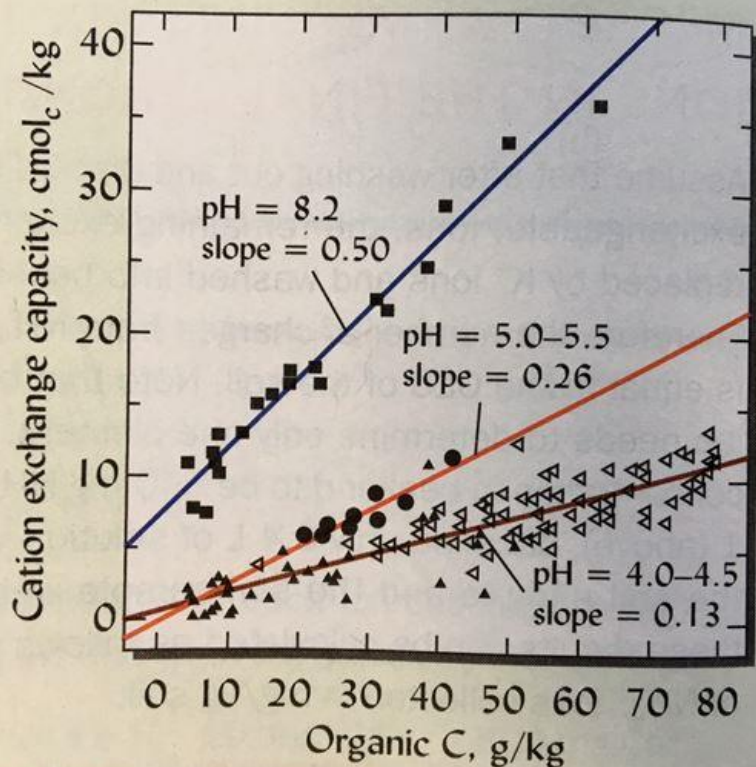


Weil, R. nature and Properties of Soil

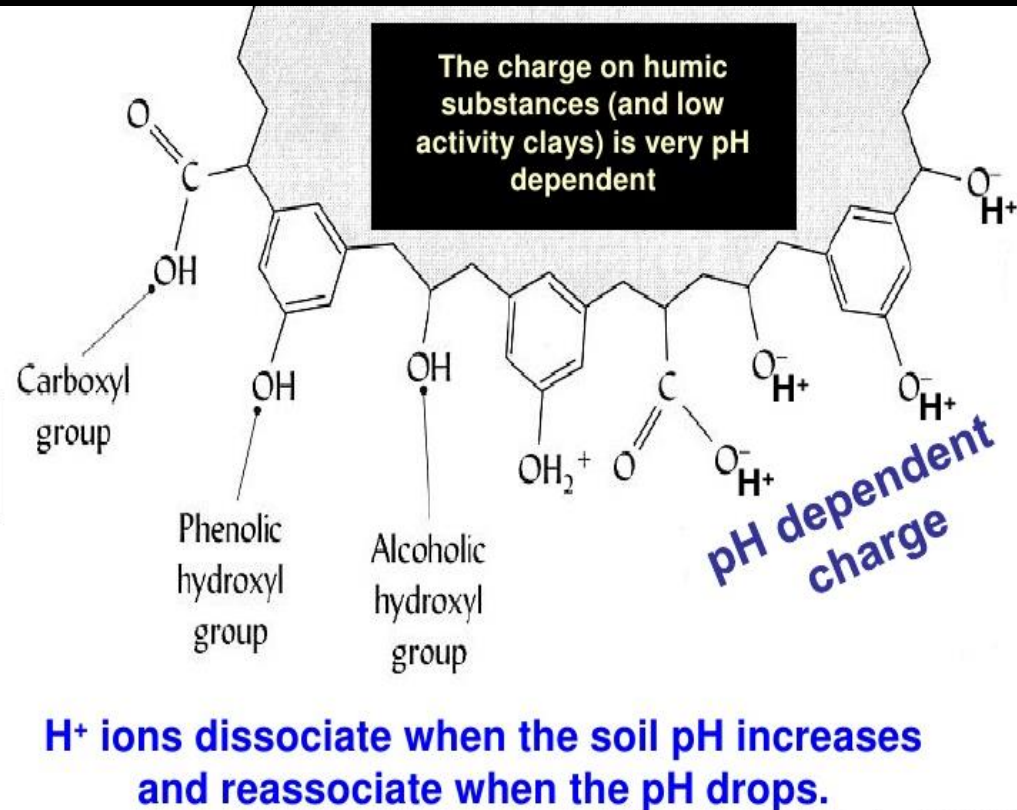
# Organic matter - humic substances CEC & pH



Practical tip: correct pH to get most out of the O.M. you have



Weil. R Nature and Properties of Soil



Brady and Weil (2002)



## Lessons from other farmers

- Francis Childs (1939 -2008)  
3 time world record maize grain yield.
- 2002: 27.7 t/ha (11.2 t/ac)



“The Foundation for producing BIG yield is **building a healthy soil environment**. It all starts with the root zone get *healthy roots* and *healthy plants*, and the yield will be high”

# Thank you