Soil Quality:
Soil Indicators

Dr. Paul Hargreaves
SRUC Dairy Research and Innovation Centre

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Soil – air, water, minerals

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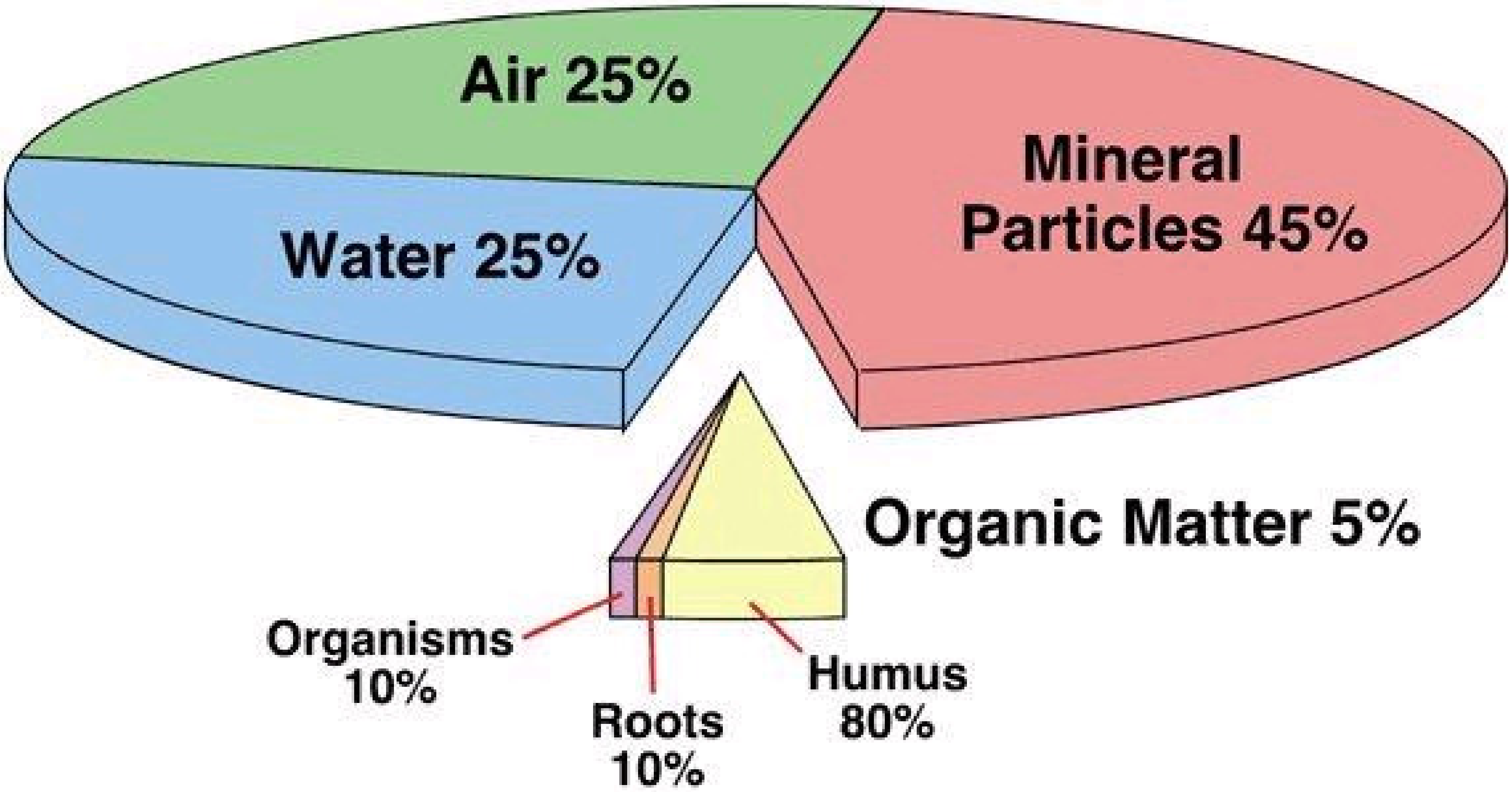

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Soil functions

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Reduce gas losses,
N_2O, N_2, NH_3 and CH_4

Support hooves and wheels

Recycle nutrients
in wastes

Store water and plant nutrients –
minimise runoff, sediment
and fertiliser losses

Prevent NO_3 and pesticide leaching losses

Good soil function increases profitability and conserves the environment

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Ecosystem services

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- **Supporting** — Nutrient recycling, primary production and soil formation, make it possible for the ecosystems to provide other services
- **Provisioning** — Food, crops, raw materials (including timber, fodder, and fertilizer), genetic resources (including crop improvement genes), water
- **Regulation** — Carbon sequestration and climate regulation, waste decomposition, purification of water, pest and disease control
- **Cultural** — Spiritual, historical, recreational

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Soil Profile

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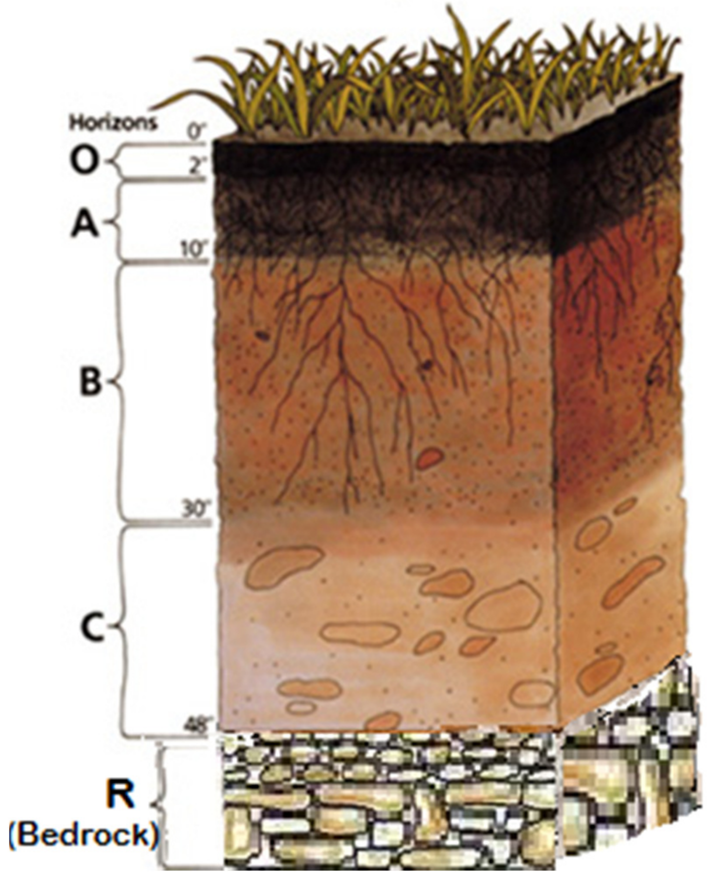

'O' horizon – Organic horizon, generally dead plant material. Can be missing - deeper in forest soils.
'A' horizon – Top-soil, usually contains most organic material and has the greater mass of roots – most biological activity, with greater soil structure
'B' horizon – Sub-soil, can be several metres thick, usually of a greater density than the top soil, less organic material, greater mineral content. Lighter in colour.
'C' horizon – Parent material, generally undefined layer containing more minerals, can be from the underlying rock material or bedrock, but not always the case.

Sand, Silt and Clay

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Sand – mostly quartz, feldspar and mica (fragments) traces of heavy metal, low surface area

size – between 0.06mm and 2.0mm

Silt – mineralogical composition is similar to sand, intermediate surface area

size – between 0.002mm and 0.06mm

Clay – reactive fraction of soil, colloidal, large surface area, high charge density

size – less than 0.002mm

The Soil Triangle

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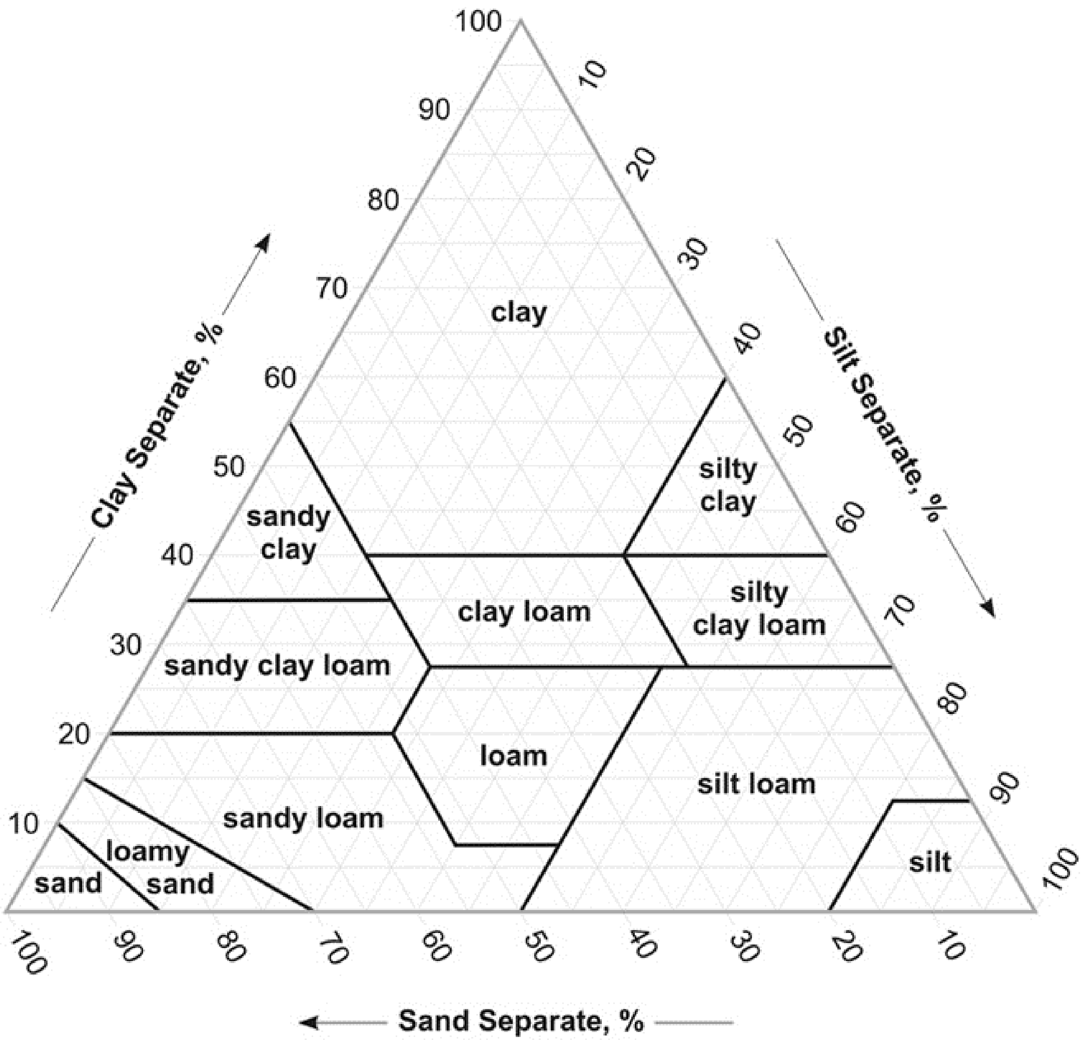

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Soil Structure

Structure is the how the particles bind together to form aggregates that allows:

- roots to anchor the plant
- water to drain through pores and cracks
- water retention
- air to roots for favourable gas exchange
- mineralisation of nutrients and release to crop roots
- biodiversity of microbes

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Organic Matter

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- Soil plays a major role in the global carbon cycle, with the global soil carbon pool estimated at 2500 gigatons, 3.3 times the size of the atmospheric pool and 4.5 times the biotic pool.
- Organic material in the soil comes from the breakdown of plant and animal material.
- Depending on their chemical structure, decomposition is rapid for sugars, starches and proteins (days), slow for cellulose, fats, waxes and resins (months) or very slow for lignin (years).
- 35-80 % of the non-living part of organic matter is humus

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Living Soils

- Huge quantity of organisms
  - Fauna: 1-5 t/ha
  - Fungi: 3.5 t/ha
  - Bacteria: 1.5 t/ha

F. Ippolito

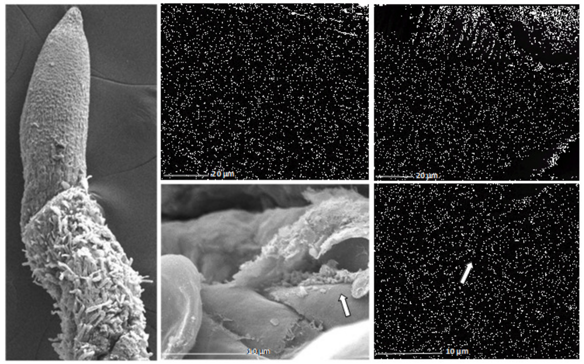
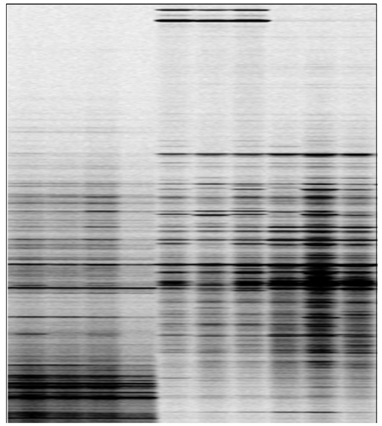


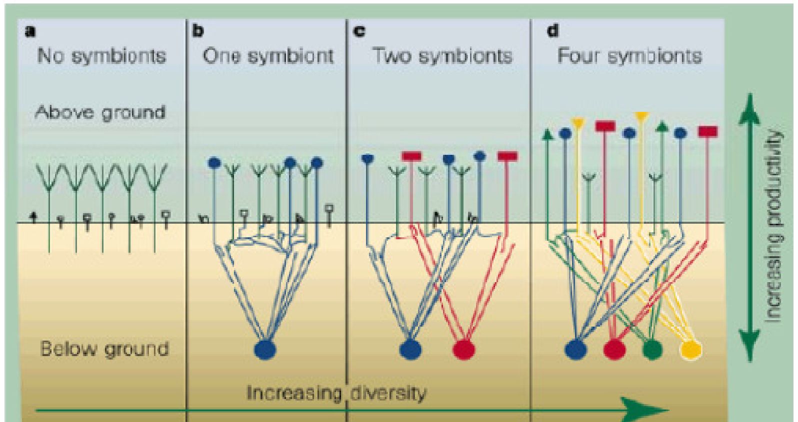
Photo : L. Avoscan & A. Viollet



- Fantastic diversity
  - Until recently: only access to culturable microorganisms
  - Methodological progresses
    ⇨possibility to extract DNA from soils

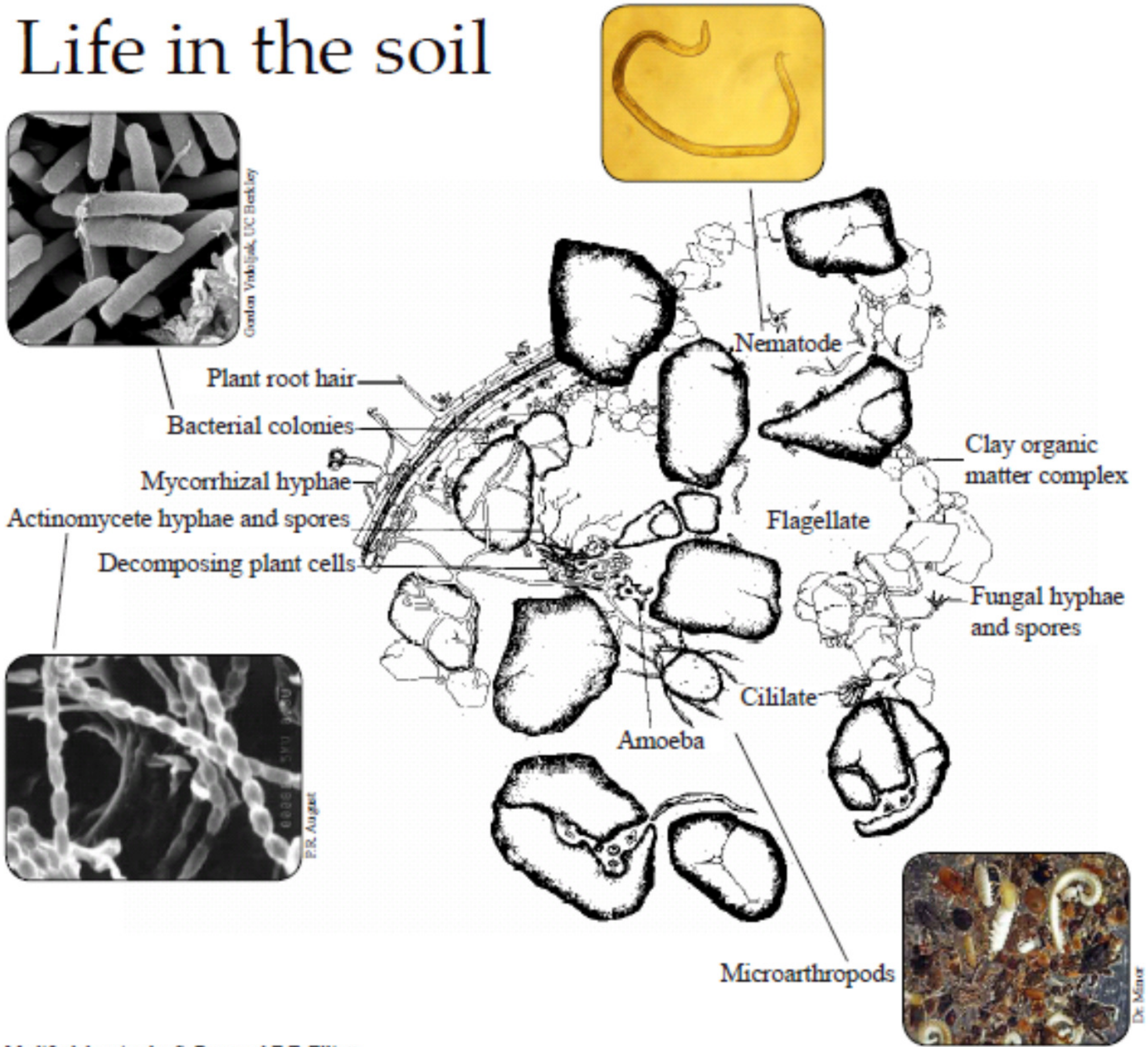
    ↳ $10^4 – 10^6$ bacterial genotypes / g soil

- A lot to be explored on the relations between below & aboveground diversity



Van der Heijden et al. 1998. Nature 396:69-72

What lives in the soil?



Modified drawing by S. Rose and E.T. Elliott

Soil Biota

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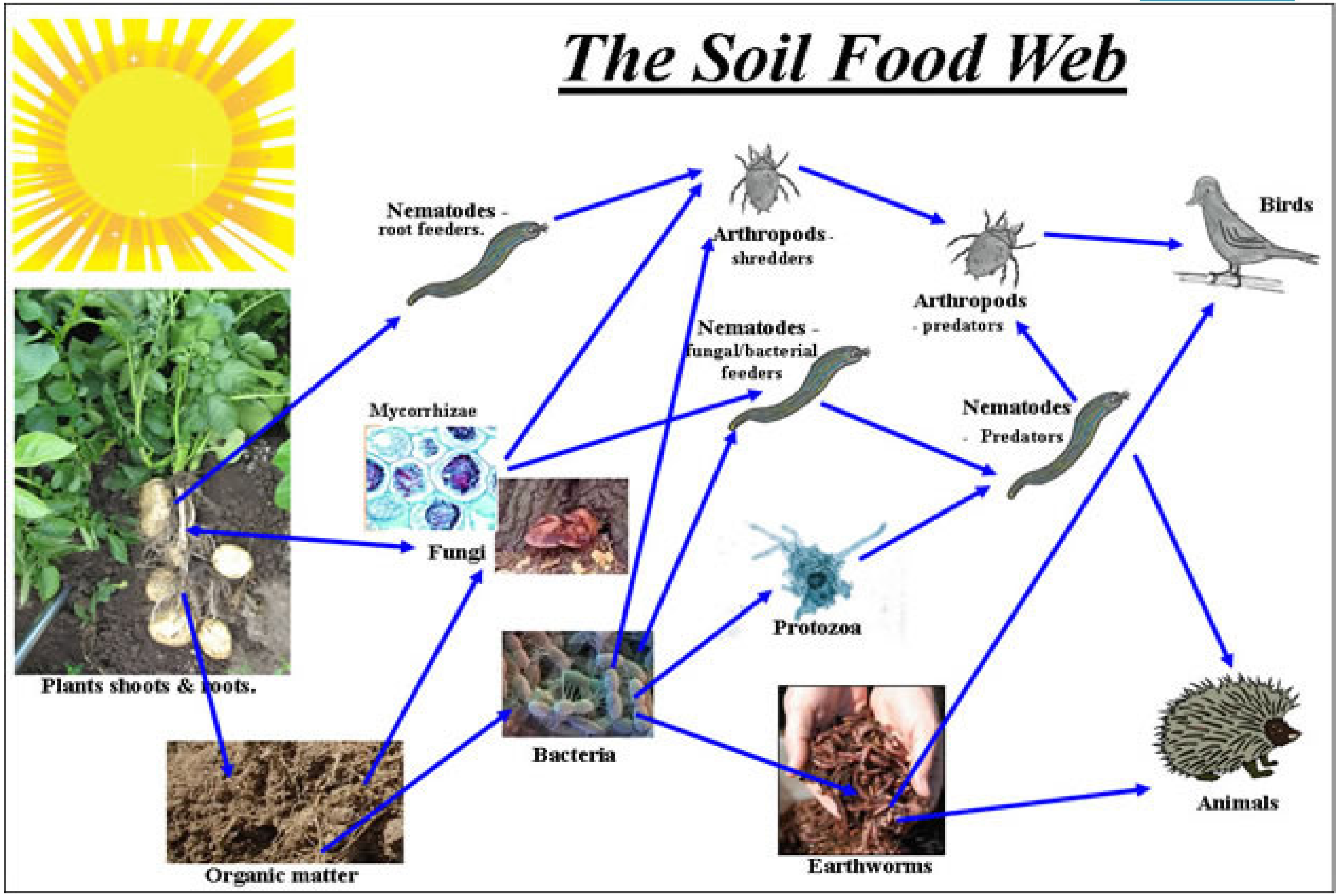

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Carbon Cycle

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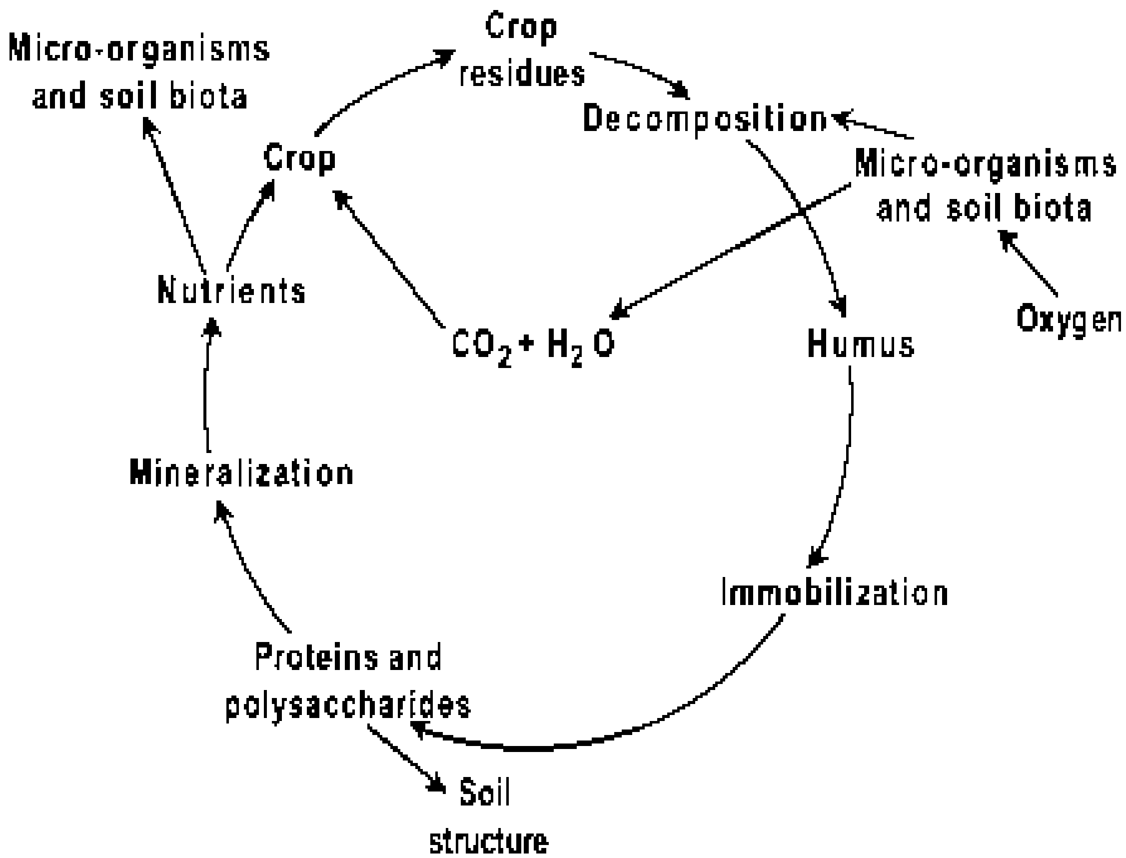

Complex organic carbon molecules are broken down to simpler molecules.

Used as an energy source
for the different fauna and flora within the soil.

Earthworms

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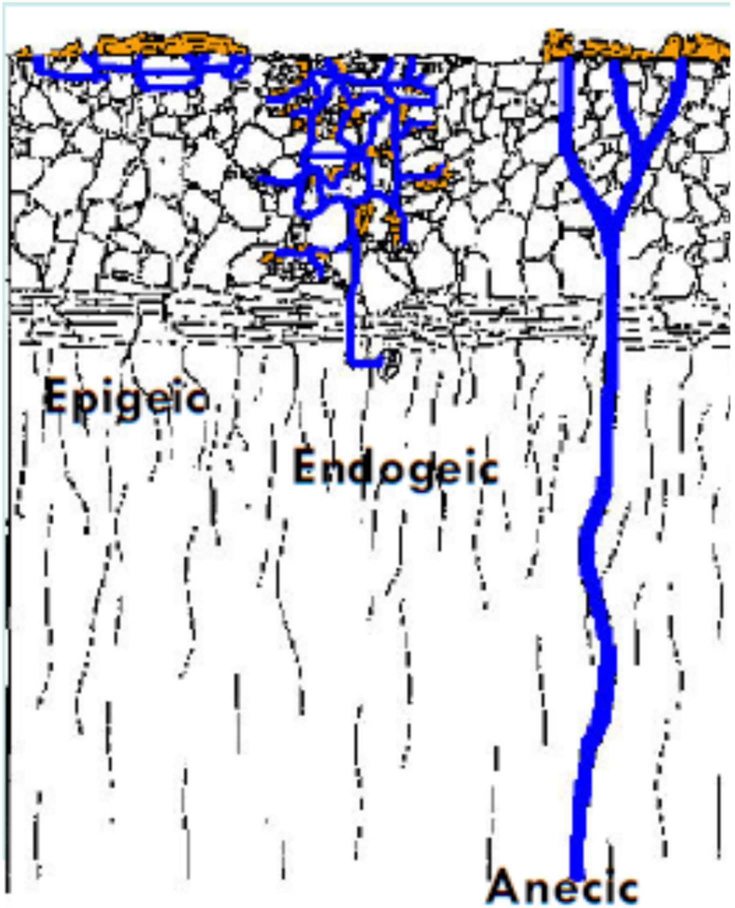
Can be very good indicator of soil quality as:

- they do not move very far (10 metres)
- can live for up to 10 years
- exposed to soil changes – pH, waterlogging, compaction, organic matter

Earthworms



Modified from Fraser and Boag 1998

Three main types:

Litter Feeders (Epigeic) – found close to the soil surface or in the litter layer

Shallow Burrowers (Endogeic) – found in extensive borrows close to the soil surface and feed on organic material

Deep Burrowers (Anecic) – more vertical borrows and mix mineral soil with organic material from the surface

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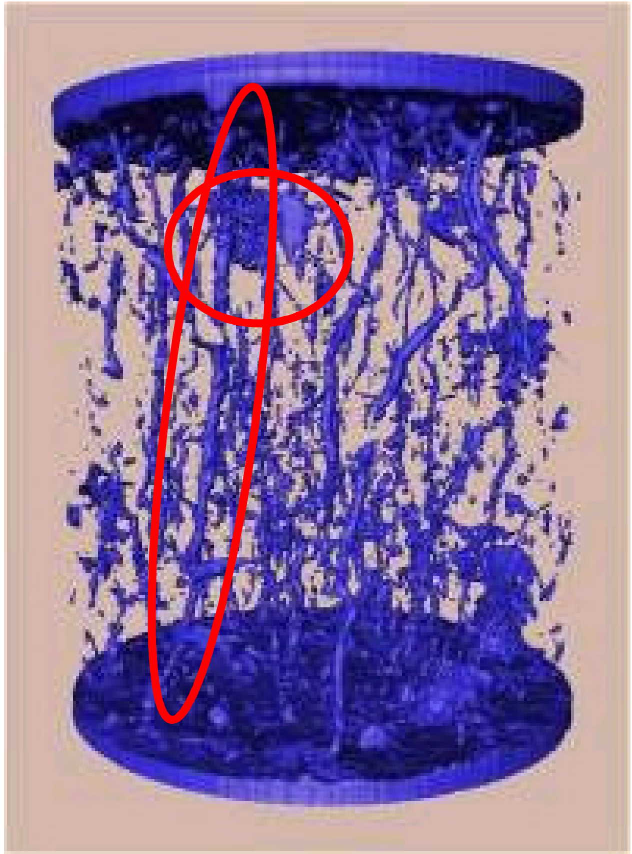
Soil Pores

Dye labelling



Computer-aided tomography

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Aggregates Sizes

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Soil After Compaction Treatments

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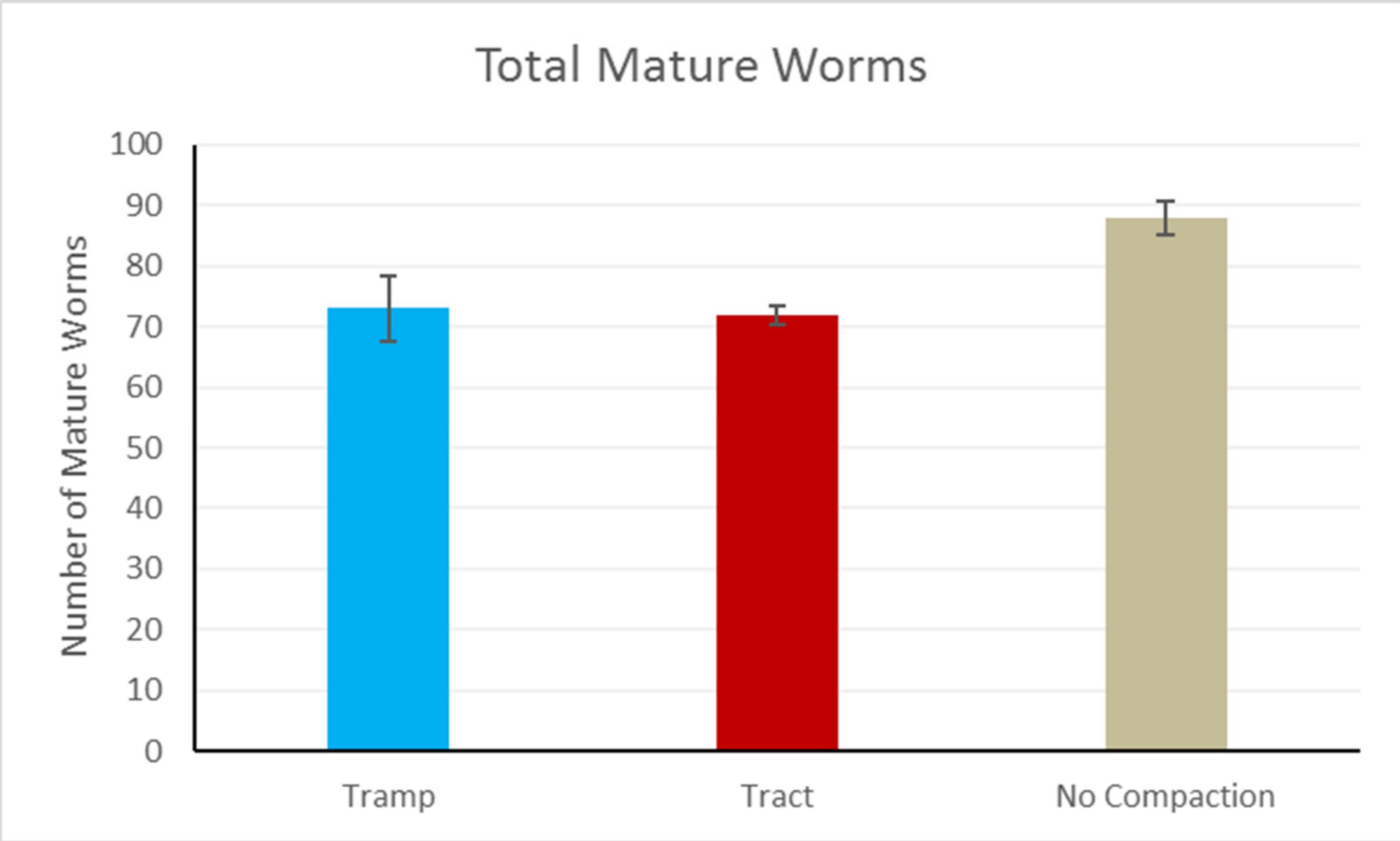
Earthworms and Compaction



Earthworms and Compaction

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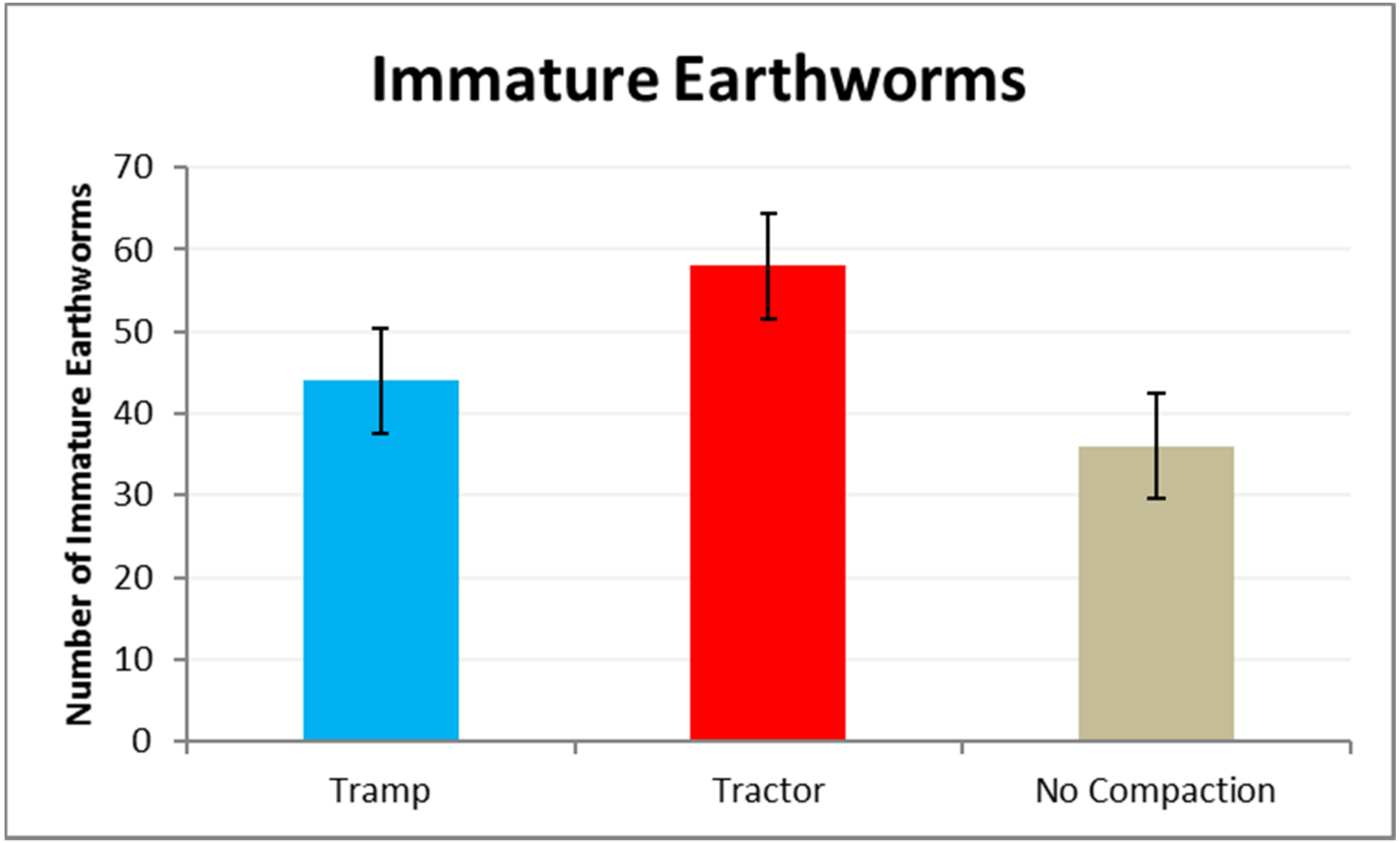

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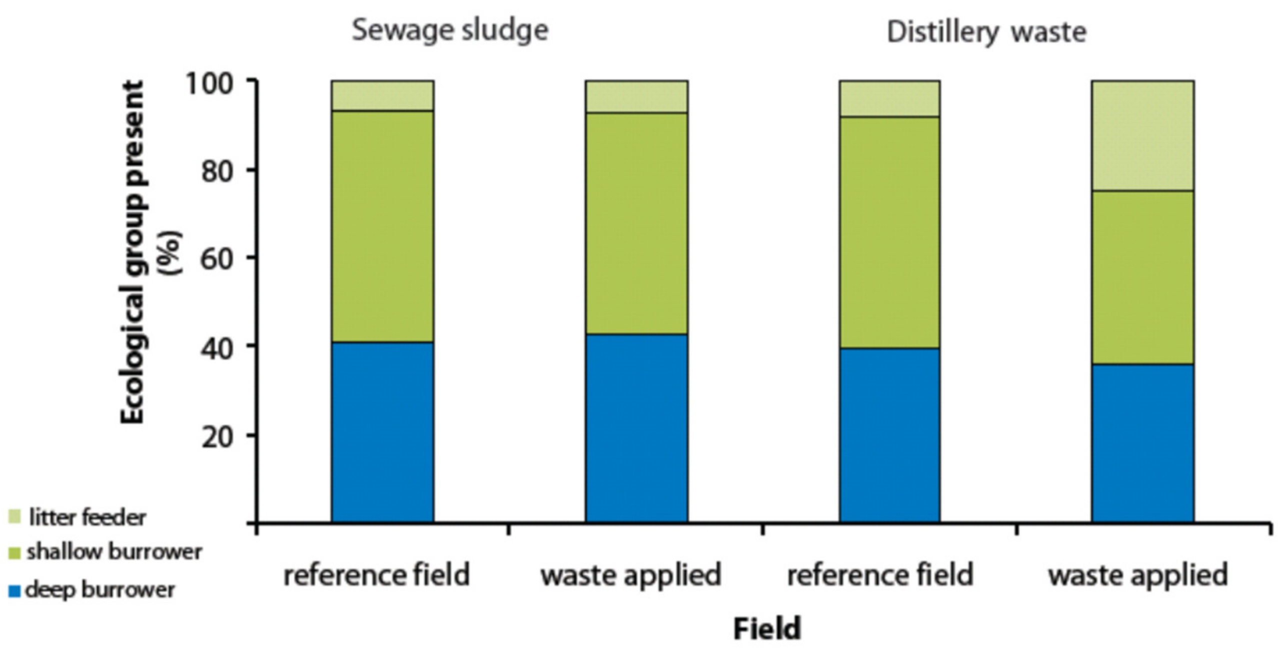
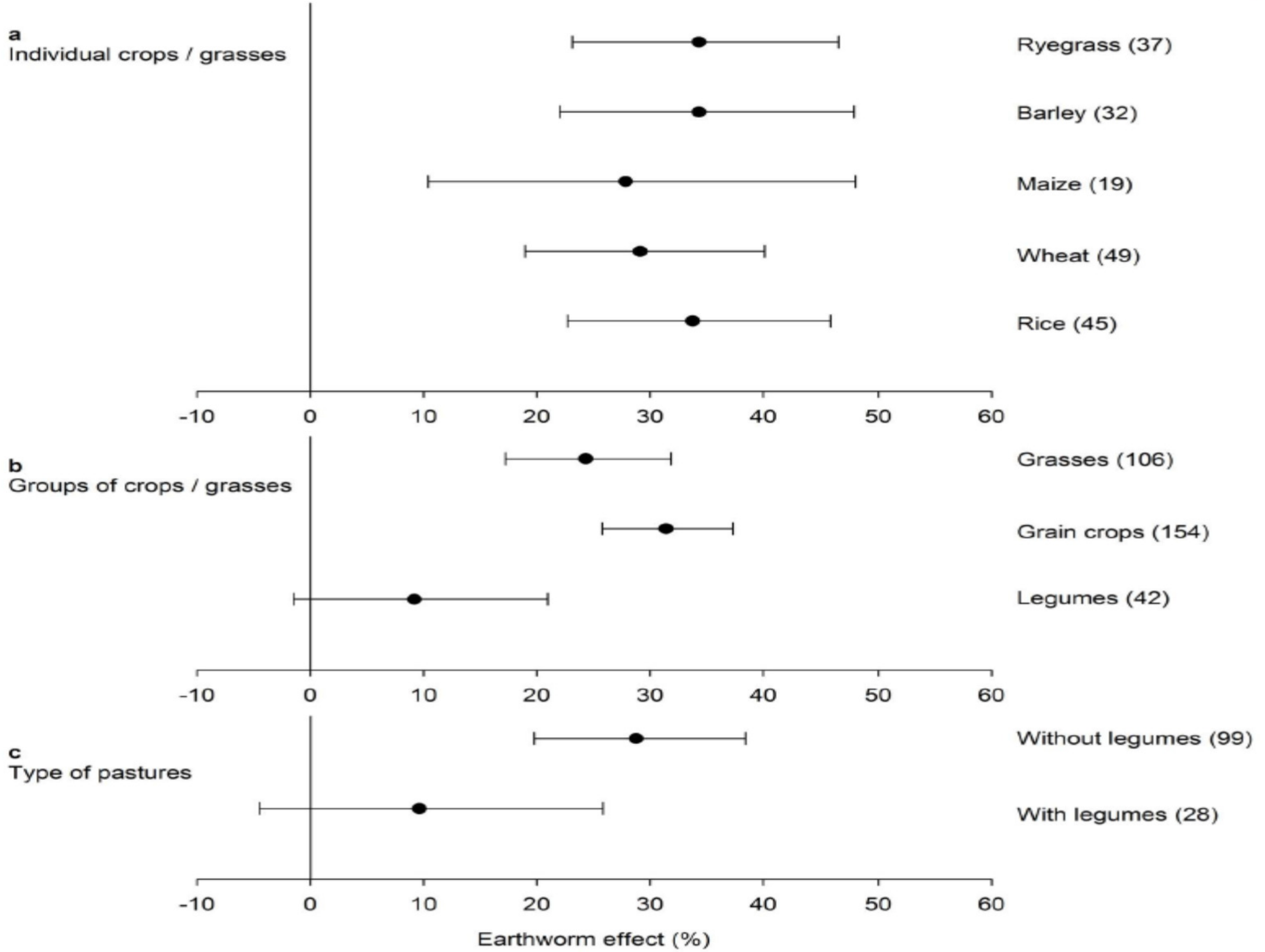
Earthworms and Compaction

Earthworms

Figure 6.3: Relative abundance of the three ecological earthworm groups in fields receiving sewage sludge, distillery waste and their respective reference fields [(SEPA's soil compliance monitoring (SEPA SCM)]



Positive effects of earthworms on yield



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Van Groenigen et al 2014

Earthworm Identification I

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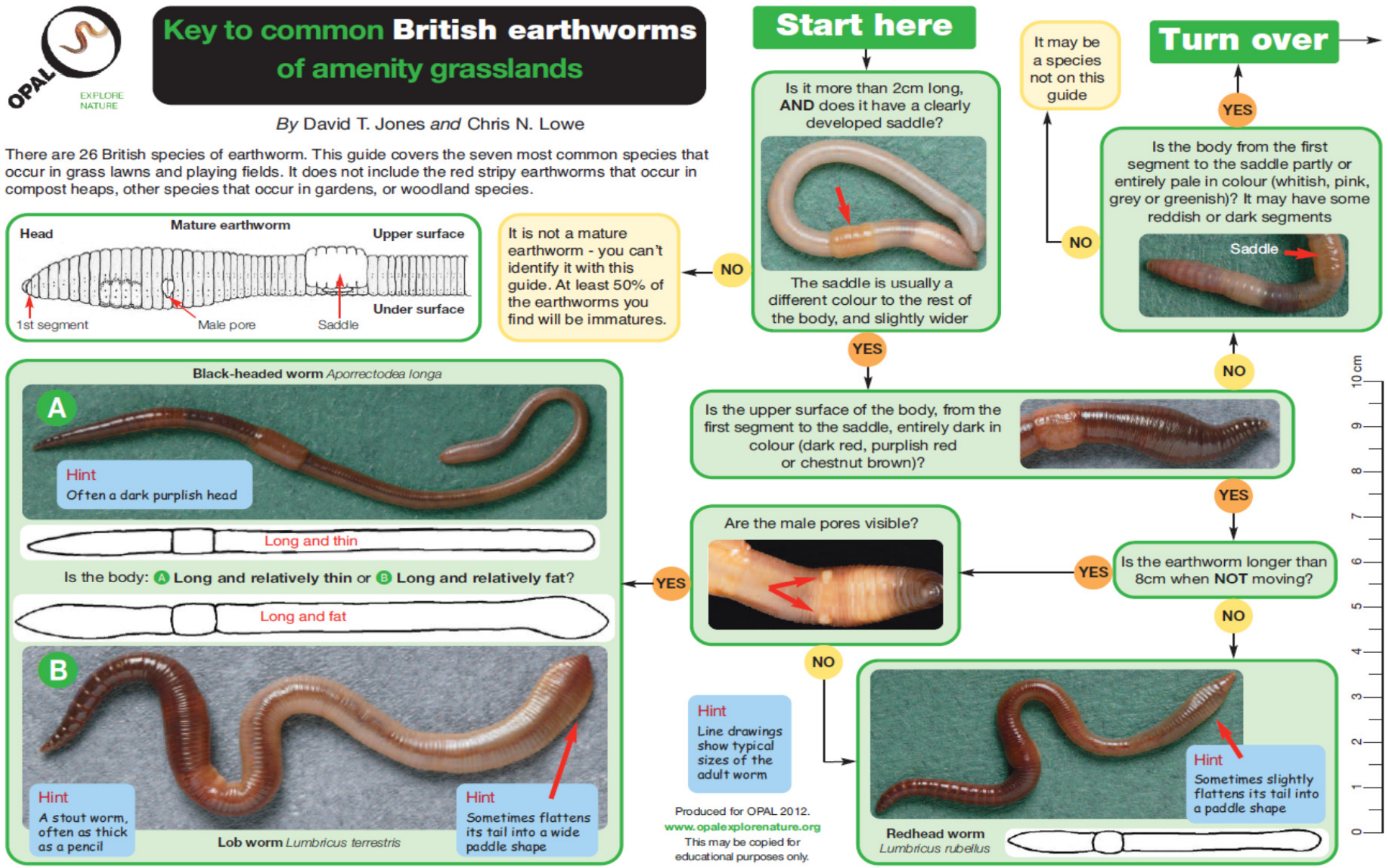

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Earthworm Identification II

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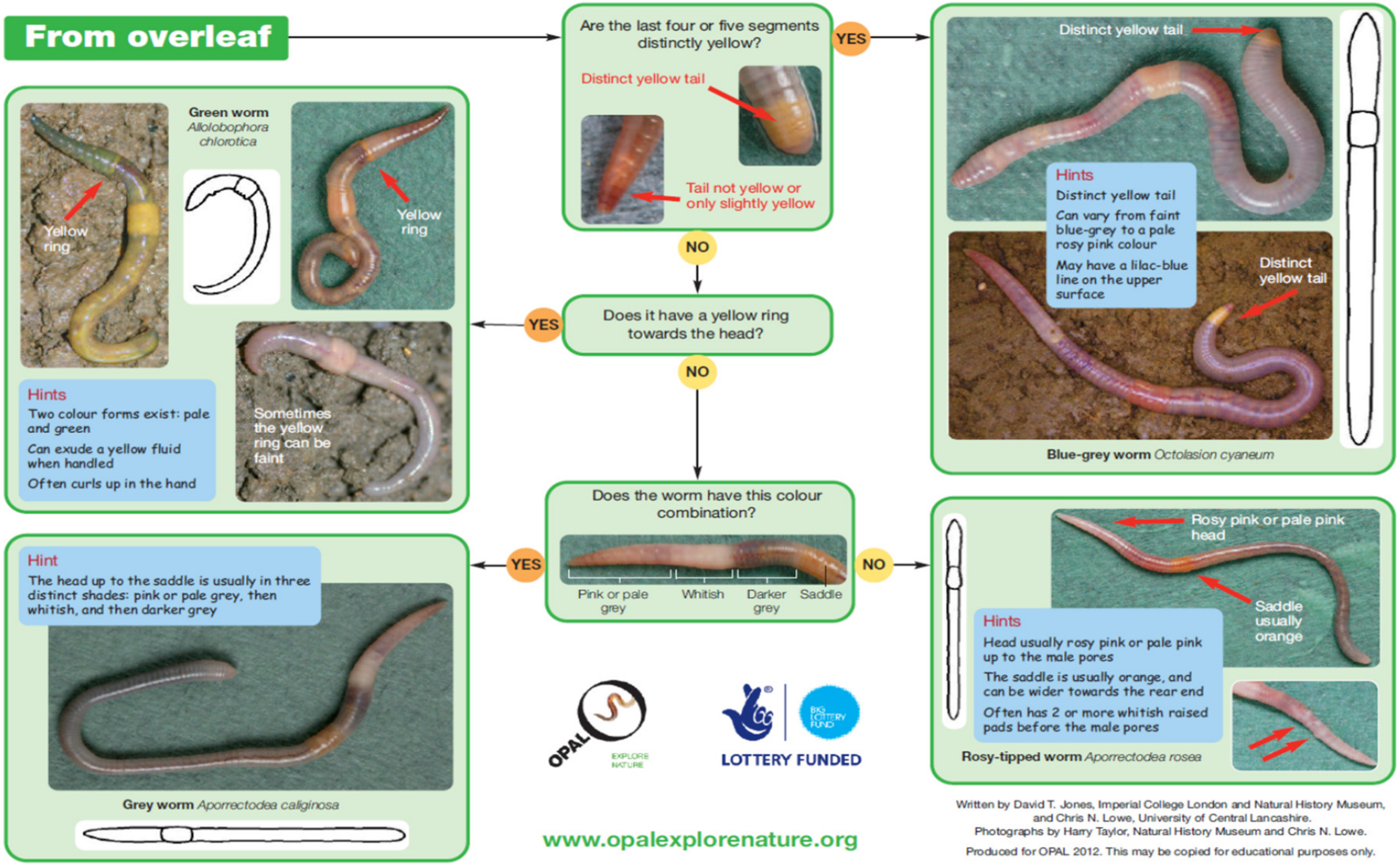

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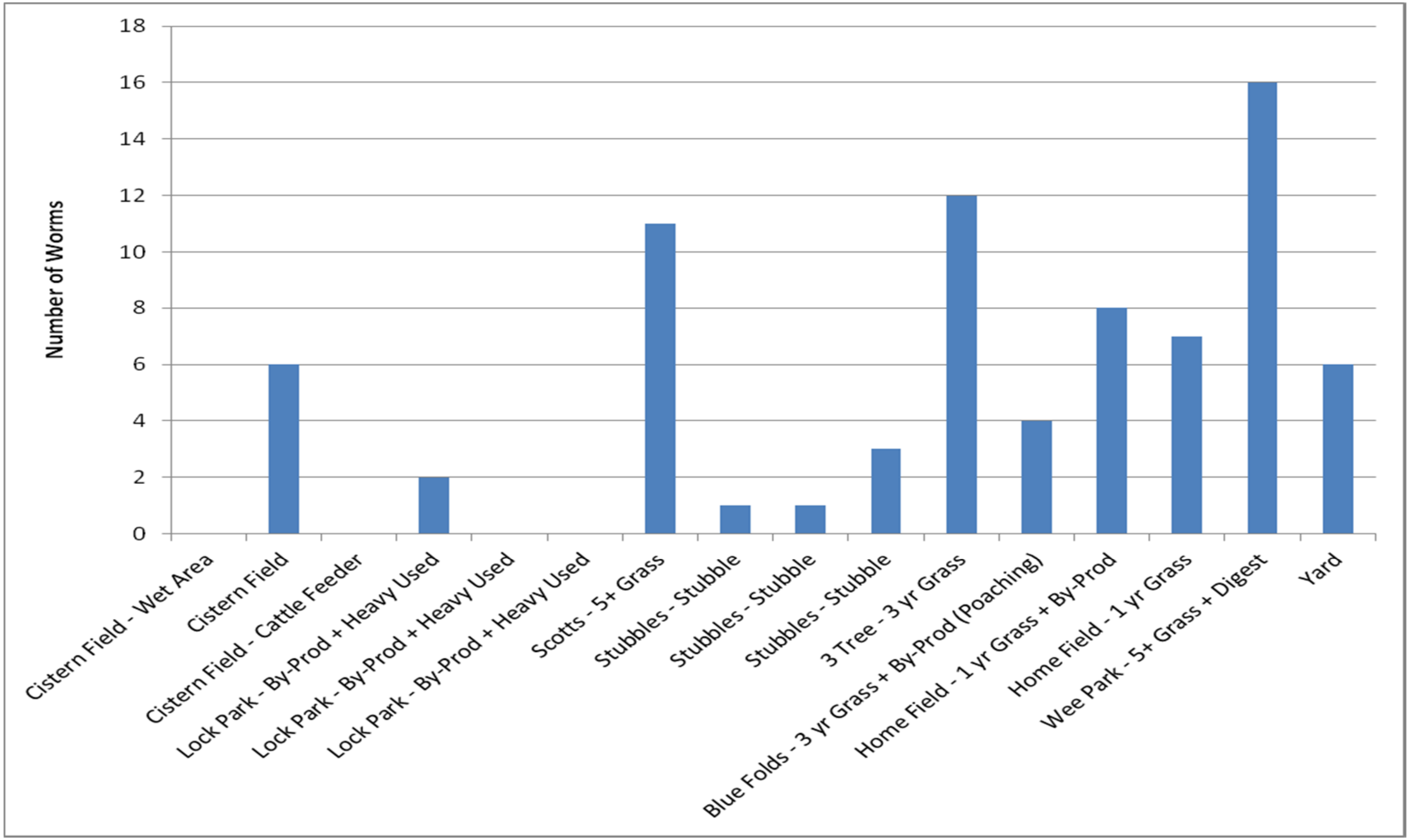
Local Worm Numbers



Other Methods

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Compaction and Nitrogen Use

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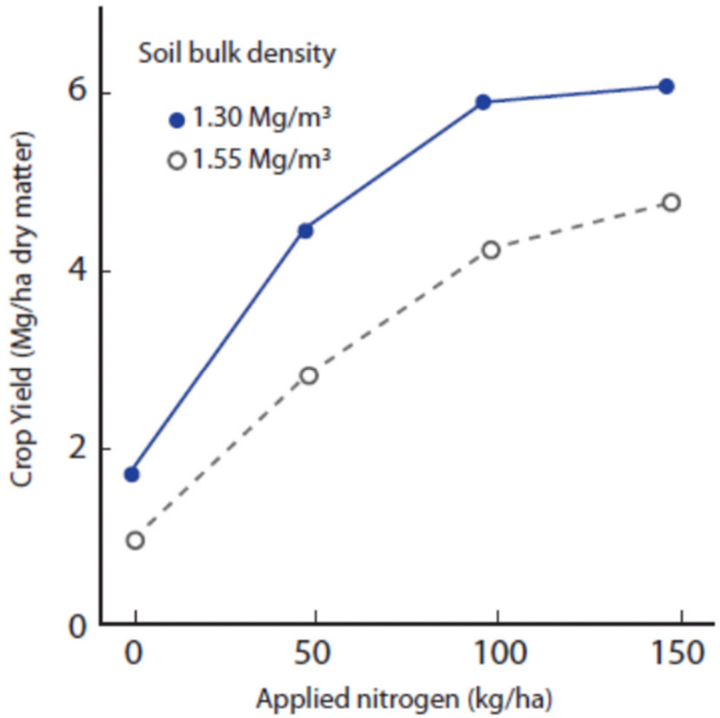

Figure 8.3: The relationship between the amount of nitrogen applied and crop yield under different compaction regimes. A compacted soil (bulk density of 1.55 Mg/m^3) may require more nitrogen to obtain a similar yield to a non-compacted soil (bulk density of 1.30 Mg/m^3). From Soane and Vanouwerkerk (1995)

Surface – Visual Clues

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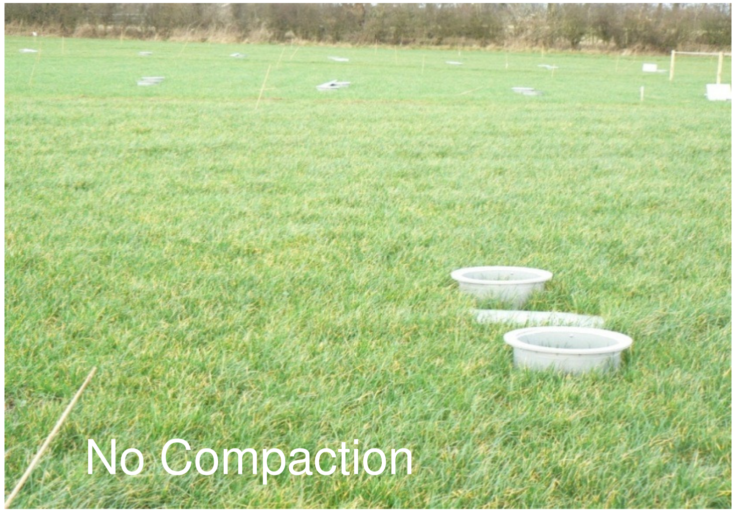

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Why measure soil quality?

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- Think of it in terms of:

- An MOT for your soil

Or A check up at the doctors

- Working towards
  - rolling out soil quality testing

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First Questions

- What is the state of my soil?
- Depends on
  - Soil type
  - What you want to do with it

- How do I tell?
  - Need indicators as can't measure everything

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Components of soil quality

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Phy

Putting it all together will need a different approach to sample collection – linking physical observation and soil samples sent for testing

ology

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Rolling out soil quality testing - Scorecard threshold values

Based on proposals for soilquality.org.uk (based on the Australian model - http://www.soilquality.org.au/) to enable utilisation of a wider database for benchmarking and ultimately advice.

The traffic light sytem represents:

RED (High risk, need to investigate urgently)
AMBER (Moderate risk, need to investigate further)
GREEN (Low risk, continue to monitor)

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Practical considerations

Selected soil health measurements:

Routine analysis (P, K, Mg, Ca, pH)
LOI
VESS
Earthworms
PMN

Why?

Combines physics, chemistry and biology
Lab set-up
Turn around time

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Potential scorecard...

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NAME	ASD-2018-4897
CUSTOMER	
TEXT_ID	
Field Name	West / Mid / East
FID	

	West		Mid		East		
Potentially Mineralisable N		30		30		36.4	mg/kg
Organic Matter (LOI)		5.39		5.38		5.74	%
pH		5.6		5.8		6.3	
Extractable Phosphorus		5.13		13.5		27.9	mg/L
Extractable Potassium		390		321		305	mg/L
Extractable Magnesium		113		118		170	mg/L
Extractable Calcium		1500		1400		2000	mg/L
Extractable Sodium		14.5		11.6		13.1	mg/L
mean VESS		2.7		1.7		2	
Mean worms		2.3		1.7		1	

		West	Mid	East
Lime req (Grass)	tonne/Hectare	4.7	3.7	0
Lime req (Arable)	tonne/Hectare	2.7	0	0

Soil texture = sandy loam

Soil health recommendation

Soil structure (VESS) low in the West field
Adding OM and upping pH should alieviate this
Depending on OM source consider extra N to account for immobilisation
Worm numbers would benefit from OM and reduced tillage

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Potential for benchmarking

- As in the current SRUC 'AGREcalc' where you can see your carbon footprint in relation to others

- You will be able to see how your soils perform against comparable soils and over time

- Benchmarking will improve the more data is entered

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Benchmarking Results

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Cradle Coast Compare Your Data

Australia / Tasmania / Cradle Coast

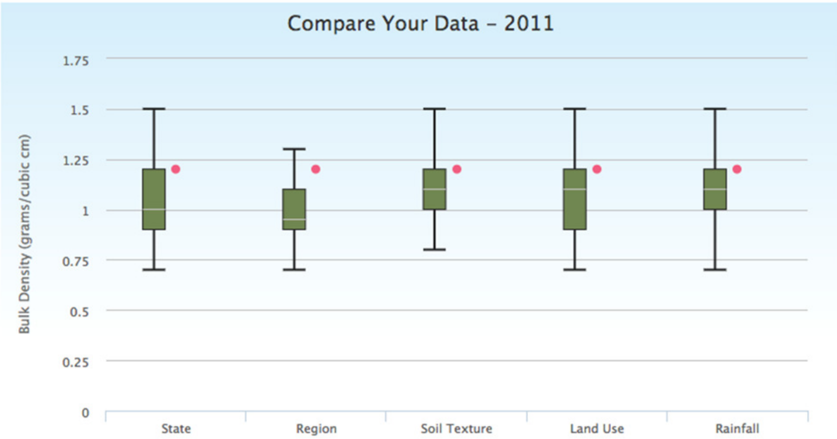
Overview | Examine | Compare | Relate

Site Report - Bulk Density - 0 - 10 cm

Return to Site Report

State
Tasmania
Region
Cradle Coast
Paddock ID
TAS0164

Management Group
Unavailable
Soil Texture
Loam
Land Use
Crop + Pasture
Rainfall
< 800mm



How To Compare Data

The circle on the graph represents your value from soil test results. This sits next to a plot showing the entire spread of that groups' data. The line in the centre is the average value of the all the data, and the box surrounding represents the middle 50% of the sample sites in this dataset. The upper and lower "tails" reflect the range for the top and bottom 25% of the sample sites in this data set.

Choose a Soil Quality indicator from one of the three tabs below to compare grouped data.

Biological

Chemical

Physical

Clay Content
- 0 - 10 cm

Bulk Density
- 0 - 10 cm
- 10 - 20 cm
- 20 - 30 cm

Gravel Content
- 0 - 10 cm
- 10 - 20 cm
- 20 - 30 cm

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Summary

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- Living soil is important for crop yield and quality
- Can be an indicator of soil health
- Soil health monitoring is a combination of methods
- Benchmarking indicates the health of a soil compared to other fields in the area

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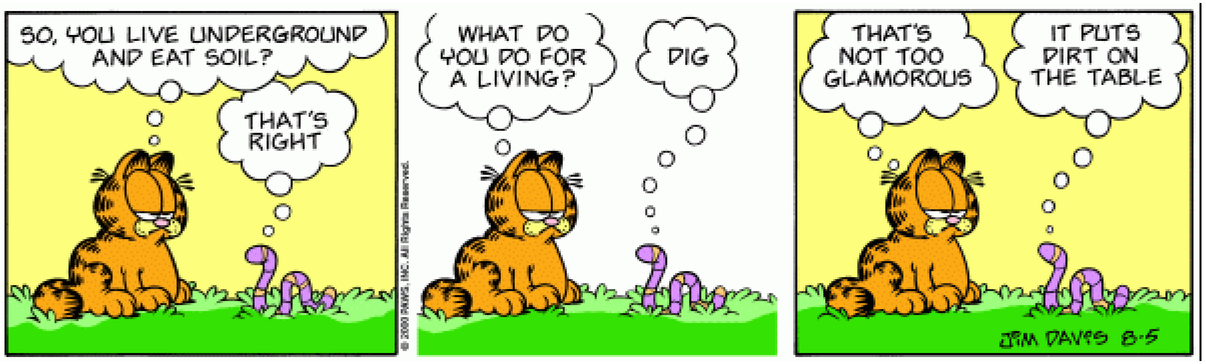
Thank you



Any Questions?

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Worm and Bait Sticks

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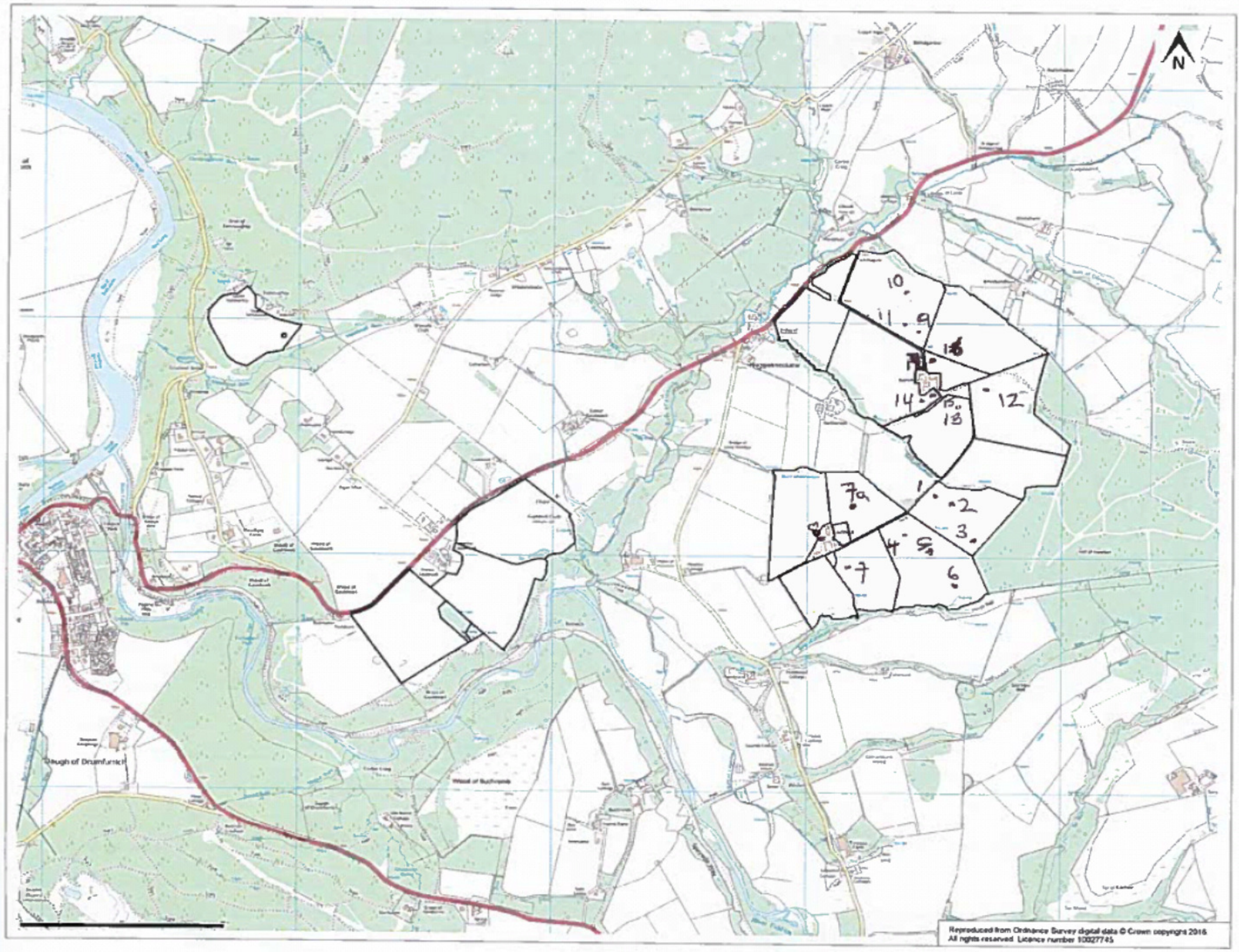

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