TRAINING OF EXPERTS TO ASSESS SOILS DAMAGED DUE TO HOSTILITIES

Sustainable soil management: what the war means for soil health

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Sustainable soil management

- Overview of soil health
- How do you measure it?
- What does this mean?

Status of the World's Soil Resources produced by FAO 2015

Identified 10 main soil threats globally, including waterlogging

Majority of the world's soil resources are only fair, poor or very poor condition
Around 33% moderately to highly degraded due to erosion, salinization, compaction, acidification and chemical pollution of soils.

Soil is a non-renewable resource

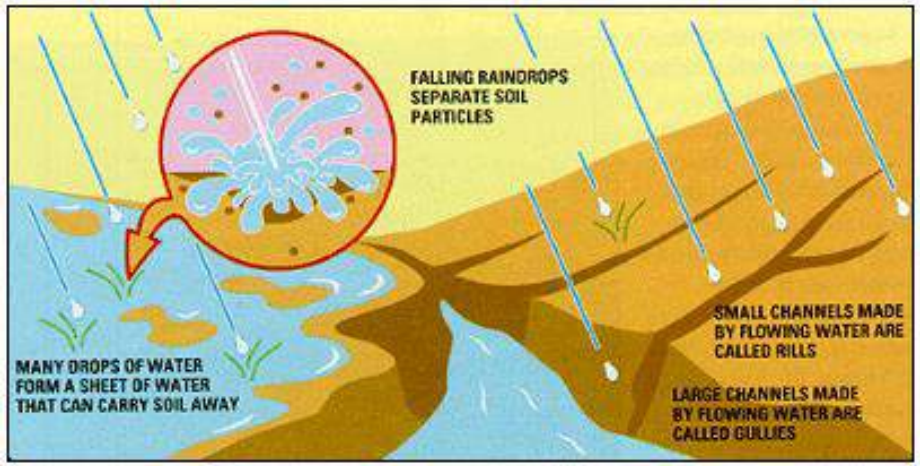
UK soil contains about 10 billion tonnes of carbon, equal to 80 years of annual greenhouse gas emissions at current rates.

Intensive agriculture has caused arable soils to lose 40 - 60% of its organic carbon, and the impacts of climate change pose further risks.

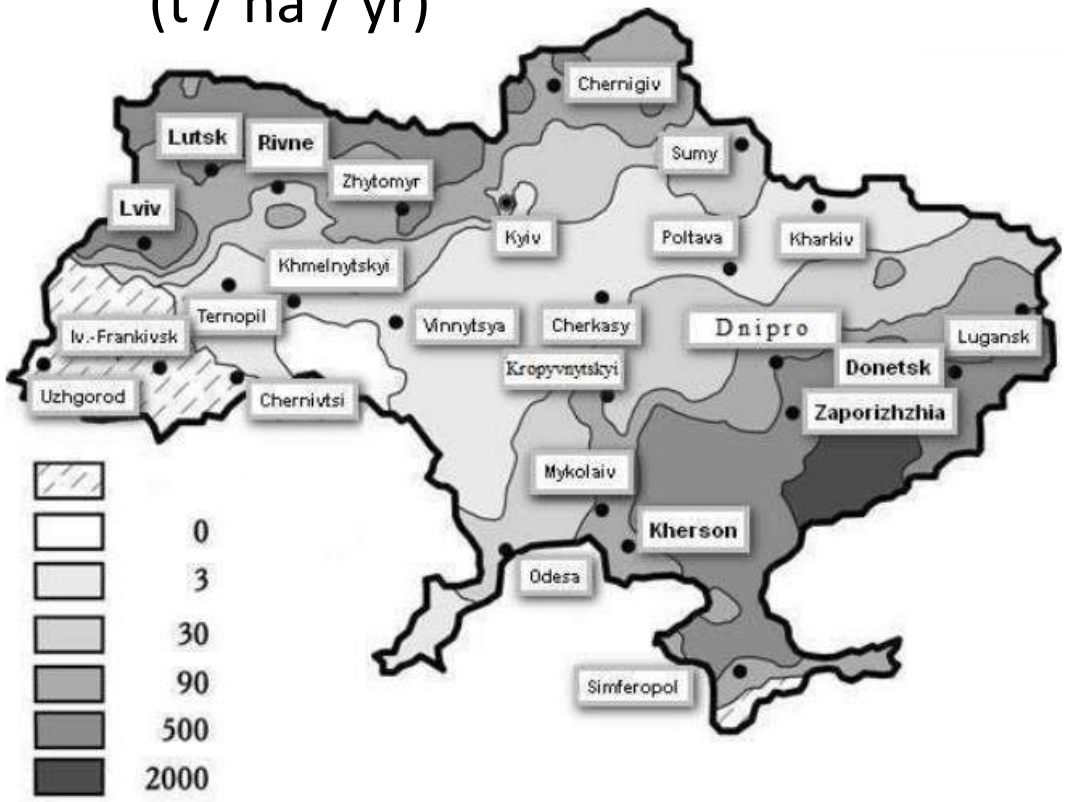
Compaction & Erosion

Apx 4 million hectares of soil is at risk of compaction in England & Wales

In 2021 calculated 57% of arable land area of Ukraine at risk of compaction



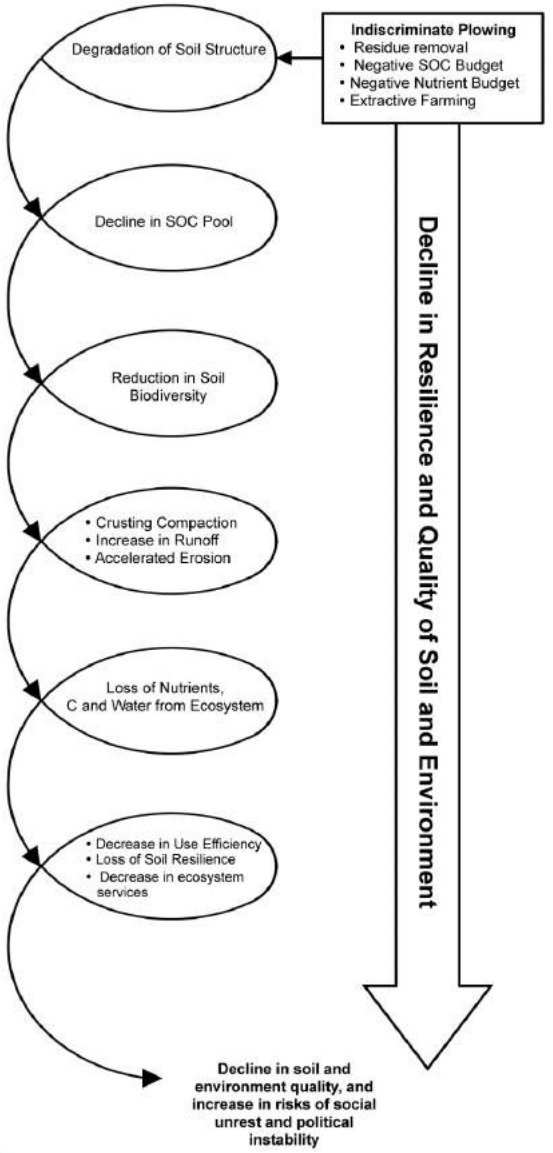
Possible soil loss from wind erosion (t / ha / yr)



Over 2 million hectares of soil at risk of EROSION in England & Wales – 17% of arable land.

Soil degradation

- Fertile soils require **significant** time to develop through the process of soil formation.
- Very easy (and quick) to lose / damage soil
- Human activities often reduce soil fertility and increase soil erosion.
- Soil conservation strategies exist and may be used to preserve soil fertility and reduce soil erosion.



Effect of conflict on soil

- Heavy metal pollution (e.g. Cu, Pb, Cd, Mo)
- Metals such as Cd and Pb can have adverse effects on human and animal health if allowed to accumulate in food chain
- Contamination from flood water – can spread pollutants over farmland, particularly in mining areas.

One litre of used motor oil can pollute up to 3784 m^2 of soil, making it non-productive for farming or plant growth for up to 100 years (Chin et al., 2012).

Ceredigion case study

- 2012 wettest summer for 100 years in Wales – leading to widespread flooding of Ceredigion area
- Mines in the area (many unused for 100 years) washed toxic metals (lead, zinc and cadmium) onto river banks and nearby areas
- Lead concentration in flood sediment 82 times above threshold levels
- Contamination of animal feed caused lead poisoning and death in cattle

ELSEVIER
Science of The Total Environment
Volumes 476–477, 1 April 2014, Pages 165-180

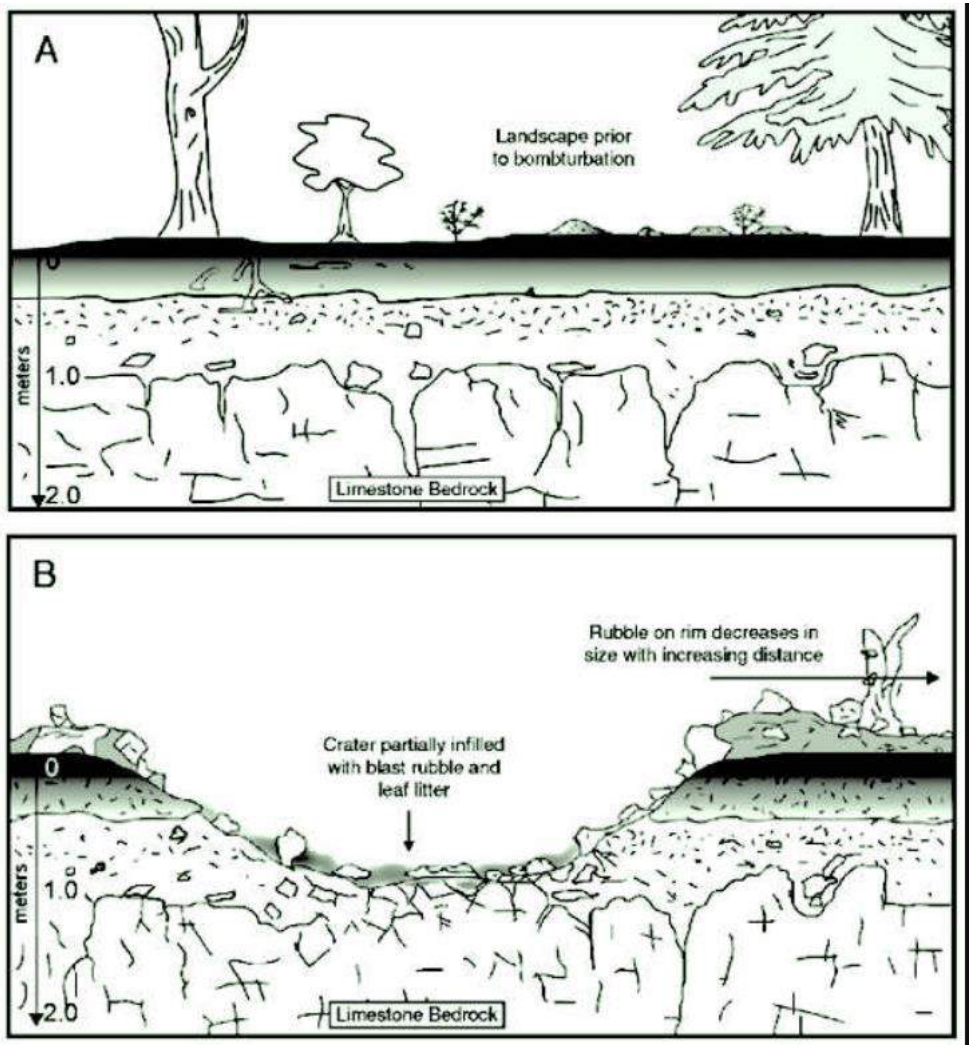
Flood-related contamination in catchments affected by historical metal mining: An unexpected and emerging hazard of climate change

S.A. Foulds [a], P.A. Brewer [a], M.G. Macklin [a], W. Haresign [b], R.E. Betson [a], S.M.E. Rassner [a]

- Silage produced from flood affected fields contained up to 1900 mg/kg of lead sediments
- Climate change means events like the summer of 2012 more likely and could intensify

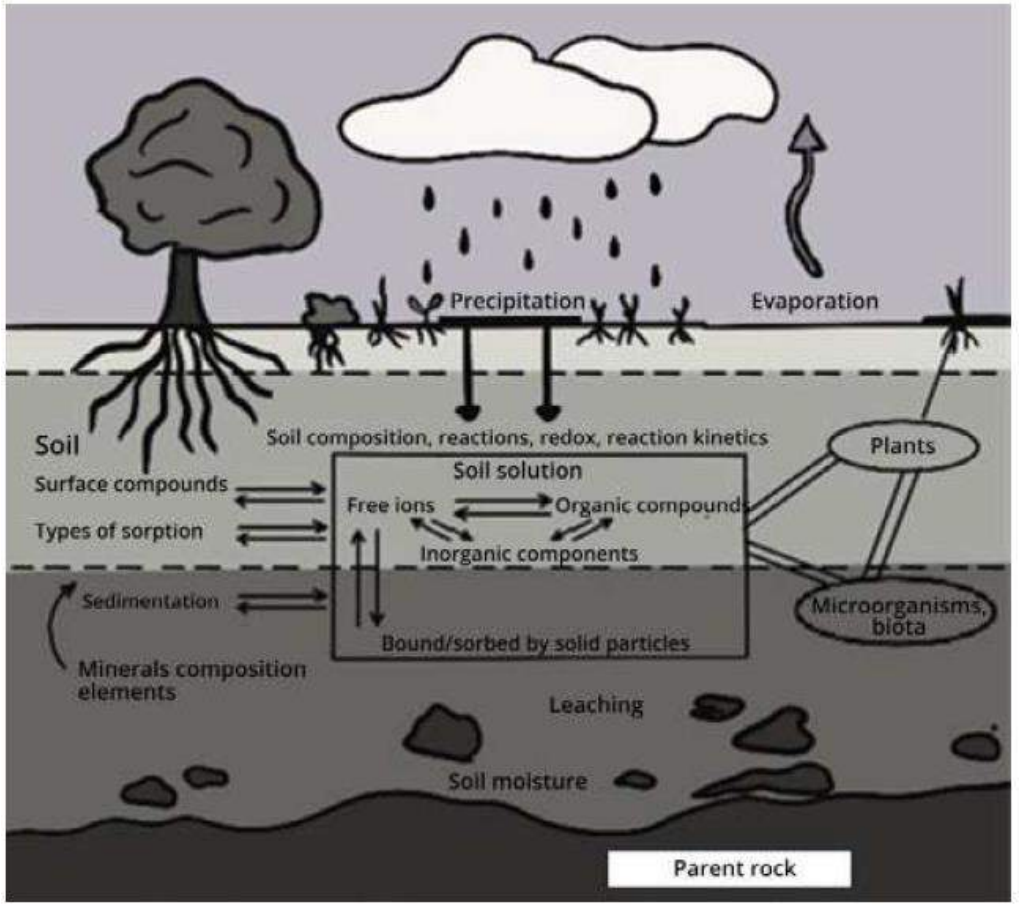
Effect of conflict on soil

- “Bombturbation” excavates a volume of soil from the site of impact; spreading the ejecta over the surrounding area (over-burden).
- Historic studies from WWII craters have found changes in pH, organic matter composition, electrical conductivity as well as heavy metals.



Physical impact and consequences

- Physical impact on soil structure
- Vibration – firing from weapons systems
- Radioactive / chemical impact (dependent on weapon type)
- Thermal impact caused by local increase in temperature during explosion



Soil degradation globally

Large scale erosion event

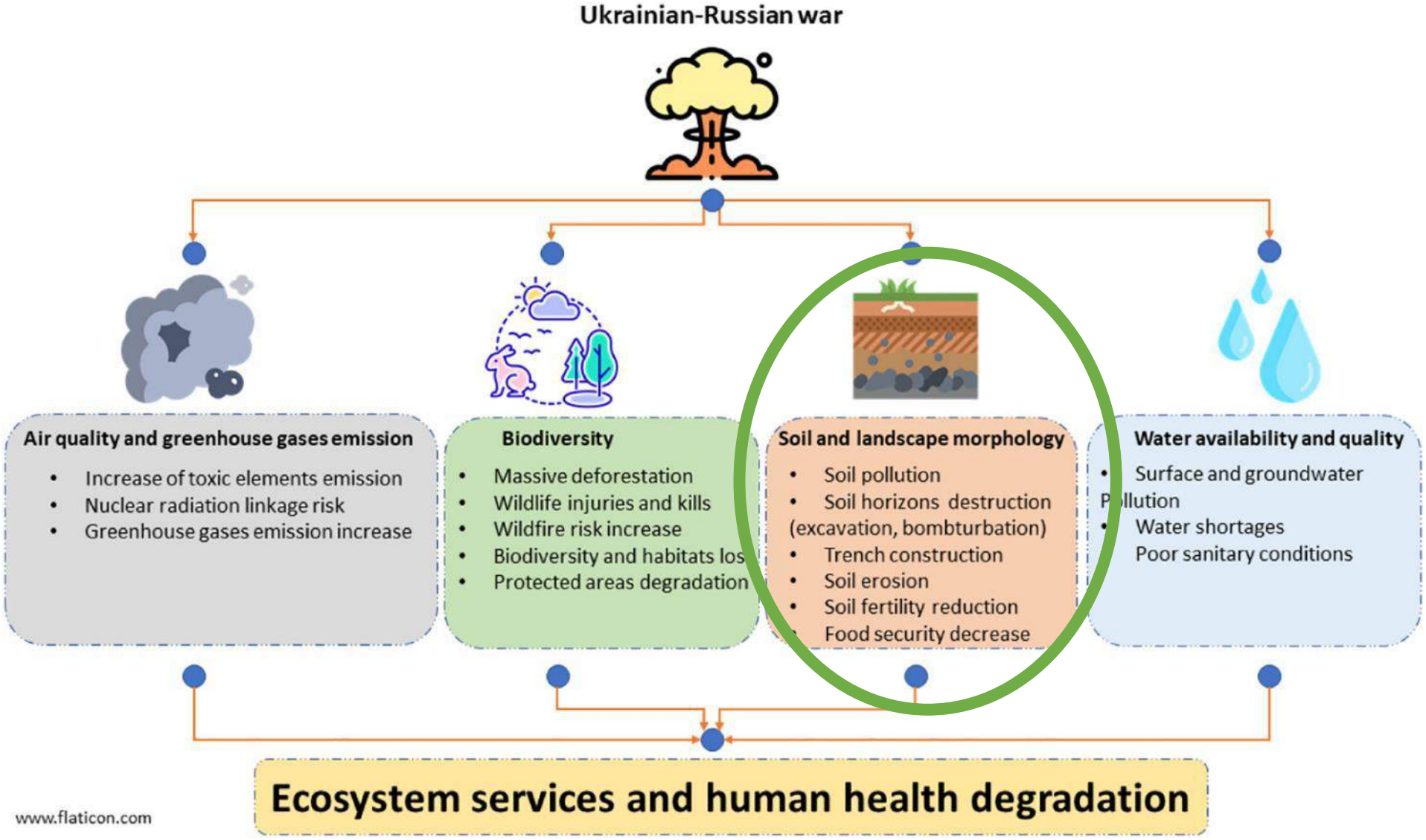
Before

After

https://www.bbc.co.uk/news/world-europe-57862894

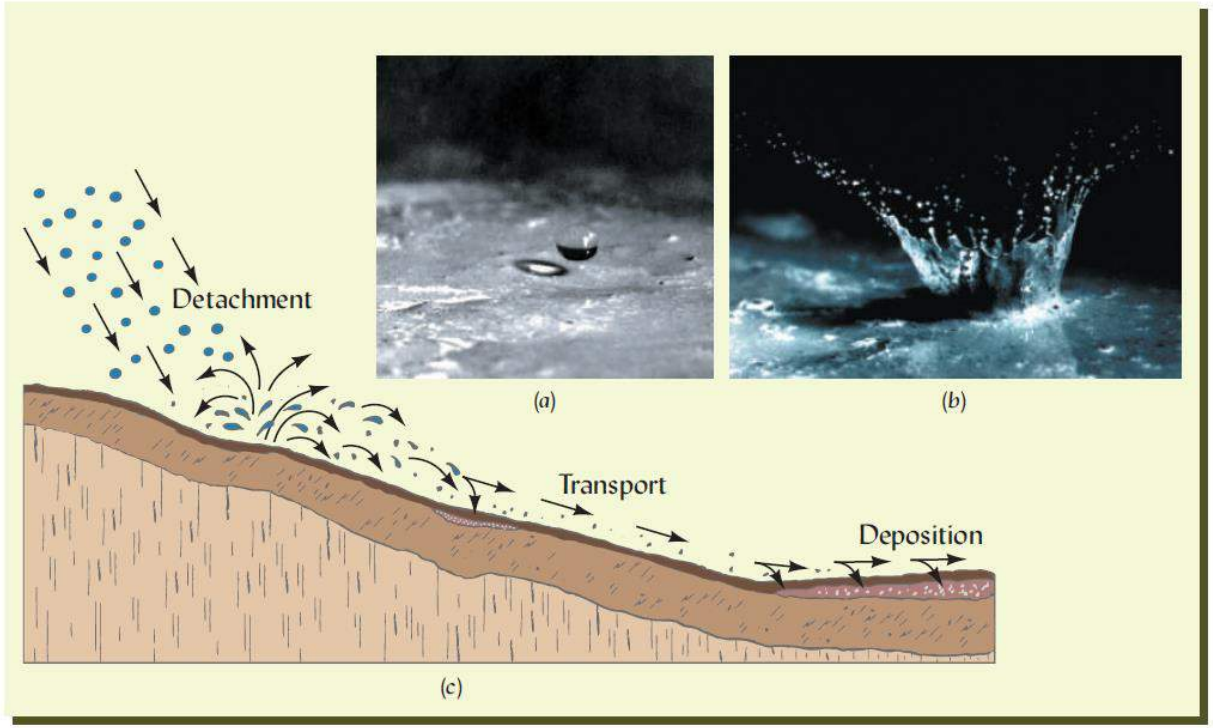
Restoration one year later

- BUT is this soil healthy?
- Will it still produce productive crops?
- If not why not?

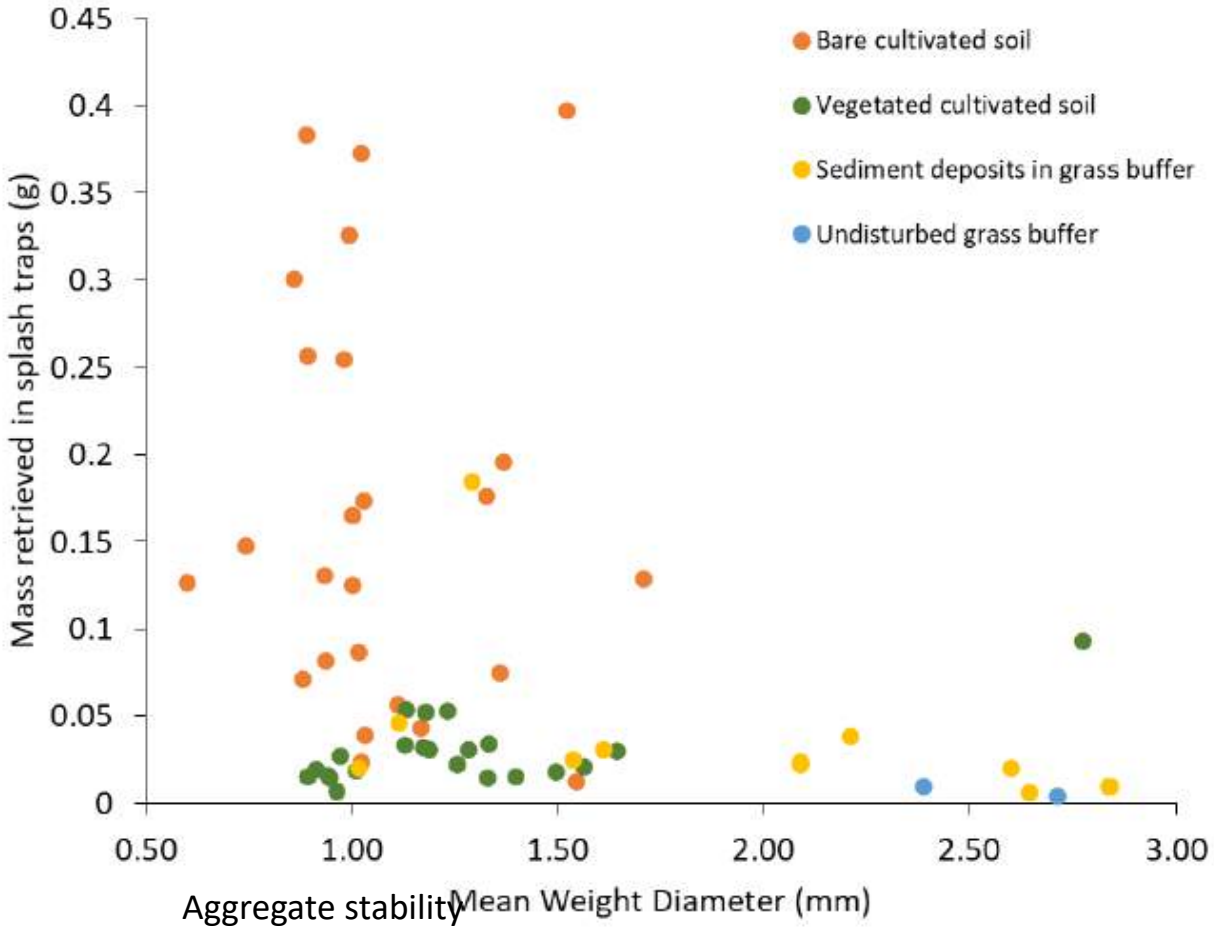

Ukrainian-Russian war
Air quality and greenhouse gases emission
• Increase of toxic elements emission
• Nuclear radiation linkage risk
• Greenhouse gases emission increase
Biodiversity
• Massive deforestation
• Wildlife injuries and kills
• Wildfire risk increase
• Biodiversity and habitats los
• Protected areas degradation
Soil and landscape morphology
• Soil pollution
• Soil horizons destruction (excavation, bombturbation)
• Trench construction
• Soil erosion
• Soil fertility reduction
• Food security decrease
Water availability and quality
• Surface and groundwater
Pollution
• Water shortages
Poor sanitary conditions
Ecosystem services and human health degradation
www.flaticon.com

Water erosion

- Can occur as soon as raindrops start falling (splash erosion).
- As runs over land or rock surface, collects weathered material (transport).
- Power of moving water increases with more water and ability to carry heavier debris
- Vegetation cover can reduce impact of erosion.



Measuring splash erosion



Aggregate stability

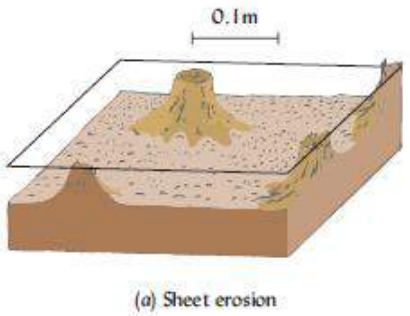
Methods

Soil properties were compared to rainsplash erosion rates on a grassland and an arable field in Southwest England. Soil cores were retrieved and measured for dry density, aggregate stability, vegetation cover, and loss on ignition. A rainsplash erosion trap consisting of a plastic funnel containing filter paper was placed into the hole left by each core, and the mass of sediment trapped over a 1-month and 2-week period was recorded.

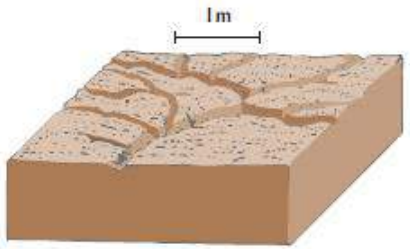
https://link.springer.com/article/10.1007/s11368-021-03098-4

Agriculture Water Erosion

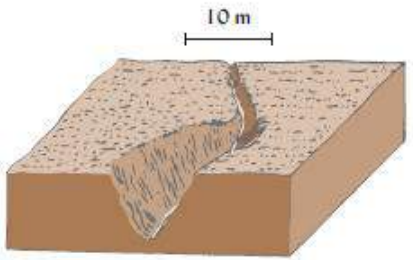
- Sheet Erosion – removal of relatively uniform, although thin layer of soil from land surfaced
- Rill Erosion – numerous small channels formed. Results from concentrated overland flow.
- Gully Erosion – larger channels formed from concentrated rill or sheet flow



(a) Sheet erosion



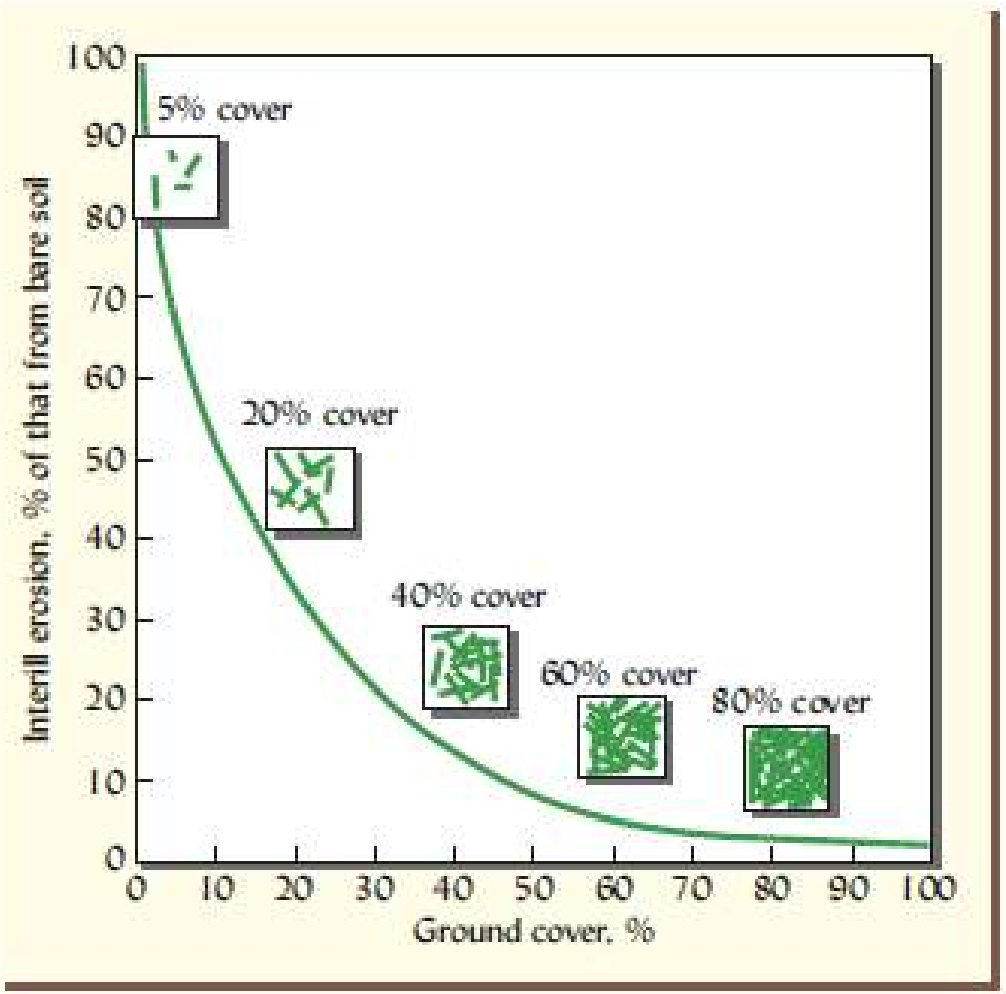
(b) Rill erosion



(c) Gully erosion

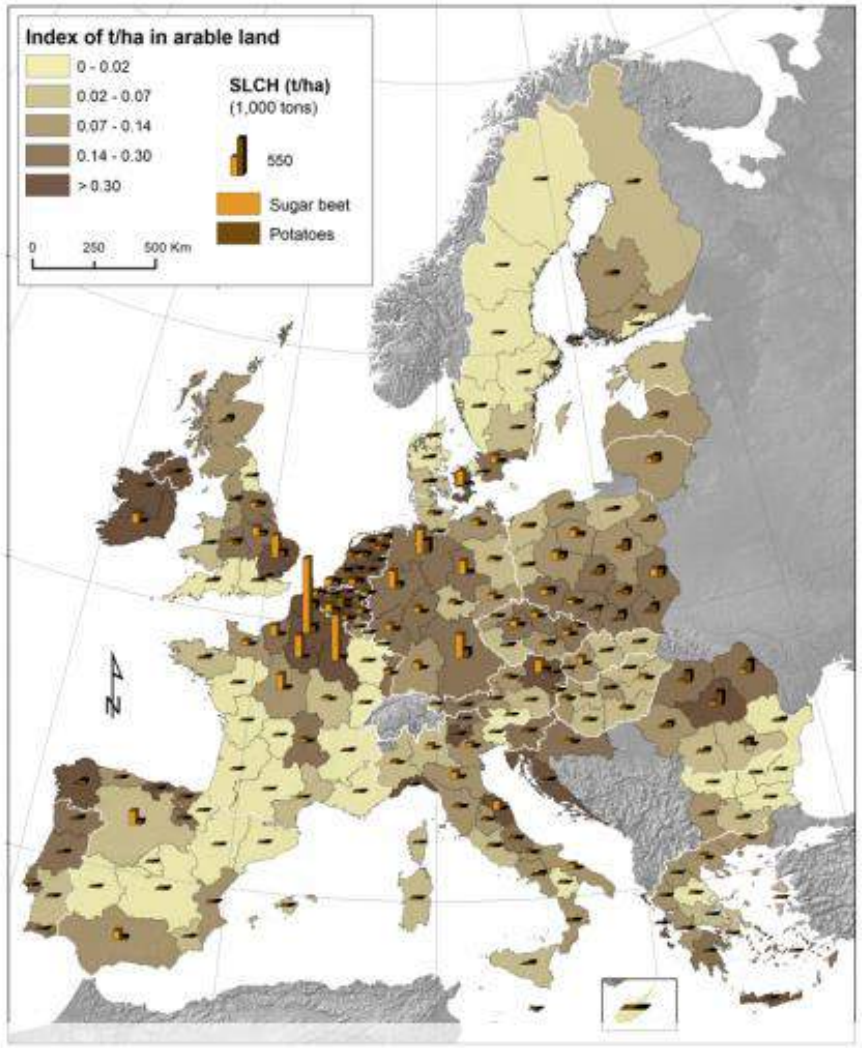
Interrill erosion

- Reduction in interrill erosion achieved by increasing ground cover percentage
- Diagrams above graph illustrate ground cover
- Note even a light covering of mulch has a major effect on soil erosion
- *Erosion may vary depending on slope



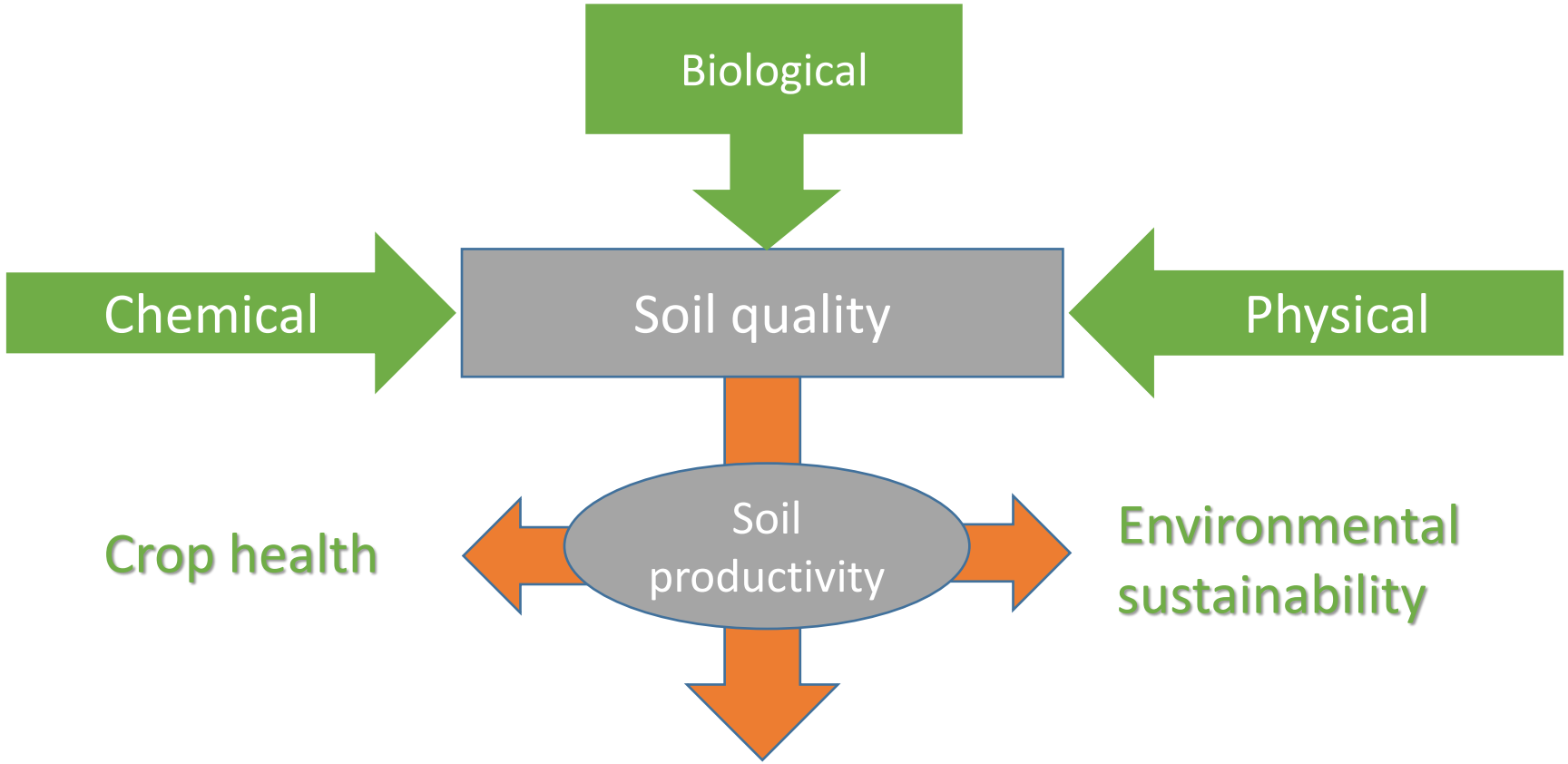
- Not just water erosion
- Also wind erosion
- “wind blow”
- Estimated over 500 million tonnes of soil are eroded annually from arable land in Ukraine
- Likelihood of erosion also dependent on soil type, agricultural management, crops grown

Soil Loss Due to Crop Harvesting in the EU



The 4.2 million ha of EU root crops contribute to 14.7 million tonnes of SLCH

What makes a “healthy” soil in agriculture?

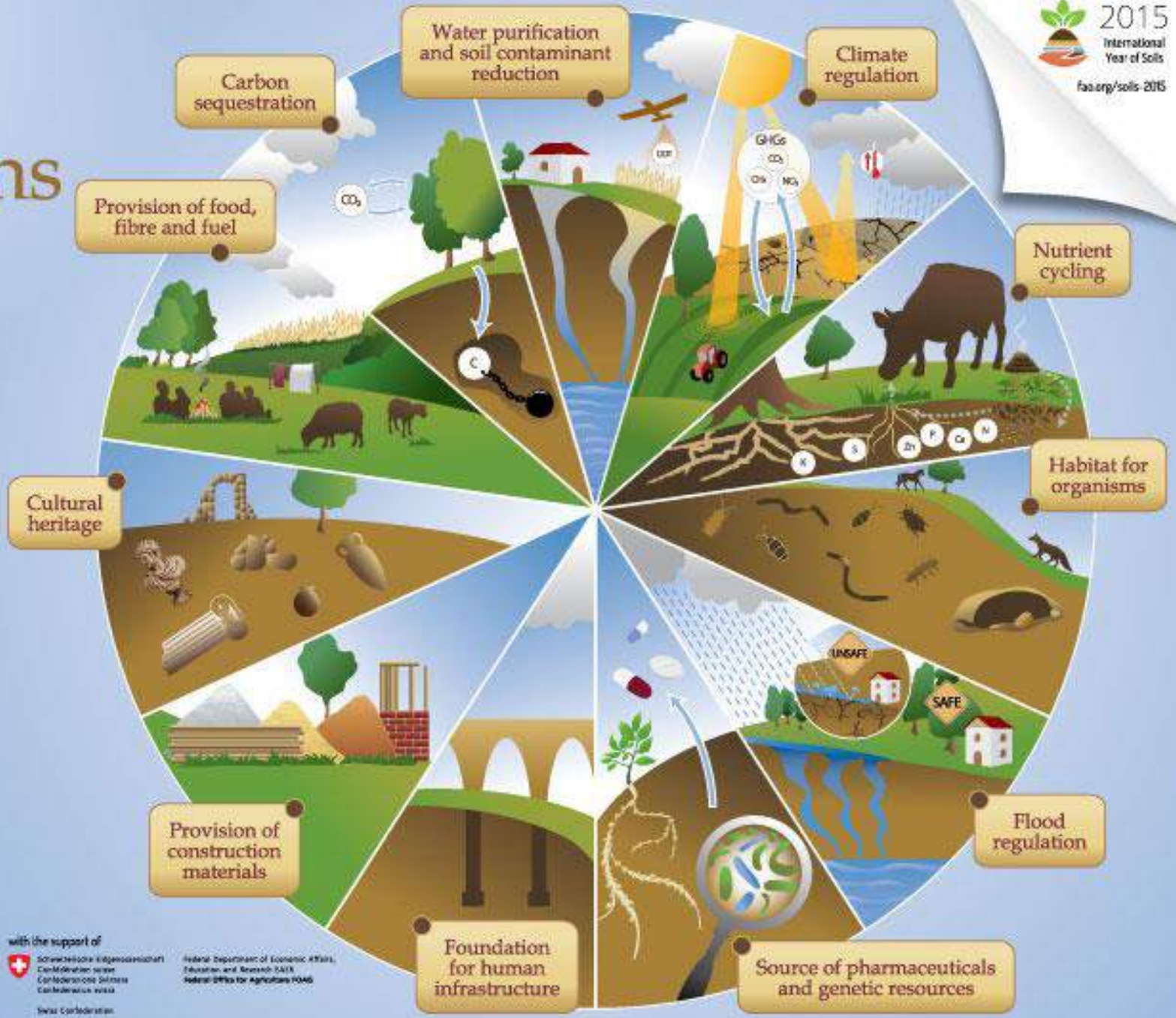


SOIL HEALTH

HEALTHY

Soil functions

Soils deliver ecosystem services that enable life on Earth



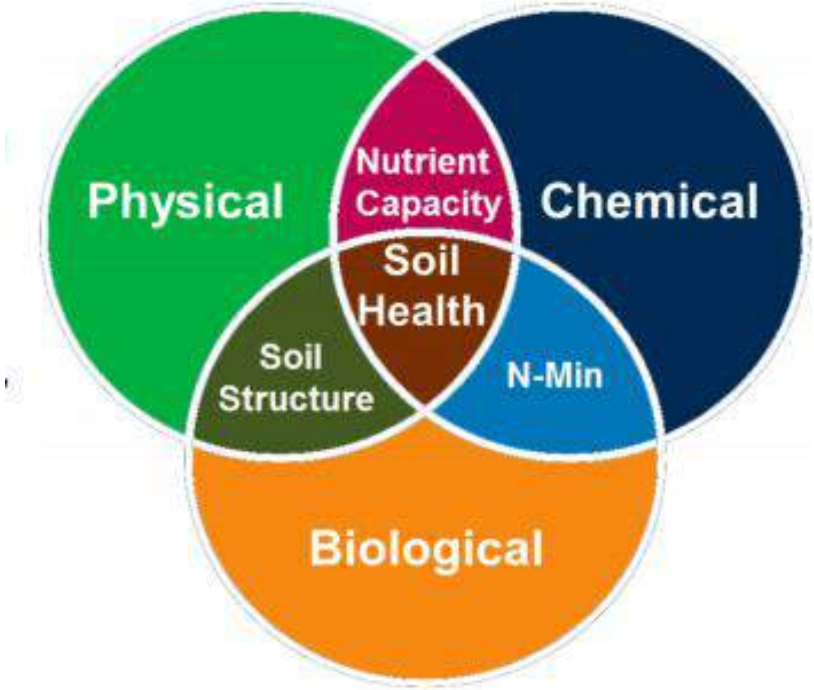
2015 International Year of Soils
fao.org/soils-2015

Food and Agriculture Organization of the United Nations

with the support of
Swiss Confederation
Federal Department of Economic Affairs, Education and Research EAER
Federal Office for Agriculture FOAG

WHAT IS SOIL HEALTH?

- Soil health refers to “the continued capacity of a soil to function” (Doran and Zeiss, 2000).
- BUT// Only something living can have health, thereby we are (unconsciously) acknowledging that we regard soil as a living ecosystem and not just an inert base for agriculture.



Strategies to improve soil quality

Strategy	Region	Process
Litter turnover	Tropics	The rate of organic matter and C supply and nutrient cycling reactivation
Forestry Plantations	Tropics	Silvo-pastoral system for nutrient cycling
Woodlot Islets	Degraded drylands	Silvo-pastoral systems in drylands
Soil Carbon Sequestration	Agroecosystems	Optimal management strategies
Integrated Nutrient Management	Sub-Saharan Africa	Soil quality management
Nutrient Management for SOC Sequestration	Sub-Tropical Red Soils (China)	Soil carbon buildup
Manuring	Indus Plains	Application of farm manure
Residue Retention as Mulch	Mexican Highlands	Improvement of soil structure
Regular Organic Inputs	Western Kenya	Nutrient retention and soil structure improvement
Urban Waste	Mediterranean Europe	Enhancing soil fertility
Soil Biological Management	Global soils	Enhance ecosystem services provisioned by SOC pool
Environmental Awareness	U.S.	Promoting technology adoption

HOW FARMERS IMPROVE SOIL HEALTH ALL YEAR ROUND

WINTER

BUFFER STRIPS ON FIELD MARGINS

- Act as a barrier to reduce wind erosion in bare soils.

LIVESTOCK HOUSED INDOORS OVER WINTER

- Reduces soil erosion and poaching in wetter months.

ANNUAL CROP ROTATION

- Maintains soil fertility.
- Helps replenish nutrients.
- Helps to control weeds.
- Reduces crop specific pest and disease problems.

SPRING

SPREADING OF SLURRY AND FARM YARD MANURE

- Less requirement for artificial fertilisers.
- Helps increase organic matter and encourages earthworms.

COW TRACKS AND MULTIPLE GATEWAY ENTRY

- Multiple gateways helps reduce soil compaction.
- Cow tracks avoid poaching.

GRASS LAND SOIL CAN BENEFIT FROM AERATION

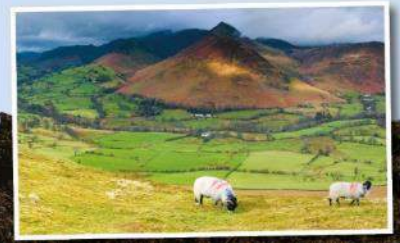
- Aeration improves soil drainage & helps keep soil aerobic.

SOIL SAMPLING AND VISUAL ASSESSMENTS

- By monitoring, measuring & managing soil health, farmers ensure that plants get the nutrients needed and earthworms are encouraged.

58% OF AGRICULTURAL LAND IS PERMANENT GRASSLAND & MEADOW

Acting as a permanent carbon storage area, this locks in greenhouse gases otherwise emitted to the atmosphere.



SUMMER

CONTROL TRAFFIC FARMING, GPS & REDUCTIONS IN TYRE PRESSURES

- Reduces soil compaction, fuel consumption and the need for traditional cultivation methods.

477,000 KM OF HEDGES IN THE UK

- Hedges act as a barrier to help reduce wind erosion.

STRAW CHOPPING AT HARVEST TIME

- Helps increase the soils organic matter content to help for the next crop.

AUTUMN

COVER CROPS AND CATCH CROPS

- Prevent post-harvest soil erosion, helps increase organic matter and rooting systems.
- Improves soil structure and infiltration.

DIRECT DRILLING OF WINTER CROPS FOLLOWING HARVEST USES A MINIMUM-TILLAGE METHOD

- Min-till or no-till methods mean fewer soil disturbances & increases in organic matter at the top level of soil.

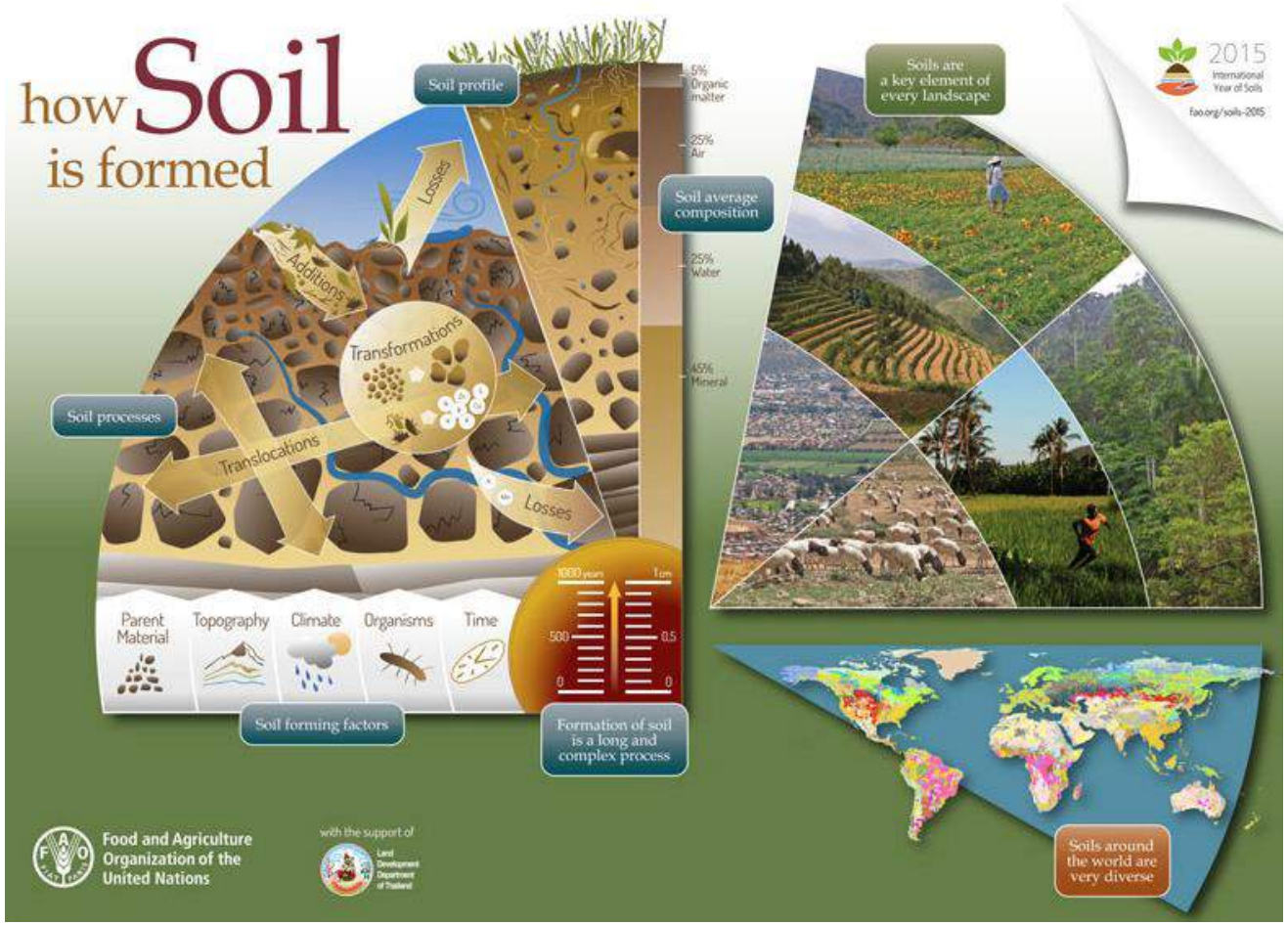
BACK BRITISH FARMING

NFU

Soil formation

- Parent material
- Topography
- Climate
- Time
- Living organisms

(Humans and Vegetation)



Climate and the biosphere progressively alter the parent (rock) material within the landscape over time….

Soil formation – parent material

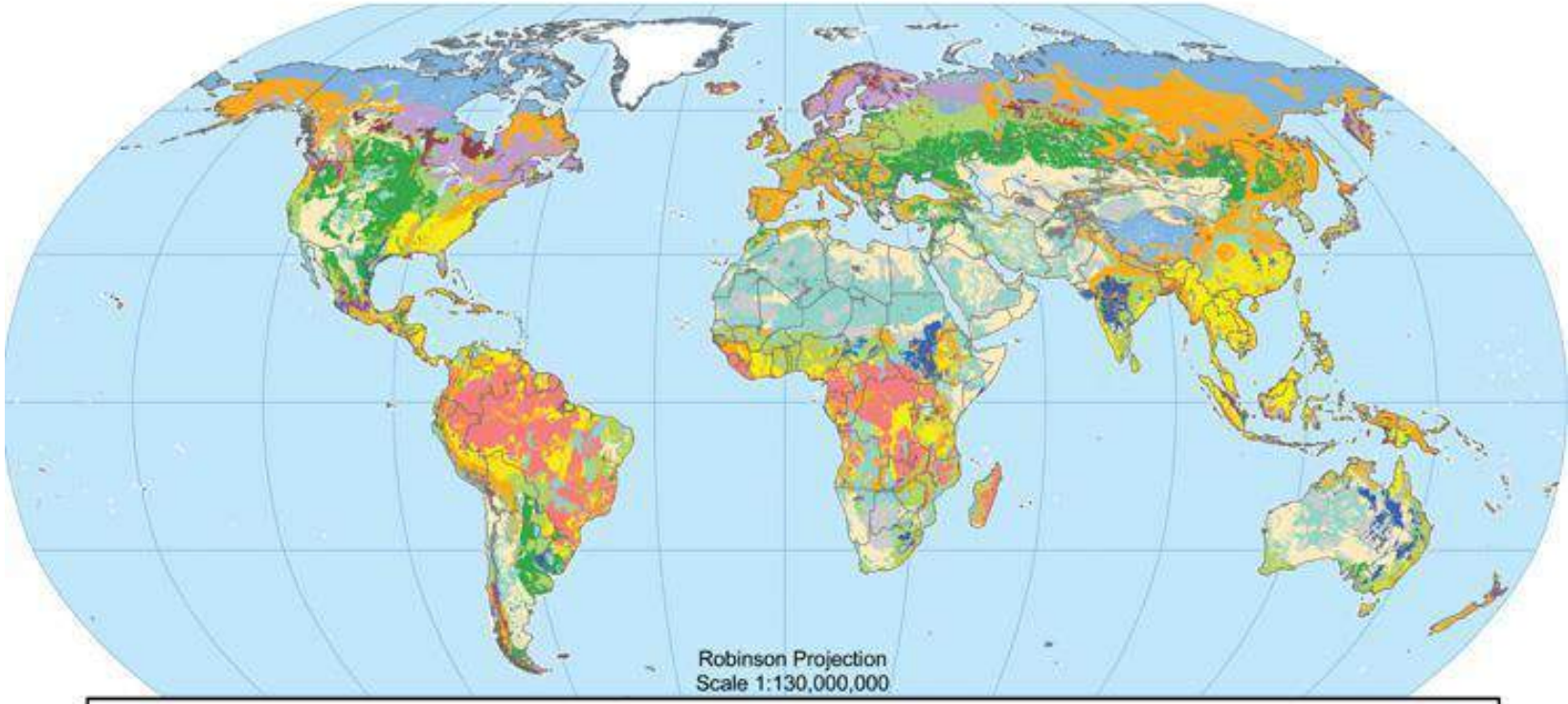
Importance:

a) Controls rate of weathering

b) Determines final texture

c) Strong influence on chemical composition

Global Soil Regions



Soil examination

Physical

- dig a pit, clean the face
- see structure
- feel texture
- consider porosity

cultivation / drainage recommendations

- **colour** - hints at parent material
  darkness = amount of OM
- **boundary sharpness** indicates worm activity or cultivation
- **structure** - assess size & shape of aggregates
- **texture** - feel the sand / silt / clay
- **root system** - if visible

Chemical

- take representative sample
- laboratory analysis
- data interpretation

fertiliser / lime recommendations

Visual evaluation of soil structure

Training of experts to assess soils damaged due to hostilities

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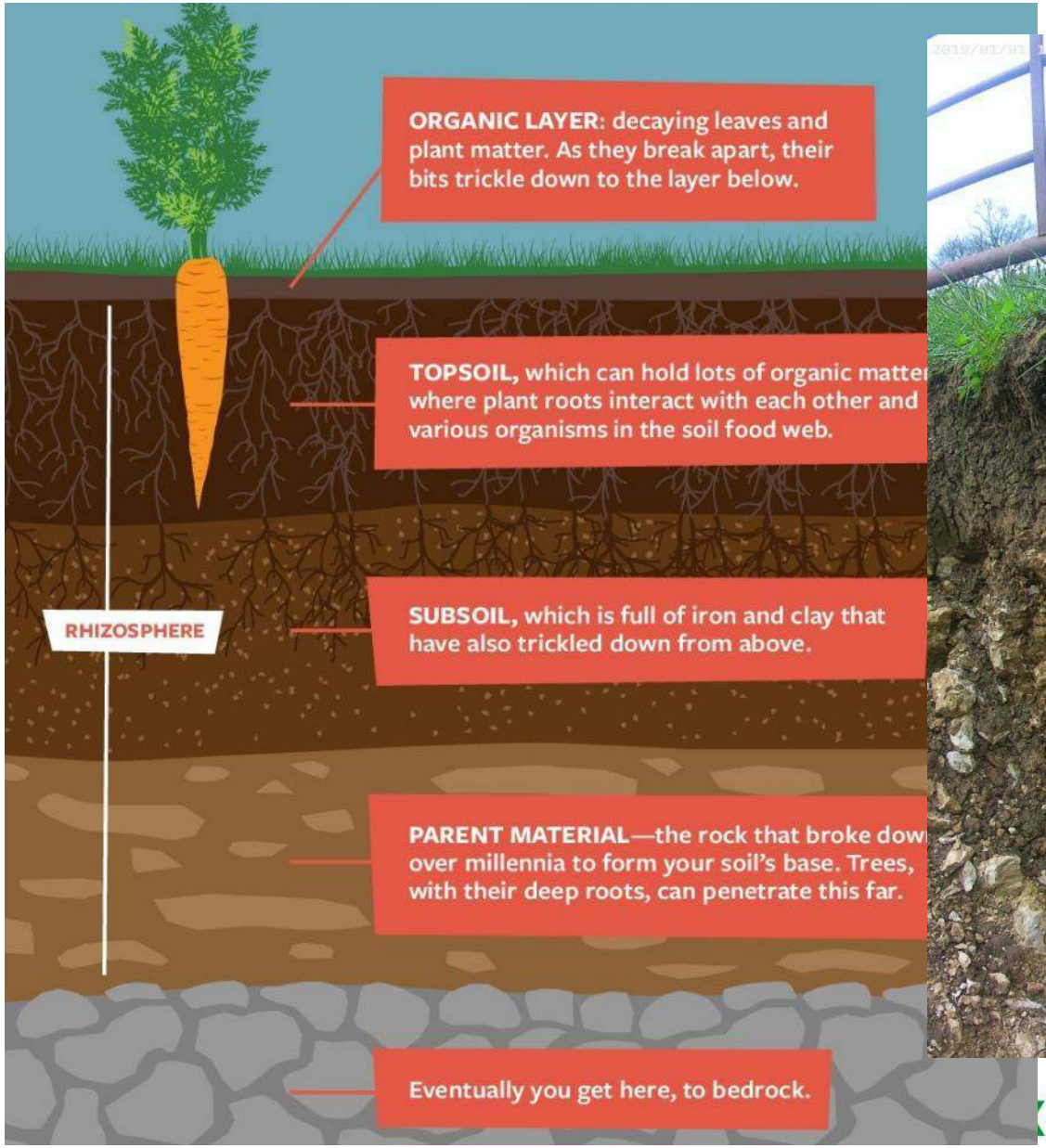
Royal Agricultural University



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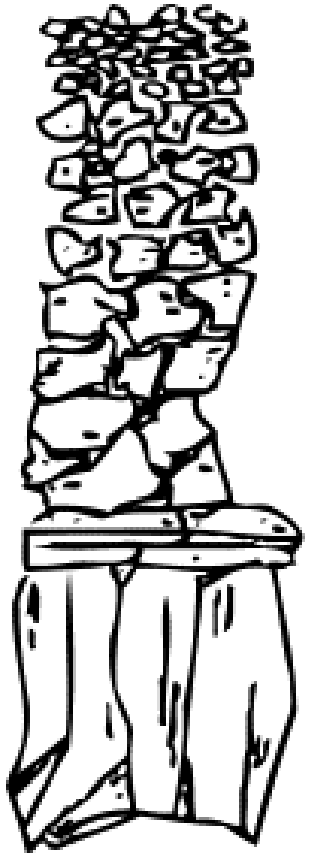
What is the difference between soil structure and soil texture?

- Soil texture an inherent characteristic (unchangeable), relative % of silt, sand and clay
- Soil structure a manageable characteristic influenced by soil biology and soil health. Arrangement of soil particles, how water, nutrients and gasses are able to diffuse through soil.



Granular structure – only 1–10 mm units
Found in the top soil

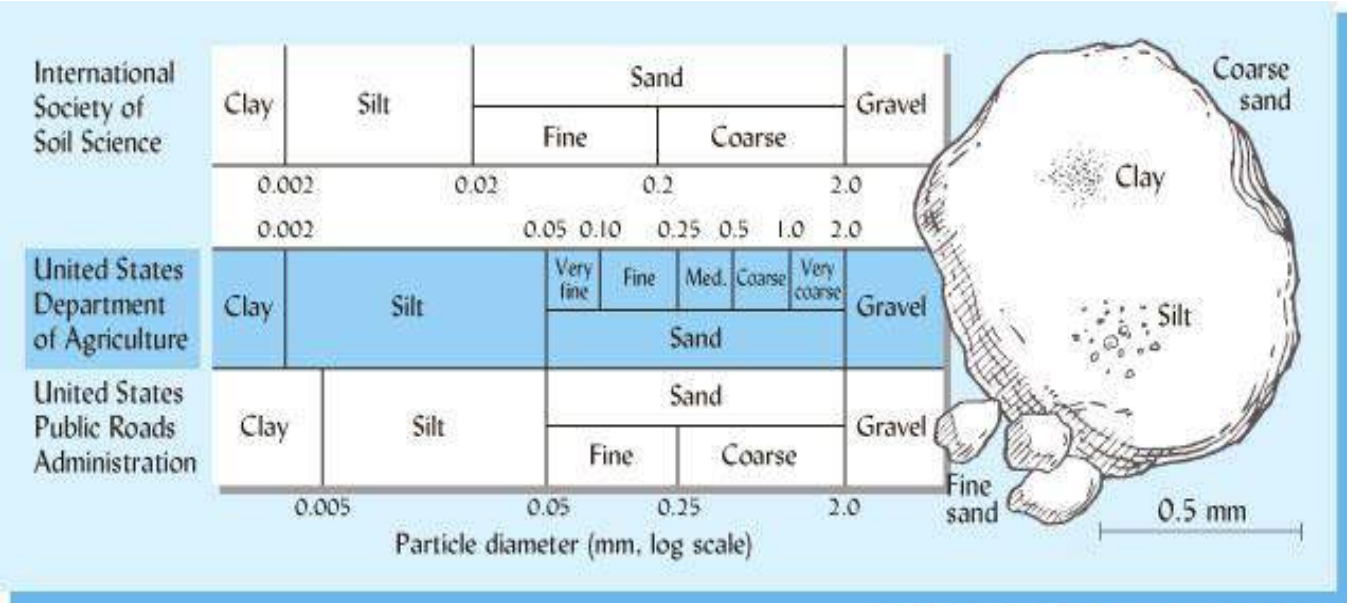
Blocky structure – 5–50 mm units
Found in subsoil of well structured soils

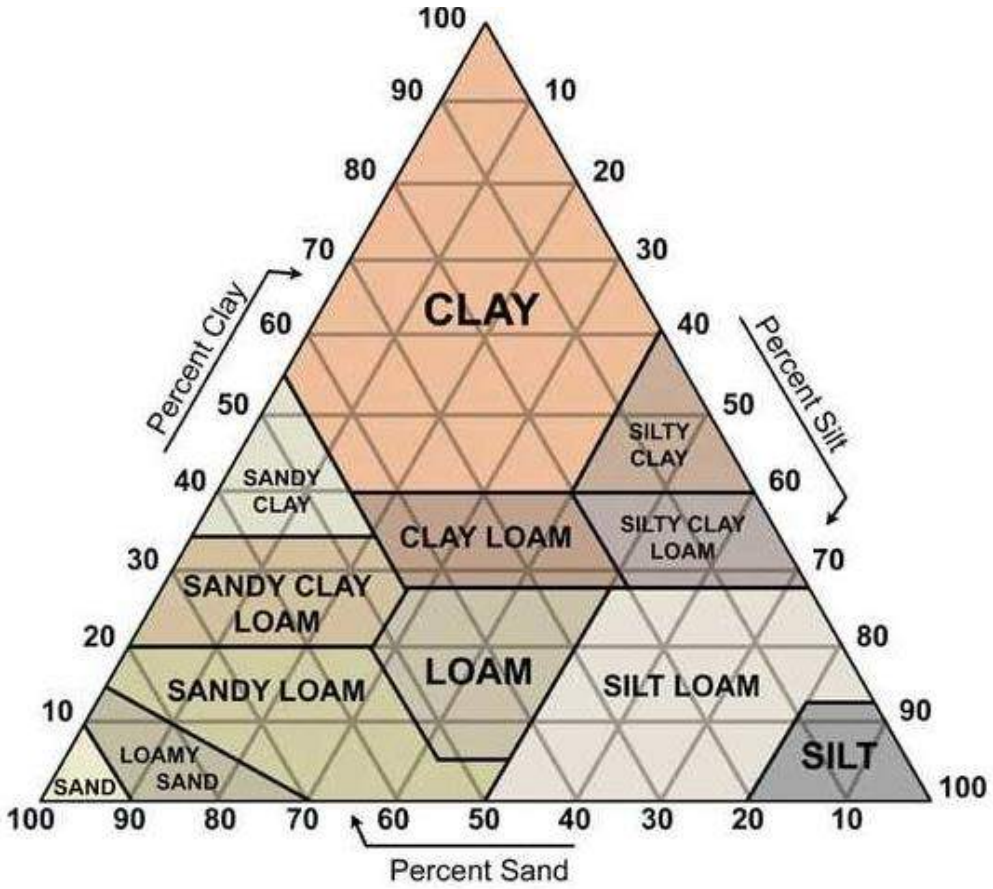
Platy structure – found when soil is compacted, e.g. if there is a plough pan

Massive prismatic structure, few cracks for water movement or root growth. Found in subsoils of heavy clays

Soil texture

- Critical for understanding soil behaviour and management
- Most permanent feature of any soil
- Particle size distribution - Sand, silt and clay only
- Stones are ignored
- OM treated separately





Soil types – Colour is important

Three major factors influence soil colours:

1. Organic matter content,
2. Water content
3. Presence and oxidation states of iron and manganese oxides in various minerals.

Form	Chemical Formula	Color
Ferrous oxide	FeO	Gray
Ferric oxide (Hematite)	Fe_2O_3	Red
Hydrated ferric oxide (Limonite)	$2Fe_2O_3 \cdot 3H_2O$	Yellow

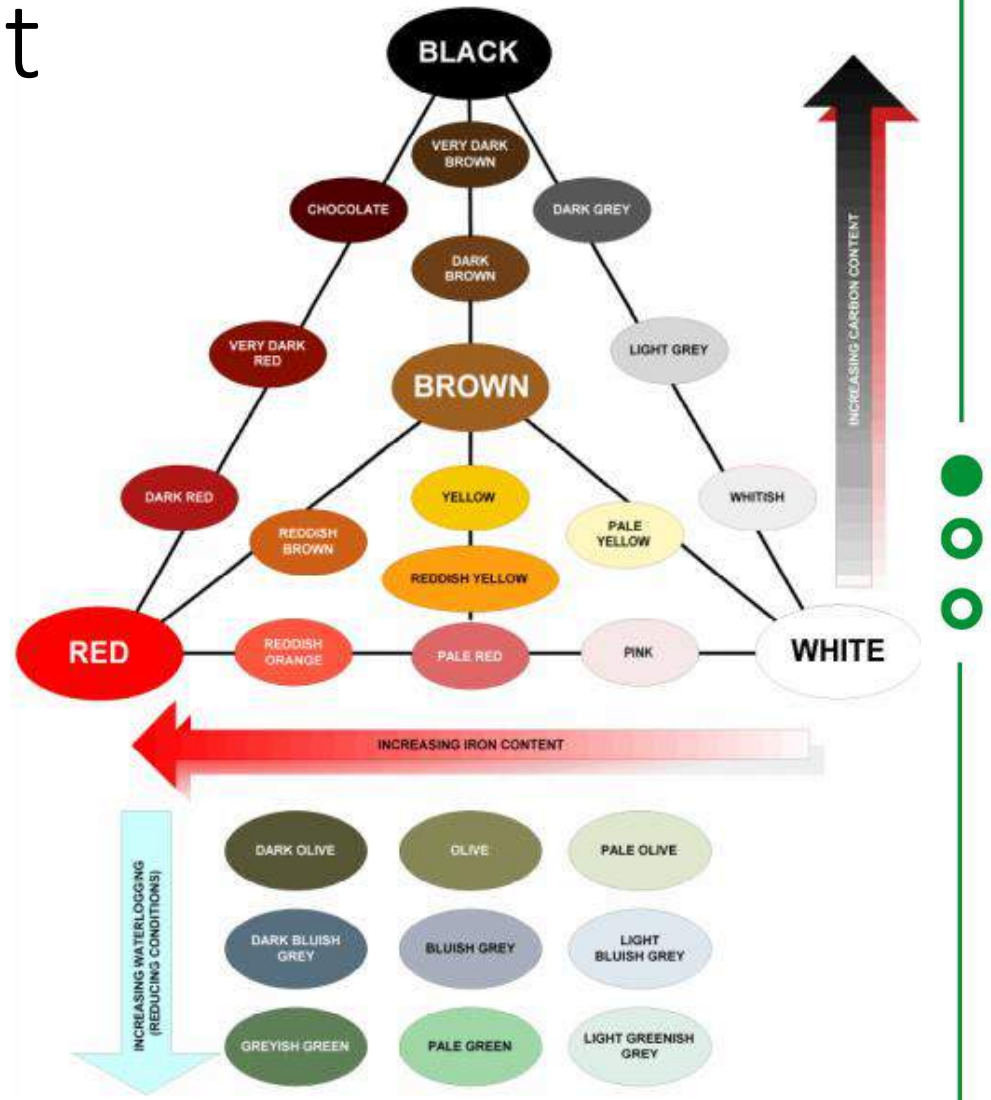


Figure 7. Examples of soil with less than 1%, 2% and 3% organic matter from left to right, respectively. Photo: Jodi DiJong-Hughes

The influence of organic matter (OM) on the stability of soil aggregates against slaking (falling apart) when wetted. Although both soils appeared well aggregated when dry (left), when the same amount of water was added to each the aggregates in the low OM soil rapidly fell apart while those in the higher OM soil remained intact.

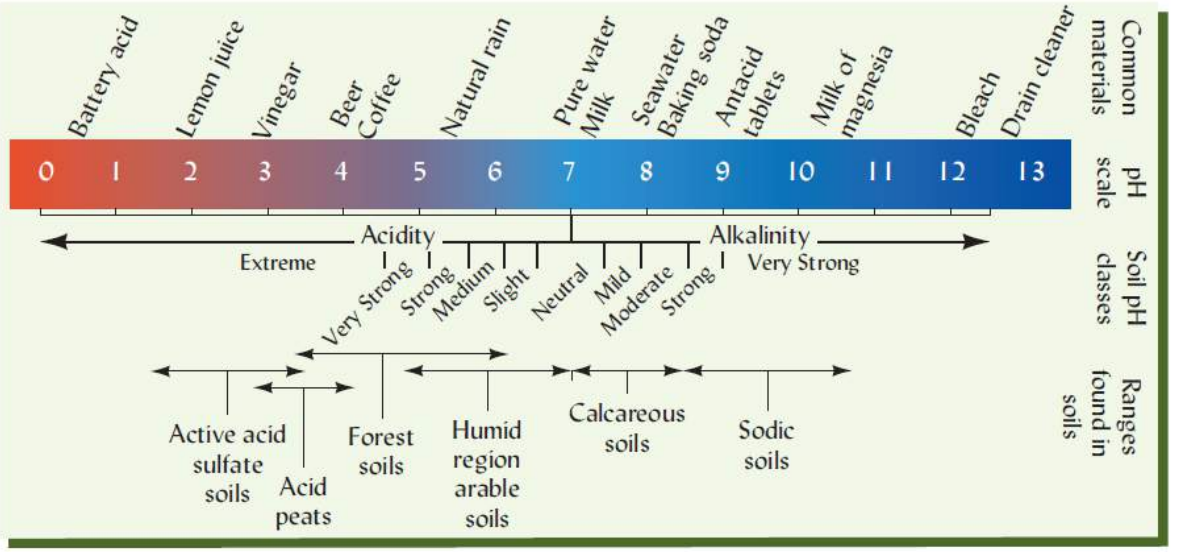
pH

measured by **pH scale**

2 ---------- 6.5 ------- 8.2 ---------- 14

acid "neutral" calcareous saline

i.e. suitable for most crops



- Balance between hydrogen ions (H^+) & hydroxyl ions (OH^-).
- 2 processes promote soil acidification.
  1. The production of H^+ ions.
  2. The washing away of nonacid cations.
- Soil acidity is closely related to the amount of annual precipitation.

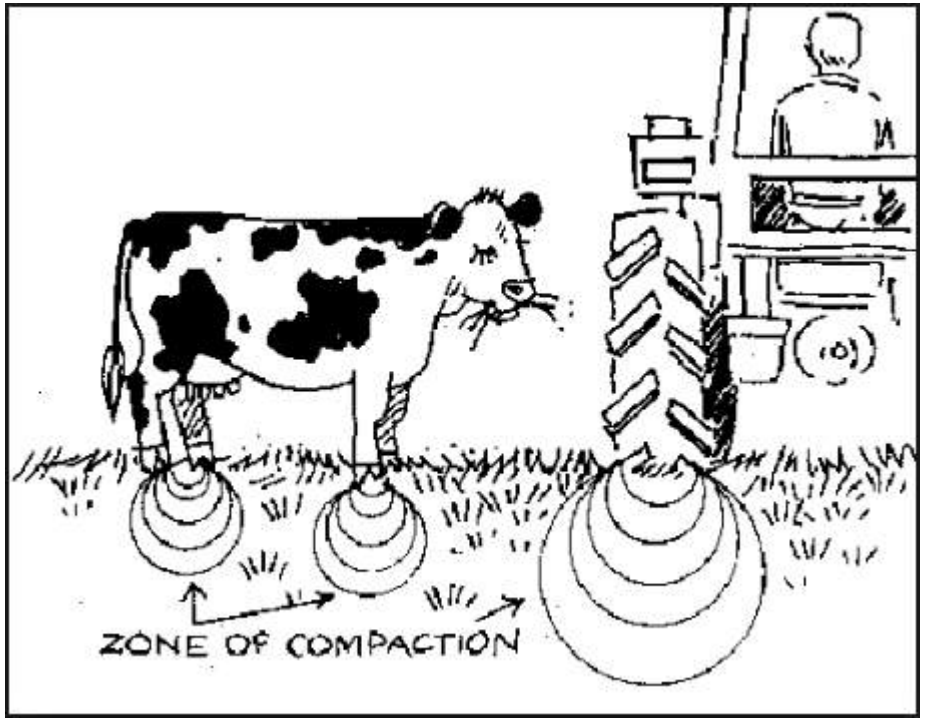
Causes:

Parent Material
Leaching
Fertiliser use
Precipitation

pH	Flower Color
4.5	deep, vivid blue
5.0	medium blue
5.5	lavender-purple
6.0	purplish-pink
6.5	mauve-pink
6.8	medium pink
7.0	deep, vivid pink

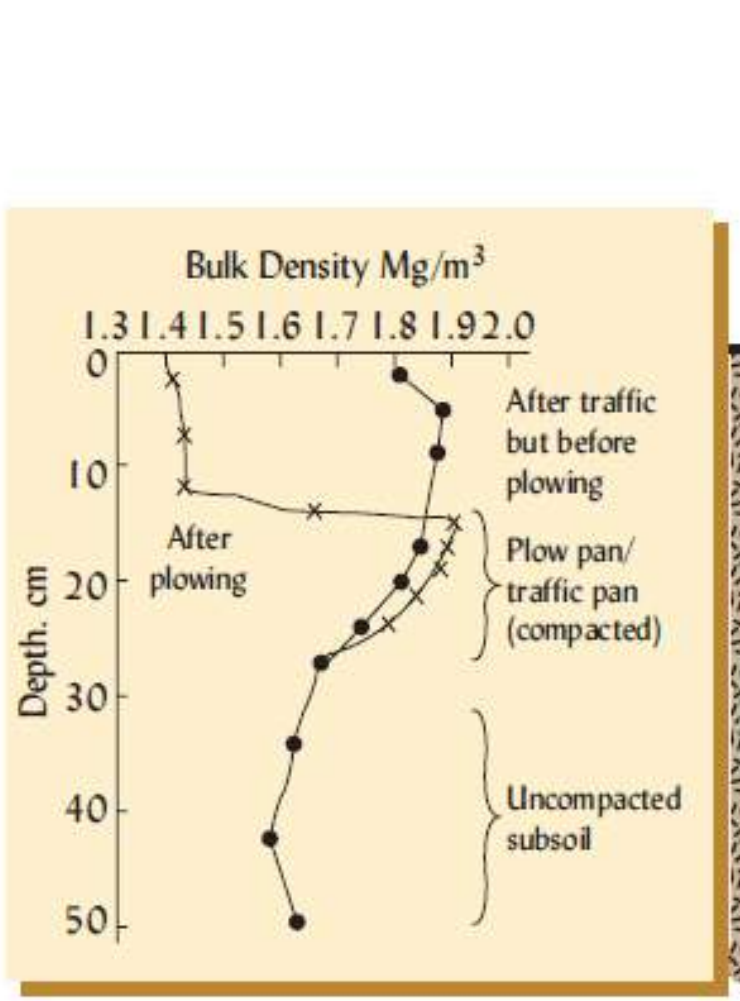
Soil structure formation

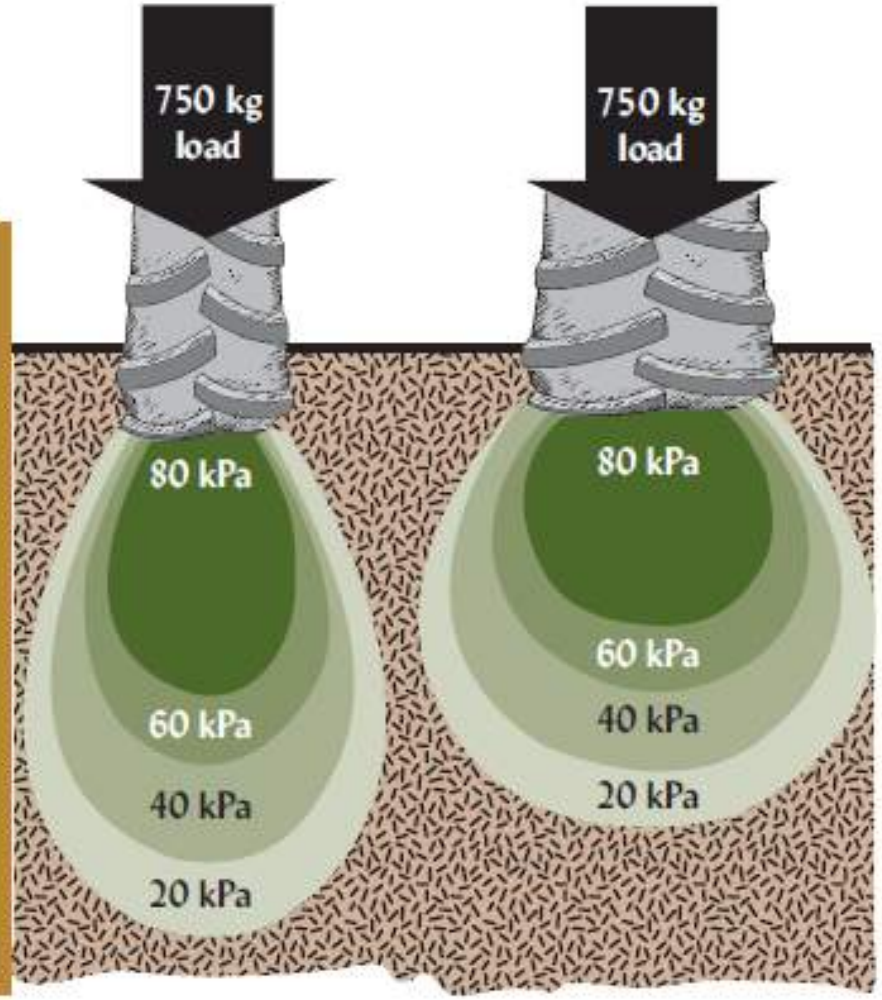
- Plant root secrete compounds gluing soil particles together
- Fungal mycelia act like threads to tie up soil particles
- Earthworms ingest and excrete soil - "crumb" structure in grasslands
- Decomposed organic matter acts to bind soil particles together
- External factors influence compaction – traffic, livestock
- Soil compaction reduces plant biomass



How to manage soil to reduce compaction

Figure 4.50 *Vehicle tires compact soil to considerable depths. (Left) Representative bulk densities associated with traffic compaction on a sandy loam soil. Plowing can temporarily loosen the compacted surface soil (plow layer), but usually increases compaction just below the plow layer. (Right) Vehicle tires (750 kg load per tire) compact soil to about 50 cm. The more narrow the tire, the deeper it sinks and the deeper its compactive effect. The tire diagram shows the compactive pressure in kPa. For tire designs that reduce compaction, see Tijink and Van der Linden (2000).* (Diagrams courtesy of Ray R. Weil)





Prevention better than cure

- Compaction is easy to do but difficult and expensive to fix
- On grassland – aeration and organic amendments
- On arable – minimise traffic from heavy machinery and utilise weigh distribution techniques (low pressure tyres), no till farming and varying conventional practice

- Subsoiling – results maybe temporary
- Add organic matter – increases fertility and biological activity
- Increase earthworm numbers!

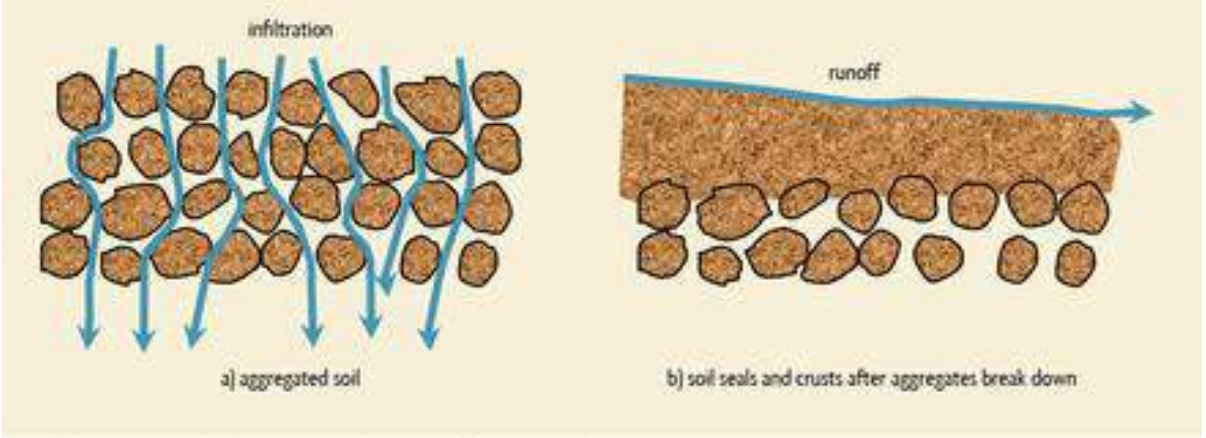
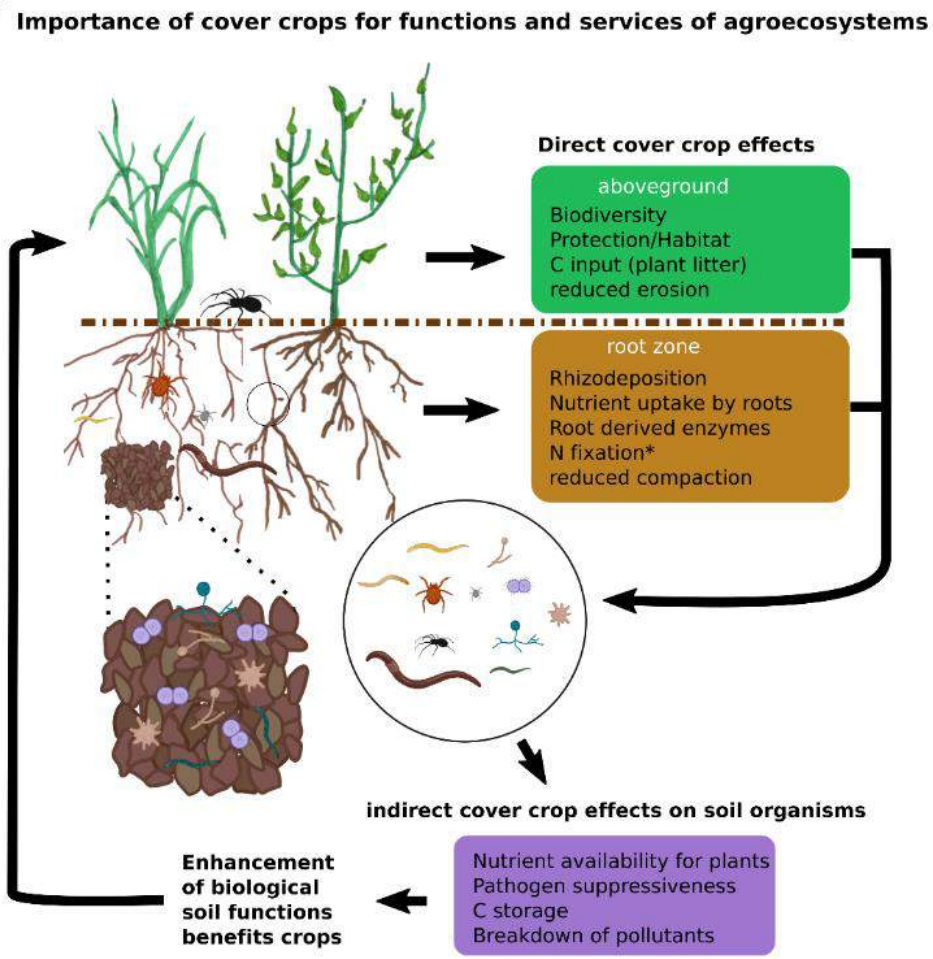


Figure 2.6. Changes in soil surface and water-flow pattern when seals and crusts develop.

Soil: The poor man's tropical rainforest

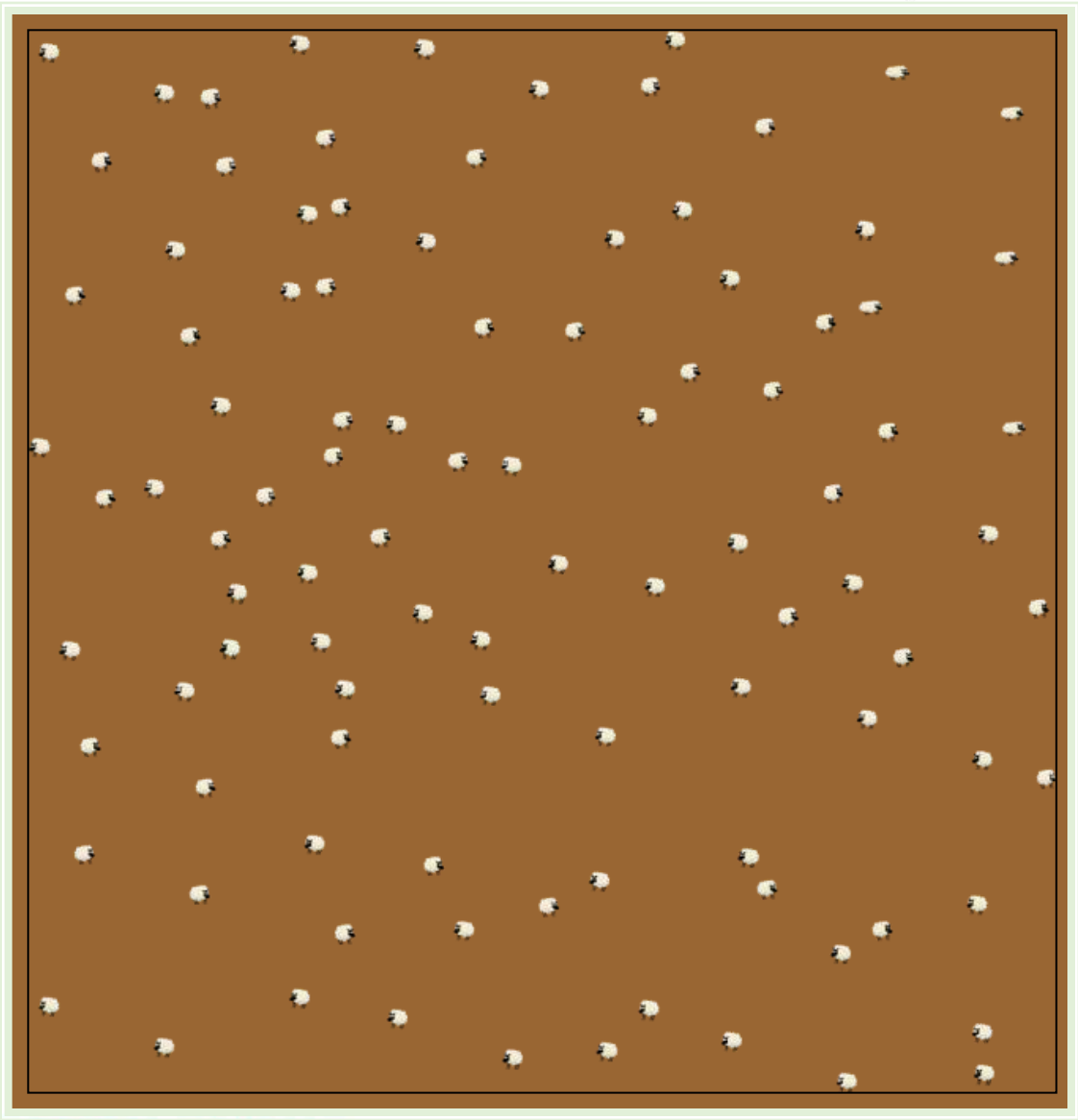
- Soil is home to ¼ of all living species on earth
- Soil organisms are driving soil functions like nutrient cycling and decomposition
- Agricultural practices can change the soil habitat influencing the abundance and diversity of soil fauna.



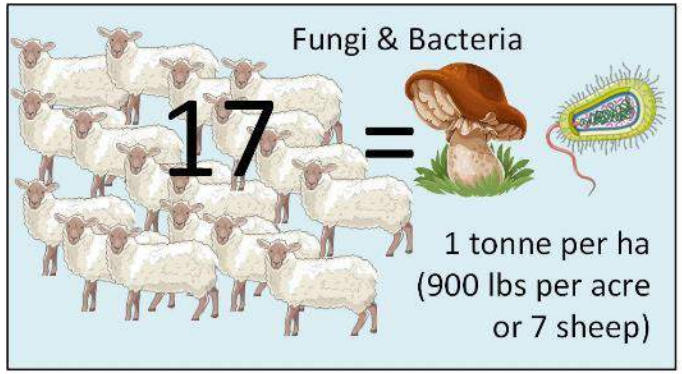
Crotty et al., 2021

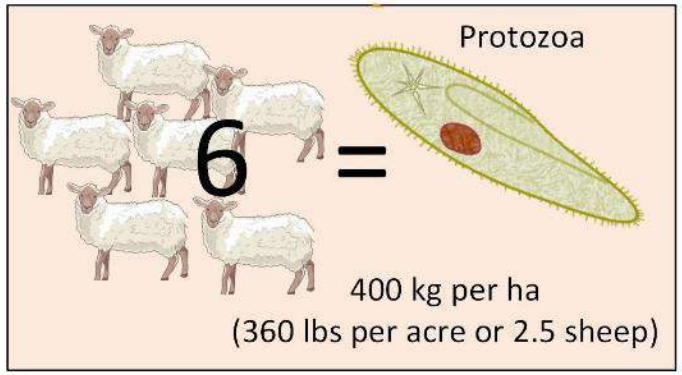
One hectare of arable soil has the equivalent to THREE TONNES of soil fauna

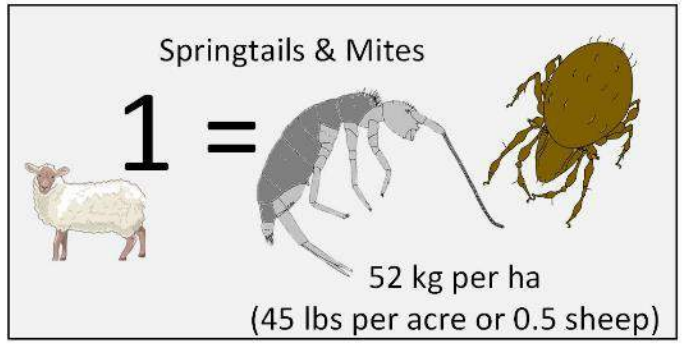
Or 53 sheep

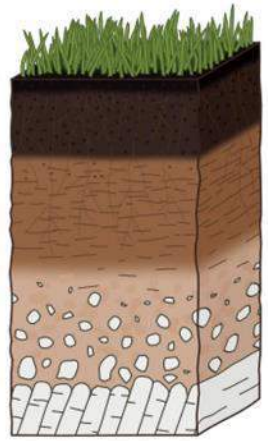


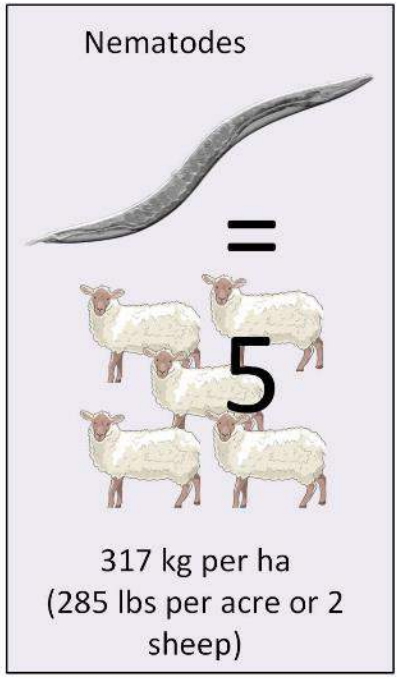
Greater weight of fauna below ground than livestock

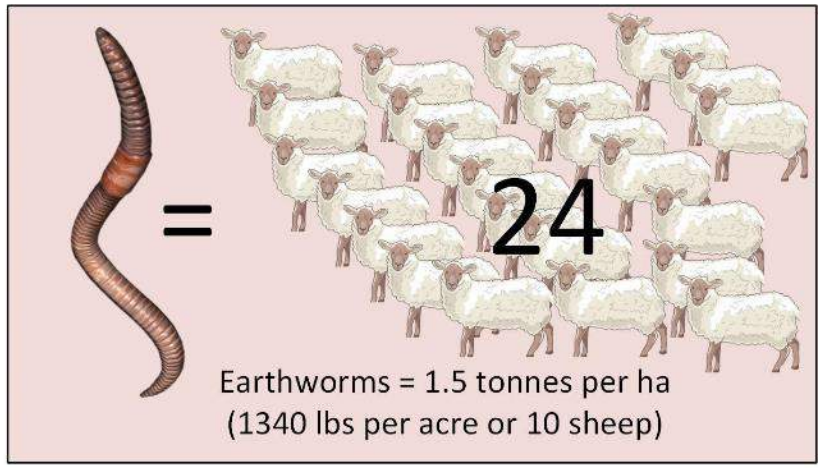


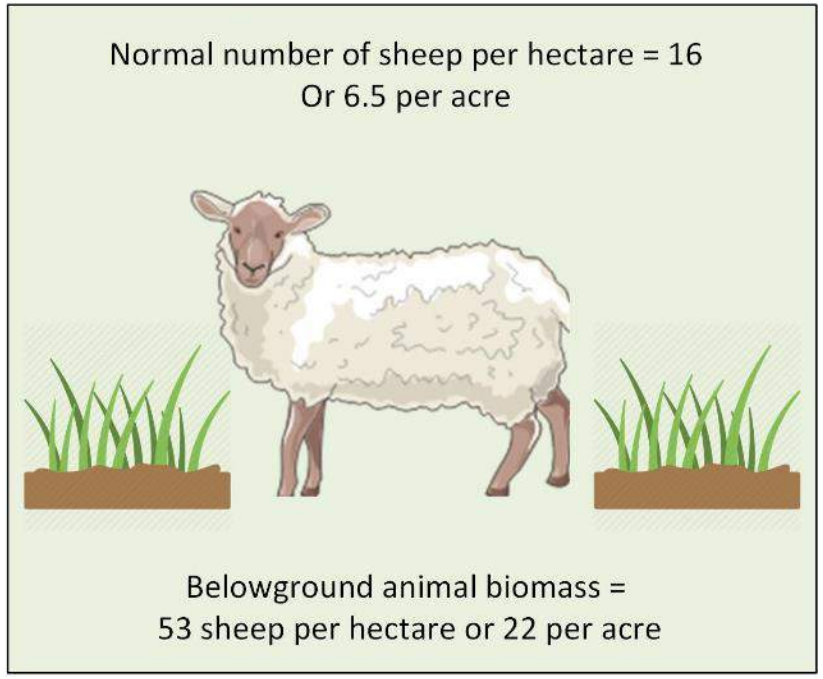












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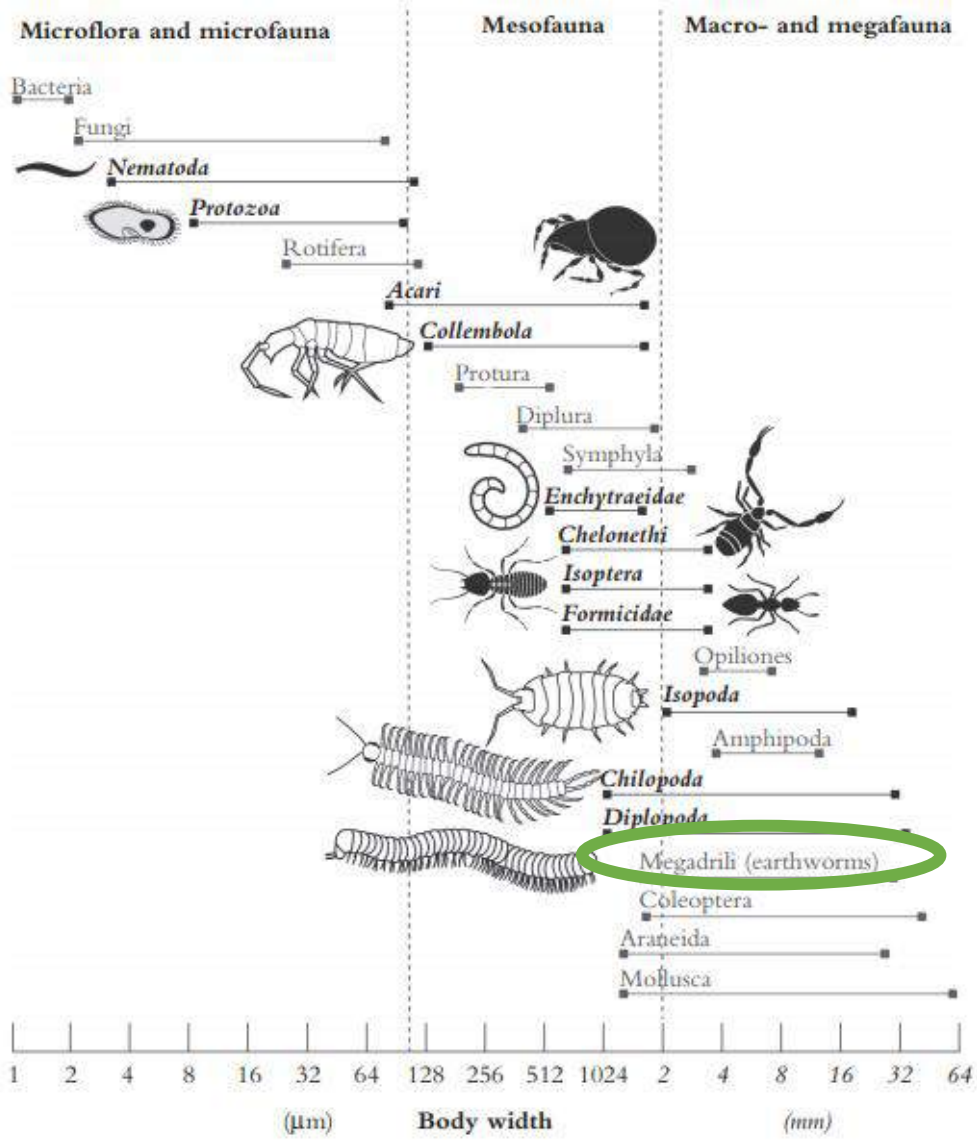
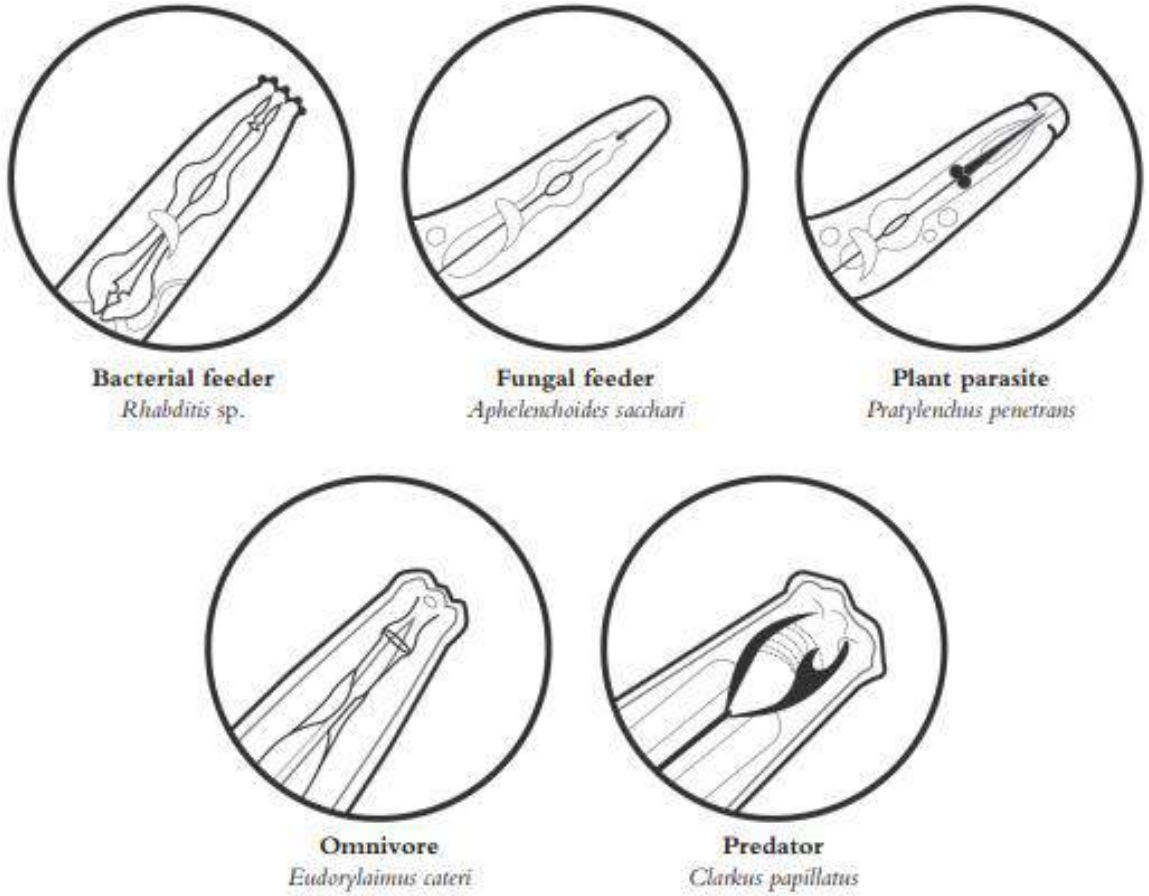
Crotty, 2022 *Frontiers for Young Minds*

MICROFAUNA, MESOFAUNA, MACROFAUNA



Microfauna:Nematodes (roundworm)

- Millions per m2 – most abundant animals on earth (80%?)
- Many functional groups: Bacteriovores, fungivores, herbivores, omnivores, predators
- Release large amounts of N while feeding -> microbial loop
- Found everywhere – important part of the soil food web and soil health
- Most focus has been on plant parasitic nematodes e.g. PCN



- Have been around for 530 million years
- Tardigrades are classified as extremophiles
- Can live in boiling water and solid ice
- Brought back to life after being rehydrated from 100+ year old moss samples
- Have survived 30 days in space
- Can repair their DNA after radiation damage
- Most tardigrades are phytophagous or bacteriophagous

But what are mesofauna?

https://www.chaosofdelight.org/collembola-springtails

But what are mesofauna?

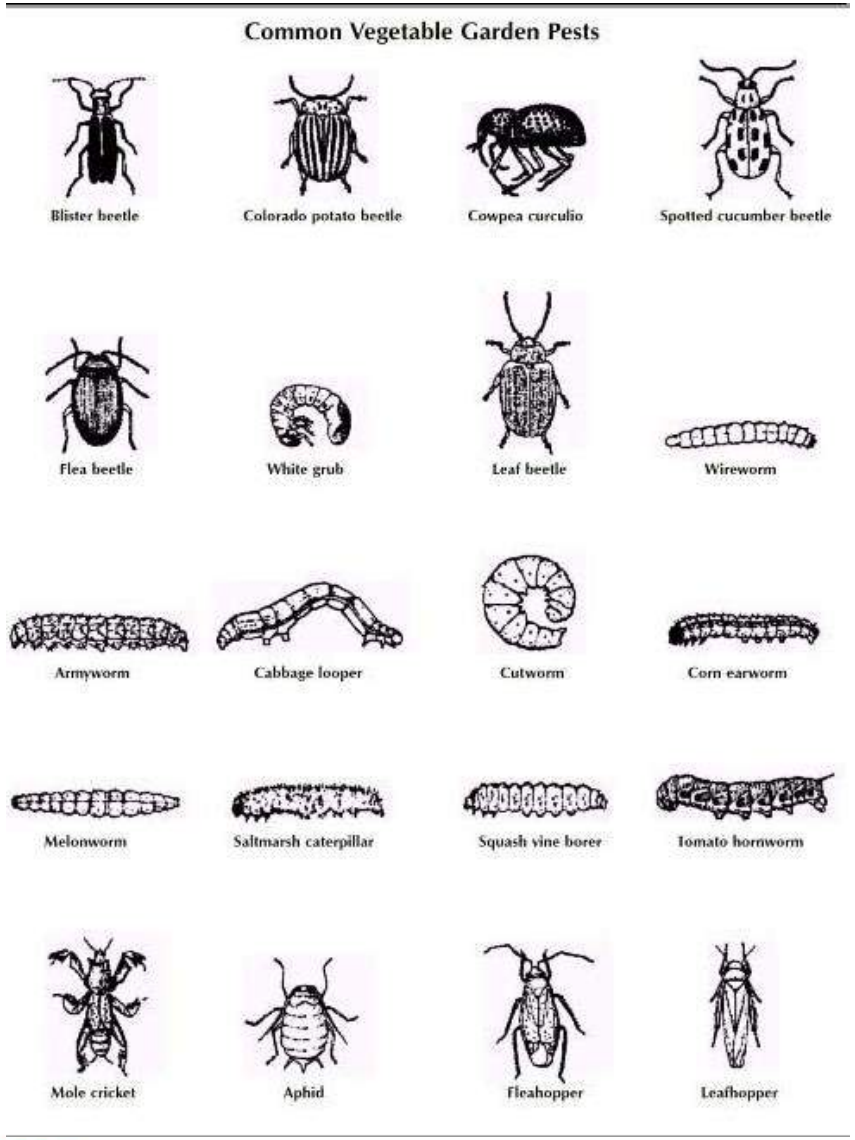
https://www.chaosofdelight.org/collembola-springtails

But what are mesofauna?

https://www.chaosofdelight.org/mites

What about pests?!

- Pest species are only a small proportion of soil organisms
- BUT are most studied within agriculture
- Why do we have a pest outbreak?
  - Limited competition for space and resources
  - Limited predation
  - Environmental conditions are right
  - Poorly timed (or no) chemical intervention



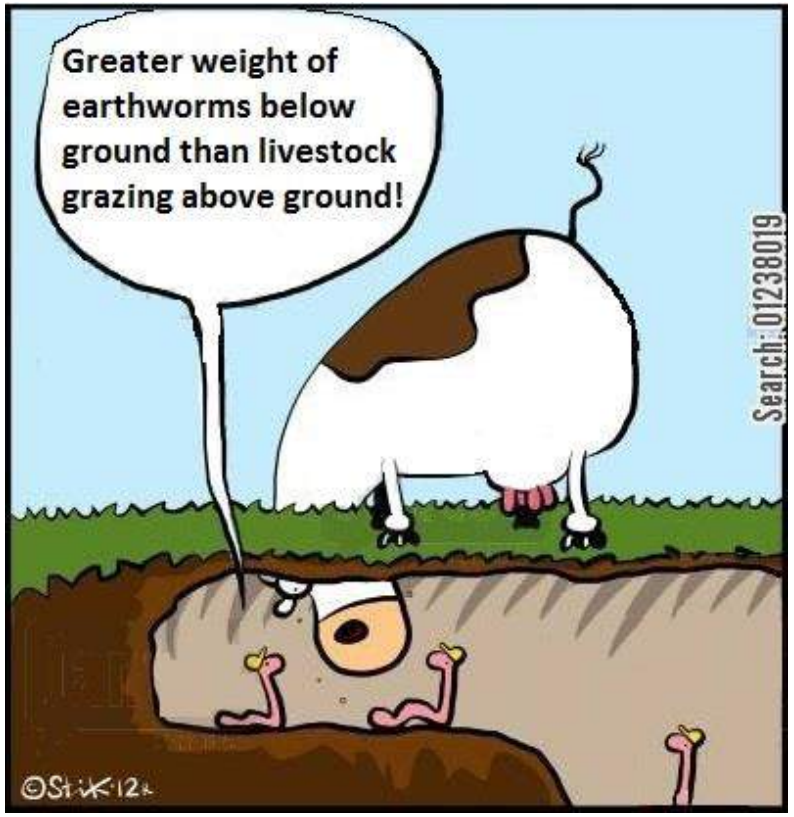
- Slugs consume about 40 times their weight per day… (if have a large outbreak – we found 177 per m2 or 1.7 MILLION per ha)
- Slugs lay up to 300 eggs over several days
- Eggs hatching is temperature dependent and can take 21 to 100 days

- Live in damp conditions
- Small component of soil fauna biomass but can have high agronomic impact
- Leatherjackets only need four per spadeful to cause economic damage

Macrofauna: дощовий черв'як
Earthworms as Ecosystem Engineers

- In UK = 30 species; in Ukraine = 96 species!!
- Found to increase CROP YIELDS up to 25%!
- Knowing how many earthworms you have is a quick and easy gauge of soil health
- More than 16 per spade-full = 400 per m^2 (approx)

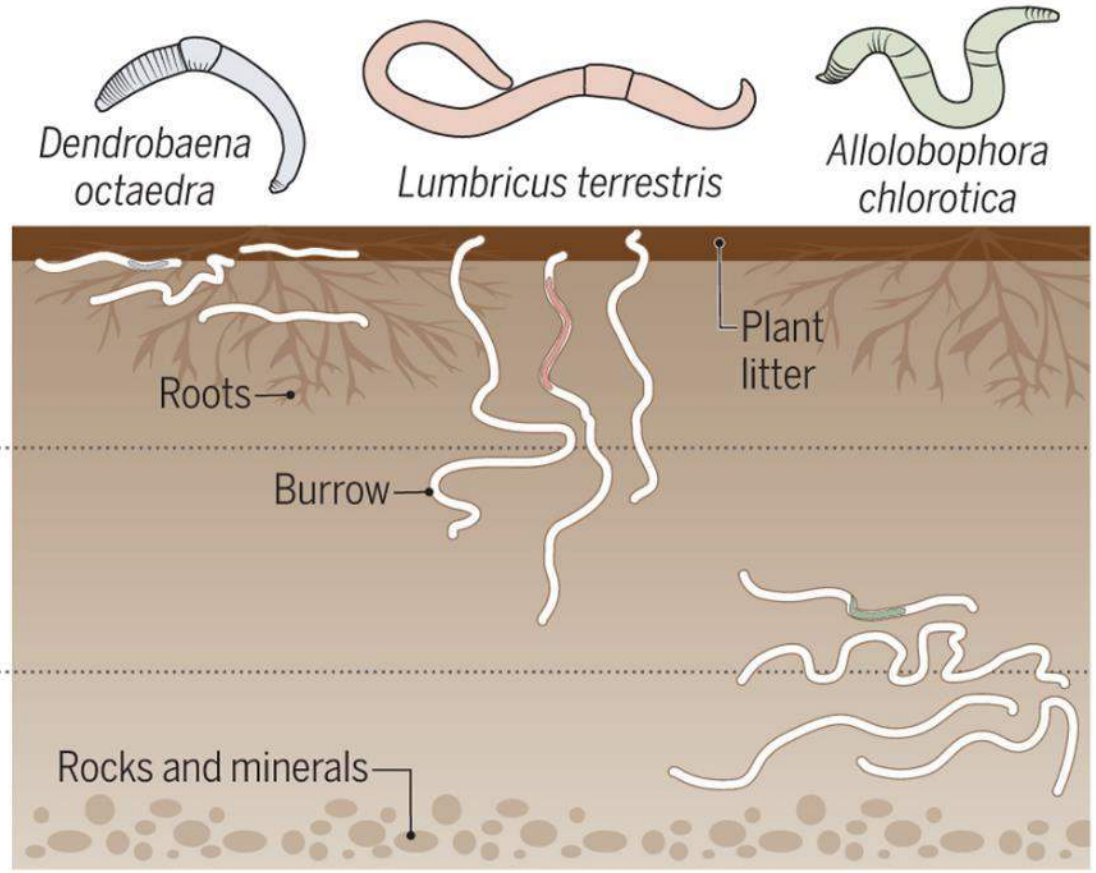
  = bench mark for a healthy soil?



Up to 3 tonnes per ha

Earthworm ecology

Shown are three main ecological categories of earthworms and examples of resident earthworm species. Not all species fall neatly into these categories, as some earthworms can vary their burrowing and feeding preferences depending on life stage and soil conditions.



Epigeic
Live close to the soil's surface and feed on plant litter

Anecic
Feed on plant litter and soil and form nearly vertical burrows

Endogeic
Live at various depths in mineral soil horizons and feed on soil

FACTSHEET

GREATSOILS

AHDB

How to count earthworms

Identifying adults and juveniles

Adult earthworms have a clearly developed **saddle** (reproductive ring) and juveniles do not.

You may need to rinse worms with water to determine if a saddle is present.

Size is not a good indicator of maturity as adult earthworms typically range in size from 2cm to 15cm, depending on species.

Training of experts to assess soils damaged due to hostilities

Sumy National Agrarian University

Royal Agricultural University

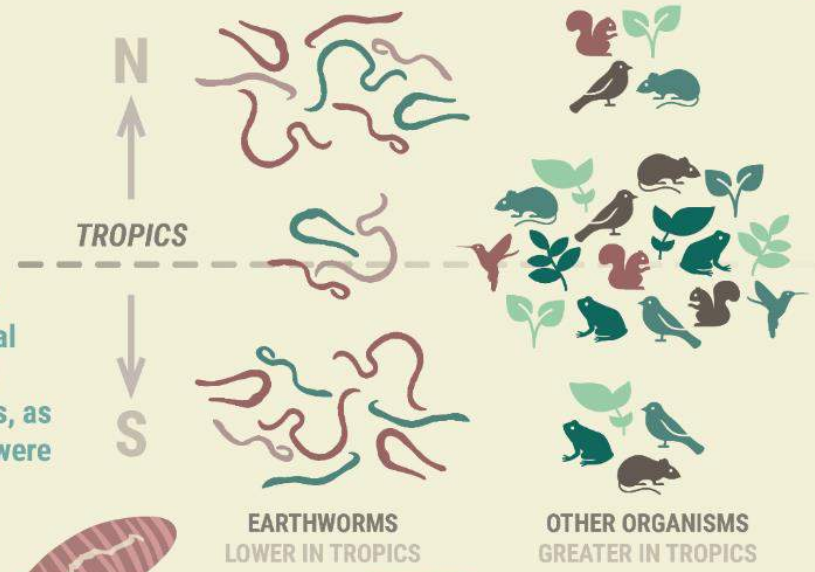
SOIL INVERTEBRATES PERFORM KEY ECOSYSTEM SERVICES. BUT DESPITE THEIR IMPORTANCE, NOT MUCH IS KNOWN ABOUT THEM AT THE GLOBAL SCALE.

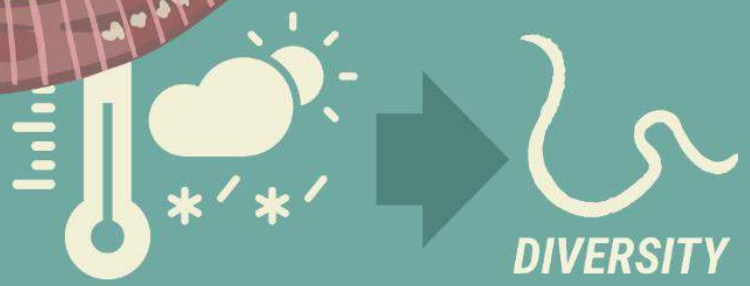
WE COMPARED THE DISTRIBUTIONS OF EARTHWORM SPECIES ACROSS THE GLOBE TO FIND OUT THEIR GEOGRAPHICAL PATTERNS AND MAIN DRIVERS.

BIODIVERSITY

Surprisingly, patterns of local earthworm diversity were opposite to those of aboveground organisms.

However, we suspect that across the tropics the total number of earthworms is greater than other regions, as earthworm communities were highly dissimilar from each other.





The biggest drivers of earthworm biodiversity were variables related to climate, meaning climate change could have serious effects on soil communities and the ecosystem services they provide.

TO LEARN MORE, CONTACT: SWORM@IDIV.DE

INFOGRAPHIC BY KATE BROADLEY OF FUSE CONSULTING LTD.

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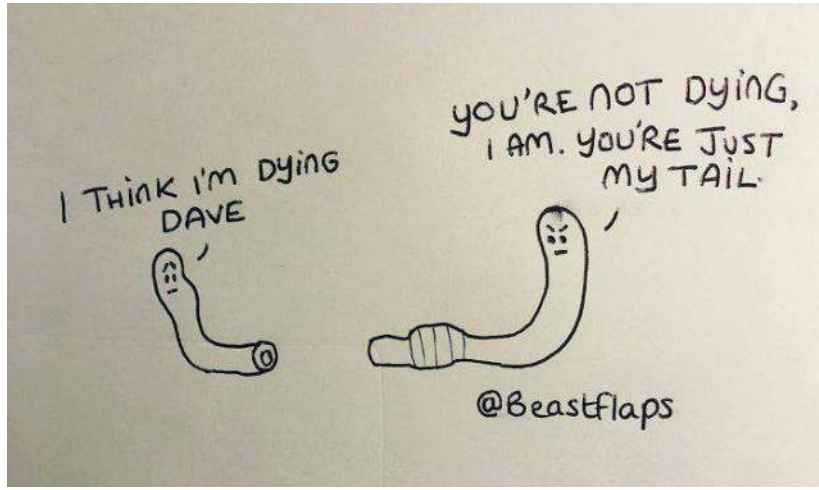
In conclusion

- Soil biodiversity has been shown to vary due to crop (food availability), crop establishment methods (ploughing disturbs habitat) and climate.
- If soil biodiversity is to be used as an indicator of soil health than these external drivers need to be considered
- The more stable the environment is (less digging) and more food provided (organic matter) the more likely soil biodiversity populations will grow
- Soil health monitoring programme is needed, to understand the state of soil
- Healthier a soil is, the more resilient it will be to future weather extremes



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