Soil Biodiversity: Exploring the World Beneath Your Feet

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Outline

What is soil?
What soil properties influence soil carbon?
- Physical
- Chemical
- Biological

Impact of soil on climate change
Impact of agricultural practices
The health of soil, plant and man is one and indivisible.

Sir Albert Howard, 1926
SOIL

• Non-renewable resource

• Vital for productivity in terrestrial environments

• More than just organic matter, minerals and water
Soil Formation

Soil forming factors:
- Parent Material
- Time
- Climate
- Organisms
- Topography

Soil forming processes:
- Transformation
- Translocation
- Addition
- Losses
What properties and characters make up soil?

Biological

Physical

Chemical
Soil health

The ability of soil to function as a vital living system to sustain biological productivity, promote air and water quality and maintain plant, animal, and human health.

(Doran et al., 2002)
What is a healthy soil?
What to measure?

- Dynamic vs. fixed
- Long term vs. short term
- Criteria
- Thresholds
- Baseline values
- Integration of variables
Physical

- Bulk density
- Texture
- Erosion potential
- Hydrology
- Topography
- Aggregate stability
What is being measured?

Physical properties
• soil depth,
• rooting depth,
• infiltration rates,
• bulk density,
• water holding capacity,
• aggregate distribution and stability,
• soil porosity,
• soil structure, and
• soil texture
Chemical

- Soil organic matter
- Macronutrients
- Micronutrients
- pH
- Salinity
- CEC
- EC
Soil Organic Matter (SOM)

Plant and animal residues at various stages of decomposition, cells and tissues of soil organisms, and substances synthesized by soil organisms.
Soil Organic Carbon (SOC)

The amount of carbon stored in the soil is a component of soil organic matter – plant and animal materials in the soil that are in various stages of decay.

Soil organic carbon is the basis of soil health
Soil organic matter (SOM) contains more than three times as much carbon as either the atmosphere or terrestrial vegetation.
Vegetation: 610
Atmosphere: 600 (pre-industrial)
Soils: 1560
Ocean mixed layer: 1000
Deep ocean: 38,000
Sediments and rocks: 66,000,000

Major carbon reservoirs (gigatons)
What is being measured?

Chemical properties
  • SOM – more than just plant matter
  • SOC

Classic humification process
  ➮ Progressive decomposition
  ➮ Soil Continuum model  (Lehmann and Kleber 2015)
Consolidated view

Soil continuum model

Plant, animal residues
Carbohydrate, protein, lignin, lipid, pyrogenic

Large biopolymers

Small biopolymers

Monomers

CO$_2$

Turnover time

Revision of SOM models

• Continuum of decomposition products
  • Faunal excrement
  • Necromass
  • Earthworm activity

(See Komarov et al (2017) and Chertov et al (2017) in Ecological Modelling, Vol 345)
Methods to assess SOM

• Thermal stability
• Particle size analysis
• Visual/infrared
  • FTIR spectroscopy
  • Drones
  • Precision agricultural technology
Managing carbon is key to soil health.
Soil Biota (from Hunt et al. 1987)

Modified from McGill & Cole, 1981

Diagram showing the interactions between different soil biota components.

-from Hunt et. al. 1987-
Biological

- Microflora
- Microfauna
- Mesofauna
- Macrofauna
SOIL BIOTA

- Dark, opaque, three-dimensional habitat
- Species diversity of soil rivals that of a coral reef
- Referred to as “the poor-man’s tropical rainforest”
- Hundreds of species/m²
- Tens of thousands of individuals/m²
<table>
<thead>
<tr>
<th>Soil biota and soil ecosystem processes</th>
<th>Decomposition</th>
<th>Nutrient cycling/availability</th>
<th>Soil structure</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Microflora</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>• Degrade SOM</td>
<td>• Mineralize</td>
<td>• Bind soil aggregates</td>
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<tr>
<td>• Fragment SOM</td>
<td>• Immobilize</td>
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<tr>
<td><strong>Microfauna</strong></td>
<td>• Fragment SOM</td>
<td>• Regulate</td>
<td>• Bind soil aggregates</td>
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<tr>
<td>• Fragment SOM</td>
<td>• Alter</td>
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<tr>
<td><strong>Mesofauna</strong></td>
<td>• Fragment SOM</td>
<td>• Regulate</td>
<td>• Faecal material</td>
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<td>• Fragment SOM</td>
<td>• Alter</td>
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<tr>
<td>• Increase surface area</td>
<td>• Regulate</td>
<td>• Faecal material</td>
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<tr>
<td>• Alter</td>
<td>• Alter</td>
<td>• Faecal material</td>
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</tr>
<tr>
<td><strong>Macrofauna</strong></td>
<td>• Fragment SOM</td>
<td>• Stimulate</td>
<td>• Redistribute</td>
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<tr>
<td>• Fragment SOM</td>
<td>• Alter</td>
<td>• Alter soil bulk density</td>
<td></td>
</tr>
<tr>
<td>• Increase surface area</td>
<td>• Alter</td>
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</table>
Biomass

- nearly 15 tonnes·ha$^{-1}$ of soil biota
  - Microflora making up 4 to 9 tonnes·ha$^{-1}$
  - Earthworm biomass 2.5 tonnes·ha$^{-1}$
- 100-200 sheep·ha$^{-1}$
Hey Canada!

It's time to #SoilYourUndies... in the name of soil conservation

Do your own soil science experiment to see how healthy your soil is and share your experience on social media.

Anyone can investigate biological activity in farm fields or backyard gardens. Bury a pair of 100% cotton underwear in topsoil for about two months and then check the level of decomposition. If there's not much left of the underwear, you have good biological activity, which indicates healthy soil. These same soil organisms can break down plant materials in much the same way.

To make a good on-farm comparison:
- Test similar soil types under different rotations and tillage management.
- Keep track of each pair by writing an identifying number on the waistband.
- Be sure to bury all underwear being compared on the same day and for the same amount of time.

WHAT YOU'LL NEED
- New pair of white 100% cotton briefs (no dyes or polyester blends)
- Shovel
- Marker flag
1) Dig a narrow trench and bury the underwear in the top six inches of soil.
2) Leave the waistband showing a little and mark the place with a flag so you'll be able to find it again.
3) Leave the underwear buried for about two months.
4) Dig it up carefully and wash it in a bucket of water to remove the soil.
Soil carbon sequestration

The removal and long-term storage of carbon from the atmosphere in carbon sinks (such as oceans, forests or soils) through physical or biological processes
Influence of agricultural practices

- Crop type and rotation
- Soil diversity
- Plant diversity
- Cover crops
- Tillage & No tillage

- Grazing
- Fertilizers
- Pesticides
- Organic amendments
- Permanent plant growth

Modification of agricultural practices can offset as much as 20% of CO$_2$ emissions annually
On-farm carbon emission reduction

• Reducing and/or displacing emissions
  • Increase efficiency

• Enhancing carbon removal
  • Interrupt natural carbon cycle
Conventional agricultural systems

• Create an homogenous soil habitat maintained at an early or intermediate stage of succession.

• Simplify biological diversity in the soil.

• Require constant human intervention and resource input.
Tillage

Changes physical & chemical properties of soil:

• Loss of soil structure
• Increased risk of soil erosion
• Loss of soil OM
• Reduction in soil biota
Tillage Impacts

- Soil dominated by bacteria
- Increased protozoa and nematode densities
- Rapid decomposition and nutrient mineralization
Minimum Zero Tillage

• Retention of crop residues
  – Promotes fungal growth
  – Short-term immobilization of nutrients
  – Slower decomposition
  – Increased density and diversity of soil biota

• Changes to physical & chemical properties
  – Moisture retention
Grazing

Changes to vegetation structure

Alter chemical and physical properties in the soil

<table>
<thead>
<tr>
<th>Decreased</th>
<th>Increased</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Soil OM</td>
<td>• Bulk density</td>
</tr>
<tr>
<td>• Litter layer</td>
<td>• Soil temperature</td>
</tr>
<tr>
<td>• Mineralizable N</td>
<td></td>
</tr>
<tr>
<td>• Aggregate stability</td>
<td></td>
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<tr>
<td>• Soil moisture</td>
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</table>
Fertilizers & Pesticides

Direct effects
  • altering chemical environment
  • lethal doses

Indirect effects
  • changes in litter quality, site hydrology or microclimate
Fertilizers

Nitrogen fertilizers

• increase osmotic pressure
• change soil pH, soil organic matter, litter input
• change food supply, soil microorganisms
• decrease Enchytraeid populations
• moderate dose = little effect on Collembola or mites
• higher doses = decrease abundances
Fertilizers cont’

Urea fertilizer
  • increases bacterial feeding nematodes

Ammonium
  • decreases bacterial feeding nematodes

Liming
  • increases earthworm abundance
  • decreases Enchytraeid abundance
Pesticides

Varying responses

Dependent upon

- Amount applied
- Level of identification
  - Species
  - Suborder
Soil Health

**Reduce**
- tillage
- annual/seasonal fallow
- mono-cropping
- annual crops
- excessive inorganic fertilizer application
- crop residue removal
- pesticide use
- herbicide use

**Enhance**
- no-till/reduce till
- cover crops
- diverse crop rotation
- perennial crops
- organic fertilizer application
- crop residue retention
- Integrated pest management
- weed control via mulching/cultural tactics
## Us & Nature

<table>
<thead>
<tr>
<th>Us</th>
<th>Nature</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Seed bed prep &amp; planting</td>
<td>• Natural seed dispersal</td>
</tr>
<tr>
<td></td>
<td>• Natural control of</td>
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<tr>
<td></td>
<td>• weeds,</td>
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<td></td>
<td>• Insect pest &amp;</td>
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<tr>
<td></td>
<td>• Pathogens</td>
</tr>
<tr>
<td>• Chemical pesticides/herbicides</td>
<td>• Decomposition &amp; nutrient cycling</td>
</tr>
<tr>
<td>• Chemical fertilizers</td>
<td></td>
</tr>
</tbody>
</table>
ASEA Soil Quality Monitoring Study
1997-2008
43 sites
soil chemical and physical properties
The Soil - Climate Connection

Food
- Greater Availability of Nutrients
- Improved Yields

Climate
- Reduced GHG Emissions
- More Soil Carbon Stored

Water
- Increased Water Retention & Supply
- Less Severe Droughts & Floods

Healthy Soil
Thank you