Critical Role of Soil
Molly Deger
THE CRITICAL ROLE OF SOILS

healthy soils, minimizing impacts, mitigating impacts

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  • Mission: Conserving Soil for Clean Water

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SOIL DEVELOPMENT

Pennsylvania’s soils are generally derived from:
- Igneous
- Sedimentary
- Metamorphic

Soil formation:
- Starts with weathering to bare rock and buried rock
- Temperature fluctuation (expansion and contraction)
- Erosion by wind, water, ice
- Plant roots growing into tiny cracks, causing them to spread
- Chemical reaction of soil minerals with water and air
Soil is a natural body comprised of solids (minerals and organic matter), liquid, and gases that occurs on the land surface, occupies space, and is characterized by one or both of the following: horizons, or layers, that are distinguishable from the initial material as a result of additions, losses, transfers, and transformations of energy and matter or the ability to support rooted plants in a natural environment.

The **upper limit** of soil is the boundary between soil and air, shallow water, live plants, or plant materials that have not begun to decompose. Areas are not considered to have soil if the surface is permanently covered by water too deep (typically more than 2.5 meters) for the growth of rooted plants.

The **lower boundary** that separates soil from the nonsoil underneath is most difficult to define. Soil consists of horizons near the Earth's surface that, in contrast to the underlying parent material, have been altered by the interactions of climate, relief, and living organisms over time. Commonly, soil grades at its lower boundary to hard rock or to earthy materials virtually devoid of animals, roots, or other marks of biological activity. For purposes of classification, the lower boundary of soil is arbitrarily set at 200 cm (6.5 FEET).
Healthy soils give us clean air and water, bountiful crops and forests, productive grazing lands, diverse wildlife, and beautiful landscapes. Soils do all this by performing five essential functions:

1. Regulating water
2. Sustaining plants and animal
3. Filtering and buffering potential pollutants
4. Cycling nutrients
5. Physical stability and support
The solid portion of a typical soil sample is made up of the following:
- Sand
- Silt
- Clay
- Humus
SOIL – CHEMICAL COMPONENTS

- Elements (Nutrients), pollutants, filter water
- Affects physical properties and biological components
- Cation-exchange capacity
- Soil pH, Soil Color
# Soil - Biological Components

## Functions of Soil Organisms

<table>
<thead>
<tr>
<th>Type of Soil Organism</th>
<th>Major Functions</th>
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<tbody>
<tr>
<td><strong>Photosynthesizers</strong></td>
<td>Capture energy</td>
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<td>Plants</td>
<td>Use solar energy to fix CO₂.</td>
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<td>Algae</td>
<td>Add organic matter to soil (biomass such as dead cells, plant litter, and secondary metabolites).</td>
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<tr>
<td>Bacteria</td>
<td>Break down residue</td>
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<td></td>
<td>Immobilize (retain) nutrients in their biomass.</td>
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<td><strong>Decomposers</strong></td>
<td>Stabilize organic matter (humus)</td>
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<tr>
<td>Bacteria</td>
<td>33% - 50%</td>
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<tr>
<td>Fungi</td>
<td>Decomposing organic matter (active fraction)</td>
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<td>33% - 50%</td>
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<tr>
<td><strong>Mutualists</strong></td>
<td>Fresh residue</td>
</tr>
<tr>
<td></td>
<td>&lt;10%</td>
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<td><strong>Pathogens</strong></td>
<td>Shred plant litter as they feed on bacteria and fungi.</td>
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<td>Provide habitat for bacteria in their guts and fecal pellets.</td>
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<td><strong>Parasites</strong></td>
<td>Enhance soil structure as they produce fecal pellets and burrow through soil.</td>
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<td><strong>Root-feeders</strong></td>
<td>Control populations</td>
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<td>Control the populations of lower trophic-level predators.</td>
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<td>Larger organisms improve soil structure by burrowing and by passing soil through their guts.</td>
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<td>Larger organisms carry smaller organisms long distances.</td>
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![Diagram showing soil components](image)

**Soil facts:**

- **Soil is made of about 45% minerals.**
- 25% water, 5% organic matter, 25% air.
- Soil has amazing water-retention capacity.
- An increase in organic matter results in as much as 25,000 gal of available soil water per acre.
- A teaspoon of healthy soil contains 10 million-90 billion individual bacteria.
- Each acre of soil contains 9 billion insects by 2050.
- Soil is the most valuable resource on earth, containing more living matter than all of the forests combined.
BASEFLOW VS. RUNOFF

FACTORS INFLUENCING INFILTRATION

- Soil Texture
- Soil Crust
- Soil compaction
- Soil Aggregation and Structure
- Water Content
- Frozen surface
- Organic Matter
- Pores
EROSION
SEDIMENT

Sediment is a naturally occurring material that is broken down by processes of weathering and erosion, and is subsequently transported by the action of wind, water, or ice, and/or by the force of gravity acting on the particles.

- Suspended vs. dissolved
- Up-stream vs. in-stream
NRCS Web Soil Survey
- [https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm](https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm)
- 70,000 soils delineated in U.S.

HYDROLOGIC SOIL GROUP
- A - high rate of water transmission.
- B - moderate rate of water transmission.
- C - slow rate of water transmission.
- D - very slow rate of water transmission.
SITE ASSESSMENT

- Test Pits
- Infiltration Testing
SITE ASSESSMENT

} Geology
} Environmental Due Diligence
COMPACTION

- Reduces infiltration
- Can be major or minor
- Caused by variety of sources – compaction equipment, construction vehicles, farm vehicles, mowing, foot traffic
- Rehabilitation can occur
Minimizing Earth Disturbance: Redevelopment

Focus on previously developed area – avoid “greenfields” or wooded lots

Incentives
- Fee Reduction
- Stormwater management requirement is reduced (most municipalities)

Challenges
- Cost
- Potential for environmental remediation (cost)
Minimizing Earth Disturbance: Sensitive Site Design

- Low Impact Development
- Minimize grading
- Minimize soil compaction
Minimizing Earth Disturbance: Municipal Ordinances

- Grading
- Tree/Landscaping
- Steep Slope
- Stormwater
- Floodplain/Riparian Buffer
Engineered Soils

- Structural (foundations)
- On-site soils amended
- Imported soils – site soils, stormwater management
- Highly engineered – tree trenches, green roofs
in situ vs. Engineered Soils

- Soil horizon
- Structural soundness
- Pollutants – naturally occurring (i.e. cobalt) or man-made
- Biological components!
Benefits to Engineered Soils

- Can rehabilitate soils that have been or will be compromised
- Can aid in stormwater management
- Make green roofs possible
Rain Garden Soils

- Highly researched
- Large discrepancies within recommendations (i.e. clay content)
- Typically high sand content
  - Well-graded seems key
- Some compost addition
  - Well aged

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[Google Scholar search for bioretention soils]

Effect of Vegetation on the Fate of Petroleum Hydrocarbons in Laboratory-Scale Rain Gardens

EM Ayers, P Kangas - Low Impact Development, Design ... 2015 - ascelibrary.org

Topsoil Development in Bioretention Cells: What Are the Implications?

EM Ayers, P Kangas - Low Impact Development Technology, Design ... 2015 - ascelibrary.org

An event-based hydrologic simulation model for bioretention systems

A Ro-Parker, T Elias - Water Science and ... 2015 - wslscience.com
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<td><strong>Decomposers</strong></td>
<td><strong>Break down residue</strong>&lt;br&gt;• Immobilize (retain) nutrients in their biomass.&lt;br&gt;• Create new organic compounds (cell constituents, waste products) that are sources of energy and nutrients for other organisms.&lt;br&gt;• Produce compounds that help bind soil into aggregates.&lt;br&gt;• Bind soil aggregates with fungal hyphae.&lt;br&gt;• Nitrifying and denitrifying bacteria convert forms of nitrogen.&lt;br&gt;• Compete with or inhibit disease-causing organisms.</td>
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<td><strong>Mutualists</strong></td>
<td><strong>Enhance plant growth</strong>&lt;br&gt;• Protect plant roots from disease-causing organisms.&lt;br&gt;• Some bacteria fix N₂.&lt;br&gt;• Some fungi form mycorrhizal associations with roots and deliver nutrients (such as P) and water to the plant.</td>
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<td><strong>Pathogens</strong></td>
<td><strong>Promote disease</strong>&lt;br&gt;• Consume roots and other plant parts, causing disease.&lt;br&gt;• Parasitize nematodes or insects, including disease-causing organisms.</td>
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<td><strong>Parasites</strong></td>
<td><strong>Consume plant roots</strong>&lt;br&gt;• Potentially cause significant crop yield losses.</td>
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<td><strong>Root-feeders</strong></td>
<td><strong>Graze</strong>&lt;br&gt;• Release plant available nitrogen (NH₄⁺) and other nutrients when feeding on bacteria.&lt;br&gt;• Control many root-feeding or disease-causing pests.&lt;br&gt;• Stimulate and control the activity of bacterial populations.</td>
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<td><strong>Bacterial-feeders</strong></td>
<td><strong>Graze</strong>&lt;br&gt;• Release plant available nitrogen (NH₄⁺) and other nutrients when feeding on fungi.&lt;br&gt;• Control many root-feeding or disease-causing pests.&lt;br&gt;• Stimulate and control the activity of fungal populations.</td>
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<td><strong>Fungal-feeders</strong></td>
<td><strong>Break down residue and enhance soil structure</strong>&lt;br&gt;• Shred plant litter as they feed on bacteria and fungi.&lt;br&gt;• Provide habitat for bacteria in their guts and fecal pellets.&lt;br&gt;• Enhance soil structure as they produce fecal pellets and burrow through soil.</td>
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<td><strong>Shredders</strong></td>
<td><strong>Control populations</strong>&lt;br&gt;• Control the populations of lower trophic-level predators.&lt;br&gt;• Larger organisms improve soil structure by burrowing and by passing soil through their guts.&lt;br&gt;• Larger organisms carry smaller organisms long distances.</td>
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Alternative Technologies

} Biochar
} Compost tea
} Proprietary bioretention systems
Summary

- Natural Conditions
- Minimizing Impacts
- Mitigating Impacts