The Science of Healthy, Living Soil

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Clean Water Summit
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U of MN Landscape Arboretum
Topics

- Vital Functions of Soil
- Soil Composition
- Soil Texture & Structure
- Organic Matter & Soil Biology
- Soil Formation & Human Impacts
- Sustaining Soil as a Natural Resource
The Year(s) of Soil 2012-13

- Arboretum “Dirt O Rama”

- Bell Museum “Dig It” Exhibit:
  - Nov. 8, 2012 – July 31, 2012

- Department of Soil, Water, and Climate Centennial and 40th Anniversary of MAPSS in 2013
Functions of Soil

- Sustains life on Earth – the medium for plant growth
- Stores and cycles nutrients essential for plants and animals
- Regulates water movement
- Filters, buffers, degrades, immobilizes, and detoxifies pollutants
- Provides support for structures

NACD = National Association of Conservation Districts
Soils are Three Dimensional

Soil Profile

Most soils have three major horizons -- the surface horizon (A), the subsoil (B), and the substratum (C).
Soil Composition

Soil is composed of solids, water, and air

- **Solids (50%)**
  - Sand, silt, clay (90-99%)
  - Organic matter (1-10%)

- **Water (25%)**
  - \( \text{H}_2\text{O} \)
  - 100-1000 ppm soluble salts

- **Air (25%)**
  - High \( \text{CO}_2 \) (10-20 times as high as the atmosphere)
Components of a Healthy Soil

All components interact

Organic matter plays a critical role

Chemical
nutrients, pH

Biological
microbes, plants, animals

Physical
texture & structure
Soil Texture

Soil texture refers to the size of soil particles and their relative proportions in a specific soil.

<table>
<thead>
<tr>
<th>Soil Particle</th>
<th>Diameter (mm)</th>
<th>Relative Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>0.05 – 2.0</td>
<td>Barrel</td>
</tr>
<tr>
<td>Silt</td>
<td>0.002 – 0.05</td>
<td>Plate</td>
</tr>
<tr>
<td>Clay</td>
<td>&lt;0.002</td>
<td>Dime</td>
</tr>
</tbody>
</table>
## Categories of Soil Texture

Soils are grouped into three general categories based on texture.

<table>
<thead>
<tr>
<th>General Name</th>
<th>Relative Texture</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandy Soil</td>
<td>Coarse</td>
<td>Sand</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Loamy Sand</td>
</tr>
<tr>
<td>Loam Soil</td>
<td>Moderately Coarse</td>
<td>Sandy Loam</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>Loam</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Silt Loam</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Silt</td>
</tr>
<tr>
<td></td>
<td>Moderately Fine</td>
<td>Sandy Clay Loam</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Silty Clay Loam</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Clay Loam</td>
</tr>
<tr>
<td>Clay Soil</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Clay</td>
</tr>
</tbody>
</table>
Textural Triangle

Texture is determined by laboratory tests and by feel.
Textural Triangle
Characteristics of Fine Soil

Clay loams and clays

- "Heavy" soils
- High nutrient and water holding capacities
  - 2.0 to 3.5 inches water/foot soil
- Poor drainage
- Most difficult to manage
Characteristics of Medium Soil

Loams and silt loams

- “Ideal” balance of soil properties
- Moderate nutrient and water holding capacities
  - 1.7 to 2.8 inches water/foot soil
- Good drainage
Characteristics of Coarse Soil

Sands, loamy sands, sandy loams

- “Light” soils
- Low water holding capacity
  - 0.6 to 1.3 inches water/foot soil
- Excessive drainage
- Low in nutrients
  - Especially N and K
Organic Soils (Peats or Mucks)

- >20-30% organic matter
- Low in P and K
- Supplies N
- Drainage problems
- Wetland areas
- Slow to warm in Spring
Soil Structure

- Arrangement of soil particles (sand, silt, clay) into groups (aggregates)

- Binding agents
  - Microbial gums, fine roots, organic matter, fungal hyphae, iron oxides, and clay bind soil particles together
Soil Structure (cont’d)

- Unlike soil texture, soil structure can be improved by management or degraded by poor management.

- Types – blocky, massive, prismatic, single grain, granular
Soil Structure (cont’d)

Improved

Granular aggregation

Degraded

Compaction reduces pore space
“Good” structure
- ~50% solids and ~50% pore space
- pore space evenly distributed
  - large, air-filled pores (drain readily)
  - smaller, water holding pores
Granular structure consists of soil particles held in loose, rounded aggregates

**Desirable for farming and gardening

- Most often found:
  - At the soil surface
  - In grassland soils
  - In soils high in **organic matter**
Soil Organic Matter

Organic matter affects almost all soil properties

Forms of organic matter
- Plant/animal residues
  - Various stages of decomposition
- Humus
  - Decomposition by-product
  - Resistant to further degradation
Soils are Alive!

Organic matter decomposition releases and recycles nutrients
- ~1 billion bacteria/gram soil
- ~5000 types of bacteria
- ~1000 lb of nitrogen per acre in soil for each 1% OM

“Organic matter functions mainly as it is decayed and destroyed. Its value lies in its dynamic nature.”
- William Albrecht, 1938

Soil Life

And it’s not just bacteria...

Fungi, Insects, Earthworms Nematodes etc...
Organic Matter Build-up and Nutrient Release from the Organic Fraction

Organic Residue

Decomposers: bacteria fungi

CO₂

Humus

Nutrient Release

mineralization

immobilization
Importance of Soil OM

- Improves soil physical properties
  - Especially on medium and fine textured soil
    - Drainage
    - Aeration
    - Easier to work

- Increases water holding capacity
  - Especially in sandy soils
Importance of SOM (cont’d)

- Improves soil fertility
  - Source of nutrients
  - Increases ability of soil to hold and release nutrients

- Drives soil biology
  - Feeds microbes and earthworms

- Reduces soil crusting
Soil Formation

There are five soil forming factors

1. Parent Material
2. Climate
3. Biota
4. Topography
5. Time

Varied combinations of these five factors cause soil to develop and behave differently

On-going process
Most parent materials in Minnesota were transported and deposited by wind, water, or ice.
Much of Minnesota’s parent material was deposited by glaciers 10-13,000 yrs ago
The “age” of a soil is not based on the number of years it has been forming, but rather on the extent to which it has developed (as a result of the other soil forming factors).
Human Impacts on Soil

Urban soils are disturbed and altered during construction and other human activities
Compacted Urban Soils

Results from initial construction or subsequent maintenance practices and traffic patterns

- Compaction is a serious problem
- Affects soil structure
- Increases bulk density and water runoff
- Decreases water infiltration and root growth
Characteristics of Urban Soil

- Often highly disturbed and may have properties that do not resemble the original soil
  - Modified soil structure/rooting depth
  - Restricted aeration/drainage
  - Soil pH usually elevated
  - Higher soil temperatures
  - Reduced organic matter
  - Soil crusting
  - Interrupted nutrient cycling/biological activity
Improving Urban Soils

- Add organic matter
  - Mix in compost
  - May not possible for perennials

- Subsoil, renovate lawns

- Do not work soil when it is wet

- Grow cover crops and reduce rototilling
Poor Soil Management

- Excessive Tillage
- Lack of plant cover
- Erosion and runoff
Provide Cover to Protect Soil and Add Organic matter
Proper Stewardship

- When possible - Include high residue and N-fixing crops in the rotation
- Manage manure properly
- Use cover crops to reduce the amount of bare soil
- Use conservation tillage and buffer strips along waterways
Cover Crops/Green Manures

- Stabilize soil
- Increase soil organic matter content
- Cycle nutrients to the surface from lower depths
- Break disease cycles, reduce weeds
- Short growing season in Minnesota is a challenge
Summary

- Soil is a complex living system that sustains all forms of life.
- Interactions between physical, biological, and chemical components of soil influence soil health and quality.
- Soil organic matter plays a key role in all soil processes.
- Soil formation is an ongoing process, but human activities can have both positive and negative effects on soil properties.
- Proper management of soil is essential for maintaining a vibrant and functional living soil.
Lester was designated as the “Official State Soil” of Minnesota in 2012.