Soil
What is Soil?

Unconsolidated mineral or organic matter on the immediate surface of the earth, that serves as a natural media for the growth of land plants.
Why is soil important for the majority of agricultural crops?

Soil is critical for holding plants to the ground, and supplies water and nutrients that are critical for photosynthesis and plant function.
Soil Formation

- Parent material
  - Igneous rocks (e.g. granite) hard rocks
  - Sedimentary rocks (e.g. limestone, sand stone, shale). Consist of pieces of rock.
  - Metamorphic rock (e.g. slate, marble) produced when igneous or sedimentary rock is intensely heated.

- Climate
  - High v low rainfall
  - Effect of climate on organisms
Organisms (Organic matter)
- Living organism effect soil formation.
- Grassland differs from forest.

Topography
- Soil formation is faster on flat relief cw slopes

Time
- Old soils v new soils
- Oil soils have a more defined soil profile
- Are they better for crops?
Soil Profile

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>Freshly fallen leaves, twigs, animal remains</td>
</tr>
<tr>
<td>A</td>
<td>Partially decomposed organic matter</td>
</tr>
<tr>
<td></td>
<td>Well-decomposed organic matter</td>
</tr>
<tr>
<td></td>
<td>Mineral layer from which leaching of aluminum and iron occur</td>
</tr>
<tr>
<td>B</td>
<td>Layer of accumulation of minerals from A horizon</td>
</tr>
<tr>
<td>C</td>
<td>Weathered bedrock material or subsoil layer</td>
</tr>
<tr>
<td>R</td>
<td>Bedrock</td>
</tr>
</tbody>
</table>
Pedalfers, leached, deficient in base minerals (Na, K, Ca, Mg), hence acidic in reaction. Naturally fertile but have low use due to low rainfall.
Entisols – Very new soils with little of no morphological development.

Alfisols – Moderately leached soils, with a subsurface zone of clay accumulation. Formed under natural deciduous forests or savanna.

Ultisols – Well developed clay horizon.

Mollisols – Soils formed under prairie grass.
Wisconsin

Entisol Profile

N. Idaho
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Ultrisol Profile
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Andisols – Formed from volcanic ash.
Aridisols – Formed in arid regions.
Inceptisols – Soils with weakly developed surface horizons, and soils with just the beginnings of profile development.
Histosols – High organic soil matter extending down 40 cm or more.
Other Soil Orders

- Spodosols – Formed from course-textured parent rocks.
- Vertisols – High concentration of swelling and cracking clays.
- Gellisols – With permafrost.
- Oxisols – highly weathered in hot tropical regions
Cation Exchange Capacity (CEC) is a measure of the number of anionic sites available on soil clay and humus particles. These are negatively charged sites which attract and hold cations (which are positively charged) in the soil. Some nutrients found as cations will be held on the cation exchange sites until needed by the plant.
## Cation Exchange Capacity

<table>
<thead>
<tr>
<th>Soil Order</th>
<th>CEC (molc kg(^{-1}))</th>
<th>Soil Order</th>
<th>CEC (molc kg(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxisols</td>
<td>0.05</td>
<td>Inceptisols</td>
<td>0.19</td>
</tr>
<tr>
<td>Ultisols</td>
<td>0.06</td>
<td>Mollisols</td>
<td>0.22</td>
</tr>
<tr>
<td>Spodosols</td>
<td>0.11</td>
<td>Vertisols</td>
<td>0.37</td>
</tr>
<tr>
<td>Alfosols</td>
<td>0.12</td>
<td>Entisols</td>
<td>0.43</td>
</tr>
<tr>
<td>Aridisols</td>
<td>0.16</td>
<td>Histosols</td>
<td>1.40</td>
</tr>
</tbody>
</table>
Soil

- There are three basic types of soil particles based on size:
  - sand – 2 to 0.02 mm in diameter.
  - silt – 0.02 to 0.002 mm in diameter.
  - clay – smaller than 0.002 mm in diameter.

- The water-holding capacity of a soil is determined by the porosity of the soil and the surface area of the soil particles in the soil.
Soil Particle Size

Coarse Sand

Sand

Fine Sand

Very Fine Sand

Silt

Clay

1 mm
Sand

Clay

Silt

Loam
10 - 30% Clay
30 - 50% Silt
25 - 50% Sand

Peat
Soil

- The size of the soil particle, size of space between soil particles and the availability of water in the soil influences the ability of a plants roots to extract water from the soil.
- The type(s) of soil particles in a particular soil controls the water-holding capacity of the soil and the tension that water is held to the surface of the soil particles.
Typical Mineral Soil

- Mineral matter: 45%
- Water: 25%
- Air: 25%
- Organic matter: 5%
Soil Compaction
Soil Compaction Symptoms

- Ponding on the soil surface
  - Also associated with drainage problems.
- Presence of dark streaks on soil surface
  - Results from prolonged water logging, usually in tire tracks.
- Increased power needed to cultivate.
- Increased run off.
- Surface soil crust.
Soil Compaction Symptoms

- Incomplete crop stands
  - Compaction usually hinders seed germination.

- Uneven crop stands
  - Plant in compacted areas will be stunted due to poor root development.

- Changes in plant color.
  - Compaction water logging causes moisture stress in plants.

- Restricted root development
- Reduced yields.
Water Erosion
Wind Erosion
Argentina
Average Annual Soil Erosion by Wind and Water on Cropland and CRP Land

Ton/acre/year

- 0 to 2
- 2 to 4
- 4 to 8
- >8
1/3 ton soil

6 ton / acre / year
Water Quality
Wind Erosion
Removes Top Soil

Exposes clay & rock
CAUTION

BLOWING DUST AHEAD
Visibility
Total Soil Eroded on U.S. Cropland (1982 to 2001)

- 1982: 3.1 billion tons
- 1987: 2.8 billion tons
- 1992: 2.1 billion tons
- 1997: 1.8 billion tons
- 2001: 1.8 billion tons
Ammonium Fertilizer

\[ \text{NH}_4^+ \]

Nitrification

\[ \rightarrow \text{NO}_2^- \]

Mineralization

\[ \text{NO}_3^- \]

Imobilization

Absorbed by Crop

\[ 2\text{H}^+ \text{ & H}_2\text{O} \text{ Acidification} \]

O

\[ \text{O}_2 \]
Ph Reaction in the Soil

Acid 4.5 5.0 5.5 6.0 6.5 7.0 7.5 8.0 Alkaline

- Nitrogen
- Phosphorous
- Potassium
- Calcium & Magnesium
- Sulphur
- Iron, Aluminium & Manganese
- Boron
## Relative yield of Crops

<table>
<thead>
<tr>
<th>Crop</th>
<th>pH 4.7</th>
<th>pH 5.0</th>
<th>pH 5.7</th>
<th>pH 6.8</th>
<th>pH 7.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>2</td>
<td>9</td>
<td>42</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Barley</td>
<td>0</td>
<td>23</td>
<td>80</td>
<td>95</td>
<td>100</td>
</tr>
<tr>
<td>Corn</td>
<td>34</td>
<td>73</td>
<td>83</td>
<td>100</td>
<td>85</td>
</tr>
<tr>
<td>Soybean</td>
<td>65</td>
<td>79</td>
<td>80</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Wheat</td>
<td>68</td>
<td>76</td>
<td>89</td>
<td>100</td>
<td>99</td>
</tr>
</tbody>
</table>
Burrowing animals (moles, gophers, prairie dogs, etc.) Usually crop destructive.

Earthworms. Most important macro animals. Ingest 2-30 times body weight of plant, animal and soil daily. Excrete large amounts of digested organic matter called casts. Most effective in spring and fall.

Arthropods and gastropods. (invertebrates with jointed foot). Includes termites, mites, beetles and ants. More localized in mounds
Soil Organisms


- Living roots. Impact soil physical properties. Secrete a variety of compounds into the soil. Area immediately surrounding the root is called rhizosphere. Some plants release allelopathic compounds.

- Soil Fungi. May be unicellular (e.g., Yeast) or multicellular (molds, rusts, mushrooms). Decompose organic matter. Help some plants absorbed nutrients through a symbiotic association called mycorrhiza.
Land Capabilities and Properties

- Class I - Few limitations, level, deep, well drained soils. Suitable for row crops and others.
- Class II – Has limitations to its use. Usually a 2 – 5 % slope. Conservation tillage desirable. Row crops can be cultivated with proper management.
- Class III – Has severe limitations. Slope of 6 – 10%. Conservation tillage required. Long term crops to conserve soils.
Land Capabilities and Properties

- **Class IV** – More severe than Class III. Row crops are not suited. Best for perennials (pasture). No-tillage should be used.
- **Class V** – Limitations impractical to rectify by conservation practices. Prone to flooding. Too rocky for tillage. May be pasture.
- **Class VI** – Limitations are extremely severe. Steep slopes. Best for woodland.
- **Class VII** – Pasture not practical. Woodland or wildlife preserve.
Nutrients