Soil Physical Properties I: Outline

- Soil color
  - See plates between pages 178 and 179 in the textbook.
- Soil texture
- Soil structure

Soil Color

- Soil color provides clues to other soil properties and to soil conditions.
- In general:
  - dark colors are caused by organic matter.
  - Iron oxides provide brown and reddish coatings.
  - Reduced iron imparts gray and greenish colors.

Soil Color

- Soil color is determined using the Munsell Color System designed by an art teacher in 1905.
- A color is defined by three parameters:
  - Hue, H
  - Value, V
  - Chroma, C
- A color is expressed as H V/C, e.g., 10 YR 3/2
- For details in the system see: www.munsell.com
The Munsell Color System

Hue
Attribute of color by which we distinguish red from green, etc.

Value
- Indicates the lightness of a color
- Range between 0 (black) and 10 (white)

Chroma
- Indicates the degree of departure of a color from the neutral color of the same value
- Lower limit is 0, but it has not upper limit.
- In soils the chroma rarely exceeds 8.

Soil color: application

Note: H is Hue, in this case 10YR

<table>
<thead>
<tr>
<th>Color</th>
<th>% organic matter</th>
<th>Range</th>
<th>Aver.</th>
</tr>
</thead>
<tbody>
<tr>
<td>H 2/1</td>
<td>3.5-7.0</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>H 3/1</td>
<td>2.5-4.0</td>
<td>3.5</td>
<td></td>
</tr>
<tr>
<td>H 3/2</td>
<td>2.0-3.0</td>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td>H 4/2</td>
<td>1.5-2.5</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>H 5/3</td>
<td>1.0-2.0</td>
<td>1.5</td>
<td></td>
</tr>
</tbody>
</table>
Soil Texture

- Soil texture is the relative proportion of sand, silt, and clay.
- Together with organic matter content, soil texture is widely used in pedotransfer functions.
- Soil texture is routinely measured as part of soil survey activities. Thus, it is readily available for most soils of the U.S.A.

Table 1. Sample linear regression correlations between the Macalister colour coordinates and soil thermal and physical properties.

<table>
<thead>
<tr>
<th></th>
<th>Hue</th>
<th>Value</th>
<th>Chroma</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>0.678</td>
<td>0.212</td>
<td>***0.531</td>
</tr>
<tr>
<td>Silt</td>
<td>-0.113</td>
<td>0.198</td>
<td>-0.165</td>
</tr>
<tr>
<td>Clay</td>
<td>-0.025</td>
<td>-0.414</td>
<td>***0.6472</td>
</tr>
<tr>
<td>CaCO&lt;sub&gt;3&lt;/sub&gt;</td>
<td>***-0.312</td>
<td>***-0.040</td>
<td>-0.771</td>
</tr>
<tr>
<td>O&lt;sub&gt;2&lt;/sub&gt;</td>
<td>0.209</td>
<td>***-0.305</td>
<td>-0.108</td>
</tr>
<tr>
<td>Fe</td>
<td>0.091</td>
<td>***-0.307</td>
<td>***-0.399</td>
</tr>
<tr>
<td>Mn</td>
<td>***0.397</td>
<td>***-0.649</td>
<td>-0.394</td>
</tr>
<tr>
<td>pH</td>
<td>-0.082</td>
<td>-0.102</td>
<td>***-0.507</td>
</tr>
<tr>
<td>CEC</td>
<td>0.346</td>
<td>***-0.726</td>
<td>***-0.3102</td>
</tr>
</tbody>
</table>

*, **, ***Significance at $P<0.05, 0.01$, and 0.001 respectively.
Unindicated values correspond to the best relationship for each colour coordinate.


Datasets for environmental modeling and management

Soil Separates

- Particle are separated into size **GROUPS** (soil separates): sand, silt, and clay.
  - Composition
    - Sand is mainly quartz and other primary minerals
    - Silt and clay are composed mainly by secondary minerals.

Distribution of Sand, Silt, and Clay Fractions

Properties of Soil Separates

- **Specific surface area** is the surface area for a given particle volume or mass.
- Size and the related specific surface area of soil separates largely determine soil properties.
- Typically, specific surface area for sand is <0.1 m$^2$/g, for silt is about 1 m$^2$/g, and for clay vary between 10-100 m$^2$/g.
Figure 4.4 The relationship between the surface area of a given mass of material and the size of its particles. In the single large cube (a) each face has 64 cm² of surface area. The cube has six faces, so the cube has a total of 384 cm² of surface area (6 faces x 64 cm² per face). If the same cube of material was cut into smaller cubes (b) so that each side was only 2 cm on each side, then the same mass of material would now be present as 64 smaller cubes (4 x 4 x 4). Each face of each small cube would have 4 cm² (2 x 2 cm) of surface area, giving 24 cm² of surface area for each cube (6 faces x 4 cm² per face). The total mass would therefore have a surface area of 1536 cm² (24 cm² per cube x 64 cubes). This is four times as much surface area as the single large cube. Since clay particles are very, very small and usually platelike in shape, their surface area is thousands of times greater than that of the same mass of sand particles.

Weathering

- Weathering leads to an increase in surface area:

![Early weathering sample](image1)

![Late weathering sample](image2)

Surface Area vs Cube Diameter

![Graph showing surface area vs cube diameter](image3)
Soils and Water, Spring 2009

Lecture 2: Physical Properties

The Meaning of the Specific Surface Area

Surface Area of the State of NJ: 20,168 km² or 20,168,000,000 m²

Soil Specific Surface Area:
15 m²/g

1 m³ of soil contains 1,470,000 g or 22,050,000 m²

Bulk density, \( \rho_b = 1.47 \) Mg/m³

Characterization of Particle Sizes

- "Feel" method: qualitative
- Soil samples are pretreated to remove organic matter and to disperse aggregates.
- Two procedures are used: sieving and sedimentation
- The sand fraction (>0.05 mm) is separated using sieves (screens with different size opening).
- Sedimentation is used for particles with diameters < 0.05 mm.

Box 4.1 A Method for Determining Texture by Feel

Figure 4.7 The "feel" method for determining soil texture class. A moist soil sample is rubbed between the thumb and forefingers and squeezed out to make a ribbon. (Top) The gritty, noncohesive appearance and short ribbon of a sandy loam with about 15% clay. (Middle) The smooth, dull appearance and crumbly ribbon characteristic of a silt loam. (Bottom) The smooth, shiny appearance and long, flexible ribbon of a clay. (Photos courtesy of R. Weil)
Determine Particle Size: Sedimentation

**PRINCIPLE:** The velocity of a particle falling through a fluid is related to its "effective" diameter.

- Terminal velocity, \( V \), is related to:
  - gravity force, \( g \)
  - particle density, \( D_s \)
  - fluid density, \( D_f \)
  - fluid viscosity, \( \eta \)
  - particle diameter, \( d \)

Stoke’s law:

\[
V = \frac{d^2 g (D_s - D_f)}{18 \eta} = k d^2
\]

Figure 4.1 Classification of soil particles according to their size. The shaded scale in the center and the names on the drawings of particles follow the U.S. Department of Agriculture system, which is widely used throughout the world and in this book. The other two systems shown are also widely used by soil scientists and by highway-construction engineers. The drawing illustrates the size of soil separates (scale inset).
Soils Particles

- **sand**
- **clay**

A Mix of Clay and Silt/Sand


Some Examples of Weathering
Formation of Clay

- Clay is a secondary mineral formed from the primary mineral existing in the parent material:

Soil Textural Classes

- The U.S. Department of Agriculture classification system recognizes 12 textural classes from pure sand to clay.
- A “textural triangle” is a ternary plot representing textural classes based on the relative amounts of sand, silt, and clay.

Particle Size Distribution for Three Samples

- Diagram showing particle size distribution for different samples.
The Textural Triangle

Soil Structure

- Soil structure refers to the arrangement of soil particles into larger units (aggregates or peds).
- Field description of soil structure includes the type, size and grade of soil aggregates.
- Recent definitions relate soil structure with the spatial variability of soil properties.
- An important aspect of soil structure is the distribution and types of pores.

Types of Soil Pores
Structured Soil Block

Soil crust

Macropores filled with Plaster of Paris
Spatial Variability of Water Flow: Field Scale

Spatial variability induced by soil structure

Spatial Variability of Water Flow: Field Scale
Figure 4.10: Bulk density $D_b$ and particle density $D_p$ of soil. Bulk density is the weight of the solid particles in a standard volume of field soil (solids plus pore space occupied by air and water). Particle density is the weight of solid particles in a standard volume of those solid particles. Follow the calculations through carefully and the terminology should be clear. In this particular case, the bulk density is one-half the particle density, and the percent pore space is 50.

Figure 5.23: Volumes of water and air associated with a 100 g slice of soil solids in a well-graded silt loam at different moisture levels. The top bar shows the situation when a representative soil is completely saturated with water. Water will soon drain out of the larger pores (macropores). The soil is then said to be at field capacity. Plants will remove water from the soil quite rapidly until they begin to wilt. When permanent wilting of the plants occurs, the soil water content is said to be at the wilting coefficient. There is still considerable water in the soil, but it is held too tightly to permit its absorption by plant roots. A further reduction in water content to the hygroscopic coefficient is illustrated in the bottom bar. At this point the water is held very tightly, mostly by the soil colloids. (Top drawings modified from Irrigation on Western Farms, published by the U.S. Departments of Agriculture and Interior.)