Soil Architecture – Texture and Structure

Ecological Agriculture Program 1-12-06
TESC
Steve Scheuerell
Plant growth is directly limited by multiple soil physical properties. These properties further interact with chemical and soil biotic factors.
Soil Physical Properties

- Soil Color
- Soil Texture
- Soil Structure

- Not covering heat transfer
- Hydrology will be covered later
- Soil as an engineering medium – opposite goals than for growing plants in the soil
Soil physical properties

FIGURE 1.17

when conditio between water two componen
Nonetheless, a erally ideal for

Percent by Volume
Soil as habitat
Soil color is an indicator of Oxidation – Reduction (Redox) conditions

PLATE 29 Oxidized (red) root zones in the A and E horizons indicate a hydric soil. They result from oxygen diffusion out from roots of wetland plants having aerenchyma tissues (air passages).

PLATE 22 The 10YR hue page of a Munsell color book. The standard notation is handwritten for the color with hue 10YR, value 5, and chroma 6.

PLATE 21 Effect of poor drainage on soil color. Gray colors and red redox concentrations in the B horizons of a Plinth-aquic Paleudalf.
Soil Texture – size distribution of mineral particles in the soil

FIGURE 1.17
When conditions between water and air are generally ideal for
Soil Texture

“You play the hand you are dealt”

• Managing field soil doesn’t modify texture

• In contrast, manufactured soils and potting mix are designed and texture can be chosen
  – Landscape architecture projects spec soil
  – Plant propagation e.g. rooting in sand
  – Potting mix
  – Green roofs
Soil Texture – proportion of sand, silt, and clay

Fig. 3.2. A visual representation of the comparative sizes of sand, silt, and clay particles.

Environmental Soil Physics. 1998. Daniel Hiller
Soil particle classification systems – particle size

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<tr>
<th>International Society of Soil Science</th>
<th>Clay</th>
<th>Silt</th>
<th>Sand</th>
<th>Gravel</th>
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**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 United States Department of Agriculture system, which is widely used throughout the world. The USDA system is also used 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 (note scale).
Particle-size distribution across soil textures

Figure 4.9
Soil textural classes

figure 4.6
Soil texture by feel

FIGURE 4.7 The “feel” method for determining soil textural class. A moist soil sample is rubbed.
Physical properties of soil particles – surface area to mass ratio. Clays have much more reactive surface area than sand.
Clay Physical Properties
Internal spaces, negative electrical charge, colloid formation

Kaolinite
Montmorillonite
Mica

Figure 8.3
Intraped micropores

Soil macropores between soil particles (sandy soil) and soil aggregates (clayey soil)

Also micropores within clayey aggregates

FIGURE 4.15 the relative area of each. There is because the clay aggregate (a), aggregates, and reason why, a more dense th
Soil Texture vs. Soil Structure

- **Texture**
  - Termed soil particles or separates
  - Sand
  - Silt
  - Clay

- **Structure**
  - Termed aggregates or peds
  - Arrangements of soil particles
  - Described based on shape and size of aggregates/peds
Soil Structure – arrangement of pores and particles – how they fit together

![Soil Structure Diagram](image)

**Figure 1.17**

When condition between water and other components. Nonetheless, generally ideal for...
Soil pore network (2 mm soil block)
Soil pore types – packing pores, interped pores, and biopores

FIGURE 4.25 Various types of soil pores. (a) Many soil pores occur as packing pores, spaces left between primary soil particles. The size and shape of these spaces is largely dependent on the size and shape of the primary sand, silt, and clay particles and their packing arrangement. (b) In soils with structural cracks, the spaces between the peds form interped pores. These may be rather planar in shape, as with the spaces between prismatic peds, or they may be more irregular, like those between loosely packed aggregates. (c) Biopores are formed by organisms such as earthworms, insects, and plant roots. Most biopores are long, sometimes branched channels, but some are round cavities left by insect nests or burrows.
Biopores

- Plant root hair
- Bacterial colonies
- Mycorrhizal hyphae
- Actinomycete hyphae and spores
- Decomposing plant cells
- Nematode
- Clay-organic matter complex
- Fungal hyphae and spores
- Flagellate
- Ciliate
- Amoeba

NRCS Soil Biology Primer
Fig. 5.5. Observable forms of soil aggregation.
FIGURE 4.28 Larger aggregates are often composed of an agglomeration of smaller aggregates. This illustration shows four levels in the hierarchy of soil aggregates. The different factors important for aggregation at each level are indicated. (a) A macroaggregate composed of roots, fungal hyphae, and mineral grains. (b) A microaggregate composed of root hairs, hyphae, and polysaccharides. (c) A submicroaggregate composed of mineral grains encrusted with plant and microbial debris and plant debris coated with clay. (d) A primary particle of silt, clay, and humus.
Soil aggregates - Humus structure
Aggregate Formation – role of humus colloids and cation bridging

**FIGURE 8.13** A simplified diagram showing the principal chemical groups responsible for the high amount of negative charge on humus colloids. The three groups highlighted all include \(-\text{OH}\) that can lose its hydrogen ion by dissociation and thus become negatively charged. Note that the **alcoholic**, **phenolic**, and **carboxylic** groups on the right side of the diagram are shown in their disassociated state, while those on the left side still have their associated hydrogen ions. Note also that association with a second hydrogen ion causes a site to exhibit a net positive charge.
Aggregate stability – Native prairie compared to cultivated soil

**FIGURE 4.27** Soil aggregates in a Mollisol in Iowa are larger and more stable under native prairie vegetation than where cultivated crops had been grown for some 90 years. In this study, soil samples were taken from a prairie area and from two nearby fields, where either corn or soybeans had been grown the previous year. Differences in past management may in part account for differences between the corn and soybean fields, but the soil in both of these fields shows distinct aggregate breakdown compared to the native grassland area. [Drawn from data in Martens (2000)]
Aggregate stability – organic polysaccharides (P) excreted by microbes
Aggregate stability – fungal hyphae, in this case mycorrhizae

Figure 4.30
Aggregate stability – fungal hyphae and glomalin from mycorrhizae

Box 4.6
Aggregate stability – effect of soil organic matter content

Before wetting
High O.M.  Low O.M.

After wetting
High O.M.  Low O.M.
Soil Compaction – affects texture or structure?

Percent by Volume

**FIGURE 1.17**
when condition between water two components. Nonetheless, generally ideal for
Compaction decreases macropores (figure 4.26)
Hardpan limits rooting depth

Root elongation in compacted soil

Fig. 11.5. Relations among root penetration and the penetrometer resistance of four soil materials. (Reprinted by permission from H. M. Taylor, G. M. Roberson, and J. J. Parham, Jr., Soil Sci. 102: 18-22. © 1966, The Williams & Wilkins Co., Baltimore, Md. U.S.A.)

Soil compaction – 110 years after wagon trail abandoned in Minnesota

<table>
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<tr>
<th>Soil Characteristic</th>
<th>Values found</th>
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<td></td>
<td>Wheel ruts</td>
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<tr>
<td>Bulk density (Mg/m3)</td>
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<tr>
<td>Water infiltration (mm/s)</td>
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</tr>
<tr>
<td>Air permeability (mm2)</td>
<td>0.11</td>
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Compaction - Increasing Bulk Density

Box 4.4
Figure 4.35 While the action of the moldboard plow lifts, turns, and loosens the upper 15 to 20 cm of soil (the furrow slice), the counterbalancing downward force compacts the next lower layer of soil. This compacted zone can develop into a plowpan. Compactive action can be understood by imagining that you are lifting a heavy weight—as you lift the weight your feet press down on the floor below. (Photo courtesy of R. Weil)
Soil compaction – wheel traffic and plow pan. Note soil bulk density values.

Figure 4.19
Soil compaction and plant rooting

Figure 4.21
Subsoiling to reduce soil compaction

Figure 4.20

Diagram showing subsoiling technique with labels for tractor wheel, final soil surface, initial soil surface, area of soil disturbance, 2.5 cm steel plate, soil surface, and bracket at 30° from horizontal.
Soil crusting and seedling germination

(Capon, 2005)
Soil Crusting

FIGURE 4.37 Scanning electron micrographs of the upper 1 mm of a soil with stable aggregation (a) compared to one with unstable aggregates (b). Note that the aggregates in the immediate surface have been destroyed and a surface crust has formed. The bean seedling (c) must break the soil crust as it emerges from the seedbed. [Photos (a) and (b) from O’Nofiok and Singer (1984), used with permission of Soil Science Society of America; photo (c) courtesy of R. Weil]
Flocculation and Dispersion of soil clays – effect of Calcium versus Sodium

FIGURE 4.29
Clays. The di- and tri-valent cations (Ca, Mg, Fe, Al) are strongly attached to clay surfaces by electrostatic forces. Calcium ions, especially, are strongly adsorbed on clay surfaces due to their high valence. Calcium ions form bridges between clay particles much more effectively than sodium ions, especially when adsorbed near the surface charge, because of the higher effective valence of calcium. This high valence is due to the hydration of calcium ions, which has an effect on the mobility of calcium ions in the clay particles.
Soil Conditioners

• Polysaccharides
  – PAH
  – Yuccah plant extract

• Gypsum
  – Calcium sulfate
Expanding soils – clay drying and wetting

FIGURE 4.43 Certain types of clays, especially the smectites, undergo significant volume changes in conjunction with changes in water content. Here, an expansive soil rich in smectitic clay has shrunk during a dry period, causing a network of large cracks to open up in the surface. (Courtesy of USDA Natural Resources Conservation Service)
Swelling soils – type of clay and sodium (Na)

Fig. 4.11. Volume changes of montmorillonite and kaolinite clays during hydration.
Roots follow vertical shrinking crack in clay

Fig. 11.6. Plant roots located in a vertical shrinkage crack of Houston Black clay. Note that the roots apparently were unable to readily penetrate the vertical face of the crack. (Photograph courtesy of E. Burnett)
Swelling soils – effect on soil structure over time

Fig. B4.1  Self-mixing in a vertisol.
Example of managing soil for increased structure with tillage systems
UC Santa Cruz Farm and Gardens

Key is organic matter additions
Greatly modified soil structure
Increased Soil Organic Matter Levels
Compost and Cover Crops
Increased Soil Organic Matter Levels
Compost and Cover Crops
Study questions Brady and Weil

• Chapter 4. Questions 2-5, 7-8