Soils, compaction, and water

Dennis McCallister
Emeritus Professor of Soil Science
Department of Agronomy and Horticulture
University of Nebraska-Lincoln

What we're going to do:

- SOILS 101 – a quick review
- Compaction – what is it, why is it a problem?
- Water entry and movement in soils – what factors are involved?
- Effects of compaction on soil water

- Before we get started, have a piece of paper and a pencil next to you
  - If you've printed out the Powerpoint slides, that will work just fine.

I. SOILS 101
   A. What is (and isn't soil)?
      Write down your thoughts

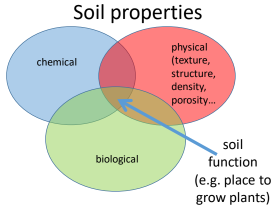
      "Formal" definition(s)
         Stuff to grow plants in
         "not-rock" (at the earth's surface?)
         stuff to manipulate to build on
         and so on…
      Depends on the user and their intentions

B. Components of soil
   Make a list!
      solids
         sand, silt, clay, organic matter (humus), living things
      liquid
         water and stuff dissolved in it
      gasses
         air (but not exactly like the air we breath)

C. What makes a soil behave as it does?
   interaction of physical, chemical, biological, and structural properties

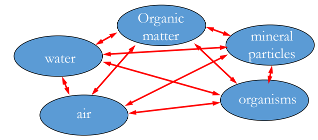
2. Soil quality/health
   - "umbrella" description of how good a soil is for some function

Soil properties



Soil is a "system"

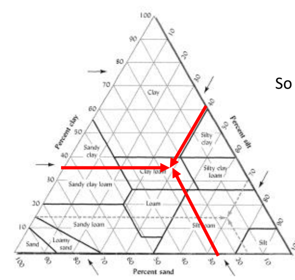
- What does that mean for us?



- multiple parts
- quantities of the parts differ
- parts interact with each other
- not always a clear "cause and effect"

- We're going to focus on the "physical" properties part
  - Most relevant to water and drainage
- What are some physical properties of soil?
  1. Texture – particle size distribution of soil
     usually expressed as percent by weight of three size groups
        sand, silt, and clay (biggest to smallest)
        supplemented by textural class names
        organized into the textural triangle

Brady & Weil. 2004. p 100



So what is the best soil texture?

It depends!!!

In the end, we usually have to live with the texture we've got

relationship of texture to soil properties

Brady & Weil. 2004. p 98

TABLE 4.1 Generalized Influence of Soil Separates on Some Properties and Behavior of Soils[a]

Property/behavior	Rating associated with soil separates: Sand	Silt	Clay
Water-holding capacity	Low	Medium to high	High
Aeration	Good	Medium	Poor
Drainage rate	High	Slow to medium	Very slow
Soil organic matter level	Low	Medium to high	High to medium
Decomposition of organic matter	Rapid	Medium	Slow
Warm-up in spring	Rapid	Moderate	Slow
Compactability	High	Medium	Low
Susceptibility to wind erosion	Moderate (high if fine sand)	High	Low
Susceptibility to water erosion	Low (unless fine sand)	High	Low if aggregated, high if not
Shrink-swell potential	Very Low	Low	Moderate to very high
Sealing of ponds, dams, and landfills	Poor	Poor	Good
Suitability for tillage after rain	Good	Medium	Poor
Pollutant leaching potential	High	Medium	Low (unless cracked)
Ability to store plant nutrients	Poor	Medium to high	High
Resistance to pH change	Low	Medium	High

[a]Exceptions to these generalizations do occur, especially as a result of soil structure and clay mineralogy.

Brady & Weil. 2004. 2nd ed. p 157

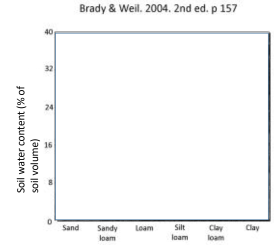
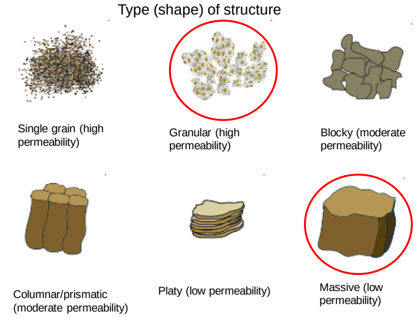


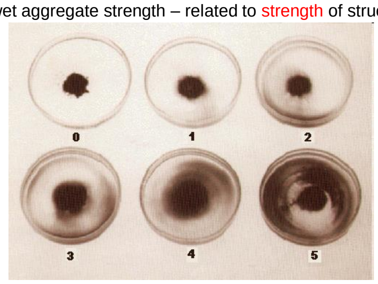
FIGURE 5.25 General relationship between soil water characteristics and soil texture. Note that the wilting coefficient increases as the texture becomes finer. The field capacity increases until we reach the silt loams, then levels off. Remember these are representative curves; individual soils would probably have values different from those shown.

- But texture isn't the whole show
  - Structure - how those sand, silt, and clay particles are put together
    - Shape
    - Size
    - Resistance to damage (strength)
  - This is where organic matter (humus) and clay are important
    - Provide the "stickiness" to form and stabilize structural units

Type (shape) of structure



wet aggregate strength – related to strength of structure



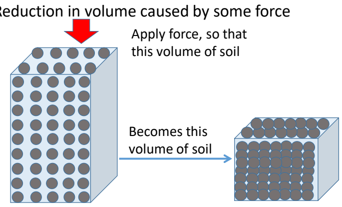
Which is the "best" strength of structure? Why?

- So texture (sand, silt, and clay) is important, but…
- The way the particles stick together (structure) is just as important, maybe more so, and…
- Structure is, most times, all we can change when we manage a soil
  - Both for good and for bad

III. Compaction – one of the bad things we can do to soil

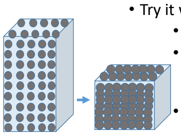
A. What is it

- Reduction in volume caused by some force



- What changes about a solid (like a soil) when we compact it?
  1. Weight of the soil?
  2. Volume of the soil?

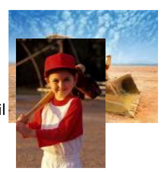
- Describe weight and volume together as density
  - weight (or mass) divided by volume
  - Density is a handy one-number (but imperfect) measure of compaction

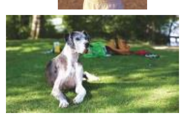


- So when we compact a soil
  - If weight does not change, but volume decreases, then…
  - Density **increases**
  - Try it with some simple numbers
    - Remember, density = weight/volume
    - Initial weight equals 1 pound and initial volume equals 1 cubic foot, so density equals 1 pound per cubic foot (1 lb/cubic foot)
    - If compacted weight is 1 pound (remember – doesn't change) and compacted volume is 0.5 cubic foot, new density equals 2 lb/cubic foot
    - **So compaction increases soil density**

- But why does compaction increase soil density?
  - When we squeeze a soil, what are we forcing out…
    - Pore space
    - Recall sponge demo (by Dr. Craig Cogger) in Laurie Stepanek's trees class
  - So a compacted soil (more generally, any higher density soil) has **less pore space** than an uncompacted soil.
- So why do we care?
  - Pore space is where water (and air) are in soil
  - Less total pore space means less ability for the soil to hold water
  - But there's more!

Short digression (sort of)



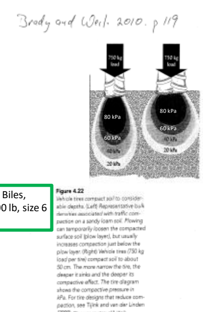


- What kind of "squeezes" (forces) can compact a soil
  - Machine traffic
    - Often during or after construction
  - Foot traffic
    - Human
    - Animal
- More accurate to say pressure compacts soil
  - Force applied to an area
  - Big force or small area (or both) are especially bad

Shaquille O'Neal, 7'1", 300 lb, size 18 feet

Simone Biles, 4'8", 100 lb, size 6 feet

Same compaction effect?



- Some soils are more successful at resisting compaction effects than others
  - Strong structure
    - What does that mean?
    - What contributes to "strong structure"?
    - Dry soils
      - Wet soils don't hold together as well as dry soils
    - Higher humus soils
    - Higher clay soils

- Take a closer look at what happens to a soil when we compact it
  - Increases density (mass/volume) because total pore space is reduced while mass stays the same
  - But it gets even worse
    - Compaction changes the kinds of pores present, not just their amount.

- Which pores will compaction eliminate first?
  1. Big pores

  3. Pores at the surface

- Small pores don't carry water away quickly, hold water **too well**
  - Compacted soils tend to become waterlogged
  - Irrigation water may not enter as fast as applied, leading to runoff

- What will happen to the geometry of pores in a compacted soil?

  2. Will become twistier and less continuous

- Hard to see pore geometry but sometimes easy to spot its effects
  - Water movement slows
  - Soils tend to become waterlogged
  - Irrigation may not enter as fast as it is applied, leading to runoff

- So for a combination of reasons, compaction can result in reduced irrigation efficiency (water waste) and excessively wet soils when water does enter
  - Recall that too much soil water means too little soil oxygen

- Finally, what does compaction do to water available to plants
  - Remember, plants can't use all water in a soil
  - Remember this diagram?
  - Available water changes because of **average** pore size
    - Big pores (in sands) don't hold water well, so available water is low
    - But if there are too many small pores (like in clay soils), they hold water **too** tightly for plants to get it

- Similar for soil with increasing degrees of compaction
  - More compaction, **less total pore space** but also **more small pores**
  - Water held **more tightly**
  - Total water retained may increase, but
  - **Available water may decrease**

- And irrigation water will enter the compacted soil more slowly than the uncompacted one

So, summing up:

1. Compaction of soil reduces the amount of soil pores, especially big pores.
2. Compaction reduces the speed of water intake (from rain or irrigation) mostly because of the loss of big pores at the surface.
3. Compacted soils may hold too much water for too long to make a good plant growing environment.

Thanks for your time and attention!