Chapter 4
Soil Physical Properties

Learning Objectives – Part 1

- Know what color tells you about a soil
- Describe the concept of soil texture and its importance
- Use the textural triangle to determine a soil's textural class based on its sand, silt and clay content

Soil Physical Properties

- Color
- Texture
- Density (particle density vs. bulk density)
- Pore space (porosity)
- Structure
- Aggregate stability

Physical properties are important

Physical Properties control plant growth through influence on:

- Soil temperature (darker = warmer)
- Soil aeration (sandy soils well aerated)
- Soil moisture content (clayey soils stay wet)

And they indicate important characteristics of a soil (e.g., lots vs. little organic matter)

also… drainage, compaction, consistency, strength, tilth

Physical properties – part 1

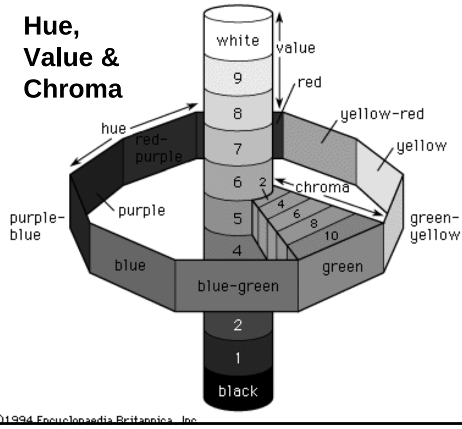
- **Color**
  - Caused by coatings on particles:
    O.M. darkens underlying colors
    Fe and Al oxides (red & yellow)
    Moisture (e.g., grey/blue vs. red/brown)
    Mineralogy (calcite, hematite, manganese, glauconite)
- **Texture**
  - Proportions of sand, silt, and clay
  - Determines water holding capacity, water availability, nutrient supply capacity…

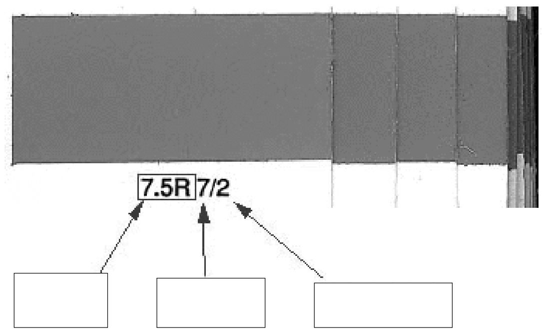
Color

"quantified" using the Munsell system

- **Hue** (e.g., **5R**) tells you *general shade*; DOES NOT tell you how dark the soil is
- **Value** (e.g., 5R **5/**) tells you *how dark* the soil is: (0 darkest) may indicate current moisture status (dark = wet) and/or amount of organic matter
- **Chroma** (e.g., 5R 5**/8**) tells you *color intensity* (0 = gray). Indicator of hydrologic regime (well drained = ↑ O_2 = high chroma)

Hue, Value & Chroma





Munsell color name contains soil information

EXAMPLE TEST QUESTION

- Which soil horizon likely has more organic matter

  5R 5/6

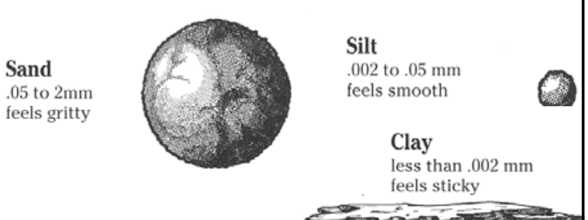
  or

  10YR 1/7?

Soil Texture

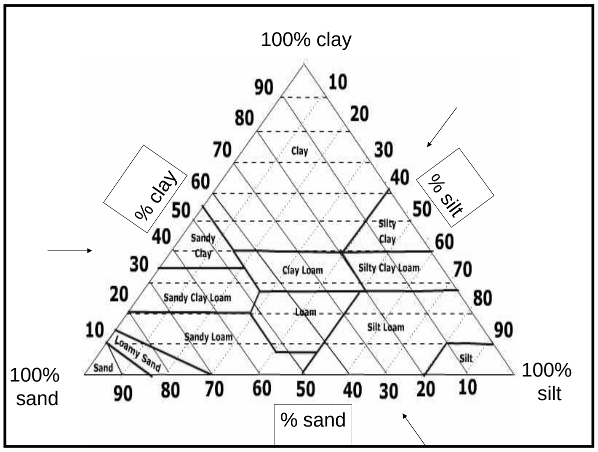
- Proportions of sand, silt, and clay (fine earth fraction)
- Not coarse fragments (>2mm)
- Not OM

Relative Size Comparison of Soil Particles (fine earth fraction)



"Big" → smaller → really small

Sand → silt → clay



Texture

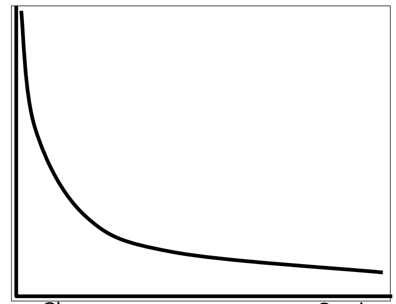
- Surface area per unit volume
  - 1 g sand ~ 0.1 m^2 — lowest
  - 1 g silt ~ 1 m^2
  - 1 g clay ~ 10-1000 m^2 — highest

Gee whiz fact: Fine clay has ~10,000 times as much surface area as the same wt. med. grain sand

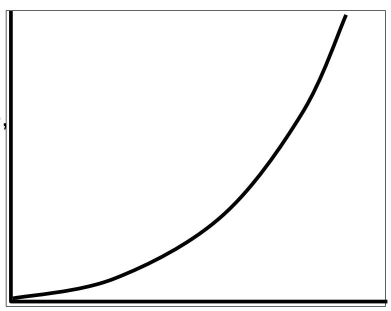
- Large surface area means more charge so greater ability to hold water and nutrients
- Coarse textured soils have larger pores, fine textured soils have greater total pore space

↑ Surface area ↑ weathering

Surface area, pore volume, nutrient supply capacity, plasticity and cohesion, swelling



Pore size, infiltration rate, drainage rate, aeration



Influence of Texture

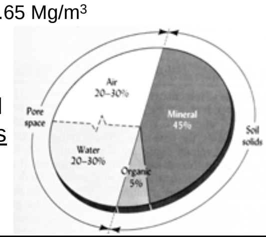
	Sand	Silt	Clay
Water-holding capacity	Low	Medium	High
Aeration	Good	Medium	Poor
Drainage	Fast	Slow	Very slow
Nutrient retention	Low	Medium	High

Ch. 4 Objectives – Part 2

- Calculate soil bulk density and % pore space
- Discuss factors influencing the above soil properties
- Identify the difference between texture and structure

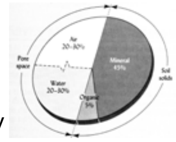
Physical properties – part 2

- Density
  - particle density: mass per unit volume (not pore space) ~ 2.65 Mg/m^3 (D_p of quartz mineral, dominant mineral in most soils)
  - bulk density: mass per unit volume (including pore space) ranges 0.1 – 2.65 Mg/m^3
- Porosity
  - the volume percentage (%) of the total bulk soil **NOT** occupied by solids

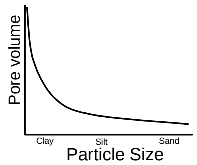


Bulk Density

Mass of **dry soil** per unit bulk volume, INCLUDING pore space



- O.M. ________ bulk density
- Compaction ________ bulk density
- Increased bulk density ______ water infiltration and restricts root growth
- Bulk density is relatively ______ in coarse-textured soils because ____________ ____



Typical Bulk Densities

- Histosols (0.1-0.7 Mg/m^3)
- Cultivated clay and silt loams (0.9-1.5 Mg/m^3)
- Cultivated sandy loams and sands (1.2-1.8 Mg/m^3)
- Concrete (ca. 2.4 Mg/m^3)
- Quartz mineral (2.65 Mg/m^3)

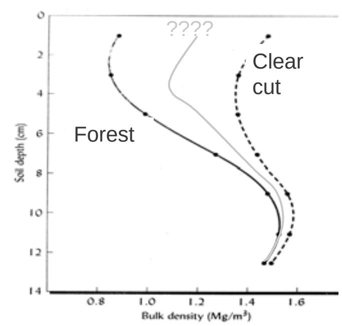
LOW → HIGH

See Fig. 4.12, p. 107 Sulzman

Typical Bulk Densities: Perhaps worth memorizing…

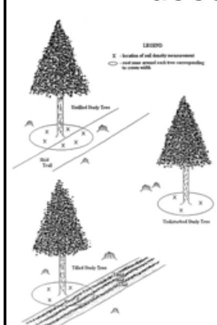
- OM: ~0.5 Mg/m^3
- "normal" soils: D_b ~ 1.2 - 1.8 Mg/m^3
  - Clayey soils lower than sandy soils
- Upper limit: ~2.65 Mg/m^3

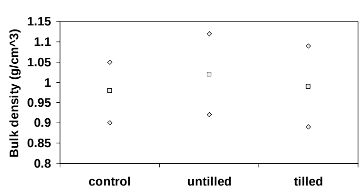
Effect of clear-cut on bulk density



Effect varies with soil texture!

Soil bulk density on skid trails: does tillage help??





Effect of cultivation on bulk density

Coarse → Fine

Texture	Yrs cropped	Increase in D_b due to texture and cultivation
Loam	58	0.18
Silt loam	40	0.26
Clay	70	0.30

In general, the finer the texture, the more it compacts if aggregates are destroyed

Effect of tillage on bulk density

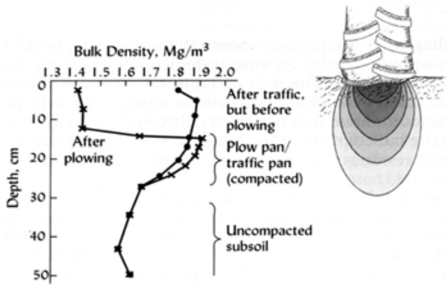
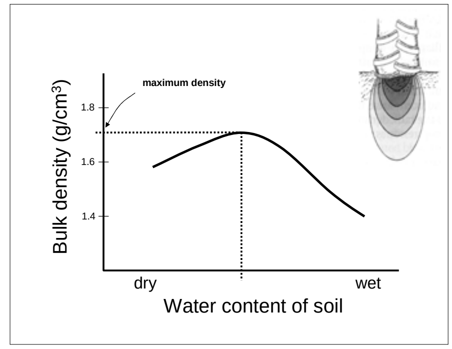


Fig 4.17 p. 113 Sulzman

Compaction and moisture content



Effect of recreational use on bulk density

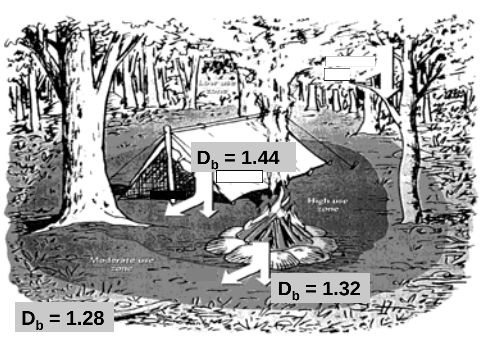
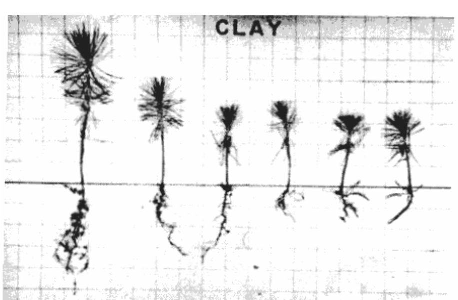


Fig 4.16 p.111 Sulzman

Effects of compaction (high Db) on plant growth

- Silt loam in Arkansas:
  decreasing D_b by 16% increased cotton yields
  13% during a normal year
  59% during a dry year **(↑ pore space= ↑ water storage capacity)**
- Medium textured soils in Washington
  D_b > 1.2 Mg/m^3; positively correlated with diseases in peas and beans

Effects of compaction: loblolly pine



Increasing soil compaction → **(increasing bulk density)**

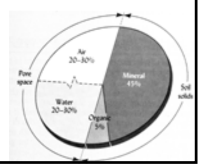
Again, typical Bulk Densities: Perhaps worth memorizing…

- OM: ~0.5 Mg/m^3
- "normal" soils: D_b ~ 1.2 - 1.8 Mg/m^3
  - Clayey soils lower than sandy soils
- Upper limit: ~2.65 Mg/m^3

Particle Density

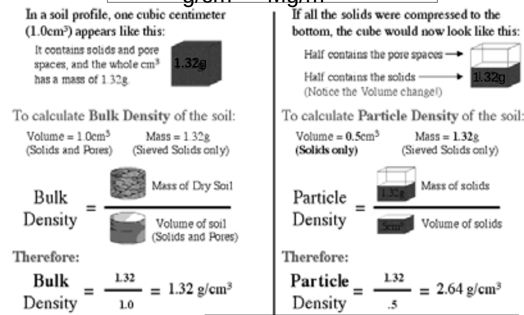
- Mass of dry soil per unit volume of solids, this EXCLUDES pore space
- So if you compact a soil, does particle density change??

NO!



Comparison of bulk and particle density

$g/cm^3 = Mg/m^3$



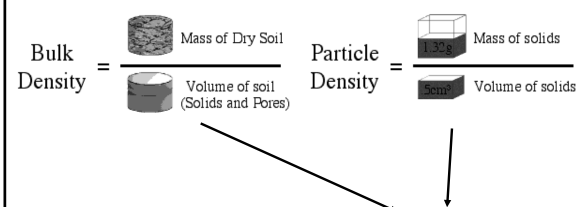
Similar to Fig 4.10 p. 106 Sulzman

Pore Space (= porosity)

$\% PS = 100 * (1-[D_b/D_p])$

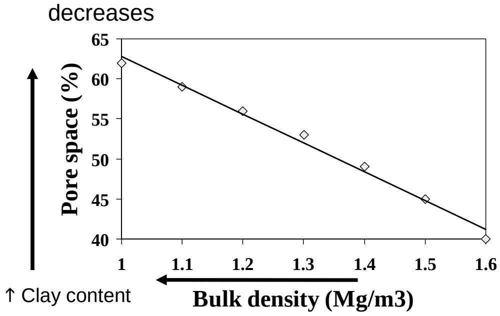
- If you compact or till a soil, the pore space decreases.
- Large pores are filled with air
- Small pores are filled with water
- Clay soils have greater total pore space than sandy soils

Calculations you must know



$\% \text{ Pore Space} = 100 * (1-[D_b/D_p])$

- A pattern to note: As clay content increases, pore volume increases and bulk density decreases



Example test question…

- Woodburn silt loam in the OSU quad
- You excavate a hole in the surface horizon and reserve all of the removed material, which you then weigh, dry, and re-weigh
- Freshly collected soil weighs 470 g
- The weight of the dried material is 390 g.
- The volume of the hole is 300 cm³

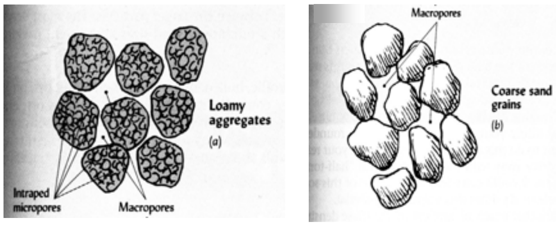
You will recall…

D_b=mass dry soil/bulk volume	= 390g/300cm³ = **1.3g/cm³**
% PS = 100 * (1-[D_b/D_p])	= 100(1-[1.3g/cm³/ g/cm3]) =

What is the bulk density of the surface horizon?

What is the % pore space of this horizon?

Macropores vs. Micropores



[redacted]

Relationship between texture and pore space (data for 10 cm depth)

Texture	O.M. (%)	Total pore space (%)	Micropores (%)	Macropores (%)
Sandy loam	2	**42**	17	25
Silt loam				
• good structure	5	**50**	27	23
• poor structure	5	**50**	40	10

Learning Objectives – part 3

- Describe soil structure and its formation and importance
- List factors that promote aggregate stability and state why a gardener or farmer would want a soil with stable aggregates

Structure and aggregate stability related: The same things that lead to strong structure make stable aggregates!

- Structure
  - spatial arrangement of primary soil particles
- Aggregate stability
  - how easily or not do the peds fall apart?

Goal of good soil mgmt. {
Low bulk density
Lots of macropores
Stable aggregates

Soil Structure

- The arrangement of primary soil particles into groupings called aggregates or peds
- Binding agents provided by plant roots (exudates), organic matter (OM), and clays
- Most important contributor to good structure is OM

Difference between texture and structure

- Texture = proportions of different particle sizes (% sand, silt, clay)
- Structure = spatial arrangement of those particles

Why there is structure

- Particles bind because organic compounds and some minerals are “sticky”
  - Biological sources: polysaccharides, proteins, bacterial “glues”
  - Mineralogical sources : oxides, carbonates, silicates (clay particles)

Characterization of Structure

- *Type*: Shape of the aggregates
  - Four (4) principal shapes
    - Granular (A), platy (E), blocky (B), prismatic (B)
- *Size*
  - fine, medium, coarse
- *Grade*: distinctness (how obvious)
  - Strong, moderate, or weak
- *In general,*
  - **if lots of clay→ STRONG structure, bigger blocks**
  - **If lots of OM→ granular structure**

Structure *type:* Spheroidal

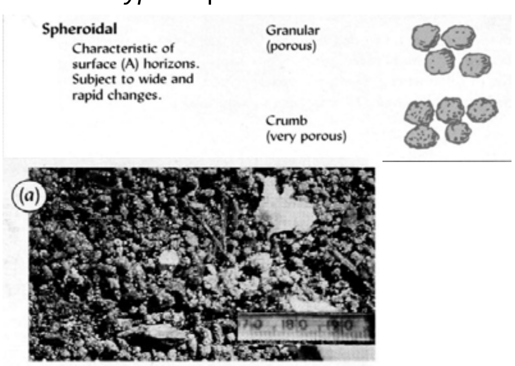
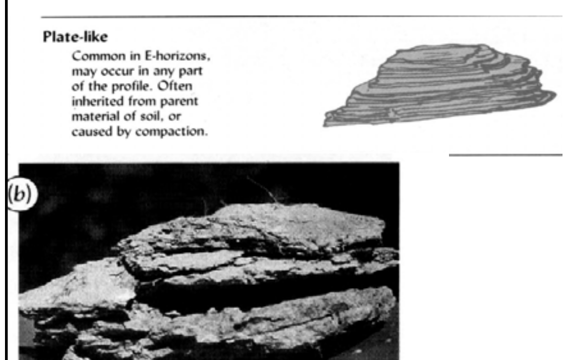
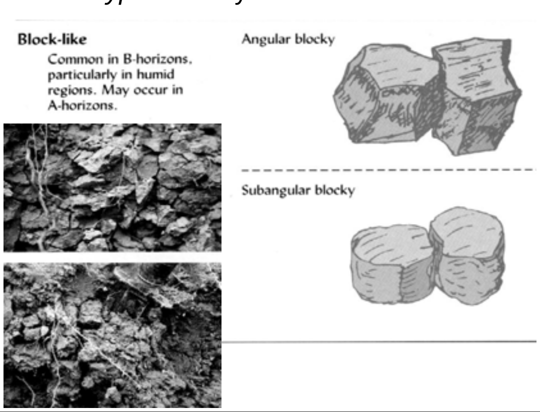


Figure 4.23 p.122 Sulzman

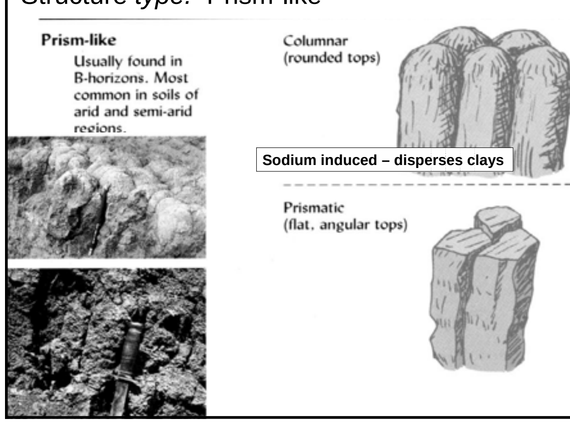
Structure *type:* Platey



Structure *type:* Blocky



Structure *type:* Prism-like



Sodium induced – disperses clays

Example of soil structure labeling

GRADE SIZE TYPE

- Moderate coarse subangular blocky
- Weak medium platy
- Strong very coarse prismatic
- Moderate very fine granular

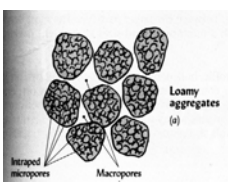
Aggregates are the units of structure

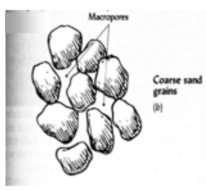
The same things that lead to strong structure make stable aggregates!

- Amount of OM
- Type and amount of clay
- Amount of stabilizing/flocculating minerals (calcium carbonate, gypsum, etc.)

Aggregates

- Aggregates contain many small pores; area between aggregates large pores





Why Are Aggregates Important?

- Increase porosity
- Increase water infiltration, drainage, decrease runoff
- Increase water holding capacity

When aggregates break down…

Conditions that Promote Aggregate Stability

1. Low disturbance
2. High root abundance
3. High fungal biomass
4. High OM
5. High clay content

Effect of OM on aggregate stability

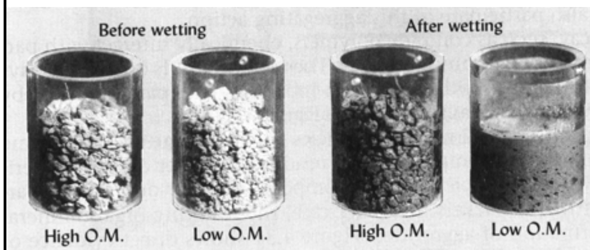


Fig 4.29 p. 128 Sulzman

Effect of roots & tillage on stability

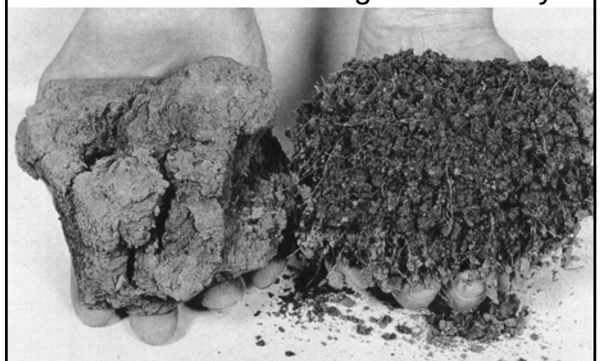
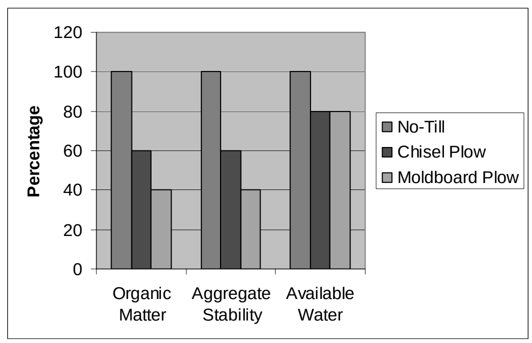


Fig 4.30, p. 129 Sulzman

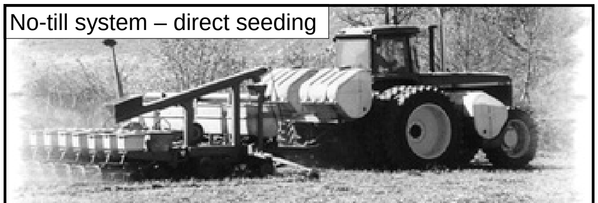
Ways to Improve Soil Structure

- Reduce disturbance
- Work soil when dry
- Mulch soil surface
- Add organic materials (crop residues, compost, manure)
- Use cover crops

Effects of tillage on soil properties



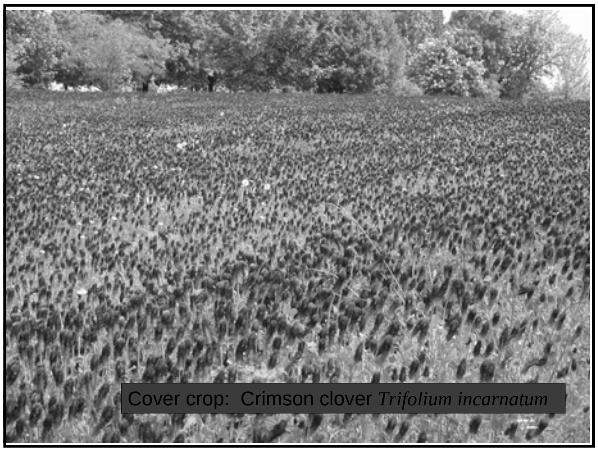
No-till system – direct seeding



- **minimizes the disturbance of soil before planting**
- **essentially stops soil erosion from wind and water**
- **saves fuel and time**
- **greater habitat for birds and other wildlife <u>BUT</u> herbicides usually required**
- **facilitates the buildup of organic matter improving soil quality and yields**

Why would you **NOT** want to use no-till?

- Bird habitat – they eat your seeds
- Residues may contain plant disease
- Weeds!
- Increased structure = better drainage and faster transport of chemicals to the subsurface



Why we **shouldn't** till wet soils

- Aggregate stability lower when wet
- Once aggregates are gone, pores clog
- Crusts can form, preventing seeds from emerging and water from infiltrating