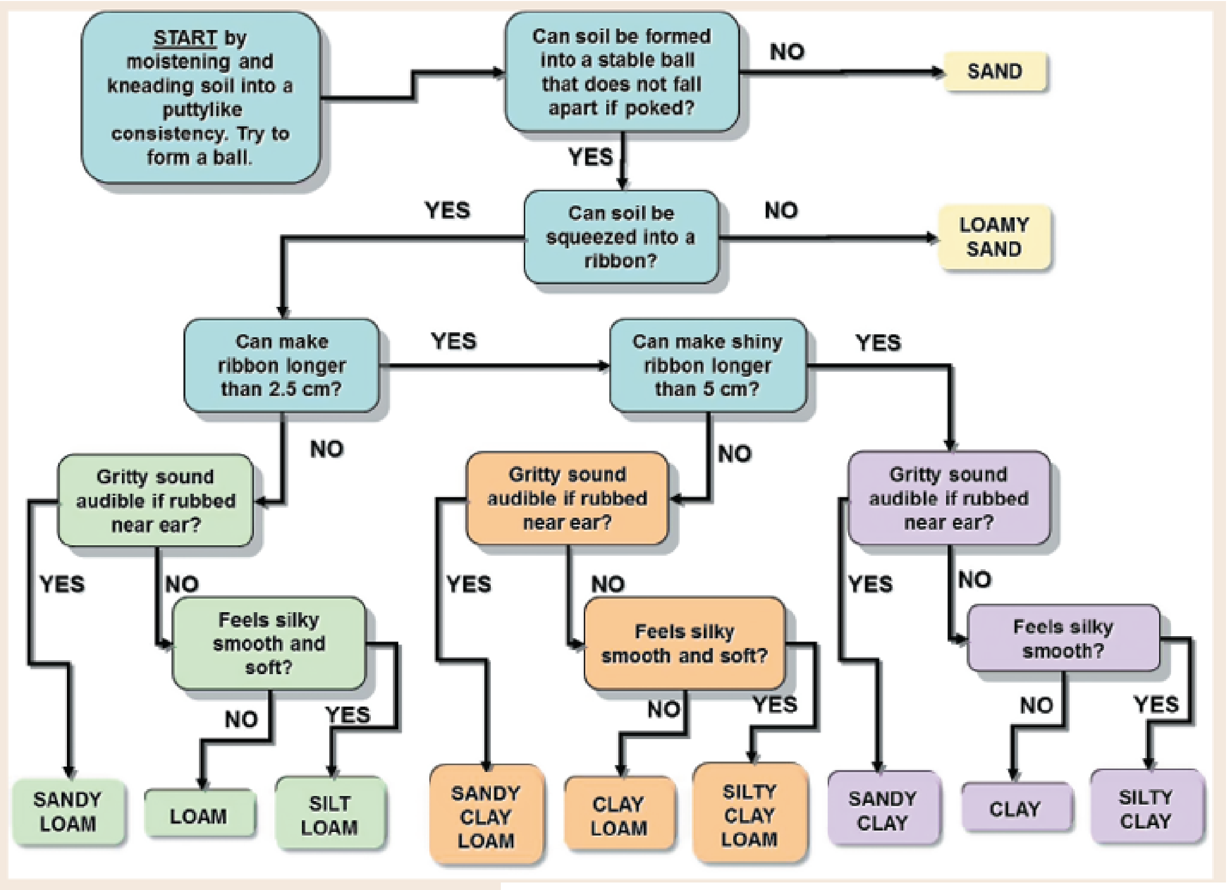
AGR 1401 – Lecture 5 Soil Organic Matter and Bulk Density

Learning Objectives:

- By the end of the lesson you should be able to:
  - Relate soil texture and particle fraction to soil stability
  - Talk about soil organic matter, its importance, how it can be increased and decreased
  - Discuss how soil texture influences bulk density and pore space
  - Compare soil bulk density and compaction
- Readings: Continue Brady Chapter 4

Recall that Soil Texture

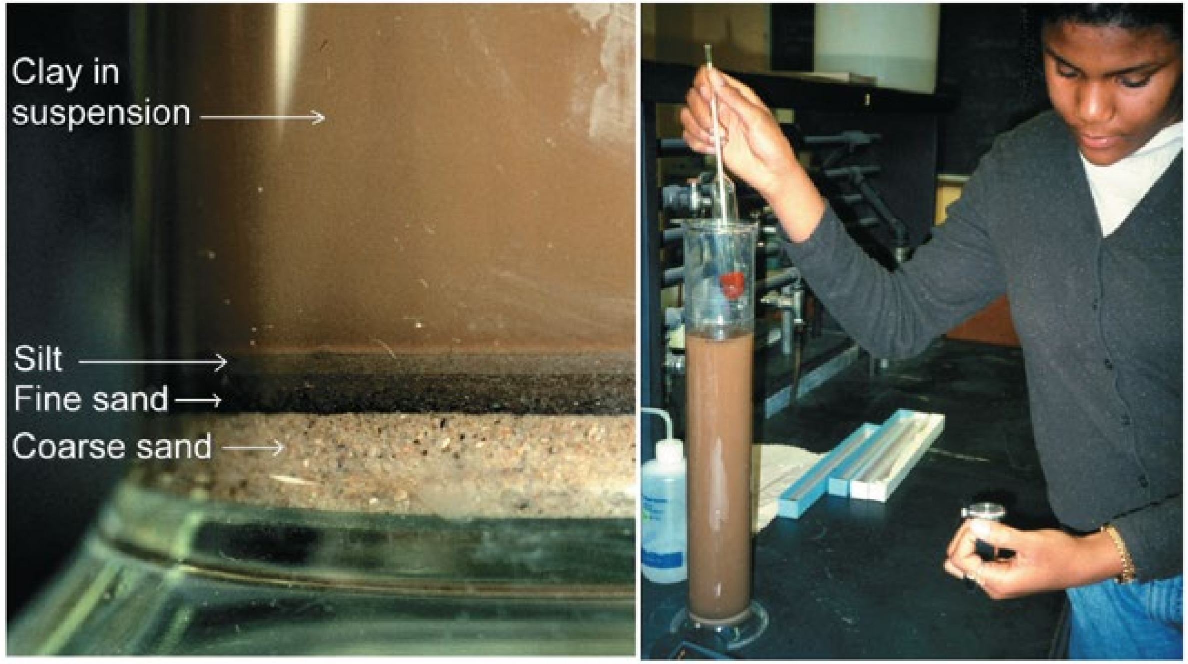
- Is based on its Sand, Silt and Clay fractions
- Texture can be measured by the feel of the soil
- Slowly weaken the soil to allow feel and determination of the particles



Source: Diagram courtesy of Ray R. Weil

Texture can be Measured by Lab Analysis

- Soil structure is purposely destroyed to separate the soil particles
- Sand – settles out quickly
- Silt – settles out more slowly
- Clay – will stay in suspension a long time
- As particles settle out the solution density changes



Source: Diagram courtesy of Ray R. Weil

Stokes Law

- Basic principle of sedimentation
- Assumes spherical particle shape
- Assumes particle density is standard throughout
- Helps us measure velocity of soil particles, and thus, the texture based on the diameter of particles

$$V = \frac{Z}{t} = \frac{D^2 g(\rho_s - \rho_L)}{18\eta}$$

D = effective particle diameter (mm)
g = gravitational acceleration = 9.81 m/s^2
ρ_s = particle density = 2.65 x 10^3 kg/m^3
ρ_L = fluid density (i.e. density of water) = 1.0 x 10^3 kg/m^3
η = fluid viscosity, i.e. viscosity of water at 20°C = 10^{-3} Ns/m^2

https://wiki.ubc.ca/images/thumb/2/2d/Stoke%27s_law.png/450px-Stoke%27s_law.png

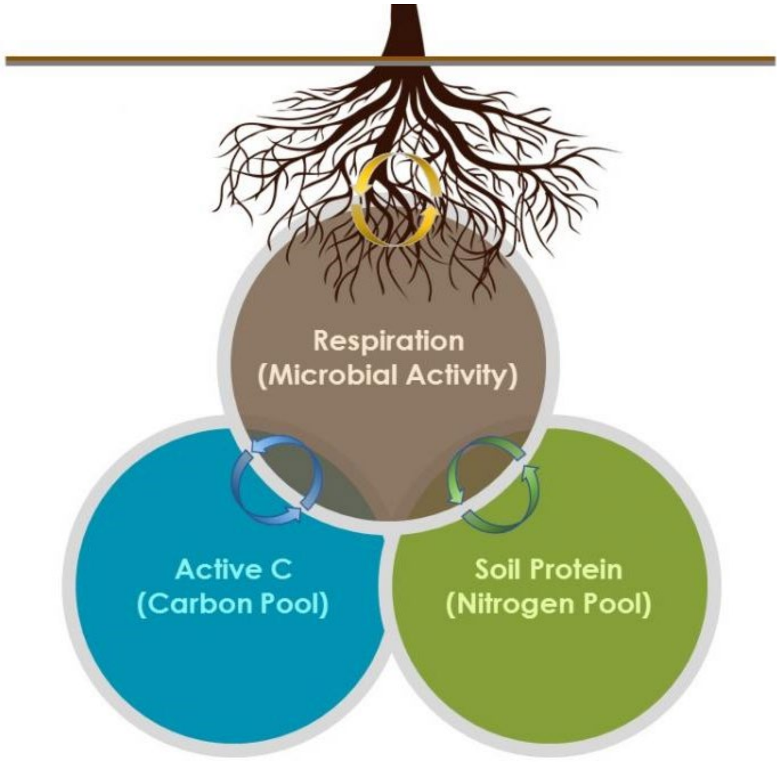
Soil Organic Matter

- Soil Organic Matter (OM) provides aggregate stability against slaking (falling apart) when wetted
- Similar soil types – about 1% more OM right sample
- Equal water added
- Soil in left falls apart

Source: Diagram courtesy of Ray R. Weil

What Builds Soil Organic Matter

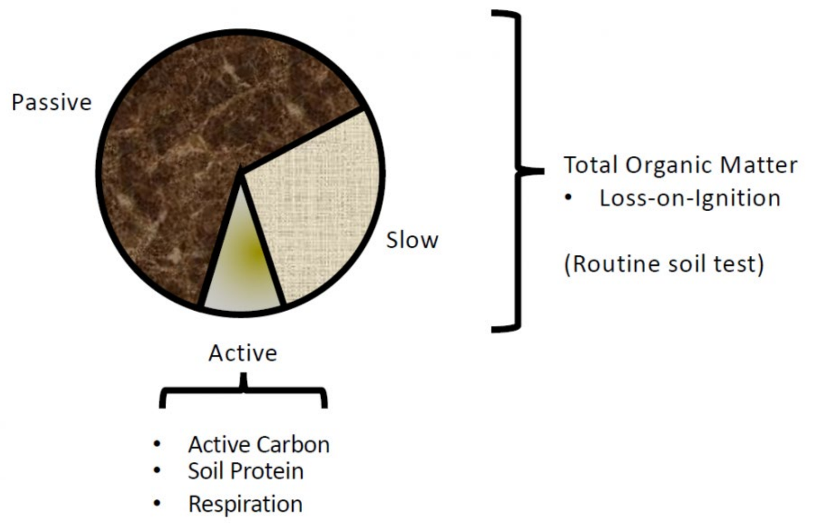
- Burrowing and molding of soil animals
- Sticky networks of roots and fungal hyphae
- Bacteria and fungi producing organic glues - sugars
- Earthworm castings
- Plant roots and burrows make channels for root growth



https://soilfertility.osu.edu/extension-and-outreach/soil-health-testing

Soil Organic Matter Fractions

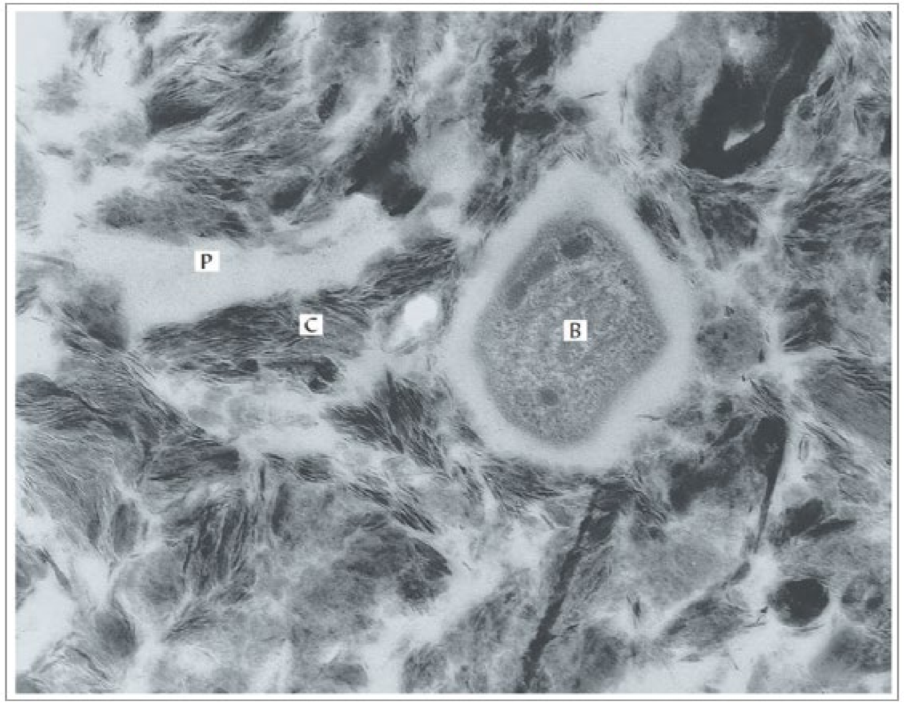
- Passive OM – Humus is not biologically active
- Slow OM – gradually decomposing cells, between passive and active OM
- Active OM – Feeds the microbes and source nutrients to feed the crop



https://soilfertility.osu.edu/extension-and-outreach/soil-health-testing

Organic Matter and Soil Balance

- C – Clays
- P – Polysaccharide sugars
- B – Bacterial cells in a water stable aggregate

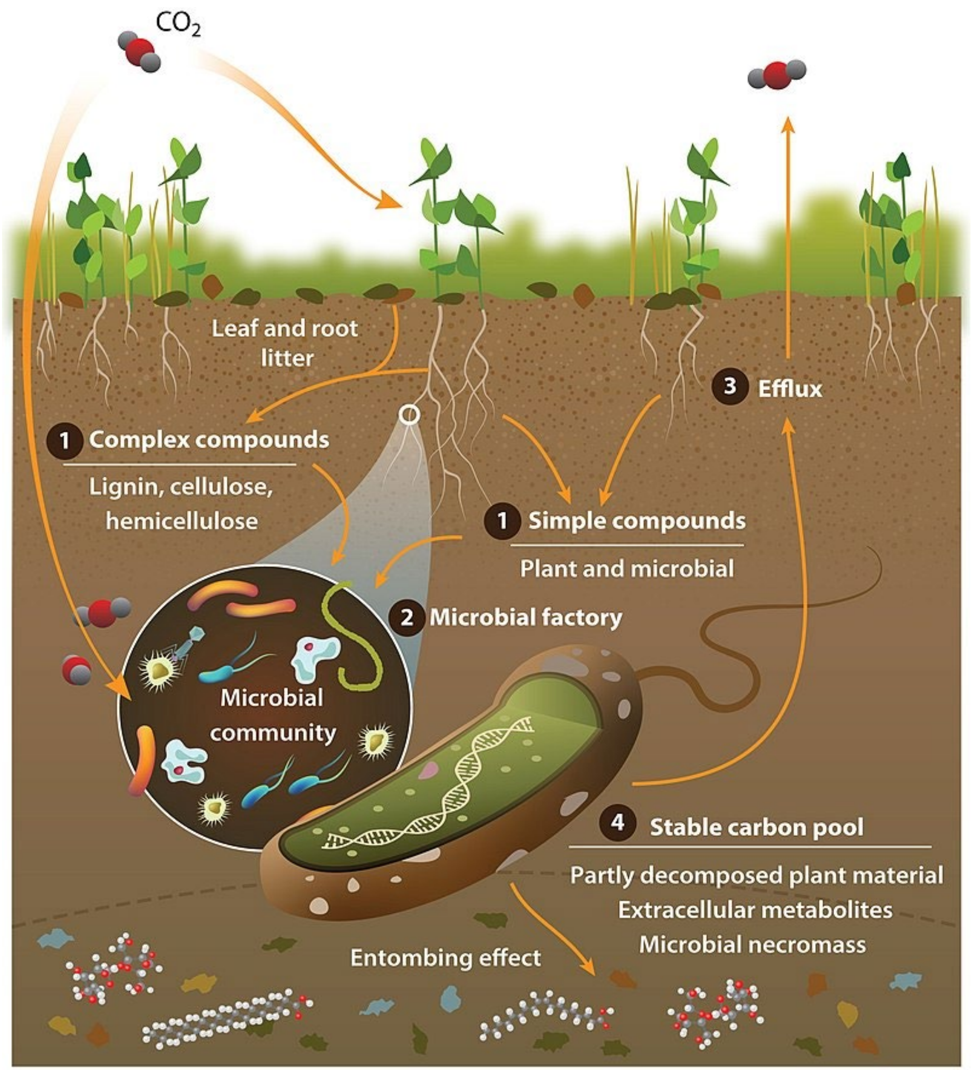


Source: From Emerson et al. (1986); Photograph provided by R. C. Foster, CSIRO, Glen Osmond,Australia; Soil Science Society of America

Source: Diagram courtesy of Ray R. Weil

Soil OM and Carbon

- About ½ OM is Carbon (~58%?)
- Supports life, currency for cycling food and energy in soil
- Tests to evaluate Active OM
  - Active Carbon
  - Soil Protein
  - Respiration
- Larger Active OM pools increase soil fertility and resiliency
- Solvita test

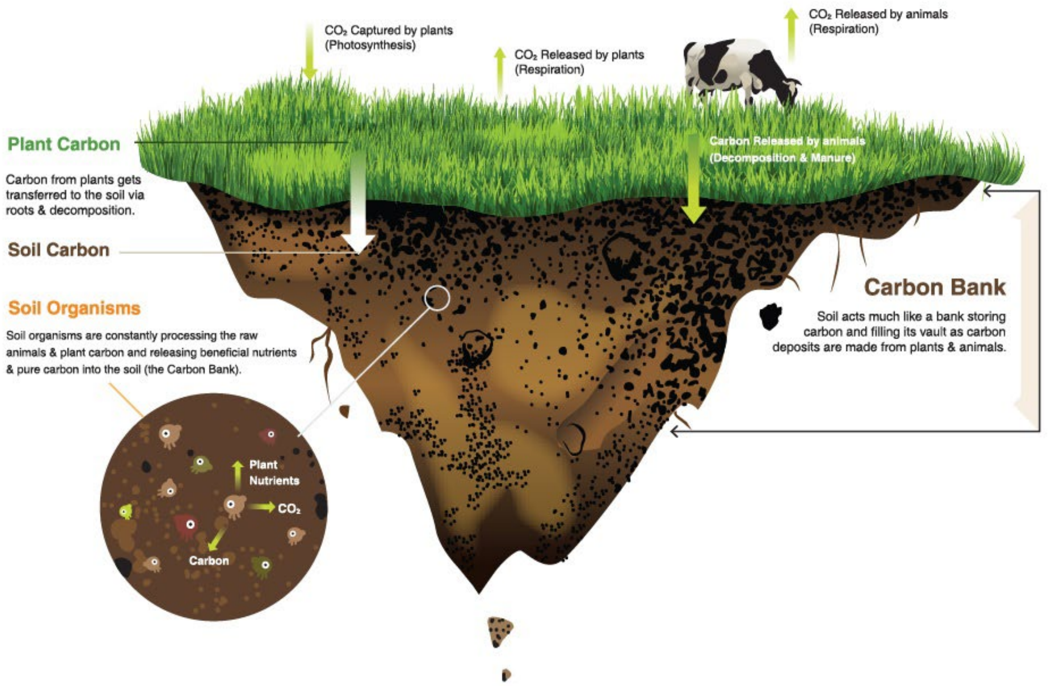


Naylor D, et al. 2020.
Annu. Rev. Environ. Resour. 45:29–59

By Dan Naylor, Natalie Sadler, Arunima Bhattacharjee, Emily B. Graham, Christopher R. Anderton, Ryan McClure, Mary Lipton, Kirsten S. Hofmockel and Janet K. Jansson - [1] doi:10.1146/annurev-environ-012320-082720, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=101300197

Carbon is the Key to Soil Health

- Good soil OM is a good indicator of soil health
- Non-stable carbon compounds that are quickly consumed but contribute to the growth and activity of the entire soil food web
- Living roots in the soil year-round and return organic materials such as crop residues and manure to the soil

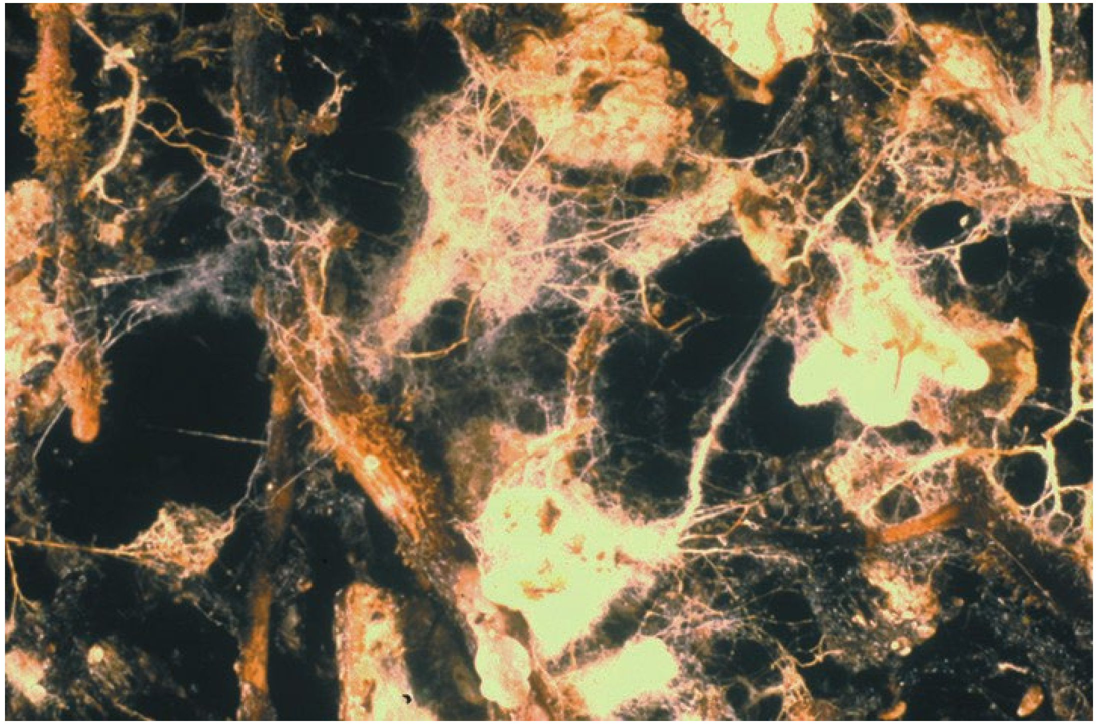


Managing carbon is key to soil health.
(*From http://australiansoil.com.au/soil-management-bebefits/*)

https://www.nrcs.usda.gov/wps/portal/nrcs/detail/pa/soils/health/?cid=nrcseprd1201408

Soil Fungi

- Decomposers – convert dead material into fungal biomass
- Mutualists – Fungi that colonize plant roots
  - Help solubilize Phosphorus – bring in mobile nutrients
  - Tillage can break up
- Pathogens or parasites – can cause plant disease or keep population balance



https://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/biology/

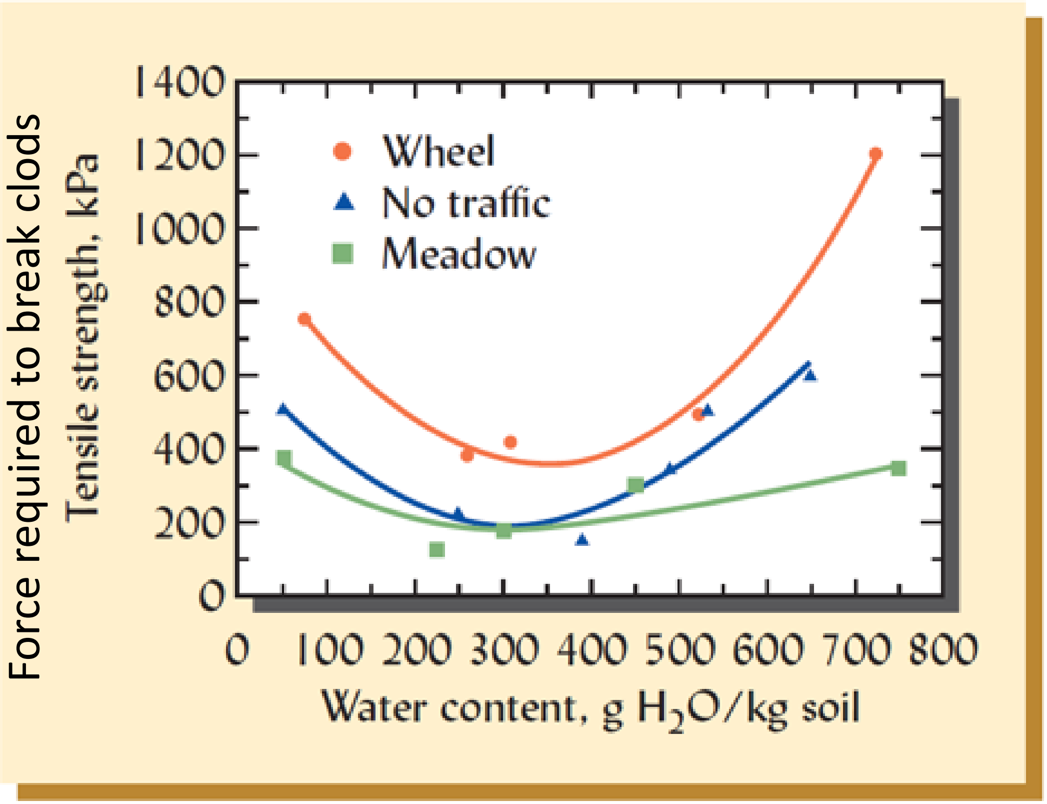
Fallow Syndrome

- Decreased colonization of plant roots by vesicular-arbuscular mycorhizae
- Often thought to occur after a field is not cropped for a year then corn is planted
- Can reduce P uptake
- Was anticipated in 2020 following Prevent Plant in 2019

https://blog-crop-news.extension.umn.edu/2020/03/how-to-prevent-fallow-syndrome-in-corn.html

Soil Bulk Density

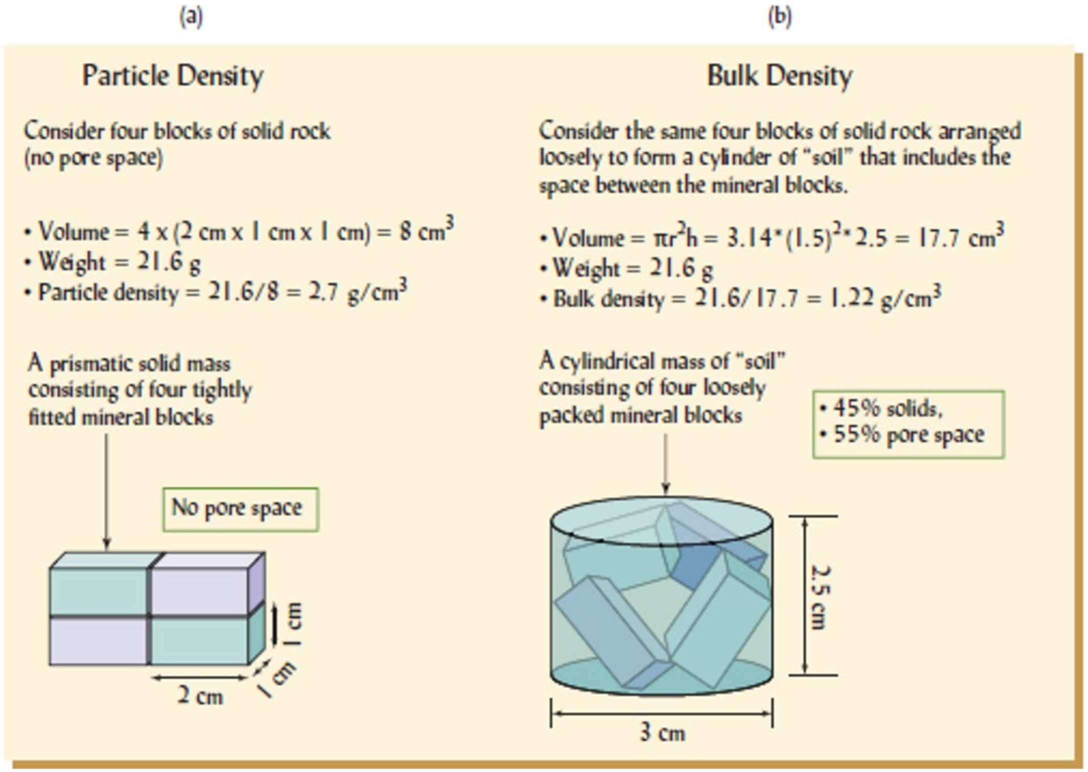
- Tillage, wheel traffic and soil moisture interact to change soil density
- Uncultivated soil breaks up easily
- Cultivation and wheel traffic requires more force to break clods
- Increasing soil water requires more force to break clods



Source: Drawn from data in Watts and Dexter (1997)

Soil Bulk Density

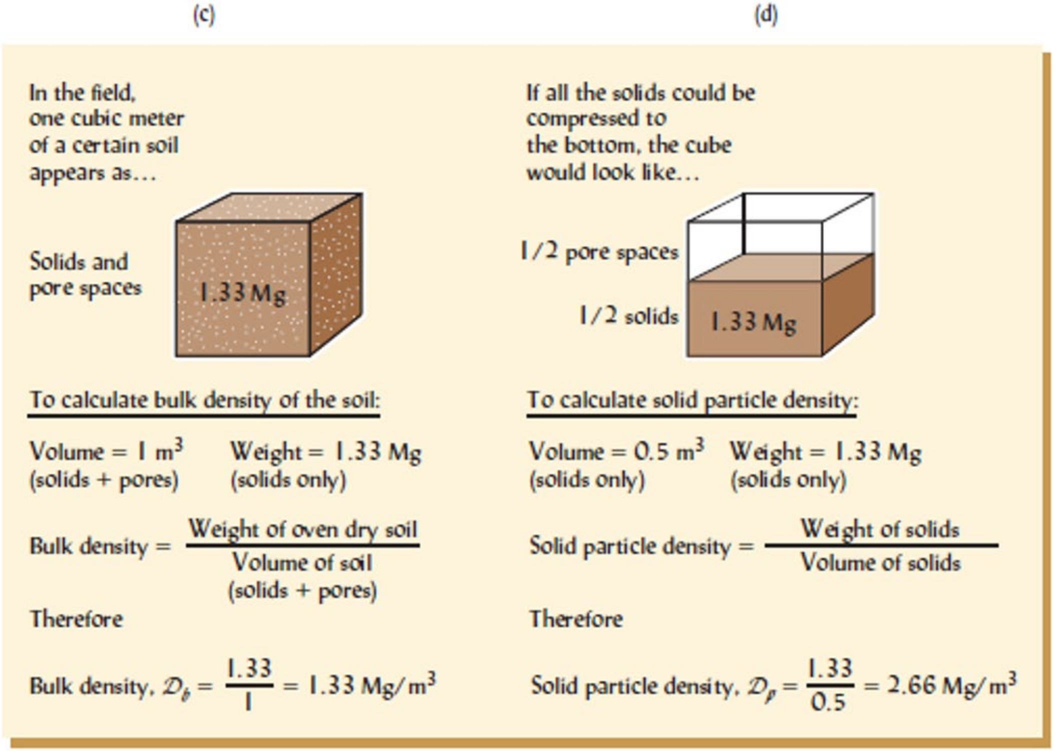
- Soil Bulk Density – Weight of the solid particles in a given volume of soil
- When confined to a volume, particles do not pack in tightly, unless forced



Source: Diagram courtesy of Ray R. Weil

Soil Bulk Density is Dynamic

- Soil can be compressed to reduce the pore space
- In this figure it is doubled



Source: Diagram courtesy of Ray R. Weil

Soil Texture and Bulk Density

- Soils with more sand will have a greater bulk density value for plant growth
- Clayey soils have a lower soil bulk density for ideal growth
- Higher bulk density value indicates compaction and restricted root growth

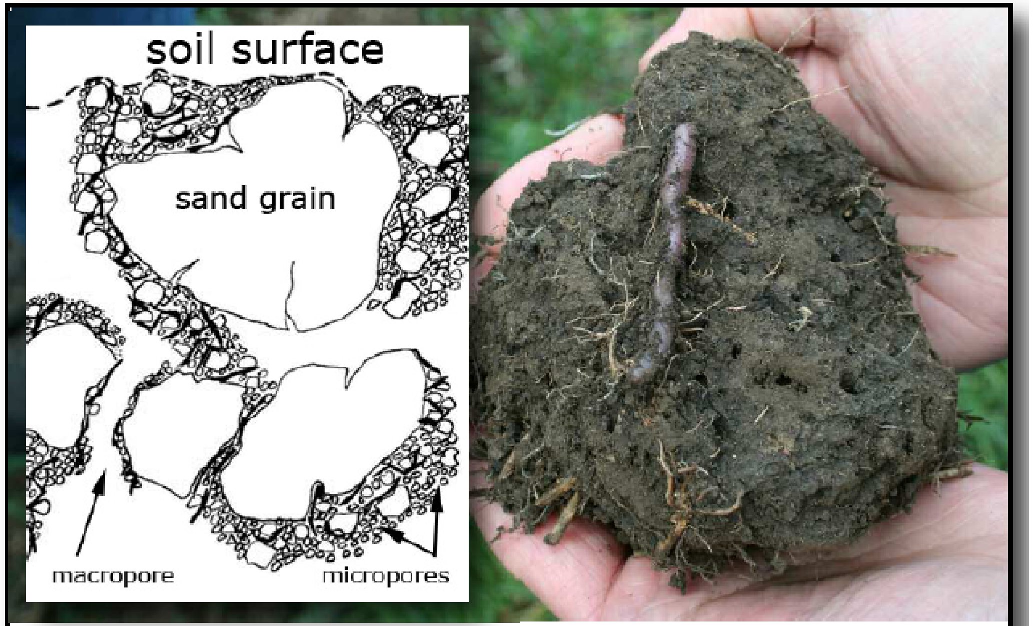
Table 1. General relationship of soil bulk density to root growth based on soil texture.

Soil Texture	Ideal bulk densities for plant growth (g/cm^3)	Bulk densities that restrict root growth (g/cm^3)
Sandy	< 1.60	> 1.80
Silty	< 1.40	> 1.65
Clayey	< 1.10	> 1.47

https://www.sdsoilhealthcoalition.org/technical-resources/physical-properties/bulk-density/

Soil Pore Space

- Macropores - large soil pores, usually between aggregates,
  - Typically greater than 0.08 mm in diameter. ...
  - They provide habitat for soil organisms and plant roots can grow into them
  - Water drains by gravity
- Micropores - small soil pores usually found within structural aggregates
  - With diameters less than 0.08 mm

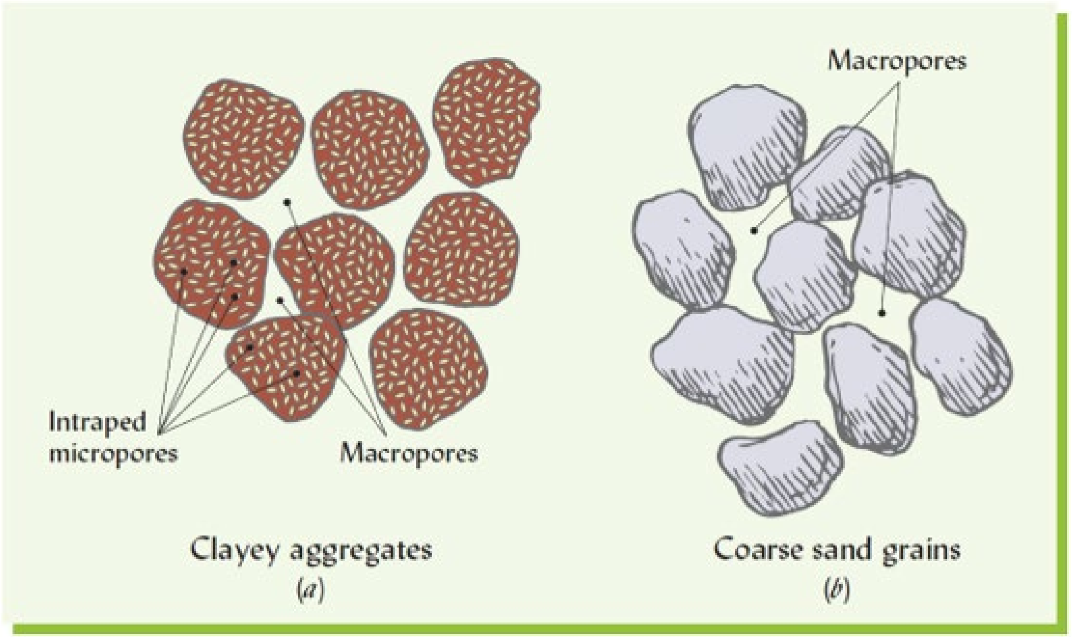


High residue and cover crops contribute organic matter to soil, while no-till management helps protect organic matter and allow accumulation. Organic matter provides food for earthworms and other soil biota. All play a role in developing or protecting soil structure and macropores to help soil function at a high level. Inset shows relationship of macro- and micropores to soil aggregates.

https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_053261.pdf

Soil Porespace and Texture

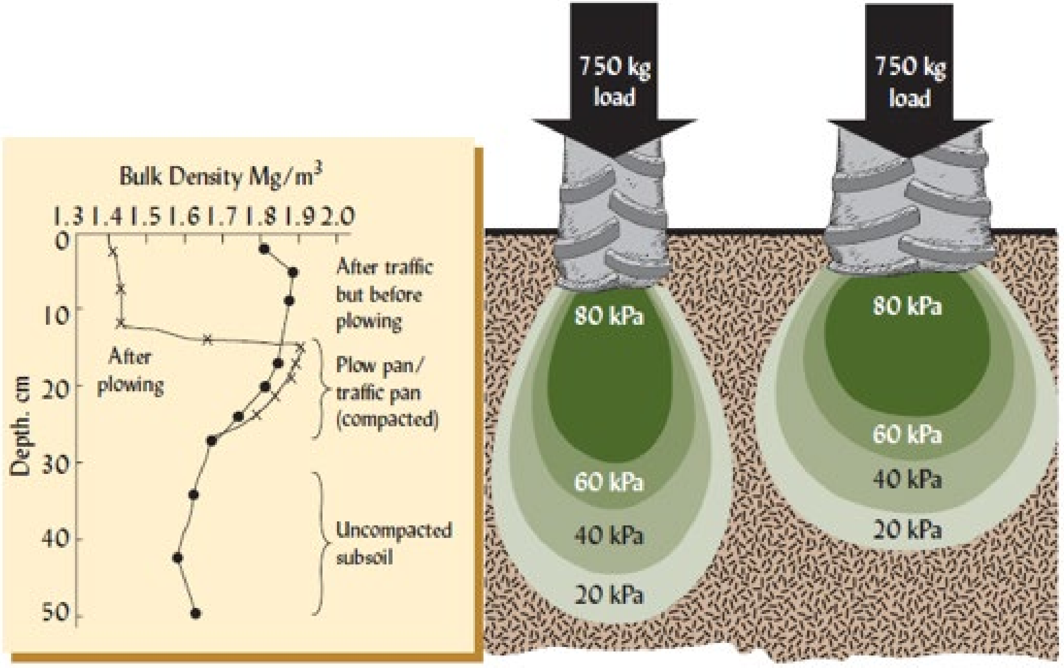
- Clay aggregates have macropores between then and micropores within them
- Sand grains have macropores between them, no micropores within them



Source: Diagram courtesy of Ray R. Weil

Tillage and Bulk Density

- Tillage softens the soil allowing bulk density to increase
  - Breaks up soil aggregates
  - Breaks up soil fungi
- Tire load, width, and height can spread weight over a wider area, reducing the effects of compaction



Source: Diagram courtesy of Ray R. Weil

Soil Compaction: a Closer Look

- Compacted soils limit the ability of plant roots to grow into new soil to extract water and nutrients
- Reducing the amount of the soil profile that is available to contribute to supplying water and nutrients
- The reduction in pore space in the soil also reduces the overall water holding capacity of the soil, meaning less water is available for plant uptake

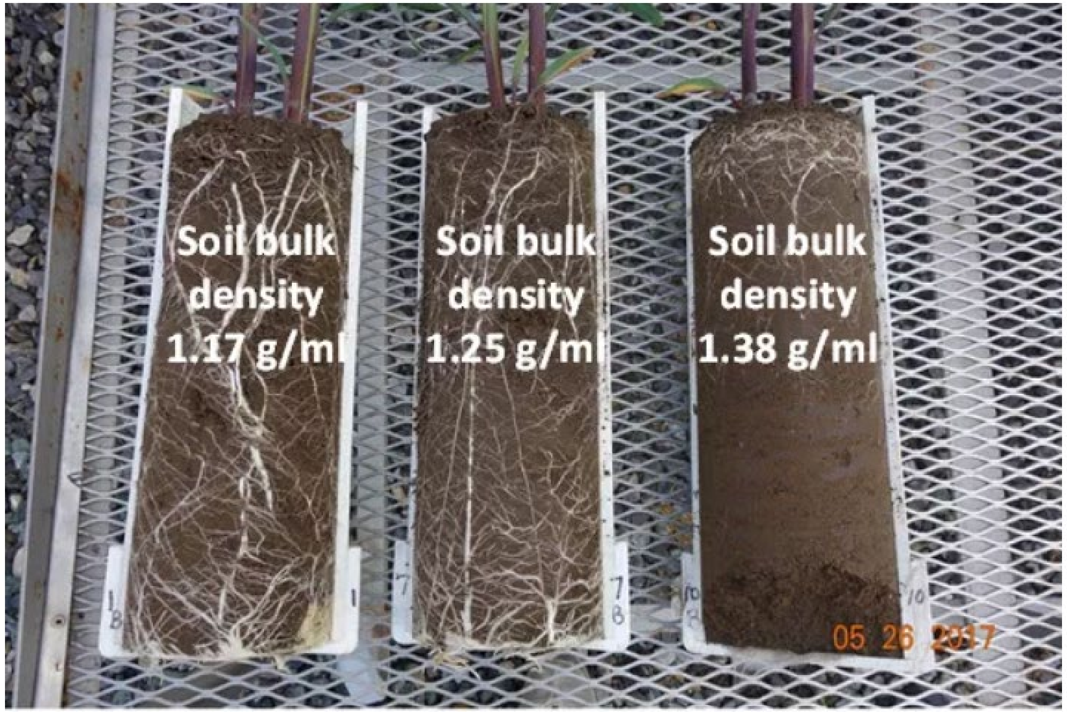


Figure 3. Root growth of corn plants (V5 growth stage) growing in soil compacted to different bulk densities before corn seeds were planted (Strachan and Jeschke 2017).

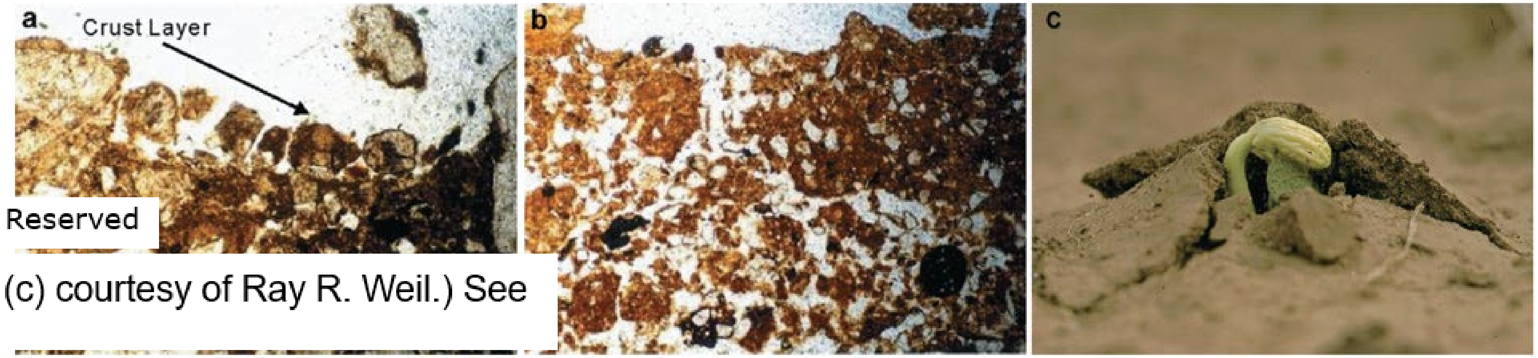
https://www.pioneer.com/us/agronomy/soil-compaction-ag-production.html

Types of Compaction

- Surface crusting – Reduces water infiltration and emergence
  - Raindrop impact forcing soil particles together
- Sidewall compaction – Wet planting conditions and excessive down force on row units

Figure 6. Left: Compaction of the seed furrow sidewall due to double-disk openers slicing through the soil in wet seedbed conditions. **Right:** Corn roots showing the effects of sidewall compaction due to wet field conditions at planting.

https://www.pioneer.com/us/agronomy/soil-compaction-ag-production.html



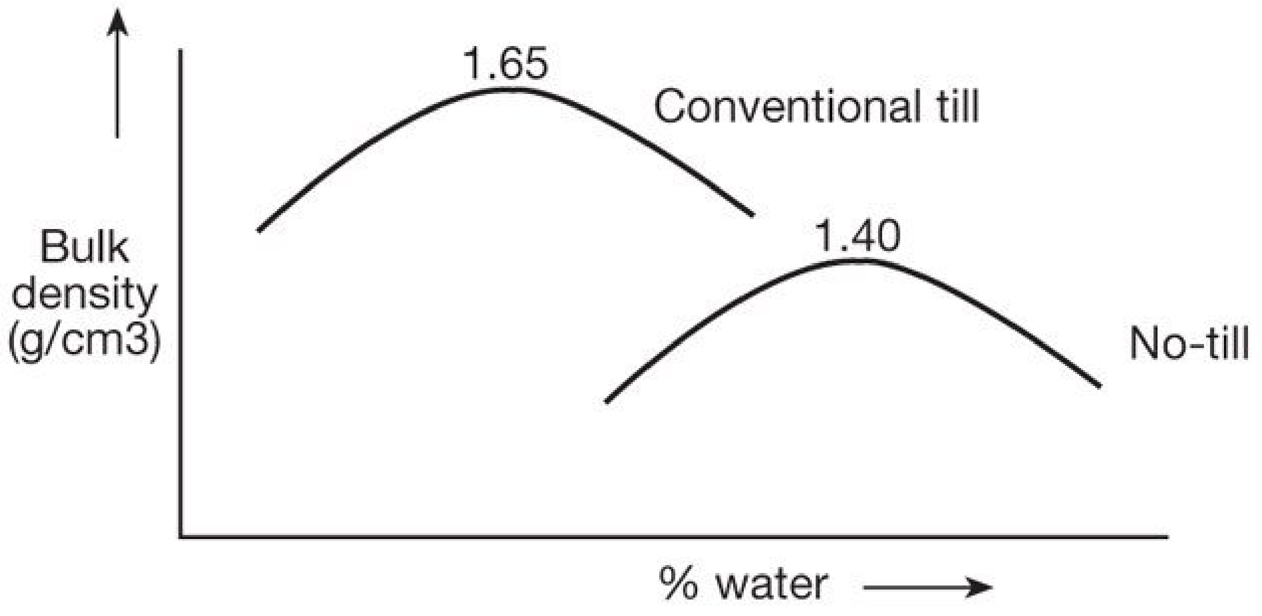
Source: Photos (a) and (b) from Hu Xia; Shunjiangli; photo (c) courtesy of Ray R. Weil.) See also Hu et al. (2012)

Compaction of the A horizon

- As discussed before, it can be human-made and create growth problems
- Occurs more often in high-traffic areas, either through walking or driving

No-Till Farming and Compaction

- No till typically has less compaction
- Better Organic Matter and microbes, less traffic
- Topsoil compaction would be less of a concern in no-till fields.
- The increased firmness of no-till soils makes them more accessible, and no-till fields may become better drained over time.



https://extension.psu.edu/effects-of-soil-compaction

Effects of Compaction

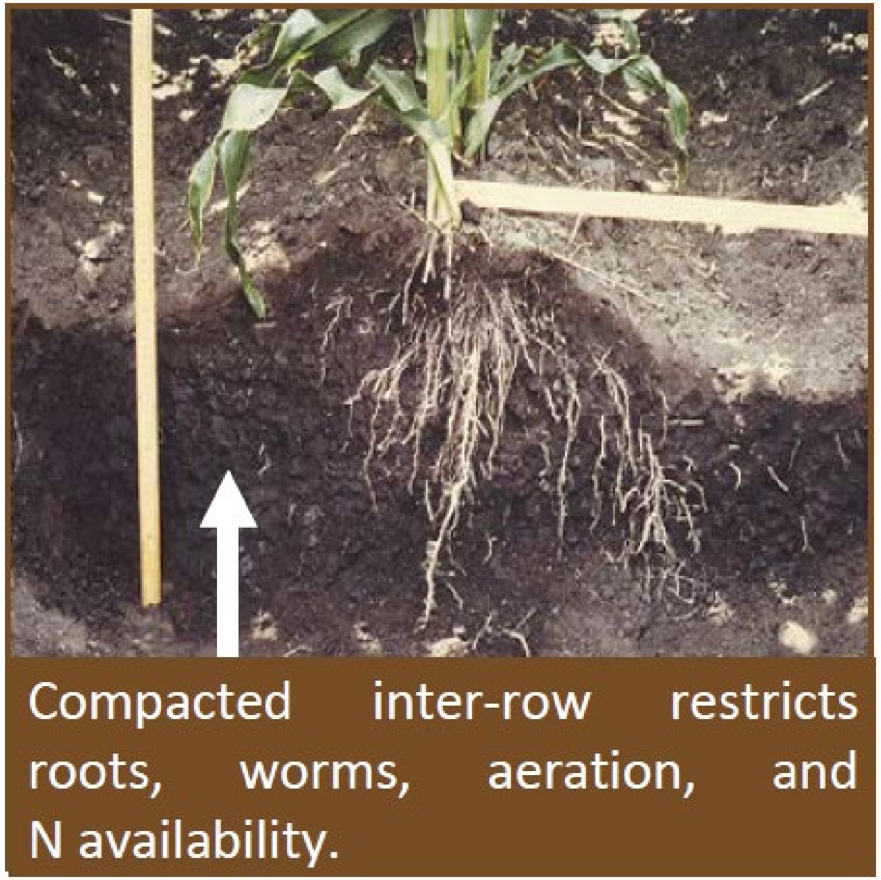


Figure 3. Compacted soil in wheel traffic row.

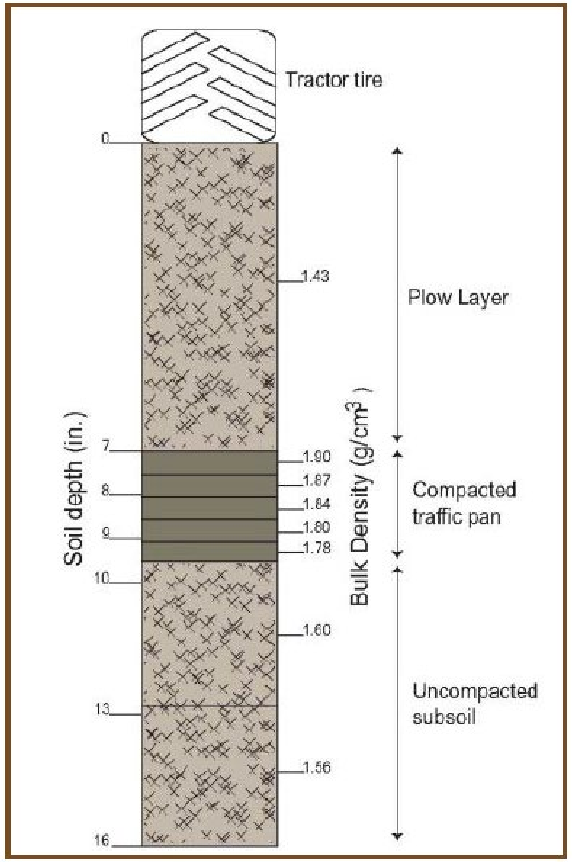


Figure 4. Compacted plow layer inhibiting root penetration and water movement through soil profile (adapted from: *The Nature and Properties of Soils*, 10th Edition).

https://extension.psu.edu/effects-of-soil-compaction

Lesson Summary

- Soil Organic Matter is the glue that binds soil particles together
- Carbon content in the soil is about ½ the Organic Matter
- Soil carbon, respiration, and protein content are measurable quantities in the soil and good indicators of soil health
- Increasing soil bulk density is a measure of compaction
- Soil compaction is reducing pore space
- Common agricultural practices increase soil compaction