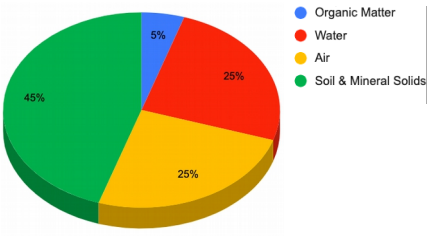
Soil bulk density

How might we measure soil compaction?

*Adapted from https://www.nrcs.usda.gov/sites/default/files/2022-10/Soil%20Bulk%20Density%20Moisture%20Aeration.pdf

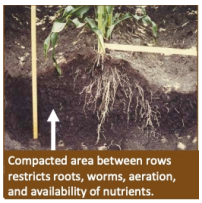
Bulk density is an indicator of soil compaction. It affects rooting depth, available water capacity, soil porosity (pore space), availability of nutrients for plant use, and activity of soil microorganisms, **all** of which influence key soil processes and productivity! Highly compacted soils contain very few spaces (pores) in between particles, resulting in soil with a higher unit weight.



Bulk density is the oven-dry weight of a soil sample. It is typically expressed as grams per cubic centimeter (g/cm3). Total volume of the surface layer consists of about 50 percent solids, of which about 45 percent is soil particles and 5 percent or less is organic matter, and about 50 percent pore space, which is filled with air or water.

Available water capacity is the amount of soil moisture available to plants. It varies with soil texture and is reduced when the soil is compacted. Bulk density can be managed by using practices that minimize compaction, improve soil structure, and increase soil organic matter content.

Soil Bulk Density Issues and the Relation to Soil Function and Loss



High bulk density is an indicator of soil compaction and low soil porosity. It impacts available water capacity, root growth, and movement of air and water through the soil. Compaction reduces crop yields and restricts the growth of plant cover that helps to protect the soil from erosion. By restricting the infiltration of water into the soil, compaction can lead to increased runoff and erosion in sloping areas or to saturated soils in more level areas.

Materials

aluminum or plastic ring to collect sample
rubber mallet or weight

sandwich bags & sharpie
teaspoon measuring scoop
drying oven or microwave
wood block
flat-bladed knife or trowel
pocket scale
drying plate or container

Measuring Bulk Density and Soil Moisture

Video

1. Carefully clear all residue from the soil surface
2. Drive the ring into soil to a depth of 3 inches with a small mallet or weight and block of wood. The top of the ring should extend 2 inches above the surface. 
3. Remove the ring by first cutting around the outside edge with a small, flat-bladed knife. Place the trowel underneath the ring (to keep the sample in the ring), and carefully lift the ring out. 
4. Remove excess soil from the bottom of the ring with the knife
5. Place the sample in a resealable plastic bag. Label the bag
6. Weigh an identical, clean, empty bag. Record weight
7. Weigh an empty ceramic drying plate to be used in step 8. Record weight in table 2.
8. Mix soil core thoroughly by kneading the plastic bag.
9. Place soil in the empty ceramic drying plate (or metal tin if using the drying oven)
10. Then in a
    - microwave, dry the sample in 4-minute cycles at medium power

    OR use a…
    - drying oven at 150°C and in 7 min intervals

    11. Weigh soil on the ceramic plate after each cycle and record weight in the table.
    - (The soil is dry when the weight no longer changes from one drying cycle to the next.)

Table 1

Sample site	Sample mass (g)	Mass of container (g)	Total mass of sample (g)
Example	490	5	485

Table 2

Sample site	mass of plate (g)	mass of soil w/ plate (g)	Dry cycle 1 soil mass (g)	Dry cycle 2 soil mass (g)	Dry cycle 3 soil mass (g)	Dry cycle 4 soil mass (g)	Dry cycle 5 soil mass (g)	g of water / g of soil
Example	4	38				31		0.259

Table 3

Sample	Sample weight in bag (g)	Sample weight w/o bag (g)	Dry weight of sample	Bulk density (g/cm^3)
Example	490	485	385	1.11

Calculations

1. Determine the g of water per g of soil.

   Take the mass of the collected soil before drying, subtract the mass of the dried soil, then divide by the mass of the dry soil. In the example above, that would be 34 (remember to subtract the mass of the container from each) minus 27, divided by 27.

   (34 - 27) / 27 = 7 / 27 = .259 g of water / g of soil

2. Determine the dry weight of the field sample.

   Divide the dry weight of the field sample by 1 + the soil water content (determined above).

   (490 - 5) / (1 + .259) = 485 / 1.259 = 385 g

3. Determine bulk density.

   Divide the dry weight of the bulk sample by the volume of the soil core. Find the volume of the soil core by multiplying the radius squared by π, then multiply by the height of the cylinder.

   For this example, the cylinder is 3 inches in diameter (which makes the radius 1.5 inches) and 3 inches in height, but the bulk density units are in cubic cm. The inches need to be converted to cm first, then

plugged into the equation for volume of a cylinder.

Radius: 1.5 in = 3.81cm

Height: 3 in = 7.62 cm

Volume of soil 3.14 * (3.81)2 * 7.62 = 347cm^3

Bulk density 385 / 347 = 1.11 g/cm^3