Add-on Test: Soil Bulk Density (BD)

Soil density and stone content are useful parameters for soil classification and in soil health assessments. Soil Bulk Density (BD) is a measure of the weight of dry material contained in a sampled volume of soil. This sampled volume includes the volume of soil particles, of stones and of soil pores. Bulk density is an indicator of soil compaction. The compacted soil in Figure 1 has more soil particles contained in the same volume as the loose soil, increasing the BD. In high organic matter soils some of the soil particles are replaced with low density organic matter resulting in decreased bulk density.

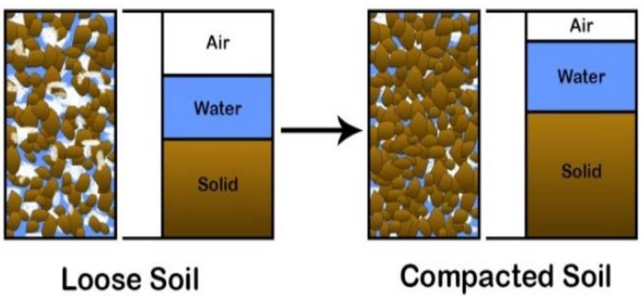

Figure 1. A loose soil has more volume available for air and water storage.
https://gharpedia.com/blog/soil-compaction-ground-improvement-method/

Samples can be taken within a field to compare soil density and compaction between locations (or depths) in the field. In Figure 2a, two BD samples are composited into a single bag. Using the known sampling ring volume, the BD and field water content at sampling can be determined. Figure 2b shows intact BD samples prepared for lab analyses of the pore size distribution in the sample.

Figure 2a. Samples collected for routine water content and BD determination. **Figure 2b.** Undisturbed BD cores are collected for pore size and pore volume studies in the laboratory. https://cdn11.bigcommerce.com/s-zgzol/images/stencil/500x659/products/13344/23519/img_6385__87690.1498754169.jpg?c=2

How Bulk Density relates to soil function

A compacted (or eroded) soil surface layer has fewer large pores to rapidly infiltrate and conduct arriving water into the profile for storage. The resulting surface water runoff can lead to erosion in the near term and soil drought in the longer term. Figure 3 contrasts water movement into an uncompacted soil with low BD and water running off from a soil with a compacted surface. Figure 4 depicts situation b).

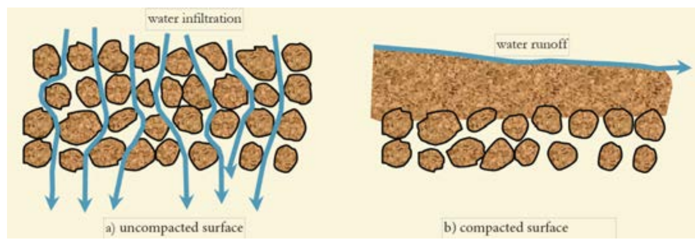

Figure 3. Water arriving at the soil surface and can a) infiltrate a low BD soil or b) run off from a compacted soil surface.
Magdoff and Van Es, Building Soils for Better Crops. ISBN-13: 978-1888626056

Figure 4. A dense, compacted surface layer restricts water infiltration into the soil profile.

Higher BD soils with few large pores for drainage can become waterlogged. A compacted soil subsurface layer can slow or prevent percolation of the water through the soil profile. This excess water in the soil can slow soil warming and delay field activities.

Plants grown on compacted soils can be stressed due to limited root extension. Vigorous root growth through the soil profile allows plants to encounter and extract needed water and nutrient resources for their growth and maintenance. When soil pores are saturated with water, lack of air restricts root extension. When the soil becomes dry, the dense, hard soil inhibits root penetration between soil particles. The root system can become stunted with roots thickening rather than extending into new soil volumes.

Add-on Test: Soil Bulk Density (BD)

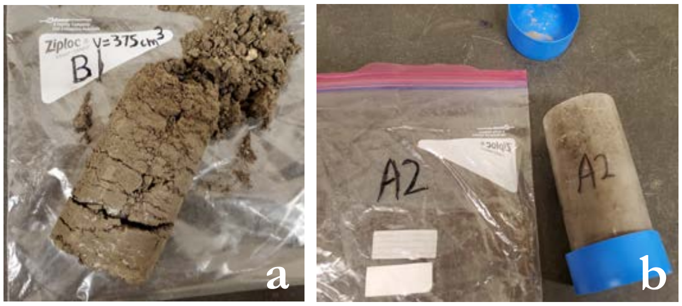

Figure 5. Soil bulk density samples can arrive a) disturbed in a sample bag or b) intact in a sleeve. The total soil volume contained in each bag must be provided for disturbed samples.

Basic protocol

Each bulk density sample is obtained by a collecting a cylinder of known soil volume through the depth of interest. This material can be removed from the cylinder in the field and placed into a bag. Sampling accuracy is increased by compositing multiple cylinders into each sample bag. Record the total volume of soil sampled and placed into each bag. A sample can also be collected in a metal or clear acetate cylinder, capped and taken to the laboratory.

At the lab, the entire sample is weighed and passed through an 8 mm sieve. A small subsample (without stones, about 100 g) is weighed and dried at 105C to determine the water content of the sample. The remaining material is passed through a 2 mm sieve. Dry soil material and stones separately at 105C and weigh. Data are reported on a with stone (As Sampled) and a without stone basis. The units used are grams of dry soil per cubic centimeter soil volume.

Managing Bulk Density and Compaction

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

Figure 6. General relationship of soil bulk density to root growth, by texture. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_053256.pdf

Most long-term solutions to bulk density and soil compaction problems revolve around reducing soil cultivation and increasing soil organic matter. Incorporating soil management practices that use cover crops, crop residues, perennial sod, and/or reduced tillage results in increased soil organic matter, less soil disturbance and reduced bulk density. Reduce traffic on compaction- prone wet soils. Identify dense soil layers to target soil decompaction efforts.

Interpretation

Soil bulk density information is useful for converting percent carbon results in soil to weight of carbon per area of soil. The weight of soil in a field to a particular depth can be determined by multiplying the area of the field by the depth measured by the bulk density. Using an example of the top 15 cm of a 1 hectare field with a BD of 1.4 g/cm^3:

$$\text{Area} * \text{Depth} * \text{BD} = \text{Weight}$$

$$10{,}000\ m^2/ha * 0.15\ m * 1400\ kg/m^3 = 2{,}100{,}000\ kg\ soil/\ ha$$

This soil data can be useful in quantifying the mass of soil carbon stored across a landscape in a particular depth interval. The percent total carbon (Tot C) or percent soil organic carbon (SOC) data is multiplied by the field soil weight as calculated above to determine the weight of carbon in the soil across an area in the particular depth interval. An example with a soil test result of 2.6% Soil Organic Carbon:

$$2{,}100{,}000\ kg\ soil/ha * (0.026\ kg\ SOC/kg\ soil) =$$

$$56{,}600\ kg\ SOC/ha = 56.6\ metric\ tonnes\ SOC/ha$$

In the US, English units are favored over metric units. The conversion of the measured bulk density data is 1 $g/cm^3 = 62.4\ lb/ft^3$. In English units, for the top 6 inches of a 1 acre field with a BD of 1.4 g/cm^3 :

$$43{,}560\ ft^2/acre * 0.5\ ft * (1.4\ g/cm^3 * 62.4\ lb/ft^3) =$$

$$1{,}902{,}700\ lb\ soil/acre * (0.026\ lb\ SOC/lb\ soil) =$$

$$49{,}470\ lb\ SOC/acre = 24.7\ tons\ SOC/\ acre$$

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