Bulk density determination

Background

Bulk density is the mass of soil present in a given volume, usually expressed in g/cm^3. Bulk density is an indicator of soil compaction and is also needed to convert element content (e.g., soil organic carbon content expressed in g C / 100 g soil) to stocks (e.g., soil organic carbon stock expressed in tons C / hectare).

Natural soils can have widely different bulk densities, ranging from 0.5 g/cm^3 for an organic topsoil to 2.2 g /cm^3 for a massive mineral subsoil layer. A well-structured mineral soil generally has a bulk density around 1.3 g/cm^3.

Bulk density is determined by sampling a known volume of undisturbed soil and weighing it after drying. For organic soils, sampling inside a frame is recommended. For mineral soils, the most common technique involves inserting a sampling cylinder into the soil. The cylinder may be used on the soil surface (afer removing organic horizons) or horizontally within each horizon. For soils dominated by cobbles and stones, a small pit may be dug. The excavated material is collected on a tarp while the volume of the excavation is determined by lining the pit with plastic film and recording the amount of water necessary to fill it.

Equipment

- Cylinder
- Mallet or Drop-hammer
- Metal trowel

Procedure

1. Insert the sampling cylinder into the soil using a mallet or drop-hammer. Do not pound directly on the cylinder but on a flat surface placed over the cylinder (e.g. board or metal trowel).
2. Carefully extract the cylinder. It may be necessary to insert a shovel behind the cylinder to make sure no soil falls out.
3. Inspect the soil core to make sure that there was no loss of material during retrieval.
4. Empty the cylinder into a labelled sampling bag or tray.
5. Air-dry the sample.
6. If the sample contains abundant gravel, sieve the soil to 2 mm.
7. Obtain the dry mass of the sample (fine earths and coarse fragments separately for gravelly soils). For fine earths, oven-drying at 105°C is necessary for complete moisture removal. The entire sample may be placed in the oven for a minimum of 48h. Alternatively, the residual

(hygroscopic) moisture content may be determined by placing an aliquot in the oven for a minimum of 16h.

8. Calculate bulk density.
9. Perform quality control on your results. Look for outliers in your data and repeat problematic measurements.

Calculations

Bulk density is simply calculated according to the formula below. The result is sometimes referred to as *gross bulk density* as it includes the whole soil (fine earths and coarse fragments).

$$BD = M_{dry\ soil} / V_{core}$$

with BD: gross bulk density (g/cm^3)

$M_{dry\ soil}$: mass of oven-dried soil (or air-dried soil corrected for residual moisture) (g)

V_{core} : volume of sampling cylinder (cm^3). For instance, for a cylinder of 2.5 cm radius and 5.1 cm in height, $V_{core} = \pi r^2 h = 100$ cm^3

For soils containing abundant coarse fragments (gravels), it is useful to calculate the fine earth BD (the bulk density of the fine earth fraction, 'removing' the coarse fragments). The fine earth BD allows for a direct comparison of samples with differing coarse fragments content.

$$\text{Fine earth BD} = M_{dry\ fine\ earth} / V_{fine\ earth} = M_{dry\ fine\ earth} / (V_{core} - V_{coarse\ fragements})$$

with $M_{dry\ fine\ earth}$: mass of < 2 mm oven-dried soil (or air-dried soil corrected for residual moisture) (g)

$V_{coarse\ fragments}$: volume of coarse fragments (cm^3).

For crystalline coarse fragments dominated by felsic minerals (e.g. granite, gneiss, quartzite), calculate the volume or coarse fragments by dividing their mass by the particle density of quartz (2.65 g/cm^3).

For crystalline coarse fragments of unknown mineralogy, determine their volume by immersing them in a graduated cylinder half-filled with water and recording the change in volume.

Finally, it may be useful to calculate the fine earth abundance (the mass of fine earth present in a given volume of undisturbed soil, g/cm^3). This result facilitates the calculation of element stocks from content data.

$$\text{Fine earth abundance} = M_{dry\ fine\ earth} / V_{core}$$