APBI403/SOIL503

Soil Physics-

LAB 3

Outline

- Soil bulk density
  - – core method
  - - excavation method
- Soil water content
  - - Volumetric water content (direct)
  - - TDR (indirect)


Soil bulk density

Why would you want to know your soil's bulk density?

- compaction (relative)
- convert Θ from gravimetric to volumetric

$$\Theta_v = \Theta_m \left(\frac{\text{kg } H_2O}{\text{kg soil}}\right) \times \rho_b \left(\frac{\text{kg soil}}{\text{m}^3 \text{ soil}}\right) \times \frac{1}{\rho_w} \left(\frac{\text{m}^3 \text{ water}}{1000 \text{ kg water}}\right)$$

- convert mg/kg to soil nutrient pool

$$\text{ppm} = \frac{\text{mg}}{\text{kg}} \times \rho_b \frac{\text{kg}}{\text{m}^3} \times 1500 \text{ m}^3 \times \frac{\text{kg}}{1000 \text{ mg}} = \frac{\text{kg}}{\text{ha f.s.}}$$

Bulk density

- Weight of soil per unit volume, on an oven dry basis

$$\rho_b = \frac{M_s}{V_t} \quad \frac{\text{kg solids}}{\text{m}^3 \text{ of bulk soil}}$$

- Inversely related to porosity

$$\Phi = 1 - \frac{\rho_b}{\rho_s} = \Theta_s$$


Soil bulk density
– core method

ρb core method

- Sample core of known volume
- Oven dry at 105 ^{o}C until constant weight (24-48 hours)

$$\rho_b = \frac{M_s}{V_t}\left(\frac{kg}{m^3}\right)$$

Soil bulk density – excavation method

- when coarse fragment > 25% by volume

http://soilweb.landfood.ubc.ca/labmodules/compaction/soil-bulk-density

Soil bulk density – excavation method

- excavate small hole (soil into sample bag)
- line hole with plastic; fill with measured volume of water (volume of sample)
- sieve out and weight coarse fragments
- oven dry and weight the soil fine fraction

$$\rho_b = \frac{M_{\text{fine fraction}}}{V_{\text{fine fraction}}}$$

Variation in bulk density

- relative proportion of organic and inorganic particles
- specific gravity of organic and inorganic particles
- porosity of soil

- Typical values
  for mineral soils: 1,100 to 1,600 kg m^{-3}


Soil moisture

Volumetric vs. Gravimetric

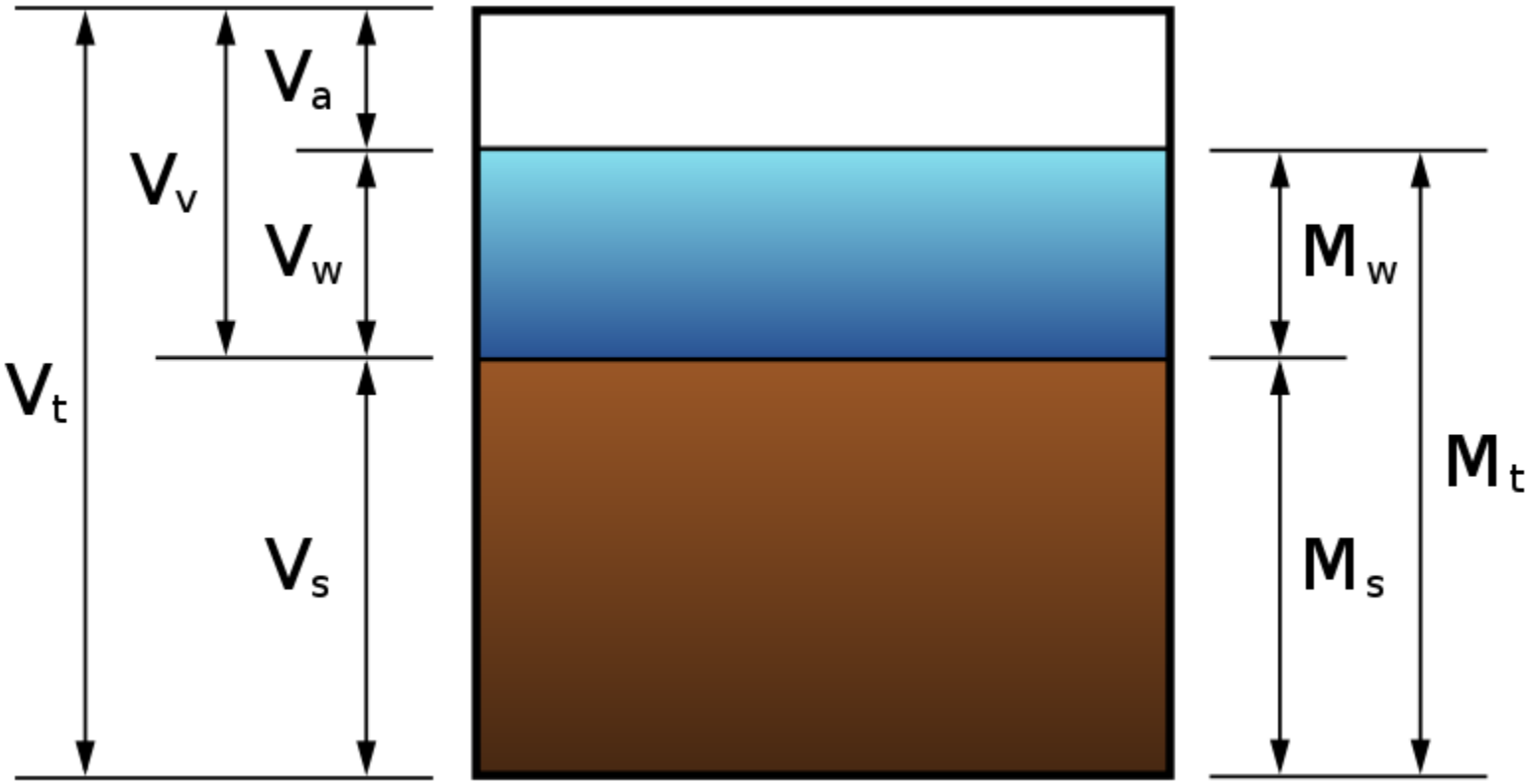
$$\theta_m = \frac{M_w}{M_t} \left(\frac{\text{kg } H_2O}{\text{kg soil}} \right)$$

$$\theta_v = \frac{V_w}{V_t} \left(\frac{m^3 H_2O}{m^3 \text{ soil}} \right)$$

Why Θ_v ?

- Irrigation calculations: need to know PAW and volume of water to apply
- Water balance: need to know available water storage (Θ_{sat} - Θ)
- Biometeorology: air filled porosity effects diffusivity

Mass – Volume relationships



Calculating Θ_v

- convert Θ from gravimetric to volumetric

$$\Theta_v \left(\frac{m^3}{m^3} \right) = \Theta_m \, x \, \frac{\rho_b}{\rho_w}$$

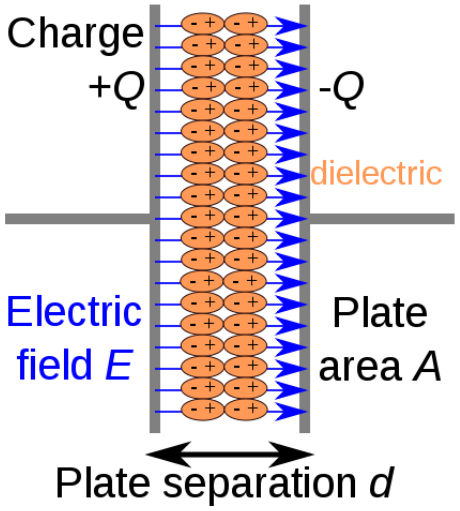

TDR

Time Domain Reflectometry

- indirect measure of Θ_v
- based on the travel time of a high frequency electro-magnetic pulse through the soil
- → calculate permittivity (dielectric constant) of the soil
- permittivity is strongly related to water content of the soil

Dielectric constant

- Dielectric = material with a high polarability
- Dielectric constant or permittivity = measure of how easily a material polarizes in response to an electric field



Dielectric constant

water ≈ 80

soil solid components ≈ 2 – 7

air ≈ 1

TDR method

- Insert probes into soil
- A very fast rise-time voltage pulse is propagated down and reflected back from the end of the probes

- The velocity of propagation used to calculated volumetric water content which is displayed on the LCD (or recorded on a data logger)

TDR Theory

$$K_a \approx K' \approx \left(\frac{c}{v} \right)^2$$

varies with soil moisture content

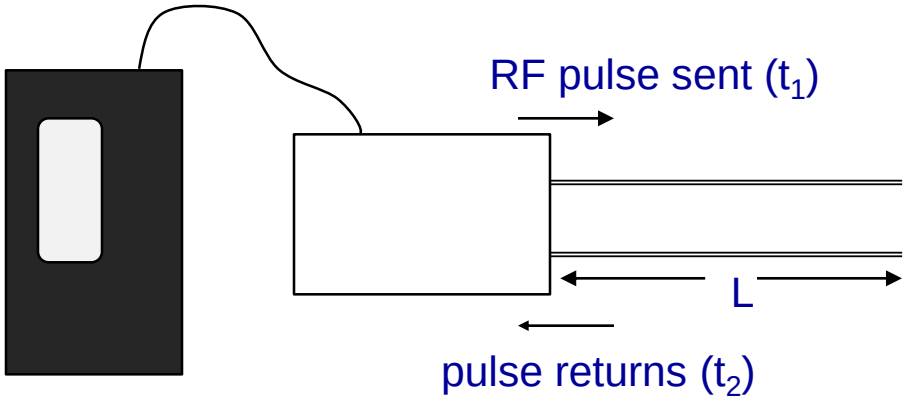
K' = real dielectric constant of soil

Ka = apparent dielectric constant

c = speed of light in a vacuum (3×10^8 m s^{-1})

v = EM (electromagnetic) pulse speed (m s^{-1})

TDR Theory



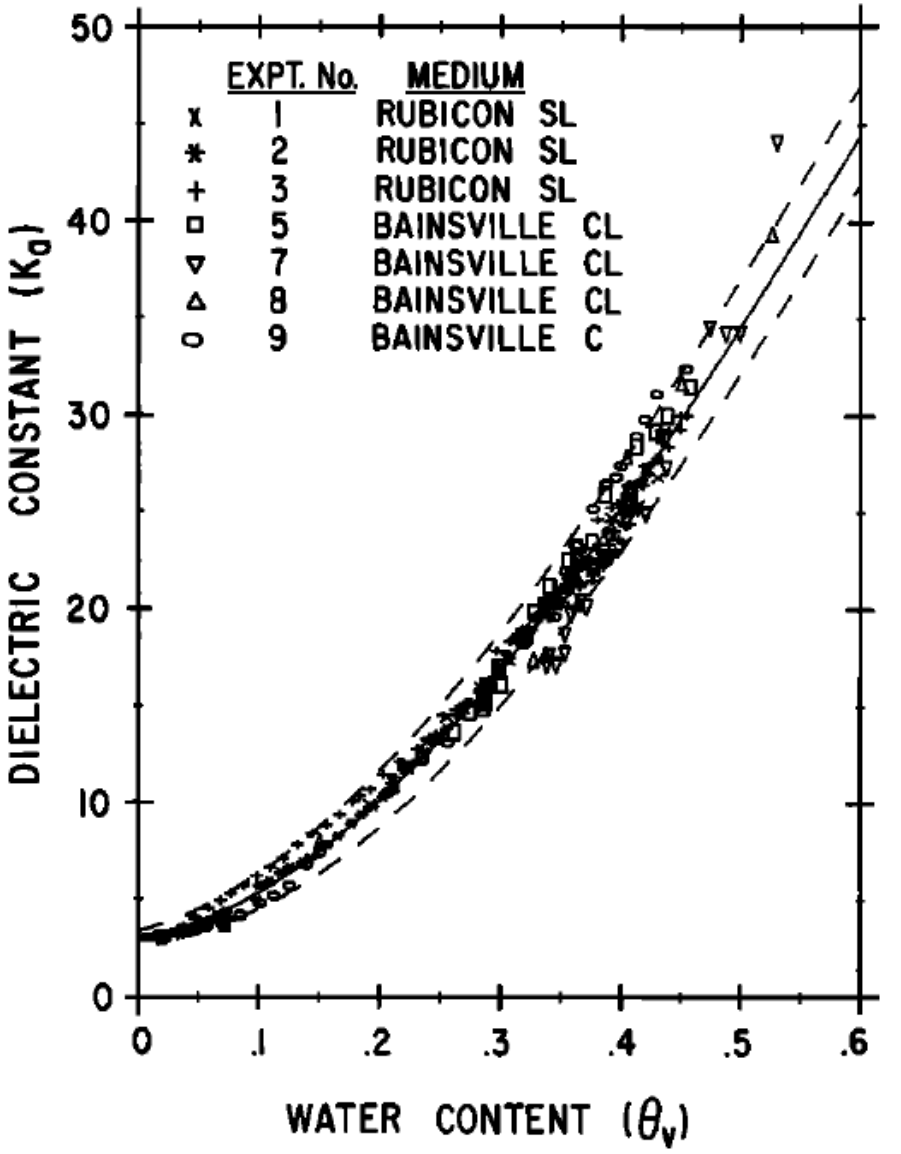
L = probe length

TDR measures $(t_2 - t_1)$

calculates K_a

$$V = \frac{L}{(t_2 - t_1)}$$

$$K_a \approx \left(\frac{c}{v}\right)^2 = \left(\frac{c\,(t_2 - t_1)}{L}\right)^2$$



Topp curves

Relationship between Θv and K_a is essentially independent of soil texture, porosity, salinity

Reference: Topp et al. 1980

$$\theta_v = -5.3x10^{-2} + 2.92 + 10^{-2}K_a - 5.4x10^{-4}K_a^2 + 4.3x10^{-6}K_a^3$$

Advantages & limitations

- rapid soil water content determination in the field
- continuous logging

- nearly universal for mineral soils

  - calibrate particularly for fine or coarse texture soils

- accuracy +/- 3% water content

http://soilweb.landfood.ubc.ca/labmodules/water/time-domain-reflectometry