Field Measurement of Soil Moisture

Brian Hornbuckle

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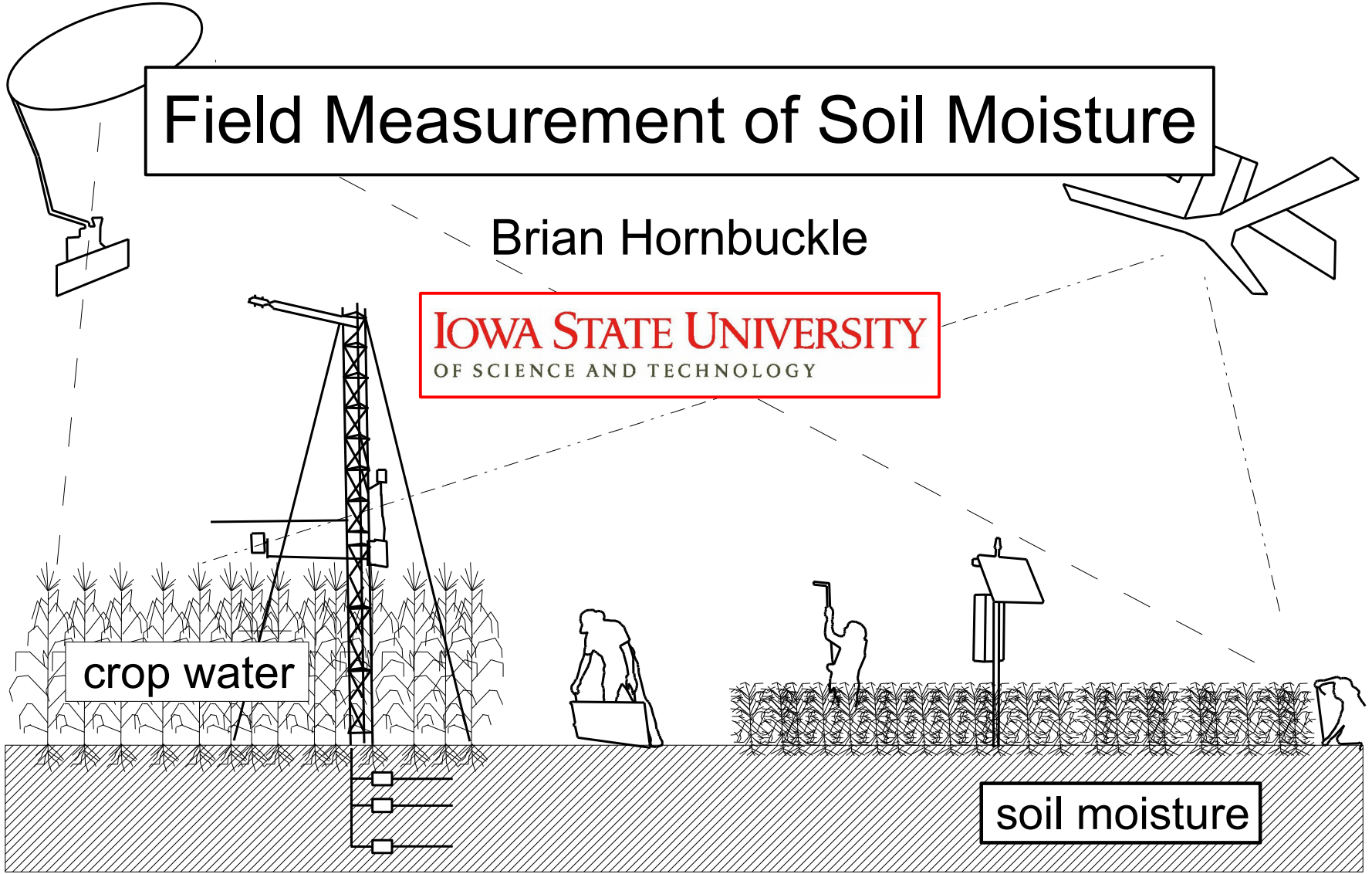

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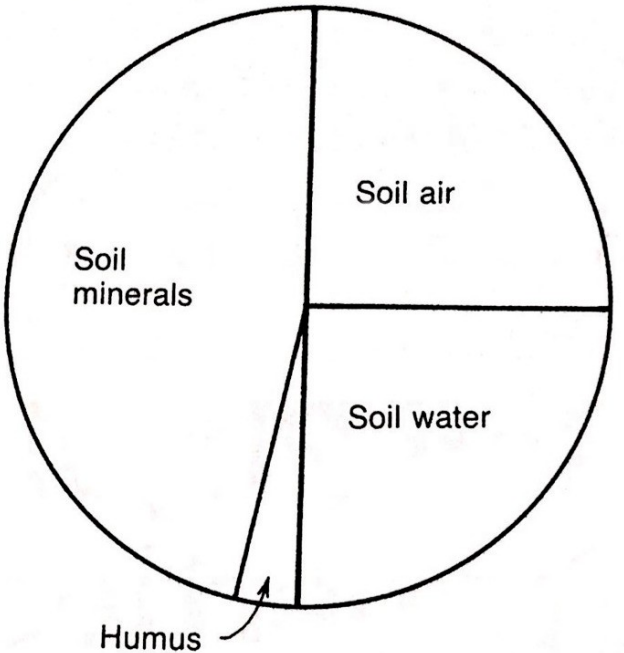
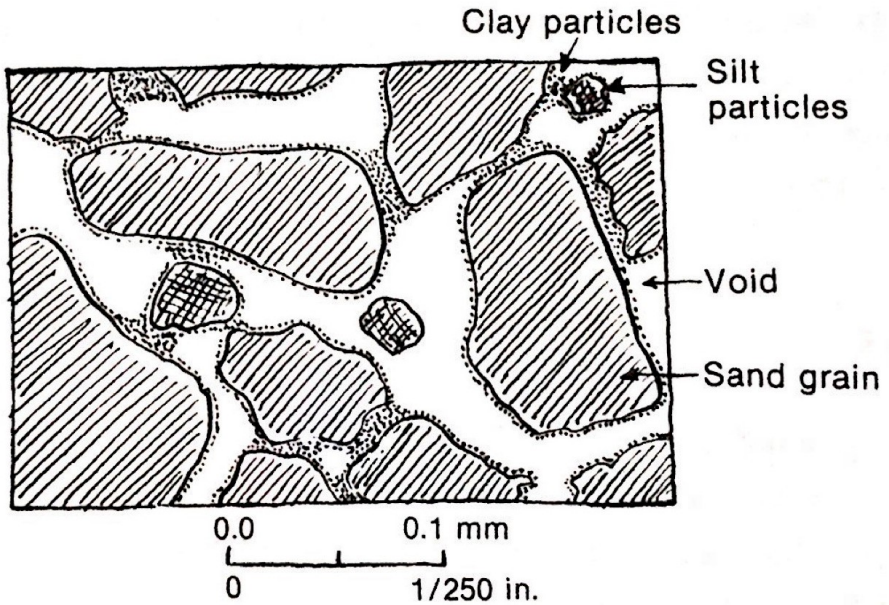
Soil is a porous medium.

soil bulk density
vs.
soil particle density

3.1. The approximate proportions of various phases by volume in a moist surface soil.



3.2. Enlarged view of a cross section of a sandy soil.



soil bulk density ~ 1.3 g cm^{-3}

density of mineral particles ~ 2.6 g cm^{-3}

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Soil moisture (soil water content) varies.

There are two ways to quantify soil moisture.

gravimetric soil moisture

$$\theta_g = \frac{\text{water mass}}{\text{dry soil mass}}$$

volumetric soil moisture

$$\theta_v = \frac{\text{water volume}}{\text{soil volume}}$$

dry soil mass = mass of soil after drying at 105 °C for a couple days

water mass = fresh mass – dry soil mass

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Why volumetric soil moisture?

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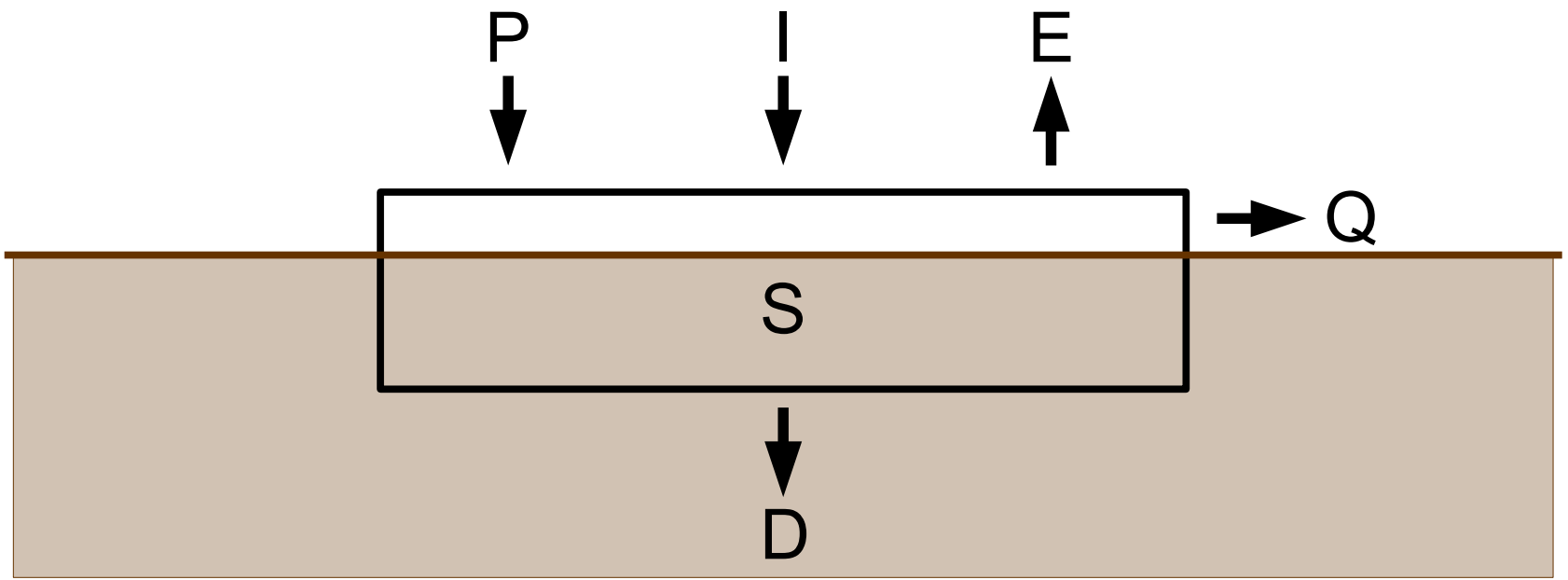
Why volumetric soil moisture?

$$P + I = Q + E + D + S$$

precipitation + irrigation = runoff + evapotranspiration + drainage + storage



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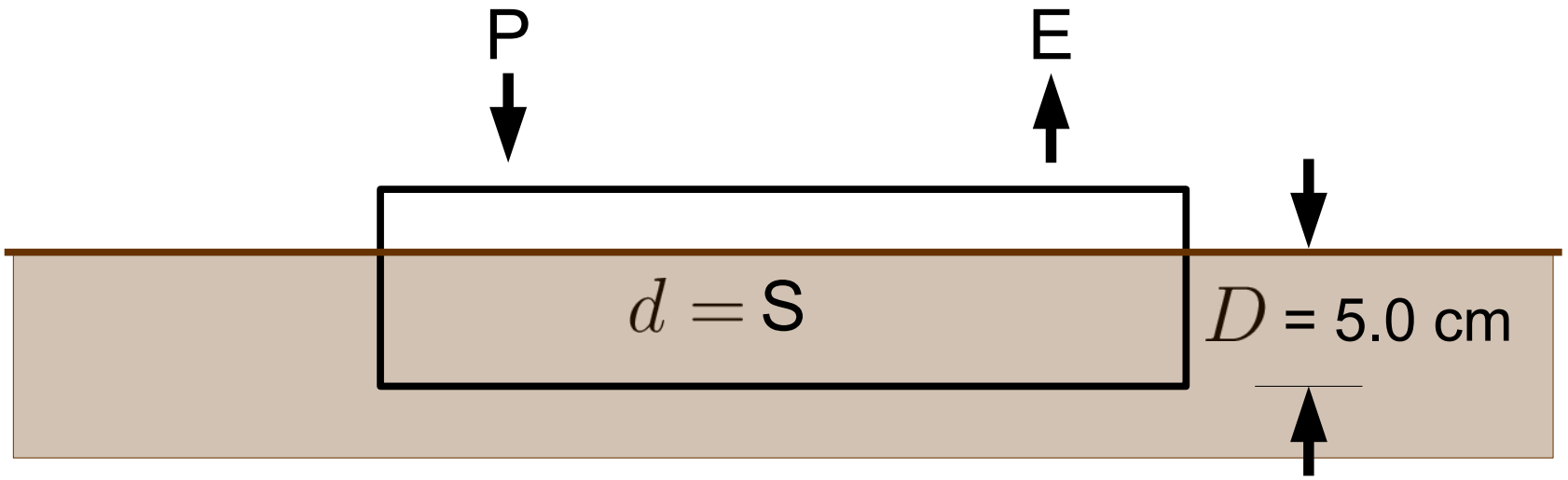
Volumetric soil moisture and equivalent depth.

$$\theta_v = \frac{d}{D} \qquad d = \theta_v D$$

d = water depth

D = total depth



$$d = 0.30\ \mathrm{m^3 \cdot m^{-3}} \times 5.0\ \mathrm{cm} =$$

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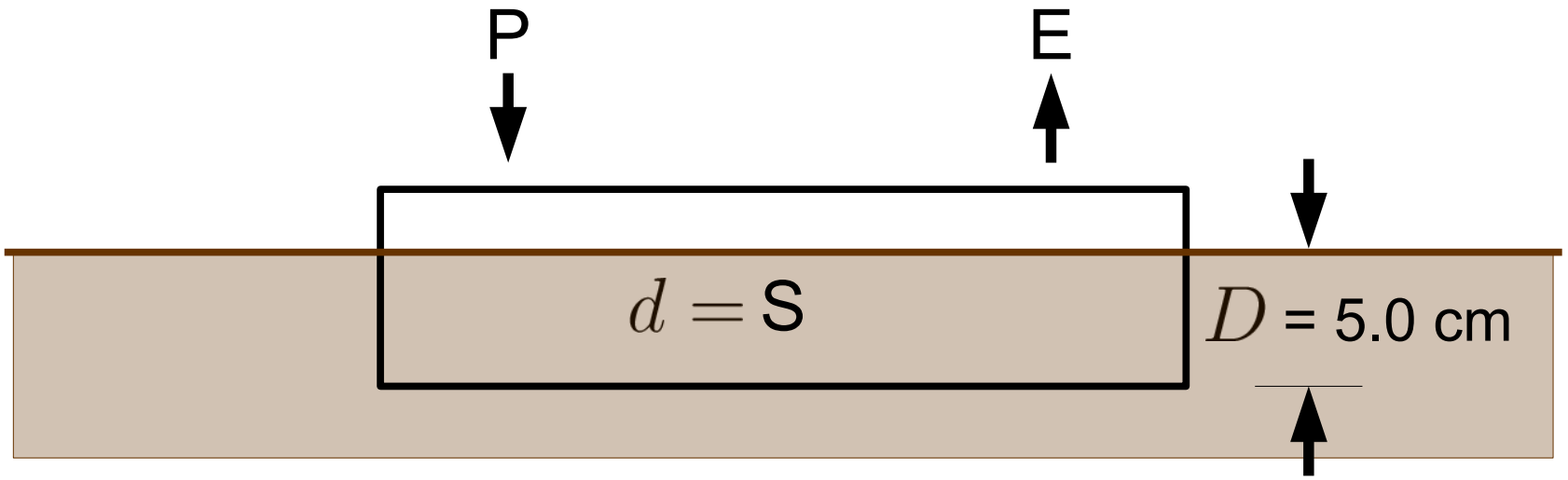

$$d = 0.30\ \mathrm{m^3 \cdot m^{-3}} \times 5.0\ \mathrm{cm} = 1.5\ \mathrm{cm} = 15\ \mathrm{mm} = 15\ \mathrm{kg \cdot m^{-2}}$$

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Importance of soil bulk density.

Volumetric soil moisture (θ_v) is what we want,

but gravimetric soil moisture (θ_g) is easy to measure in situ.

They are related by soil bulk density.

$$\theta_v = \frac{\rho_b}{\rho_w}\theta_g$$

ρ_b = soil bulk density

ρ_w = liquid water density

$$\theta_g = \frac{\text{water mass}}{\text{dry soil mass}} \qquad \theta_v = \frac{\text{water volume}}{\text{soil volume}}$$

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How is ρ_b defined?

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$$\frac{\text{m}^3 \text{ water}}{\text{m}^3 \text{ soil}} = \frac{\frac{\text{kg dry soil}}{\text{m}^3 \text{ soil}}}{\frac{\text{kg water}}{\text{m}^3 \text{ water}}} \times \frac{\text{kg dry soil}}{\text{kg water}}$$

$$\rho_b = \frac{\text{mass of } \textit{dry} \text{ soil}}{\text{soil volume}}$$

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Soil bulk density can change in space, time.

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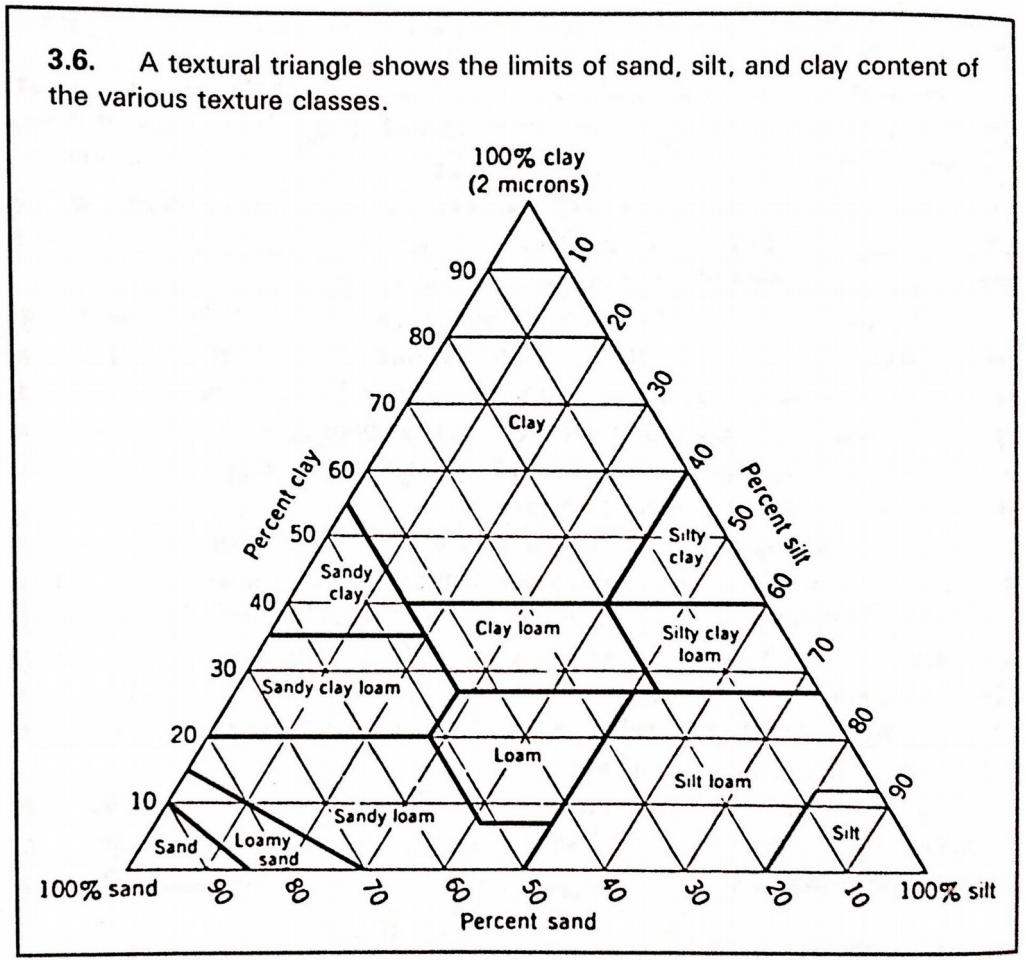
Soil bulk density can change in space, time.



answer: different types of soil

particle sizes

sand: 2 to 0.05 mm

silt: 0.050 mm to 0.002 mm

clay: < 0.002 mm = 2 um

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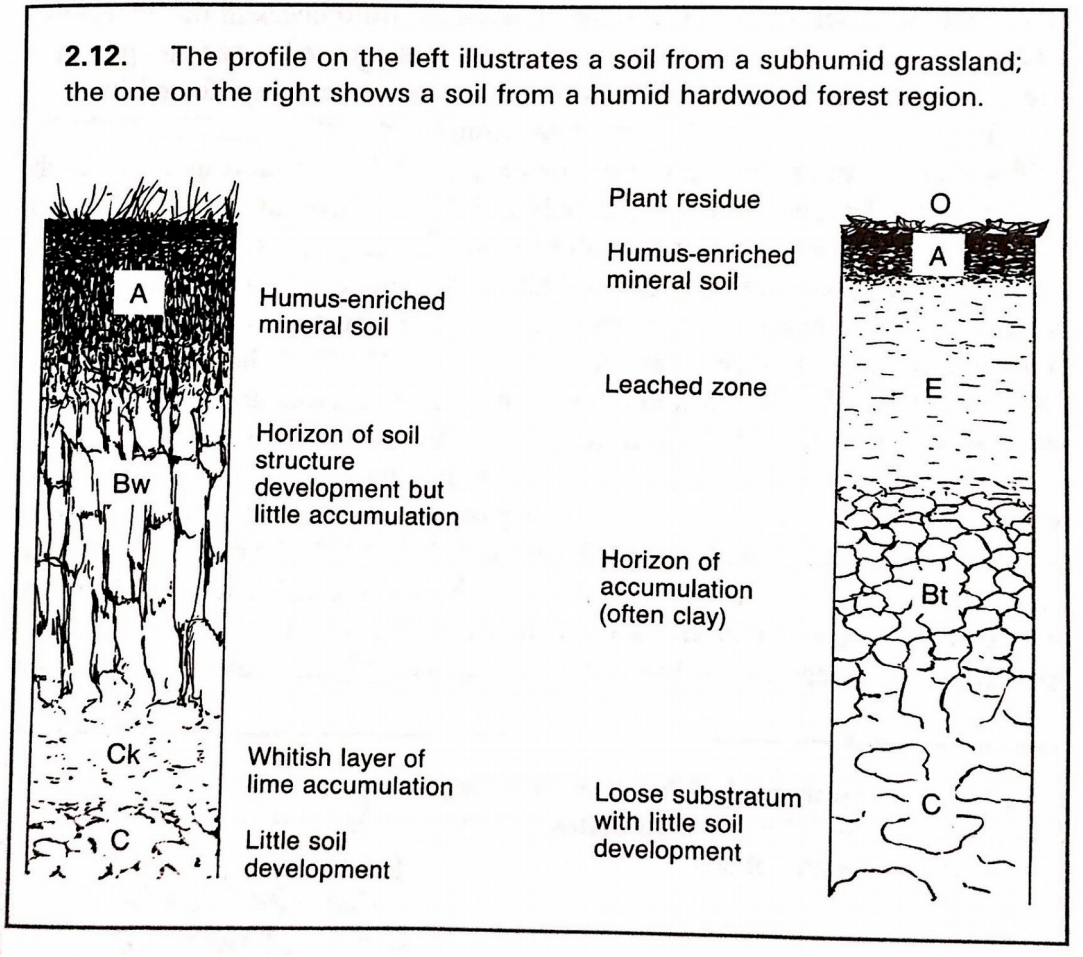
Soil bulk density can change in space, time.

answer: soil horizons

"mineral soil" vs. "organic soil"



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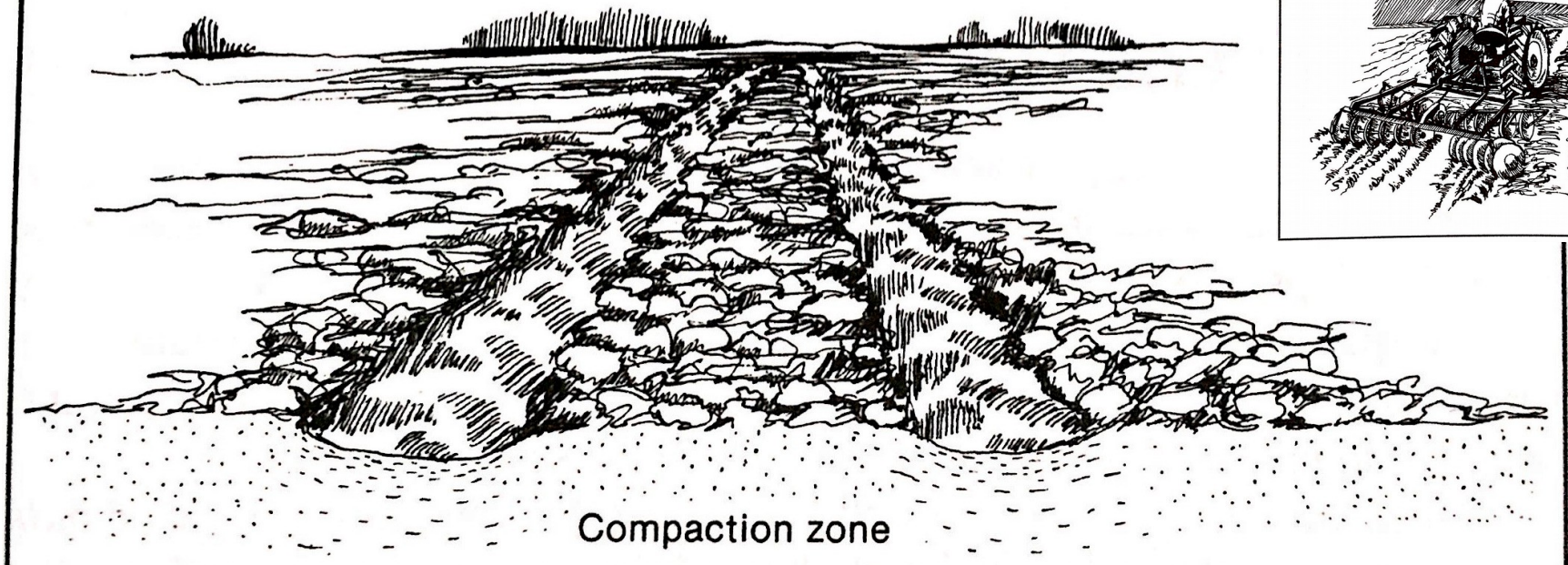
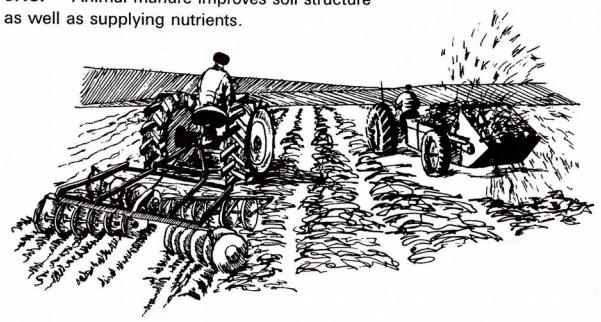
Soil bulk density can change in space, time.

answer: soil management

3.9. The zone of compaction has a higher bulk density and lower permeability.



8.13. Animal manure improves soil structure as well as supplying nutrients.



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Instruments for in situ volumetric soil moisture.

impedance probe

time-domain reflectometry

soil water potential

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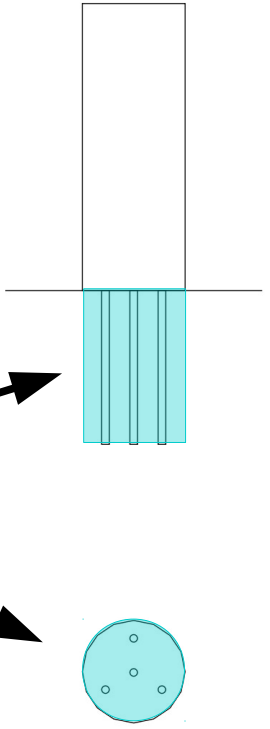
Instruments: impedance probe.



sensing volume
(support)

$$V = (n_{\text{soil}} - 1.1)\,/4.44$$

$$n_{\text{soil}} = \sqrt{\epsilon_{\text{soil}}} \sim \text{volumetric soil moisture}$$

100 MHz frequency

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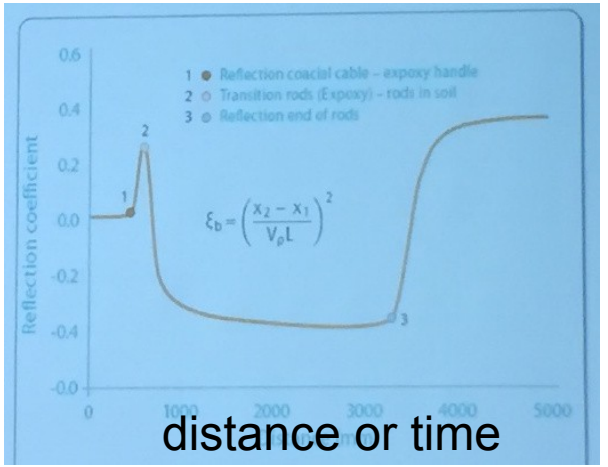
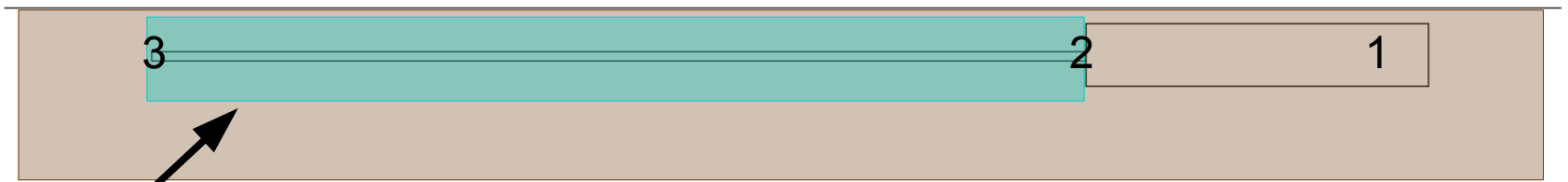
Instruments: time-domain reflectometry.



From Binayak Mohanty presentation yesterday.



side view

sensing volume (support)

top view

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Summary

We want in situ volumetric soil moisture,
but gravimetric soil moisture is easiest to measure.

Volumetric and gravimetric soil moisture are related by soil bulk density.

Soil bulk density is the mass of dry soil per volume.
It varies in space and in time.

Impedance probes and time-domain reflectometry are the most common methods of automated in situ soil moisture measurement.

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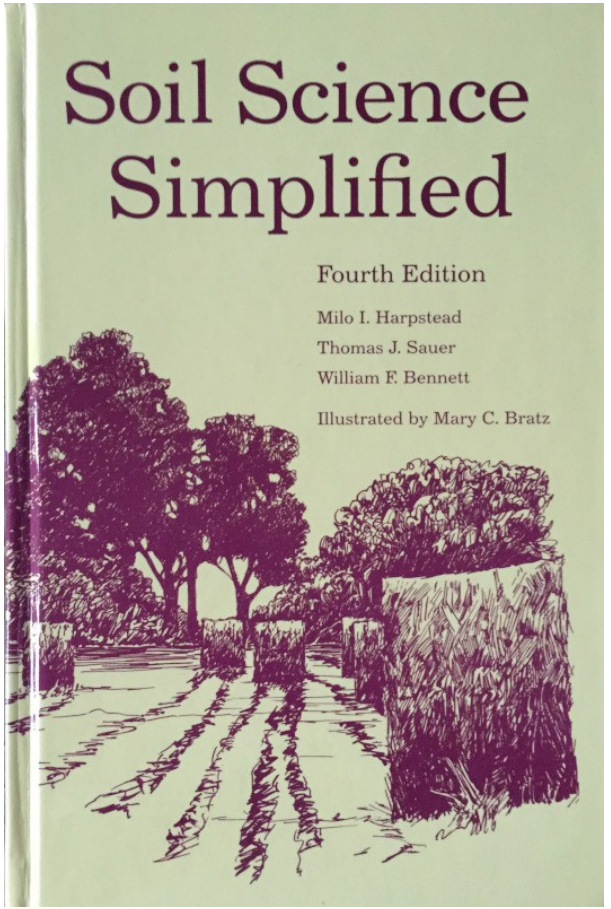
Further information...



All numbered figures from

Soil Science Simplified, Fourth Edition

by Harpstead, Sauer, and Bennett,

with illustrations by Mary C. Bratz.

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Instructions for field activity...

soil bulk density

"USDA method"

"soil scoop"

Download instructions: Google "Brian Hornbuckle Iowa State" then go to "Teaching."