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ASAC 1101 : FUNDAMENTALS OF SOIL SCIENCE (2+1)

Level : B.Sc (Ag), I semester

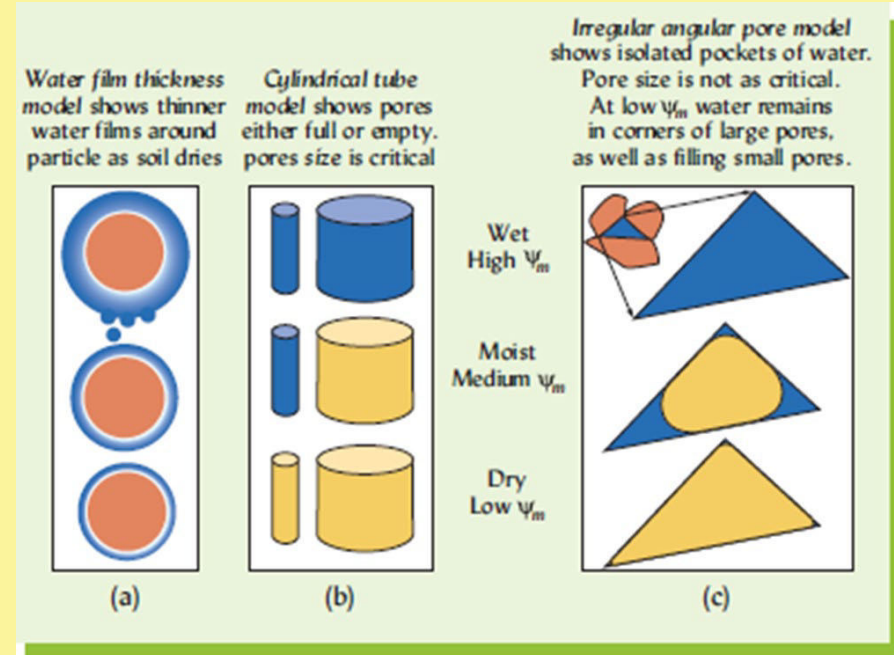
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Topic

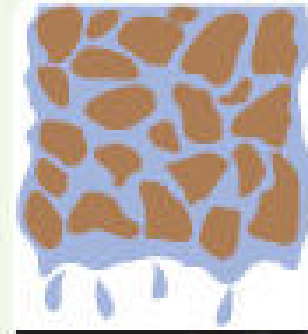
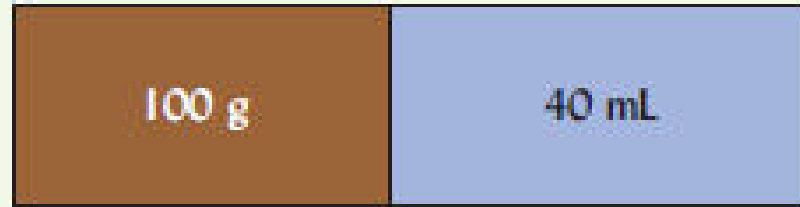
**Soil moisture constants and
measuring techniques**

Drying of initially water-saturated soil

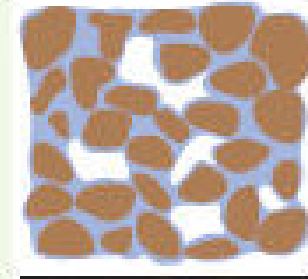
- Undergo a series of gradual changes in physical behavior and in their relationships with plants.
- Water remaining in the drying soil is found in smaller pores, in thinner films or in smaller pore corners where the water potential is lowered principally by the action of matric forces.
- Matric potential therefore accounts for an increasing proportion of the total soil water potential, while the proportion attributable to gravitational potential decreases.
- Varying degrees of soil wetness



Saturated soil
 $\psi = 0 \text{ kPa}$

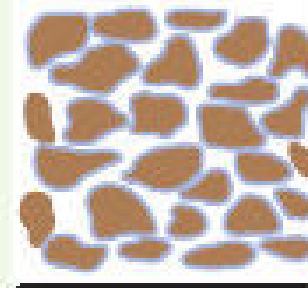


Field capacity
 $\psi = -10 \text{ kPa}$



AWHC

Wilting coefficient
 $\psi = -1500 \text{ kPa}$

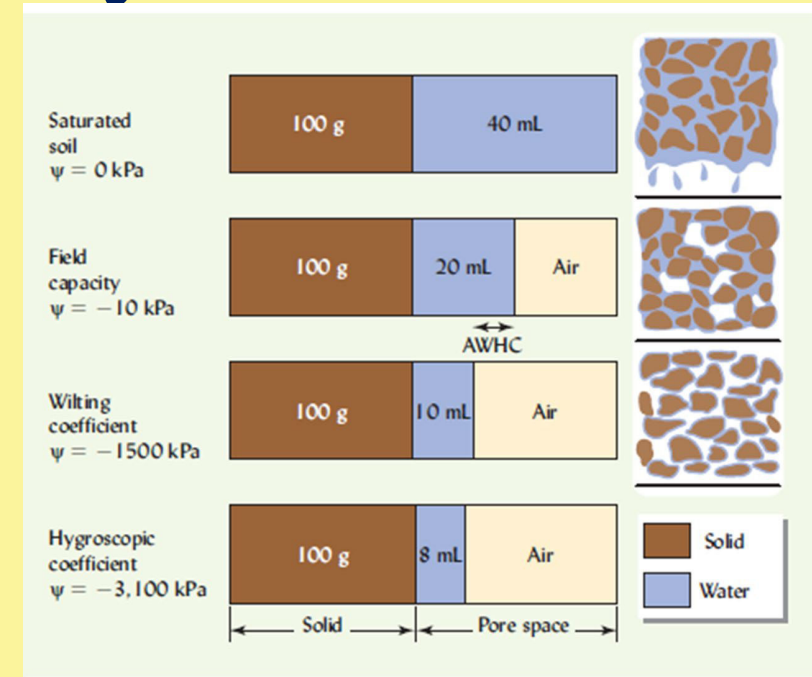


Hygroscopic coefficient
 $\psi = -3,100 \text{ kPa}$



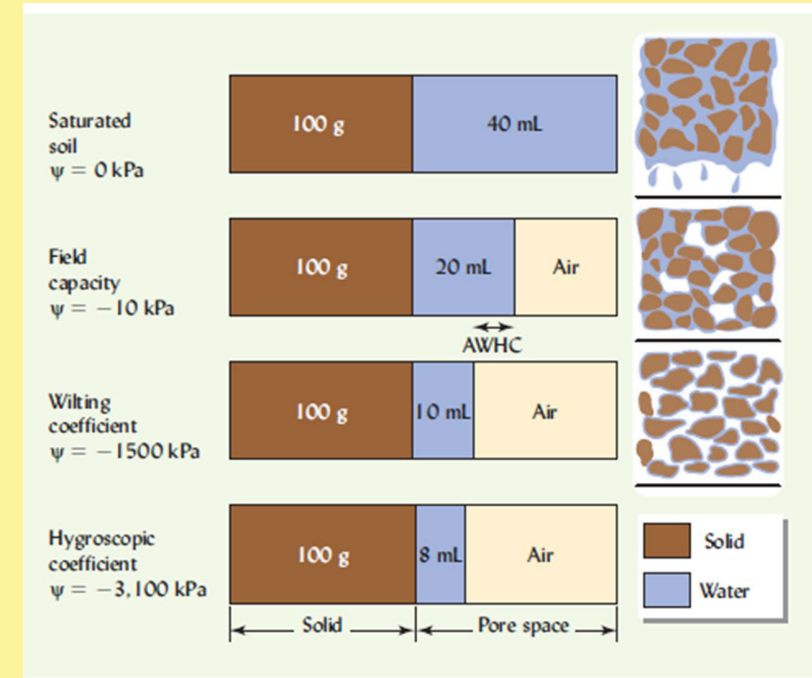
Maximum retentive capacity

- All soil pores are filled with water (water-saturated soil)
- The matric potential is close to zero, nearly the same as that of free water.
- The volumetric water content is essentially the same as the total porosity.
- The soil will remain at maximum retentive capacity only so long as water continues to infiltrate, for the water in the largest pores (sometimes termed **gravitational water**) will percolate downward, mainly under the influence of gravitational forces.

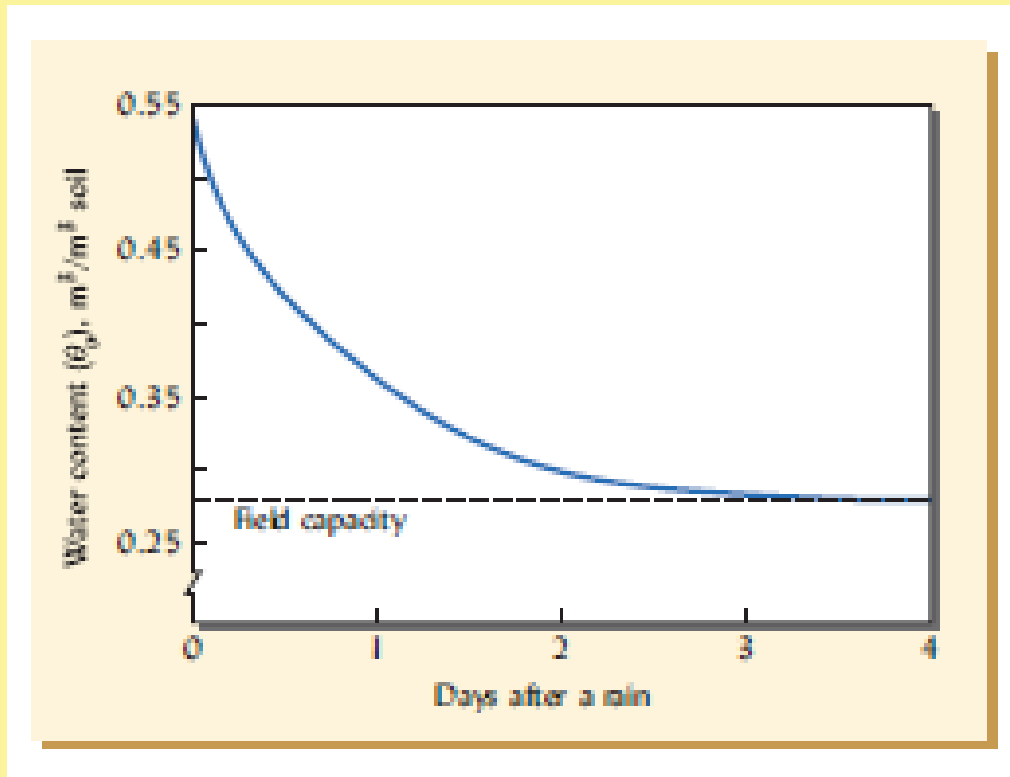


Field capacity

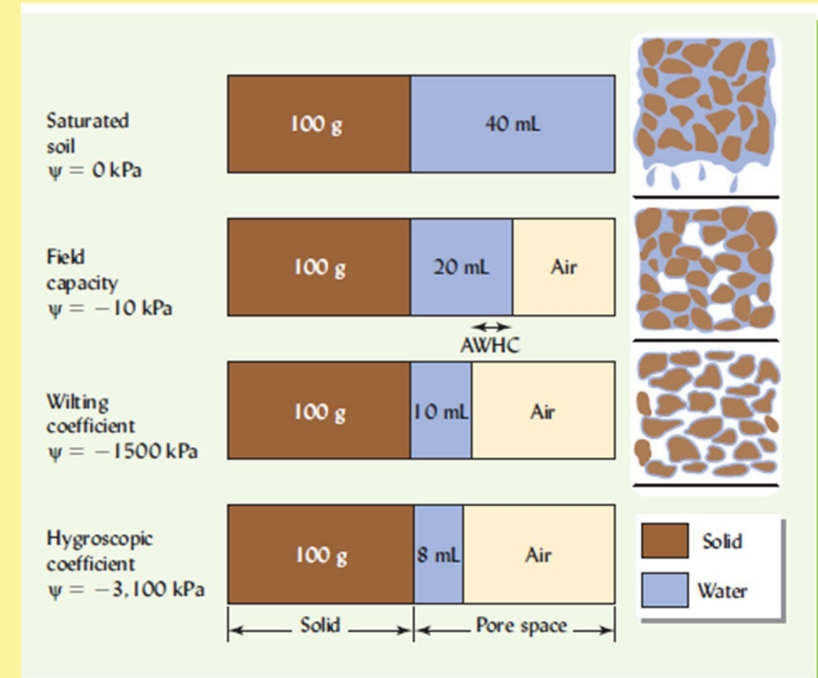
- Once the rain or irrigation has ceased, water in the largest soil pores will drain downward quite rapidly in response to the hydraulic gradient (mostly gravity).
- After one to three days, this rapid downward movement will become negligible as matric forces play a greater role in the movement of the remaining water.
- The soil then is said to be at its **field capacity**.
- In this condition, water has moved out of the macropores and air has moved in to take its place. The micropores or capillary pores are still filled with water and can supply plants with needed water.
- The matric potential vary slightly from -10 to -30 kPa



Field capacity

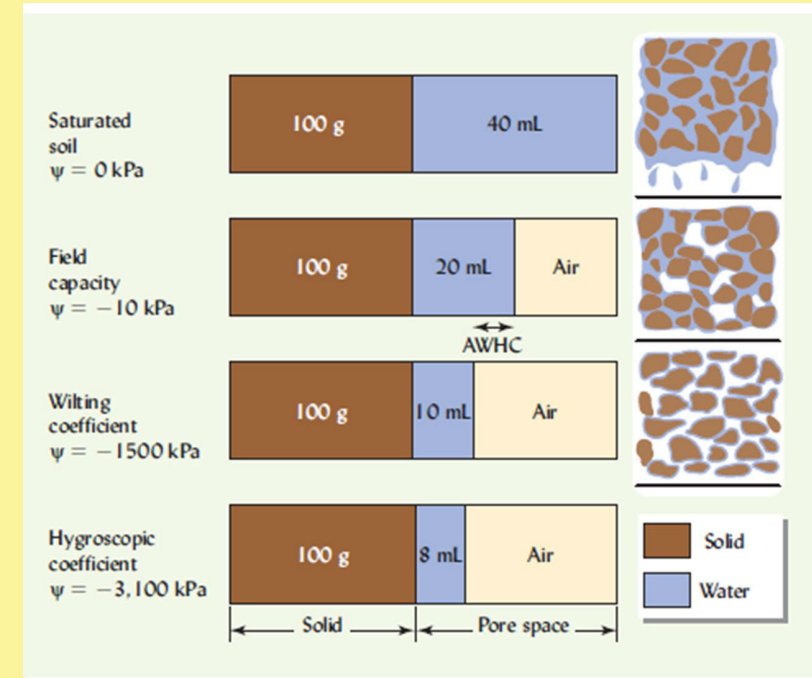


Ray R. Weil



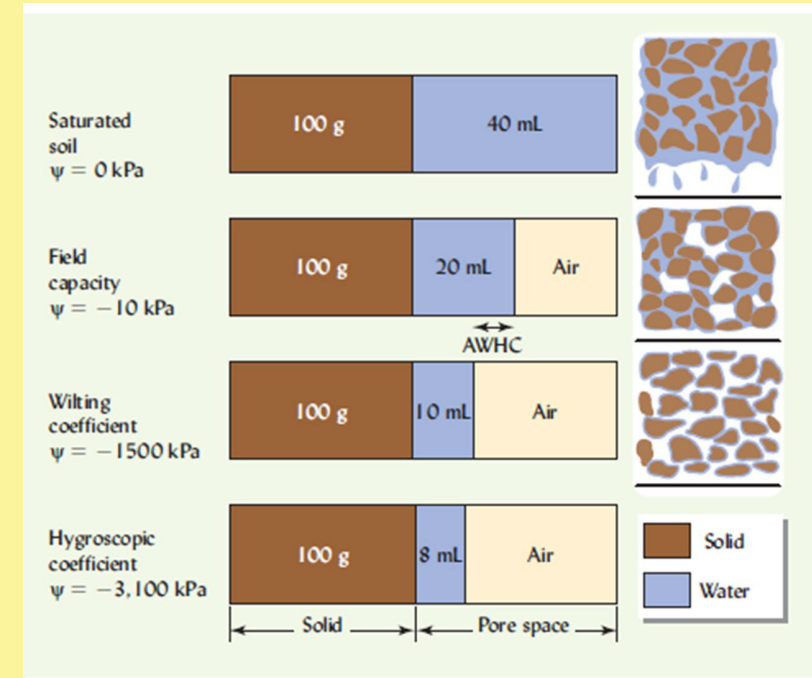
Gravitational water

- The portion of soil water that readily drains away between the states of maximum retentive capacity and field capacity
- Most soil leaching occurs as gravitational water that drains from the larger pores before field capacity is reached
- Gravitational water therefore includes much of the water that transports chemicals such as nutrient ions, pesticides, and organic contaminants into the groundwater and, ultimately, into streams and rivers



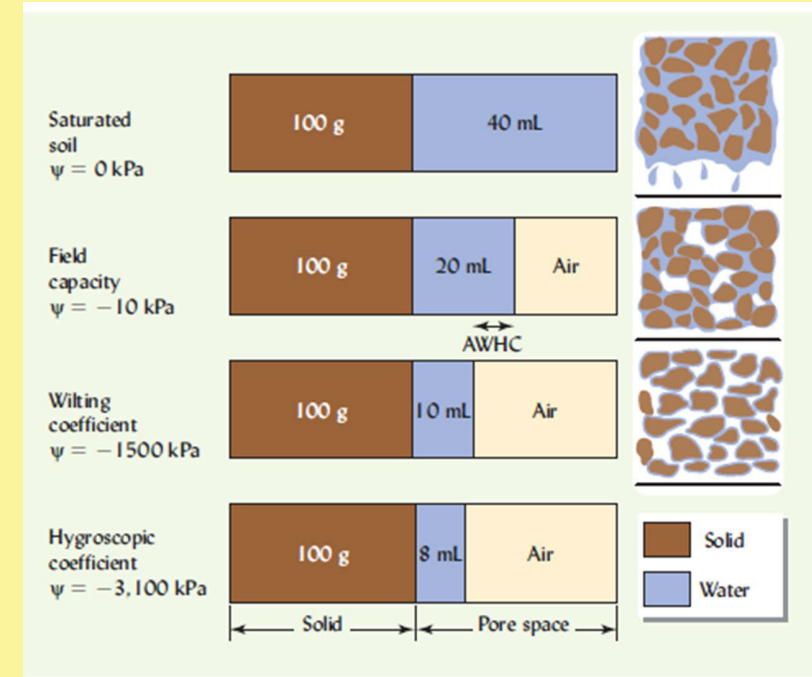
Field capacity and plant

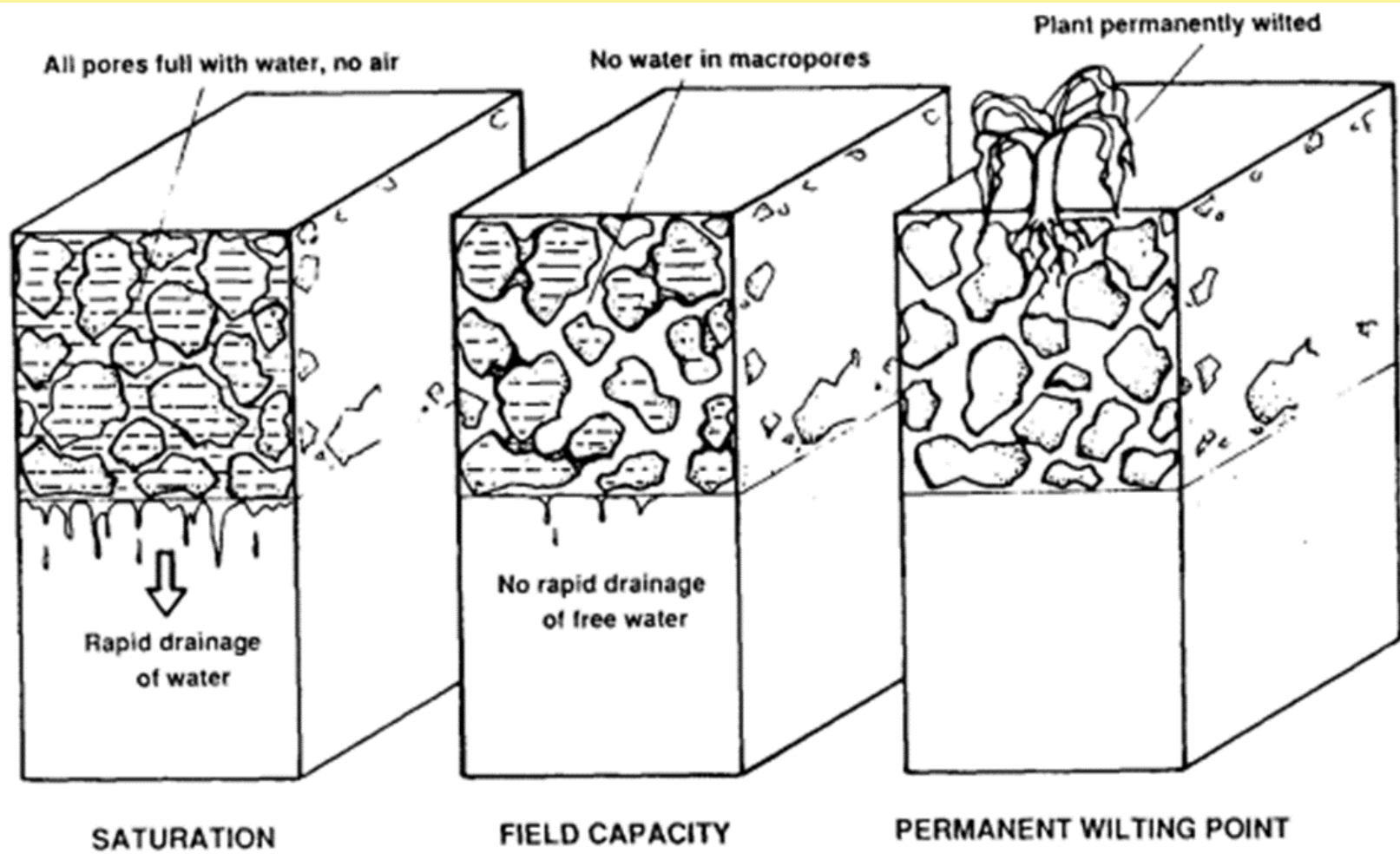
- At field capacity, a soil is holding the maximal amount of water useful to plants
- At field capacity, the soil is near its lower plastic limit—that is, the soil behaves as a crumbly semisolid at water contents below field capacity, and as a plastic putty-like material that easily turns to mud at water contents above field capacity. Therefore, field capacity approximates the upper limit of soil wetness for easy tillage or excavation
- At field capacity, sufficient pore space is filled with air to allow optimal aeration for most aerobic microbial activity and for the growth of most plants



PWP

- As the soil dries, the rate of plant water removal may fail to keep up with water losses.
- Plants will then close the openings (stomata)-> growth stops-> wilting
- $\Psi = -1500 \text{ kPa}$ (-15 bars)
- $\text{FC-PWP} = \text{AWC}$



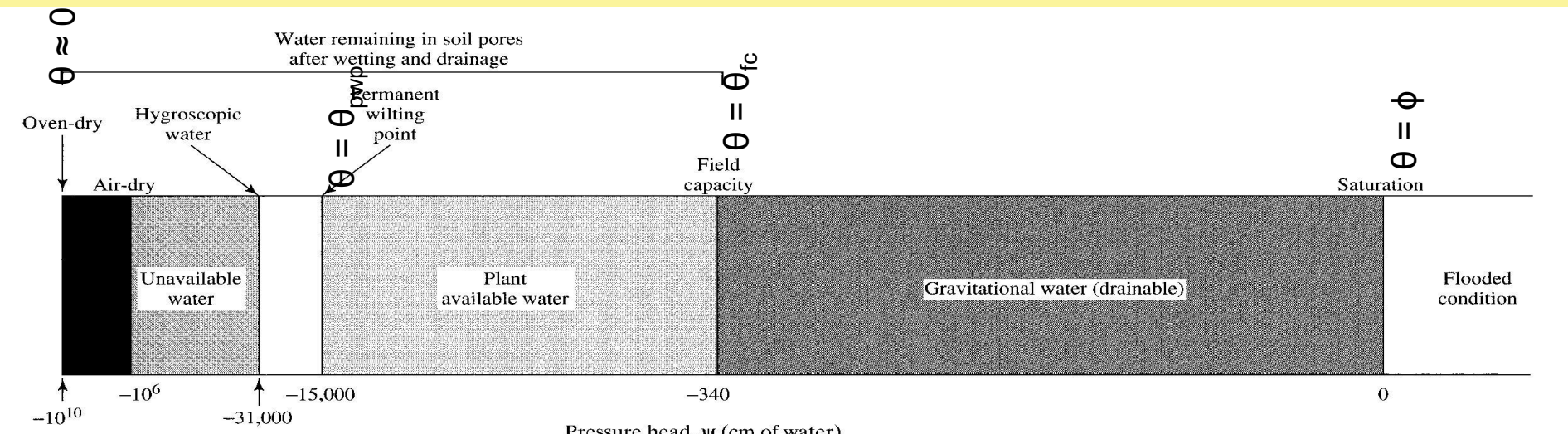


Available Water Content (θ_a):

- The difference between the field capacity and the permanent wilting point is the **available water content** for plant use:

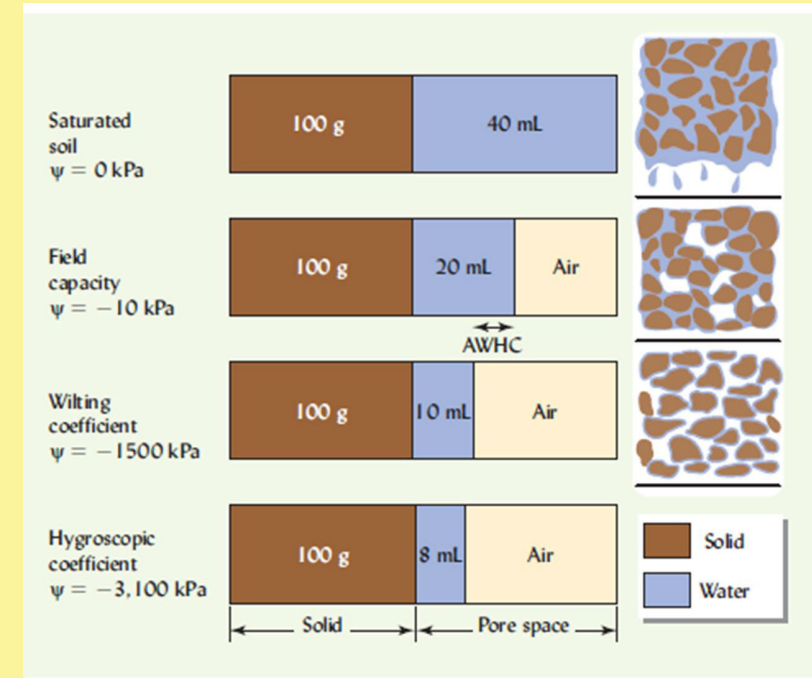
$$\theta_a = \theta_{fc} - \theta_{pwp}$$

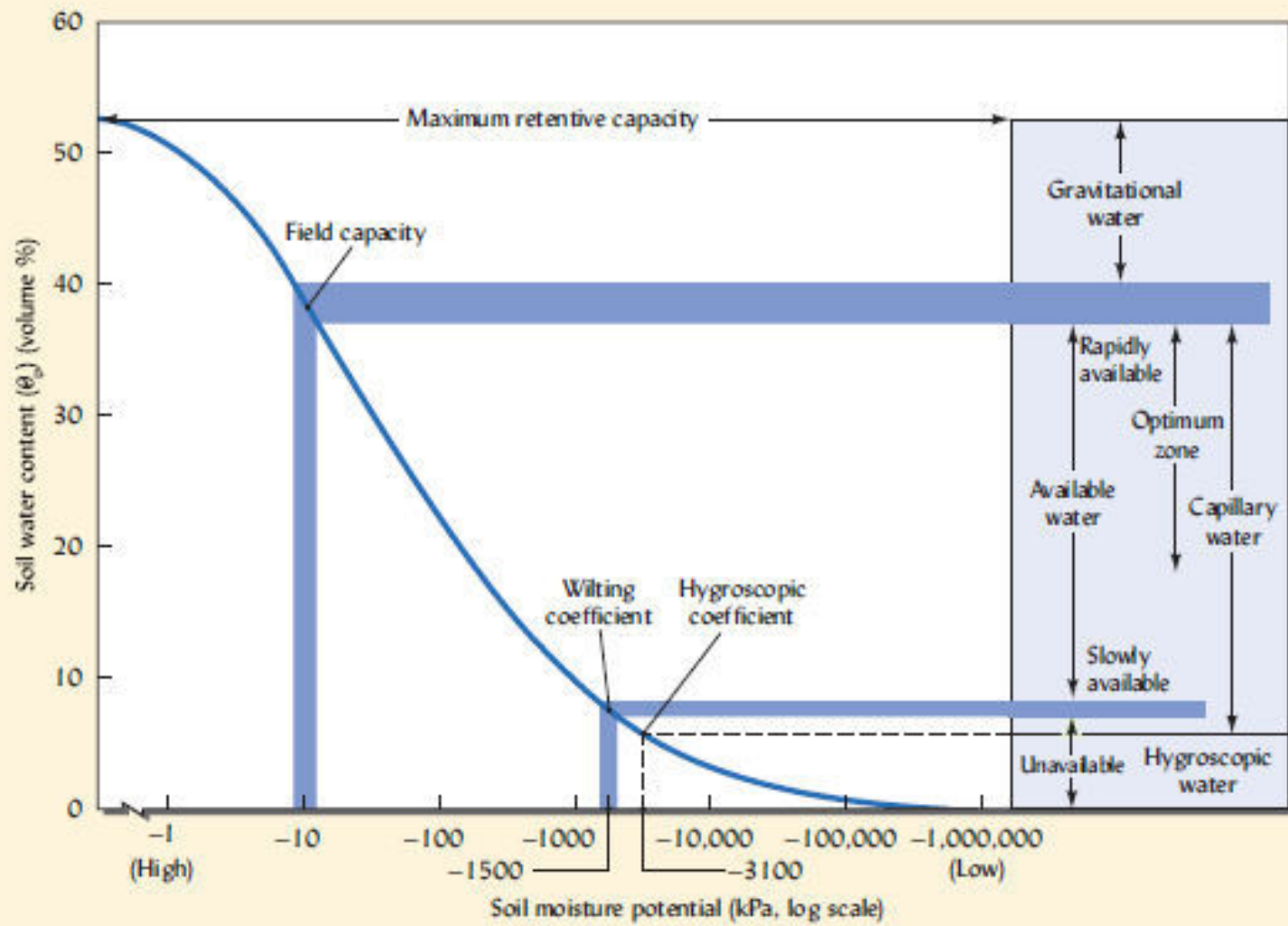
• Soil-water Status:



Hygroscopic Coefficient

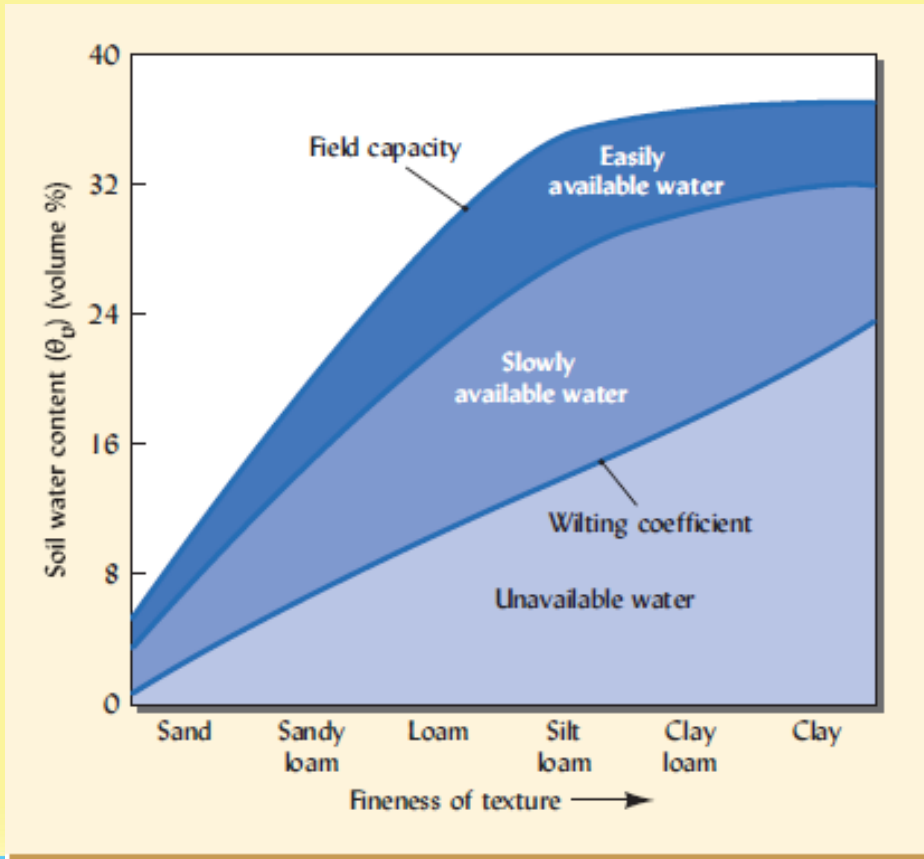
- Although plant roots do not generally dry the soil beyond the permanent wilting percentage, if the soil is exposed to the air, water will continue to be lost by evaporation
- Water molecules that remain are very tightly held, mostly being adsorbed by colloidal soil surfaces
- $\Psi = -3100$ kPa
- The water is thought to be in films only four or five molecules thick and is held so rigidly that much of it is considered nonliquid and can move only in the vapor phase
- Unavailable to plant





Factors affecting AWC

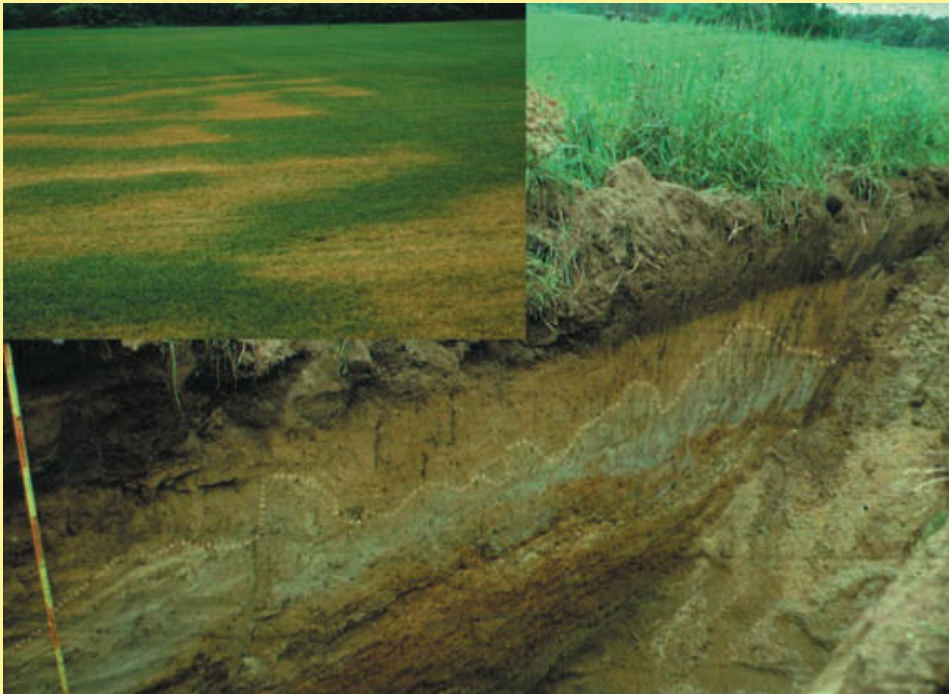
Water Content–Potential Relationship



- ✓ Increase in available moisture storage from sands to loams and silt loams

Factors affecting AWC

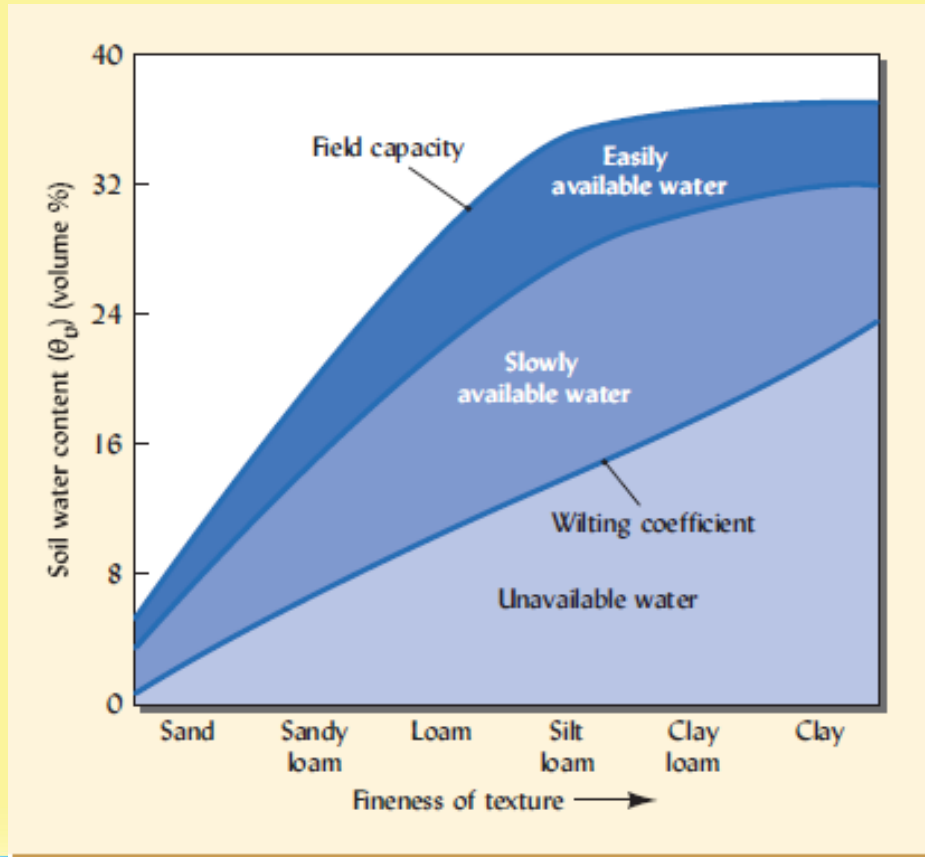
Water Content–Potential Relationship



- ✓ Plants growing on sandy soils are more apt to suffer from drought than are those growing on a silt loam in the same area
- ✓ The influence of soil texture and depth on plant-available water holding capacity.

Factors affecting AWC

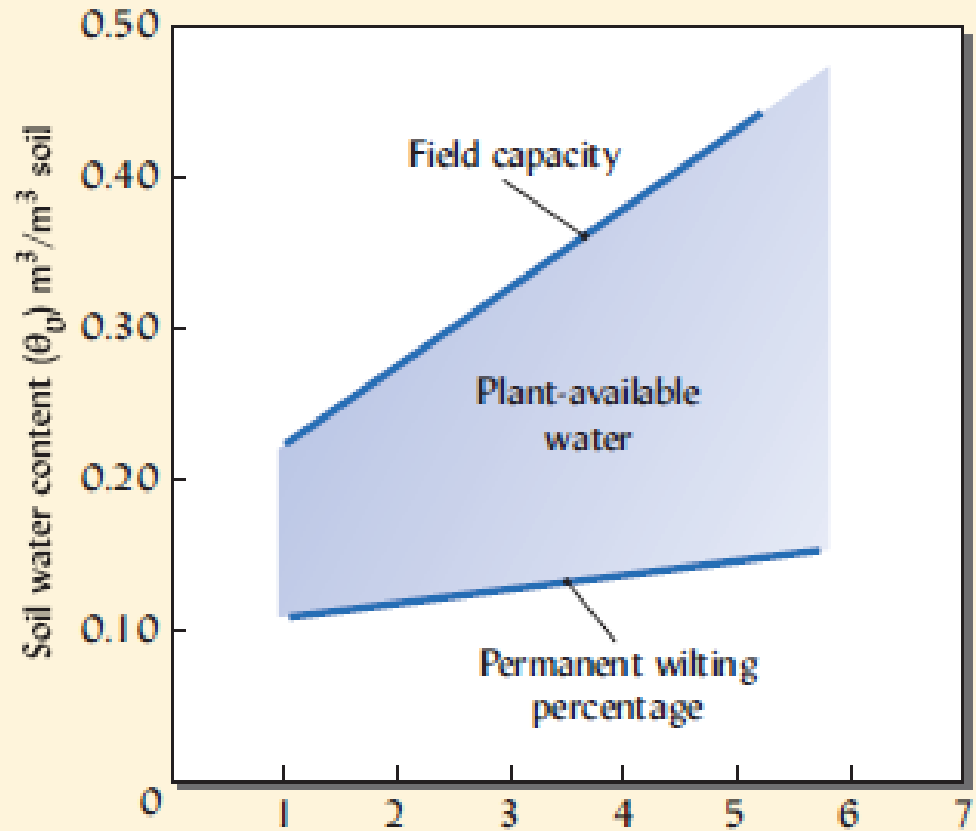
Water Content–Potential Relationship



- ✓ Clay soils frequently provide less available water than do well-granulated silt loams since the clays tend to have a high wilting coefficient
- ✓ Soil organic matter exerts both direct and indirect influences that contribute increased soil water availability
 - ✓ Direct: high θ of organic matter
 - ✓ Indirect: soil structure \rightarrow improves WHC

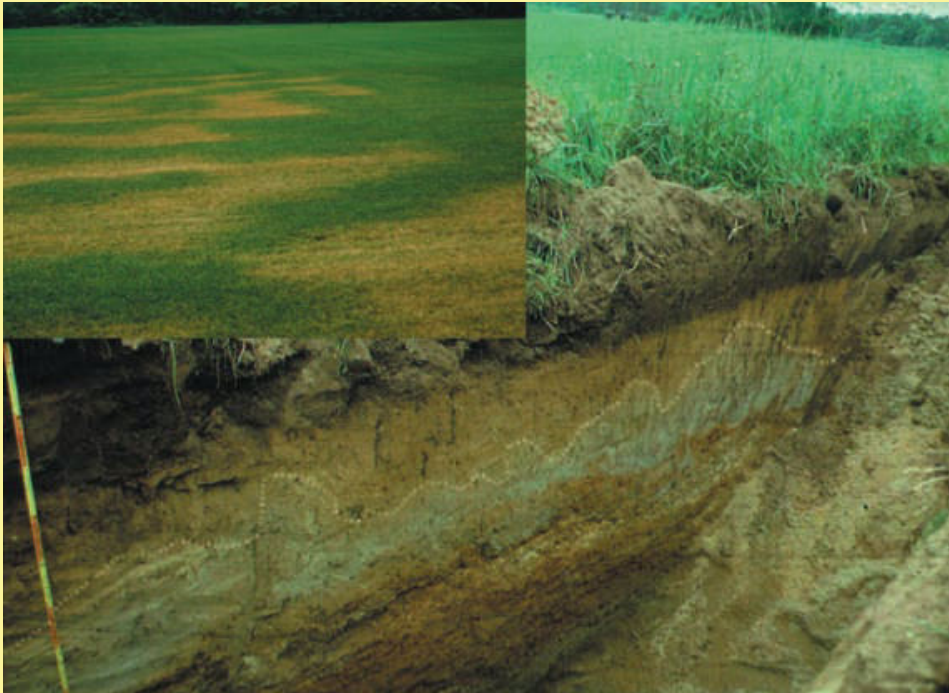
Factors affecting AWC

Water Content–Potential Relationship



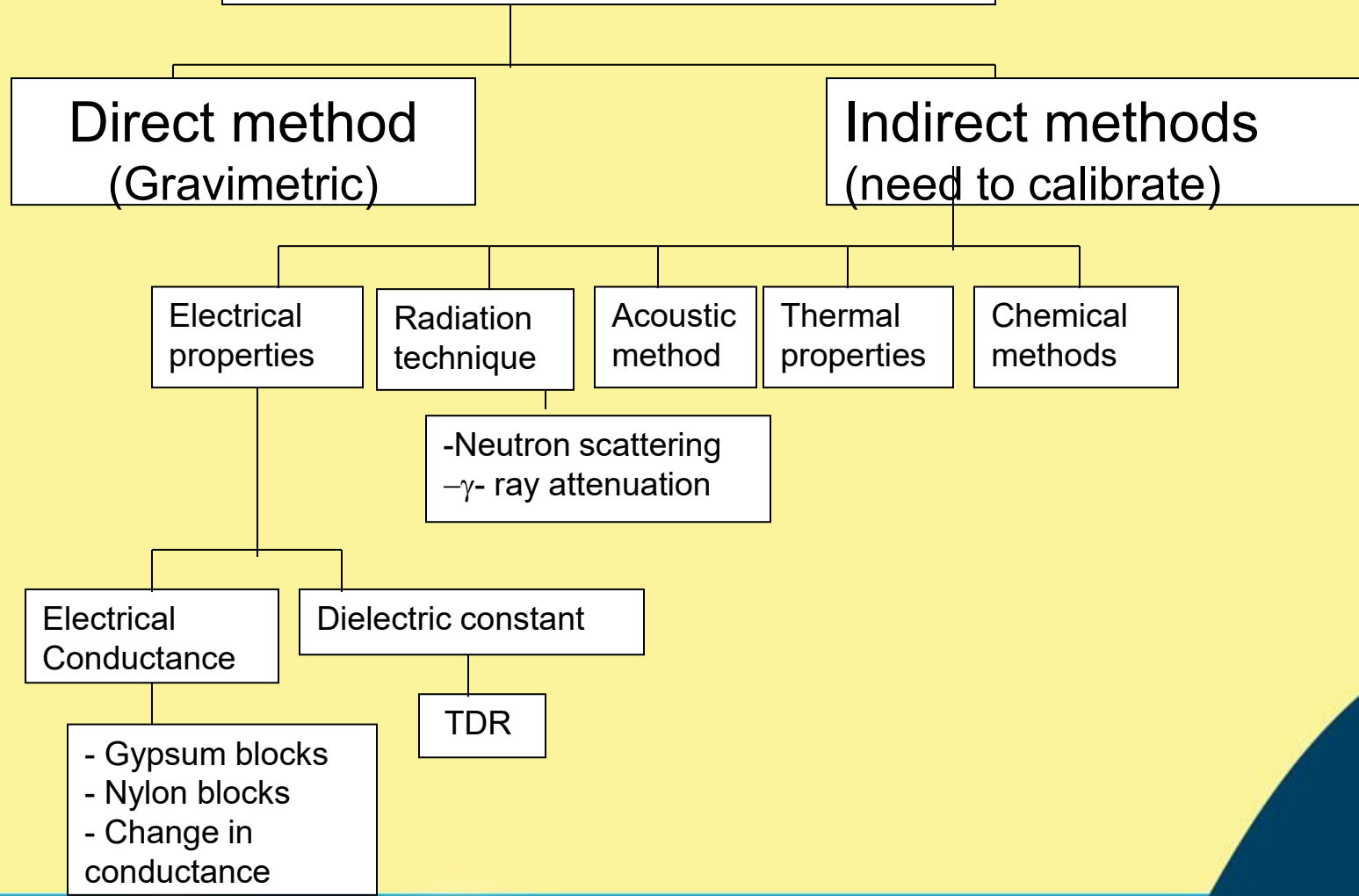
Factors affecting AWC

Compaction effect



- ✓ Reduces the amount of water that plants can take up by
 1. Crushes macropores to micropores
 2. High BD= limits root penetration
 3. Decreases total pore space

Methods for measuring soil water content



Measuring water content

Water that may be evaporated from soil by heating at 105°C to a constant weight

$$\text{Gravimetric moisture content (w)} = \frac{\text{mass of water evaporated (g)}}{\text{mass of dry soil (g)}}$$

$$\text{Volumetric moisture content (\theta)} = \frac{\text{volume of water evaporated (cm}^3\text{)}}{\text{volume of soil (cm}^3\text{)}}$$

$$\theta = w * \frac{\text{bulk density of soil}}{\text{density of water}}$$

$$\text{Bulk density of soil (Db)} = \frac{\text{mass of dry soil (g)}}{\text{volume of soil (cm}^3\text{)}}$$

Example: A soil is sampled by a cylinder measuring 7.6 cm in diameter and 7.6 cm length. Calculate gravimetric and volumetric water contents, and dry bulk density using the following data:

1. Weight of empty cylinder = 300 g
2. Weight of cylinder + wet soil = 1000 g
3. Weight of cylinder + oven dry (105⁰C) soil = 860 g

Volume of cylinder = $\pi * r^2 * h = 3.14 * (7.6/2)^2 * 7.6 = 345 \text{ cm}^3$

Weight of wet soil = $1000 - 300 = 700 \text{ g}$

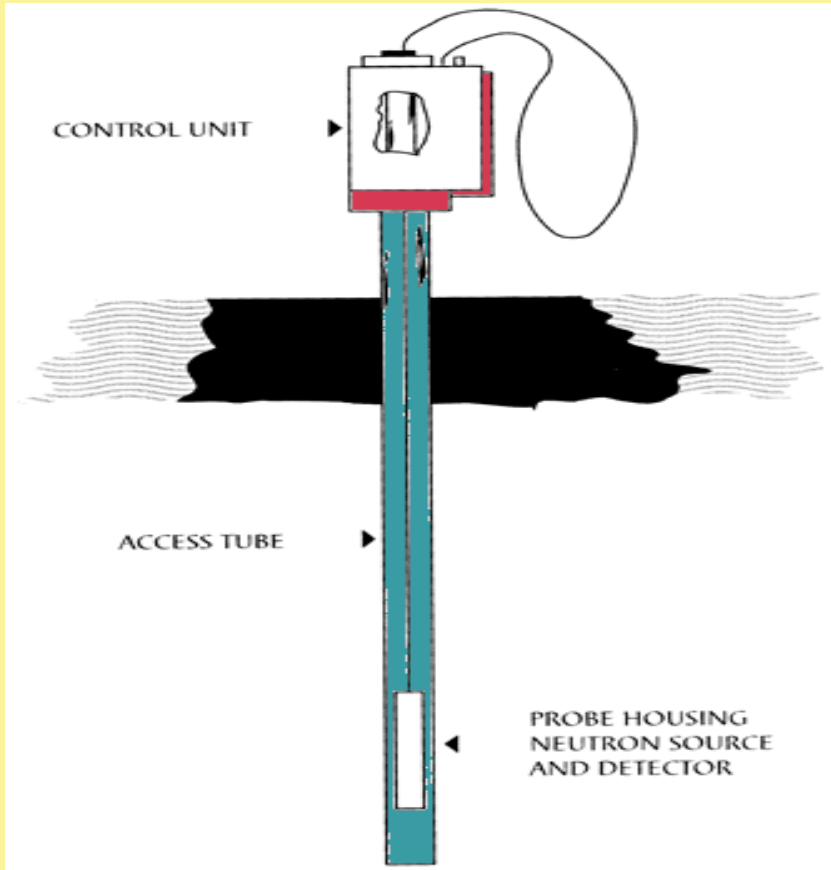
Weight of dry soil = $860 - 300 = 560 \text{ g}$

Dry bulk density = $560/345 = 1.62 \text{ g cm}^{-3}$

Gravimetric moisture content = $(700-560)/560 = 0.25$ or 25%

Volumetric moisture content = $D_b * w = 1.62 * 0.25 = 0.41$ or 41%

Neutron scattering

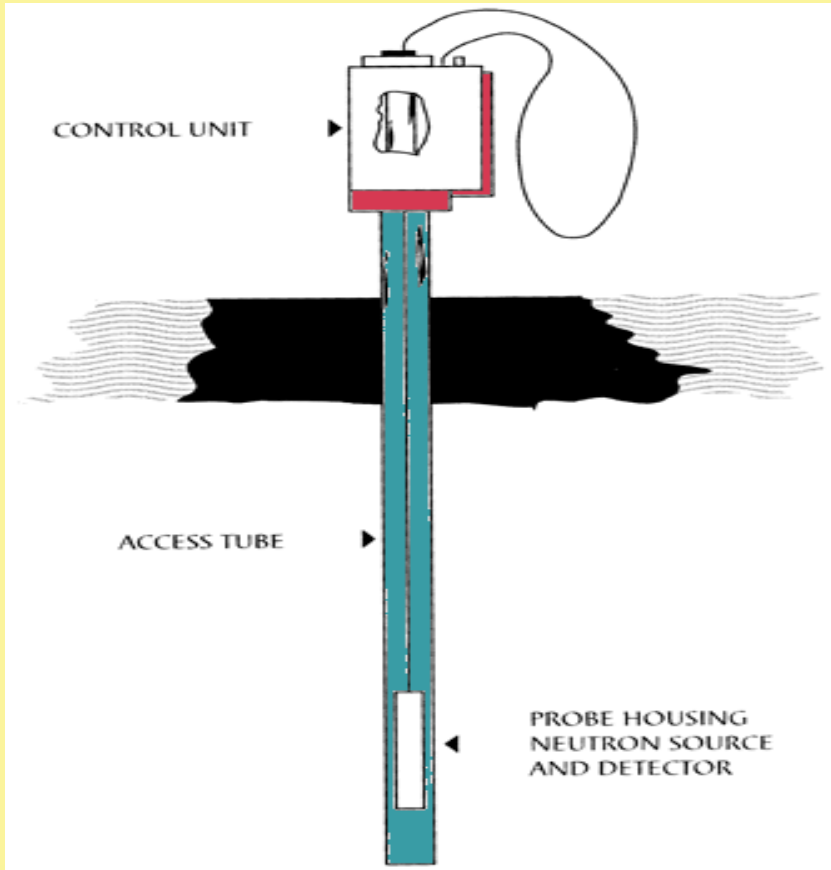


Neutron Moisture Probe

- Lowered into the soil via a previously installed access tube
- Contains a source of fast neutrons and a detector for slow neutrons
- When fast neutrons collide with hydrogen atoms (most of which are part of water molecules), the neutrons slow down and scatter
- The number of slow neutrons counted by a detector corresponds to the soil water content

Neutron scattering: drawbacks

1. Radiation permit needed
2. Expensive equipment
3. Not good in high OM soils
4. Requires access tube.



TDR (time domain reflectometer)

- A dielectric material is poor at conducting an electric current, but can support an electrostatic field (something like a magnetic field)
- Instruments that measure the dielectric properties of soil can be used to determine the proportion of the soil volume comprised of water because the dielectric constant for water (81) is far greater than for mineral particles (3–5) or for air (1).
- Therefore, the dielectric constant for the whole soil is nearly proportional to the volume of water in the soil in the immediate vicinity (3–4 cm) of the sensor

TDR (measures both soil moisture content and salinity)

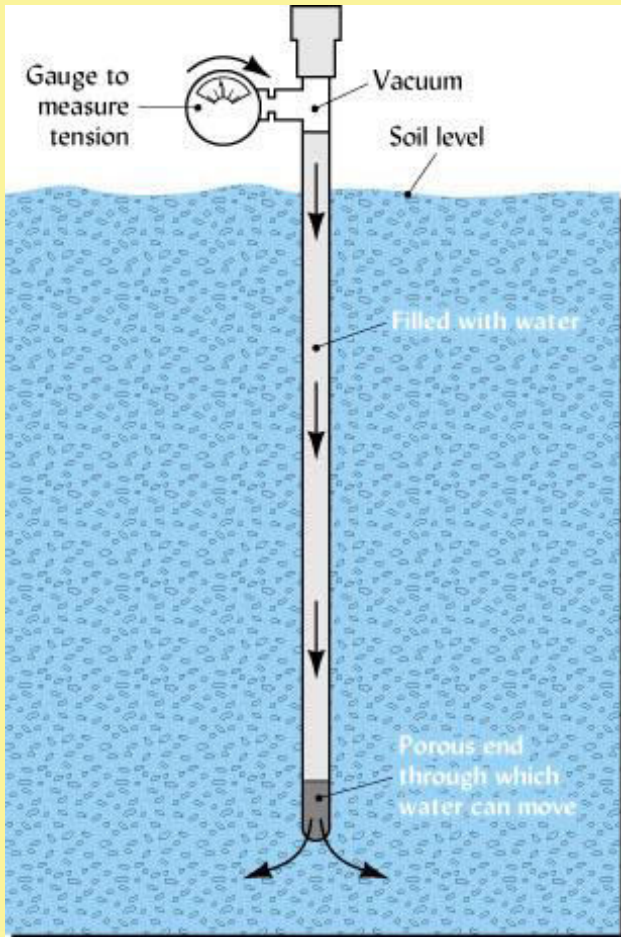


P.C: Ray R. Weil



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Measuring soil water (matric) potentials



- The tenacity with which water is attracted to soil particles is an expression of matric water potential Ψ_m .
- Field tensiometers measure this attraction or *tension*
- The tensiometer is basically a water-filled tube closed at the bottom with a porous ceramic cup and at the top with an airtight seal
- Useful between 0 to -85 kPa

Measuring soil water (matric) potentials

- **Electrical Resistance Blocks (cheap but calibration required)**

- Blocks are made of porous gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$), embedded with electrodes
- When placed in moist soil, the fine pores in the block absorb water in proportion to the soil water potential
- The more tightly the water is being held in the soil, the less water the block will be able to absorb.
- The resistance to electricity flow between the electrodes embedded in the block decreases in proportion to how much water has been absorbed in the block



Iowa State University

Measuring soil water (matric) potentials



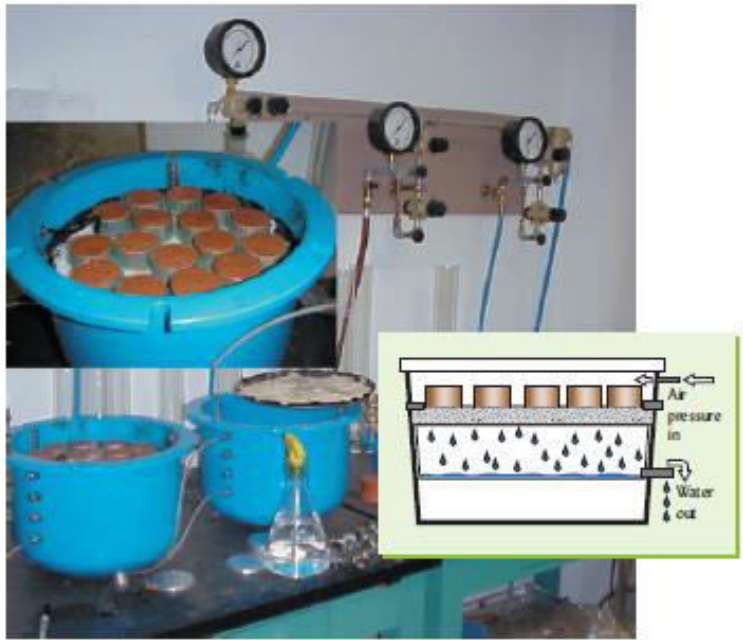
Decagon Devices

Thermocouple Psychrometer

- Since plant roots must overcome both **matric** and **osmotic forces** when they draw water from the soil, there is sometimes a need for an instrument that measures both
- In a thermocouple psychrometer, a voltage generated by the evaporation of a water drop is converted into a readout of soil water potential ($\Psi_m + \Psi_0$)
- Most useful in relatively dry soils

Measuring soil water (matric) potentials

- **Pressure Membrane Apparatus**



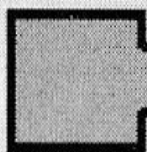
(Photos and diagram courtesy of Ray R. Weil)

- Used to subject soils to matric potentials as low as -10,000 kPa.
- After application of a specific matric potential to a set of soil samples, their soil water contents are determined gravimetrically
- This important laboratory tool makes possible accurate measurement of water content over a wide range of matric potentials in a relatively short time

TENSIOMETER

ELECTRICAL RESISTANCE BLOCK

Gauge



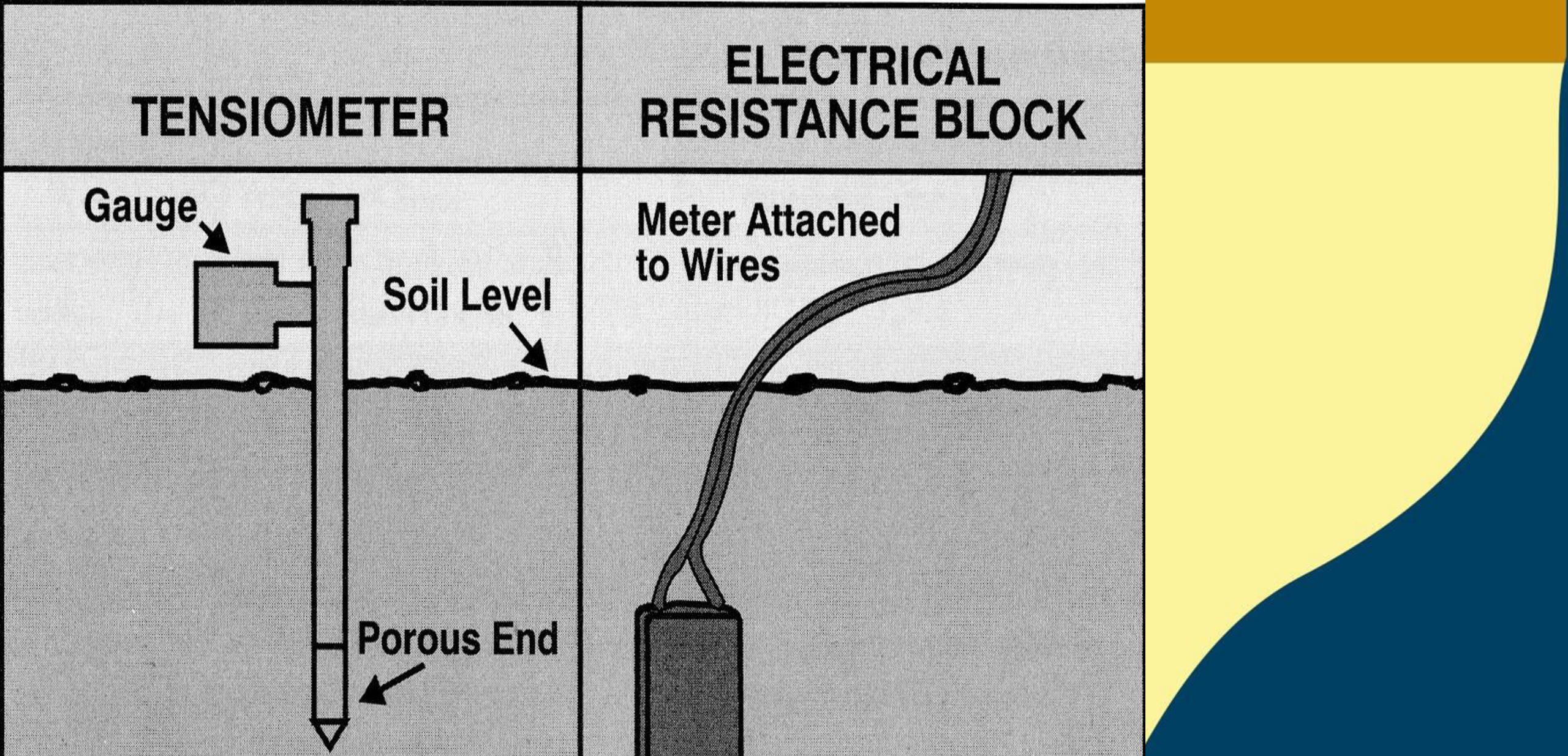
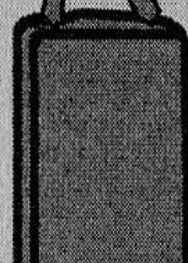
Soil Level



Porous End



Meter Attached to Wires



NEUTRON PROBE

TIME DOMAIN REFLECTOMETER (TDR)

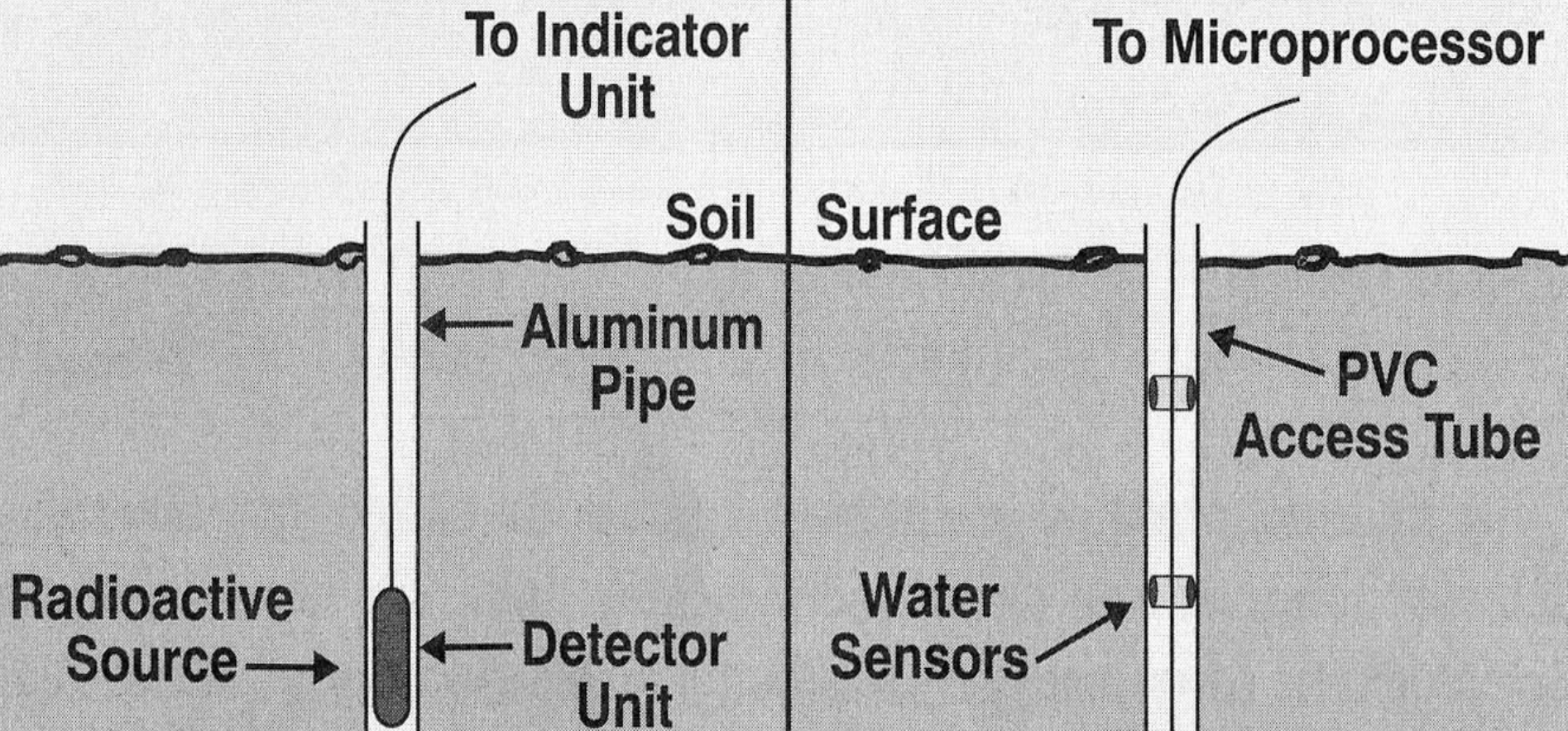


TABLE 5.2 Some Methods of Measuring Soil Water

Note that more than one method may be needed to cover the entire range of soil moisture conditions.

Method	Measures soil water		Useful range, kPa	Used mainly in		Comments
	Content	Potential		Field	Lab	
1. Gravimetric	×		0 to <-10,000		×	Destructive sampling; slow (1 to 2 days) unless microwave used. The standard for calibration.
2. Resistance blocks		×	-100 to <-1,500	×		Can be automated; not sensitive near optimum plant water contents.
3. Neutron scattering	×		0 to <-1,500	×		Radiation permit needed; expensive equipment; not good in high-organic-matter soils; requires access tube.
4. Time domain reflectometry (TDR)	×		0 to <-10,000	×	×	May be automated; accurate to 1 kPa; requires wave guides; expensive instrument.
5. Tensiometer		×	0 to -85	×		Accurate to 0.1 to 1 kPa; limited range; inexpensive; can be automated; needs periodic servicing.
6. Thermocouple psychrometer		×	50 to <-10,000	×	×	Moderately expensive; wide range; accurate only to ±50 kPa.
7. Pressure membrane apparatus		×	50 to <-10,000		×	Used in conjunction with gravimetric method to construct water characteristic curve.