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

Level : B.Sc (Ag), I semester

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SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

**M.S.SWAMINATHAN SCHOOL OF AGRICULTURE,CUTM,
PARLAKHEMUNDI**

Topic

Soil water-properties, classification

Soil water potential

Hysteresis

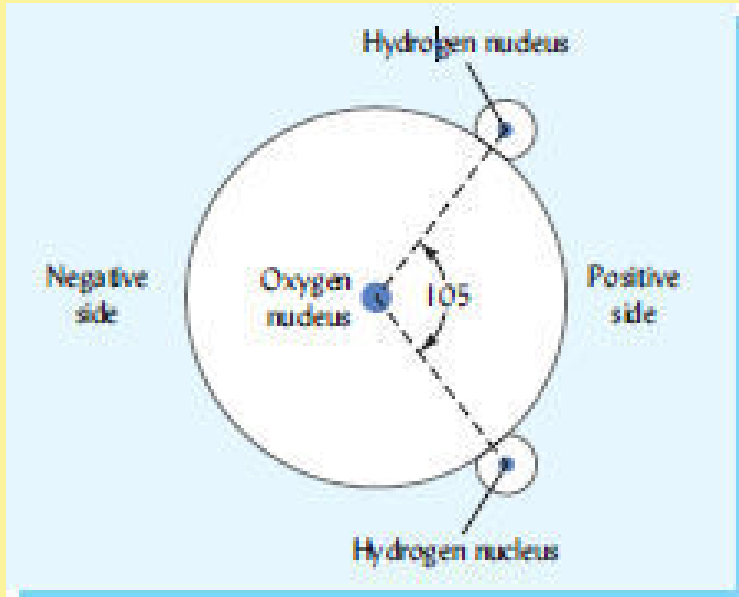
Soil water: importance

- Extremely important for soil physical, chemical and biological processes
- Weathering of minerals to decomposition of organic matter
- In the soil
 - Water can flow up as well as down
 - Plants may wilt and die in a soil whose profile contains a million kilograms of water in a hectare
 - A layer of sand or gravel in a soil profile may actually inhibit drainage, rather than enhance it

Soil water: importance

- Soil–water interactions influences
 - ✓ Water loss by leaching
 - ✓ Surface runoff
 - ✓ ET
 - ✓ Air and water balance in soil pores
 - ✓ Rate of change in soil temperature
 - ✓ Rate and kind of metabolism of soil organisms, and
 - ✓ Capacity of soil to store and provide water for plant growth

Structure and properties of water

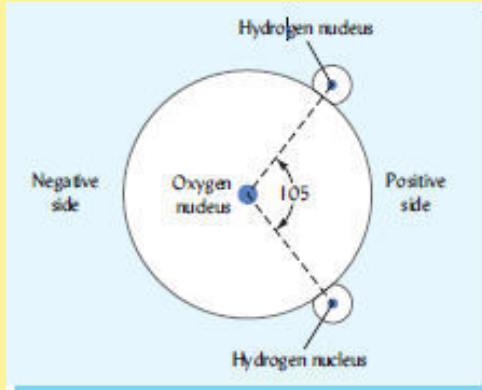


Two-dimensional representation of a water molecule showing a large oxygen atom and two much smaller hydrogen atoms.

The H-O-H angle of 105° results in an asymmetrical arrangement.

One side of the water molecule (that with the two hydrogens) is electropositive; the other is electronegative. This accounts for the polarity of water.

Structure and properties of water

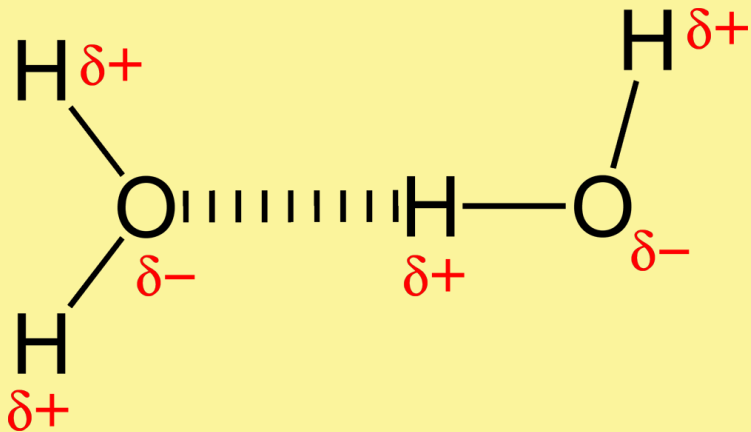


1. Polarity

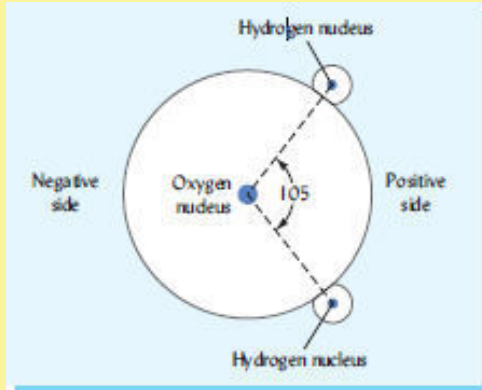
2. H-bonding

a) hydrogen atom of one water molecule is attracted to the oxygen end of a neighboring water molecule, thereby forming a low-energy bond between the two molecule

b) accounts for the polymerization of water

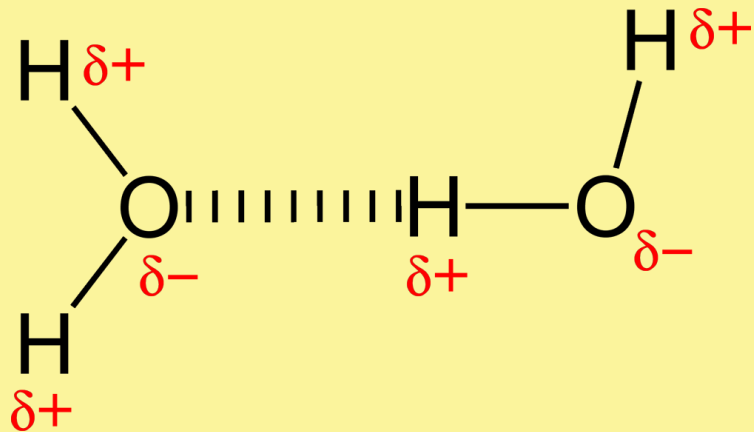


Structure and properties of water

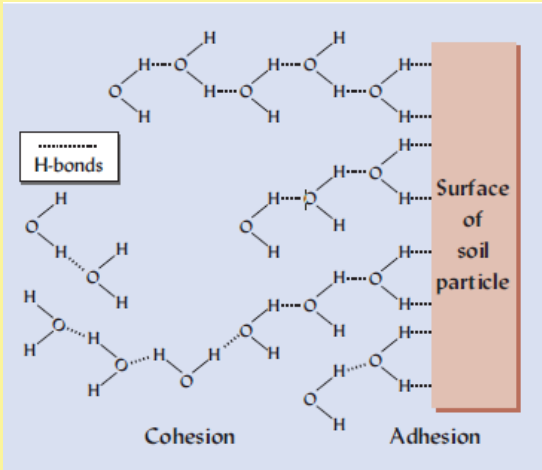


1. Polarity
2. H-bonding
3. Hydration

- a) Cations such as H^+ , Na^+ , K^+ , and Ca^{2+} become hydrated through their attraction to the oxygen (negative) end
- b) Negatively charged clay surfaces attract water, this time through the hydrogen (positive) end of the molecule
- c) Dissolution of salts in water



Structure and properties of water



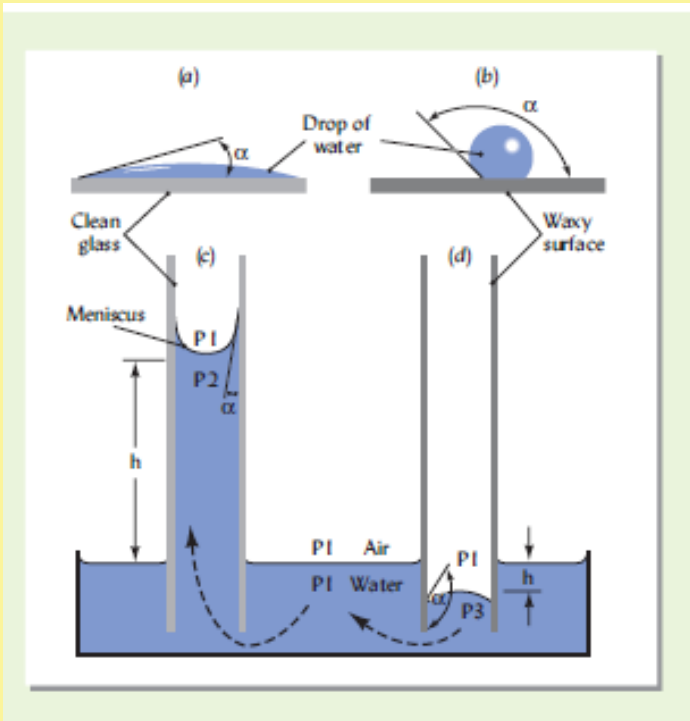
1. Polarity
2. H-bonding
3. Hydration
4. Cohesion vs. Adhesion
5. Surface tension

- a) Evident at liquid–air interfaces
- b) Results from the greater attraction of water molecules for each other (cohesion) than for the air above



Capillary mechanism

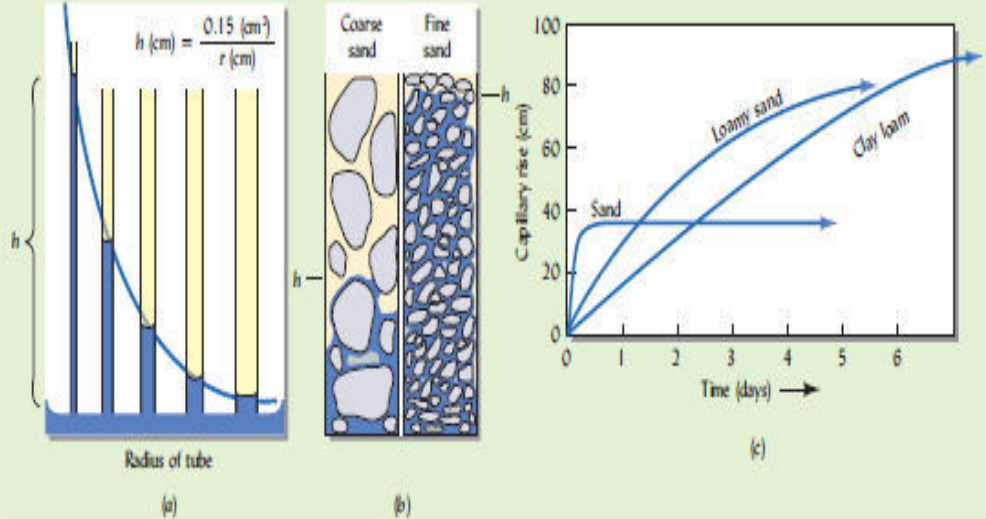
1. Capillarity can be demonstrated by placing one end of a fine (< 1 mm diameter), clean glass tube in water
2. The water rises in the tube; the smaller the tube bore, the higher the water rises.
3. The water molecules are attracted to the sides of the tube (adhesion) and start to spread out along the glass in response to this attraction.
4. The cohesive forces hold the water molecules together and create surface tension, causing a curved surface (called a meniscus).
5. Lower pressure under the meniscus in the glass tube (P_2) allows the higher pressure (P_1) on the free water to push water up the tube. The process continues until the water in the tube has risen high enough that its weight just balances the pressure differential across the meniscus



$$h = 0.15/r$$

Capillary mechanism in soil

Water movement by capillarity



D.C: Ray R. Weil

1. The height of rise h doubles when the tube inside radius is halved
2. The same relationship using glass tubes of different bore size
3. The same principle also relates pore sizes in a soil and height of capillary rise, but the rise of water in a soil is rather jerky and irregular because of the tortuous shape and variability in size of the soil pores (as well as because of pockets of trapped air)
4. The finer the soil texture, the greater the proportion of small-sized pores and, hence, the higher the ultimate rise of water above a free-water table.
5. However, because of the much greater frictional forces in the smaller pores, the capillary rise is much slower in the finer-textured soil than in the sand

Capillary movement of soil water in both direction



Surface runoff collection basin



Stream bank

Soil water energy concepts

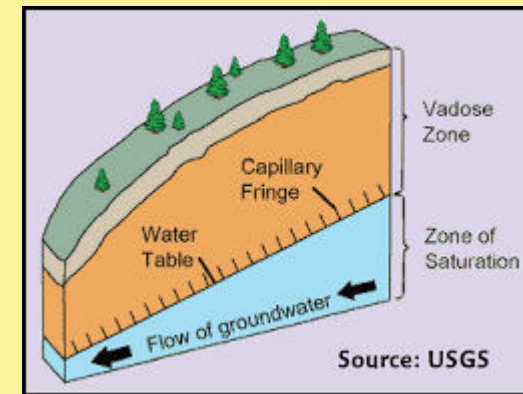
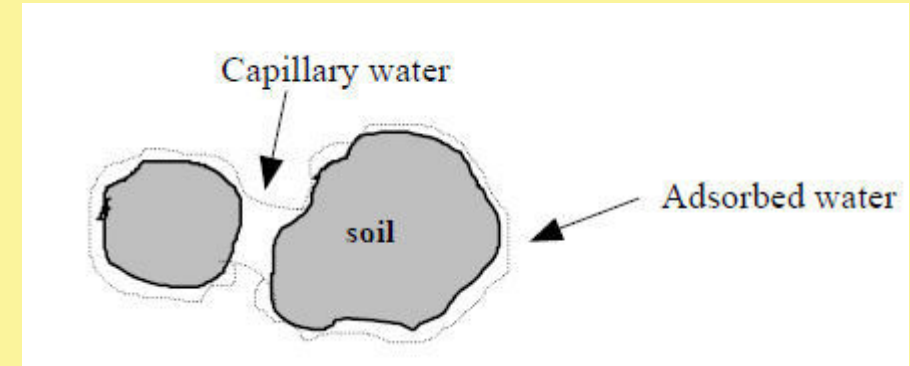
1. The retention and movement of water in soils, its uptake and translocation in plants, and its loss to the atmosphere are all energy-related phenomena
2. Kinetic energy is certainly an important factor in the rapid, turbulent flow of water in a river, but the movement of water in soil is so slow that the kinetic energy component is usually negligible.
3. **Potential energy** is most important in determining the status and movement of soil water.
4. Higher energy state → lower energy state

Soil water energy concepts

The total energy state of soil water is defined by its equivalent potential energy, as determined by the various forces acting on the water per unit quantity.

Forces acting on soil water (in the vadose zone) are:

1. Capillary forces
2. Adsorptive forces (adhesion of water to solid soil surfaces): Capillary and adsorptive forces together result in soil matric potential
3. Gravitational forces
4. Drag or shear forces (at soil surface-water interface)



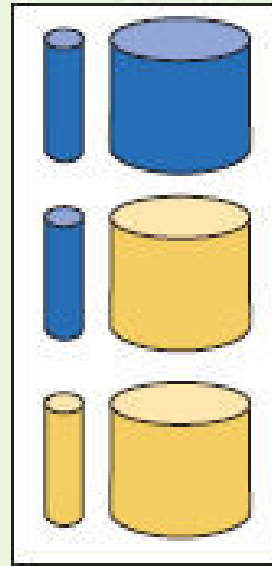
3 models of water distribution

Water film thickness model shows thinner water films around particle as soil dries



(a)

Cylindrical tube model shows pores either full or empty. pore size is critical



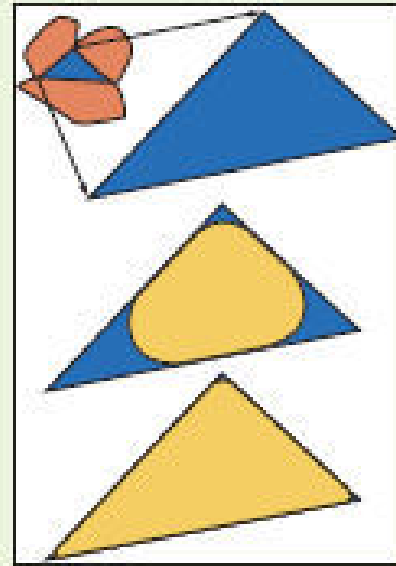
(b)

Irregular angular pore model shows isolated pockets of water. Pore size is not as critical. At low ψ_m water remains in corners of large pores, as well as filling small pores.

Wet
High ψ_m

Moist
Medium ψ_m

Dry
Low ψ_m

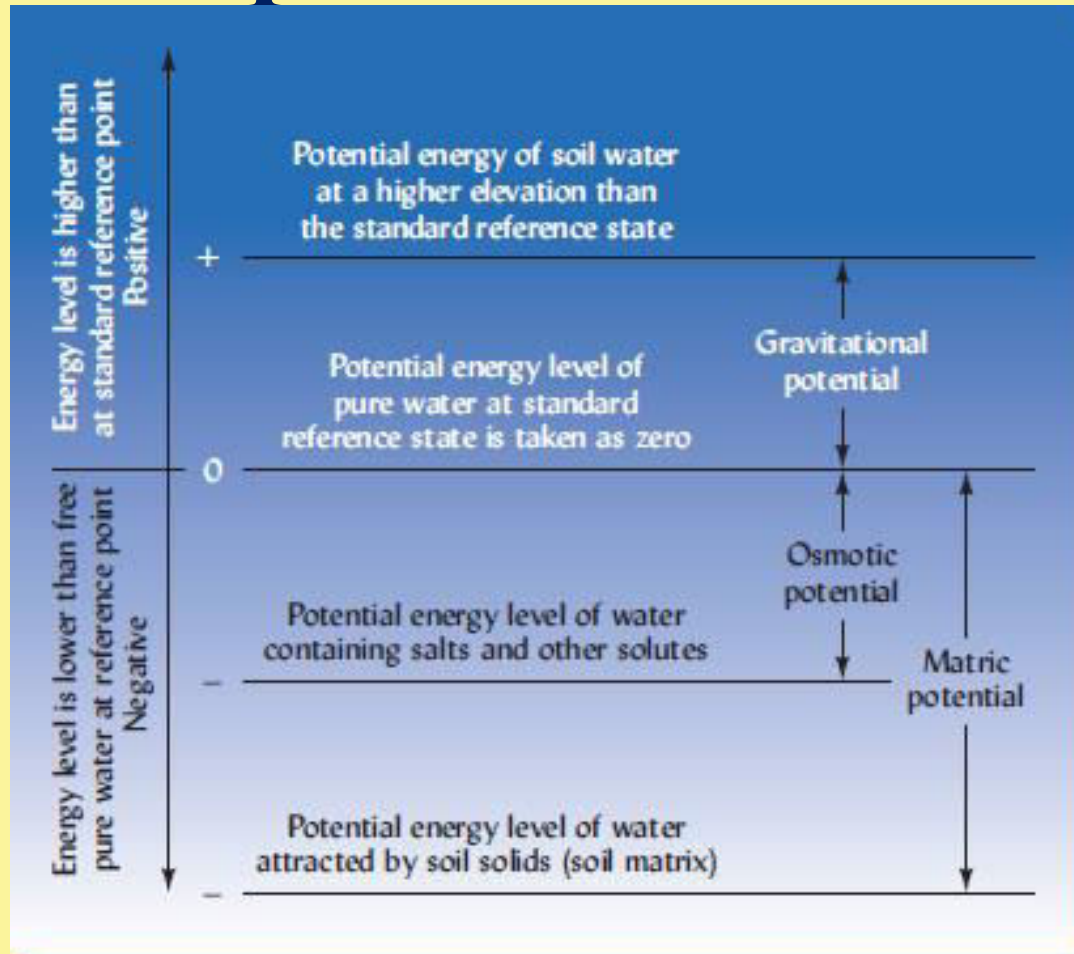


(c)

Soil water potential

1. To quantify potential energy state of soil water, a **reference state** is needed.
2. **Reference state**: potential energy of pure water, with no external forces acting on it, at a reference pressure (atmospheric), reference temperature, and reference elevation.
3. Soil water potential is then determined as potential energy per unit quantity of water, **RELATIVE** to the reference potential of zero.

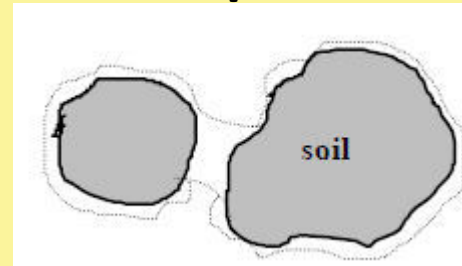
Soil water potential



Soil water potential

Formal definition: Total soil water potential is defined as the amount of work per unit quantity of pure water that must be done by external forces to transfer reversibly and isothermally an infinitesimal amount of water from the standard state to the soil at the point under consideration.

Since water in soil has various forces acting upon it, potential energy usually differs from point to point, and hence its potential energy is variable as well.



REMEMBER: Potential = Force x Distance = $mgl = \rho_w Vgl$ (Nm)

Total Soil water potential

$$\Psi_T = \Psi_g + \Psi_m + \Psi_o + \Psi_h + \dots \text{(N/m}^2\text{)}$$

Ψ_g = gravitation potential

Ψ_m = matric potential

Ψ_o = osmotic potential

Ψ_h = hydrostatic potential

Gravitation potential



P.C: Ray R. Weil

The force of gravity acts on soil water the same as it does on any other body , the attraction being toward the Earth's center. The gravitational potential Ψ_g of soil water may be expressed mathematically as:

$$\Psi_g = gh$$

Pressure potential (Hydrostatic + Matric)

Includes:

- (1) The positive hydrostatic pressure due to the weight of overlying water in saturated soils and aquifers
- (2) The negative pressure due to the attractive forces between the water and the soil solids or the soil matrix

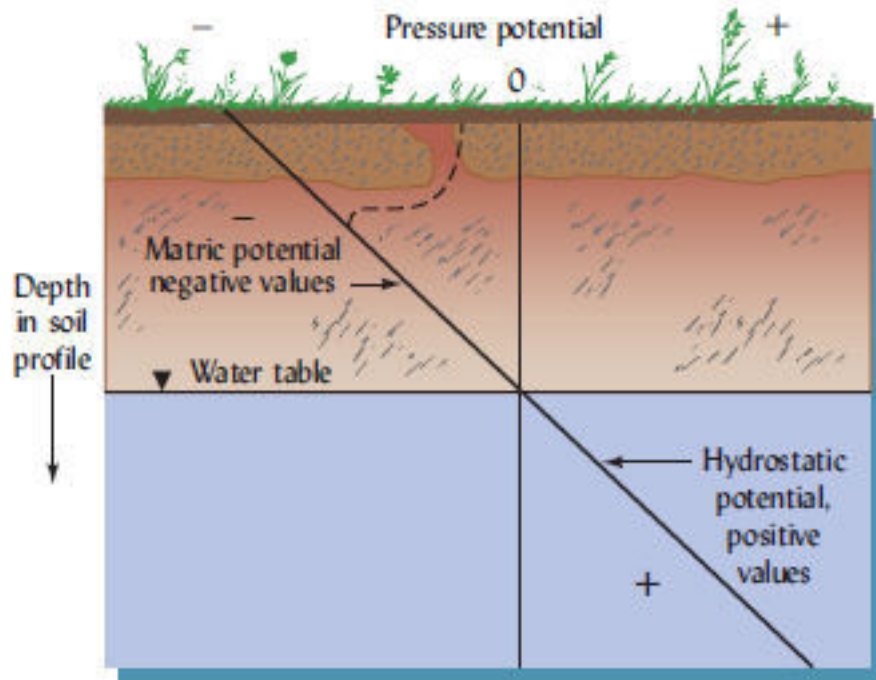
Hydrostatic potential

- (1) The hydrostatic pressures give rise to what is often termed the hydrostatic potential Ψ_h , a component that is operational only for water in saturated zones below the water table
- (2) Anyone who has dived to the bottom of a swimming pool has felt hydrostatic pressure on his or her eardrums

Matric potential

- (1) The attraction of water to solid surfaces gives rise to the matric potential Ψ_m
- (2) Always negative because the water attracted by the soil matrix has an energy state lower than that of pure water

Pressure potential



- The top of the saturated zone is termed the water table.
- Above the water table, the soil is unsaturated and its water subject to the influence of matric potentials
- Water below the water table in saturated soil is subject to hydrostatic potentials

Osmotic potential

- The osmotic potential Ψ_o is attributable to the presence of both inorganic and organic substances dissolved in water.
- As water molecules cluster around solute ions or molecules, the freedom of movement (and therefore the potential energy) of the water is reduced.
- The greater the concentration of solutes, the more osmotic potential is lowered. As always, water will tend to move to where its energy level will be lower, in this case to the zone of higher solute concentration.

Soil water potential

Potential per unit mass (μ) : $\mu = \text{potential/mass} = gl \text{ (Nm/kg)} = gl \text{ (joules/kg)}$

Potential per unit weight (h) : $h = \text{potential/weight} = mgl / mg = l \text{ (m, head unit)} = \text{equivalent height of water}$

Potential per unit volume (ψ) : $\psi = \text{potential/volume} = \rho_w Vgl / V = \rho_w gl \text{ (N/m}^2\text{, water pressure units)}$
 $= \rho_w gl \text{ Pa(SI Unit)}$

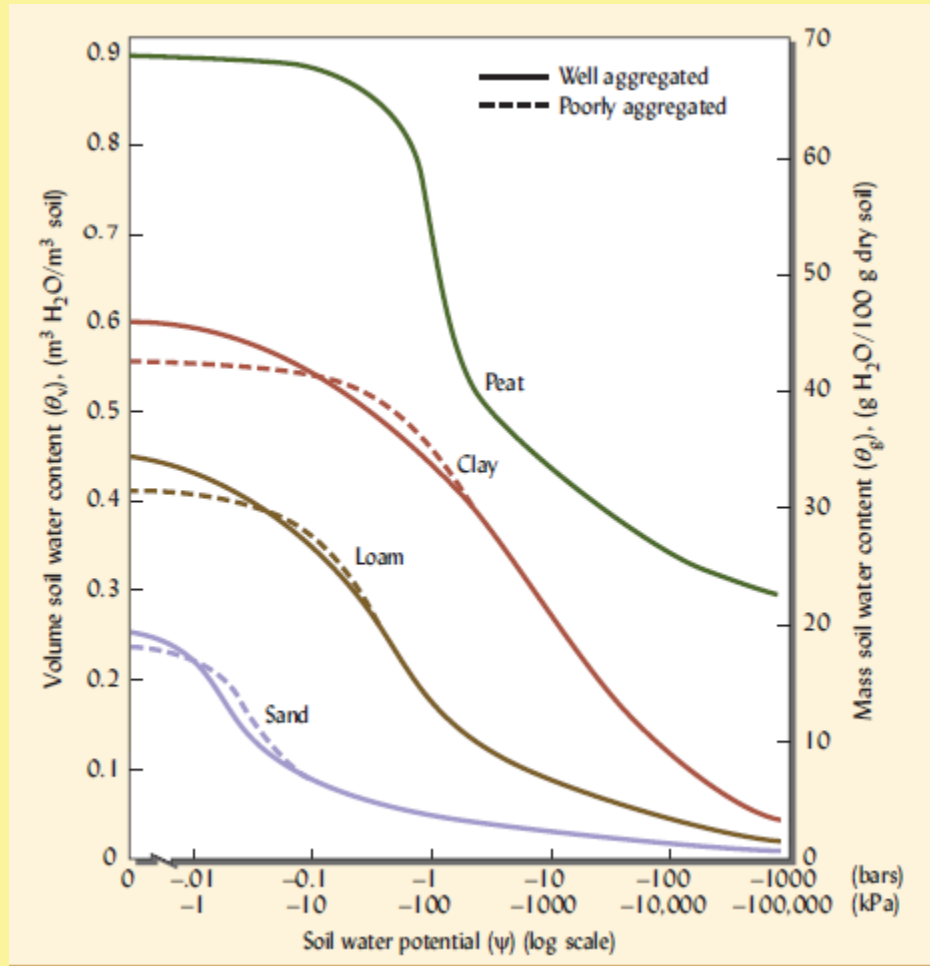
Consequently, we do not need to compute the soil-water potential directly by computing the amount of work needed, but measure the soil-water potential indirectly from pressure or water height measurements !!!!

Expression of soil water potential

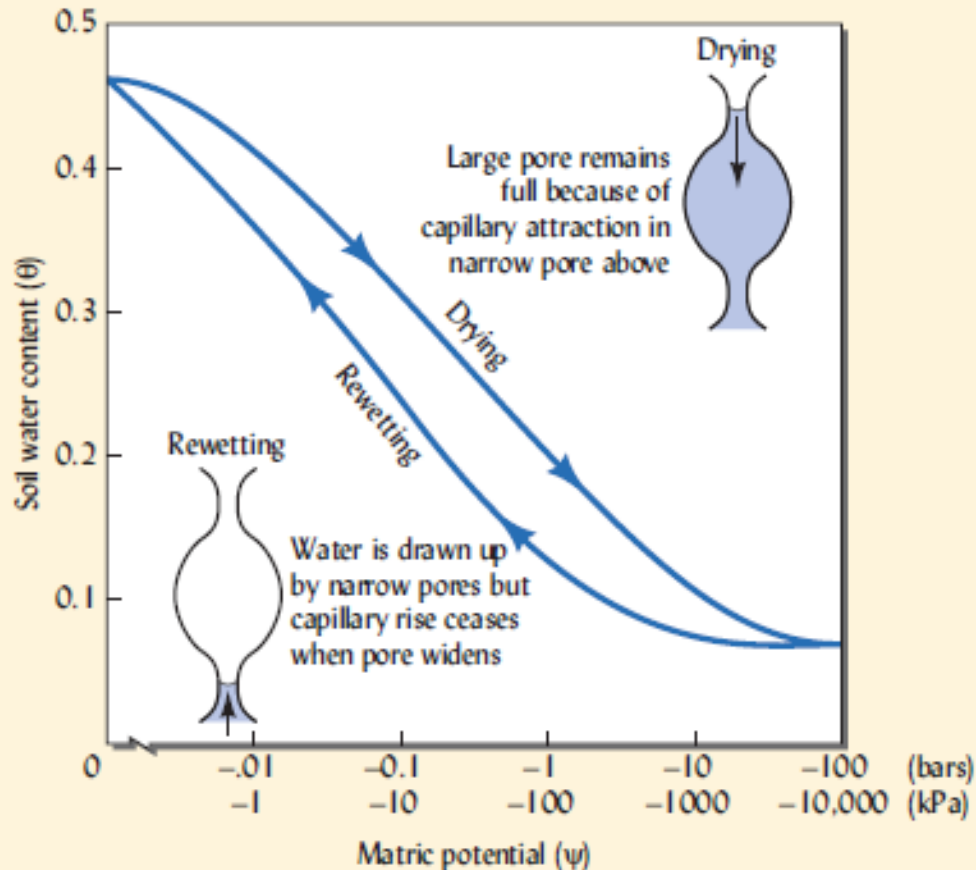
Height of unit column of water, cm	Soil water potential, bars	Soil water potential, ^a kPa
0	0	0
10.2	-0.01	-1
102	-0.1	-10
306	-0.3	-30
1,020	-1.0	-100
15,300	-15	-1,500
31,700	-31	-3,100
102,000	-100	-10,000

^aThe SI unit kilopascal (kPa) is equivalent to 0.01 bars.

Water characteristic curves



Hysteresis



- The relationship between soil water content and matric potential of a soil upon being dried and then rewetted
- Due to factors such as the nonuniformity of soil pores, entrapped air, and swelling and shrinking
- As soils are wetted, some of the smaller pores are bypassed, leaving entrapped air that prevents water penetration.