Hydrological Measurements

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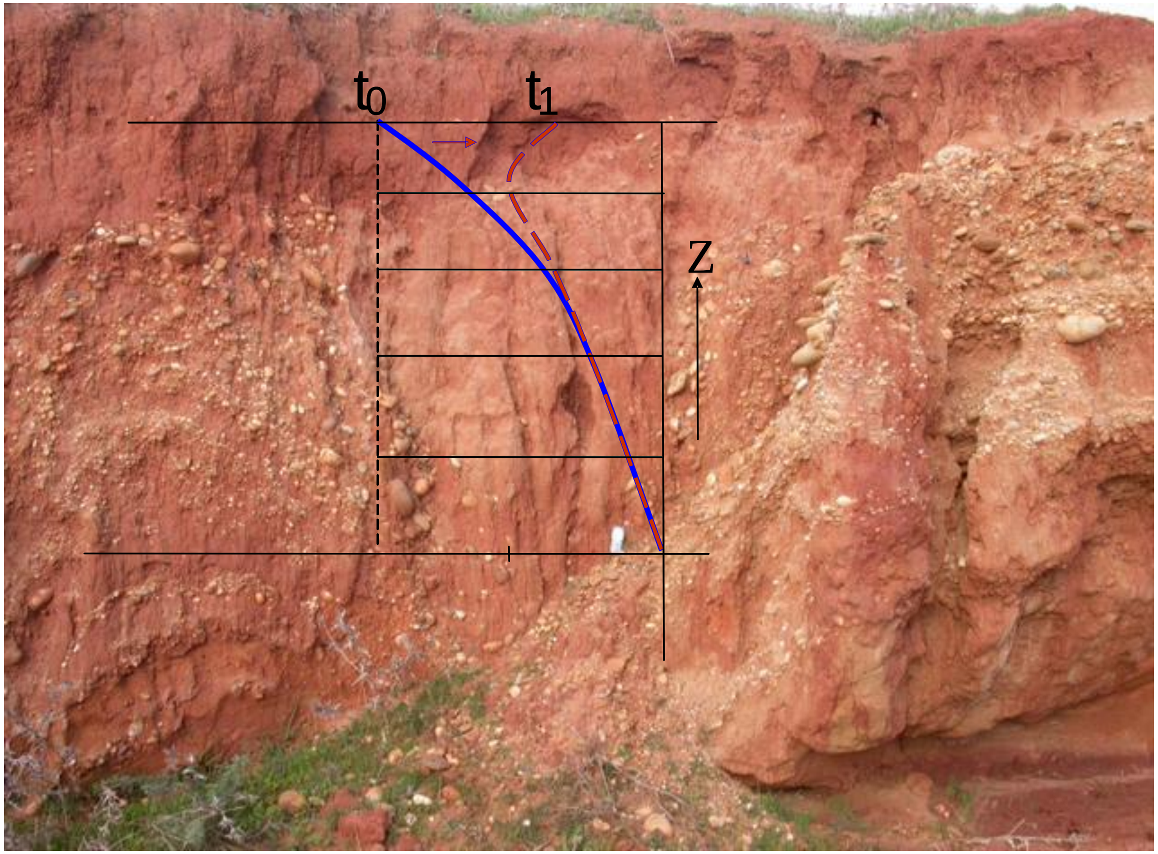
3. Soil Hydrology

CEI 4440 Soil Hydrology



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Learning objectives

After successfully finishing this part of the course the student :

- is acquainted with the basis of soil physics and hydrological processes and measurements and can quantify the stocks and fluxes in the unsaturated zone.

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Learning objectives

- Active knowledge of soil physics
- Perform calculations for unsaturated zone fluxes
- Have basic knowledge of field and lab measurement techniques

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Set up of lecture today

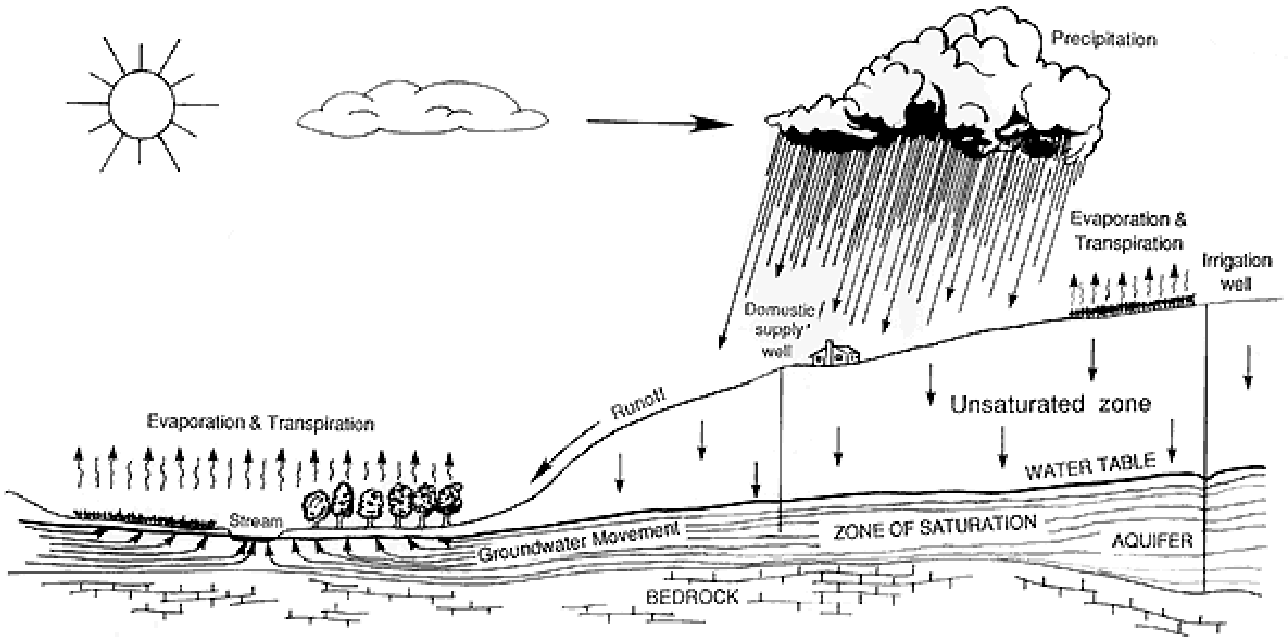
1. Soil physics; Measuring soil moisture
2. Hydrostatics; Measuring soil tension
3. Soil hydraulics; pF curves
4. Soil infiltration and field tests
5. Soil hydraulics; Permeability

Soil hydrology, the movie…

- “The Matrix” – the soil
- “The Force” – the forces stirring the water
- “Dogma” – the laws and equations concerning movement of water
- “The Edge” – the boundary conditions

Definitions

- The unsaturated zone is part of the soil situated between the soil surface and the water table (phreatic level) where some of the spaces between the soil particles are filled with air.



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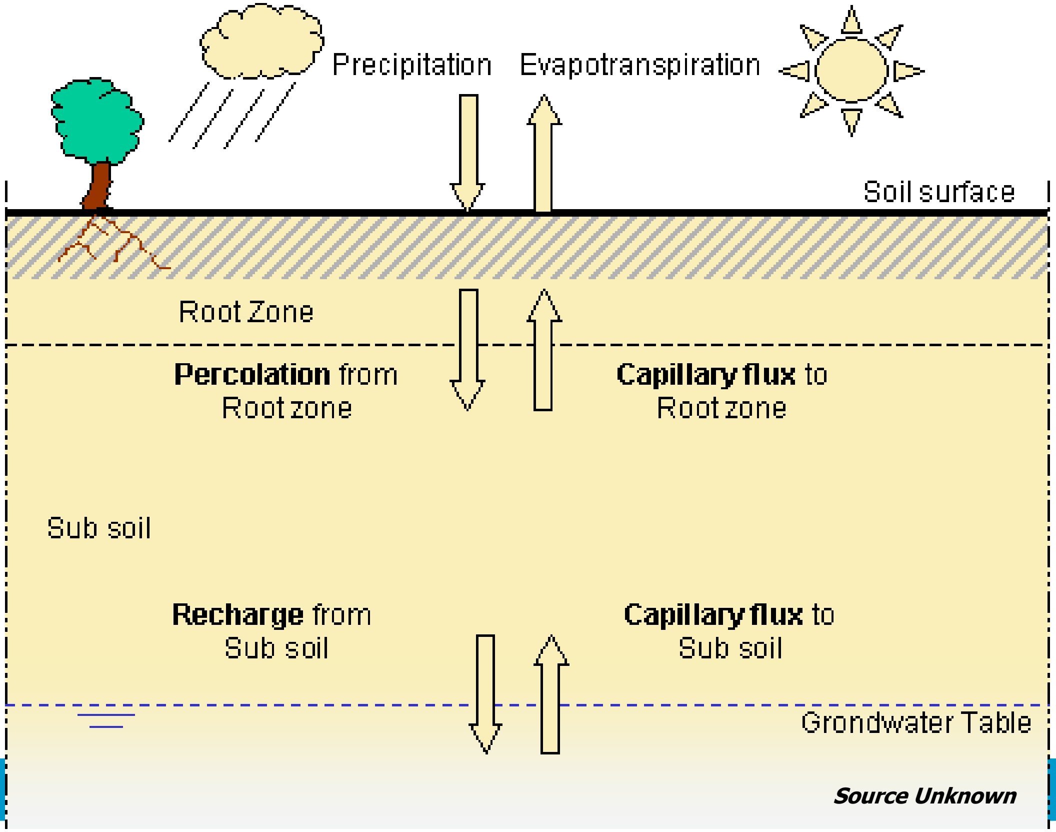
Definition

The unsaturated zone = the zone of aeration = the subsurface sediment above the water table containing air and water (Dictionary of Earth Science 2nd ed. 2002)

Other terms
- Vadose zone
- Root zone
- Percolation zone
- Capillary fringe

The UZ can be temporarily saturated but usually it is not



The unsaturated zone is important for:

- Storage of precipitation: influence on local high water
- Availability of moisture and growth of plants (natural vegetation, agriculture)
- Groundwater recharge
- Land degradation processes at the surface: overland flow, erosion
- Land degradation processes below the surface: mass movement

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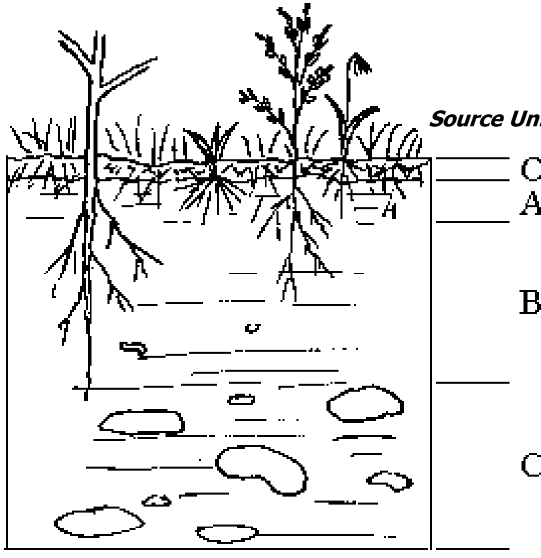


Two main themes in soil hydrology

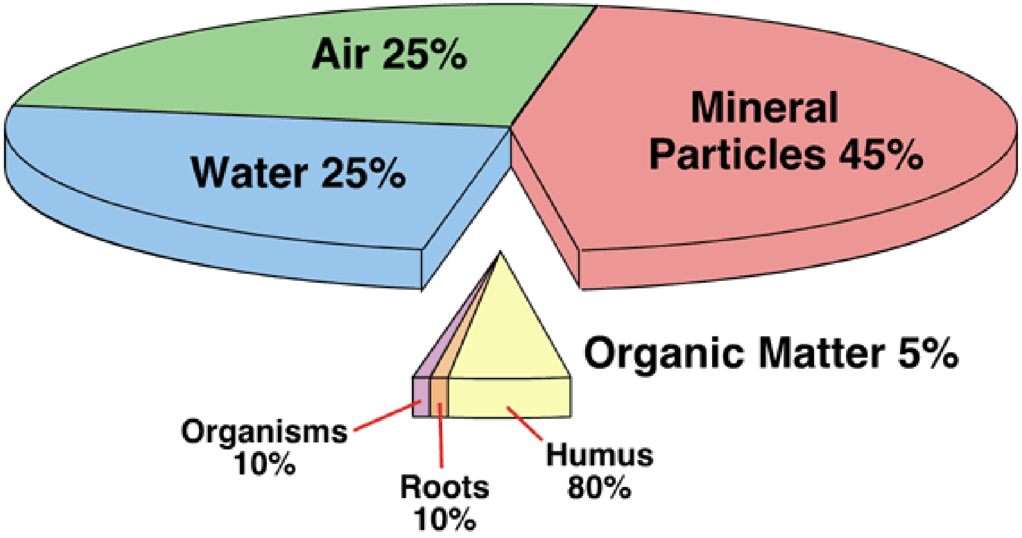
- moisture content: how much water is present in the soil?
- Moisture flow: how fast does the water flow and how fast does the soil moisture content change?

In other words:

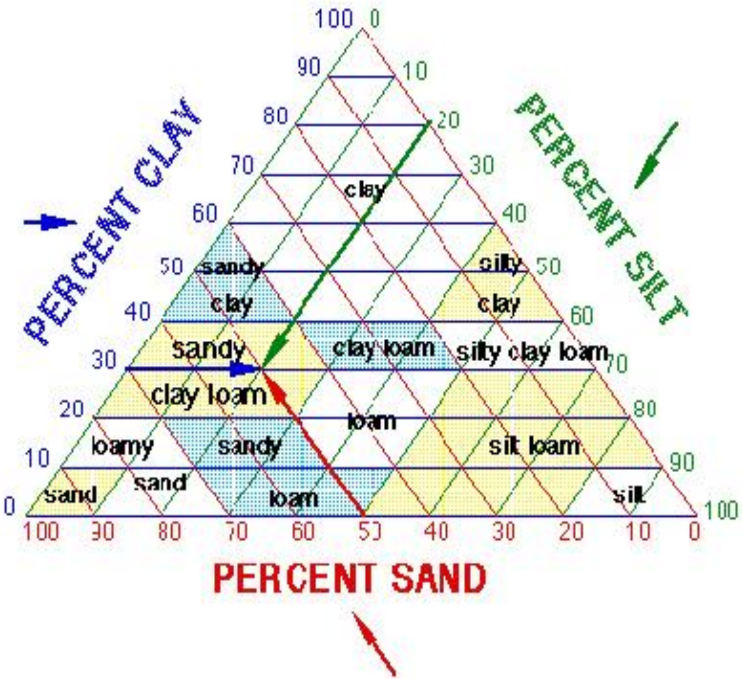
- the moisture content gives the state of the soil
- the moisture content changes (dynamic system)

Soil components

- minerals
  - coarse sand (2000 μm - 200 μm)
  - fine sand (200 μm - 50 μm)
  - silt (50 μm - 2 μm)
  - clay (< 2 μm)
- organic matter
- water
- air



texture triangle



Proportions :

weather-balloon = sand
basketball = silt
rice-grains = clay

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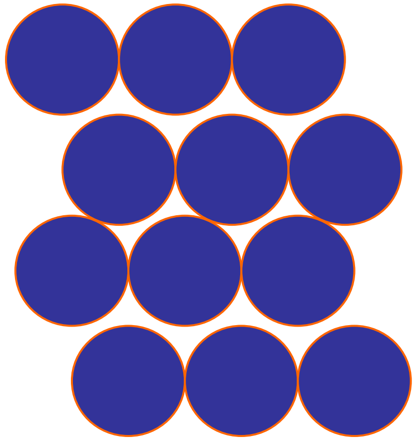
Porosity

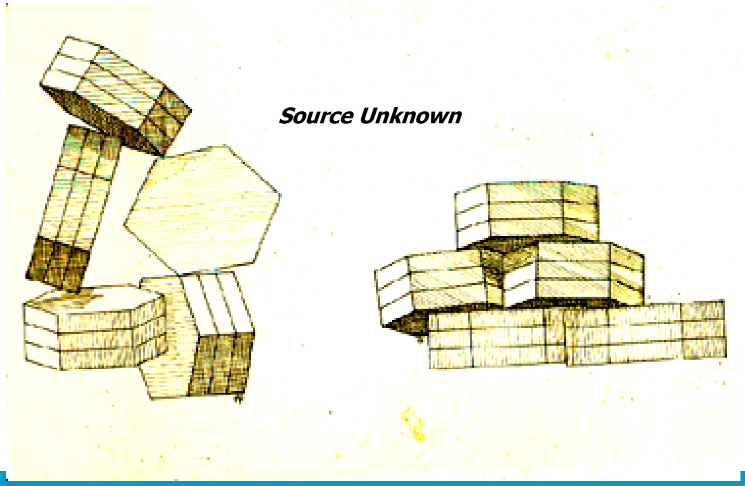
$P = \theta_s$ = volume pores / total volume (cm^3/cm^3)

- sandy soils: P = 0.37 (0.30 - 0.56)
- silty soils: P = 0.45 (0.39 - 0.56)
- loamy soils: P = 0.50 (0.30 - 0.55)
- clayey soils: P = 0.53 (0.35 - 0.70)
- peaty soils: P = 0.80 - 0.85

P sand < P clay ?



Sand: large grains; closely packed; relatively small volume of pores; many large pores



Clay: small sheets of SiO and AlO; arbitrarily packed; a large volume of pores; pores of different sizes

Moisture content

- volumetric
  θ = volume water / total volume (cm^3/cm^3)

- gravimetric (wetness)
  w = mass water / mass solid matter (g/g)

- relative moisture content (0 -1)
  $\theta_E = \theta / P$

Moisture content is being determined by heating 24 hours at 105 ^oC

Examples of calculation:

- Rainfall of 10 mm at a soil with P = 0.4 and θ = 0.3 in first instance reaches a depth of how many mm?

  10 / (0.4-0.3) = 100 mm (and percolates afterwards under gravity)

- A soil which due to compaction in volume of pores recedes from 0.43 to 0.37 looses in the upper 10 cm (100 mm) looses how much storage capacity?

  (0.43-0.37)*100 = 6 mm storage capacity

Bulk density

ρ = mass solid matter / total volume

- sandy soils: 1.16 - 1.70 g/cm^3
- silty soils: 1.26 - 1.61 g/cm^3
- loamy soils: 1.20 - 1.85 g/cm^3
- clayey soils: 0.88 - 1.72 g/cm^3
- peaty soils: 0.2 - 1 g/cm^3

Relations

- bulk density and volume of pores

  ρ = (1-P) * particle density

  ρ = (1-P) * 2.65 (s.m. quartz, when little org. matter)

- volumetric and gravimetric moisture content

  $\theta = w * \rho$
  = (g water /g solid) / (g solid / volume)
  = g water / volume
  = volume water / volume

(in order to translate from gravimetric moisture content to volumetric moisture content one needs to know the bulk density)

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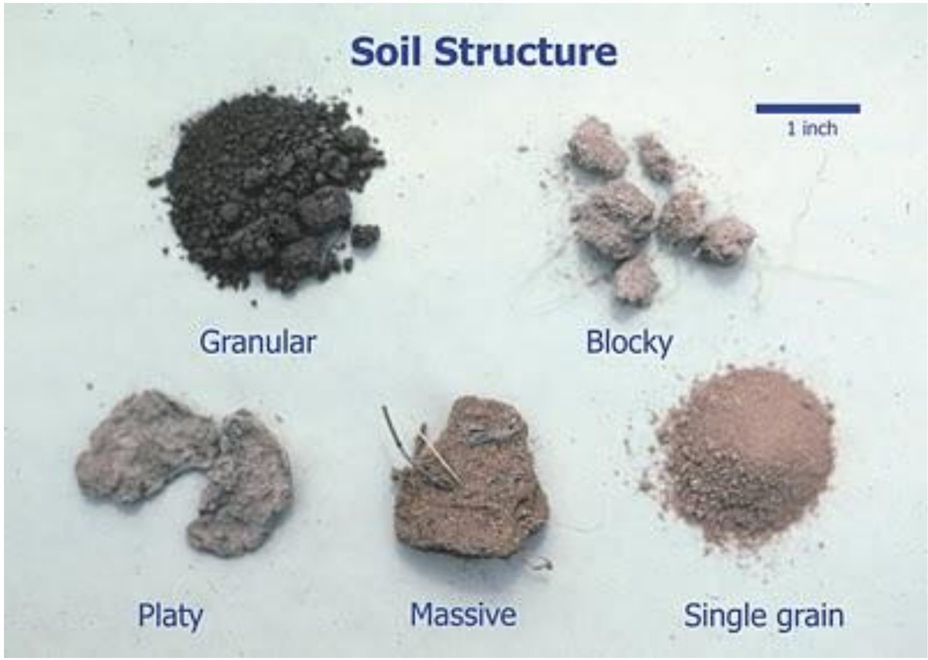
Soil texture vs Soil structure



Soil structure is determined by how individual soil granules clump or bind together and aggregate, and therefore, the arrangement of soil pores between them. Soil structure has a major influence on water and air movement, biological activity, root growth and seedling emergence. (source Wikipedia)

Classes of pores

- Macropores (structural porosity):
  - no capillary binding
  - cracks, bio-activity (roots, animals)
  - agriculture (formation of aggregates)

- Normal pores (textural porosity):
  - capillary binding of water
  - porosity of the aggregates themselves

- Sub-microscopical pores
  - molecular level
  - no flow

Classes of pores: note that

- Macropores may cause a large discrepancy between the volumetric moisture content P and the gravimetric moisture content w
- When taking a gravimetric sample moisture is only present in the normal pores because macropores can't hold moisture against gravity
- Sub-microscopical pores can only be emptied by heating, the water does not 'flow' and is not released under the influence of normal forces in the soil ('residual water', θ_r)

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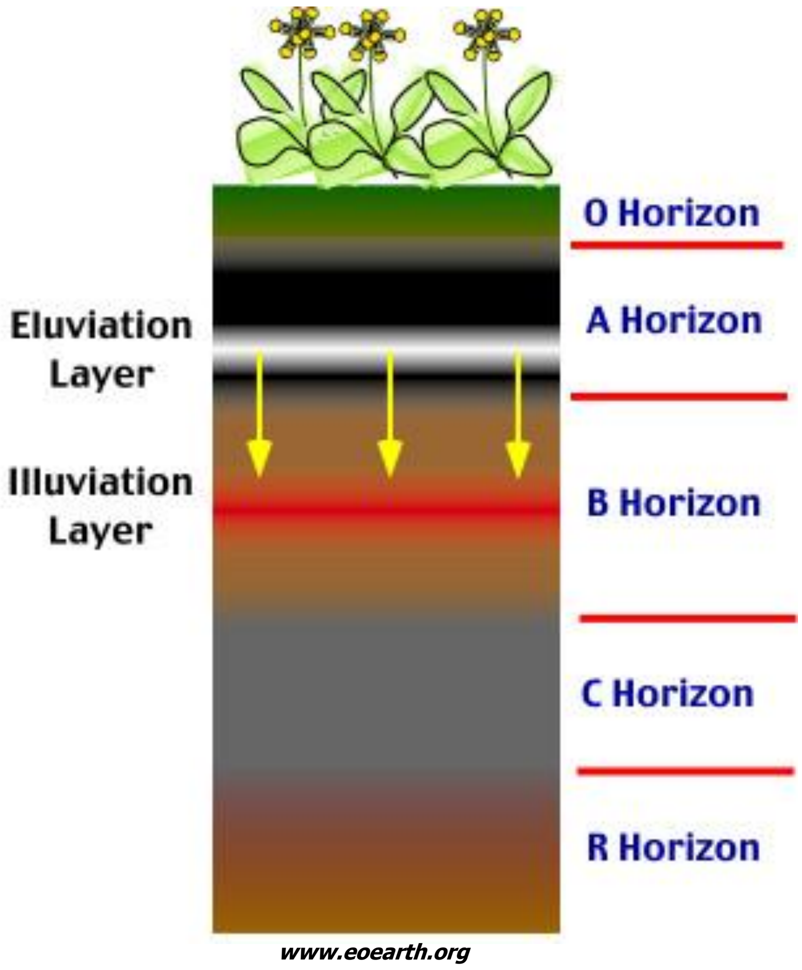
The soil



Litter, humus

Mineral soil with OM mixed.

Eluviation small particles & soluble substances

Illuviation

Enriched in small particles, > bulk density

Weathered parent material

Unweathered parent material

Critical Zone Observatories

Where rock meets life!

www. http://steveholbrook.com