LECTURE IN SOIL SCIENCE

‘’SOIL HAS A SKELETON JUST LIKE A HUMAN BODY”

Soil Physical Characteristics (Part-I)

KONYA FOOD AND AGRICULTURE UNIVERSITY
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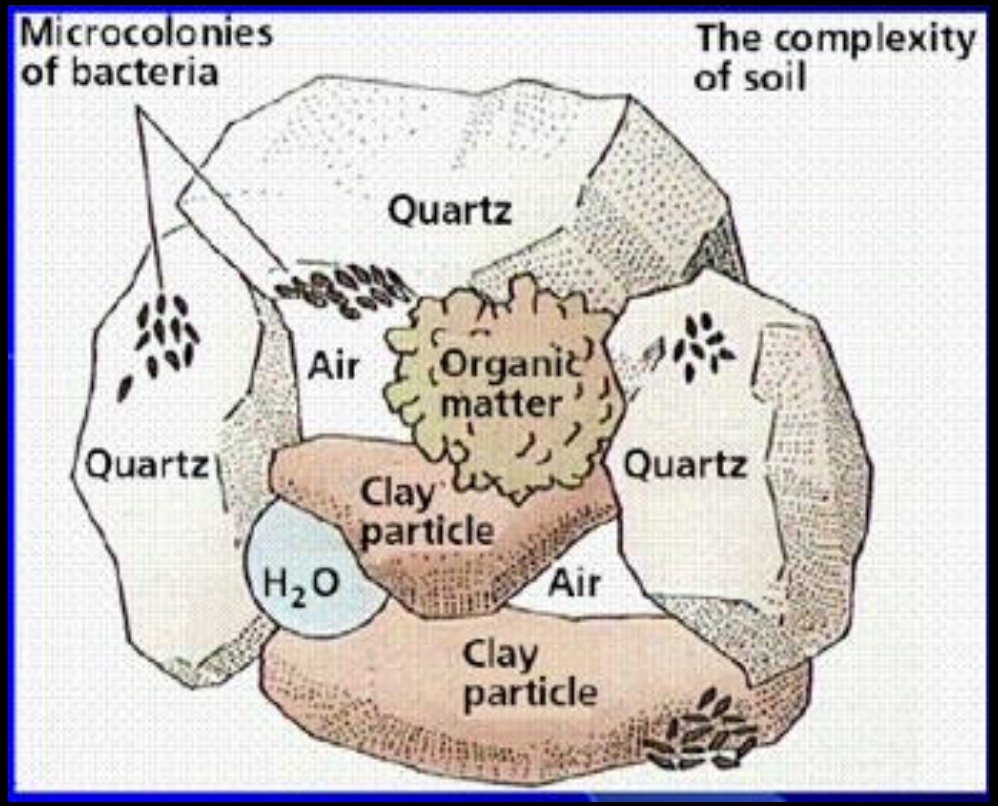
A tiny piece of soil contains air, water, organic matter, living cells and inorganic minerals.

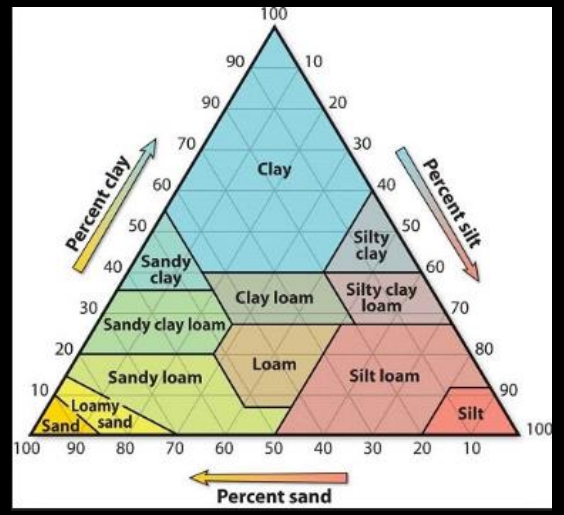
Soil physics is a study field of soil science dealing with the dynamics of physical soil components (i.e. air water and inorganic particles)

It requires to know principles of physics, physical chemistry, engineering, and meteorology as well.



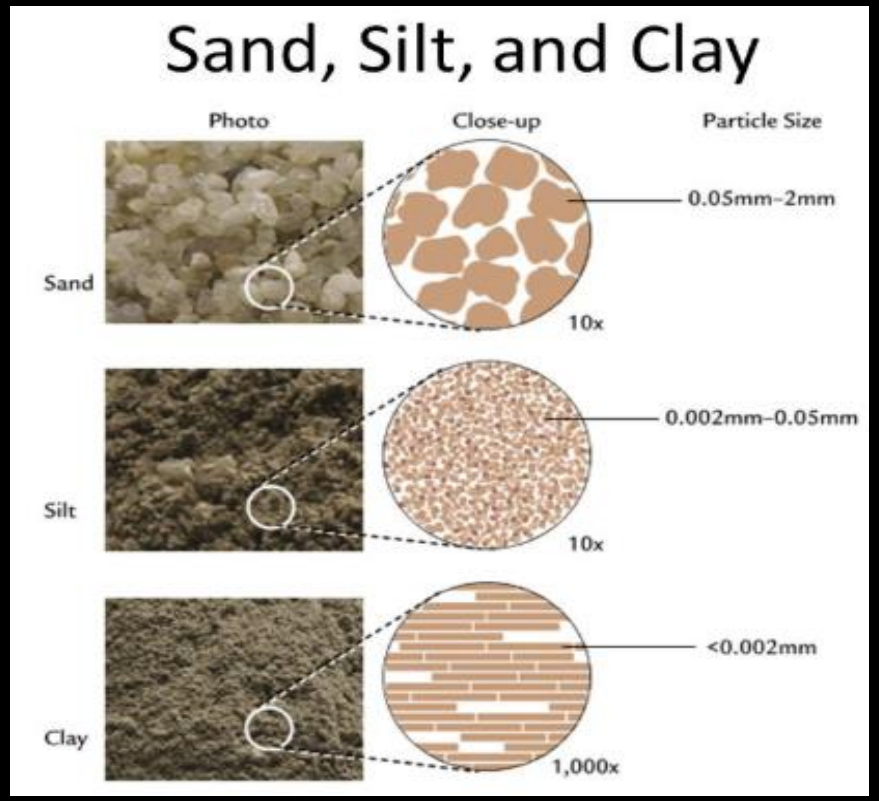
PHYSICAL PROPERTIES OF MINERAL SOILS

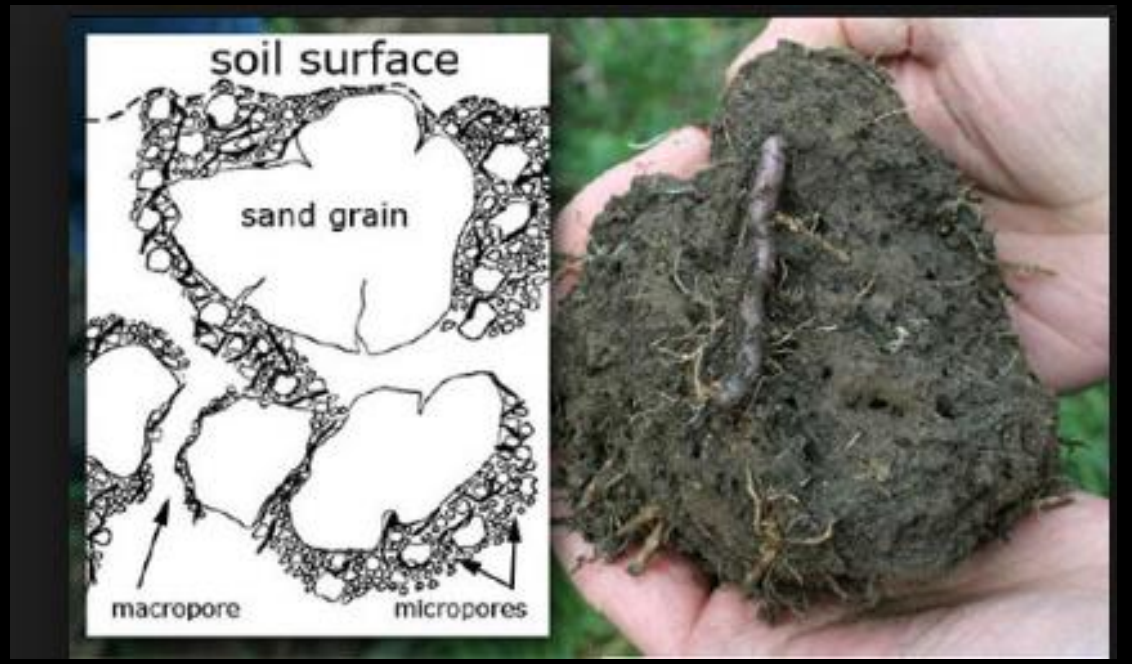
Soil texture
Soil structure
Water holding capacity
Aggregate stability
Aeration
Permeability
Soil temperature
Color of soil
Soil consistency limits



WHAT IS SOIL TEXTURE ?

- Percentage of individual particles in a soil is called soil texture (relative amounts of sand, silt and clay)
- Soil particles consist of primary and secondary soil particles
  - Primary soil particles; are non-bonded particles of sand, silt and clay
  - Secondary soil particles; are bounded particles of sand, silt and clay (ped or aggregates)

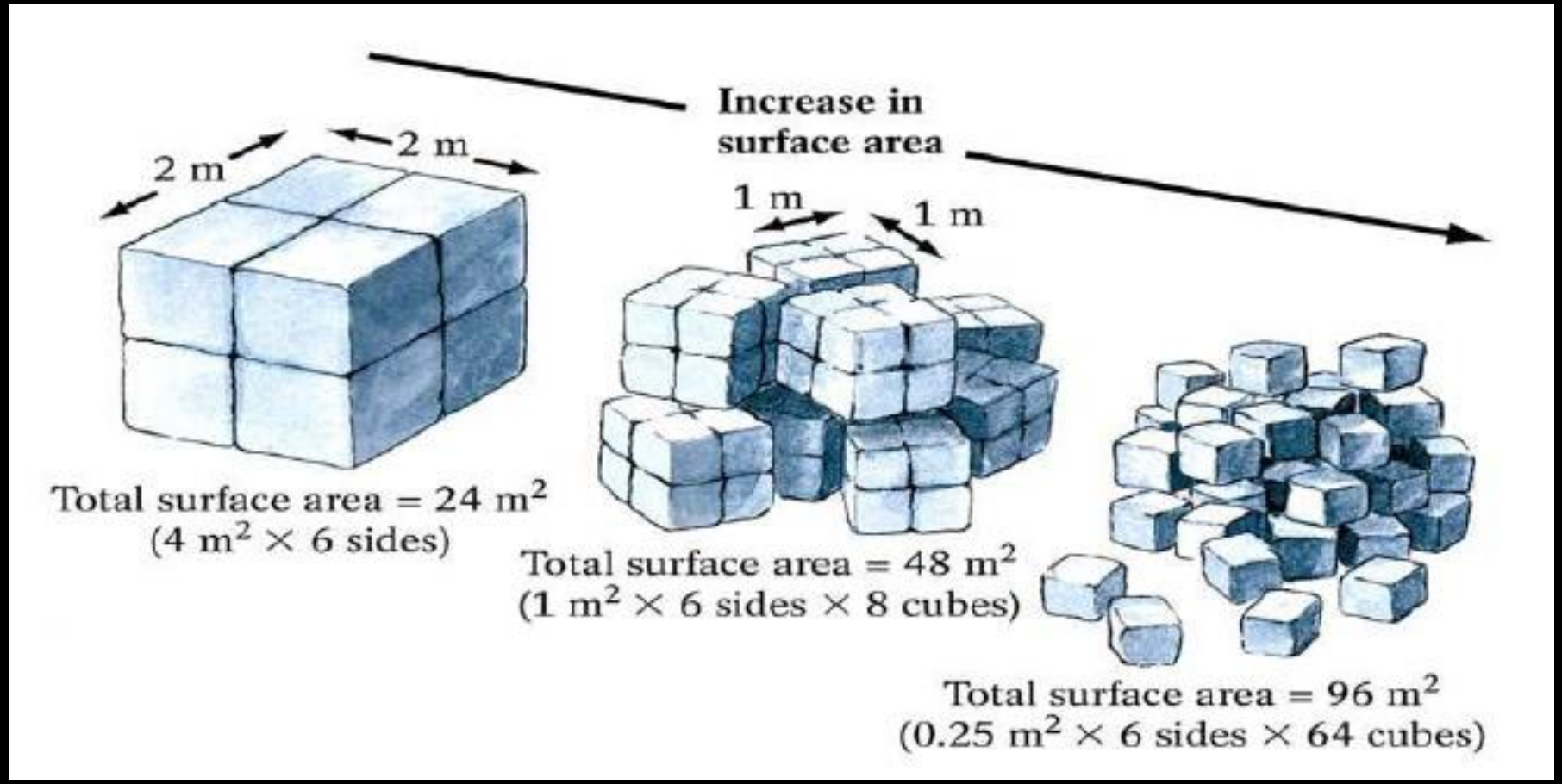




Q: Why size of soil particles matter?

WHAT IS SOIL SURFACE AREA ??

- As the diameter of a mineral particle decreases, surface area increases (very important fact to explain nutrient and water retention in soil .



Water retention capacity makes a soil ‘light’ or ‘’heavy’’

- **A light soil;** is rich in coarse particles (sand); has low water holding capacity and high leakage capacity (sandy soil)

- **A heavy soil** consists of small particles (clay); has a high water holding but low leakage capacity; and also high plasticity and adhesion (difficul to till)


Sandy soil


Sandy soil

Heavy soil


A very clayey soil

Heavy soil

Relationships between soil texure and soil properties

HEAVY TEXTURED	INTERMEDIATE TEXTURED	COARSE TEXTURED
(clayey soils)	(loamy soil)	(sandy soil)
water retention capacity ↑		water retention capacity ↓
water permeability ↓		water permeability ↑
compacted		Loose structure
plant nutrition content ↑	best for agriculture	plant nutrition content ↓
chemical chracteristics ↑		chemical chracteristics ↓
Physical characteristics ↑		Physical characteristics ↓
(slow warming, difficult to till)	physically and chemically reclamable	(fast warming, easy to till)
continous meadows		continous forest
(not suitable for agriculture) chemically good; physically bad soil conditions		(not suitable for agriculture) Physically good; chemically bad soil conditions

Soil Texture Testing by Feel

- take a small amount of the soil from your sample
- put it in the palm of your hand
- add quite a bit of water
- rub the soil against your palm using your finger




- SAND feels like ‘’sandpaper’’ (no shape and dirt in your hands)
- SILT gives a ‘’velvet’’ feeling (hardly shaped and little dirty)
- CLAY, feels like ‘’soap’’ (sitcky, easily shape up and dirty your hands)
- add quite a bit of water and then using your finger rub the soil against your palm
- Soil texture can (approximately) be determined depending on your experience

https://www.the-compost-gardener.com/soil-texture-testing.html

Türkiye'de yüzde satürasyona göre toprak tekstürünün bölgesel dağılımı (Çevre Bakanlığı 1997)

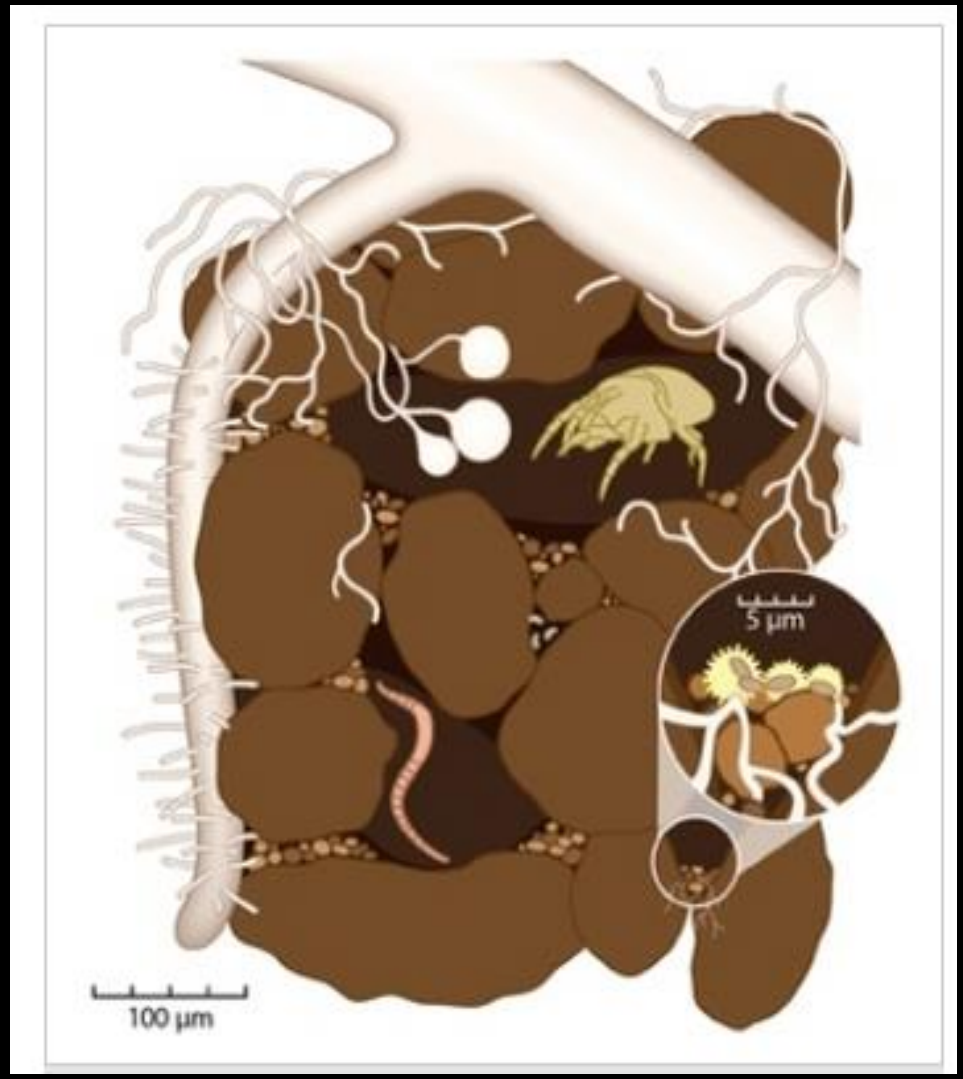
Bölgeler	Toprak sayısı	< 30 kumlu	30-50 tınlı	50-70 killi-tınlı	70-110 killi
Trakya ve Marmara	8577	7.3	38.0	44.1	10.2
Karadeniz	101137	1.9	25.6	55.9	16.4
Orta Anadolu	25706	3.6	40.2	48.1	7.5
Güneydoğu	4061	1.6	33.9	56.1	8.4
Doğu Anadolu	1329	0.5	37.8	55.4	6.0
Ege	7342	1.9	47.1	37.2	13.6
Göller	3759	6.2	45.8	38.5	8.9
Akdeniz	3168	0.9	32.1	52.0	14.6
Türkiye ortalaması (%)		3.4	37.9	47.9	10.4

Soil Structure

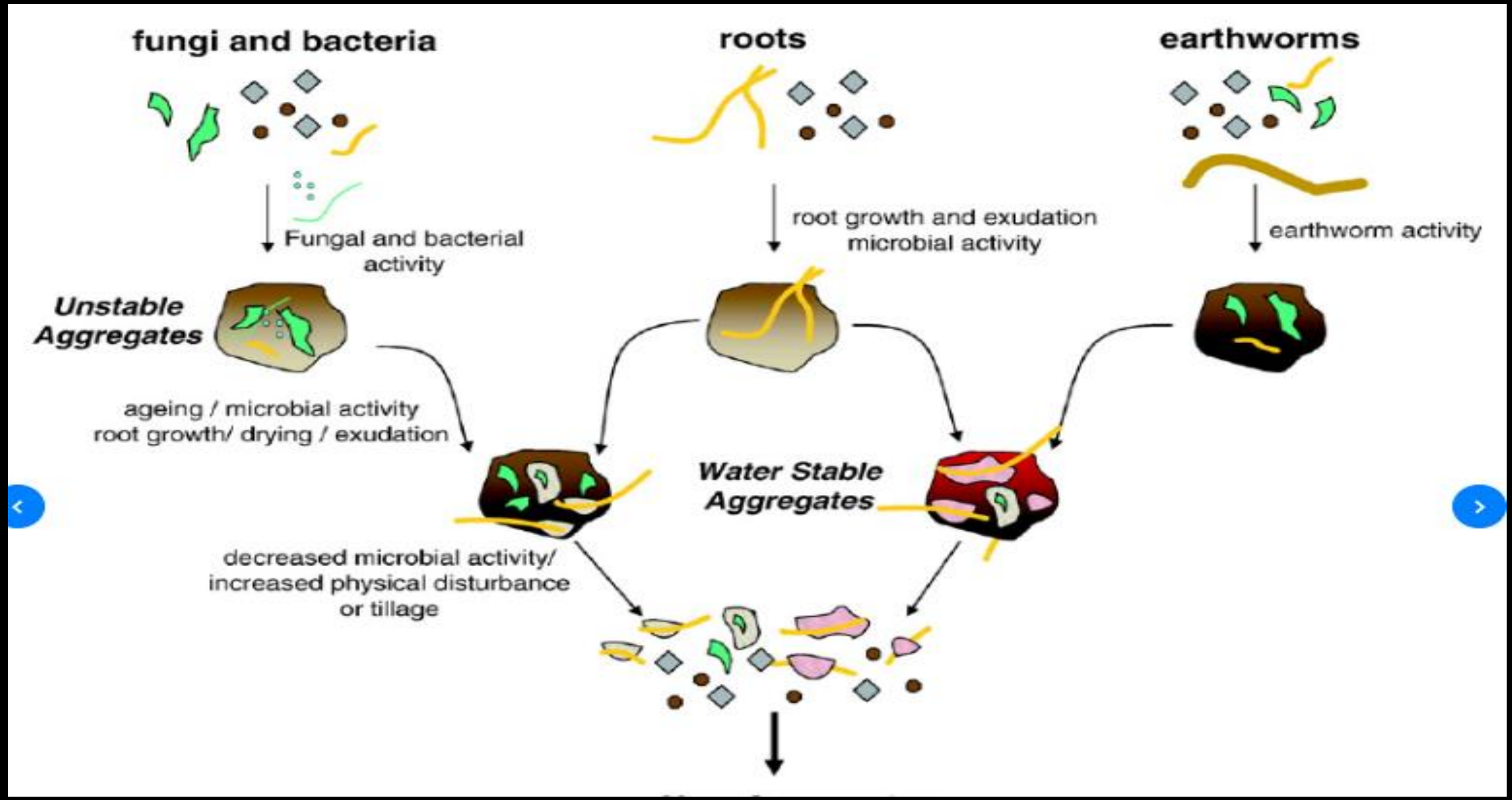
- Soil structure refers to the arrangement of soil particles into certain units named ‘’soil aggregates’.
- An aggregate contains solids and pores for air and water transfer through soil layers
- An aggregate is usually dominated by clay particles but silt and fine sand particles can also be part of an aggregate.
- Soil structure is an important soil physical characteristic especially for plant growth

Aggregation Processes in Soil

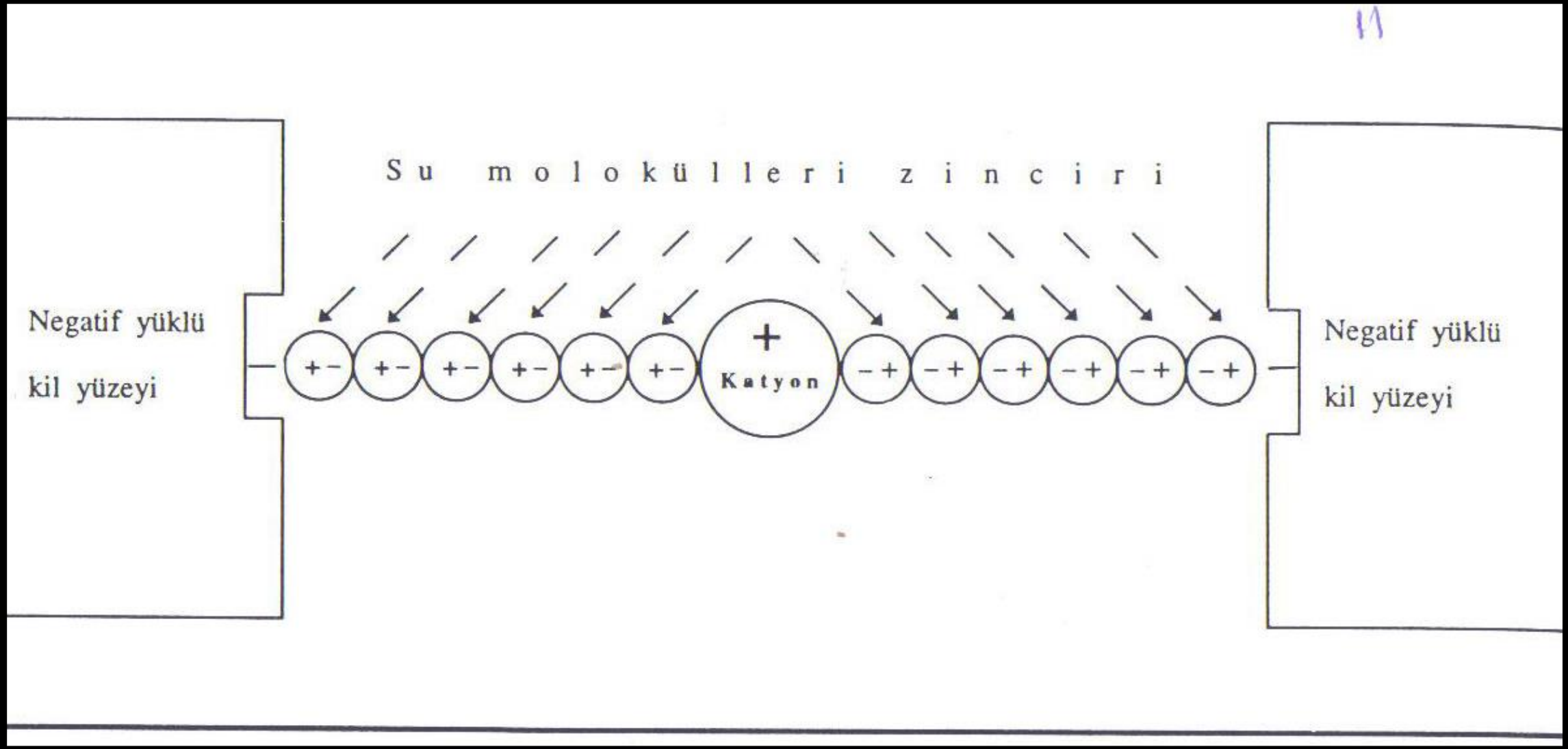
- **Organic matter (amount and type)**
- **Biological activity (microbes)**
- **Cations adsorbed**
- **Soil tillage**
- **Freezing and thawing**



Biological Aggregation Processes in Soil



Chemical Aggregation in Soil



Important notes for soil aggregation

- **Controlling the amount of water and air in soil**
- **Regulation of water movemment in the soil profile**
- **controls soil erodibility**

Level of soil aggregation in different conditions

Q-1: How is soil aggregation in arid regions?

- **High** …… microbial decomposition
- **Low** ……. amount of organic matter
- **Low** ……. amount of sticky compounds binding soil particles

Aggregation level is low

Level of soil aggregation in different conditions

Q-1: How is soil aggregation in rainy and cold regions?

- High precipitation
- Low oxygenation-microbial decomposition
- High amount of organic matter
- High leaching (of clay and SOM)
- Low amount of sticky compounds binding soil particles

Again, aggregation level is low!

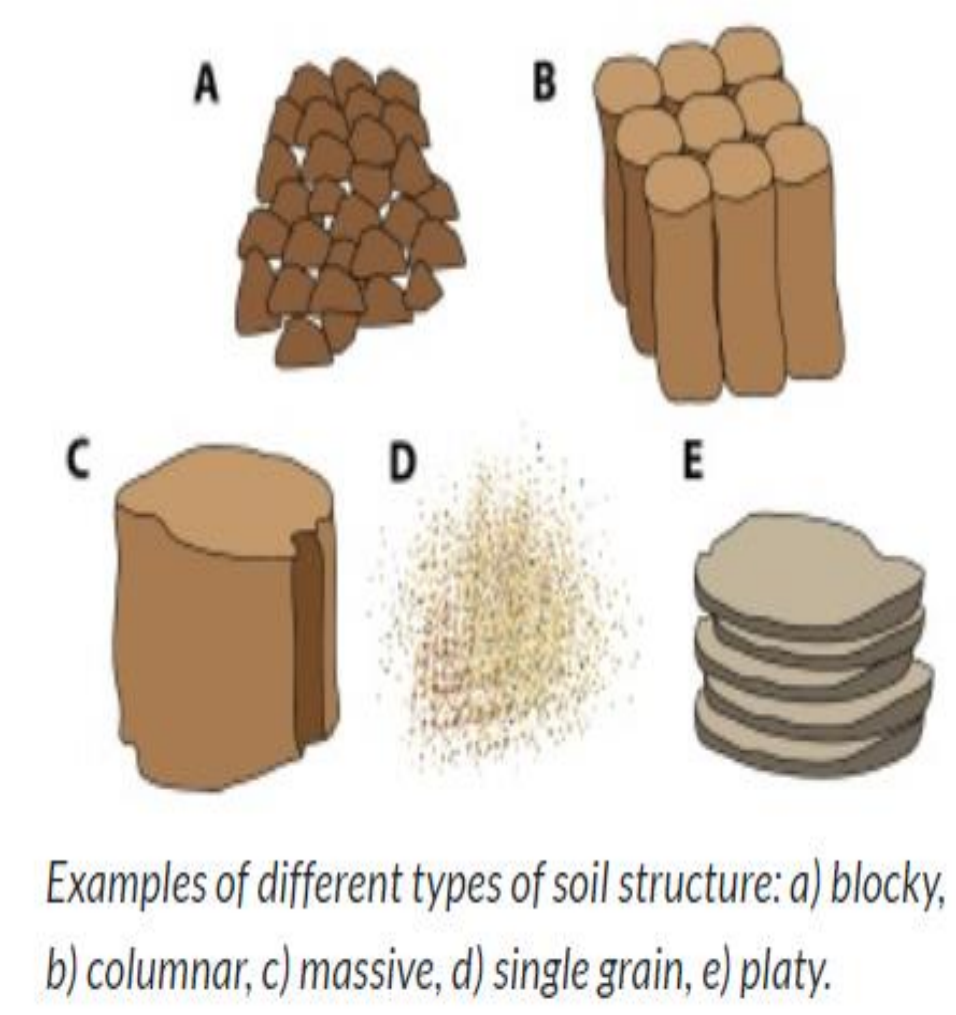
Level of soil aggregation in different conditions

Q-1: How is soil aggregation in rainy and hot regions?

- **High** …… precipitation
- **Low** …… oxygenation-microbial decomposition
- **High** …… amount of organic matter
- **High** …… leaching (of clay and SOM)
- **High** …… amount of Fe oxides binding soil particles

Aggregation level is high!

Soil structural types



Examples of different types of soil structure: a) blocky, b) columnar, c) massive, d) single grain, e) platy.

Type A: Cube-like with flattened surface and sharp corners

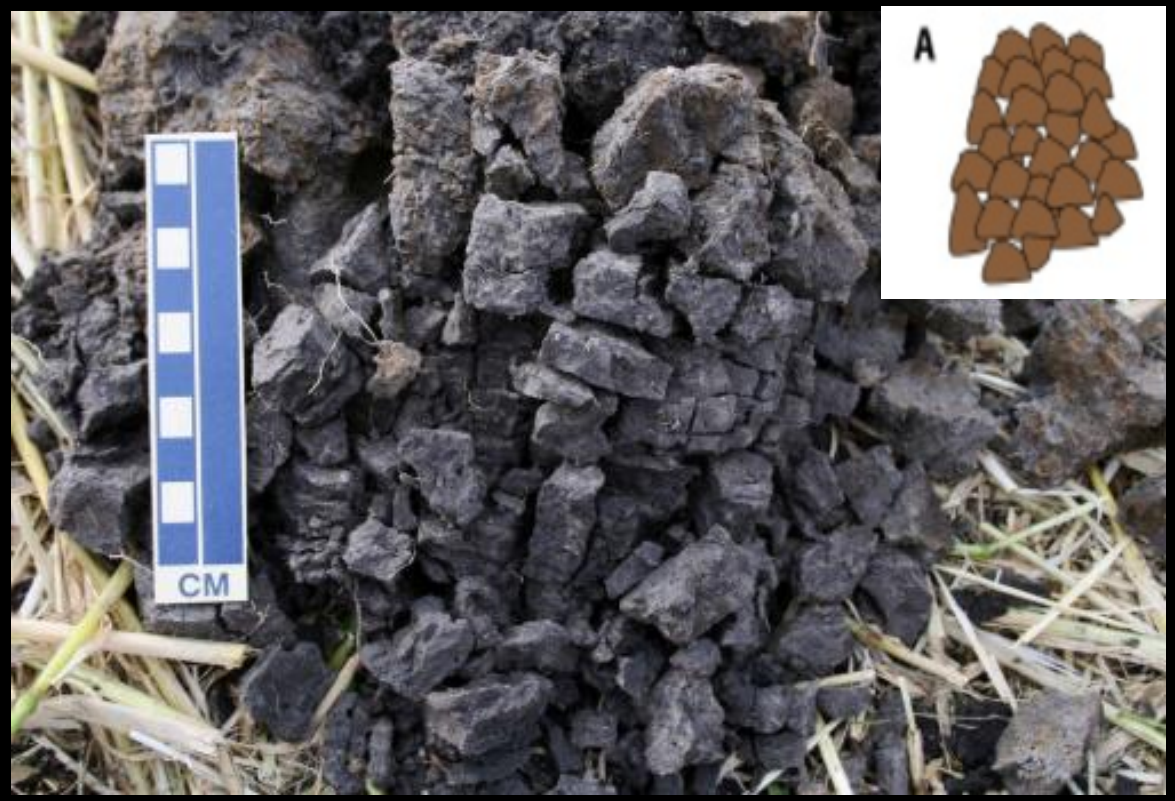
Type B: Rectangular with a long vertical dimension and flattered top (prismatic)

Type C: Very large clods with equal vertical and horizontal dimensions

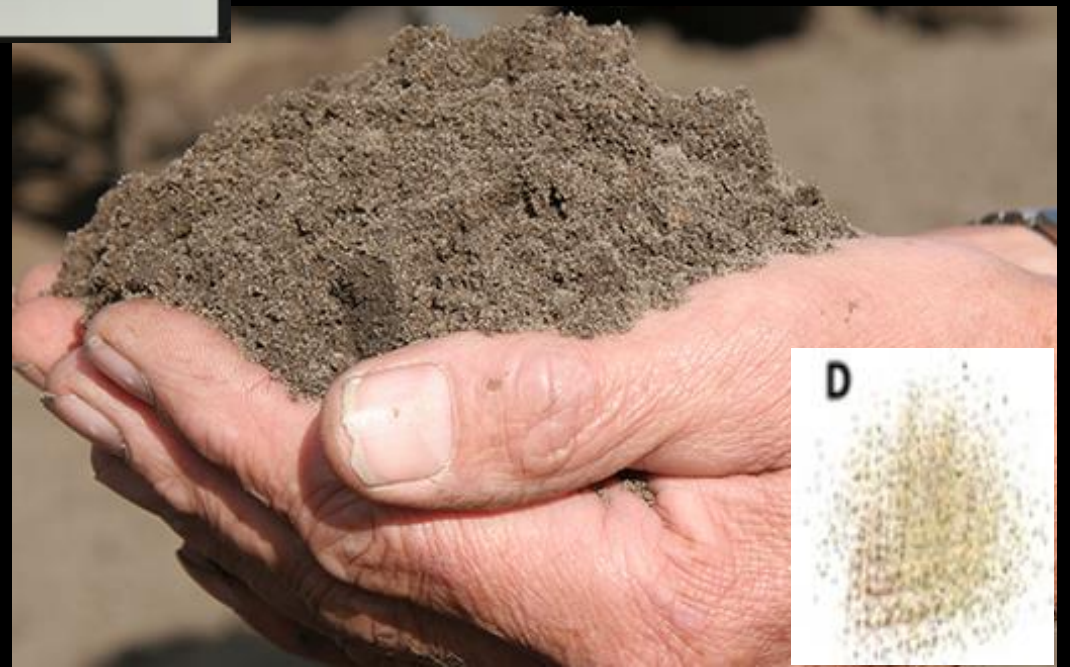
Type D: No aggregation of coarse particles when dry

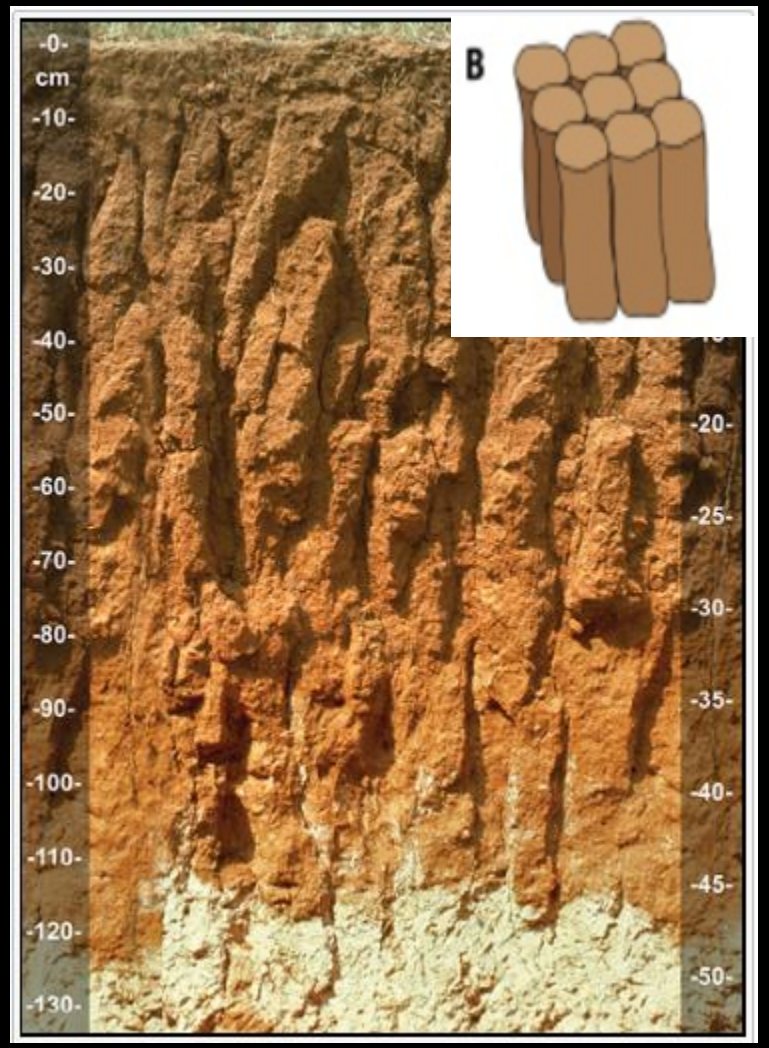
Type E: Rectangular with a long horizontal dimension

Soil structural types



Soil structural types





Factors involved in the formation of soil structure

- Clay, iron and aluminum oxides, colloidal fractions of organic matter
- Slowly decomposing organic matter
- Monovalent (Na^{+1}, K^{+1}) and divalent (Ca^{+2}, Mg^{+2}) cations
- Plant roots (pressure)
- Fungi (mycelium)
- Earthworms (excretion)
- Climatic conditions (i.e. Good aggregation in rainy and temperate laterite soils, but not good in podzol soils)
- Wetting and drying cycles
- Freezing and dissolution
- Soil cultivation under appropriate conditions (autumn and spring)
- Culture plants
- Fertilization

What is the most colorful soil characteristics?

What makes this difference ?

Soil has colours….

- **Organic matter type and amount,**
- **Content of lime and free iron oxide**
- **Mineralogical composition,**
- **Soil water characteristics**

Soil has colours….

Laterite soils (later means ‘’brick’’ in latin)

- reddish to yellow in color
- a lower content of N, P, K, Mg, and $CaCO_3$
- rich in Fe, Al, Ti and Mn-oxides
- widespread in tropical climates

Podzol soils (pod”, means “under” and “zola,” meaning “ash”)

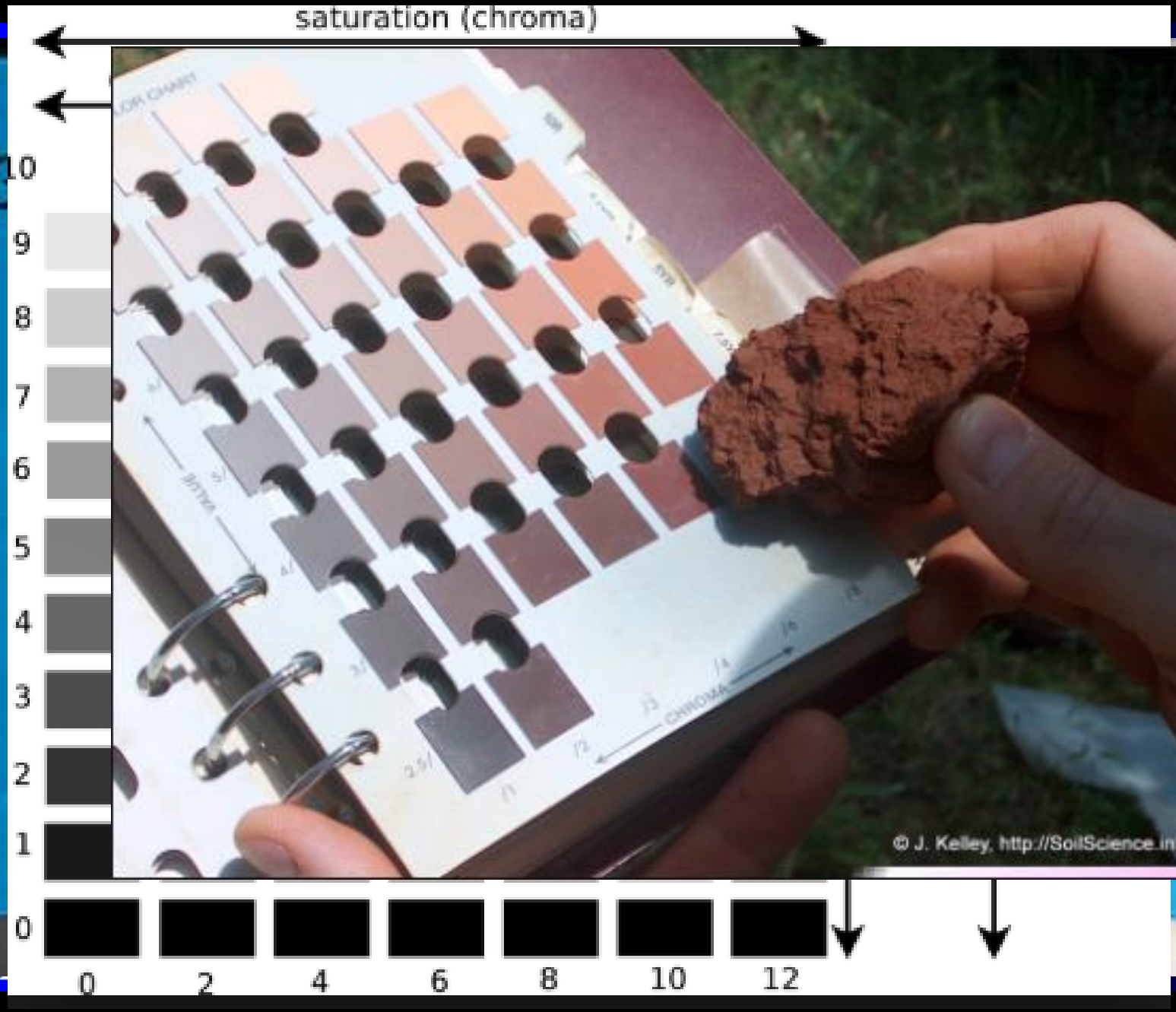
- White to grey in color
- a lower content of Ca, Mg, K in upper layers
- rich in Fe, Al and humus below layers
- Typical forest soil is podzol

Water matters all the time !!

Soil has colours

- **Soil color is described by MUNSEN COLOR SYSTEM based on three properties of color, HUE VALUE (lightness) and CHROMA (purity).**

Hue – Color, such as red or yellow, or an intermediate color.
Value – Relative darkness or lightness of a color, from black to white.
Chroma – Relative purity of a color, from dull to bright.


saturation (chroma)
10
9
8
7
6
5
4
3
2
1
0
0
2
4
6
8
10
12
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RENK

- ÖRNEK: 10YR 3 / 4 (koyu sarımsı kahve.)

HÜ VALÜ KROMA

TOPRAK RENGİ;

-Kuru (hava kuru toprakta) ve

-Yaş (ıslatıldıkça rengin değişmediği nem içeriğinde) olmak üzere

iki ayrı nem içeriğinde belirlenir.

We can have a rough idea just by looking soil color about;

- Amount of organic matter in soil
- Drainage conditions of soil
- Aeration conditions (well oxygenated or not)
- Mineralogical backgrouns of soil
- Soil formation processes

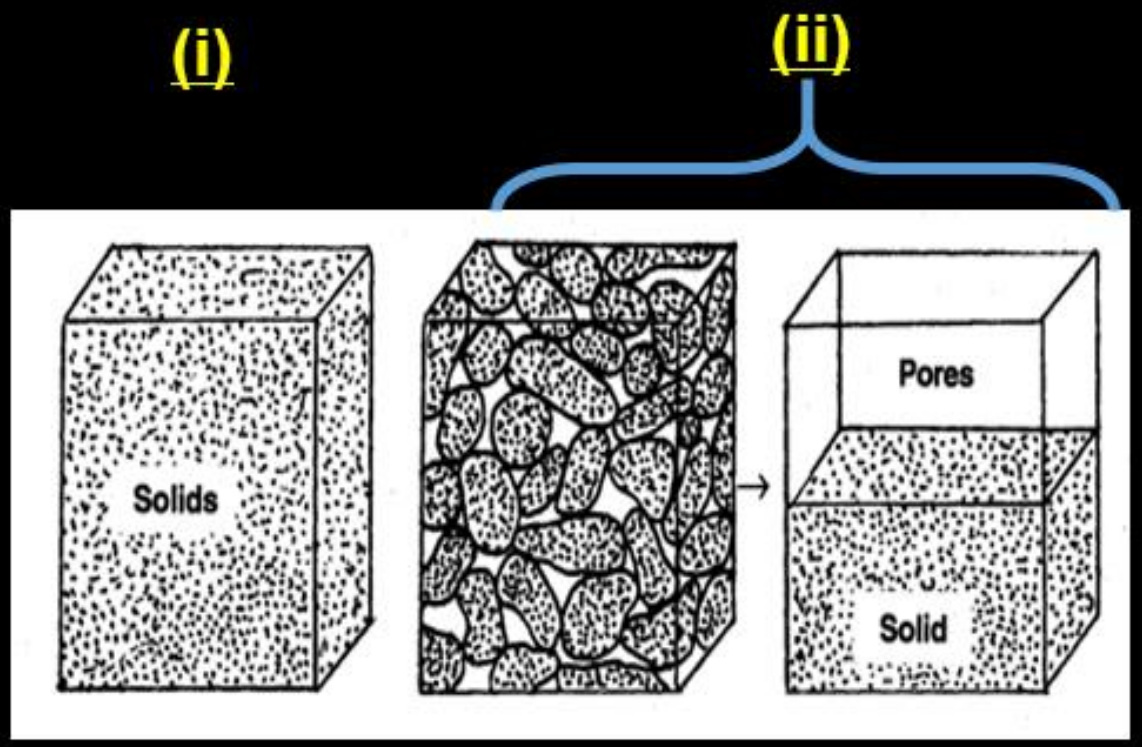
- Organic matter and managanese compounds gives black and grey color to soil
- Iron compounds are the reasons for black, red, yellow, greenish and bluish color n soil

Physical Properties in Terms of Density (Weight and Volume)

The soil weight is related to the amount of the soil and can be calculated in two ways;

(i) Density calculation based on ONLY soil mass (ignoring pore volume) is particle density (ρk)

(ii) Density calculation including pore volume to soil mass is bulk density (ρb)

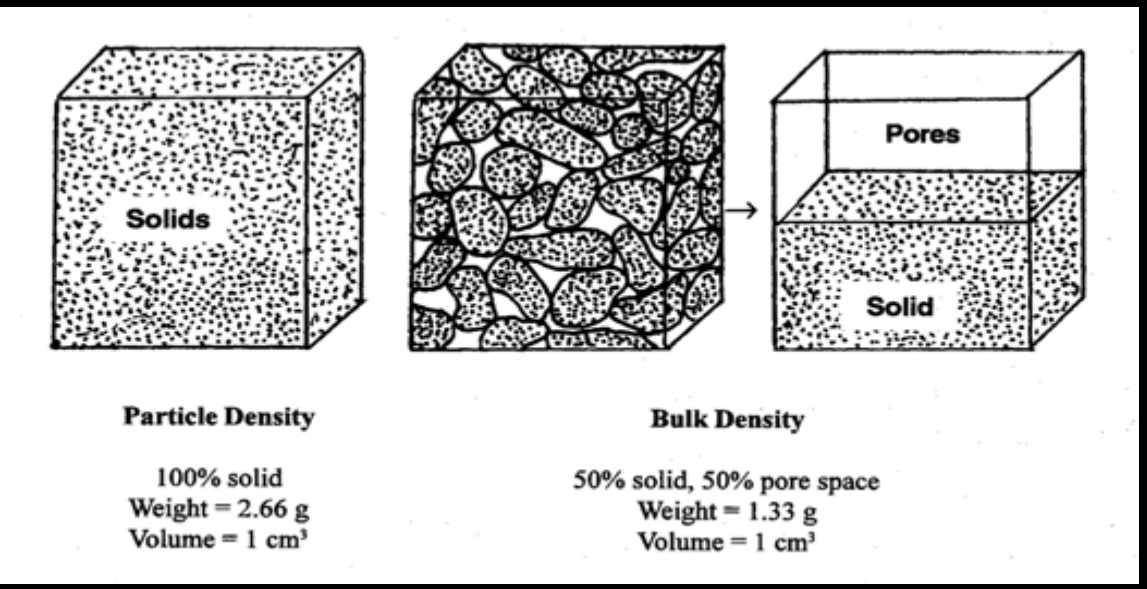


How to calculate Particle Density (ρk) and Bulk Density (ρk)

$\rho k = Wk / Vk$, g/cm^3

Wk: weight of solid
Vk: volume of solid

- Particle density-specific weight or specific gravity, (g/cm^3)
- The particle density of mineral soils on the surface of the earth is 2.5-2.8 g/cm^3, (average 2.66 g/cm^3)



Example:

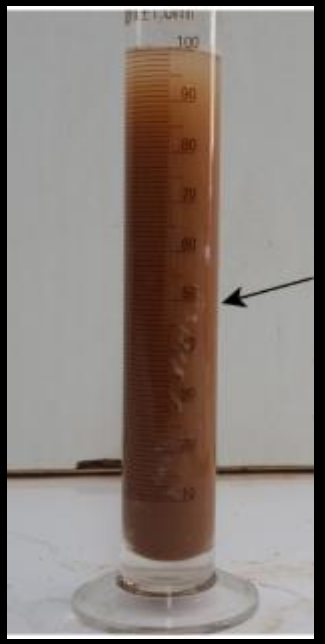
- Ideally, one-half of soil is solids, and one-half is pore space. This means 1 cm^3 volume consists of 0.5 cm^3 of pore space and 0.5 cm^3 of solids.
- Pore space filled with air weighs 0 g. Organic matter is ignored (very small portion of the solids),
- Multiplying particle density by the volume of solids you can reach to weight of solids;

  2.66 g /cm^3 x 0.5 cm^3 = 1.33 g
- The bulk density, then, is the dry weight of soil divided by the volume of soil;

  1.33 g / 1 cm^3 = 1.33 g/cm^3

How to Measure Particle Density (ρk)

- Weigh 100 g soil, (dry basis)
- Fill 500 cm^3 cylinder up to half with water,
- Transfer soil into the cylinder and shake
- Record the increase in the cylinder due to soil addition



Example:
- This increase is 38 cm3,
- ρk = 100/38
- ρk = 2.63

How to Measure Bulk Density (ρb)

(Weight of unit volume of dry soil in natural state including volume of pores in soil)

- Undisturbed soil sampling ring (V:100 cm^3)

- Insert sampling ring into soil and remove intact soil sample carefully
- Dry sampling ring at 105 ^{0}C overnight
- Weigh sampling ring (i.e. 130 g)

$$\rho_b = \frac{W_k}{V}$$

- ρb = 130 / 100
- ρb = 1,30 g/cm3

Texture – Bulk Density Relationships

good

Q: Make a comment between ''low/high'' ρb and;

- plant rooting depth
- available water capacity,
- soil porosity, plant nutrient availability,
- soil microorganism activity.

Toprağın Bünye Sınıfı	Ortalama Hacim Ağırlık gr/cm³
Organik topraklar	0.2-0.9
Kil topraklar	1.1-1.3
Milli-Kil topraklar	1.20
Kumlu-Kil topraklar	1.23
Kumlu-Killi-Tın topraklar	1.25
Killi-Tın topraklar	1.28
Tın topraklar	1.40
Kumlu-Tın topraklar	1.52
Tın-Kum topraklar	1.57
Kum topraklar	1.60

- Q: Why ρb of clay, sand and organic soils are so different?

A: loose, well aggregated, porous soils and those rich in organic matter have lower bulk density

A: Sandy soils have relatively high bulk density because total pore space in sands is less than clayey or silty soils.

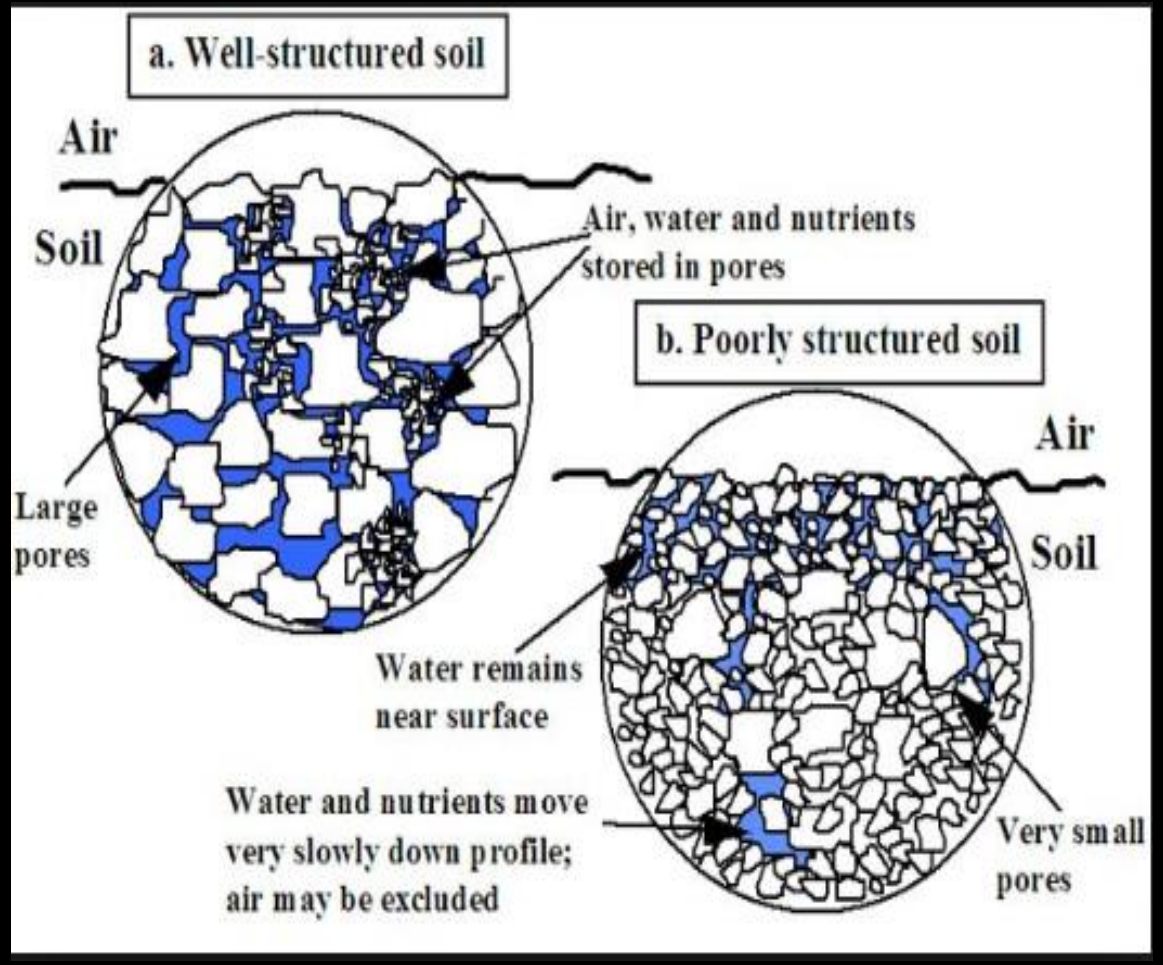
	low ρb	high ρb
Plant rooting depth		
Available water capacity		
Soil porosity		
Plant nutrient availability		
Microbal activity		

Soil Porosity
(amount of pores, or open space, between soil particles)

Soil with a 50% porosity, including both small and big spaces is physically ideal for agriculture.

Porosity %= 100 – $\frac{(\rho k)}{(\rho k \times 100)}$

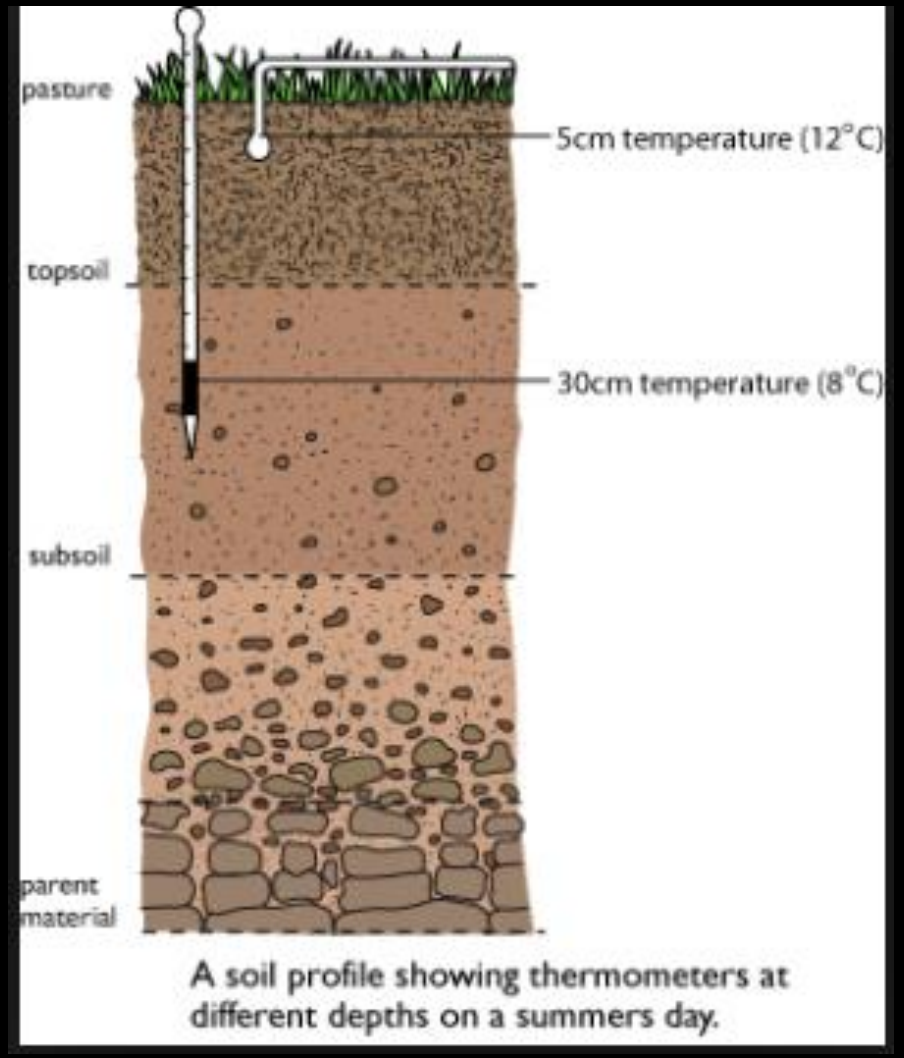
$$P = 1 - \left(\frac{\rho_b}{\rho_k} \right)$$



Soil Temperature

- ❖ Seed germination
- ❖ Plant development,
- ❖ Moisture content of soil
- ❖ Formation of soil structure
- ❖ Biological activities
- ❖ Decomposition of plant residues,
- ❖ Nutrient availability
- ❖ Rock wheathering

Are all related temperature changes in soil..

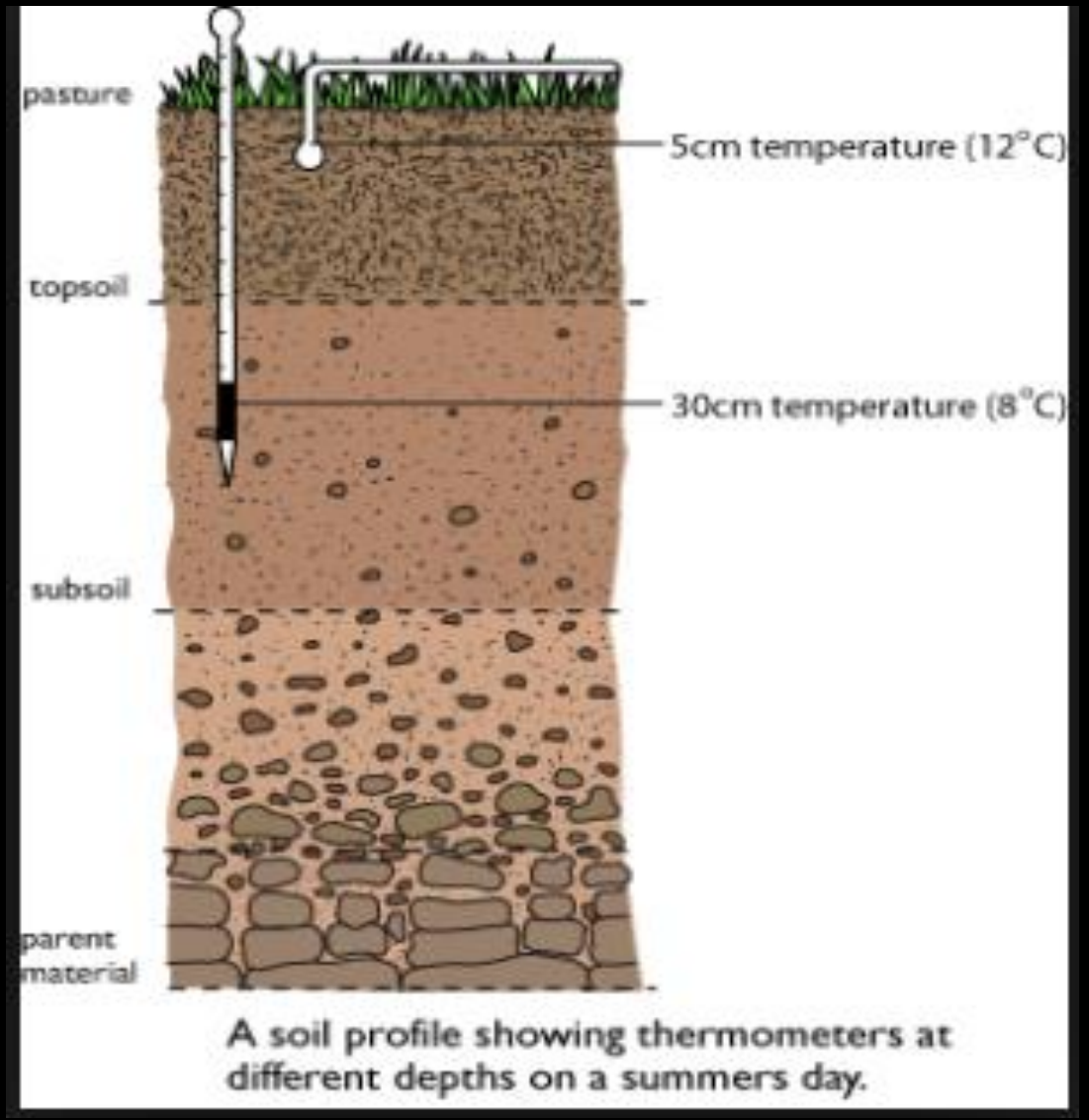


A soil profile showing thermometers at different depths on a summers day.

Soil Temperature

Factors affecting soil temperature:

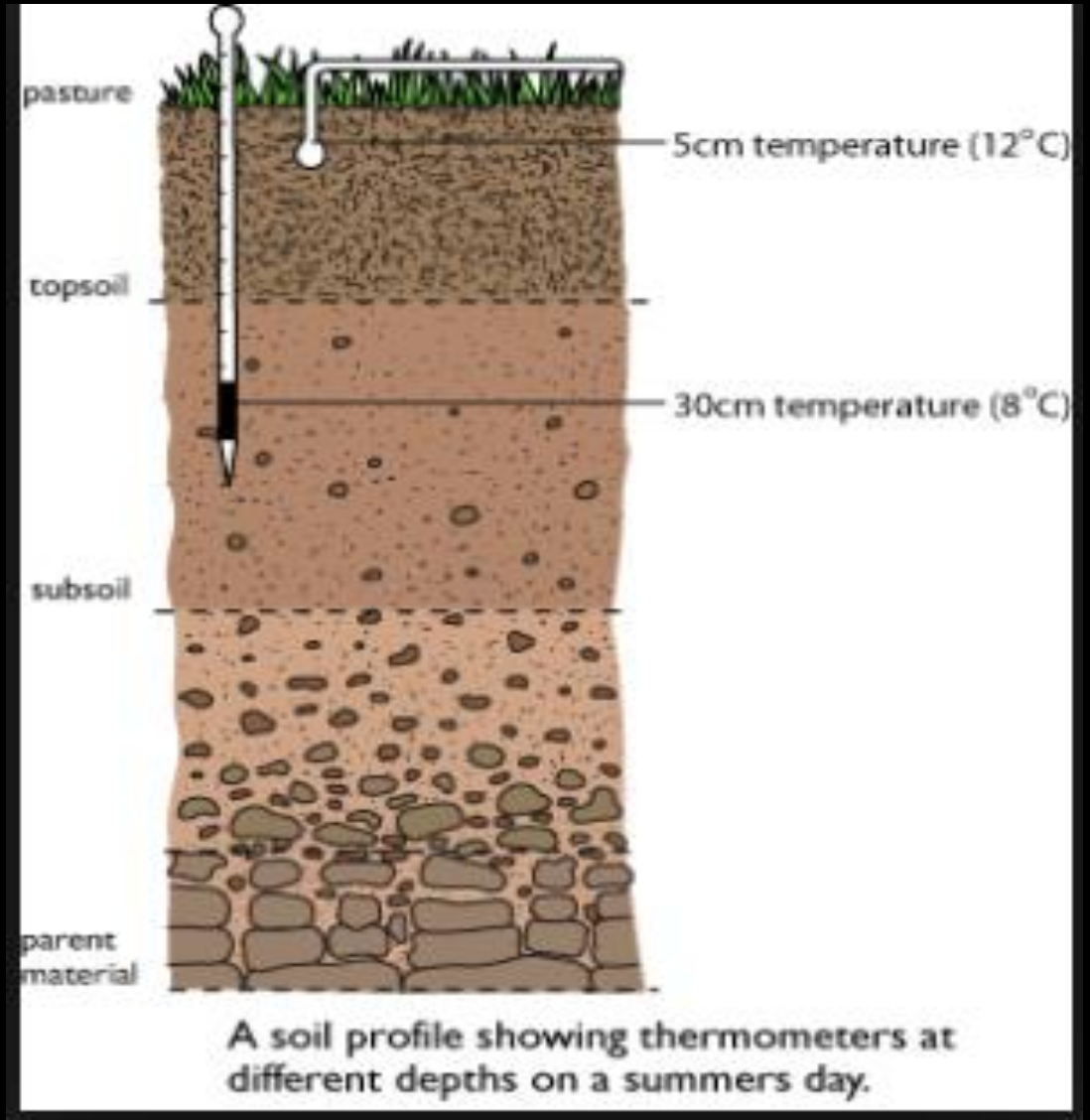
- The slope,
- Degree of altitude,
- Atmospheric events,
- Color of soil
- Soil structure,
- Soil porosity,
- Soil water,
- Plant cover,
- Snow cover.



A soil profile showing thermometers at different depths on a summers day.

Soil Temperature Management

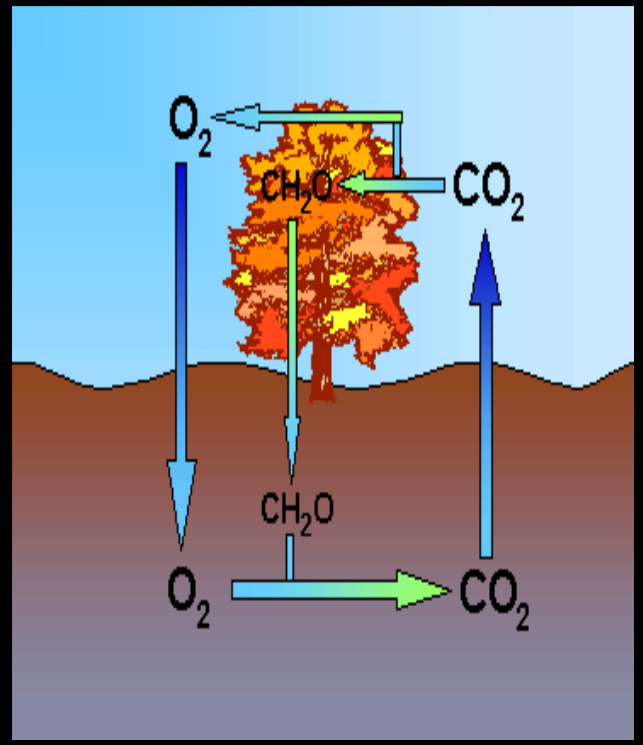
- Mulching
- Irrigation and drainage
- Soil surface management



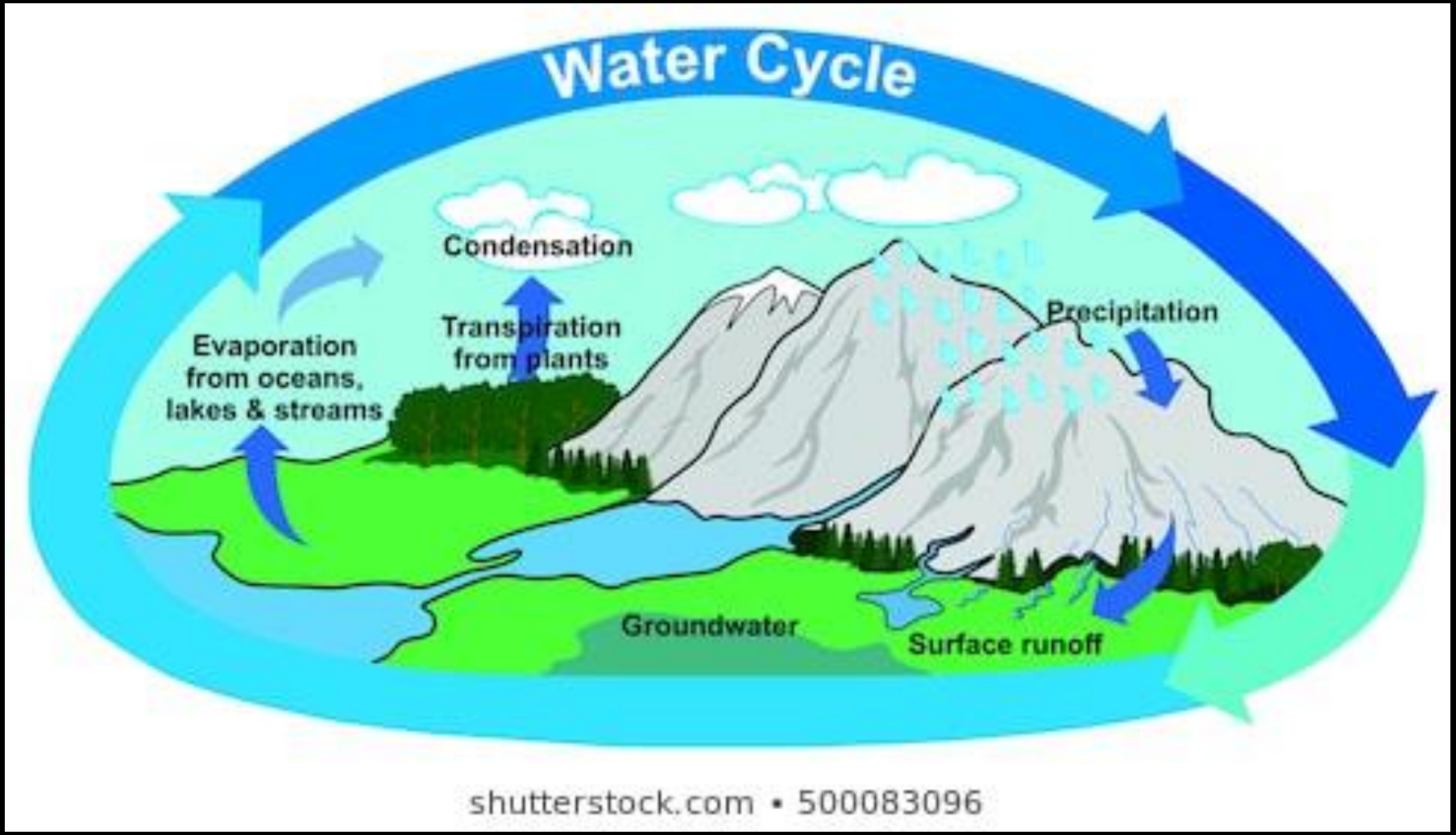
A soil profile showing thermometers at different depths on a summers day.

Soil Air

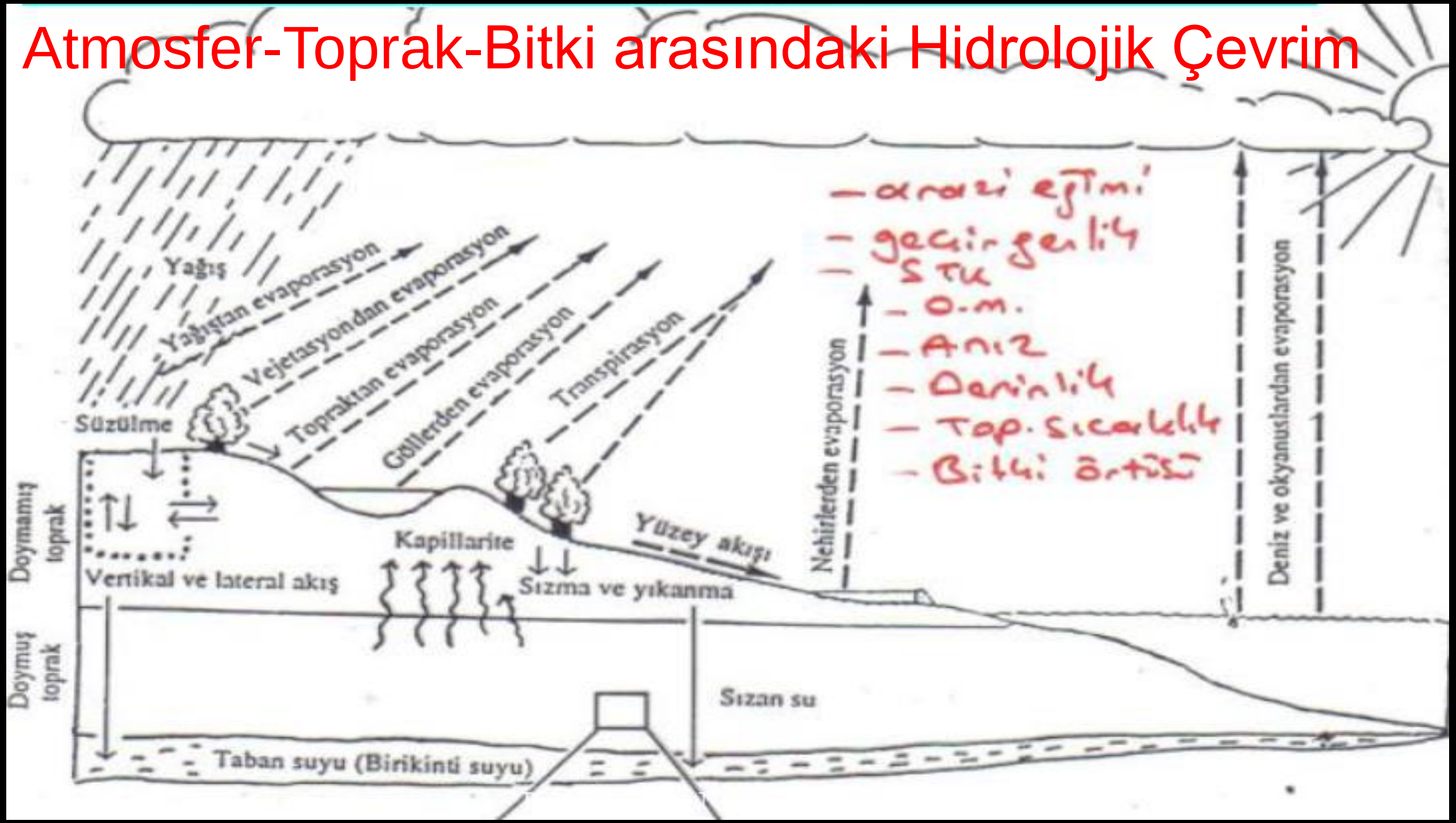
- Soil CO_2 > Air CO_2 (in general)
- Soil CO_2 in cultivated soils > Soil CO_2 in uncultivated
- Wet soil CO_2 > Dry soil CO_2 (due to limited difusion)
- CO_2 in heavy/clayey soil > Air CO_2 in coarsa/sandy soil
- Below Soil CO_2 > Above soil CO_2



Soil Water


Water Cycle
Condensation
Transpiration from plants
Evaporation from oceans, lakes & streams
Precipitation
Groundwater
Surface runoff
shutterstock.com • 500083096

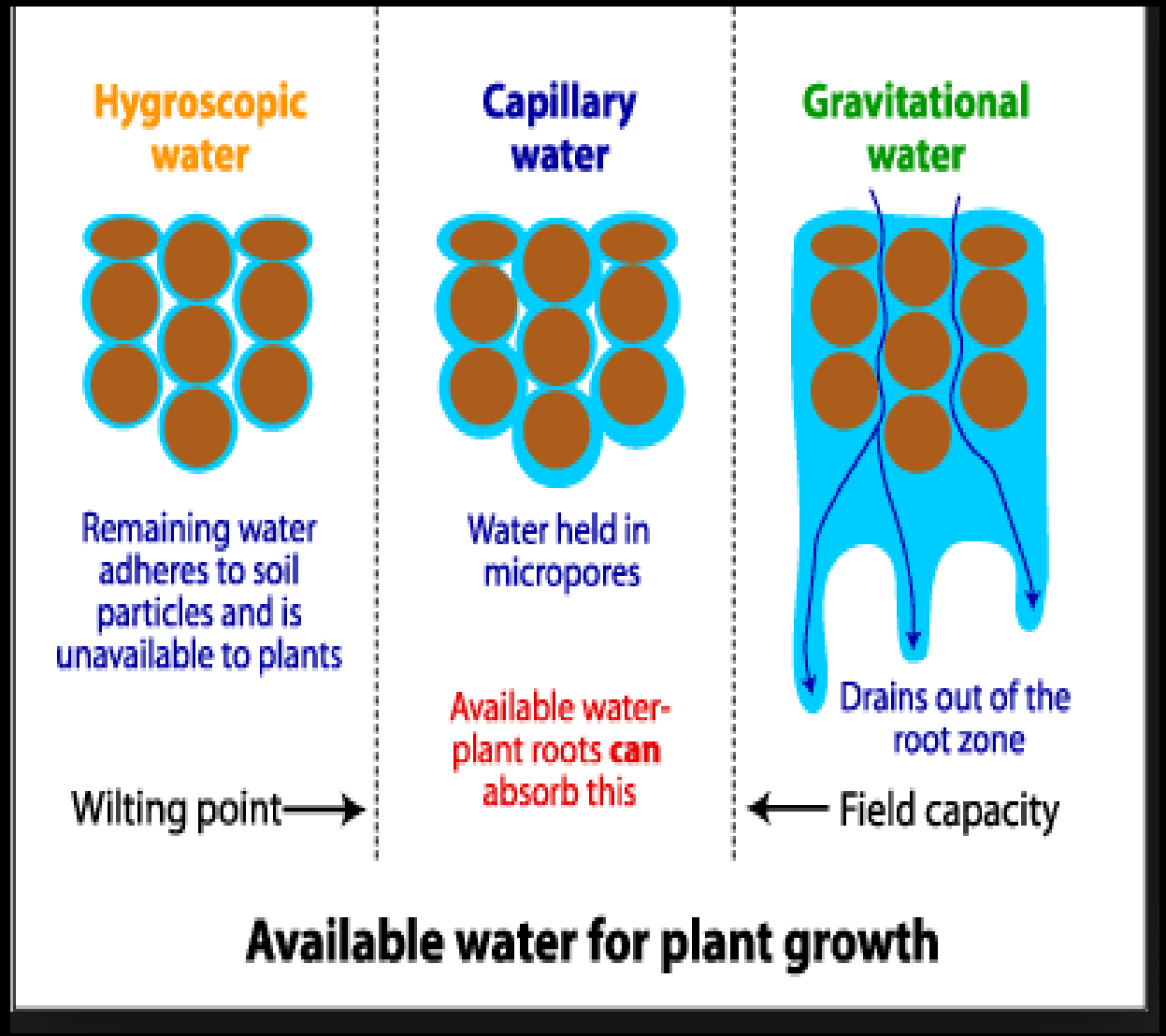
Atmosfer-Toprak-Bitki arasındaki Hidrolojik Çevrim



Soil Water

Functions of soil water in general:

- Formation of soil solution
- Spread of plant nutrient
- Germination timely
- Healthy plant growth



Important Facts about Soil Water

Two major forces to hold water in soil

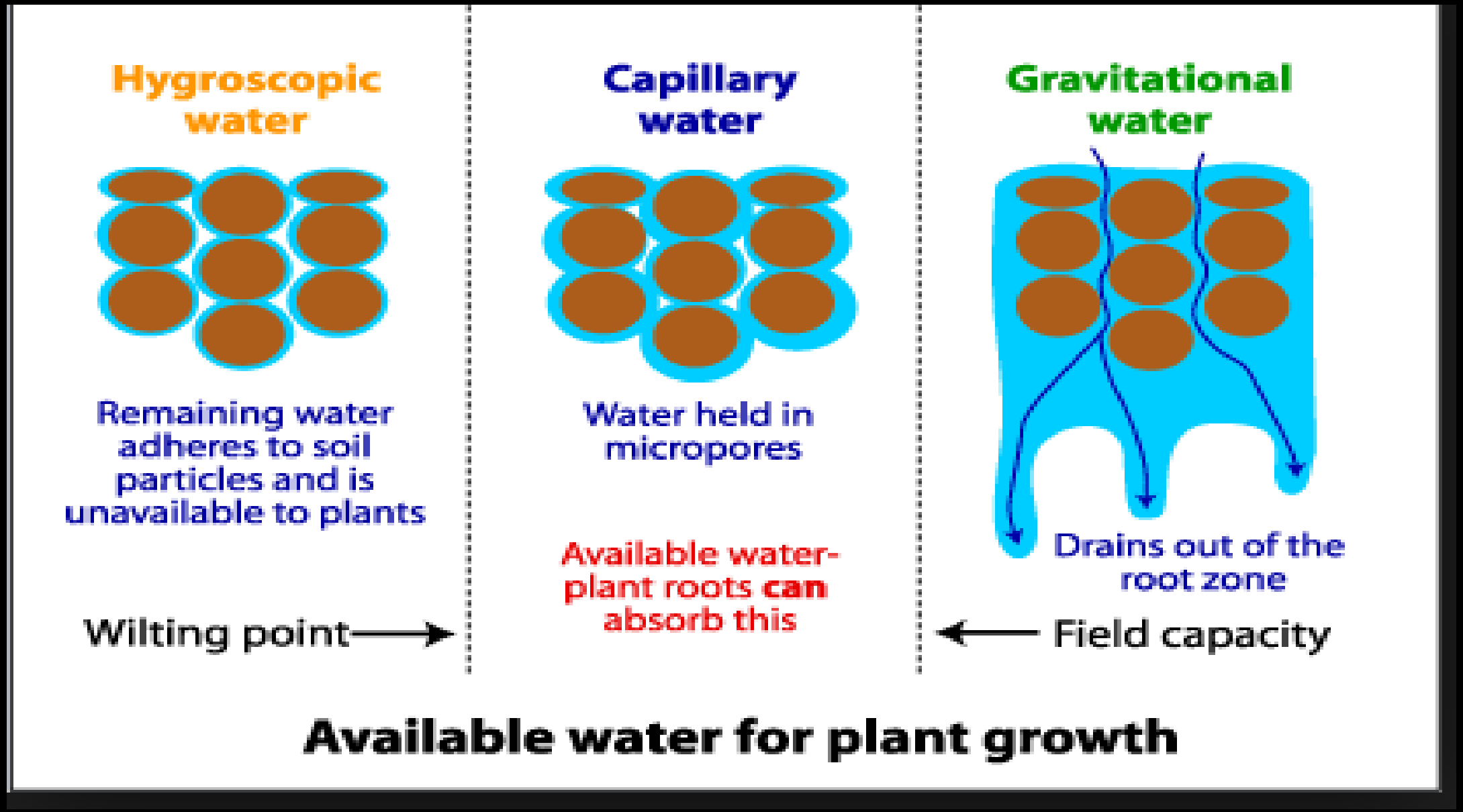
1) Adhesion: water molecules - other solid surfaces (about 50 atm)
2) Cohesion: between water molecules (where adhesion is absent)

Water holding energy of soil is defined as log of water column height (in cm) and indicated by ‘’pF’’ (where p: potential, F: energy of water)

pF= 10^7 cm water, $Log_{10}{}^7$= 7 (pF=7)

The max water suction is 10.000 atm in soil

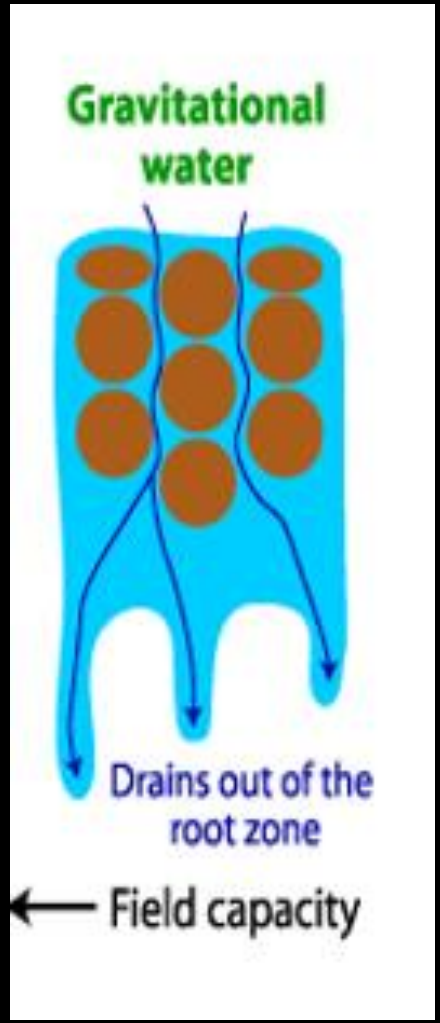
Soil Water Classification (!)



Gravitational Soil Water (GSW)

Amount of water that can move down the profile due to gravitation (up to 2.54 pF, 1/3 atm pressure)

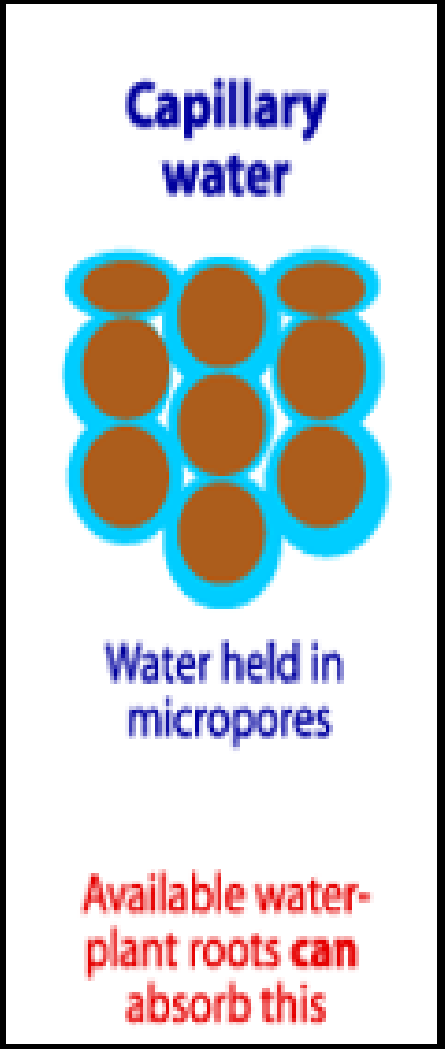
- Plant cannot use GSW
- It causes to rise in ‘’water table’’
- Drainage may be required to remove it from upper soil profile to do agriculture



Capillar Soil Water (CSW)

Level of water held in small soil pores (<30 μ), following percolation of excess (gravitational) water

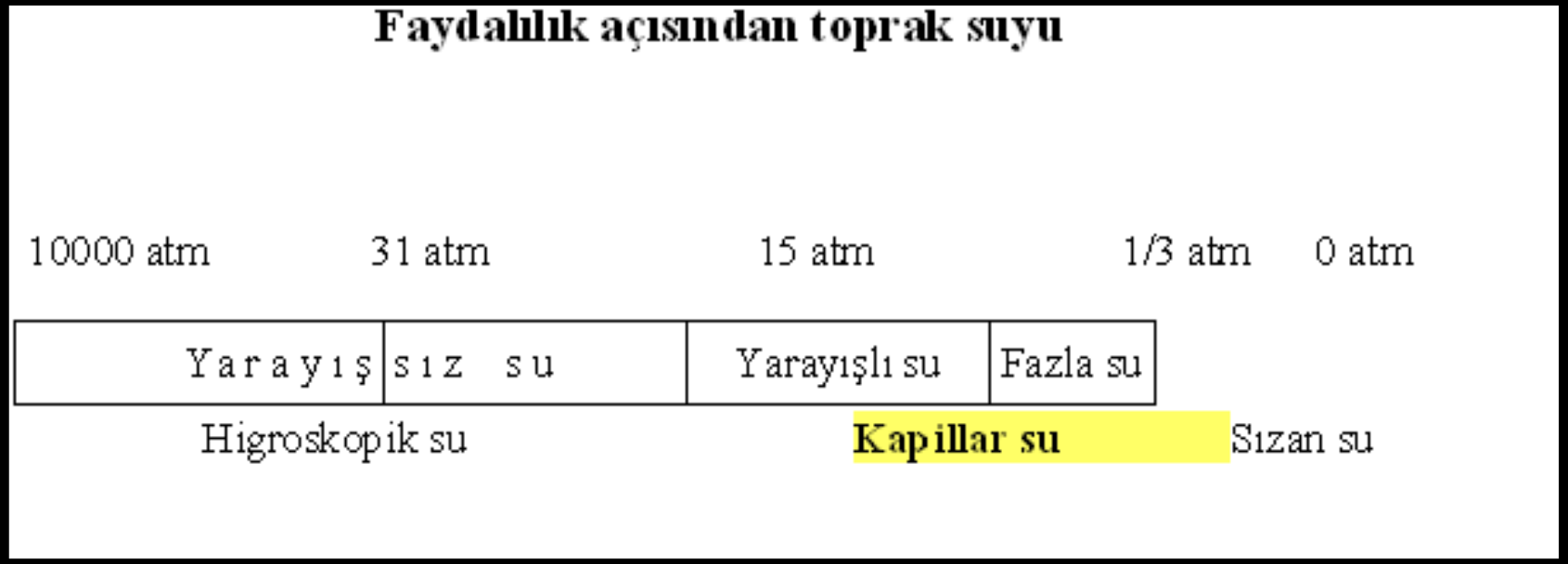
- CSW is driven by adhesion and cohesion forces between 1/3 to 31 atm (or 2.54-4.5 pF) pressure
- CSW is ‘’plant-available’’ water fraction
- Light textured soils have a high ‘’capillar porosity’’ therefore ……????
- Soil temperature, texture, structure and organic matter affects CSW



Hygroscopic Soil Water (HSW)

Level of water held on colloidal soil surfaces with a pressure higher than 31 atm (4.5 pF)

- HSW can be considered as the amount of water held in dried clothes
- No available for plant use



Terms defining the limits of different water levels in soil

Field Capacity (1/3 atm or 2,54 pF) refers to level of water held by soil surfaces after percolation of gravitational water

- ❖ FC of clayey soils is ……., than coarse textured soils.
- ❖ High organic matter in soil means …….. in terms of FC of soil

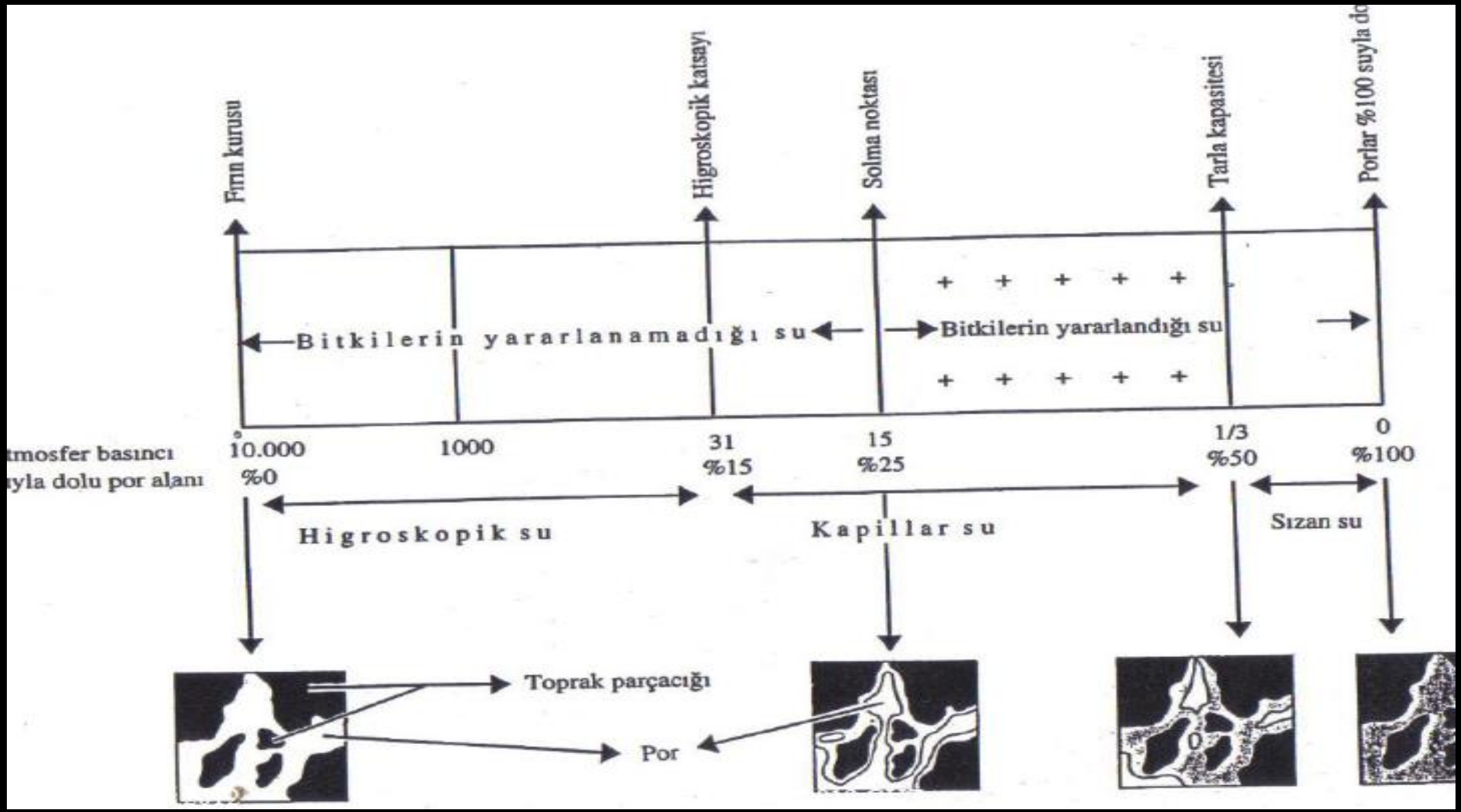
Wilting Point (15 atm or 4,2 pF) refers to level of water at which the plant start to die due to water scarce

- ❖ Definitely need irrigation to grow plant if water level is WP (EMERGENCY!!)

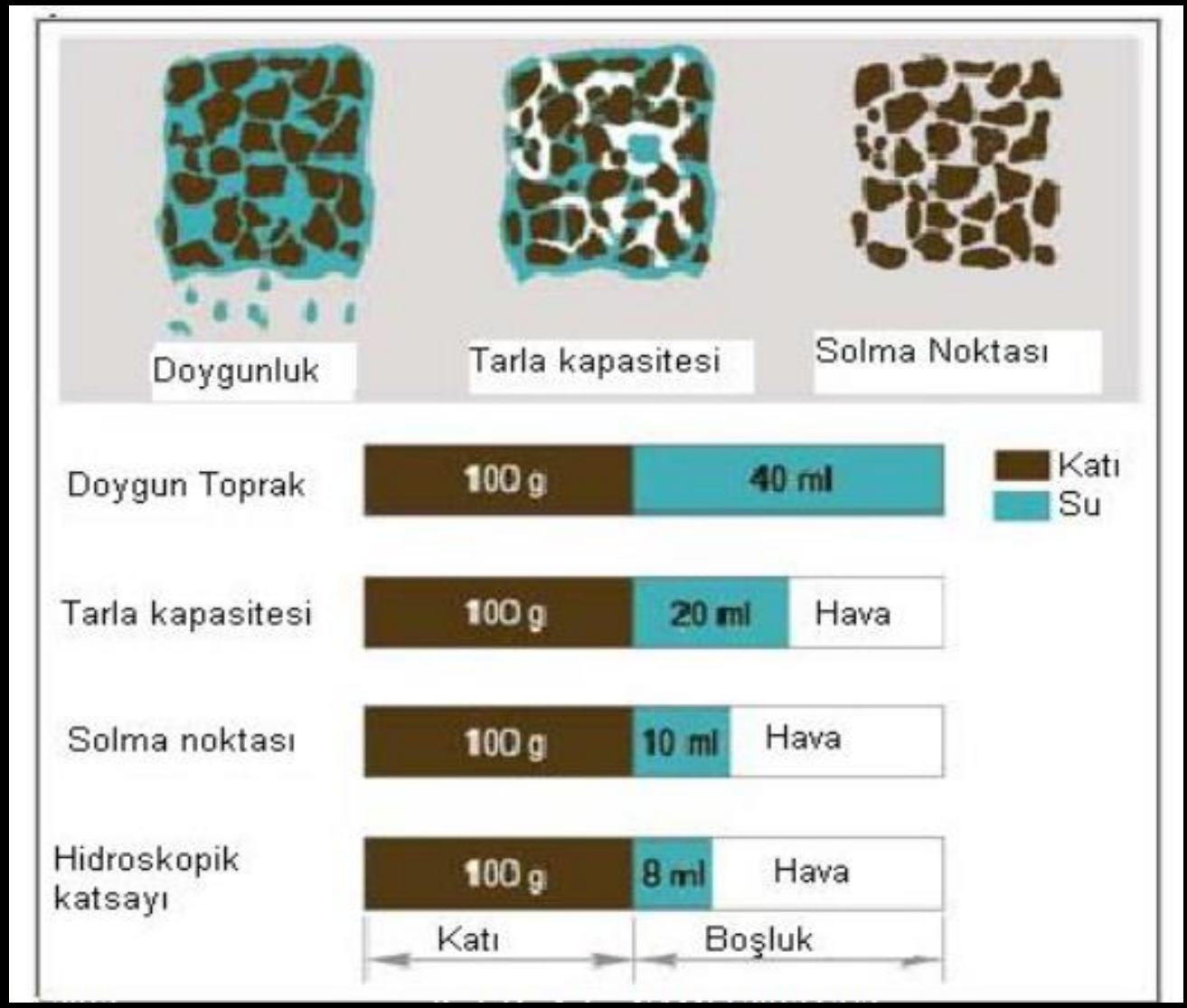
Plant Available Water (1/3-15 atm or 2.54-4,2 pF) refers to the amount of water held in soil between level of FC and WP

- ❖ $PAW_{\%} = FC_{\%} - WP_{\%}$

Soil Water Classification



Soil Water Classification



Soil Moisture

Functions of soil water:

- ❖ Formation of soil solution
- ❖ Spread of plant nutrient
- ❖ Germination timely
- ❖ Healthy plant growth

The amount of water held in unit mass or volume of soil is defined as ‘’soil moisture’’.

- Moisture content, w(%)

$$w(\%) = \frac{M_w}{M_s} \times 100 \quad \textit{but not} \quad \cancel{\frac{M_w}{M_T}}$$

Mw: water content (in mass) present at the time of sampling
Ms: weight of soil particles (dried at 105 ° C)

Why do we need to know all these things about soil water ?

- We need to know how to manage ‘’evaporation from soil surface’ in arid, semi-arid regions i.e. Central Anatolia, Turkey

- No way out except for irrigation below 600 mm rainfall

- Succesful Breeding and Growth of wheat, barley, corn etc

- Water control by effective weed management
-
- Water protection strategies
    - Soil tillage methods
    - Fallow (left untilled or unsowed after plowing)
    - Mulching (use of plant residues or other suitable materials on the soil surface, primarily to prevent evaporation of water and erosion of soil)

Fallow

Mulching

Mulching