Lecture 4 and 5

TOPICS

- **PHYSICAL PROPERTIES OF SOIL**

Soil physics is a branch of soil science which study of soil physical properties (e.g., texture, structure, water retention, etc.) and processes (e.g., aeration, diffusion, etc.).

Soil physics deals with the dynamics of physical soil components and their **phases** as **solid, liquids** and **gases.**

The most common soil physical processes are:	The most important soil physical properties are: Soil
1- Physical weathering 2- Soil compaction 3- Leaching 4-Infltration 5- Percolation 6- Aeration 7- Diffusion	1- color 2- texture 3- structure 4- density, 5- porosity 6- water 7- air

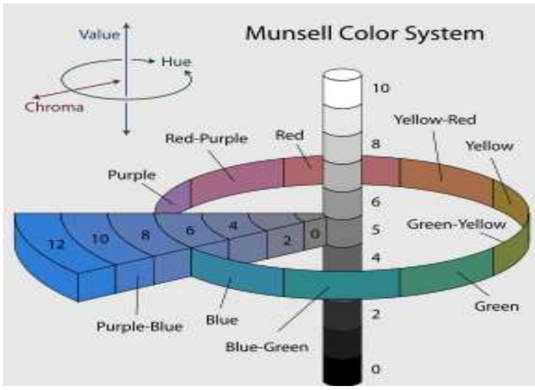
1- Soil Color

Soil color is one physical property that can be used to describe soil horizons and soil morphology. The soil color does not affect the behavior of the soils, but provides insights into environmental conditions, formation processes, and other influences on the soil.

Soil color is described by the parameters called hue, value and chroma.

- **Hue** represents the dominant wave length or color of the light.
- **Value** refers to the lightness of the color.
- **Chroma** relative purity or strength of the color.

The color of the soil in terms of the above parameters could be quickly determined by comparison of the sample with a standard set of color chips mounted in a note-book called MUNSELL.



2- SOIL DENSITY

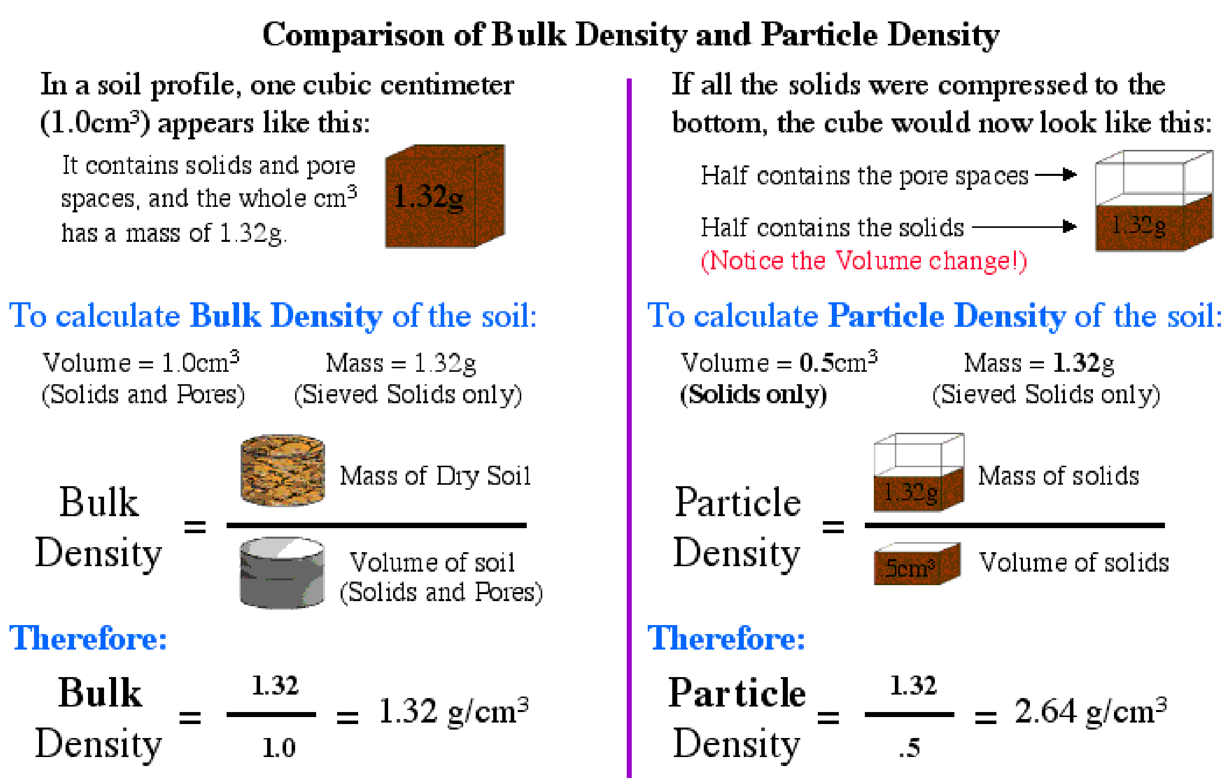
1- **Particle density:** defined as mass of solid divided by the volume of solid

$$\text{PARTICLE DENSITY } (PD) = \frac{mass\ of solid(g)}{volume\ of\ solid(cm3)}$$

2- Bulk density: mass of solid divided by the volume of the whole soil (solid + pores

$$\text{BULK DENSITY } (BD) = \frac{mass\ of solid(g)}{soil\ volume\ (cm3)}$$

- Particle density is the density of soil solids, which is assumed to be constant at 2.65 g/cm^3.
- Bulk densities of mineral soils are usually in the range of 1.1 to 1.7 g/cm3.
- Typical soil with 50% solid and 50% pore by volume, bulk density is around 1.33 g cm $^{-3}$



Examples:

1- Calculate the bulk density of a 400 cm^3 soil sample that weighs 575 g (oven dry weight).

$$B.D.= M_s/V_s = 575g/400cm^3 = 1.44g/ cm^3$$

2- Calculate the bulk density of a 400 cm3 soil sample that weighs 600 g and that is 10% moisture.

Oven dry wt. = A. Ds/ 1+W% = 600/1.1

Oven dry wt. = 600/1.1 = 545.45

$$B.D.= M_s/V_s = 545.45g/400cm^3 = 1.36 g/cm^3$$

3- Calculate the bulk density of a rectangular soil sample with dimensions 12 cm by 6 cm by 4 cm that is 15% moisture content and weighs 320 g.

Vol. of soil = 12cm x 6cm x 4cm = 288cm^3

Oven dry wt. = 320/1.15 = 278.26gm

$$B.D.= M_s/V_s = 278.26/288 = 0.96g/cm^3$$

Factors influencing bulk density

1- Soil with high ratio of pore to solid has higher bulk density.
2- Texture: fine textured soils have lower bd compared to coarse textured soils- why?
3- Depth in soil profile: bd increases with depth. Why?
4- Organic matter content

What is the importance of soil bulk density?

Bulk density reflects the soil's ability to function for structural support, water and solute movement, and soil aeration.

General relationship of soil bulk density (g/cm3) to root growth based on soil texture.		
Soil Texture	**Ideal bulk densities for plant growth**	**Bulk densities that restrict root growth**
Sandy	**< 1.60**	**> 1.80**
Silty	**< 1.40**	**> 1.65**
Clayey	**< 1.10**	**> 1.47**

Bulk density Increases with compaction and tends to increase with depth and it is resulted in reduces the uptake of water and nutrients by plants

3-Soil Water (Liquid Phase)

- **Soil water:** It refers to water contained within or flowing through the soil profile.
- **Soil water** occupies micro and macro pores.
- **In saturated** soil both pores are occupied by water.

In soil water is adsorbed by soil moisture tension.

- **In dry** soil water is adsorbed at high tension and it occupies the micro pores.
- **In wet** saturated soil water is held by weaker soil

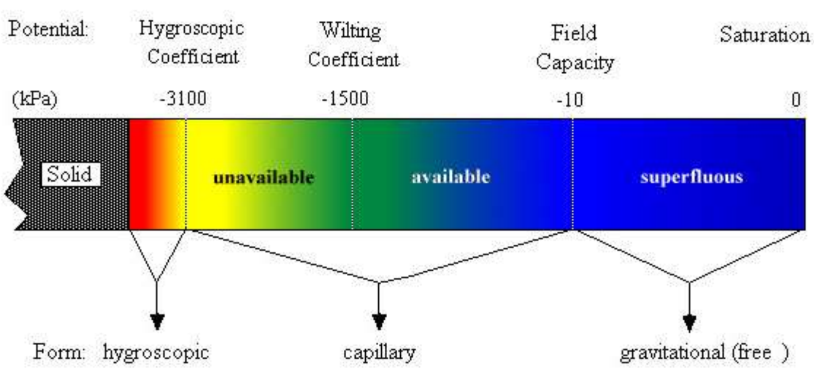
Soil moisture is very important because it affects plasticity, soil consistency, soil conductivity, soil aeration, temperature, nutrient movement.

Water is essential to plants for these reasons:

1- It constitutes 80%-95% of the plant's protoplasm.
2- It is essential for photosynthesis.
3- It is the solvent in which nutrients are carried to, into and throughout the plant.
4- It provides the turgidity by which the plant keeps itself in proper position
Regulate plant temperature.

Soil water types or Classification of soil water:

Classification of soil water



Saturation Point: It is the soil water content when all pores are filled with water (Maximum water holding capacity). It occurs immediately following irrigation

Field Capacity: is the amount of soil moisture or water content held in the soil after excess water (extra water) has drained away and Soil is holding maximum amount of water available to plants

Permanent Wilting Point: Amount of water in soil when plants begin to wilt. Plants can no longer recover from wilting roots.

Available Water: the amount of water between field capacity and wilting point.

Water table, also called Groundwater Table, upper level of an underground surface which the soil is saturated with water.

Measuring soil water

1- Tensiometers: This tension is a direct measure of the availability of water to a plant.

2- Electrical Resistance block

- Measures the conductivity through a block of gypsum or other buffering material. More water the less resistance. This device can easily be hooked to a watering device to automatically water a given field.

3- Gravimetric Measurements:

Weight difference between wet soil and oven dried soil = percentage of weight of the water.

$$P_w = \frac{\text{(Mass of wet soil – Mass of oven dry soil)}}{\text{Mass of oven dry soil}} \times 100$$

4- Volumetric

The volume of water in a given volume of soil (m^3 of water per m^3 of soil).

$$P_v = \frac{(\text{Volume of Water in } cm^3)}{(\text{Volume of soil in } cm^3)} \times 100$$

Or

$$P_V = P_w \times \text{Bulk density}$$

A soil sample has a weight of 0.7 kg and the volume was found to be 3.5×10^{-4} m^3 after drying out the weight was reduced to 0.6 kg. Determine the water content.

Mass of water = weight of soil – oven dry weight of soil = 0.7 kg - 0.6 kg = 0.1 kg

$$P_w = M_w/M_s \times 100 = 0.1/0.6 \times 100 = 14.3\%$$

From the above example calculate volume moisture content; assume that particle density of soil 2.64 kg/m^3

$$P_v = \frac{(\text{Volume of Water in } cm^3)}{(\text{Volume of soil in } cm^3)} \times 100$$

Vw = Mw because density of water is equal 1

P_d = Ms/Vs → 2.64 = 0.6/vs

Vs = 0.6 / 2.64 = 0.227m^3

:. **P_v = 0.1/0.227 X100= 44%**

Available water capacity or **available water content** (**AWC**) is the range of available water that can be stored in soil and be available for growing crops.

AWC = FC - WP
= - 0.33 bar - (- 15 bar)

Factors that affecting the soil water content:

I. **Texture.**
II. **Structure –** total and distribution of pore space (macro and micro pores)
III. **Organic matter content.**
IV. **Salt content.**

4- Soil Texture

Soil texture is a term used to describe the distribution of the different sizes of mineral particles in a soil. Or it is the relative amounts of sand, silt, and clay in a soil.

Texture is the single most important physical properties. It can give you information on: It affects soil behavior and soil management.

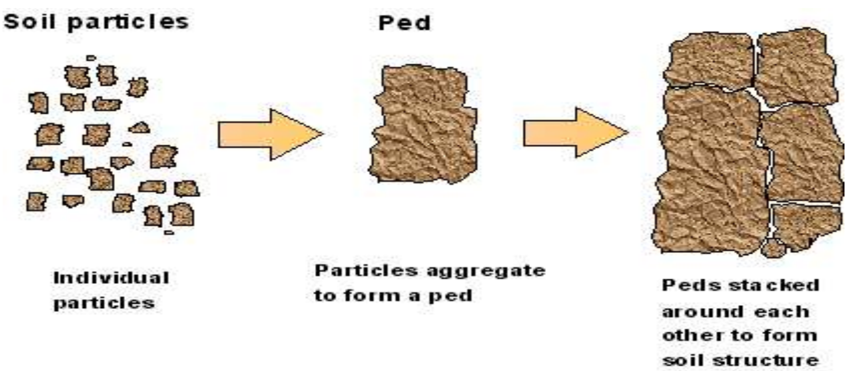
1) **Water flow potential.**
2) **Water holding capacity and movement.**
3) **Potential fertility.**
4) **Suitability for various uses like support capacity.**
5) **Soil aeration and porosity.**

TEXTURE TRIANGLE is used to describe equal properties of sand, silt, and clay in a soil sample, and lends to the naming of even more classifications, e.g. "clay loam" or "silt loam".

5-Soil Structure: The arrangement of sand, silt, and clay particles to form larger aggregates or peds.

Structure formation by:

- **Flocculation (sodium, calcium, polymer)**
- **Organic (humus)**
- **Non-organic (salt, $CaCO_3$)**
- **Biological activity (worms, roots)**



Characteristics of soil structure

1- ***Type***: Shape of aggregates
– Granular, *Crumbs*, *blocky*, *prismatic*, *platy.*

2- ***Size***:
– fine (micro aggregates) <0.25 mm
– coarse (macro aggregates) >0.25 mm

3- ***Degree of structure***:
– Without st., weak st., highly developed st.

4- ***General***
– Lots of clay strong structure, big blocks
– Lots of organics crumby structure

Soil structure types are:

Type	*Description*
Granular	Rounded surfaces
Crumb	Rounded surfaces but larger than granular
Subangular blocky	Cube-like with flattened surfaces and rounded corners
Blocky	Cube-like with flattened surfaces and sharp corners
Prismatic	Rectangular with a long vertical dimension and flattened top
Columnar	Rectangular with a long vertical dimension and rounded top
Platy	Rectangular with a long horizontal dimension
Single grain	No aggregation of coarse particles when dry
Structureless	No aggregation of fine particles when dry

6-Porosity: Pore space is that part of the bulk volume that is not occupied by either mineral or organic matter but it is open space occupied by either gases or water. Ideally, the total pore space should be 50% of the soil volume.

- SOIL POROSITY, defined as pore volume divided by total soil volume (solid and pore)
- Under field conditions, pore space is filled with a variable mix of water and air:
- **INVERSE RELATIONSHIP WITH BULK DENSITY**
    - If soil particles are packed closely together, total porosity will be low and bulk density will be high.
    - If soil particles are arranged in porous aggregates, total porosity will be high and bulk density will be low.

Porosity value generally ranges from 0.3 to 0.6 (30–60%).

In clayey soils, the porosity is highly variable because the soil alternately swells, shrinks, aggregates, disperses, compacts, and cracks

Factors influence soil porosity?

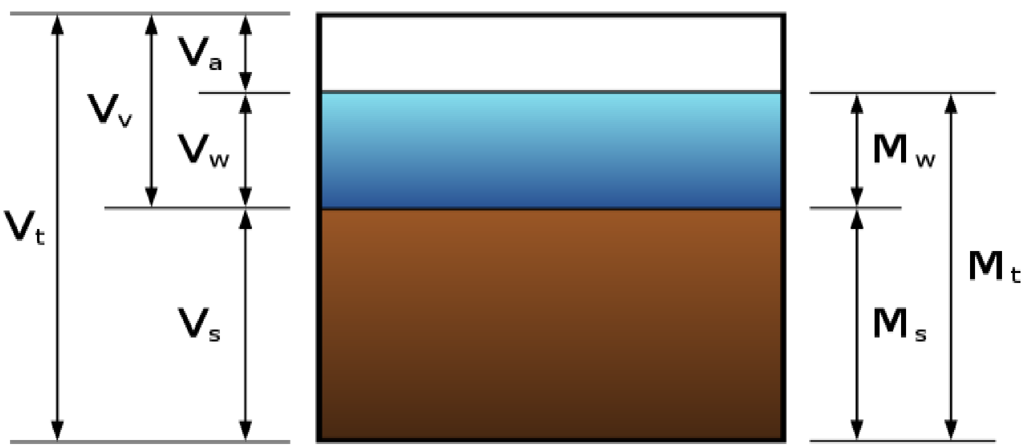
- Texture, Structure, Organic matter, tillage and macro organisms (ie. Earthworm)

How to calculate Porosity (f) and Void Ratio (e)?

Porosity = Pore Volume / Bulk Volume. To express that value as a percent, you would multiply it by 100%

1- **Porosity f** = Vf/Vt = (Va + Vw)/(Vs + Va + Vw)
2- **% Porosity f** = (1- Bulk density / Particle density) X 100
3- **Void ratio e** = Vf/Vs = (Va + Vw)/ (Vt - Vf)

Soil composition by phase: s-soil (dry), **v**-void (pores filled with water or air), **w**-water, **a**-air. **V** is volume, **M** is mass.



Examples:

1- Calculate the porosity (n) of a 250 cm³ clod that contains 140 cm³ water when its saturated.

Porosity = $V_{air} + V_{water}/V_{total}$ = $140cm^3/250cm^3$ = 56%

2- Calculate the porosity of a soil sample that has a bulk density of 1.35 g/cm³?

Answer: we can assume that particle density is 2.65 g/cm³.

Porosity = $(1-(B_d/P_d))$ x 100 = (1-(1.35/2.65)) x 100 = 49%.

3- Calculate the porosity of a 250 g sample that contains 65 g of water when 55% of the pores are full of water.

Types of soil porosity

1- Micropores: Pores smaller than about 0.05 mm (or finer than sand) in diameter are typically called ***micropores.***
2- Macropores: Pores larger than 0.05 mm are called *macropores.*

7- Soil Air (Gases): They are the gases found in the air space between soil components.

- The primary natural soil gases include nitrogen, carbon dioxide and oxygen.
- The oxygen is critical because it allows for respiration of both plant roots and soil organisms.

Soil air is Important for the following:

1- Required for root growth
2- Required by soil organism such as fungi, worms, bacteria etc.
3- Affect soil reaction – oxidation and reduction.
4- The content of water in soil depends on air content. Under normal condition:

e.g. : loam soil 50% solid, 25% air and 25% water.

Aeration is affected by

1- Pore space: total distribution of micro and macro.
2- Water content.

Aeration can be improved by

1. Cultivation – plowing.

2. Improve drainage.

3. Improve soil structure.