

PHYSICAL AND CHEMICAL PROPERTIES OF SOIL



**GEOGRAPHY SEMESTER 4(CBCS) _
CC PAPER_10_UNIT_1_TOPIC 3&4**

Presented and Compiled By

**Dr. Rajashree Dasgupta
Asst. Professor,
Dept. of Geography**

**Government Girls' General Degree College,
Kolkata -23**

WHAT IS SOIL?

- ▶ **Soil is a collection of natural bodies of earth's surface, in places modified or even made by man or earthy materials, containing living matter and supporting or capable of supporting plants outdoors.**



Physical properties of soil

1. Soil Texture
2. Soil Structure
3. Soil Density
4. Soil Porosity
5. Soil Consistance
6. Soil Colour



Soil Texture

- Texture refers to the relative proportion of sand, silt and clay in a soil.
- Soil containing equal amount of sand, silt and clay is called “loam”.

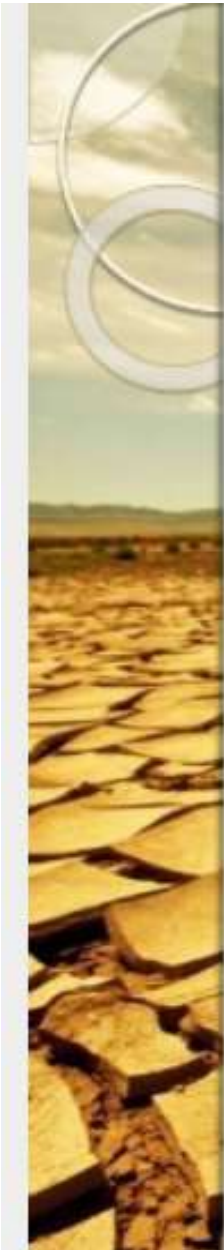
sand + clay + silt = Loam

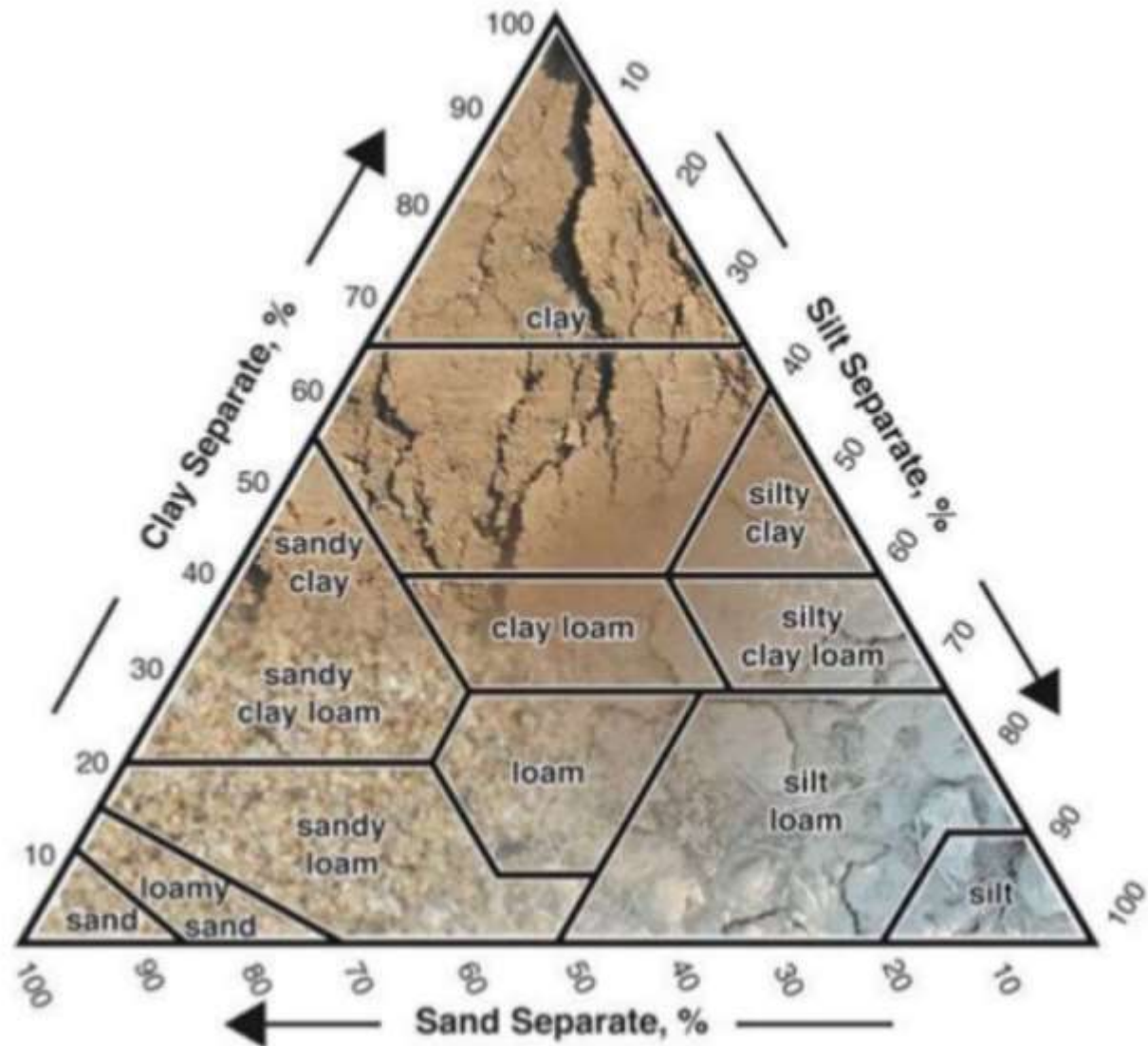
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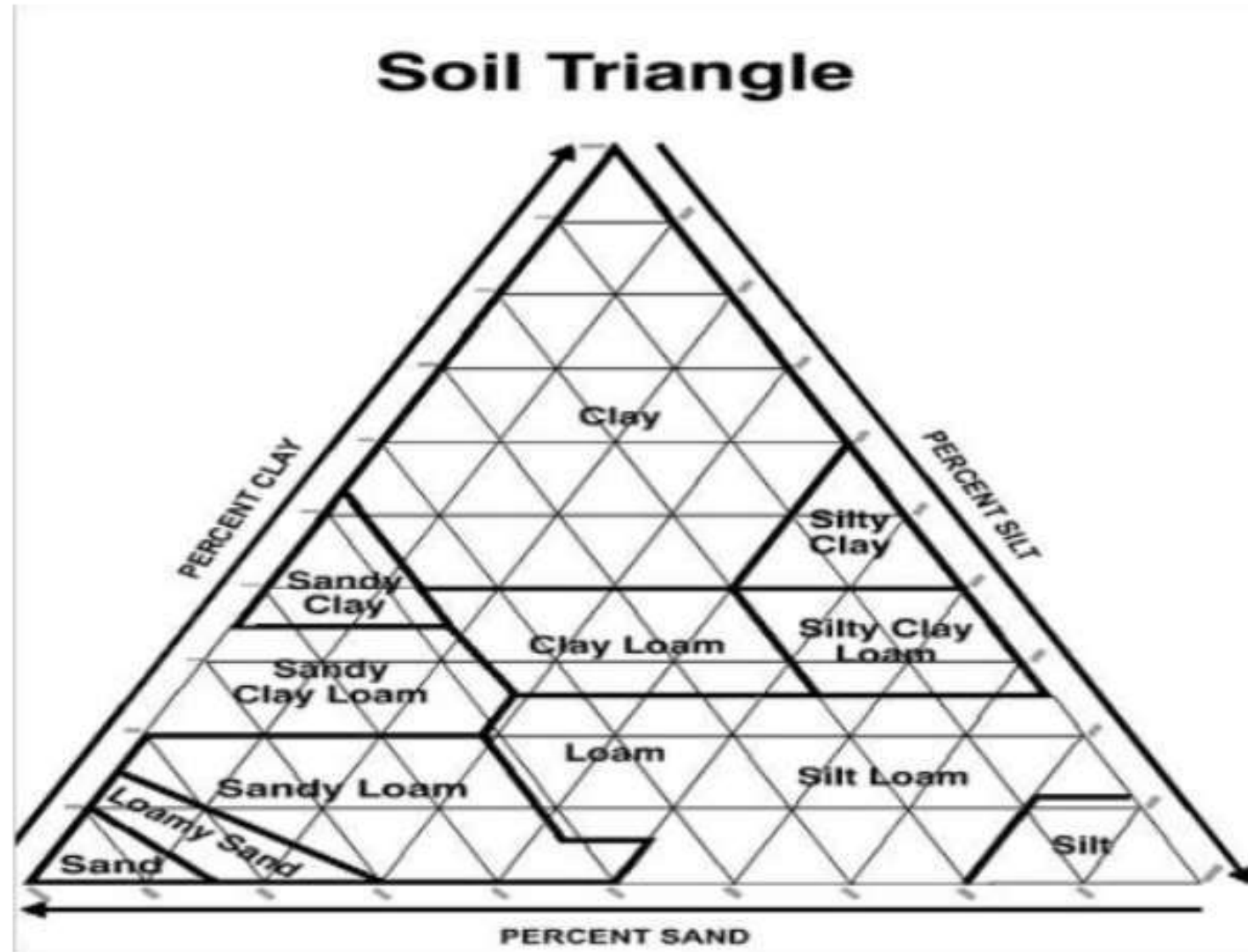
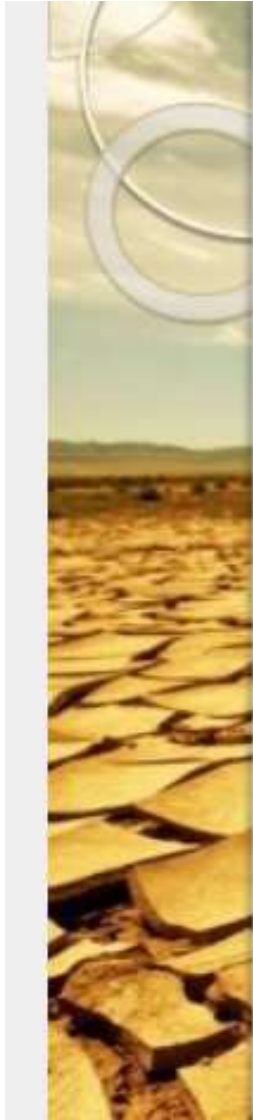
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For ex. 15 % clay, 20% silt and 65% sand is called “sandy loam”.









Soil Texture: (mm)

size

- Clay <0.002
- Silt 0.002- 0.02
- Sand fine 0.02-0.2
- Sand coarse 0.2-2.0
- Gravel fine 2.0-5.0
- Gravel coarse >5.0



Soil texture could be estimated by

Feel method :

- In the feel method soil is moistened with water and rubbed with finger and thumb.
- The way the wet soil “slicks out” gives a good idea of the clay content.
- The sand particles are gritty.
- The silt has a floury or talcum - powder feel when dry and is only moderately plastic and sticky when wet.



Soil Structure:

- The term texture is used in reference to the size of individual soil particles but when the arrangement of the particles is considered the term structure is used.
- Structure refers to the aggregation of primary soil particles (sand, silt and clay) into compound particles or cluster of primary particles which are separated by the adjoining aggregates by surfaces of weakness.
- Structure modifies the effect of texture in regard to moisture and air relationships, availability of nutrients, action of microorganisms and root growth.
- E.g. a highly plastic clay (60% clay) is good for crop product if it has a well developed granular structure which facilitates aeration and water movement.
- Similarly a soil though has a heavy texture, can have a strongly developed structure, thus making it not very satisfactory for aquaculture as a result of this soil allowing high seepage losses.
- Structure is defined in terms of grade, class and type of aggregates.



Crumb or granular



Platy



Blocky



Prismatic or columnar



Common Types of Soil Structure



GRANULAR



CRUMB



PLATY



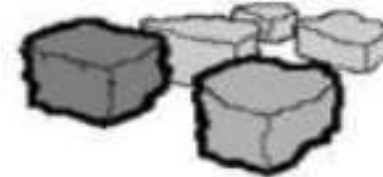
PRISMATIC



MASSIVE



COLUMNAR



BLOCKY



SINGLE GRAIN



Concept of Available Soil Moisture for Crops.

1. The range of available water that can be stored in soil and be available for growing crops is known as available soil water/moisture.
2. It is the difference between the amount of water in the soil at field capacity and the amount at the permanent wilting point referred to as the available water or moisture.
3. Readily available water (RAW) is that portion of available water which the crop uses without affecting its evapotranspiration and growth. This portion is often indicated as a fraction of available water which is dependent primarily on the type of crop and evaporative demand.
4. Many shallow rooted crops, such as most vegetables, require high moisture levels for acceptable yields. Deeper rooted crops will generally tolerate higher depletions.
5. The water readily available to plants is the difference between water content at field capacity (θ_{fc}) and permanent wilting point (θ_{pwp})

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

The term availability involves two notions:

(a) The ability of plant root to absorb and use the water with which it is in contact and

(b) The readiness or velocity with which the soil water moves in to replace that which has been used by the plant.

7. The water is readily absorbed by the plant roots between field capacity (-0.33 bar) to Permanent wilting point (-15 bar).

Field Capacity:

a. Field capacity is the amount of soil moisture or water content held in soil after excess water has drained away and the rate of downward movement has materially decreased, which usually takes place within 2-3 days after a rain or irrigation in pervious soils of uniform structure and texture.

The physical definition of field capacity (expressed symbolically as θ_{fc} “the bulk water content retained in soil at -33 J/kg (or -0.33 bar) of hydraulic head or suction pressure”).

b. Field capacity (FC) is the amount of water that a soil can hold against drainage by gravity. This usually occurs between 1/10 atm. (coarse soils) and 1/3 atm (heavy soil).

c. Field capacity is considered as upper limit of available water.

d. Field capacity is characterised by measuring water content after wetting a soil profile, covering it (to prevent evaporation) and monitoring the change in soil moisture in the profile. Water content when the rate of change is relatively small is indicative of when drainage ceases and is called Field Capacity, it is also termed drained upper limit (DUL).

Permanent Wilting Point (PWP) or Wilting Point (WP):

- a. The soil moisture content at which the plant will wilt and die. While there still may be water in the soil, the plant is not able to extract sufficient water from the soil to meet its needs.
- b. Permanent wilting point (PWP) is the moisture content of a soil at which plants permanently wilt and will not recover. This occurs between 10 and 20 atm. of tension.
- c. Permanent wilting point is defined as the minimal point of soil moisture that plant requires not to wilt.
- d. If moisture decreases to this or any lower point a plant wilts and can no longer recover its turgidity when placed in a saturated atmosphere for 12 hours.
- e. The physical definition of the wilting point (symbolically expressed θ_{pwp} or θ_{wp}) is defined as the water content at -1500 J/kg (or -15 bars) of suction pressure, or negative hydraulic head.
- f. PWP values under field conditions are not constant for any given soil, but are determined by the integrated effects of plant, soil and atmospheric conditions.
- g. PWP is considered as lower limit of available water.

Kinds of soil water:

- i. Gravitational water
- ii. Capillary water
- iii. Hygroscopic water

(i) Gravitational water:

Water in the micro-pores that moves downward freely under the influence of gravity ($< 1/3$ bar) beyond the root zone is called gravitational water. It is not available to plants.

(ii) Capillary water:

Water retained by the soil in capillary pores (micro-pores), against gravity ($-1/3$ to -31 bar) by the force of surface tension as continuous film around soil particles is called capillary water. It is available for plant growth.

(iii) Hygroscopic water:

When water is held tightly as thin film around soil particles by adsorption forces and no longer moves in capillary pores, is called hygroscopic water. It flows at gravity of > -31 bar.

Factors Affecting Soil Water Availability

- 1. Soil texture** Fine textured soils have more water holding and retention capacity, so more water availability.
- 2. Soil structure** Well aggregated soils have more retention of water, so have more available water.
- 3. Organic matter** Soils with higher organic matter have higher water holding, thus more water is available for plants
- 4. Soil compaction** Less compact soils have higher number of total pore space which results in high water retention.
- 5. Soluble salt** Presence of high soluble salts in the soil increase osmotic potential results in low available water content.
- 6. Soil depth** High soil depth has high available water content.



Soil Density :

- Soil density is expressed in two well accepted concept as - bulk density
 - particle density
- 1. Particle Density: - The weight per unit volume of the solid portion of soil is called particle density.
 - Generally particle density of normal soils is 2.65 grams per cubic centimeter.
 - The particle density is higher if large amount of heavy minerals such as magnetite; limonite and hematite are present in the soil.
 - With increase in organic matter of the soil the particle density decreases. Particle density is also termed as true density.



Bulk Density :

- The oven dry weight of a unit volume of soil inclusive of pore spaces is called bulk density.
- The bulk density of a soil is always smaller than its particle density.
- The bulk density of sandy soil is about 1.6 g / cm^3

Bulk Density :

Textural class	Bulk density (g/cc)	Pore space (%)
Sandy soil	1.6	40
Loam	1.4	47
Silt loam	1.3	50
Clay	1.1	58



Soil Porosity :

- The spaces occupied by air and water between particles in a given volume of soil are called pore spaces.
- The percentage of soil volume occupied by pore space or by the interstitial spaces is called porosity of the soil.
- It depends upon the texture, structure, compactness and organic content of the soil.
- Porosity of the soil increases with the increase in the percentage of organic matter in the soil.
- Porosity of soil also decreases as the soil particles become much smaller in their dimension because of decrease in pore spaces.
- It also decreases with depth of the soil. The pore spaces are responsible for better plant growth because they contain enough air and moisture.
- Percentage of solids in soils can be determined by comparing bulk density and particle density and multiplying by hundred.

Soil Porosity:

$$\text{Percentage of solids} = \frac{\text{bulk density}}{\text{particle density}} \times 100$$

This percentage of solids subtracted from total volume (100%) will give the percentage of pore space. Hence, the formula :

$$100\% - \left[\frac{\text{bulk density}}{\text{particle density}} \times 100 \right] = \text{percentage of pore space.}$$

Depending upon the size pore spaces fall into two categories.

These are:

(1) Micro-pore spaces (capillary pore spaces)

(2) Macro-pore spaces (non-capillary pore spaces)

Capillary pore spaces can hold more water and restrict the free movement of water and air in soil to a considerable extent, whereas macro-pore spaces have little water holding capacity and allow free movement of moisture and air in the soil under normal conditions.



Soil Consistence:

- Soil consistence is the resistance of a soil to deformation or rupture and is determined by the cohesive and adhesive properties of the soil mass.
- This is a term used to designate the manifestation of the cohesive and adhesive properties of soil at various moisture contents.
- A knowledge of the consistence of the soil is important in tillage operations, traffic and pond constructions.
- Consistence gives also an indication of the soil texture.
- Consistence is described for three moisture levels:
 1. **Wet soil** - non sticky, slightly sticky, sticky, very sticky; non plastic, slightly plastic, plastic and very plastic.
 2. **Moist soil** - loose, very friable, friable, firm, very firm, extremely firm.
 3. **Dry soil** - loose, soft, slightly hard, hard, very hard, extremely hard



Soil colour:

- Soil colour gives an indication of the various processes going-on in the soil as well as the type of minerals in the soil.
- For example the red colour in the soil is due to the abundance of iron oxide under oxidised conditions (well-drainage) in the soil;
- dark colour is generally due to the accumulation of highly decayed organic matter;
- yellow colour is due to hydrated iron oxides and hydroxide; black nodules are due to manganese oxides;
- mottling and gleying are associated with poor drainage and/or high water table.
- Abundant pale yellow mottles coupled with very low pH are indicative of possible acid sulphate soils.
- Colours of soil matrix and mottles are indicative of the water and drainage conditions in the soil and hence suitability of the soil for aquaculture.

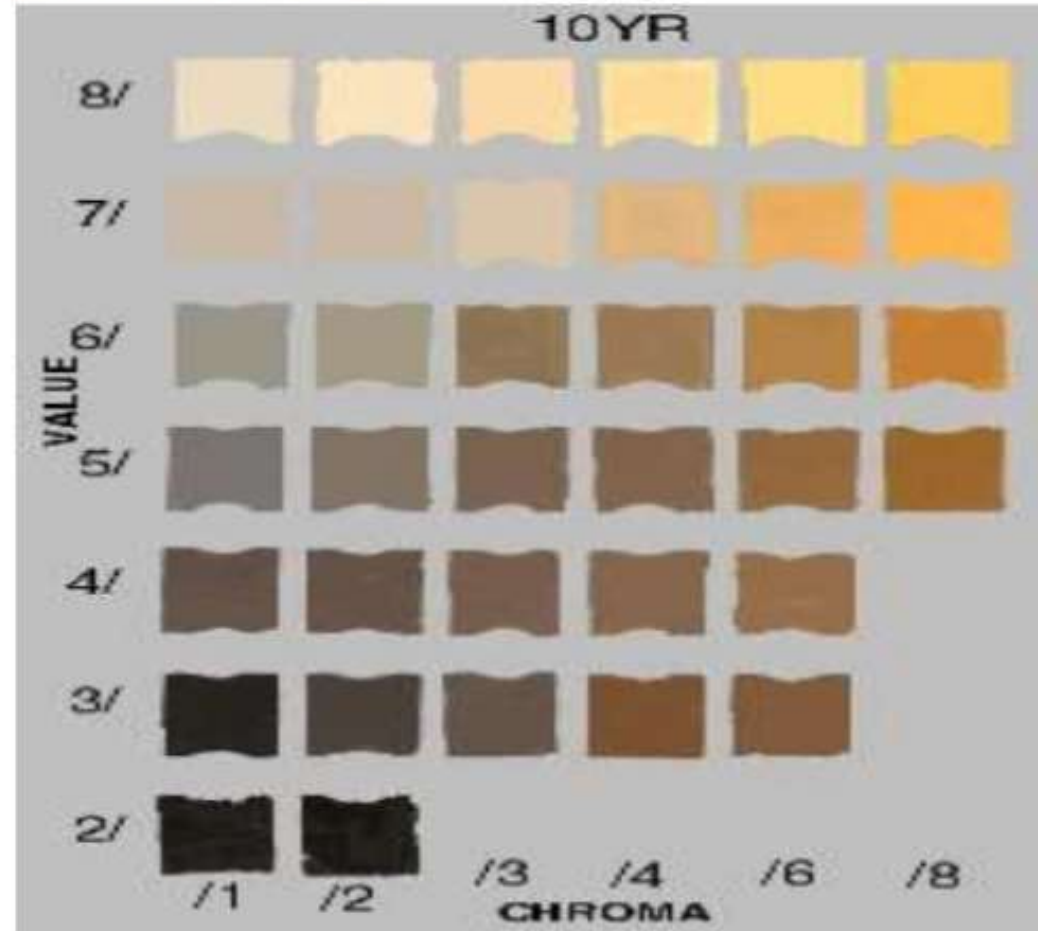


Soil colour:

- Soil colour is described by the parameters called hue, value and chroma.
- Hue represents the dominant wave length or colour of the light; value, refers to the lightness of the colour; chroma, relative purity or strength of the colour.
- The colour of the soil in terms of the above parameters could be quickly determined by comparison of the sample with a standard set of colour chips mounted in a note-book called **MUNSELL SOIL COLOUR CHARTS** (Munsell Soil Colour Charts, 1973).
- In these charts, the right hand top corner represents the Hue; the vertical axis, the value; and the horizontal axis, the chroma.



MUNSELL SOIL COLOUR CHARTS





Reference book:

Pedology

Concept and Application

J.sehgal

kalyaniprakashan

CHEMICAL PROPERTIES OF SOILS

by

Prof. A. Balasubramanian
Centre for Advanced Studies in Earth Science
University of Mysore
India

1. Introduction:

Healthy soil is the foundation of the food system. It produces healthy crops that in turn nourish people.

Plants obtain nutrients from two natural sources of soils.

They are 1) organic matter and 2) the minerals.

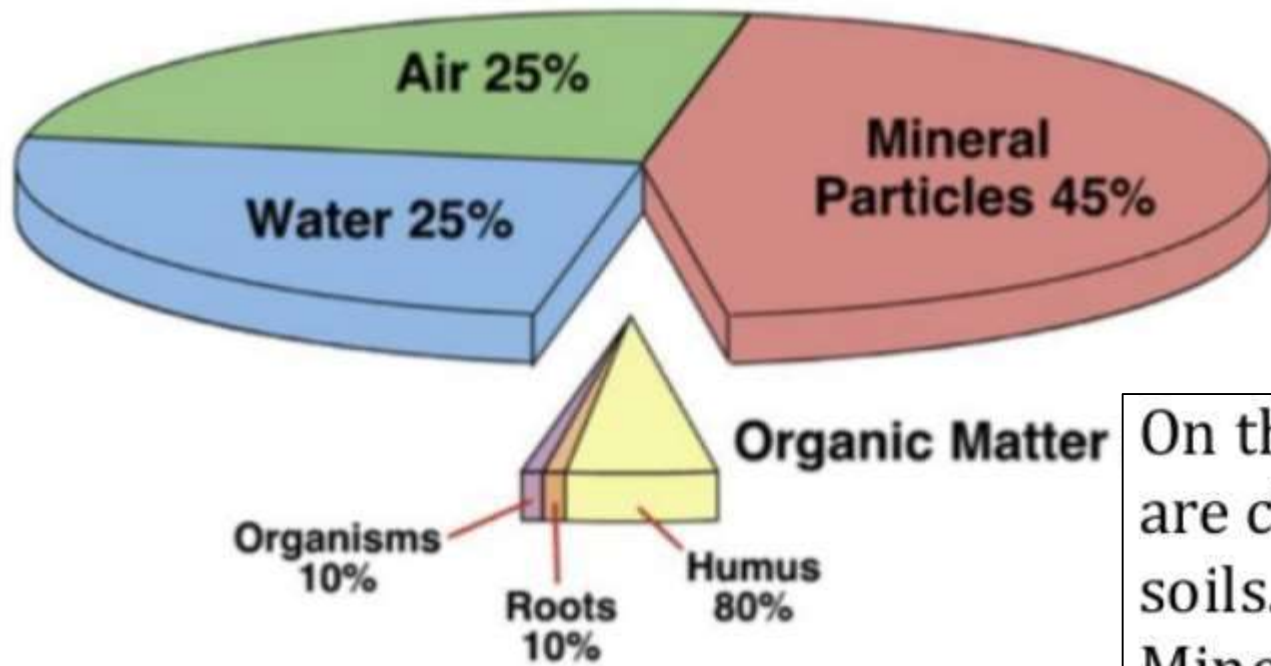
Organic matter includes any plant or animal material that returns to the soil and goes through the decomposition process.

In addition to providing nutrients and habitat to organisms living in the soil, organic matter also binds soil particles into form soil aggregates and improves the water holding capacity of soil.

2. Soil is a complex earth mass composed of following five major components :

1. mineral matter obtained by the distintergration and decomposition of rocks;
2. organic matter, obtained by the decay of plant residues, animal remains and microbial tissues;

3. water, obtained from the atmosphere and the reactions in soil (chemical, physical and microbial);
4. air or gases, from atmosphere, reactions of roots, microbes and chemicals in the soil
5. living organisms, both big (worms, insects) and small (microbes).



On the basis of organic matter content, soils are characterized as mineral soils or organic soils.

Mineral soils form most of the world's cultivated land and may contain from a trace concentration to 30 percent of organic matter. The chemistry of soil plays the primary role in all concepts of soil ecology.

3. The Chemical properties of soils include the following aspects:

- (1) Inorganic matters of soil
 - (2) Organic matters in soil
 - (3) Colloidal properties of soil particles and
 - (4) Soil reactions and Buffering action
- (i) Acidic soils
 - (ii) Basic soils.

4. Inorganic Matters of Soil(Soil Mineralogy):

The inorganic component (mineral matter) of the soil is composed of many types of minerals which influence the properties of the soil. The differences among soils are due mainly to the differences in the type and relative abundance of such minerals.

Minerals are naturally occurring inorganic compounds having definite crystalline structures. They are classified into primary and secondary minerals.

Primary minerals are those formed at elevated temperature and inherited unchanged from igneous and metamorphic rocks.

The secondary minerals are formed at low temperature reactions and either inherited from sedimentary rocks or formed directly by weathering in soils.

5. The major mineral groups commonly found in soil include:

- (1) aluminosilicates,
- (2) oxides, and
- (3) organic matter.

Through their surface electrochemical properties, these soil minerals control adsorption, transformation, and other behavior of chemical constituents. Soil-surface electrochemical properties vary between soil types and depend on factors such as parent material, climate, and vegetation.

6. Aluminosilicate Minerals:

Aluminosilicates are also called as phyllosilicates .

These are inorganic crystalline structures which make up a large part of the < 0.2 mm soil-sized particles.

These minerals, commonly referred to as clay minerals.

7. Primary minerals of soils include:

Quartz, Muscovite, Biotite, Feldspars,
Orthoclase, Microcline, Albite, Amphiboles,
Tremolite
Pyroxenes, Enstatite, Diopside, Rhodonite,
Olivine, Tourmaline.

Secondary Minerals:

Clay minerals, Kaolinite, Montmorillonite,
Vermiculite, Chlorite, Allophane
Goethite, Hematite, Maghemite, Ferrihydrite,
Gibbsite, Pyrolusite, Dolomite, Calcite,
Gypsum.

The sand and silt fraction consists mainly of quartz and other primary minerals like feldspars, micas, pyroxene, olivine.

In addition to these, some small amounts of secondary minerals such as oxides of aluminium (gibbsite) and iron (hematite) are also found in soils.

The clay fraction is mainly composed of secondary silicate minerals such as kaolinite, illite and montmorillonite.

Metal-Oxides

Iron and manganese are commonly found in soils and often in large quantities. Metal oxides are present in soils as: Free oxides, Clay mineral coatings and Clay edges.

8. Soil Organic Matter (SOM):

Most of the soil organic matter originates from plant tissues.

Plant residues contain 60–90 percent of moisture.

The remaining dry matter consists of carbon (C), oxygen, hydrogen (H) and small amounts of sulphur (S), nitrogen (N), phosphorus (P),

potassium (K), calcium (Ca) and magnesium (Mg).

Although present in small amounts, these nutrients are very important from the viewpoint of soil fertility management.

9. Soil organic matter consists of two general groups of components:

- (i) fresh or partially decomposed plant and animal residues having some recognisable physical structures traceable to its origin; and
- (ii) the humus, which is a more resistant product of decomposition and colloidal in nature.

10. Organic component of the soil consists of substances of organic origin; living and dead.

In sandy soil of arid zone, it is found in very poor quantity (one or less than one per cent) but in peaty soil, it may be as high as 90%. When the plants and animals die, their dead remains are subjected to decomposition.

As a result of decomposition a number of different organic products or compounds are formed from the original residues.

In the course of decomposition, the original materials are converted into dark coloured organic complexes, called **humus**.

Sometimes the living micro-organisms also add sufficient amount of organic matters in to the soil in the form of metabolic wastes.

Only small fraction of total organic matter is soluble in water but majority of them are soluble in alkali solution.

11. Decomposition of organic matter

Decomposition of organic matter is largely a biological process that occurs naturally.

Its speed is determined by three major factors: soil organisms, the physical environment and the quality of the organic matter.

In the decomposition process, different products are released: carbon dioxide (CO₂), energy, water, plant nutrients and resynthesized organic carbon compounds. Successive decomposition of dead material and modified organic matter results in the formation of a more complex organic matter called humus. This process is called humification.

12. Peat, muck and Humus:

Peat is formed from the undecomposed plant tissues. Muck is highly decomposed organic material. Mucky peat is of intermediate in decomposition.

The black or brown colour usually observed in the surface layers of soil profiles is due to the presence of humus.

Humus is the most reactive part of the organic matter.

Humus affects soil properties.

As it slowly decomposes, it colours the soil darker; increases soil aggregation and aggregate stability; increases the CEC (the ability to attract and retain nutrients); and contributes N, P and other nutrients.

Soil organisms, including micro-organisms, use soil organic matter as food. As they break down the organic matter, any excess nutrients (N, P and S) are released into the soil in forms that plants can use. This release process is called mineralization. Its capacity to hold water and nutrients greatly exceeds that of clay, its inorganic counterpart.

The fresh and partially decomposed plant and animal residues generally occur in the sand and silt fraction of the soil and the humus occurs in the clay fraction.

13. Compounds and function of humus

Humus is a relatively stable component formed by humic substances, including humic acids, fulvic acids, humatomelanic acids and humins.

It is probably the most widely distributed organic carbon-containing material in terrestrial and aquatic environments.

Humus cannot be decomposed readily because of its intimate interactions with soil mineral phases and is chemically too complex to be used by most organisms.

One of the most striking characteristics of humic substances is their ability to interact with metal ions, oxides, hydroxides, mineral and organic compounds, including toxic pollutants, to form water-soluble and water-insoluble complexes.

Humic and fulvic substances enhance plant growth directly through physiological and nutritional effects. Some of these substances function as natural plant hormones.

14. Chemically humus contains the following organic molecules:

- A. Amino Acids
- B. Proteins
- C. Aromatic Molecules
- D. Uronic Acids
- E. Aliphatic Acids
- F. Aminosugars
- G. Pentose Sugars
- H. Hexose Sugars

I. Sugar Alcohols

J. Methyl Sugars.

Besides these compound, the soil also contains

fats, oils, waxes,
resins, tannin, lignin and some pigments.

15. Rate of decomposition of materials in soils:

The organic matter is also classified on the basis of their rate of decomposition:

1. Rapidly decomposed : Sugars, starches, proteins etc.
2. Less rapidly decomposed : Hemicelluloses, celluloses etc.
3. Very slowly decomposed : Fats, waxes, resins, lignins ,etc

16. Non-humic substances: significance and function

Non-humic organic molecules are released directly from cells of fresh residues, such as proteins, amino acids, sugars, and starches. This part of soil organic matter is the active, or easily decomposed, fraction.

This active fraction is influenced strongly by weather conditions, moisture status of the soil, growth stage of the vegetation, addition of organic residues, and cultural practices, such as tillage.

It is the main food supply for various organisms in the soil.

17. Carbohydrates occur in the soil in three main forms: free sugars in the soil solution, cellulose and hemicellulose; complex polysaccharides; and polymeric molecules of various sizes and shapes that are attached strongly to clay colloids and humic substances.

The simple sugars, cellulose and hemicellulose, may constitute 5–25 percent of the organic matter in most soils, but are easily broken down by micro-organisms.

18. Polysaccharides (repeating units of sugar-type molecules connected in longer chains) promote better soil structure through their ability to bind inorganic soil particles into stable aggregates.

The soil lipids form a very diverse group of materials, of which fats, waxes and resins make up 2–6 percent of soil organic matter.

19. Natural factors influencing the amount of organic matter

The transformation and movement of materials within the soil organic matter part is a dynamic process.

It is influenced by climate, soil type, vegetation and soil organisms.

All these factors operate within a hierarchical and spatial scale.

20. Practices that influence the amount of organic matter:

Human interventions that influence soil organic matter are many.

Various types of human activities decrease the soil organic matter contents and their biological activities.

The practices that decrease soil organic matter include repetitive tillage or burning of vegetation, burning of crop residues.

Overgrazing and removal of crop residues also reduce SOM.

21. Ways to increase organic matter contents of soils

- compost
- cover crops/green manure crops
- crop rotation
- perennial forage crops
- zero or reduced tillage
- agroforestry

22. Colloidal Fraction of Soil:

There are two types of colloids in the soil.

These are:

- (1) Mineral colloids or clay colloids, and
- (2) Organic or humus colloids.

These two colloidal fractions of soil are very intimate to each other and it is very difficult to separate them.

The inorganic colloids occur as very fine particles and organic colloids occur in the form of humus particles.

1. Clay colloids:

As regards the size, clay fraction of soil contains both non-colloidal and colloidal particles.

The clay particles are formed mainly of silica, alumina, iron and combined water.

2. Organic colloids or humus colloids:

Organic colloids in the soil are chiefly due to presence of humus.

The humus contains 8% each of lignin, protein, polyuronides (sugars and uronic acid complex).

Organic colloids may be present in appreciable proportion in the soils.

In sandy soil, it forms minor part of colloids.

In peaty soil, organic colloids may be more than 50%.

These colloids show adsorptive capacity many times greater than clay colloids.

Organic colloids are negatively charged like clay colloids.

Addition of organic colloids to the sandy soil increases temporarily its moisture and nutrient retaining capacity.

23. Colloidal Properties of Soil Particles:

There are two types of substances occurring in soils, as crystalloids and colloids.

Crystalloids are those crystalline solid substances which form true solution on being mixed with other substances.

In true solution, crystal particles cannot be seen with the help of microscope.

The word colloid was first coined by Graham (1849).

It is derived from Greek words kolla meaning glue and eoids meaning appearance, i.e., glue like in appearance.

Colloid is in amorphous state of the substances which do not form true solution if mixed with other substances.

The particles of colloidal substances float in the solvent in suspension state but do not tend to settle at the bottom.

Colloids are not found in ionic or molecular form but are found in aggregates of atoms or molecules.

A major portion of the clay fraction (2 μ) exists in the colloidal state (1 to 200 μ). This fraction exhibit the typical colloidal properties such as Tyndall effect, Brownian movement and possession of electric charges.

Colloidal system or suspension contains two phases which are:

- (i) Dispersion phase, i.e., medium in which the particles are suspended, and
- (ii) Dispersed phase, i.e., suspended particles.

Colloidal suspension may be of different kinds, such as:

- (1) Suspension of liquid, in liquid, as milk (fats in water).

(2) Suspension of solid in liquid as India ink (or clay suspension in water).

(3) Suspension of solid in gas, as smoke (coal particles suspended in air).

(4) Suspension of liquid in gas, e.g., cloud and fogs in atmosphere.

The commonest colloids are those which remain suspended in a liquid medium:

If the colloidal suspension exhibits properties of fluid, it is called sol, but sometimes sols exhibit solid like behaviour and form solid or nearly so.

This condition is called gel. Some sols form reversible gel while the others form irreversible gel.

Some of the important properties of colloids in general are as follows:

1. Particle size: Crystalloids and colloids differ from each other in their size range.

Particles of crystalloid in true solution are 0.2 to 1 m μ (millimicron) while those of colloids in suspension are 1 to 200 m μ .

2. Adsorption:

Because the colloidal particles of dispersed phase are very small, they have got large exposed surface areas.

Owing to their large exposed surface areas, these colloidal particles show great adsorptive capacity. In adsorption, particles of particular substances come to lie on the surface of colloids and they do not enter deep in the colloidal particles.

3. Electrical properties:

The electrically charged colloids are termed as micelles.

Colloids have some electrical charge on them. They may be charged either positively or negatively.

Colloidal particles of one electrical charge have tendency to attract colloids of opposite charge.

In the soil clay particles are negatively charged, thus they attract cations (+ charged ions).

Colloid particles differ from electrolytes in the fact that when electric current is passed in the colloidal suspension, all the colloidal particles are attracted towards one electrode or the other depending upon the nature of charge they carry on them. This phenomenon is called **electrophoresis**.

The electrolytes, when dissolved in solvent, dissociate into two types of ions among which half will bear positive charge (cations) and remaining half will bear negative charge (anions).

When electric current is passed in the solution of electrolyte all the positively charged ions will accumulate on negative pole and remaining negatively charged ions will collect on positive pole.

The **soil colloid particles** show almost all the characteristics of typical colloidal system, i.e., adsorption, Tyndal effect, Brownian movement, coagulation, electrophoresis, dialysis, etc.

4. Coagulation or flocculation of colloidal particles:

Colloidal particles in the suspension can be coagulated either by heating or by adding some substances which contain opposite charged ions.

When substances carrying positive ions are added in suspension containing negatively charged colloid particles, ions will move and accumulate on the surface of colloids carrying opposite charge.

Finally a stage comes when colloidal particles cannot attract more opposite charged ions. This is called **isoelectric point**. As a result of ion accumulation on their surface, the colloids first become large and heavier and finally they tend to settle at the bottom in floccules. This process is known as **flocculation**.

5. Tyndal phenomenon:

Colloidal particles in suspension can be seen when a strong beam of light is passed through suspension and observer looks it from the place at right angle to the path of light.

The colloidal particles become visible as strongly illuminated particles and they appear bigger than normal size. This phenomenon is known as “**Tyndal effect**”.

6. Brownian movement:

Colloidal particles when suspended in dispersion medium show a characteristic continuous zig-zag motion, called Brownian movement.

This type of movement was first observed by English botanist Robert Brown, hence it is called **Brownian movement**.

The movement is exhibited because of characteristic collision of one particle with others.

This prevents the particles from settling down.

7. Dialysis:

Because colloidal particles in suspension are larger than the particles of crystalloid in true solution and are larger than the diameter of pores of porous membranes, e.g., parchment membrane, they are not allowed to be filtered down and are retained the membrane.

Thus, they can be separated in pure state from the mixture of crystalloids and colloids by filtration process.

This separation process is known as **dialysis**.

25. Cation Exchange Capacity of soils(CEC):

Since the soil colloids (clay and organic colloids) have negative charges on them, they attract and hold positive ions (cations).

When cations are added to the soils such as

a) Ca^{++} in the form of lime,

b) K^+ ions in the form of potassium fertilizer,

and c) NH^{++} in the form of ammonium fertilizer, the adsorption of cations will take place on the surface of colloid micelle.

This will be accompanied by release of one or more ions held by colloid micelle.

This is known as cationic exchange.

The cation exchange in the soil may take place between:

(1) Cations present in the soil solutions and those already present on surface of soil colloids

(2) Cations released by plant roots and those present on the surface of soil colloids, and

(3) Cations present on the surface of two clay crystals either two organic colloids or an organic colloid and a clay colloid.

The Exchange reaction is always very quick and reversible.

The exchange of ions continues till an equilibrium stage is attained.

All cations are not adsorbed with equal ease. Some are easily adsorbed while others are replaced with difficulty.

Divalent cations are more effective than the monovalent ones.

Hydrogen is exception because, it is held by colloids most tenaciously and it is the most powerful replacer of cations.

Replacing capacities of some cations are as follows:

$H^+ > Ca^{++} > K^+ > Na^+ > Na^+$

The number of cations adsorbed per unit weight of one hundred grams dry soil is called cation exchange capacity. It is the sum total of exchangeable cations adsorbed per unit weight of one hundred gms of dry soil.

Factors which are responsible for cation exchange or base exchange are as follows:

- (1) Relative concentration and number of cations present in the soil,
- (2) Replacing capacity of the ions, and
- (3) Number of charges on the ions.

26. Anion Exchange Capacity:

Soils rich in organic colloids show anion exchange also.

In this process, negatively charged ions held by colloids are replaced by OH^- , H_2PO_4^- , SO_4^- , and NO_3^- ions.

The relative order of exchange is

$\text{OH}^- > \text{H}_2\text{PO}_4^- > \text{SO}_4^- > \text{NO}_3^-$

Among these anions, exchange of PO_4^- ions is most important.

SO_4^- and NO_3^- are not retained in the soil for long period of time, hence not available for anionic exchange.

The knowledge of cation and anion exchange is of great help in reclaiming acidic and saline or alkaline soils.

27. Soil Reactions:

Many chemical properties of soils centre round the soil reactions.

As regards their nature, some soils are neutral, some are acidic and some basic. The acidity, alkalinity and neutrality of soils are described in terms of hydrogen ion concentrations or pH values. In order to understand soil reaction, the knowledge of pH is very much necessary.

It can be understood in the following ways:

Water dissociates into H^+ ion and OH^- ion.

Hence the ionic constant of water can be represented as follows:

Ionic constant of water = $[H^+][OH^-]/[H_2O]$.

But the rate of dissociation of water is so slow that ionization constant of water can be expressed simply as product of concentration of H^+ and OH^- ions, thus ionization constant of water $K_w = [H^+][OH^-]$.

Concentration of H⁺ and OH⁻ ions are expressed in terms of equivalents per litre.

Only one molecule in ten million water molecules is in dissociated condition.

At neutrality, H⁺ concentration is 0.0000001 or 10⁻⁷ gm of hydrogen per litre solution.

The ionization constant of water is 10⁻¹⁴ at 25°C and thus in any aqueous system products of H⁺ and OH⁻ ion concentration is 10⁻¹⁴.

Now, the above equation can be written as: $10^{-14} = [H^+][OH^-]$

This can also be represented in the following way by dividing both sides in one and taking logarithms.

Hence, $\log \frac{1}{K_w} = \log \frac{1}{[OH^-]} + \log \frac{1}{[H^+]} = 14$

The value of $\log 1/[H^+]$ and $\log 1/[OH^-]$ are generally pH and pOH respectively.

These pH and pOH are indices of the acidity and alkalinity respectively.

Thus, pH can be defined as negative logarithms of the H^+ ion concentration.

When the system is neutral, pH will be equal to pOH and when K_w is 10^{-14} , the value of pH and pOH at neutral point will be 7 for each. When pH value is less than 7, it is acidic. The pH value above 7 indicates alkalinity. If in a system, hydrogen ion concentration is $1/0.000001$ or 000001 gm/litre, the pH value will be 6.

28. Buffering in Soil:

It refers to the resistance to change in pH of a system.

Some solutions are reasonably permanent in pH value even after addition of some alkali or acid to them.

These are called as solutions with reserved acidity or alkalinity or more often “**buffer solutions**”.

Suppose, a certain amount of acid is added to distilled water, the resulting solution will show acidic reaction and that will have a pH below 7, but if the same quantity of acid is added to a neutral soil suspension, there would be very minor change in pH.

This property of soil to resist a change in pH is called “**buffer action**”.

Buffer solutions are usually formed of a mixture of salt of weak acid and acid itself in various proportions, as for example, a mixture of sodium acetate and acetic acid if added to water will result in a buffer solution.

Soils should have good buffering capacity. Therefore, it is necessary to add considerably large amount of acids or alkalis in order to bring about any change in the original pH of soil.

Buffering action is due to presence of large quantity of weak acids and their salts in the soil.

Phosphates, carbonates, bicarbonates and other salts of weak inorganic acids and corresponding acids themselves are important buffering agents in the soils.

Besides these, colloids associated with cations are important buffering agents.

The buffering action of soil is directly governed by the amount and nature of clay and organic or humus colloids present in it.

Buffering action of soil is important in agriculture in the following respects:

(1) Stabilization of pH:

This protects the higher plants and micro-organisms from direct adverse and injurious effects of sudden change in soil reaction.

(2) Amount of amendments necessary to correct the soil reaction:

The greater is the buffering capacity of soil the smaller will be the amount of the amendments required such as lime, sulphur etc. to correct the acidity or alkalinity.

THANK YOU