(Fundamentals of Soil Science)

SOIL – PEDOLOGICAL AND EDAPHOLOGICAL CONCEPTS

Soil science is the study of soil as a natural resource on the surface of the earth including soil formation, classification and mapping; physical, chemical, biological, and fertility properties of soils; and these properties in relation to the use and management of soils.

Sometimes terms which refer to branches of soil science, such as pedology (formation, chemistry, morphology and classification of soil) and edaphology (influence of soil on organisms, especially plants), are used as if synonymous with soil science.

Soil scientists have raised concerns about how to preserve soil and arable land in a world with a growing population, possible future water crisis, increasing per capita food consumption, and land degradation.

Soil occupies the pedosphere, one of Earth's spheres that the geosciences use to organize the Earth conceptually. This is the conceptual perspective of pedology and edaphology, the two main branches of soil science. Pedology is the study of soil in its natural setting. Edaphology is the study of soil in relation to soil-dependent uses. Both branches apply a combination of soil physics, soil chemistry, and soil biology. Due to the numerous interactions between the biosphere, atmosphere and hydrosphere that are hosted within the pedosphere, more integrated, less soilcentric concepts are also valuable. Many concepts essential to understanding soil comes from individuals not identifiable strictly as soil scientists. This highlights the interdisciplinary nature of soil concepts.

Soil Science

"The science dealing with soil as a natural resource on the surface of the earth, including Pedology (soil genesis, classification and mapping), physical, chemical, biological and fertility properties of soil and these properties in relation to their management for crop production." Soil Science has six well defined and developed disciplines

Soil fertility : Nutrient supplying properties of soil
Soil chemistry : Chemical constituents, chemical properties and the chemical reactions

Soil physics : Involves the study of physical properties

Soil microbiology : Deals with micro organisms, its population, classification, its role in transformations

Soil conservation : Dealing with protection of soil against physical loss by erosion or against chemical deterioration i.e. excessive loss of nutrients either natural or artificial means. Soil Pedology : Dealing with the genesis, survey and classification

Views on Soil (Science)

The term SOIL was derived from the Latin Word "SOLUM" Means FLOOR

- For a Layman soil is dirt or debris
- For an Agriculturist soil is a habitat for plant growth (to grow crops)
- For a Mining Engineer soil is a debris covering the Rocks
- For a Civil Engineer soil is a material on which road bed or house bed is formed
- For a Home Owner soil is a mellow or loamy or hard material

Definitions

Generally soil refers to the loose surface of the earth as identified from the original rocks and minerals from which it is derived through weathering process.

Whitney (1892): Soil is a nutrient bin which supplies all the nutrients required for plant growth Hilgard (1892): Soil is more or less a loose and friable material in which plants, by means of their roots, find a foothold for nourishment as well as for other conditions of growth" Dokuchaiev (1900): Russian scientist - Father of soil science - Soil is a natural body composed of mineral and organic constituents, having a definite genesis and a distinct nature of its own.

Joffe (1936): "Soil is a natural body of mineral and organic constituents differentiated into horizons - usually unconsolidated - of variable depth which differs among themselves as well as from the underlying parent material in morphology, physical makeup, chemical properties and composition and biological characteristics".

Jenny (1941): Soil is a naturally occurring body that has been formed due to combined influence of climate and living organisms acting on parent material as conditioned by relief over a period of time.

Ruffin and Simonson (1968): Soil is a mixture of Earth's uppermost mantle of weathered rock and organic matter

Buckman and Brady (1969): Soil is a dynamic natural body on the surface of the earth in which plants grow, composed of mineral and organic materials and living forms Soil Science Society of America (1970)

(i) Soil is the unconsolidated mineral matter on the surface of the earth that has been subjected to and influenced by genetic and environmental factors of parent material, climate (including moisture and temperature effects), macro and microorganisms and topography, all affecting over a period of time and producing a product, that is "SOIL" that differs from the material from which it is derived in many, physical, chemical, biological and morphological properties and characteristics.

(ii) The unconsolidated mineral material on the immediate surface of the earth that serves as a natural medium for the growth of land plants. Dr. W.E.H. Blum

Soils not only serve for agriculture and forestry, but also for filtering, buffering and transformation activities between the atmosphere and the ground water, protecting the food chain and drinking water against pollution and biodiversity

As soil provides nutrients, water, air and anchorage and supports life on Earth, it can be called as

<u>Soul Of Infinite Life (SOIL)</u>

Soil as a three dimensional body

Soil is a three dimensional body having length, breadth and depth. They form a continuation over the land surface and differ in properties from place to place. Its upper boundary is air or water and lower boundary is the rock lithosphere.

Composition of soil on volume basis (Soil components)

Mineral matter : 45%

Organic matter : 5%

Soil water : 25%

Soil air : 25%

Soil can be compared to various systems of animals Digestive system : Organic matter decomposition Respiratory system : Air circulation & exchange of Gases Circulatory system (blood) : Water movement within Soil Excretory system : Leaching out of excess salts

Brain : Soil clay

Colour : Soil colour
Height : Soil depth

Approaches of Soil Study

Two Concepts: One treats soil as a natural body, weathered and synthesized product in nature (Pedology) while other treats soil as a medium for plant growth (Edaphology).

Pedological Approach: The origin of the soil, its classification and its description are examined in Pedology. (From Greek word pedon, means soil or earth). Pedology is the study of soil as a natural body and does not focus on the soil's immediate practical use. A pedologist studies, examines and classifies soil as they occur in their natural environment.

Edaphological Approach: Edophology (from Greek word edaphos, means soil or ground) is the study of soil from the stand point of higher plants. Edaphologists consider the various properties of soil in relation to plant production. They are practical and have the production of food and fibre as their ultimate goal. They must determine the reasons for variation in the productivity of soils and find means for improvement.

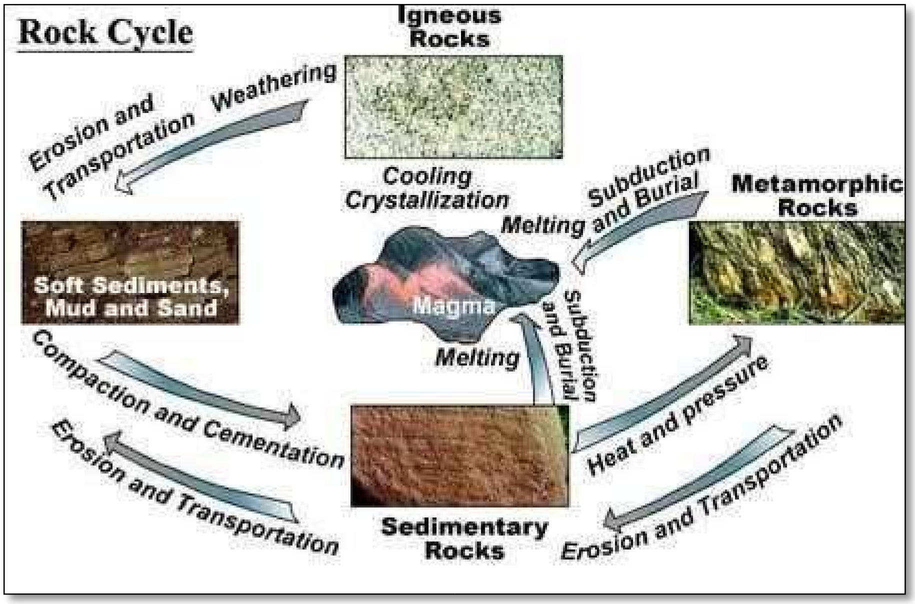
SOIL GENESIS: SOIL FORMING ROCKS AND MINERALS

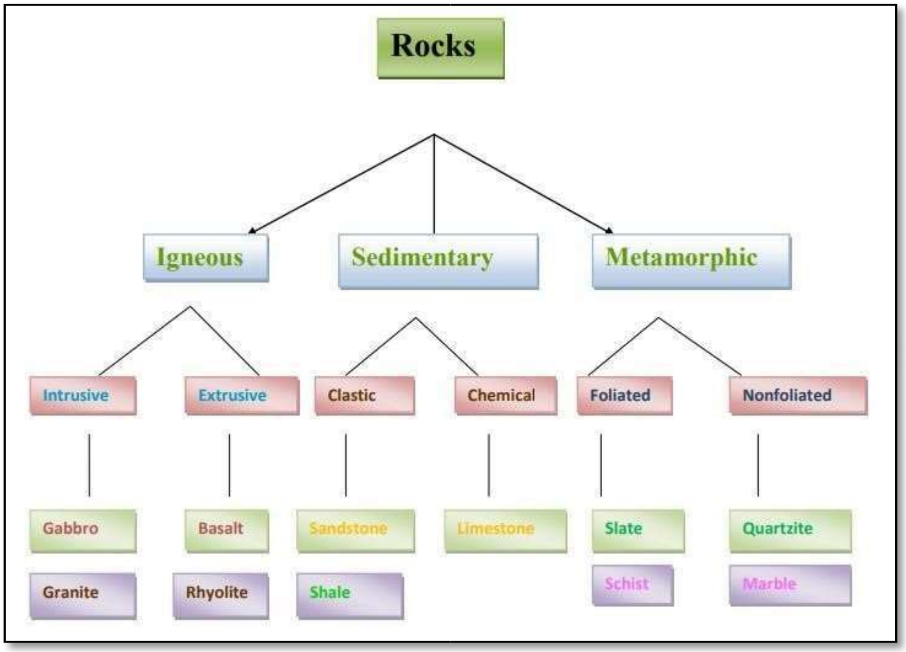
What is Rocks?

Rocks are the materials that form the essential part of the Earth's solid crust. "Rocks are hard mass of mineral matter comprising one or more rock forming minerals". Rocks are formed from the molten material known as magma. The study of rocks is called Petrology (in Greek, petra means rock, logos means science). Petrology deals with the description of rocks; petrogenesis is the study of the origin of rocks.

Formation of rocks

1. Cooling and consolidation of molten magma within or on the surface of earth = Igneous or Primary rocks
2. Transportation and cementation of primary rocks = Sedimentary or Secondary rocks
3. Alteration of the existing primary and secondary rocks = Metamorphic rocks





1. Igneous rocks (primary or massive rocks)

These are first formed in the earth crust due to the solidification of molten magma. Based on the mode of formation, they are further classified as extrusive and intrusive rocks.

- Extrusive rocks or volcanic rocks

These rocks are formed due to the consolidation of magma on the surface of the earth. The magma, when it flows on the Earth surface is called LAVA. E.g. Basalt. Intrusive rocks or plutonic rocks

These rocks are produced due to solidification of magma below the surface of the earth. Plutonic – intrusive rocks solidifies at greater depth and Hypabassal rocks solidifies at shallow depth from the surface. E.g. Granite, syenite, diorite, Gabbro etc. Rocks formed in vertical cracks are called dykes and in horizontal cracks are called sills.

Vesicular rocks: Molten magma cools on the surface. Steam of water is entrapped into rocks and forms vesicles.

BASED ON THE SILICA CONTENT, ROCKS ARE ALSO CLASSIFIED AS

1. Acid rocks : >65% SiO_2 (Granite, Rhyolite)
2. Intermediate : 56 to 65% SiO_2

   (Sub acid rocks 60 to 65% SiO_2 (Syenite and Trachyte)) (Sub basic rocks 56 to 60 % SiO_2 (Diorite and Andesite))
3. Basic rocks : 40 to 55% (Gabbro, basalt)

Igneous rocks

S.No	Rocks	Origin	Essential minerals	Common minerals	Average specific gravity	Remarks
i.	Granite	Plutonic holocrystalline	Quartz (20 to 30%)	Hornblende, magnetite, mica	2.64	Light coloured white or reddish
ii.	Syenite	Plutonic Holocrystalline	Quartz, orthoclase	Hornblende, magnetite, biotite	2.80	Light coloured white or reddish
iii.	Diorite	Plutonic Holocrystalline	Quartz	Hornblende, magnetite, biotite	2.85	Darker

iv	Gabbro	Plutonic Holocrystalline	Labradorite, augite, olivine	Hornblende, ilmenite	3.0	Blakish
v.	Dolerite	Hypabasal	Labradorite, augite, olivine	Hornblende, ilmenite	3.0	Blakish
vi.	Basalt	Volcanic with crystalline glassy mass	Labradorite, augite, olivine	Hornblende, ilmenite	3.0	

2. Sedimentary rocks

These rocks are formed from the consolidation of sediments accumulated through wind or water action at the surface of the earth. Many are deposited in layer or formed through chemical reactions as precipitates from aqueous solutions. Sediments may contain various size particles cemented together by substances like SiO_2, Fe_2O_3 or lime. These rocks are also called as clastic rocks.

BASED ON THE ORIGIN, THE SEDIMENTARY ROCKS ARE CLASSIFIED AS

1. Residual : Laterite
2. Transported
   a. Deposited as solids in suspension : Sandstone, shale
   b. Deposited by chemical precipitation : Limestone, ironstone
   c. Deposited through agency of organic matter: Peat, Phosphatic deposits

BASED ON THE GRAIN SIZE, SEDIMENTARY ROCKS ARE CLASSIFIED AS

1. Rocks with boulder pebbles sized minerals (Rudaceous) : Conglomerate
2. Rocks with sand size particles (Arenaceous) : Sandstone
3. Rocks with silt size particles (silt rocks) : Siltstone
4. Rocks with clay size particles (Argillaceous) : Shale

Sedimentary rocks

S.No	Rock	Mineral composition	Colour and structure
1.	Sandstone	Mainly quartz with some $CaCO_3$, iron oxides and clay	Light to red, granular
2.	Shale	Clay minerals, quartz and some organic matter	Light to dark thinly laminated
3.	Limestone	Mainly calcite with some dolomite, iron oxides, clay, phosphate and organic matter	Light grey to yellow, fine grained and compact

3. Metamorphic rocks

These are formed from igneous and sedimentary rocks under the influence of heat, pressure, chemically active liquids and gases. Change may occur in mineral composition or texture or both. The changes due to water is called hydro metamorphosis and due to pressure is called dynamo metamorphosis

Sand stone : Quartzite

Shale : Slate/mica, schist

Lime stone : Marble

Granite : granite gneiss

Dolerite : Hornblende gneiss

Metamorphic rocks

S.No.	Rock	Mineral composition	Colour and structure
1.	Gneiss	Formed from granite	Alternating light and dark colours, banded and foliated
2.	Schist	Formed from basalt or shale	As original rock, foliated
3.	Quartzite	Formed from sandstone	Light or brown, compact and uniform

			texture, foliated structure
4.	Slate	Formed from shale	Grey to black, compact and uniform texture, foliated structure
5.	Marble	Formed from lime stone	Light red, green, black, compact fine to coarse texture, foliated structure

WEATHERING

A process of disintegration and decomposition of rocks and minerals which are brought about by physical agents and chemical processes, leading to the formation of Regolith (unconsolidated residues of the weathering rock on the earth's surface or above the solid rocks).

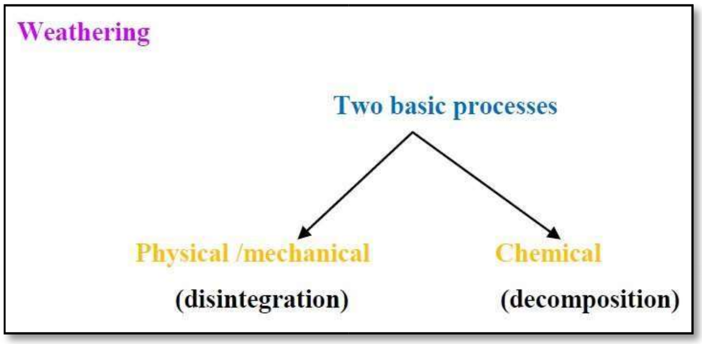
(OR)

The process by which the earth's crust or lithosphere is broken down by the activities of the atmosphere, with the aid of the hydrosphere and biosphere. (OR)

The process of transformation of solid rocks into parent material or Regolith.

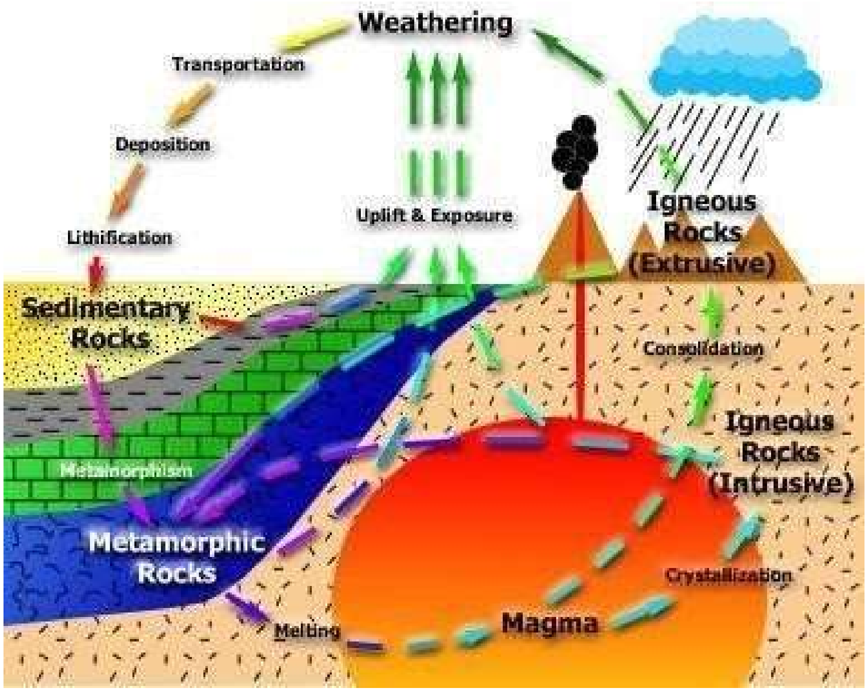
Parent material

It is the regolith or at least it's upper portion. May be defined as the unconsolidated and more or less chemically weathered mineral material from which soil are developed.



In addition, another process: Biological and all these processes are work hand in hand. Depending up on the agents taking part in weathering processes, it is classified into three types.

Weathering of Rocks



Different agents of weathering

Physical/ Mechanical (disintegration)	Chemical (decomposition)	Biological (disint + decomp)
1.Physical condition of rock	1.Hydration	1.Man & animals
2.Change in temperature	2.Hydrolysis	2. Higher plants & their roots
3.Action of H_2O	3.Solution	3.Micro organisms
-fragment & transport	4.Carbonation	
- action of freezing	5.Oxidation	
- action of glaciers	6.Reduction	
4.Action of wind		

Physical weathering

The rocks are disintegrated and are broken down to comparatively smaller pieces, without producing any new substances

1. Physical condition of rocks

The permeability of rocks is the most important single factor. Coarse textured (porous) sand stone weather more readily than a fine textured (almost solid) basalt. Unconsolidated volcanic ash weather quickly as compared to unconsolidated coarse deposits such as gravels.

2. Action of Temperature

The variations in temperature exert great influence on the disintegration of rocks.

- During day time, the rocks get heated up by the sun and expand. At night, the temperature falls and the rocks get cooled and contract.
- This alternate expansion and contraction weakens the surface of the rock and crumbles it because the rocks do not conduct heat easily.
- The minerals within the rock also vary in their rate of expansion and contraction
    - The cubical expansion of quartz is twice as feldspar
    - Dark coloured rocks are subjected to fast changes in temperature as compared to light coloured rocks
- The differential expansion of minerals in a rock surface generates stress between the heated surface and cooled un expanded parts resulting in fragmentation of rocks.
- This process causes the surface layer to peel off from the parent mass and the rock ultimately disintegrates. This process is called Exfoliation

3. Action of Water

Water acts as a disintegrating, transporting and depositing agent.

i) Fragmentation and transport

Water beats over the surface of the rock when the rain occurs and starts flowing towards the ocean

- Moving water has the great cutting and carrying force.
- It forms gullies and ravines and carries with the suspended soil material of variable sizes.
- Transporting power of water varies. It is estimated that the transporting power of stream varies as the sixth power of its velocity i.e the greater the speed of water, more is the transporting power and carrying capacity.

Speed/Sec	Carrying capacity
15 cm	Fine sand
30 cm	Gravel
1.2 m	Stones (1kg)
9.0 m	Boulders (several tons)

The disintegration is greater near the source of river than its mouth ii)

Action of freezing

Frost is much more effective than heat in producing physical weathering

- In cold regions, the water in the cracks and crevices freezes into ice and the volume increases to one tenth
- As the freezing starts from the top there is no possibility of its upward expansion. Hence, the increase in volume creates enormous out ward pressure which breaks apart the rocks

iii) Alternate wetting and Drying

Some natural substances increase considerably in volume on wetting and shrink on drying. (e.g.) smectite, montmorilonite

- During dry summer/ dry weather – these clays shrink considerably forming deep cracks or wide cracks.
- On subsequent wetting, it swells.
- This alternate swelling and shrinking/ wetting or drying of clay enriched rocks make them loose and eventually breaks

iv). Action of glaciers

- In cold regions, when snow falls, it accumulates and change into a ice sheet.
- These big glaciers start moving owing to the change in temperature and/or gradient.
- On moving, these exert tremendous pressure over the rock on which they pass and carry the loose materials
- These materials get deposited on reaching the warmer regions, where its movement stops with the melting of ice

4. Action of wind

- Wind has an erosive and transporting effect. Often when the wind is laden with fine material viz., fine sand, silt or clay particles, it has a serious abrasive effect and the sand laden winds itch the rocks and ultimately breaks down under its force.
- The dust storm may transport tons of material from one place to another. The shifting of soil causes serious wind erosion problem and may render cultivated land as degraded (e.g) Rajasthan deserts

5. Atmospheric electrical phenomenon

It is an important factor causing break down during rainy season and lightning breaks up rocks and or widens cracks

Chemical Weathering

Decomposition of rocks and minerals by various chemical processes is called chemical weathering. It is the most important process for soil formation.

Chemical weathering takes place mainly at the surface of rocks and minerals with disappearance of certain minerals and the formation of secondary products (new materials). This is called chemical transformation.

Feldspar + water → clay mineral + soluble cations and anions

Chemical weathering becomes more effective as the surface area of the rock increases.

Since the chemical reactions occur largely on the surface of the rocks, therefore the smaller the fragments, the greater the surface area per unit volume available for reaction.

The effectiveness of chemical weathering is closely related to the mineral composition of rocks. (e.g) quartz responds far slowly to the chemical attack than olivine or pyroxene.

Average mineralogical composition (%)

Composition	Granite	Basalt	Shale	S. Stone	L.Stone
Feldspar	52.4	46.2	30.0	11.5	-
Quartz	31.3	-	2.3	66.8	-
Pyrox-amphi	-	44.5	-	-	-
FeO mineral	2.0	9.3	10.5	2.0	-
Clay mineral	14.3	-	25.0	6.6	24.0
Carbonates	-	-	5.7	11.1	76.0

Chemical Processes of weathering:

1. Hydration

Chemical combination of water molecules with a particular substance or mineral leading to a change in structure. Soil forming minerals in rocks do not contain any water and they under go hydration when exposed to humid conditions. Up on hydration there is swelling and increase in volume of minerals. The minerals loose their luster and become soft. It is one of the most common processes in nature and works with secondary minerals, such as aluminium oxide and iron oxide minerals and gypsum.

2. Hydrolysis

Most important process in chemical weathering. It is due to the dissociation of H2O into H+ and OH- ions which chemically combine with minerals and bring about changes, such as exchange, decomposition of crystalline structure and formation of new compounds. Water acts as a weak acid on silicate minerals.

3. Solution

Some substances present in the rocks are directly soluble in water. The soluble substances are removed by the continuous action of water and the rock no longer remains solid and form holes, rills or rough surface and ultimately falls into pieces or decomposes. The action is considerably increased when the water is acidified by the dissolution of organic and inorganic acids. (e.g) halites, NaCl.

4. Carbonation

Carbon di-oxide when dissolved in water it forms carbonic acid. This carbonic acid attacks many rocks and minerals and brings them into solution. The carbonated water has an etching effect up on some rocks, especially lime stone. The removal of cement that holds sand particles together leads to their disintegration.

5. Oxidation

The process of addition and combination of oxygen to minerals. The absorption is usually from O2 dissolved in soil water and that present in atmosphere. The oxidation is more active in the presence of moisture and results in hydrated oxides. (e.g) minerals containing Fe and Mg.

6. Reduction

The process of removal of oxygen and is the reverse of oxidation and is equally important in changing soil colour to grey, blue or green as ferric iron is converted to ferrous iron compounds. Under the conditions of excess water or water logged condition (less or no oxygen), reduction takes place.

In conclusion, during chemical weathering igneous and metamorphic rocks can be regarded as involving destruction of primary minerals and the production of secondary minerals. In sedimentary rocks, which is made up of primary and secondary minerals, weathering acts initially to destroy any relatively weak bonding agents (FeO) and the particles are freed and can be individually subjected to weathering.

Biological Weathering

Unlike physical and chemical weathering, the biological or living agents are responsible for both decomposition and disintegration of rocks and minerals. The biological life is mainly controlled largely by the prevailing environment.

1. Man and Animals

- The action of man in disintegration of rocks is well known as he cuts rocks to build dams, channels and construct roads and buildings. All these activities result in increasing the surface area of the rocks for attack of chemical agents and accelerate the process of rock decomposition.

- A large number of animals, birds, insects and worms, by their activities they make holes in them and thus aid for weathering.
- In tropical and sub tropical regions, ants and termites build galleries and passages and carry materials from lower to upper surface and excrete acids. The oxygen and water with many dissolved substances, reach every part of the rock through the cracks, holes and galleries, and thus brings about speedy disintegration.
- Rabbits, by burrowing in to the ground, destroy soft rocks. Moles, ants and bodies of the dead animals, provides substances which react with minerals and aid in decaying process.
- The earthworms pass the soil through the alimentary canal and thus brings about physical and chemical changes in soil material.

2. Higher Plants and Roots

The roots of trees and other plants penetrates into the joints and crevices of the rocks. As they grew, they exert a great disruptive force and the hard rock may broken apart. (e.g) pipal tree growing on walls/ rocks.

The grass roots form a sponge like mass, prevents erosion and conserve moisture and thus allowing moisture and air to enter in to the rock for further action.

Some roots penetrate deep into the soil and may open some sort of drainage channel. The roots running in crevices in lime stone and marble produces acids . These acids have a solvent action on carbonates.

The dead roots and plant residues decompose and produce carbon dioxide which is of great importance in weathering.

3. Micro- organisms

In early stages of mineral decomposition and soil formation, the lower forms of plants and animals like, mosses, bacteria and fungi and actinomycetes play an important role. They extract nutrients from the rock and N from air and live with a small quantity of water. In due course of time, the soil develops under the cluster of these micro-organisms.

These organisms closely associated with the decay of plant and animal remains and thus liberate nutrients for the use of next generation plants and also produce CO_2 and organic compounds which aid in mineral decomposition.

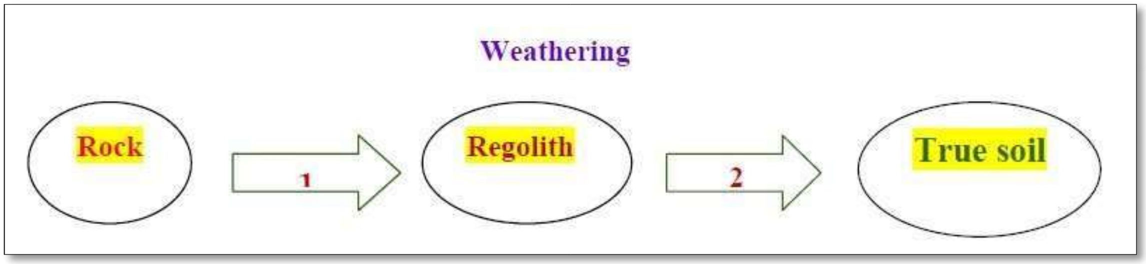
SOIL FORMATION FACTORS AND PROCESSES

The soil formation is the process of two consecutive stages.

1. The weathering of rock (R) into Regolith
2. The formation of true soil from Regolith

The evolution of true soil from regolith takes place by the combined action of soil forming factors and processes.

- The first step is accomplished by weathering (disintegration & decomposition)
- The second step is associated with the action of Soil Forming Factors



Factors

Dokuchaiev (1889) established that the soils develop as a result of the action of soil forming factors.

$$S = f(P, Cl, O)$$

Further, Jenny (1941) formulated the following equation

$$S = f(Cl, O, R, P, T, \ldots)$$

Where,

Cl – environmental climate

O – Organisms and vegetation (biosphere)

R – Relief or topography

P – Parent material

T- Time

… - additional unspecified factors

The five soil forming factors, acting simultaneously at any point on the surface of the earth, to produce soil.

Two groups

Passive : i) Parent material, ii) Relief, iii) Time

Active : iv) Climate, v) Vegetation & organism

Passive Soil forming factors

The passive soil forming factors are those which represent the source of soil forming mass and conditions affecting it. These provide a base on which the active soil forming factors work or act for the development of soil. Parent Material

It is that mass (consolidated material) from which the soil has formed. Two groups of parent material

- Sedentary

  Formed in original place. It is the residual parent material. The parent material differ as widely as the rocks

- Transported

  The parent material transported from their place of origin. They are named according to the main force responsible for the transport and redeposition.

  a) by gravity - Colluvial
  b) by water - Alluvial , Marine , Locustrine
  c) by ice – Glacial
  d) by wind - Eolian

Colluvium- It is the poorly sorted materials near the base of strong slopes transported by the action of gravity.
Alluvium- The material transported and deposited by water is, found along major stream courses at the bottom of slopes of mountains and along small streams flowing out of drainage basins.
Lacustrine- Consists of materials that have settled out of the quiet water of lakes.

Moraine- Consists of all the materials picked up, mixed, disintegrated, transported and deposited through the action of glacial ice or of water resulting primarily from melting of glaciers.
Loess or Aeolian- These are the wind blown materials. When the texture is silty - loss; when it is sand.
Eolian- The soils developed on such transported parent materials bear the name of the parent material; viz. Alluvial soils from alluvium, colluvial soils from colluvium etc. In the initial stages, however, the soil properties are mainly determined by the kind of parent material.

Endodynamomorphic soils

With advanced development and excessive leaching, the influence of parent material on soil characteristics gradually diminishes. There are soils wherein the composition of parent material subdues the effects of climate and vegetation. These soils are temporary and persist only until the chemical decomposition becomes active under the influence of climate and vegetation.

Ectodynamomorphic soils

Development of normal profile under the influence of climate and vegetation.

Soil properties as influenced by parent material: Different parent materials affect profile development and produce different soils, especially in the initial stages.

- Acid igneous rocks (like granite, rhyolite) produce light-textured soils (Alfisols).
- Basic igneous rocks (basalt), alluvium or colluvium derived from limestone or basalt, produce finetextured cracking-clay soils (Vertisols).
- Basic alluvium or aeolian materials produce fine to coarse-textured soils (Entisols or Inceptisols).
- The nature of the elements released during the decaying of rocks has a specific role in soil formation. (e.g.) Si and Al forms the skeleton for the production of secondary clay minerals.
- Iron and manganese are important for imparting red colour to soils and for oxidation and reduction phenomena.
- Sodium and potassium are important dispersing agents for day and humus colloids.
- Calcium and magnesium have a flocculating effect and result in favorable and stable soil structure for plant growth.

2. Relief or Topography

The relief and topography sometimes are used as synonymous terms. They denote the configuration of the land surface. The topography refers to the differences in elevation of the land surface on a broad scale.

The prominent types of topography designations, as given in FAO Guidelines (1990) are:

Land surface	With slopes of
1 Flat to Almost flat	0 – 2 % 2
Gently undulating	2 - 5 %
3 Undulating	5 – 10 %
4 Rolling	10 – 15 %
5 Hilly	15 –3 0 %
6 Steeply dissect	> 30 % with moderate range of elevation (<300 m)
7 Mountainous	> 30% with great range of elevation (>300 m)

Soil formation on flat to almost flat position

On level topographic positions, almost the entire water received through rain percolates through the soil. Under such conditions, the soils formed may be considered as representative of the regional climate. They have normal solum with distinct horizons. But vast and monotonous level land with little gradient often has impaired drainage conditions. Soil formation on undulating topography

The soils on steep slopes are generally shallow, stony and have weakly- developed profiles with less distinct horizonation. It is due to accelerated erosion, which removes surface material before it has the time to develop. Reduced percolation of water through soil is because of surface runoff, and lack of water for the growth of plants, which are responsible for checking of erosion and promote soil formation.

Soil formation in depression

The depression areas in semi-arid and sub humid regions reflect more moist conditions than actually observed on level topographic positions due to the additional water received as runoff. Such conditions (as in the Tarai region of the Uttar Pradesh) favour more vegetative growth and slower rate of decay of organic remains. This results in the formation of comparatively dark-coloured soils rich in organic matter (Mollisols).

Soil formation and Exposure/ Aspect

Topography affects soil formation by affecting temperature and vegetative growth through slope exposures (aspect}. The southern exposures (facing the sun) are warmer and subject to marked fluctuations in temperature and moisture. The northern exposures, on the other hand are cooler and more humid. The eastern and western exposures occupy intermediate position in this respect.

3. Time

Soil formation is a very slow process requiring thousands of years to develop a mature pedon. The period taken by a given soil from the stage of weathered rock (i.e. regolith) up to the stage of maturity is considered as time. The matured soils mean the soils with fully developed horizons (A, B, C). It takes hundreds of years to develop an inch of soil. The time that nature devotes to the formation of soils is termed as Pedologic Time.

It has been observed that rocks and minerals disintegrate and/or decompose at different rates; the coarse particles of limestone are more resistant to disintegration than those of sandstone. However, in general, limestone decomposes more readily than sandstone (by chemical weathering).

Weathering stages in soil formation

Stages	Characteristic
1 Initial	Un weathered parent material
2 Juvenile	Weathering started but much of the original material still un weathered
3 Virile	Easily weatherable minerals fairly decomposed; clay content increased, slowly weatherable minerals still appreciable
4 Senile	Decomposition reaches at a final stage; only most resistant minerals survive
5 Final	Soil development completed under prevailing environments

- The soil properties also change with time, for instance nitrogen and organic matter contents increase with time provided the soil temperature is not high.
- $CaCO_3$ content may decrease or even lost with time provided the climatic conditions are not arid
- In humid regions, the H+ concentration increases with time because of chemical weathering.

Active Soil Forming Factors

The active soil forming factors are those which supply energy that acts on the mass for the purpose of soil formation. These factors are climate and vegetation (biosphere).

1. Climate

Climate is the most significant factor controlling the type and rate of soil formation. The dominant climates recognized are:

- Arid climate: The precipitation here is far less than the water-need. Hence the soils remain dry for most of the time in a year.
- Humid climate: The precipitation here is much more than the water need. The excess water results in leaching of salt and bases followed by translocation of clay colloids.
- Oceanic climate: Moderate seasonal variation of rainfall and temperature.

- Mediterranean climate: The moderate precipitation. Winters and summers are dry and hot.
- Continental climate: Warm summers and extremely cool or cold winters.
- Temperate climate: Cold humid conditions with warm summers.
- Tropical and subtropical climate: Warm to hot humid with isothermal conditions in the tropical zone.

Climate affects the soil formation directly and indirectly.

Directly, climate affects the soil formation by supplying water and heat to react with parent material. Indirectly, it determines the fauna and flora activities which furnish a source of energy in the form of organic matter. This energy acts on the rocks and minerals in the form of acids, and salts are released. The indirect effects of climate on soil formation are most clearly seen in the relationship of soils to vegetation.

Precipitation and temperature are the two major climatic elements which contribute most to soil formation.

Precipitation

Precipitation is the most important among the climatic factors. As it percolates and moves from one part of the parent material to another. It carries with it substances in solution as well as in suspension. The substances so carried are re deposited in another part or completely removed from the material through percolation when the soil moisture at the surface evaporates causing an upward movement of water. The soluble substances move with it and are translocated to the upper layer. Thus rainfall brings about a redistribution of substances both soluble as well as in suspension in soil body.

Temperature

- Temperature is another climatic agent influencing the process of soil formation.
- High temperature hinders the process of leaching and causes an upward movement of soluble salts.
- High temperature favors rapid decomposition of organic matter and increase microbial activities in soil while low temperatures induce leaching by reducing evaporation and there by favour the accumulation of organic matter by slowing down the process of decomposition. Temperature thus controls the rate of chemical and biological reactions taking place in the parent material.

Jenney (1941} computed that in the tropical regions the rate of weathering proceeds three times faster than in temperate regions and nine times faster than in arctic .

2. Organism & Vegetation Organism

- The active components of soil ecosystem are plants, animals, microorganisms and man.
- The role of microorganisms in soil formation is related to the humification and mineralization of vegetation
- The action of animals especially burrowing animals to dig and mix-up the soil mass and thus disturb the parent material
- Man influences the soil formation through his manipulation of natural vegetation, agricultural practices etc.
- Compaction by traffic of man and animals decrease the rate of water infiltration into the soil and thereby increase the rate of runoff and erosion. Vegetation
- The roots of the plants penetrate into the parent material and act both mechanically and chemically.
- They facilitate percolation and drainage and bring about greater dissolution of minerals through the action of CO2 and acidic substances secreted by them.
- The decomposition and humification of the materials further adds to the solubilization of minerals
  - Forests – reduces temperature, increases humidity, reduce evaporation and increases precipitation.
- Grasses reduce runoff and result greater penetration of water in to the parent material.

SOIL FORMING PROCESSES

The pedogenic processes, although slow in terms of human life, yet work faster than the geological processes in changing lifeless parent material into true soil full of life.

- The pedogenic processes are extremely complex and dynamic involving many chemical and biological reactions, and usually operate simultaneously in a given area.
- One process may counteract another, or two different processes may work simultaneously to achieve the same result.
- Different processes or combination of processes operate under varying natural environment. The collective interaction of various soil forming factors under different environmental conditions set a course to certain recognized soil forming processes.

The basic process involved in soil formation (Simonson, 1959) includes the following.

- Gains or Additions of water, mostly as rainfall, organic and mineral matter to the soil.
- Losses of the above materials from the soil.

- Transformation of mineral and organic substances within the soil.
- Translocation or the movement of soil materials from one point to another within the soil. It is usually divided into
    - movement of solution (leaching) and
    - movement in suspension (eluviation) of clay, organic matter and hydrous oxides

A. Fundamental Soil forming Processes Humification

Humification is the process of transformation of raw organic matter into humus. It is extremely a complex process involving various organisms.

First, simple compounds such as sugars and starches are attacked followed by proteins and cellulose and finally very resistant compounds, such as tannins, are decomposed and the dark coloured substance, known as humus, is formed.

Eluviation

It is the mobilization and translocation of certain constituent's viz. Clay, Fe2O3, Al2O3, SiO2, humus, CaCO3, other salts etc. from one point of soil body to another. Eluviation means washing out. It is the process of removal of constituents in suspension or solution by the percolating water from the upper to lower layers. The eluviation encompasses mobilization and translocation of mobile constituents resulting in textural differences. The horizon formed by the process of eluviation is termed as eluvial horizon (A or E horizon). Translocation depends upon relative mobility of elements and depth of percolation.

Illuviation

The process of deposition of soil materials (removed from the eluvial horizon) in the lower layer (or horizon of gains having the property of stabilizing translocated clay materials) is termed as Illuviation. The horizons formed by this process are termed as illuvial horizons (B-horizons, especially Bt) The process leads to textural contrast between E and Bt horizons, and higher fine: total clay ratio in the Bt horizon.

Horizonation

It is the process of differentiation of soil in different horizons along the depth of the soil body. The differentiation is due to the fundamental processes, humification, eluviation and illuviation.

B. Specific Soil Forming Processes

The basic pedologic processes provide a framework for later operation of more specific processes

1. Calcification

It is the process of precipitation and accumulation of calcium carbonate ($CaCO_3$) in some part of the profile. The accumulation of $CaCO_3$ may result in the development of a calcic horizon. Calcium is readily soluble in acid soil water and/or when CO_2 concentration is high in root zone as:

$$CO_2 + H_2O \rightarrow H_2CO_3$$

$$H_2CO_3 + Ca \rightarrow Ca(HCO_3)_2 \text{ (soluble) Temp.}$$

$$Ca(HCO_3)_2 \rightarrow CaCO_3 + H_2O + CO_2 \text{ (precipitates) } 3$$

The process of precipitation after mobilization under these conditions is called calcification and the resulting illuviated horizon of carbonates is designated as Bk horizon (Bca).

2. Decalcification

It is the reverse of calcification that is the process of removal of CaCO3 or calcium ions from the soil by leaching

Temp.

$$CaCO_3 + CO_2 + H_2O \rightarrow Ca(HCO_3) \text{ (soluble)}$$

(insoluble)

3. Podzolization

It is a process of soil formation resulting in the formation of Podzols and Podzolic soils. In many respects, podzolization is the negative of calcification. The calcification process tends to concentrate calcium in the lower part of the B horizon, whereas podzolization leaches the entire solum of calcium carbonates. Apart from calcium, the other bases are also removed and the whole soil becomes distinctly acidic. In fact, the process is essentially one of acid leaching.

The process operates under favorable combination of the following environments.

i) Climate: A cold and humid climate is most favorable for podzolization.

ii) Parent material: Siliceous (Sandy) material, having poor reserves of weatherable minerals, favor the operation of podzolization as it helps in easy percolation of water. iii) Vegetation: Acid producing vegetation such as coniferous pines is essential iv) Leaching and Translocation of Sesquioxide: In the process of decomposition of organic matter various organic acids are produced. The organic acids thus formed act with Sesquioxide and the remaining clay minerals, forming organic- Sesquioxide and organic clay complexes, which are soluble and move with the percolating water to the lower horizons (Bh, Bs). Aluminium ions in a water solution hydrolyze and make the soil solution very acidic.

As iron and aluminium move about, the A horizon gives a bleached grey or ashy appearance. The Russians used the term Podzols (pod means under, the zola means ash like i.e. ash-like horizon appearing beneath the surface horizon) for such soils.

To conclude, the Podzolization is a soil forming process which prevails in a cold and humid climate where coniferous and acid forming vegetations dominate. The humus and Sesquioxide become mobile and leached out from the upper horizon s and deposited in the lower horizon.

4. Laterization

The term laterite is derived from the word later meaning brick or tile and was originally applied to a group of high clay Indian soils found in Malabar hills of Kerala, Tamil Nadu, Karnataka and Maharashtra.

It refers specifically to a particular cemented horizon in certain soils which when dried, become very hard, like a brick. Such soils (in tropics) when massively impregnated with sesquioxides (iron and aluminium oxides) to extent of 70 to 80 per cent of the total mass, are called laterites or latosols (Oxisols). The soil forming process is called Laterization or Latozation.

Laterization is the process that removes silica, instead of sesquioxides from the upper layers and thereby leaving sesquioxides to concentrate in the solum. The process operates under the following conditions. i) Climate

Unlike podzolization, the process of laterization operates most favorable in warm and humid (tropical) climate with 2000 to 2500 mm rainfall and continuous high temperature (25°C) throughout the year. ii) Natural vegetation

The rain forests of tropical areas are favorable for the process.

iii) Parent Material

Basic parent materials, having sufficient iron bearing ferromagnesian minerals (Pyroxene, amphiboles, biotite and chlorite), which on weathering release iron, are congenial for the development of laterites.

5. Gleization

The term glei is of Russian origin means blue, grey or green clay. The Gleization is a process of soil formation resulting in the development of a glei (or gley horizon) in the lower part of the soil profile above the parent material due to poor drainage condition (lack of oxygen) and where waterlogged conditions prevail. Such soils are called hydro orphic soils.

The process is not particularly dependent on climate (high rainfall as in humid regions) but often on drainage conditions.

The poor drainage conditions result from:

- Lower topographic position, such as depression land, where water stands continuously at or close to the surface.
- Impervious soil parent material, and.
- Lack of aeration.

Under such conditions, iron compounds are reduced to soluble ferrous forms. The reduction of iron is primarily biological and requires both organic matter and microorganisms capable of respiring anaerobically. The solubility of Ca, Mg, Fe, and Mn is increased and most of the iron exists as Fe^{++} organo-complexes in solution or as mixed precipitate of ferric and ferrous hydroxides.

This is responsible for the production of typical bluish to grayish horizon with mottling of yellow and or reddish brown colors.

6. Salinization

It is the process of accumulation of salts, such as sulphates and chlorides of calcium, magnesium, sodium and potassium, in soils in the form of a salty (salic) horizon. It is quite common in arid and semi arid regions. It may also take place through capillary rise of saline ground water and by inundation with seawater in marine and coastal soils. Salt accumulation may also result from irrigation or seepage in areas of impeded drainage.

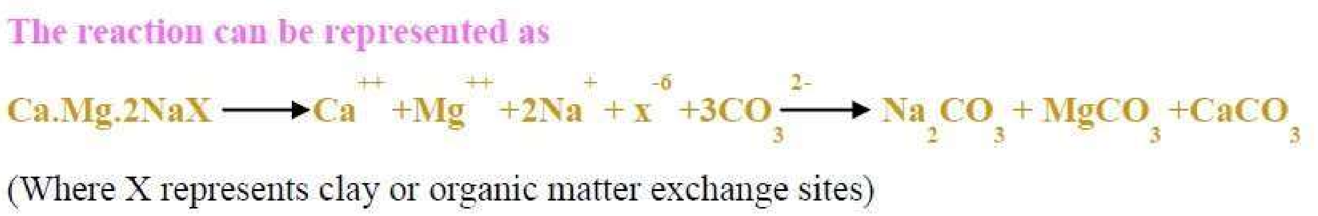
7. Desalinization

It is the removal by leaching of excess soluble salts from horizons or soil profile (that contained enough soluble salts to impair the plant growth) by ponding water and improving the drainage conditions by installing artificial drainage network.

8. Solonization or Alkalization

The process involves the accumulation of sodium ions on the exchange complex of the clay, resulting in the formation of sodic soils (Solonetz).

All cations in solution are engaged in a reversible reaction with the exchange sites on the clay and organic matter particles.



The reaction can be represented as

$$Ca.Mg.2NaX \longrightarrow Ca^{++} + Mg^{++} + 2Na^{+} + x^{-6} + 3CO_3^{2-} \longrightarrow Na_2CO_3 + MgCO_3 + CaCO_3$$

(Where X represents clay or organic matter exchange sites)

9. Solodization or dealkalization

The process refers to the removal of Na^+ from the exchange sites. This process involves dispersion of clay. Dispersion occurs when Na^+ ions become hydrated.

Much of the dispersion can be eliminated if Ca^{++} and or Mg^{++} ions are concentrated in the water, which is used to leach the soonest. These Ca and Mg ion can replace the Na on exchange complex, and the salts of sodium are leached out as :

$$2NaX + CaSO_4 \longrightarrow Na_2SO_4 + CaX$$

(leachable)

10. Pedoturbation

Another process that may be operative in soils is pedoturbation. It is the process of mixing of the soil.

Mixing to a certain extent takes place in all soils. The most common types of pedoturbation are:

- **Faunal pedoturbation:** It is the mixing of soil by animals such as ants, earthworms, moles, rodents, and man himself
- **Floral pedoturbation :** It is the mixing of soil by plants as in tree tipping that forms pits and mounds
- **Argillic pedoturbation:** It is the mixing of materials in the solum by the churning process caused by swell shrink clays as observed in deep Black Cotton Soils.

SOIL PROFILE

The vertical section of the soil showing the various layers from the surface to the unaffected parent material is known as a soil profile.

The various layers are known as horizons. A soil profile contains three main horizons.
They are named as horizon A, horizon B and horizon C.

- The surface soil or that layer of soil at the top which is liable to leaching and from which some soil constituents have been removed is known as horizon A or the horizon of eluviation.
- The intermediate layer in which the materials leached from horizon A have been re- deposited is known as horizon B or the horizon of illuviation.
- The parent material from which the soil is formed is known as horizon C .

A Study of soil profile is important as it is historic record of all the soil forming processes and it forms the basis for the study in pedagogical investigations. Soil profile is the key for the soil classification and also forms the basis for the practical utility of soils.

A hypothetical mineral soil profile will include O, A, B, C and R master horizons and all the possible subhorizons.

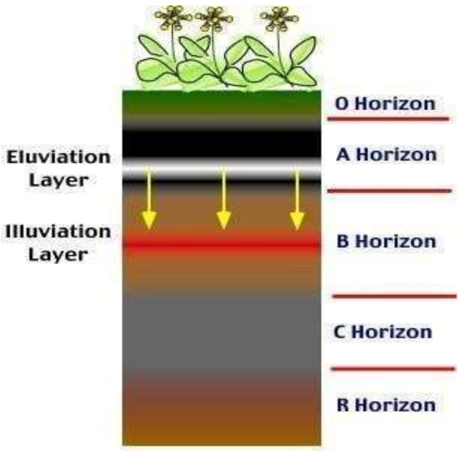
Master horizons and sub horizons

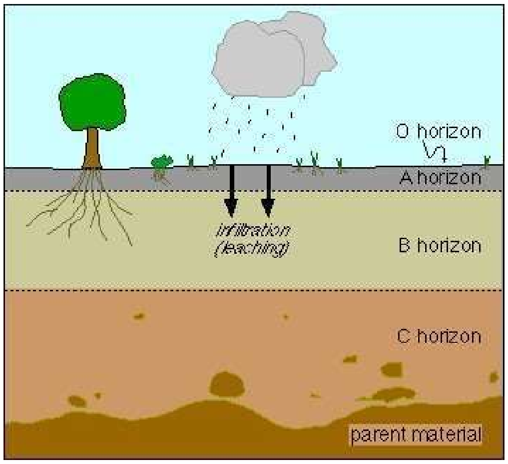
O horizon - It is called as organic horizon. It is formed in the upper part of the mineral soil, dominated by fresh or partly decomposed organic materials.

- This horizon contains more than 30% organic matter if mineral fraction has more than 50 % clay (or) more than 20 % organic matter if mineral fraction has less clay.
- The organic horizons are commonly seen in forest areas and generally absent in grassland, cultivated soils.
- O1 - Organic horizon in which the original forms of the plant and animal residues can be recognized through naked eye.
- O2 - Organic horizon in which the original plant or animal matter can not be recognized through naked eye.
- A horizon - Horizon of organic matter accumulation adjacent to surface and that has lost clay, iron and aluminium.
- A1 - Top most mineral horizon formed adjacent to the surface. There will be accumulation of humified organic matter associated with mineral fraction and darker in Colour than that of lower horizons due to organic matter.
- A2 - Horizon of maximum eluviation of clay, iron and aluminium oxides and organic matter. Loss of these constituents generally results in accumulation of quartz and other sand and silt size resistant minerals. Generally lighter in Colour than horizons above and below.
- A3 - A transitional layer between A and B horizons with more dominated properties of A1 or A2 above than the underlying B horizon. This horizon is sometimes absent. Solum.
- B horizon - Horizon in which the dominant features are accumulation of clay, iron, aluminium or humus alone or in combination. Coating of sesquioxides will impart darker, stronger of red Colour than overlying or underlying horizons.
- B1 - A transitional layer between A and B. More like A than B.

- B2 - Zone of maximum accumulation of clay, iron and aluminium oxide that may have moved down from upper horizons or may have formed in situ. The organic matter content is generally higher and Colour darker than that of A2 horizon above.
- B3 - Transitional horizon between B and C and with properties more similar to that of overlying B2 than underlying C.
- C horizon - It is the horizon below the solum (A + B), relatively less affected by soil forming processes. It is outside the zone of major biological activity. It may contain accumulation of carbonates or sulphates, calcium and magnesium .
- R - Underlying consolidated bed rock and it may or may not be like the parent rock from which the solum is formed.

Besides, lower case letters are used to indicate the special features of master horizons. This case letters follow the subdivisions of master horizons. eg. Ap - ploughed layer eg. B2t - illuvial clay When two or more genetically unrelated (contrasting) materials are present in a profile as in the case of alluvial or colluvial soils then the phenomenon is known as lithological discontinuity. This is indicated by the use of Roman letters as prefixes to the master horizons. eg. Ap, B2, II B22, IIIC.





Special Features

Soil Individual or Polypedon: The Soil Survey Staff (1960) defined the soil individual or polypedon (Pedon, Ground) as a natural unit of soil that differs from its adjoining unit on the landscape in one or more properties.

The term pedon has been proposed for small basic soil entities that are part of the continuum mantling the land.

A pedon is the smallest volume that can be called "a soil". The set of pedons must fit within the range of one series and occur in a contiguous group to form a polypedon.

A polypedon is therefore, defined as a contiguous similar pedons bounded on all sides by "not- soil or by pedons of unlike characters. It is a real physical soils body which has a minimum area of more than 1 sq. km and an unspecified maximum area.

COMPONENTS OF SOIL

Plants obtain inorganic elements from the soil, which serves as a natural medium for land plants. Soil is the outer, loose layer that covers the surface of Earth. Soil quality, a major determinant, along with climate, of plant distribution and growth, depends not only on the chemical composition of the soil, but also the topography (regional surface features) and the presence of living organisms.

Soil consists of these major components:

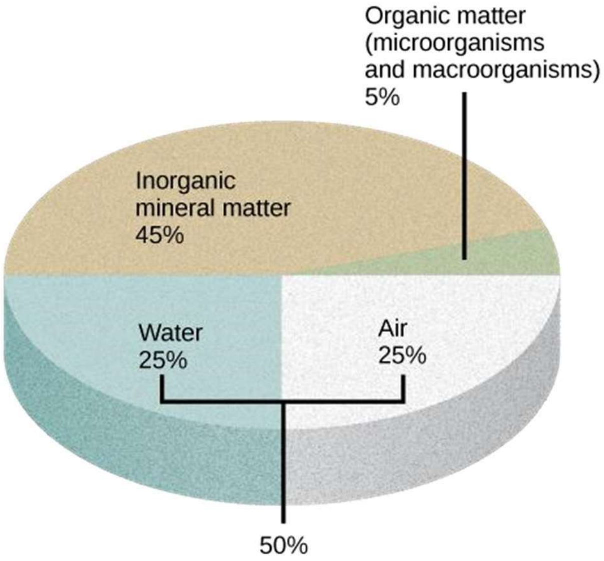


Fig: Components of soil

- Inorganic mineral matter (40 to 45 %)
- Organic matter (5 %)
- Water (25 %)
- Air (25 %)

The amount of each of the four major components of soil depends on the quantity of vegetation, soil compaction, and water present in the soil. A good, healthy soil has sufficient air, water, minerals, and organic material to promote and sustain plant life.

The organic material of soil, called humus, is made up of microorganisms (dead and alive), and dead animals and plants in varying stages of decay. Humus improves soil structure, providing plants with water and minerals. The inorganic material of soil is composed of rock, slowly broken down into smaller particles that vary in size. Soil particles that are 0.1 to 2 mm in diameter are sand. Soil particles between 0.002 and 0.1 mm are called silt, and even smaller particles, less than 0.002 mm in diameter, are called clay. Some soils have no dominant particle size, containing a mixture of sand, silt, and humus; these soils are called loams.

SOIL PHYSICAL PROPERTIES

Physical properties (mechanical behaviour) of a soil greatly influence its use and behaviour towards plant growth. The plant support, root penetration, drainage, aeration, retention of moisture, and plant nutrients are linked with the physical condition of the soil. Physical properties also influence the chemical and biological behaviour of soil. The physical properties of a soil depend on the amount, size, shape, arrangement and mineral composition of its particles. These properties also depend on organic matter content and pore spaces.

Important physical properties of soils.

1. Soil texture, 2. Soil structure, 3. Surface area, 4. Soil density,
5. Soil porosity, 6.Soil colour, 7.Soil consistence

Soil texture- Textural classes- Particle size distribution Definition

Soil texture refers to the relative proportion of particles or it is the relative percentage by weight of the three soil separates viz., sand, silt and clay or simply refers to the size of soil particles. The proportion of each size group in a given soil (the texture) cannot be easily altered and it is considered as a basic property of a soil. The soil separates are defined in terms of diameter in millimeters of the particles Soil particles less than 2 mm in diameter are excluded from soil textural determinations. Stones and gravels may influence the use and management of land because of tillage difficulties but these larger particles make little or no contribution to soil properties such as WHC and capacity to store plant nutrients and their supply.

Gravels : 2 – 4 mm

Pebbles : 4 – 64 mm

Cobbles : 64 – 256 mm

Boulders : > 256 mm

Particles less than 2 mm is called fine earth, normally considered in chemical and mechanical analysis.

The components of fine earth: Sand, Silt and Clay (Soil separates. The size limits of these fractions have been established by various organizations. There are a number of systems of naming soil separates.

(a) The American system developed by USDA

(b) The English system or British system (BSI)

(c) The International system (ISSS)

(d) European system

USDA

Soil separates	Diameter (mm)
Clay	< 0.002 mm
Silt	0.002 – 0.05
Very Fine Sand	0.05 – 0.10
Fine Sand	0.10 – 0.25
Medium Sand	0.25 - 0.50
Coarse Sand	0.50 - 1.00
Very Coarse Sand	1.00 – 2.00

Sand

- Usually consists of quartz but may also contain fragments of feldspar, mica and occasionally heavy minerals viz., zircon, Tourmaline and hornblende.
- Has uniform dimensions
- Can be represented as spherical
- Not necessarily smooth and has jagged surface

Silt

- Particle size intermediate between sand and clay
- Since the size is smaller, the surface area is more

- Coated with clay
- Has the physico- chemical properties as that of clay to a limited extent
- Sand and Silt forms the SKELETON

Clay

- Particle size less than 0.002 mm
- Plate like or needle like in shape
- Belong to alumino silicate group of minerals
- Sometimes considerable concentration of fine particles which does not belong to alumino silicates. (eg). iron oxide and $CaCO_3$
- These are secondary minerals derived from primary minerals in the rock
- Flesh of the soil

Knowledge on Texture is important. It is a guide to the value of the land .Land use capability and methods of soil management depends on Texture Particle size distribution/ determination

The determination of relative distribution of the ultimate or individual soil particles below 2 mm diameter is called as Particle size analysis or Mechanical analysis

Two steps are involved

i) Separation of all the particles from each other i.e. Complete dispersion into ultimate particles

ii) Measuring the amount of each group

Separation

S.No	Aggregating agents	Dispersion method
1	Lime and Oxides of Fe & Al	Dissolving in HCl
2	Organic matter	Oxidises with H_2O_2
3	High concn. of electrolytes (soluble salts)	Precipitate and decant or filter with suction
4	Surface tension	Elimination of air by stirring with water or boiling

After removing the cementing agents , disperse by adding NaOH

Measurement

Once the soil particles are dispersed into ultimate particles, measurement can be done
i) Coarser fractions – sieving – sieves used in the mechanical analysis corresponds to the desired particle size separation

For 2 mm, 1 mm and 0.5 mm – sieves with circular holes

For smaller sizes, wire mesh screens are used (screening)

ii) Finer fractions – by settling in a medium

The settling or the velocity of the fall of particles is influenced by

Viscosity of the medium

Difference in density between the medium and falling particles

Size and shape of object Stokes'

Law

Particle size analysis is based on a simple principle i.e. "when soil particles are suspended in water they tend to sink. Because there is little variation in the density of most soil particles, their velocity (V) of settling is proportional to the square of the radius 'r' of each particles.

Thus $V = kr^2$, where k is a constant. This equation is referred to as Stokes' law.

Stokes (1851) was the first to suggest the relationship between the radius of the particles and its rate of fall in a liquid. He stated that "the velocity of a falling particle is proportional to the square of the radius and not to its surface. The relation between the diameter of a particle and its settling velocity is governed by Stokes' Law:

$$V = \frac{2gr^{2}(ds - dw)}{9n}$$

Where ,

V - velocity of settling particle (cm/sec.)

g - acceleration due to gravity cm/ sec^{2} (981)

ds - density of soil particle (2.65)

dw - density of water (1)

n - coefficient of viscosity of water (0.0015 at 4oC)

r - radius of spherical particles (cm).

Assumptions and Limitations of Stokes' Law

Particles are rigid and spherical / smooth. This requirement is very difficult to fulfill, because the particles are not completely smooth over the surface and spherical. It is established that the particles are not spherical and irregularly shaped such as plate and other shapes.

The particles are large in comparison with the molecules of the liquid so that in comparison with the particle the medium can be considered as homogenous. Ie the particles must be big enough to avoid Brownian movement. The particles less than 0.0002 mm exhibit this movement so that the rate of falling is varied.

The fall of the particles is not hindered or affected by the proximity (very near) of the wall of the vessel or of the adjacent particles. Many fast falling particles may drag finer particles down along with them.

The density of the particles and water and as well as the viscosity of the medium remain constant. But this is usually not so because of their different chemical and mineralogical composition.

The suspension must be still. Any movement in the suspension will alter the velocity of fall and such movement is brought by the sedimentation of larger particles (> 0.08 mm). They settle so fast and create turbulence in the medium.

The temperature should be kept constant so that convection currents are not set up.

Methods of Textural determination

Numerous methods for lab and field use have been developed

i) Elutriation method – Water & Air ; ii)Pipette method iii)

Decantation/ beaker method ; iv) Test tube shaking method

v) Feel method – Applicable to the field – quick method – by feeling the soil between thumb and fingers

Feel Method

Evaluated by attempting to squeeze the moistened soil into a thin ribbon as it is pressed with rolling motion between thumb and pre finger or alternately to roll the soil into a thin wire.

η Four aspects to be seen – i) Feel by fingers, ii)Ball formation , iii) Stickiness and iv) Ribbon formation

Soil Textural Classes

To convey an idea of the textural make up of soils and to give an indication of their physical properties, soil textural class names are used. These are grouped into three main fractions viz., Sand, Silt and Clay.

According to the proportion of these three fractions a soil is given a name to indicate its textural composition. Such a name gives an idea not only of the textural composition of a soil but also of its various properties in general.

On this basis soils are classified into various textural classes like sands clays, silts, loams etc Sands

The sand group includes all soils in which the sand separates make up at least 70% and the clay separate 15% or less of the material by weight. The properties of such soils are therefore characteristically those of sand in contrast to the stickier nature of clays. Two specific textural classes are recognized in this group sandy and loamy sand although in practice two subclasses are also used Loamy fine sand and loamy very fine sand.

Silt

The silt group includes soils with at least 80% silt and 12% or less clay. Naturally the properties of this group are dominated by those of silt. Only one textural class - Silt is included in this group.

Clays

To be designated a clay a soi1 must contain at least 35% of the clay separate and in most cases not less than 40%. In such soils the characteristics of the clay separates are distinctly dominant, and the class names are clay, sandy clay and silty clay. Sandy clays may contain more sand than clay. Likewise, the silt content of silty clays usually exceeds clay fraction.

Loams

The loam group, which contains many subdivisions, is a more complicated soil textural class. An ideal loam may be defined as a mixture of sand, silt and day particles that exhibits the properties of those separates in about equal proportions. Loam soils do not exhibit dominant physical properties of sand, silt or clay. Loam does not contain equal percentage of sand, silt and clay. However, exhibit approximately equal properties of sand, silt and clay.

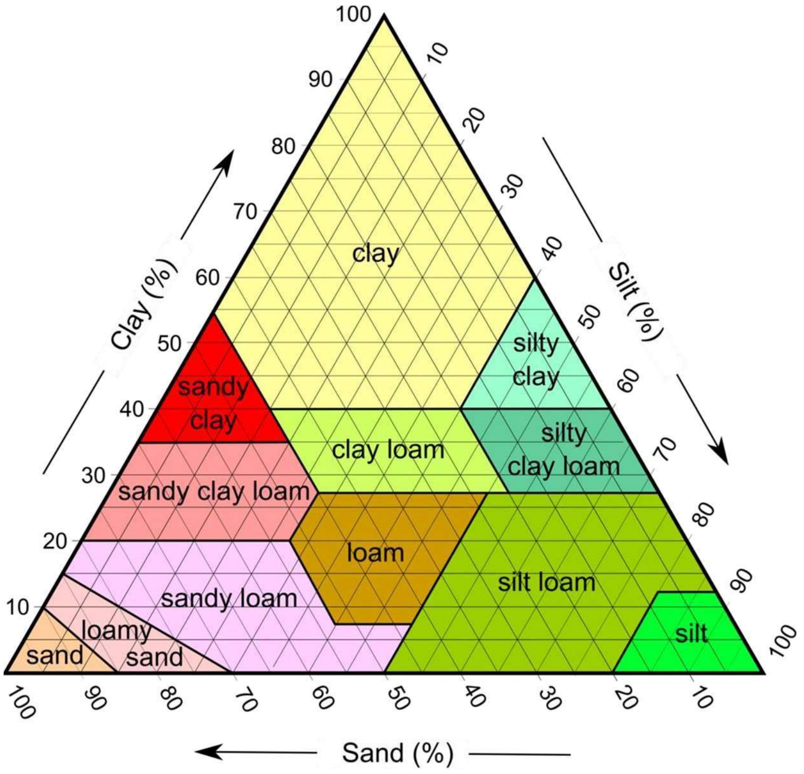
Determination of Textural Class

In the American system as developed by the United State Department of Agriculture twelve textural classes are proposed.

The textural triangle

It is used to determine the soil textural name after the percentages of sand, silt, and clay are determined from a laboratory analysis. Since the soil's textural classification includes only mineral particles and those of less than 2mm diameter, the sand plus silt plus clay percentages equal 100 percent. (note that organic matter is not included.) Knowing the amount of any two fractions automatically fixes the percentage of the third one.

To use the diagram, locate the percentage of clay first and project inward parallel to sand line. Do likewise for the per cent silt and project inward parallel to clay line and for sand, project inward parallel to silt. The point at which the projections cross or intersect will identify the class name Some times, the intersecting point exactly fall on the line between the textural classes. Then it is customary to use the name of the finer fraction when it happens. (eg). Soil containing 40% clay, 30% sand.



Importance of Soil Texture

Presence of each type of soil particles makes its contribution to the nature and properties of soil as a whole

- Texture has good effect on management and productivity of soil. Sandy soils are of open character usually loose and friable.
- Such type of the texture is easy to handle in tillage operations.
- Sand facilitates drainage and aeration. It allows rapid evaporation and percolation.
- Sandy soils have very little water holding capacity. Such soils can not stand drought and unsuitable for dry farming.
- Sandy soils are poor store house of plant nutrients
- Contain low organic matter
- Leaching of applied nutrients is very high.
- In sandy soil, few crops can be grown such as potato, groundnut and cucumbers.
- Clay particles play a very important role in soil fertility.
- Clayey soils are difficult to till and require much skill in handling. When moist clayey soils are exceedingly sticky and when dry, become very hard and difficult to break.

- They have fine pores, and are poor in drainage and aeration.
- They have a high water holding capacity and poor percolation, which usually results in water logging.
- They are generally very fertile soils, in respect of plant nutrient content. Rice, jute, sugarcane can be grown very successfully in these soils.
- Loam and Silt loam soils are highly desirable for cultivation
- Generally, the best agriculture soils are those contain 10 – 20 per cent clay, 5 – 10 per cent organic matter and the rest equally shared by silt and sand and 30% silt - called as clay rather than clay loam.

SOIL STRUCTURE

Soil conditions and characteristics such as water movement, heat transfer, aeration, and porosity are much influenced by structure. In fact, the important physical changes imposed by the farmer in ploughing, cultivating, draining, liming, and manuring his land are structural rather than textural.

Definition

The arrangement and organization of primary and secondary particles in a soil mass is known as soil structure. Soil structure controls the amount of water and air present in soil. Plant roots and germinating seeds require sufficient air and oxygen for respiration. Bacterial activities also depend upon the supply of water and air in the soil.

Formation of soil structure

Soil particles may be present either as single individual grains or as aggregate i.e. group of particles bound together into granules or compound particles. These granules or compound particles are known as secondary particles. A majority of particles in a sandy or silty soil are present as single individual grains while in clayey soil they are present in granulated condition. The individual particles are usually solid, while the aggregates are not solid but they possess a porous or spongy character. Most soils are mixture of single grain and compound particle. Soils, which predominate with single grains are said to be structureless, while those possess majority of secondary particles are said to be aggregate, granulated or crumb structure.

Mechanism of Aggregate Formation

The bonding of the soil particles into structural unit is the genesis of soil structure. The bonding between individual particles in the structural units is generally considered to be stronger than the structural units themselves.

In aggregate formation, a number of primary particles such as sand, silt and clay are brought together by the cementing or binding effect of soil colloids. The cementing materials taking part in aggregate formation are colloidal clay, iron and aluminium hydroxides and decomposing organic matter. Whatever may be the cementing material, it is ultimately the dehydration of colloidal matter accompanied with pressure that completes the process of aggregation.

Colloidal clay

By virtue of high surface area and surface charge, clay particles play a key role in the formation of soil aggregates. Sand and silt particles can not form aggregates as they do not possess the power of adhesion and cohesion. These particles usually carry a coating of clay particles; they are enmeshed in the aggregates formed by the adhering clay particles. Colloidal particles form aggregates only when they are flocculated. There is vast difference between flocculation and aggregation. Flocculation is brought about by coalescence of colloidal particles and is the first step in aggregation.

Aggregation is something more than flocculation involving a combination of different factors such as hydration, pressure, dehydration etc. and required cementation of flocculated particles. The cementation may be caused by cations, oxides of Fe and Al, humus substances and products of microbial excretion and synthesis. Clay particles form aggregates only if they are wetted by a liquid like water whose molecules possess an appreciable dipole moment.

The aggregation also depends upon the nature of clay particles, size and amount of clay particles, dehydration of clay particles, cations like calcium and anions like phosphate.

Fe and Al oxides

The colloidal Fe oxides act as cementing agent in aggregation. Al oxides bind the sand and silt particles. These act in two ways. A part of the hydroxides acts as a flocculating agent and the rest as a cementing agent.

Organic matter: It also plays an important role in forming soil aggregates.

- During decomposition, cellulosic substances produce a sticky material very much resembling mucus or mucilage. The sticky properly may be due to the presence of humic or humic acid or related compounds produced.
- Certain polysaccharides formed during decomposition.
- Some fungi and bacteria have cementing effect probably due to the presence of slimes and gums on the surface of the living organisms produced as a result of the microbial activity.

Classification

The primary particles –sand, silt and clay - usually occur grouped together in the form of aggregates. Natural aggregates are called peds where as clod is an artificially formed soil mass. Structure is studied in the field under natural conditions and it is described under three categories

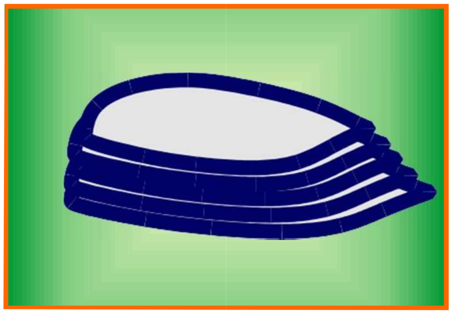
1 Type - Shape or form and arrangement pattern of peds 2 Class - Size of Peds

3 Grade - Degree of distinctness of peds

Types of Structure: There are four principal forms of soil structure

Plate-like (Platy)

In this type, the aggregates are arranged in relatively thin horizontal plates or leaflets. The horizontal axis or dimensions are larger than the vertical axis. When the units/ layers are thick they are called platy. When they are thin then it is laminar. Platy structure is most noticeable in the surface layers of virgin soils but may be present in the subsoil. This type is inherited from the parent material, especially by the action of water or ice.



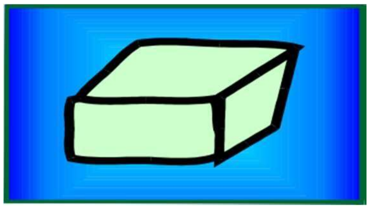
Prism-like

The vertical axis is more developed than horizontal, giving a pillar like shape.

Vary in length from 1- 10 cm. Commonly occur in sub soil horizons of Arid and Semi arid regions. When the tops are rounded, the structure is termed as columnar when the tops are flat / plane, level and clear cut - prismatic.

Block like

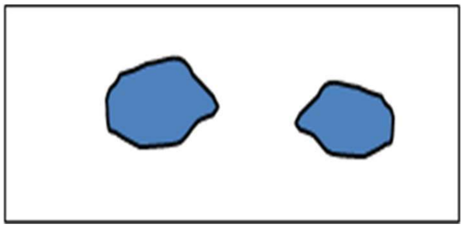
All three dimensions are about the same size. The aggregates have been reduced to blocks .Irregularly six faced with their three dimensions more or less equal. When the faces are flat and distinct and the edges are sharp angular, the structure is named as angular blocky.
When the faces and edges are mainly rounded it is called sub angular blocky. These types usually are confined to the sub soil and characteristics have much to do with soil drainage, aeration and root penetration.

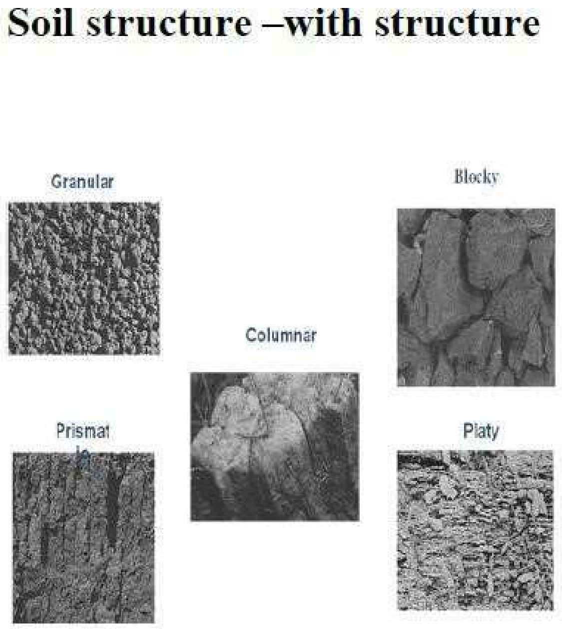


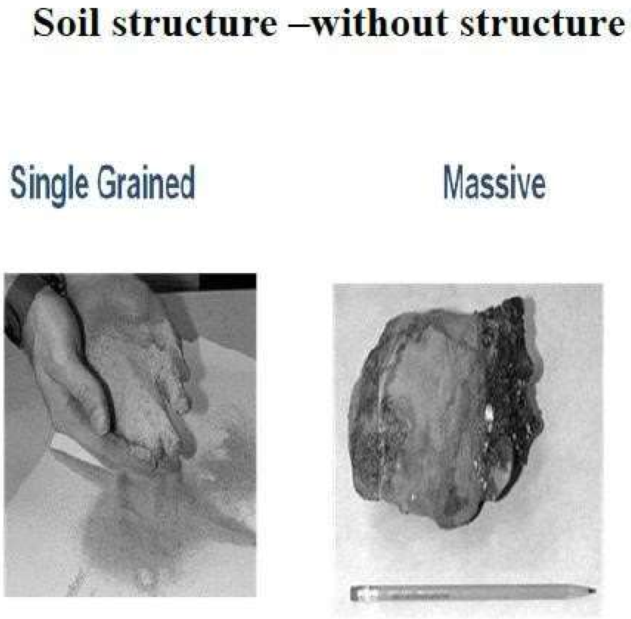
Spheroidal (Sphere like)

All rounded aggregates (peds) may be placed in this category. Not exceeding an inch in diameter. These rounded complexes usually loosely arranged and readily separated. When wetted, the intervening spaces generally are not closed so readily by swelling as may be the case with a blocky structural condition. Therefore in sphere-like structure, infiltration, percolation and aeration are not affected by wetting of soil. The aggregates of this group are usually termed as granular which are relatively less porous. When the granules are very porous, it is termed as crumb. This is specific to surface soil particularly high in organic matter/ grass land soils.

Classes of Structure: Each primary structural type of soil is differentiated into 5 size classes depending upon the size of the individual peds.







The terms commonly used for the size classes are

1. Very fine or very thin
2. Fine or thin
3. Medium

4. Coarse or thick
5. Very Coarse or very thick

The terms thin and thick are used for platy types, while the terms fine and coarse are used for other structural types.

Grades of Structure

Grades indicate the degree of distinctness of the individual peds. It is determined by the stability of the aggregates. Grade of structure is influenced by the moisture content of the soil. Grade also depends on organic matter, texture etc. Four terms commonly used to describe the grade of soil structure are:

1. Structureless: There is no noticeable aggregation, such as conditions exhibited by loose sand.
2. Weak Structure: Poorly formed, indistinct formation of peds, which are not durable and much un aggregated material.
3. Moderate structure: Moderately well developed peds, which are fairly durable and distinct.
4. Strong structure: Very well formed peds, which are quite durable and distinct.

Structure naming

For naming a soil structure the sequence followed is grade, class and type; for example strong coarse angular blocky, moderate thin platy, weak fine prismatic.

Factors Affecting Soil Structure

The development of structure in arable soil depends on the following factors:

1. Climate

Climate has considerable influence on the degree of aggregation as well as on the type of structure. In arid regions there is very little aggregation of primary particles. In semi arid regions, the degree of aggregation is greater.

2. Organic matter

Organic matter improves the structure of a sandy soil as well as of a clay soil. In case of a sandy soil, the sticky and slimy material produced by the decomposing organic matter and the associated microorganism cement the sand particles together to form aggregates. In case of clayey soil, it modifies the properties of clay by reducing its cohesiveness. This helps making clay more crumby.

3. Tillage

Cultivation implements break down the large clods into smaller fragments and aggregates. For obtaining good granular and crumby structure, optimum moisture content in the soil is necessary. If the moisture content is too high it will form large clods on drying. If it is too low some of the existing aggregates will be broken down.

4. Plants, Roots and Residues

Excretion of gelatinous organic compounds and exudates from roots serve as a link Root hairs make soil particles to cling together. – Grass and cereal roots Vs other roots Pressure exerted by the roots also held the particles together

Dehydration of soil - strains the soil due to shrinkage □ result in cracks □ lead to aggregation Plant tops and residues – shade the soil – prevent it from extreme and sudden temperature and moisture changes and also from rain drop impedance.

Plant residues – serve as a food to microbes – which are the prime aggregate builders.

5. Animals

Among the soil fauna small animals like earthworms, moles and insects etc., that burrow in the soil are the chief agents that take part in the aggregation of finer particles.

6. Microbes

Algae, fungi, actinomycetes and fungi keep the soil particles together. Fungi and actinomycetes exert mechanical binding by mycelia, Cementation by the products of decomposition and materials synthesized by bacteria.

7. Fertilizers

Fertilizer like Sodium Nitrate destroys granulation by reducing the stability of aggregates.

Few fertilizers for example, CAN help in development of good structures.

8. Wetting and drying

When a dry soil is wetted, the soil colloids swell on absorbing water. On drying, shrinkage produces strains in the soil mass gives rise to cracks, which break it up into clods and granules of various sizes.

9. Exchangeable cations

Ca, Mg -------------H, Na

Flocculating

Deflocculating Good

structure Poor structure

10. Inorganic cements: $CaCO_3$ and Sesquioxides

11. Clay 12. Water

Effect of Soil Structure on other Physical Properties

Porosity

Porosity of a soil is easily changed. In plate like structure, pore spaces are less where as in crumby structure pore spaces are more.

Temperature

Crumby structure provides good aeration and percolation of water in the soil. Thus these characteristics help in keeping optimum temperature in comparison to plate like structure. Density: Bulk density varies with the total pore space present in the soil. Structure chiefly influences pore spaces Platy structure with less total pore spaces has high bulk density where as crumby structure with more total pore spaces has low bulk density.

Consistence

Consistence of soil also depends on structure. Plate-like structure exhibits strong plasticity.

Colour

Bluish and greenish colors of soil are generally due to poor drainage of soil. Platy structure normally hinders free drainage.

Importance of Structure: Soil structure influences rather indirectly by the formation of an array of pores of various shapes and sizes. These pores are controlling factors governing water, air and temperature in soil.

The role of soil structure in relation to plant growth

- Soil structure influences the amount and nature of porosity.
- Structure controls the amount of water and air present in the soil. Not only the amount of water and air dependent on soil structure, but their movement and circulation are also controlled by soil structure.
- It affects tillage practices.
- Structure controls runoff and erosion.
- Platy structure normally hinders free drainage whereas sphere like structure (granular and crumby) helps in drainage.
- Crumby and granular structure provides optimum infiltration, water holding capacity, aeration and drainage. It also provides good habitat for microorganisms and supply of nutrients.

Class of Soil Structure as differentiated by size of soil peds

Class	Platy	Prismatic	Columnar	Blocky	S.A.Blocky	Granular	Crumb
V.Fine or V.Thin	<1	<10	<10	<5	<5	<1	<1
Fine or Thin	1-2	10-20	10-20	5-10	5-10	1-2	1-2
Medium	2-5	20-50	20-50	10-20	10-20	2-5	2-5
Coarse or Thick	5-10	50-100	50-100	20-50	20-50	5-10	-
V.C or V Thick	>10	>100	>100	>50	>50	>10	-

SOIL DENSITY AND POROSITY

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.

Table: Particle density of different soil textural classes

Textural class	Particle density (g/ cm^3)
Coarse sand	2.655
Fine sand	2.659
Silt	2.798
Clay	2.837

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 , whereas that of organic matter is about 0.5. Bulk density normally decreases, as mineral soils become finer in texture. The bulk density varies indirectly with the total pore space present in the soil and gives a good estimate of the porosity of the soil.

Bulk density is of greater importance than particle density in understanding the physical behavior of the soil. Generally soils with low bulk densities have favorable physical conditions.

Bulk density of different textural classes

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

Factors affecting bulk density

1. Pore space

   Since bulk density relates to the combined volume of the solids and pore spaces, soils with high proportion of pore space to solids have lower bulk densities than those that are more compact and have less pore space. Consequently, any factor that influences soil pore space will affect bulk density.

2. Texture

Fine textured surface soils such as silt loams, clays and clay loams generally have lower bulk densities than sandy soils. This is because the fine textured soils tend to organize in porous grains especially because of adequate organic matter content. This results in high pore space and low bulk density. However, in sandy soils, organic matter content is generally low, the solid particles lie close together and the bulk density is commonly higher than in fine textured soils.

3. Organic matter content

More the organic matter content in soil results in high pore space there by shows lower bulk density of soil and vice-versa.

POROSITY

Soil porosity refers to that part of a soil volume that is not occupied by soil particles or organic matter.

The pore space of a soil is the space occupied by air and water. The amount or ratio of pore space in a soil is determined by the arrangement of soil particles like sand, silt and clay. In sandy soils, the particles are arranged closely and the pore space is low. In clay soils, the particles are arranged in popous aggregates and the pore space is high. Presence of organic matter increases the pore space.

Factors influencing pore space Soil Texture

Sandy surface soil : 35 to 50

% Medium to fine textured soils : 50 to 60

% Compact sub soils : 25 to 30%

Crops / vegetation

Some crops like blue grass increases the porosity to 57.2% from the original 50% cropping reduces the porosity as cultivation reduces the organic matter content and hence decrease in granulation. Virgin soils have more pore space.

Continuous cropping reduces pore space than intermittent cropping. More the number of crops per year, lesser will be the pore space particularly macro pores.

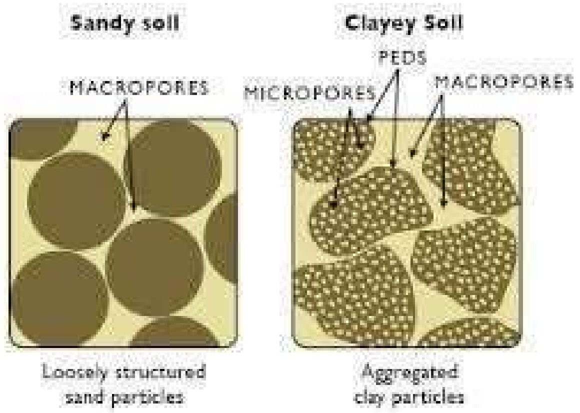
Conservation tillage and no tillage reduces porosity than conventional tillage

Size of pores

1. Macro pores (non-capillary pores) : diameter >0.05 mm
2. Micro pores (capillary pores) : diameter < 0.05 mm

In macro pores, air and water moves freely due to gravitation and mass flow. In micro pores, the movement of air and water is very slow and restricted to capillary movement and diffusion. Sandy soil have more macro pores and clay soils have more micro pores. So in sandy soils, water and air movement is rapid due to macro pores though the pore space is higher and in clay soils the air and water is slower due to micro pores though the total pore space is higher.

Loamy soils will have 50% porosity and have equal portion of macro and micro pores.



SOIL COLOUR

Soil colour indicates many soil features. A change in soil colour from the adjacent soils indicates a difference in the soil`s mineral origin (parent material) or in the soil development. Soil colour varies among different kinds as well as within the soil profile of the same kind of soil. It is an important soil properties through which its description and classification can be made.

Kinds of soil colour

Soil colour is inherited from its parent material and that is referred to as lithochromic, e.g. red soils developed from red sandstone. Besides soil colour also develops during soil formation through different soil forming processes and that is referred to as acquired or pedochromic colour, e.g. red soils developed from granite or schist.

Factors affecting soil colour

There are various factors or soil constituents that influence the soil colour which are as follows:

- Organic matter: soils containing high amount of organic matter show the colour variation from black to dark brown.

- Iron compounds: soil containing higher amount of iron compounds generally impart red, brown and yellow tinge colour.
- Silica, lime and other salts: Sometimes soils contain either large amounts of silica and lime or both. Due to presence of such materials in the soil the colour of the soil appears like white or light coloured.
- Mixture of organic matter and iron oxides: Very often soils contain a certain amount of organic matter and iron oxides. As a result of their existence in soil, the most common soil colour is found and known as brown.
- Alternate wetting and drying condition: During monsoon period due to heavy rain the reduction of soil occurs and during dry period the oxidation of soil also takes place. Due to development of such alternating oxidation and reduction condition, the colour of soil in different horizons of the soil profile is variegated or mottled. This mottled colour is due to residual products of this process especially iron and manganese compounds.
- Oxidation-reduction conditions: when soils are waterlogged for a longer period, the permanent reduced condition will develop. The presence of ferrous compounds resulting from the reducing condition in waterlogged soils impart bluish and greenish colour. Therefore, it may be concluded that soil colour indirectly indicative of many other important soil properties. Besides soil colour directly modify the soil temperature e.g. dark coloured soils absorb more heat than light coloured soils.

Determination of soil colour:

- The soil colours are determined by using Munsell colour chart. In this chart, different colour chips are systematically arranged by three variables namely Hue, Value and Chroma.
- Hue - it indicates the dominant spectral colour (red, yellow, blue and green).
- Value - it indicates lightness or darkness of a colour (the amount of reflected light).
- Chroma - it represents the purity of the colour (strength of the colour).
- The hue is written on the top right hand corner of the chart.
- The values are written on the left hand side and the colour becomes lighter as we move upward.
- The chroma is written at the bottom and increases towards right hand side.
- The combination of these variables is used to describe the colour of a soil as “Munsell notation”. The Munsell colour notations are systematic, numerical with letter designations of each of these three variables (Hue, value and chroma).

- English names of the colours are written on the left page. They have more uniformity for internation use.
- For example, the numerical notation 2.5 YR 5/6 suggests a hue of 2.5 YR, value of 5 and chroma of 6. The equivalent or parallel soil colour name for this Munsell notation is 'red'.

SOIL CONSISTENCY AND PLASTICITY

- Soil consistency is a term used to describe the resistance of soil to mechanical stress or manipulation at various moisture contents.
- According to Russell and Russell (1950), "Soil consistency designates the manifestations of the physical forces of cohesion and adhesion acting within the soil at various moisture contents including the behaviour towards gravity, pressure, thrust and pull, tendency to adhere to foreign bodies and the sensations which are evidenced (by the fingers of the observer) as feel".

Soil consistence is described at three moisture levels namely 'wet', 'moist' and 'dry'.

1. Wet Soils

- In wet soils the consistency is denoted by terms stickiness and plasticity.
- Stickiness is grouped into four categories namely
  - i) non sticky,
  - ii) slightly sticky, iii) sticky and iv) very sticky
- Plasticity of a soil is its capacity to be moulded (to change its shape depending on stress) and to retain the shape even when the stress is removed.
- Soils containing more than 15% clay exhibit plasticity – pliability and the capacity of being molded.
- There are four degrees in plasticity namely
  - i) non plastic, ii) slightly plastic, iii) plastic and iv) very plastic

2. Moist Soil

- Moist soil with least coherence adheres very strongly and resists crushing between the thumb and forefinger.

- The different categories are

  i. Loose-non coherent, ii. Very friable - coherent,
  but very easily crushed, iii. Friable - easily crushed,
  iv. Firm - crushable with moderate pressure,
  v. Very firm - crushable only under strong pressure and vi. Extremely firm -
  completely resistant to crushing. (type and amount of clay and humus influence this
  consistency)

3. Dry Soil

- In dry soil, the degree of resistance is related to the attraction of particles for each other.
- The different categories are

  i. Loose - non coherent ii. Soft - breaks with slight pressure
  and becomes powder iii. Slightly hard - break under
  moderate pressure iv. Hard - breaks with difficulty with
  pressure v. Very hard - very resistant to pressure vi.
  Extremely hard - extreme resistance and cannot be broken.

Atterberg's Limits of Soil Consistency

- Atterberg's limits are used to measure the physical condition of soil at different water contents. These limits can be seen as the indices of workability of soil at various water contents. These depend on texture, organic matter content and amount of clay in the soil.
- It is generally described at three soil moisture levels such as dry, moist and wet and terms used to describe soil consistency are hard or harsh for dry soil, soft or friable for moist soil and plastic and sticky for wet soil.
- Friable consistency is the optimum condition for tillage and other agricultural operations and plastic consistency is optimum condition for puddling.
- Soils are rated for consistency as a part of describing a soil profile and for estimating suitability for traffic and tillage.
- Knowledge of plastic limit and plasticity index is required to characterize the shear strength, in terms of the normal stress applied and the water content of the soil.
- From a practical point of view, the sticky point provides an estimate of the maximum water content at which normal soils will scour during tillage.
- Based on water content, limits of soil consistency are briefly described below:

- Flocculation limit: Moisture content at which soil suspension is transformed from liquid state to a semi-liquid state with appreciable increase in viscosity.
- Liquid limit (upper plastic limit): Moisture content at which soil-water system changes from viscous fluid to a plastic body. Soil is near saturation, it behaves like softened butter.
- Lower Plastic limit: Water content at which soil changes from a plastic to semirigid and friable state. Between upper and lower plastic limits, soil can be moulded into various shapes without breaking.
- Shrinkage limit: Moisture content at which soil changes from semi-rigid to a rigid solid with no change in specific volume as drying proceeds further.
- Sticky limit: Minimum moisture content at which soil paste will adhere to a steel spatula drawn over its surface.
- Plasticity index: Difference in moisture contents between liquid limit and lower plastic limit. It indicates 'clayeyness' or potential plasticity of soil. It depends upon clay content and nature of clay.
- Friable (soft) consistency: The water content in this range permits easier crumbling of the soil. Friable consistency presents the optimum conditions for tillage and preparation of seed-bed. This is reached at moisture contents slightly less than lower plastic limit.
- Harsh consistency: Upon dehydration soil becomes hard due to clay cementation and the consistency is called harsh. It requires more power to plough soil at this water content and soil becomes cloddy when ploughed.

SOIL TAXONOMY

In order to overcome different anomalies in earlier system of soil classification a new comprehensive system has been developed. Initially started in 1951, several approximations were made after taking critical suggestions from pedologists of different countries. The 7th approximation was published in 1960 with supplements in 1964 and 1967. "Soil Taxonomy - A Basic System of Soil Classification for Making and Interpreting Soil Surveys" was published in 1975. The 7th approximation lays more stress on the morphology of soils themselves rather than on the environmental factors.

7th APPROXIMATION

1. It is a natural classification of soil.

2. The classification is based on properties of the soils.
3. The properties selected should be observable or measurable. Properties which can be measured quantitatively should be preferred.
4. The properties selected should be those either affect soil genesis or result from soil genesis.
5. The properties with the greater significance to plant growth should be selected for the higher category.
6. The classification system is flexible.

Categories

There are six categories of classification in Soil Taxonomy (i) order (ii) sub-order (iii) great group (iv) sub-group (v) family and (vi) series.

(i) Order: The order is based on soil forming process. In a given order, soil properties are similar in their genesis. There are following eleven soil orders in soil taxonomy.

S.No.	Soil order	Formative element	Major characteristics
1	Entisols	ent	Little profile development, Ochric epipedon common
2	Inceptisols	ept	Embryonic soils with few diagnostic features, Ochric or umbric epipedon; Cambic horizon
3	Mollisols	oll	Mollic epipedon, high base saturation, dark soils, some with argillic or nitric horizons
4	Alfisols	alf	Argillic or nitric horizon; high to medium base saturation
5	Ultisols	ult	Argillic (clay) horizon; low base saturation
6	Oxisols	ox	Oxic horizon, no argillic horizon, highly weathered
7	Vertisols	ert	High in swelling clays, deep cracks when soil dry, dark colour
8	Aridisols	id	Dry soil, ochric epipedon, sometimes argillic or nitric horizon

9	Spodosols	od	Spodic horizon commonly with Fe, Al, and humus accumulation, forest
10	Histosols	ist	Peat or bog; more than 30% organic matter (organic soil)
11	Andisols*	and	From volcanic ejects, dominated by allophane or Alhumic complexes
12	Gelisols	el	Permafrost often with cryoturbation (frost churning)

*Recently added as a soil order.

(ii) Sub order: The sub-orders are sub-divisions of orders. The sub-order indicates genetic homogeneity. Climatic environment, vegetation and wetness help in determining the genetic processes. Forty seven sub-orders have been recognized.

Formative Element	Derivatives	Connotation of formative element
alb	L. albus, white	Presence of albic horizon (a bleached eluvial horizon)
anthr	Gk.anthropos, human	Presence of anthropic or plaggen epipedon
aqu	L. aqua, water	Characteristics associated with wetness
ar	L. arare, to plow	Mixed horizon
arg	L. argilla, white clay	Presence of argillic horizon (with illuvial clay)

calc	L. calcis lime	Presence of calcic horizon
camb	L. cambriar, to change	Presence of cambric horizon
cry	Gk. kryos, icy cold	Cold
dur	L. durus, hard	Presence of a duripan
fibr	L. fibra, fibre	Least decomposed stage
fluv	L. fluvius, river	Floodplain
fol	L. folia, leaf	Mass of leaves
gyps	L. gypsum, gypsum	Presence of gypsic horizon
hem	Gk. hemi, half	Intermediate stage of decomposition
hist	Gk. histos, tissue	Presence of histic epipedon
hum	L. humas, earth	Presence of organic matter
orth	Gk. orhos, true	The common ones
per	L. per, throughout time	Of year-round humid climates, perudic moisture regime

psamm	Gk. psammos, sand	Sand textures
rend	Modified from rendzina	Rendzinalike-high in carbonates
sal	L. sal, salt	Presence of salic (saline) horizon
sapr	Gk. sapros, rotten	Most decomposed stage
tor	L. torridus, hot and dry	Usually dry
tur	L. turbidus, disturbed	Cryoturbation
ud	L. udus, humid	Of humid climate
ust	L. ustus, burnt	Of dry climates, usually hot in summer
vitr	L. vitreus, glass	Resembling glass
xer	Gk. xeros, dry	Dry summers, moist winters

(iii) Great group: Diagnostic horizons are the primary bases for differentiating the great group in a given sub-order. Nearly 230 great groups are recognized.

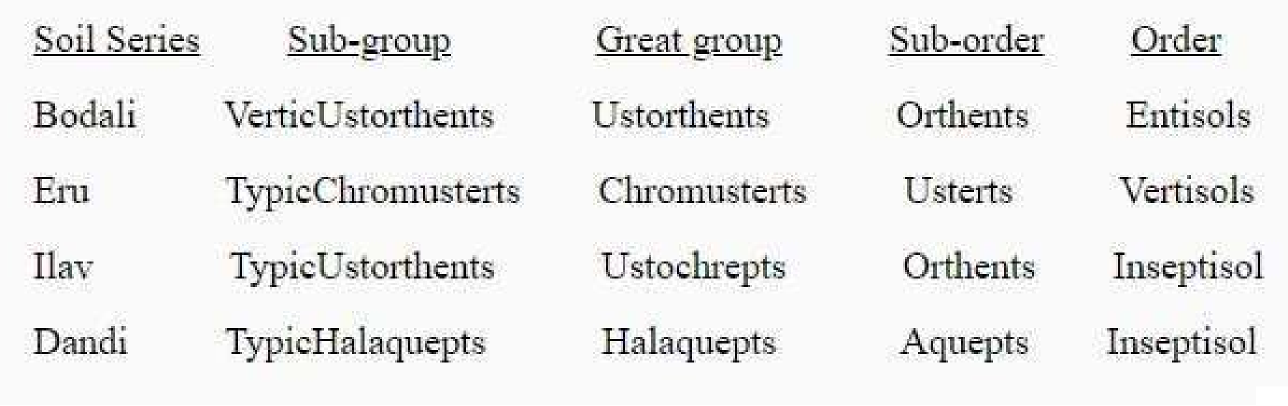
(iv) Sub-group: The sub-groups are sub-divisions of the great groups. There are more than 1200 sub-groups.

(v) Family: The family is differentiated on the basis of texture, mineralogy, and temperature and soil depth. Some 6600 families are recognized.

(vi) Series: The series is a sub-division of the family and is the most specific unit of classification. Differentiating characteristics are primarily based on the kind arrangement of horizons. About 16,800 soils series are recognized.

Nomenclature in soil taxonomy:

1. Order: ends with - Soil e.g. arid soil.
2. Sub-order: It is composed of formative element of order + any differentiating character like temperature, moisture, drainage, diagnostic horizon etc. e.g. Aquolls wet soil-Mollisols (oil), Aquents wet soil- Entisols (ent), Argid aridi soil (id).
3. Great group: It is composed of order + sub-order + one or more specific characters which modify the sub-order e.g. Argiaqoll Molli soil –order, aqoll - sub-order wetness, Arg -argillic horizon.
4. Sub-group: It is identified with a binomial nomenclature. e.g. A 'Typic' adjective is used when sub-group represent a 'Central concept' of the great group. e.g. Typic Argiaqoll. There are integrated between different sub-groups or between great groups in the same order.
5. Family: In nomenclature of family- we have textural class, mineralogy, temperature regime and some time reaction, drainage class and topography. e.g. Fine-clay/Very fine clayey, mixed montmorillonitic, calcareous, hyperthermic, Typic Chromustert.
6. Series: Name of the series is given on the basis where it is described. e.g.



Soil Series	Sub-group	Great group	Sub-order	Order
Bodali	VerticUstorthents	Ustorthents	Orthents	Entisols
Eru	TypicChromusterts	Chromusterts	Usterts	Vertisols
Ilav	TypicUstorthents	Ustochrepts	Orthents	Inseptisol
Dandi	TypicHalaquepts	Halaquepts	Aquepts	Inseptisol

SOILS OF INDIA

Soils of India have been divided into the following eleven major groups:

(1) Red soils (2) Lateritic soils (3) Black soil (4) Alluvial soils (5) Desert soils (6) Saline and alkaline soils (7) Peaty and marshy soils (8) Tarai soils (9) Brown hill soils (10) Sub-mountain soils (11) Mountain meadow soils.

SOIL WATER RETENTION, MOVEMENT AND AVAILABILITY

SOIL WATER

- Water present in soil pores is called soil water.
- It is an important component of the soil which influences soil organisms and plant growth.
- It serves as a solvent and carrier of nutrients for plant growth.
- It regulates soil temperature and helps in chemical and biological activities of soil.
- It is essential for soil forming processes and weathering.

Forms of soil water 1. Gravitational water (free water)

- This form of water is loosely held in soil (in macro pores) and move downwards freely under the influence of gravity.
- Water in excess of the field capacity is termed gravitational water.
- The drainage or deep percolation loss of water results from downward movement of this gravity water.
- It has a suction of less than 1/3 atmosphere.
- The plants can not absorb it as it drains out of root zone in short period of time.

2. Capillary water

- Capillary water is held in the capillary pores (micro pores) with a suction ranging from 1/3 and 31 atmospheres. Capillary water is retained on the soil particles by surface forces.
- It is held so strongly that gravity cannot remove it from the soil particles.
- The availability of capillary water to plant roots depends on pore diameter which controls the pressure of water. The narrower the capillary pore, lesser is the availability.

3. Hygroscopic water

- This form of soil water is held with a high suction ranging from 31 to 10000 atmospheres. It is held tightly on the surface of soil colloidal particles.
- Generally, it includes first two molecular layers of water on soil particles. Plants can not absorb this form of water.

Soil moisture constants

- These are of practical importance for irrigation and drainage management. These are also used to compare water retention capacity of different soils.

1. Field capacity

- If a soil is saturated, gravity water starts moving downwards. When all the gravitational water is drained away, and then the wet soil is almost uniformly moist.
- The amount of water held by the soil at this stage is known as the field capacity of that soil. It is the capacity of the soil to retain water against the downward pull of the force of gravity.
- At this stage only micro-pores or capillary pores are filled with water and plants absorb water for their use.
- At field capacity water is held with a suction of 1/3 atmosphere.

2. Wilting coefficient

- As the soil water content decreases, a point is reached when the water is so firmly held by the soil particles that plant roots are unable to extract water at a rate sufficient to meet the transpiration needs.
- The plant begins to wilt. At this stage even if the plant is kept in a saturated atmosphere it does not regain its turgidity and wilts unless water is applied to the soil.
- The stage at which this occurs is termed the wilting point and the percentage amount of water held by the soil at this stage is known as the wilting coefficient.
- Water at wilting coefficient is held with a force of 15 atmospheres (pF=4.2).

3. Hygroscopic coefficient

- The hygroscopic coefficient is the maximum amount of hygroscopic water absorbed by 100 g of dry soil under standard conditions of humidity (50% relative humidity) and temperature (15°C).
- This tension is equal to a force of 31 atmospheres (pF=4.5).
- Water at this tension is not available to plant but may be available to certain bacteria.

Available water capacity

- The available water is the difference in the amount of water at field capacity (- 0.3 bar) and the amount of water at the permanent wilting point (- 15 bars).

Maximum water holding capacity

- It is the amount of moisture in a soil when all of its pore spaces both micro and macro are completely filled with water.

Energy concept of soil water

- The retention and movement of water in soils, its uptake and translocation in plants and its loss to the atmosphere are all energy related phenomenon.

- The more strongly water is held in the soil, the greater is the heat (energy) required. In other words, if water is to be removed from a moist soil, work has to be done against adsorptive forces.
- Conversely, when water is adsorbed by the soil, a negative amount of work is done. The movement is from a zone where the free energy of water is high (standing water table) to one where the free energy is low (a dry soil). This is called energy concept of soil water.
- The difference between the energy states of soil water and pure free water is known as soil water potential.

Forces influencing free energy of water 1. Gravitational force

- This acts on soil water, the attraction is towards the earth's center, which tends to pull the water down ward. This force is always positive.

2. Matric force

- It is the attraction of the soil solids for water (adsorption) which markedly reduces the free energy (movement) of the adsorbed water molecules.

3. Osmotic force

- It is the attraction of ions and other solutes for water which reduces the free energy of soil solution.
- Matric and Osmotic potentials are negative and reduce the free energy level of the soil water. These negative potentials are referred as suction or tension. Total soil water potential (ψ_t) is the sum of gravitational potential (ψ_g), matric potential (ψ_m) and the Osmotic potential or solute potential (ψ_o).
  - $\psi_t = \psi_g + \psi_m + \psi_o$
- Soil water potential is expressed in terms of atmospheres or bars. Atmosphere is the average air pressure at sea level.

Units: Soil water potential is expressed in different units i.e. pF, height in cm of unit water column whose weight is just equals to the potential under consideration, bar, standard atmospheric pressure at sea level which is equal to 14.7 lb/inch2, 760 mm of Hg, or 1020 cm of water. Now a days, megapascal (MPa) which is numerically equal to 10 bars is also used. 10cm height of water column=1 pF= - 0.01 bar = 0.01 atm = -0.001MPa

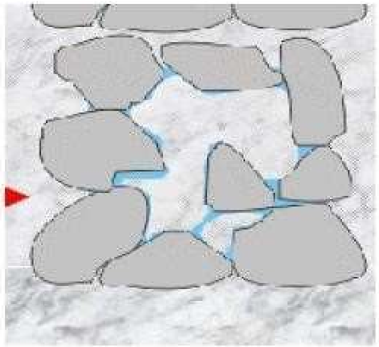
SOIL WATER RETENTION

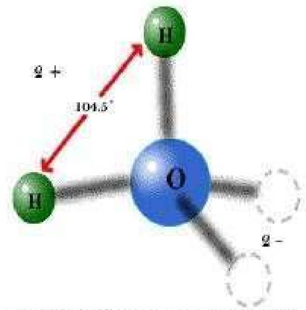
The soils hold water (moisture) due to their colloidal properties and aggregation qualities. The water is held on the surface of the colloids and other particles and in the pores. The forces responsible for retention of water in the soil after the drainage has stopped are due to surface tension and surface attraction and are called surface moisture tension. This refers to the energy concept in moisture retention relationships. The force with which water is held is also termed as suction.

The water retained in the soil by following ways

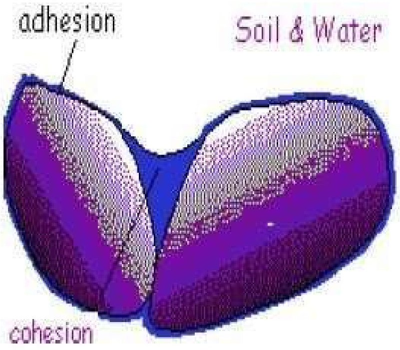
1. Cohesion and adhesion forces: These two basic forces are responsible for water retention in the soil. One is the attraction of molecules for each other i.e., cohesion. The other is the attraction of water molecules for the solid surface of soil i.e. adhesion. By adhesion, solids (soil) hold water molecules rigidly at their soil - water interfaces. These water molecules in turn hold by cohesion. Together, these forces make it possible for the soil solids to retain water.

Adhesion

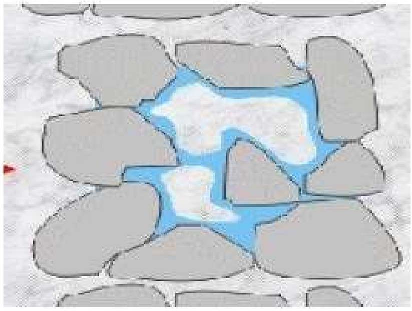


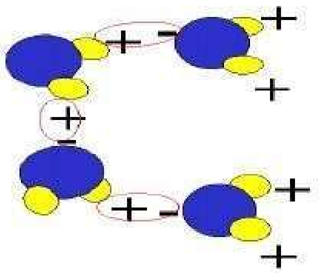


Ball and stick model of water.

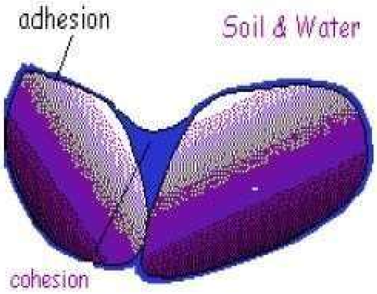


Cohesion





Cohesion



2. Surface tension: This phenomenon is commonly evidenced at water- air interfaces. Water behaves as if its surface is covered with a stretched elastic membrane. At the surface, the attraction of the air for the water molecules is much less than that of water molecules for each other.

Consequently, there is a net downward force on the surface molecules, resulting in sort of a compressed film (membrane) at the surface. This phenomenon is called surface tension.

3. Polarity or dipole character: The retention of water molecules on the surface of clay micelle is based on the dipole character of the molecule of water. The water molecules are held by electrostatic force that exists on the surface of colloidal particles. By virtue of their dipole character and under the influence of electrostatic forces, the molecules of water get oriented (arranged) on the surface of the clay particles in a particular manner.

Each water molecule carries both negative and positive charges. The clay particle is negatively charged. The positive end of water molecule gets attached to the negatively charged surface of clay and leaving its negative end outward. The water molecules attached to the clay surface in this way present a layer of negative charges to which another layer of oriented water molecules is attached. The number of successive molecular layers goes on increasing as long as the water molecules oriented. As the molecular layer gets thicker, orientation becomes weaker, and at a certain distance from the particle surface the water molecules cease to orientate and capillary water (liquid water) begins to appear. Due to the forces of adsorption (attraction) exerted by the surface of soil particles, water gets attached on the soil surface. The force of gravity also acts simultaneously, which tries to pull it downwards. The surface force is far greater than the force of gravity so water may remain attached to the soil particle. The water remains attached to the soil particle or move downward into the lower layers, depending on the magnitude of the resultant force.

SOIL WATER MOVEMENT

- Water is highly dynamic component in soil system. It moves in all the three phases viz. solid, liquid and vapour.
- In a flooded or saturated soil, soil water moves in liquid phase, while in a partially dry or unsaturated soil, it moves in both liquid and vapour phases.
- Movement in solid phase, commonly occurring in the frozen soil, takes place close to clay surface.
- Movement of water within the soil influences water supply to roots and also contributes to underground water table.
- Water movement in the soil occurs in three distinct ways namely saturated flow, unsaturated flow and vapour movement.

Saturated flow

- This flow occurs when the soil pores are completely filled with water. Water in liquid form flows through water filled macro-pores under the influence of gravity.
- It begins with infiltration, which is water movement into soil when rain or irrigation water is on the soil surface. When the soil profile is wetted, the movement of more water flowing through the wetted soil is termed percolation.

Unsaturated flow

- In this type of flow, water moves in thin films surrounding soil particles under the influence of surface tension (matric forces) that are much stronger than gravity.
- Even though the driving force is usually greater than for saturated flow, the resistance to flow is enormous. Water will flow toward a lower (more negative) potential regardless of direction. Vapour movement: In this water vapour moves through air filled pore spaces under the influence of vapour pressure gradient.

Comparison of three types of water movement in soil

S.No.	Particulars	Saturated flow	Unsaturated flow	Vapour movement
1	Major driving force	Gravitational	Matric potential difference	Vapour pressure gradient
2	Water form	Liquid	Liquid	Vapours
3	Major direction of flow	Downward	All directions	All directions
4	Pore space used	All pores	Micropores	All empty pores
5	Rate of flow	Fast (1-100 cm/day)	Slow (< 1 cm/day)	-

SOIL AIR

Soil air is a continuation of the atmospheric air. Unlike the other components, it is constant state of motion from the soil pores into the atmosphere and from the atmosphere into the pore space. This constant movement or circulation of air in the soil mass resulting in the renewal of its component gases is known as soil aeration. .

Composition of Soil Air:

The soil air contains a number of gases of which nitrogen, oxygen, carbon dioxide and water vapour are the most important. Soil air constantly moves from the soil pores into the atmosphere and from the atmosphere into the pore space. Soil air and atmospheric air differ in the compositions. Soil air contains a much greater proportion of carbon dioxide and a lesser amount of oxygen than atmospheric air. At the same time, soil air contains a far great amount of water vapour than atmospheric air. The amount of nitrogen in soil air is almost the same as in the atmosphere.

Component	Per cent by volume	
	Soil air	Atmospheric air
Nitrogen	79.10	79.00
Oxygen	20.60	20.79
Carbon dioxide	0.25	0.03

Exchange of Gases between Soil and Atmosphere

The exchange of gases between the soil and the atmosphere is facilitated by two mechanisms

1. Mass flow: With every rain or irrigation, a part of the soil air moves out into the atmosphere as it is displaced by the incoming water. As and when moisture is lost by evaporation and transpiration, the atmospheric air enters the soil pores. The variations in soil temperature cause changes in the temperature of soil air. As the soil air gets heated during the day, it expands and the expanded air moves out into the atmosphere. On the other hand, when the soil begins to cool, the soil air contracts and the atmospheric air is drawn in.

2. Diffusion: Most of the gaseous interchange in soils occurs by diffusion. Atmospheric and soil air contains a number of gases such as nitrogen, oxygen, carbon dioxide etc., each of which exerts its own partial pressure in proportion to its concentration.

The movement of each gas is regulated by the partial pressure under which it exists. If the partial pressure on one of the gases (i.e. carbon dioxide) is greater in the soil air than in the atmospheric air, it (CO2) moves out into the atmosphere. Hence, the concentration of CO2 is more in soil air.

On the other hand, partial pressure of oxygen is low in the soil air, as oxygen present in soil air is consumed as a result of biological activities. The oxygen present in the atmospheric air (partial pressure of O2 is greater) therefore, diffuses into the soil air till equilibrium is established.

Thus, diffusion allows extensive movement and continual change of gases between the soil air and the atmospheric air. Oxygen and carbon dioxide are the two important gases that take in diffusion Importance of Soil Aeration:

1. Plant and root growth: Soil aeration is an important factor in the normal growth of plants. The supply of oxygen to roots in adequate quantities and the removal of CO2 from the soil atmosphere are very essential for healthy plant growth.

When the supply of oxygen is inadequate, the plant growth either retards or ceases completely as the accumulated CO2 hampers the growth of plant roots. The abnormal effect of insufficient aeration on root development is most noticeable on the root crops. Abnormally shaped roots of these plants are common on the compact and poorly aerated soils. The penetration and development of root are poor. Such undeveloped root system cannot absorb sufficient moisture and nutrients from the soil

2. Microorganism population and activity: The microorganisms living in the soil also require oxygen for respiration and metabolism. Some of the important microbial activities such as the decomposition of organic matter, nitrification, Sulphur oxidation etc depend upon oxygen present in the soil air. The deficiency of air (oxygen) in soil slows down the rate of microbial activity.
For example, the decomposition of organic matter is retarded and nitrification arrested. The microorganism population is also drastically affected by poor aeration.

3. Formation of toxic material: Poor aeration results in the development of toxin and other injurious substances such as ferrous oxide, H2S gas, CO2 gas etc in the soil.

4. Water and nutrient absorption: A deficiency of oxygen has been found to check the nutrient and water absorption by plants. The energy of respiration is utilized in absorption of water and nutrients. Under poor aeration condition (this condition may arise when soil is water logged), plants exhibit water and nutrient deficiency.

5. Development of plant diseases: Insufficient aeration of the soil also lead to the development of diseases. For example, wilt of gram and dieback of citrus and peach.

SOIL TEMPERATURE

- Soil temperature greatly affects the physical, chemical and biological processes which occur in the soil. Since, with every 10°C rise in temperature, rate of chemical reaction get almost doubled
- Hence, it affects plant growth directly and also indirectly by influencing moisture, aeration, structure, microbial and enzyme activities, rate of organic matter decomposition, nutrient availability and other soil chemical reactions.

Sources of heat to soil

- Solar radiation (sun rays) is the primary source of energy to warm the soil.
- The dust particles, clouds and other suspended particles intercept the sun rays. They absorb, scatter or reflect the solar energy. Only a small part of the total radiation actually reaches earth.
- Thermal energy is transmitted in the form of thermal infrared radiation from the sun across the space and through the atmosphere.
- Other sources of heat for soil are processes like microbial decomposition of organic matter and respiration by soil organisms including plants.

Factors influencing soil temperature

There are three main factors affecting soil temperature as described below:

1. Solar radiation

- Amount of solar energy received by soil depends on the constituents of the atmosphere. Clouds, water vapour and dust particles reduce the solar energy reaching soil surface.
- Some energy is used for evaporation and transpiration, and some reflected back. Only 10 per cent energy is used to warm the soil.

2. Aspect and slope

- The land in three situations viz. southern aspect, level and northern aspect receive different amounts of solar energy, and the soil will warm accordingly.
- Solar radiation reaching perpendicular to the soil surface will heat it more as these concentrate on a smaller area than when the same amount of radiation reach a slope where they get spread on a larger area. Thus, equatorial zones are warmer than temperate and arctic regions.
- In Northern hemisphere, south facing slope is warmer than the north facing slope.

3. Soil factors

 These factors are soil colour, soil moisture, mulching, vegetative cover and organic matter content. These affect the warming of soils through solar radiation.

Effect of soil temperature on plant growth

a) Soil temperature requirements of plants: The soil temperature requirements of plants vary with the species. The temperature at which a plant thrives and produces best growth is called optimum range (temperature). The entire range of temperature under which a plant can grow including the optimum range is called growth range. The maximum and minimum temperatures beyond which the plant will die are called survival limits.

Range	Maize (°C)	Wheat (°C)
Optimum range	25 - 35	15 - 27
Growth range	10 - 39	5 - 35
Survival limits	0 - 43	0 - 43

Availability of soil water and plant nutrients: The free energy of water increases with temperature. Up to wilting point limit, warming of soil increases water availability beyond which it decreases. Low temperatures reduce the nutrient availability, microbial activities and root growth and branching. The ability to absorb nutrients and water by plants reduces at low temperatures.

SOIL REACTION

Soil pH

Soils can be naturally acid or alkaline, and this can be measured by testing their pH value. Having the correct pH is important for healthy plant growth. Being aware of the long-term effects of different soil management practices on soil pH is also important. Research has demonstrated that some agricultural practices significantly alter soil pH.

Soil pH is a measure of the acidity or alkalinity of the soil.

A pH value is actually a measure of hydrogen ion concentration. Because hydrogen ion concentration varies over a wide range, a logarithmic scale (pH) is used: for a pH decrease of 1, the acidity increases by a factor of 10.

It is a ‘reverse’ scale in that a very acid soil has a low pH and a high hydrogen ion concentration. Therefore, at high (alkaline) pH values, the hydrogen ion concentration is low.

Most soils have pH values between 3.5 and 10. In higher rainfall areas the natural pH of soils typically ranges from 5 to 7, while in drier areas the range is 6.5 to 9.

Soils can be classified according to their pH value:

- 6.5 to 7.5—neutral
- over 7.5—alkaline
- less than 6.5—acidic, and soils with pH less than 5.5 are considered strongly acidic.

Soil pH buffering

The buffering capacity of a soil indicates the capacity of the soil to resist pH change. Hydrogen ions in soil are present both in the soil solution and adsorbed onto the soil surfaces. pH measures the concentration of hydrogen ions in the soil solution. Soils differ in the number of surface sites able to accommodate hydrogen ions. Soils with large numbers of sites able to hold hydrogen ions are able to resist change in the concentration of hydrogen ions in the soil solution and therefore have a high buffering capacity.

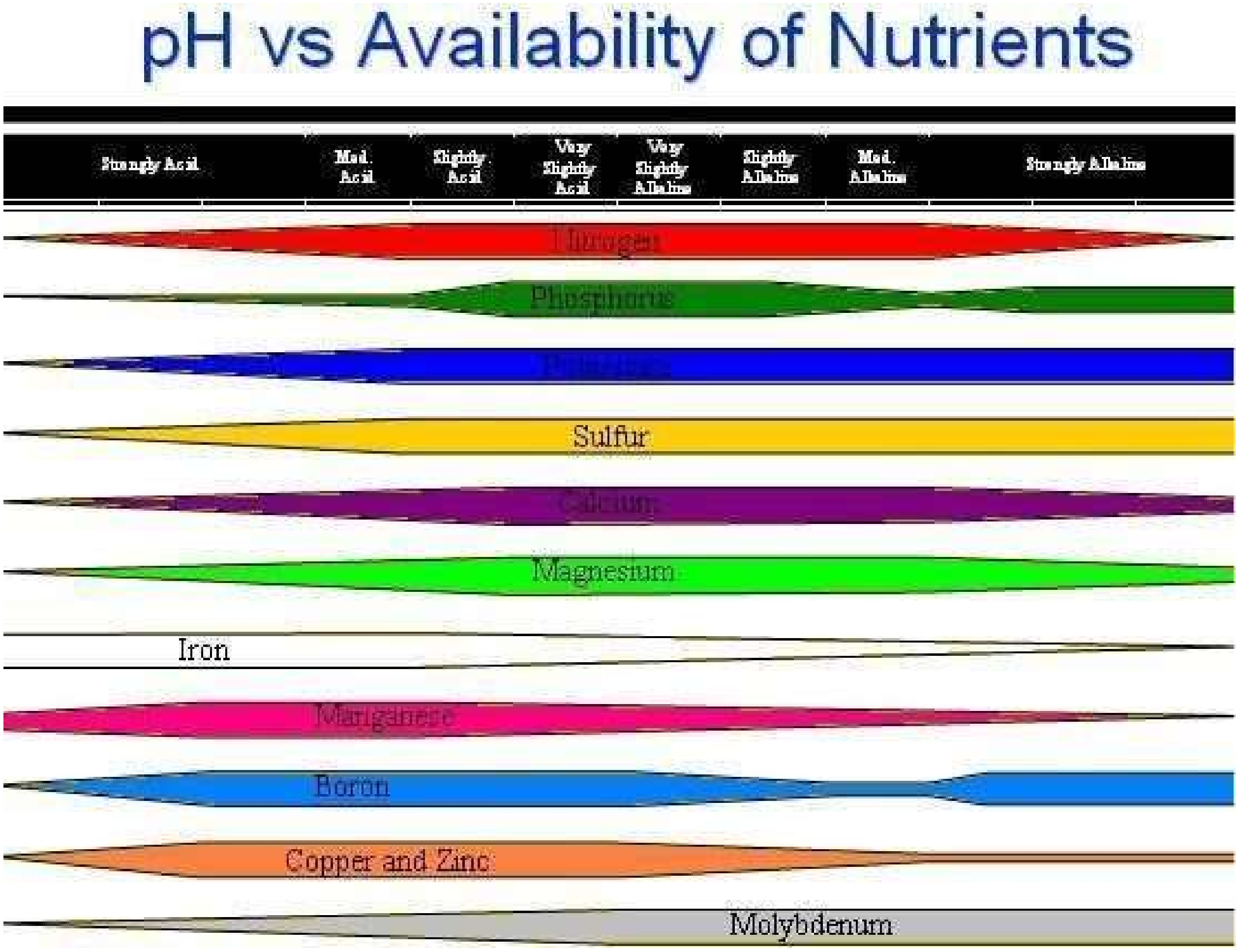
Soils with a high proportion of clay or organic matter have a larger number of surface sites able to hold hydrogen ions and are able to resist a decrease in pH. However, once acidic, highly buffered soils are able to resist an increase in pH. When hydrogen ions in the soil solution are neutralized by lime, hydrogen ions from the soil surfaces are release into the soil solution to maintain equilibrium and resist increase in pH. Better buffered soils are slower to acidify but require more lime to lift pH when they do acidify. Clays are generally better buffered than loams, which in turn are better buffered than sands.

Effect of pH on nutrient availability

Soil pH affects nutrient availability by changing the form of the nutrient in the soil. Adjusting soil pH to a recommended value can increase the availability of important nutrients. Plants usually grow well at pH values above 5.5. Soil pH of 6.5 is usually considered optimum for nutrient availability.

Lower pH increases the solubility of Al, Mn, and Fe, which are toxic to plants in excess. A critical effect of excess soluble Al is the slowing or stopping of root growth.

Extreme pH values decrease the availability of most nutrients. Low pH reduces the availability of the macro- and secondary nutrients, while high pH reduces the availability of most micronutrients. Microbial activity may also be reduced or changed.



SOIL COLLOIDS

The colloidal state refers to a two-phase system in which one material in a very finely divided state is dispersed through second phase. The examples are: Solid in liquid (Dispersion of clay in water) and Liquid in gas (Fog or clouds in atmosphere). The clay fraction of the soil contains particles less than 0.002 mm in size. Particles less than 0.001 mm size possess colloidal properties and are known as soil colloids.

General Properties of Soil Colloids 1. Size

The inorganic and organic colloids are extremely small size - smaller than 2 micrometers in diameter. These particles cannot be seen using an ordinary light microscope but can be seen only with an electron microscope.

2. Surface area

Because of their small size, all soil colloids have a larger external surface area per unit mass. The external surface area of 1 g of colloidal clay is 1000 times that of 1 g of coarse sand. Certain silicate clays have extensive internal surfaces occurring between plate like crystal units that make up each particle and often greatly exceed the external surface area. The total surface area of soil colloids ranges from 10 m2/g for clays with only external surfaces to more than 800 m2/g for clays with extensive internal surfaces. The colloid surface area in the upper 15 cm of a hectare of a clay soil could be as high as 700,000 km^2 g^{-1}.

3. Surface charges

Both external and internal surfaces of soil colloids carry negative and/or positive charges. Most of the organic and inorganic soil colloids carry a negative charge. When an electric current is passed through a suspension of soil colloidal particles they migrate to anode, the positive electrode indicating that they carry a negative charge. The magnitude of the charge is known as zeta potential. The presence and intensity of the particle charge influence the attraction and repulsion of the particles towards each other, there by influencing both physical and chemical properties. The sources of negative charge on clays comes from i) ionizable hydrogen ions ii) isomorphous substitution.

i) Ionizable hydrogen ions: These are hydrogen from hydroxyl (OH) ions on clay surfaces. The -Al-OH or -Si-OH portion of the clay ionizes the H and leaves an un-neutralized negative charge on the oxygen (-AlO- or - SiO-). The extent of ionized hydrogen depends on solution pH and hence these negative charges are pH dependent charges. More ionization occurs in alkaline (basic) solutions.

ii) Isomorphous substitution: This is due to the substitution of a cation of higher valence with another cation of lower valence but similar size in the clay crystal structure. In clay crystals some ions fit exactly into mineral lattice sites because of their convenient size and charge. Dominantly, clays have Si4+ in tetrahedral sites and $A1^{3+}$ in octahedral sites. Other ions present in large amounts during clay crystallization can replace some of the $A1^{3+}$ and Si^{4+} cations. Common substitutions are the Si^{4+} replaced by $A1^{3+}$, and replacement of $A1^{3+}$ by Fe^{3+}, Fe^{2+}, Mg^{2+} or Zn^{2+}. As the total negative charge from the anions (oxygen) remains unchanged, the lower positive charge of the substituted cations result in excess negative charges on clay crystals.

4. Adsorption of cations: As soil colloids possess negative charge they attract and attach the ions of positive charge on the colloidal surfaces. They attract cations like H^+, $A1^{3+}$, Ca^{2+} and Mg^{2+}. This gives rise to an ionic double layer.

The Isomorphous substitution in the colloidal particle makes the external and internal layers of clay minerals negatively charged and these surfaces act as huge anions, which form the inner layer of the double layer. The outer layer is made up of a swarm of loosely held (adsorbed) cations attracted to the negatively charged surfaces.

5. Adsorption of water: A large number of water molecules are associated with soil colloidal particles. Some water molecules are attracted to the adsorbed cations and the cation is said to be in hydrated state. Others water molecules are held in the internal surfaces of the colloidal clay particles. These water molecules play a critical role in determining both the physical and chemical properties of soil.

6. Cohesion: (Attractive force between similar molecules or materials). Cohesion indicates the tendency of clay particles to stick together. This tendency is due to the attraction of clay particles for water molecules held between them. Whencolloidal substances are wetted, water first adheres to individual clay particles and then brings about cohesion between two or more adjacent colloidal particles.

7. Adhesion: (Attractive force between different molecules or materials). Adhesion refers to the attraction of colloida1 materials to the surface of any other body or substance with which it comes in contact.

8. Swelling and shrinkage: Some soil clay colloids belonging to smectite group like Montmorillonite swell when wet and shrink when dry. After a prolonged dry spell, soils high in smectite clay (e.g. Black soil -Vertisols) often show crises-cross wide and deep cracks. These cracks first allow rain to penetrate rapidly. Later, because of swelling, the cracks will close and become impervious. But soils dominated by kaolinite, chlorite, or fine grained micas do not swell or shrink. Vermiculite is intermediate in its swelling and shrinking characteristics.

9. Dispersion and flocculation: As long as the colloidal particles remain negatively charged, they repel each other and the suspension remains stable. If onany account they loose their charge, or if the magnitude of the charge is reduced, the particles coalesce, form flock or loose aggregates,

and settle down. This phenomenon of coalescence and formation of flocks is known as flocculation. The reverse process of the breaking up of flocks into individual particles is known as de-flocculation or dispersion.

10. Brownian movement: When a suspension of colloidal particles is examined under a microscope the particles seem to oscillate. The oscillation is due to the collision of colloidal particles or molecules with those of the liquid in which they are suspended. Soil colloidal particles with those of water in which they are suspended are always in a constant state of motion. The smaller the particle, the more rapid is its movement.

11. Non permeability: Colloids, as opposed to crystalloids, are unable to pass through a semipermeable membrane. Even though the colloidal particles areextremely small, they are bigger than molecules of crystalloid dissolved in water. The membrane allows the passage of water and of the dissolved substance throughits pores, but retains the colloidal particles.

TYPES OF SOIL COLLOIDS

There are four major types of colloids present in soil

1. Layer silicate clays
2. Iron and aluminum oxide clays (sesquioxide clays)
3. Allophane and associated amorphous clays
4. Humus

Layer silicate clays, iron and aluminum oxide clays, allophane and associated amorphous clays are inorganic colloids while humus is an organic colloid.

1. Layer silicate clays

These important silicate clays are also known as phyllosilicates (Phyllon - leaf) because of their leaf-like or plate like structure. These are made up of two kinds of horizontal sheets. One dominated by silicon and other by aluminum and/or magnesium.

Silica tetrahedron: The basic building block for the silica-dominated sheet is a unit composed of one silicon atom surrounded by four oxygen atoms. It is called the silica tetrahedron because of its four-sided configuration. An interlocking array or a series of these silica tetrahedra tied together horizontally by shared oxygen anions gives a tetrahedral sheet.

Alumina octahedron: Aluminium and/or magnesium ions are the key cations surrounded by six oxygen atoms or hydroxyl group giving an eight sided building block termed octahedron.

Numerous octahedra linked together horizontally comprise the octahedral sheet.

An aluminum-dominated sheet is known as a di-octahedral sheet, whereas one dominated by magnesium is called a tri-octahedral sheet. The distinction is due to the fact that two aluminum ions in a di-octahedral sheet satisfy the same negative charge from surrounding oxygen and hydroxyls as three magnesium ions in a tri-octahedral sheet.

The tetrahedral and octahedral sheets are the fundamental structural units of silicate clays. These sheets are bound together within the crystals by shared oxygen atoms into different layers. The specific nature and combination of sheets in these layers vary from one type of clay to another and control the physical and chemical properties of each clay.

2. Iron and aluminum oxide clays (sesquioxide clays): Under conditions of extensive leaching by rainfall and long time intensive weathering of minerals in humid warm climates, most of the silica and alumina in primary minerals are dissolved and slowly leached away. The remnant materials, which have lower solubility are called sesquioxides. Sesquioxides (metal oxides) are mixtures of aluminum hydroxide, $Al\ (OH)_3$, and iron oxide, Fe_2O_3, or iron hydroxide, $Fe(OH)_3$. The Latin word sesqui means one and one-half times, meaning one and one-half times more oxygen than Al and Fe. These clays can grade from amorphous to crystalline. Examples of iron and aluminum oxides common in soils are gibbsite ($Al_2O_3.3H_2O$) and geothite ($Fe_2O_3.H_2O$). Less is known about these clays than about the layer silicates. These clays do not swell, not sticky and have high phosphorus adsorption capacity.
3. Allophane and other amorphous minerals: These silicate clays are mixtures of silica and alumina. They are amorphous in nature. Even mixture of other weathered oxides (iron oxide) may be a part of the mixture. Typically, these clays occur where large amount of weathered products existed. These clays are common in soils forming from volcanic ash (e.g., Allophane). These clays have high anion exchange capacity or even high cation exchange capacity. Almost all of their charge is from accessible hydroxyl ions (OH^-), which can attract a positive ion or lose the H^+ attached. These clays have a variable charge that depends on H^+ in solution (the soil acidity).
4. Humus (Organic Colloid)

Humus is amorphous, dark brown to black, nearly insoluble in water, but mostly soluble in dilute alkali (NaOH or KOH) solutions. It is a temporary intermediate product left after considerable decomposition of plant and animal remains. They are temporary intermediate because the organic substances remain continue to decompose slowly. The humus is often referred to as an organic colloid and consists of various chains and loops of linked carbon atoms. The humus colloids are not crystalline. They are composed basically of carbon, hydrogen, and oxygen rather than of silicon, aluminum, iron, oxygen, and hydroxyl groups.

The organic colloidal particles vary in size, but they may be at least as small as the silicate clay particles. The negative charges of humus are associated with partially dissociated enolic (-OH), carboxyl (-COOH), and phenolic groups; these groups in turn are associated with central units of varying size and complexity.

Silicate clay

Silicate clay are the electro- microscopic clay minerals, which diameter less than 2 microns. It is the textural classes of soil and developed more in the horizontal axis than the vertical axis of soil profile. It is the characteristics minerals of the earths near surface environments. They form in soils and sediments. E.g: kaolinite, Micas, Vermiculite, Chlorite etc.

Some Important Features of Silicate Clays

Chemical Composition: The chemical analysis of clay indicates the presence of silica, alumina, iron and combined water. These make up from 90-98 percent of the colloidal clay. The soil colloidal matter contains plant nutrients like Ca, Mg and K etc. Shape: Silicate clay minerals have been examined by electron microscope and found that the particles are laminated made up of layers of plates or flakes or even rods. Each clay particle is made up of a large number of plates like structural units.

Surface Area: The surface area of a clay particle is usually defined as the area of the particle that is accessible to ions or molecules when the clay is in an aqueous solution. All clay particles (finer fraction of soil) must expose a large amount of external surface. Surface areas of clay particles can be measured by using cetylpyridinium bromide (dissolving in water) for fully dispersed clay suspension. Surface area for clays like vermiculites and some mixed layer clays 300-500 m2/g; micaceous clays 100-300 m2/g; kaolinitic clays 5-100 m2/g; and amorphous clays have surface areas between 100 and 500 m2/g.

Electronegative Charge: Clay micelles (micro cells) carry negative charges and so a number of oppositely charged ions (cations) are attracted to each colloidal clay crystal. The colloidal clay particles have inner ionic layer (surfaces of highly negative charge) and the outer ionic layer (highly positive charge layer). Adsorbed Cations: Clay micelles adsorb a number of cationshumid, arid and semiarid regions colloids-cations are H+, Al3+, Ca2+, Mg/+, Na+ and K+.

Cations adsorbed on the clay colloids very oftenly determines the physical and chemical properties of the soil and thereby influence the plant growth.

Significance of soil colloids

The organic and inorganic contaminats are often transported via colloidal particles. Majority of surface area and electrostatic charge in a soil resides in the less than I µm size fraction, with particles with radii between 20 and 1000 mm constituting the major part of soil surface area. Since major part of the surface areais in the colloidal fraction of the soil, almost all surface controlled processes including adsorption reactions, nucleation and precipitation involve colloids. In addition to these chemical processes, colloids are mobile in soils, and thus affect not only the chemical transport of otherwise immobile chemicals, but also exert a strong influence on soil hydraulic properties.

Ion exchange

Ion exchange involves the movement of cations (positively charged elements like calcium, magnesium, and sodium) and anions (negatively charged elements like chloride, and compounds like nitrate) through the soils. In the United States, cation exchange is much more common.

Cation Exchange Capacity (CEC)

Cation exchange capacity (CEC) is a fundamental soil property used to predict plant nutrient availability and retention in the soil. It is the potential of available nutrient supply, not a direct measurement of available nutrients. Soil CEC typically increases as clay content and organic matter increase because cation exchange occurs on surfaces of clay minerals, organic matter, and roots.

Cation exchange capacity is defined as a soil’s total quantity of negative surface charges. It is measured commonly in commercial soil testing labs by summing cations (positively charged ions that are attracted to the negative surface charges in soil).

Exchangeable cations include base cations, calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^{+}) and sodium (Na^{+}), as well as acid cations such as hydrogen (H^{+}), aluminum (Al^{3+}) and ammonium (NH_4^{+}).

$$\text{CEC} = \text{Base cations} + \text{Acid cations}$$

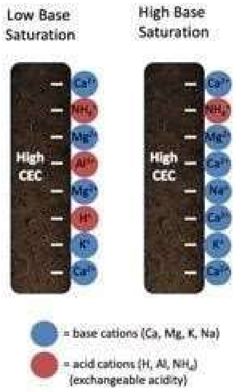
Base Saturation

Base saturation is calculated as the percentage of CEC occupied by base cations. Base saturation is closely related to pH; as base saturation increases, pH increases.

$$\text{Base Saturation (\%)} = (\text{Base cations/CEC}) \times 100\times 100$$

Similarly, we can calculate the base saturation for each individual base cation. Calcium base saturation is calculated as the percentage of CEC occupied by calcium cations.

$$\text{Calcium Saturation (\%)} = (\text{Calcium cations/CEC}) \times 100$$



Cation exchange capacity and base saturation are important soil measurements that help determine how a soil is managed and fertilized. While standard soil testing laboratories commonly calculate and report these values in soil test reports, it is helpful to have a solid understanding of CEC and base saturation calculations.

SOIL ORGANIC MATTER

Substances containing carbon are organic matter. Soil organic matter consists of decomposing plant and animal residues. It also includes substances of organic origin either leaving or dead.

Soil organic matter plays an important role in deciding / maintaining soil physical conditions. It also influences soil chemical properties especially cation exchange capacity. Organic matters supply the energy sources for soil micro organisms. Soil development is another aspect which is influenced by the soil organic matter.

Plant tissue is the major source. Animals are considered as the secondary sources. They attack original plant tissues, contribute waste products and leave their own bodies after death.

Factors affecting soil organic matter

1. Climate
2. Natural vegetation
3. Texture
4. Drainage
5. Cropping and Tillage
6. Crop rotations, residues and plant nutrients.

1. Climate: Temperature and rainfall exert a dominant influence on the amounts of N and organic matter found in soils.

a) Temperature: The organic matter and N content of comparable soils tend to increase if one moves from warmer to cooler areas. The decomposition of organic matter is accelerated in warm climates as compared to cooler climates. For each 10 °C decline in mean annual temperature, the total organic matter and N increases by two to three times.

b) Rainfall: There is an increase in organic matter with an increase in rainfall. Under comparable conditions, the N and organic matter increase as the effective moisture becomes greater.

2. Natural Vegetation: The total organic matter is higher in soils developed under grasslands than those under forests.

3. Texture: Fine textured soils are generally higher in organic matter than coarse textured soils.

4. Drainage: Poorly drained soils because of their high moisture content and relatively poor aeration are much higher in organic matter and N than well drained soils.

5. Cropping and Tillage: The cropped lands have much low N and organic matter than comparable virgin soils. Modern conservation tillage practices helps to maintain high OM levels as compared to conventional tillage.

6. Rotations, residues and plant nutrients: Crop rotations of cereals with legumes results in higher soil organic matter. Higher organic matter levels, preferably where a crop rotation is followed.

Composition of organic residues:

Plant residues contain 75% moisture and 25% dry matter. This 25% is made up of Carbon (10-12%), Oxygen (9-10%) , Hydrogen (1.5-2.5%) , N(1-2%) and mineral matter (13%).

Importance of organic matter

- It is the food source for soil microorganisms and soil fauna. If there is no organic matter the soil would be almost sterile and consequently, extremly infertile . Organic matter also supplies hormones (Auxin ,Gibberellins , IAA) and antibiotics for plant growth.
- Organic matter is an index of the productivity of the soil since it is a store house of essential plant nutrients for plant growth. It functions as a reservoir of nitrogen, phosphorus and sulphur and thereby contribute significantly to the supply of these nutrients to higher plants.
- Humus (a highly decomposed organic matter) provides a storehouse for the exchangeable and available cations.

- Soil organic matter contributes to nutrient release from soil minerals by weathering reactions and thus helps in nutrient availability in soils. Organic acids released from decomposing organic matter help to reduce alkalinity in soils; organic acids along with released CO_2 dissolve minerals and make them more available.
- It acts as a buffering agent which checks rapid chemical changes in pH and soil reaction.
- Organic matter creates a granular condition of soil which maintains favorable condition of aeration and permeability.
- Water holding capacity of soil is increased and surface runoff, erosion etc., are reduced as there is good infiltration due to the addition of organic matter.
- Surface mulching with coarse organic matter lowers wind erosion and lowers soil temperatures in the summer and keeps the soil warmer in winter. □ The organic substances influence various soil processes leading to soil formation □ It is the prime decider of soil health and soil quality. Importance of organic matter on soil properties

Soil organic matter affects the chemical and physical properties of the soil and its overall health. Its composition and breakdown rate affect: the soil structure and porosity; the water infiltration rate and moisture holding capacity of soils; the diversity and biological activity of soil organisms; and plant nutrient availability. Many common agricultural practices, especially ploughing, disctillage and vegetation burning, accelerate the decomposition of soil organic matter and leave the soil susceptible to wind and water erosion. However, there are alternative management practices that enhance soil health and allow sustained agricultural productivity.

Soil organic matter content is a function of organic matter inputs (residues and roots) and litter decomposition. It is related to moisture, temperature and aeration, physical and chemical properties of the soils as well as bioturbation (mixing by soil macrofauna), leaching by water and humus stabilization (organomineral complexes and aggregates). Land use and management practices also affect soil organic matter.

Humic substances

Humic substances (HS) can be defined as naturally occurring biogenic, heterogeneous organic substances. They are widely-spread natural complexing ligands occurring in nature. It is known that HS are the most important pool of transient refractory organic carbon in the geosphere.

Humus

Humus is a complex and rather resistant mixture of brown or dark brown amorphous and colloidal organic substance that results from microbial decomposition and synthesis and has chemical and physical properties of great significance to soils and plants.

Humus Formation

The humus compounds have resulted from two general types of biochemical reactions:

Decomposition and Synthesis

1. Decomposition:

a) Chemicals in the plant residues are broken down by soil microbes including lignin.

b) Other simpler organic compounds that result from the breakdown take part immediately in the second of the humus-forming processes, biochemical synthesis.

c) These simpler chemicals are metabolized into new compounds in the body tissue of soil microbes.

d) The new compounds are subject to further modification and synthesis as the microbial tissue is subsequently attacked by other soil microbes.

2. Synthesis: Involve such breakdown products of lignin as the phenols and quinones.

a) These monomers undergo polymerization by which polyphenols and polyquinones are formed.

b) These high molecular weight compounds interact with N-containing amino compounds and forms a significant component of resistant humus.

c) Colloidal clays encourage formation of these polymers.

d) Generally two groups of compounds that collectively make up humus, the humic group and the non-humic group. Soil organic matter fractions

- Humic matter
- Non humic matter

When soil is extracted with alkali the humic substances go into solution. The insoluble portion forms the non humic matter.

Humic group

- This group makes up about 60-80% of the soil organic matter.
- They are most complex. They are most resistant to microbial attack.
- Humic substances have aromatic ring type structures.
- These include polyphenols and poly quinones.
- These are formed by decomposition, synthesis and polymerization.

The humic substances are classified based on resistance to degradation and solubility in acids and alkalis into:

- Humic acid
- Fulvic acid Humin

Non humic group

- This group makes upto 20-30% of the organic matter in soil.
- These are less complex and less resistant to microbial attack as compared to humic substances.
- They are polysaccharides, polymers having sugar like structures and polyuronides.
- These include proteins, carbohydrates, lignins, fats, waxes, resins, tannins and some compounds of low molecular weight. Properties of Humus

- The tiny colloidal particles are composed of C,H, and O_2.
- The colloidal particles are negatively charged (-OH, -COOH or phenolic groups), has very high surface area, higher CEC (150 – 300 cmol/kg), 4 - 5 times higher WHC than that of silicate clays.
- Humus has a very favorable effect on aggregate formation and stability.
- Impart black colour to soils.

Soil organisms

Productive, healthy soil is much more than just dirt. It is a living, breathing dynamic ecosystem! It contains untold billions (even trillions) of organisms; and the health of the soil and all it produces depend on them. Just as most of the micro-biotic community living in and on the human body, the vast majority of these organisms are beneficial. Organisms in the soil are categorized as micro or macro organisms and all have a critical role to play in making soil living, dynamic, and productive.

1. Micro-organisms: Those which cannot be seen with the naked eye.

a. Bacteria: In a teaspoon (5-7 grams of soil) there are typically 100 billion bacteria representing one aspect of a well-developed and functional microscopic ecosystem beneath the soil surface. Aside from the possible disease aspects of bacteria, the average person has a minimal concept of the diversity and essential roles that bacteria play in the health of all living things and the soil we depend so heavily upon. There are four general categories of bacteria in the soil; decomposers, mutualists, pathogens (these are generally on the mind of most people), and lithotrophs. Lithotrophs are critical to nitrogen recycling and pollutant degradation. Soil bacteria are critical to water dynamics, nutrient recycling, disease suppression, and the health and productivity of soils.

b. Fungi: Interestingly, while fungi are often thought of as some aberrant form of life, they are more closely related to us than bacteria, and play a critical role in decomposition of dead and/or living organic material.1 Additionally, mutualist fungi such as ecto- or endo-mycorrhizae play a crucial role in the root efficiencies of a wide variety of plants facilitating the uptake of moisture, carbon, minerals. As the name indicates, they either grow on the surface areas (ecto) of the roots of woody plants and trees, or grow within the root structures of grasses, garden plants, and smaller woody shrubs. Finally, as in all good things, there are pathogenic and parasitic fungi which cause much loss in production and the death of plants in the garden and landscape. On the positive side, many fungi parasitize disease causing nematodes and damaging insects.

c. Protozoa: Single cell animals requiring bacteria to eat and water for movement. They will also feed on each other and can reduce bacterial diseases by consuming large number of pathogenic bacteria. The regulation of bacterial populations through grazing releases excess nitrogen in the form of ammonium ($NH4^+$) providing nitrogen for plant growth as protozoa generally occupy soil zones within the rhizosphere adjacent to root structures.

d. Nematodes: Small diameter microscopic worms living in the water surrounding root zones are the final microbiological life form responsible for living soil. They can provide both benefits and problems in the garden.4 Excessive irrigation favors some parasitic omnivore nematodes which may greatly reduce production. Otherwise, similar to other micro life forms discussed above, nematodes consume fungi, bacteria, protozoa, and each other returning nutrients to the soil and maintaining a balanced ecosystem under the soil.

2. Macro-organisms: Those which can be seen with the naked eye.

a. Arthropods; which include mites, millipedes, spiders, scorpions, and beetles are the primary macro organisms responsible for maintaining the health of our living soils. They constitute a population of predator/prey organisms which facilitate nutrient release, recycling, and utilization. They are grouped as shredders, predators, herbivores, and fungal feeders. All occupy critical roles with respect to maintaining healthy, living, and productive soils. Larger arthropods live on the soil surface and shred organic debris, and each other, into small parts aiding in decomposition and incorporation into the soil. If a gardener has ever spread organic mulch on the soil, and then marveled at how quickly it seems to vanish, blame the shedders! Examples are millipedes, sow bugs, earwigs, and some beetles. Other arthropods such as spiders and pseudo scorpions predate each other and the shredders. The results of all this frenetic interaction are copious streams of recycled organic material and body parts circulating throughout the soil ecosystem.

b. Earthworms: The final candidate for evaluation is the most visible feature of living soil systems. What do they contribute to the conversation? Most importantly they alter and mix soil structure to better facilitate water movement and holding capacity, bury and shred surface organic material, provide channels for root growth and development, maintain nutrient dynamics, facilitate plant growth, and stimulate microbial activity.

SOIL POLLUTION

Soil pollution refers to anything that causes contamination of soil and degrades the soil quality. It occurs when the pollutants causing the pollution reduce the quality of the soil and convert the soil inhabitable for microorganisms and macro organisms living in the soil.

Soil contamination or soil pollution can occur either because of human activities or because of natural processes. However, mostly it is due to human activities. The soil contamination can occur due to the presence of chemicals such as pesticides, herbicides, ammonia, petroleum hydrocarbons, lead, nitrate, mercury, naphthalene, etc in an excess amount.

There are many different ways that soil can become polluted, such as:

- Seepage from a landfill
- Discharge of industrial waste into the soil

- Percolation of contaminated water into the soil
- Rupture of underground storage tanks
- Excess application of pesticides, herbicides or fertilizer
- Solid waste seepage

The most common chemicals involved in causing soil pollution are:

- Petroleum hydrocarbons
- Heavy metals
- Pesticides
- Solvents

Causes of Soil pollution

Soil pollution is mostly caused by mindless human activities such as:

Industrial waste- Industries are by far the worst polluters of the soil with all the chemicals they release into the environment be it in liquid or solid form.

Deforestation- Clearing of trees leaves soil exposed to the elements so they are easily carried away by soil erosion. This leaves land barren and incapable of supporting vegetation.

Excessive use of fertilizers and pesticides- The increased demand for food has forced farmers to use fertilizers and pesticides that release nothing but toxins into the soil, killing useful microorganisms that are important in plant growth.

Garbage pollution- Garbage that cannot be recycled is disposed of carelessly and this is not only an eyesore but pollutes the land. Some of this waste can literally take thousands of years to decompose.

Prevention and mitigation of soil pollution

Reforestation- This is an effective measure to curb soil erosion. Governments should also take punitive action against those who cut down trees without a care in the world.

Controlled farming practices- Practices such as over cropping and overgrazing should be avoided since they increase soil erosion.

Bioremediation- This is the introduction of microorganisms into the soil that break down contaminants. This is a perfectly environmental friendly approach since it allows nature to take its course thus restoring balance.

Reduce, Recycle, and Reuse- Items that can be used again should not be disposed of; things made of paper, glass, aluminum and the like should be recycled; lastly, where excesses such as the use of polythene paper can be avoided, then, by all means, reduce their use.

Use biodegradable products- Where possible, opt to use biodegradable products such as cartons for packaging; if they were to be disposed of, they would easily be broken down to become part of the soil.

Reduce the use of pesticides and fertilizers- Pesticides and fertilizers are major contributors to soil contamination so cutting down on their usage could do a world of good to the soil.