Class: Ph.D. Soil Science & Agril. Chem.

Subject: Soil Genesis and Micropedology (Soils-604)

Course Instructors Name: Dr. B. S. Dwivedi

Topic: Processes and Factors of Soil forming

College of Agriculture, Jabalpur

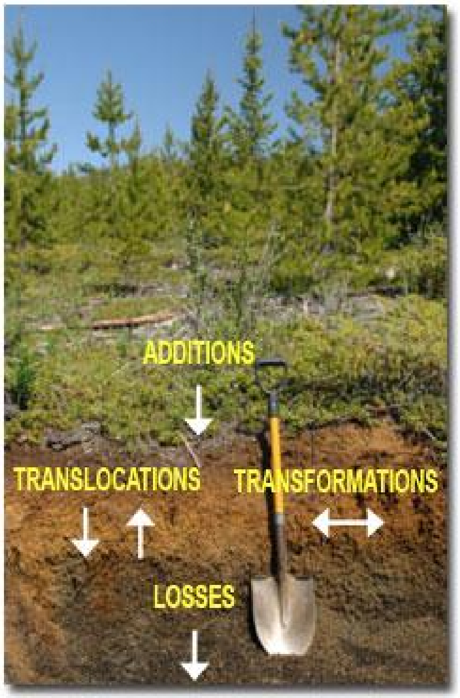
Processes and Factors of Soil forming

Soils are the products of weathering from some parent rocks. All soils initially come from some pre-existing rocks. They are called as 'parent materials'. The Parent Material may be directly below the soil, or at great distances away from it. It is necessary to understand the factors and processes that are responsible for the formation of soils.

Soil formation is a long term process. It takes several million years to form a thin layer of soil. As soil is a complex mixture of various components, its formation is also more complex. The formation of a particular type of soil depends upon the physico-chemical properties of the parent rock, intensity and duration of weathering, climatic and other parameters.

Four Soil Forming Processes

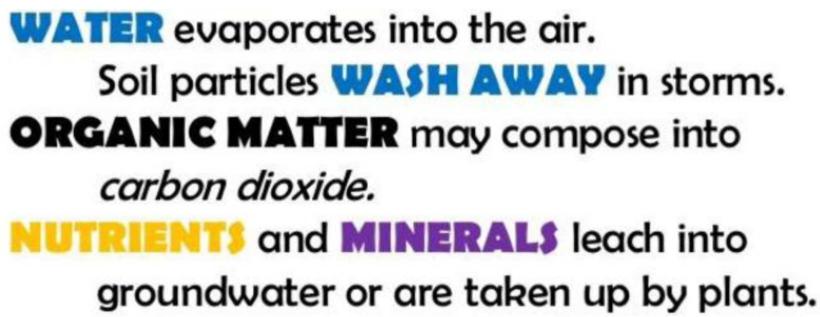
A. Additions
B. Losses
C. Translocations
D. Transformations



A. **Additions:** Materials added to the soil, such as decomposing vegetation and organisms (organic matter--OM), or new mineral materials deposited by wind or water.

Rain adds **WATER**.
Dust adds **MINERALS**.
Animal waste add **ORGANIC MATTER** and **NUTRIENTS**.
Humans add **FERTILIZER**.

B. Losses: Through the movement of wind or water, or uptake by plants, soil particles (sand, silt, clay, and OM) or chemical compounds can be eroded, leached, or harvested from the soil, altering the chemical and physical makeup of the soil.



C. **Transformations:** The chemical weathering of sand and formation of clay minerals, transformation of coarse OM into decay resistant organic compounds (humus).

D. **Translocations:** Movement of soil constituents (organic or mineral) within the profile and/or between horizons. Over time, this process is one of the more visibly noticeable as alterations in color, texture, and structure become apparent.

The fundamental processes are accumulation of humus or decayed organic material, eluviation, illuviation and horizonation. Humification is the process of decomposition of organic matter and synthesis of new organic substances. Soil genesis is associated with the origin and development of the biosphere. In a specific situation, viz. under forest in a temperate climatic zone, there is accumulation of undecomposed as well as hunk-fled organic matter. The soil humus is dispersed to a certain extent throughout the solum. Eluviation is the mobilization and translocation of certain constituents, viz. clay, Fe_20_3, Al_20_3, $Si0_2$, humus, $CaCO_3$, other salts, etc.

from one point of soil body to another. Illuviation is the immobilization and accumulation of the eluviated constituents at a depth beneath the soil surface.

A number of other processes operate in the course of soil formation. Calcification and gypsification are the soil forming processes of arid and semi-arid regions and refer to the formation and accumulation of calcium carbonate and gypsum, respectively. Most parent materials in these climatic regions are rich in lime and gypsum. Low rainfall is unable to move them downwards. In regions where some water percolates through the soil profile, decalcification takes place leading to the formation of calcic horizon or gypsic horizon down below. In humid regions, calcium carbonate reacts with water containing dissolved carbon dioxide to form soluble bicarbonate which may completely leached out of the soil profile. Podzolization Russian, pod means "under" and zola means "ash") is the process of eluviation of oxides of iron and aluminium and also of humus under acid condition (pH 4-5), removal of carbonates by organic acids formed by organic matter, and illuviation of these squioxides and humus in subsurface horizons. Abundant organic matter, commonly found under forest, cool climate and abundant water under humid climatic condition are favourable for such processes. The eluviated horizon assumes a bleached grey appearance and is left in a highly acid, siliceous condition. Because of the grey colour and ashy appearance, the term podzol has been use for such soils. Laterization, in contrast to Pozolization, is the process of desilication, i.e. the removal of silica and accumulation of sesquioxides. Hydrolytic separation of silica followed by its removal by leaching in the presence of base, resulting in a relative accumulation of sesquioxides and formation of 1 : 1-type clay minerals of the kaolinitic group are characteristics of such a process which operates in the hot and humid climatic conditions of the tropical and subtropical regions of the world. The word laterite was originally suggested by Buchaman in 1807 as a name for a highly ferruginous deposit he first observed in Malabar (India). The word is derived from the Latin word, later—a brick and obviously refers to its use as building material and not to its colour. Salinization is the process of accumulation of soluble salts in soil. The intensity and depth of accumulation vary with the amount of water available for leaching. Salinization is quite common in arid and semi-arid 'regions. Salinization may also take place through capillary rise of saline ground water and by inundation with sea water in marine and coastal soils. Salt accumulation may also result 'from irrigation or seepage in areas of impeded drainage. Desalinization is effected by leaching of soluble salts from soil, either with rain water or with irrigation water of good quality. Drainage is essential for desalinization. Alkalization (solonization) is the process by which soils with high exchangeagile sodium and pH greater than 8.5 are formed; often sodium carbonate and sodium bicarbonate are formed in extreme cases of alkalization. Such soils are called sodic soils or alkali soils. Dealkalization (solodization) is effected by intensive leaching and degradation which takes place in older soils. In this process exchangeable sodium is replaced by hydrogen ions. There is a simultaneous process of argillation which results in the leaching of dispersed clay particles from the upper to the lower horizons, giving rise to a textural horizon. Gleization is the process of reduction, due to anaerobic condition, of iron in waterlogged soils with the formation of mottles and concretions of iron and manganese.

The soil forming processes which lead to the formation, transformation and rearrangement of soil materials in a soil body leave their imprint on the different genetic soil horizons which constitute the soil morphology. Horizonation includes those processes by which the soil materials are differentiated into several horizons in a soil profile. The soil horizons may be pronounced to be observed, visually or may have to be differentiated by means of certain soil characteristics. Intermixing of soil horizons takes place in certain soils due to external factors. This process of mixing in the soil body has been termed *pedoturbation.*

Factors of Soil forming

Soils are dynamic, forming continuously over a long period of time. Soil types differ, depending on the parent materials from which they came and from the surrounding environment. The way in which soil forms depends on:

I. Parent material
II. Climate
III. Topography
IV. Biota (Living organisms)
V. Time

Soil is a natural medium made up of five major components:

- mineral particles: clay, silt, sand and gravel

- organic matter: decaying plant and animal material
- water
- air
- living organisms (soil biota): ranging from bacteria, fungi and earthworms

A healthy soil should have a balance of these components.

The Jenny equation

Soil scientist, Hans Jenny has suggested that type of soil found on any site is dependent upon the interaction of five factors.

Jenny’s state factor equation for soil genesis:

S = f (C, O, R, P, T, . . .)

C = Climate

O = Organisms

R = Relief (topography)

P = Parent Material

T = Time

...= Other unspecified factors

Any of the physical, chemical or biological processes taking place in the soil as a result of these factors are called pedogenic processes .

State Factor Analysis

Folger’s concept of sediment genesis

Se = f (G, H, B) (G, H, B) „

Se = sediment characteristics „

G = source geology

H = hydrology (flow regime)

B = bathymetry

Parent Material

Soil parent material is the material that soil develops from, and may be rock that has decomposed in place, or material that has been deposited by wind, water, or ice. The character and chemical composition of the parent material plays an important role in determining soil properties, especially during the early stages of development.

Soils developed on parent material that is coarse grained and composed of minerals resistant to weathering are likely to exhibit coarse grain texture. Fine grain soils develop where the parent material is composed of unstable minerals that readily weather.

Parent material composition has a direct impact on soil chemistry and fertility. Parent materials rich in soluble ions-calcium, magnesium, potassium, and sodium, are easily dissolved in water and made available to plants. Limestone and basaltic lava both have a high content of soluble bases and produce fertile soil in humid climates. If parent materials are low in soluble ions, water moving through the soil removes the bases and substitutes them with hydrogen ions making the soil acidic and unsuitable for agriculture. Soils developed over sandstone are low in soluble bases and coarse in texture which facilitates leaching. Parent material influence on soil properties tends to decrease with time as it is altered and climate becomes more important.

Climate

Temperature and precipitation

Temperature and precipitation influence how fast parent materials weather and, thus, soil properties such as mineral composition and organic matter content. Temperature directly influences the speed of chemical reactions. The warmer the temperature, the faster reactions occur. Temperature fluctuations increase physical weathering of rocks. Precipitation governs water movement in the soil. The amount of water the soil receives and the amount of evapotranspiration that occurs influence water movement.

Evapotranspiration

Evapotranspiration is the combination of water evaporated from the soil surface and water transpired by growing plants. As air temperatures increase, evapotranspiration increases. High evapotranspiration relative to precipitation means less water is available to move through the soil.

Moisture index

A leaching index or moisture index is calculated by subtracting evapotranspiration from precipitation. This index is an indicator of average soil moisture conditions. The greater the index, the more soil moisture is present. Higher soil moisture increases chemical weathering and moves minerals, such as bases, deeper into the soil profile. This affects management practices.

Topography

This refers to the landscape position and the slopes it has. Steep, long slopes mean water will run down faster and potentially erode the surfaces of slopes. The effect will be poor soils on the slopes, and richer deposits at the foot of the slopes. Also, slopes may be exposed to more direct sunlight, which may dry out soil moisture and render it less fertile.

Biota (organisms)

Biotic agents have greatly affected the soil formation process. These include organisms that live in the soil, such as bacteria and gophers, and vegetation growing on the surface.

Soil organisms

Organisms in the soil can speed up or slow down soil formation. For example, microorganisms can facilitate chemical reactions or excrete organic substances to improve water infiltration in the soil. Other organisms such as gophers slow soil formation by digging and mixing soil materials, and destroying soil horizons that have formed.

Vegetation

Generally soils have been formed under two major types of vegetation: Forest and prairie. Soils formed under forests tend to be more weathered (older in soil terms) because forests grow in higher rainfall areas. There’s more water movement in the root zone, and a smaller amount of organic matter forms. Soils formed in prairie tend to be in areas with less precipitation. Grasses tend to use the provided moisture, reducing the water movement through the soil profile. Organic matter forms in large quantities and to a deeper depth in the soil surface than forest soils.

Time:

Soils can take many years to form. Younger soils have some characteristics from their parent material, but as they age, the addition of organic matter, exposure to moisture and other environmental factors may change its features. With time, they settle and are buried deeper below the surface, taking time to transform. Eventually, they may change from one soil type to another. Time is the fifth factor in soil formation. Over time, vegetation and climate act on parent material and topography. Development, not chronological age, determines a soil's age. The degree of aging depends on the intensity of the other four soil-forming factors. Factors that slow soil formation include:

- High lime content in parent material.
- High quartz content in parent material.
- High clay content in parent material.
- Hard rock parent material (resistant to weathering).
- Low rainfall.
- Low humidity.
- Cold temperature.
- Steep slopes.
- High water table.
- Severe erosion.
- Constant deposition, accumulations and mixing by animals or man.

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Weathering: Definition and its classification

Weathering is a key part of the process of soil formation, and soil is critical to our existence on Earth. In other words, we owe our existence to weathering, and we need to take care of our soil!

Soils are formed from the different kind of rocks through the intermediate stage of regolith which is the result of weathering.

Weathering is the name given to the process by which rocks are broken down to form soils. Rocks and geological sediments are the main parent materials of soils (the materials from which soils have formed). There is a very wide variety of rocks in the world, some acidic, some alkaline, some coarse-textured like sands, and some fine-textured and clayey. It is from the rocks and sediments that soils inherit their particular texture. When you see rocks in the landscape it is easy to appreciate how long the process of breaking down rocks to form soil takes. In fact, it can take over 500 years to form just one centimetre of soil from some of the harder rocks. Fortunately, in some respects at least, huge amounts of rocks were broken down during the Ice Age over 10,000 years ago and converted into clays, sands or gravels, from which state it was easier to form soils.

There are three main types of weathering;

- Physical,
- Chemical
- Biological.

Physical weathering

Physical weathering is the influence of processes such as freezing and thawing, wetting and drying, and shrinking and swelling on rocks and other sediments, leading to their breakdown into finer and finer particles.

Physical weathering is a particularly important process in the early stages of soil formation. This is the process whereby solid rock first starts to break down into a soft and easily workable soil. As erosion removes layers of rock, and the underlying rocks come closer and closer to the surface, through erosion occurring in the landscape or through more catastrophic events such as volcanic activity and mountain building, so the rock becomes destabilised. These changes occur as the rock is no longer in equilibrium with the conditions deep below the surface of the earth but is now coming under the influence of the atmosphere, rainwater, snow and different temperature regimes. The solid rocks are attacked, broken down and eroded by these different processes.

One of the most influential of these physical processes is *freeze-thaw* by which water enters cracks and joints in the rocks, and then freezes. In freezing, the water expands, causing the rock to shatter into smaller pieces. This process is repeated time and time again until the smaller and smaller rock fragments reach the size of sand, silt and clay particles. The last Ice Age lasted some 2 million years, during which there were several long periods of freezing and thawing conditions. There were centuries of freezing followed by centuries of thawing during which rocks were scoured and broken down into finer grained sediments, called glacial deposits or till. These deposits had a major influence on, and became, the soil parent materials in many countries. Many soils have formed in these often deep glacial deposits and these are some of the most fertile and productive soils in the world. Physical weathering is continuing all the time, helping to produce new soils and making existing ones deeper.

There are several other physical processes in addition to freeze-thaw which contribute to soil formation. These include wetting and drying in which the surface soil material and underlying parent materials undergo periods of wetting, for instance after heavy rainstorms, followed by periods of drying. Some soil materials, particularly the more clayey ones, expand when wet, swelling up but when soils dry out they shrink. These alternating wetting and drying periods can break down rocks, minerals and sediments into smaller particles and also cause disruption to the ground. The forces involved can be large as demonstrated by the damage done to buildings and infrastructure built on soils that have high shrink-swell potential. Alternate*heating and cooling* is also an important way in which rocks break down to form soils. In hot climates, temperatures may rise greatly during the day but fall greatly at night. This can lead to differential expansion and contraction in rocks and minerals causing weaknesses to develop and eventual breakdown of the rocks into smaller fragments. *Soil erosion* by wind or water is also a widespread mechanism by which particles are moved across the landscape. In the process of this many particles become abraded and reduced in size. When re-deposited these particles will contribute to new soil development. Soil erosion is a threat to soil development in many areas but the re-deposited sediment can also become the parent material for the next generation of soils.

Chemical weathering

Chemical weathering is the decomposition of rocks through a series of chemical processes such as acidification, dissolution and oxidation. Some minerals, while stable within solid rock, become less stable on being more exposed to the atmosphere and so begin to alter in the rocks near the surface, destabilising the rocks.

Hydration: In hydration, water combines with rock minerals and results in the formation of a new chemical compound. The chemical reaction causes a change in volume and decomposition of rock into small particles.

An example of hydration reaction that is taking place in soils is the hydrolysis of SiO_2

SiO_2+ $2H_2O$ —> $Si(OH)_4$

Carbonation: It is a type of chemical decomposition in which carbon dioxide in the atmosphere combines with water to form carbonic acid. The carbonic acid reacts chemically with rocks and causes their decomposition.

Sedimentary rocks which contain calcium carbonate are the products of chemical reaction of rocks by carbonation.

Oxidation: Oxidation occurs when oxygen ions combine with minerals in rock. Oxidation results in decomposition of rocks.

Solution: Some of the rock minerals form a solution with water when they get dissolved in water. Chemical reaction takes place in the solution and the soils are formed.

Hydrolysis: It is a chemical process in which water gets dissociated into H^+ and OH^- ions. The hydrogen cations replace the metallic ions such as calcium, sodium and potassium in rock minerals and soils are formed with a new chemical composition.

Most of the clay minerals are derived from chemical decomposition. Plastic properties in soils are imparted by clay minerals. Hence clay soil are major products of chemical decomposition of rocks.

Biological weathering

Biological weathering is the effect of living organisms on the break down of rock. This involves, for example, the effects of plant roots and soil organisms. Respiration of carbon dioxide by plant roots can lead to the formation of carbonic acid which can chemically attack rocks and sediments and help to turn them into soils. There are a whole range of weathering processes at work near the surface of the soil, acting together to break down rocks and minerals to form soil. These weathering processes have given rise to most of the world's soils.

Biological weathering comes from two main sources, the components of organic matter and the roots and tendrils of plants. Rocks that become exposed on the surface of the ground, such as one sees in the uplands, gradually become converted into soils with the help of plant and animal life that begin to colonise them. For example, the first colonisers of a rock are often lichens, which are a symbiotic relationship between a fungi and algae. Lichens start a biological weathering cycle of the rock which is continued through mosses and the roots of grasses, each vegetation group playing a part in the weathering of the rocks through the acids they release. Eventually the roots of plants can get a hold in the rock and these can continue the process of the breakdown of the rock through the acids they release and through penetrating cracks in the rocks. Biological weathering is enhanced by various other biological processes including *respiration* from plant roots which releases carbon dioxide which then can combine with water to release carbonic acid. Carbonic acid is just one of the acids in soils that can help the chemical breakdown of rocks. Organisms can also form organic substances known as *chelates* which can remove some of the chemical components of rocks, thus aiding their decomposition. Although physical, biological and chemical weathering are treated separately in this section, in nature the processes unite to form the soils we see in our landscapes today and which provide many different functions for life on earth.

A key concept to understand is how erosion, and thus soil formation, is a continual process. As rocks and sediments are eroded away, so more of the solid rock beneath becomes vulnerable in turn to weathering and breakdown. The natural processes of nature, in the form of wind, rain, snow and ice, start to have their effect on these rocks and sediments as they 'come within their range'. Once the process starts, then other physical, chemical and biological processes also start to contribute to the breakdown of the rocks, leading to the formation of the precious soil. Most of the tiny particles making up our soils will have started as solid rock. Little or nothing will grow directly in rock; before plant life can flourish the rock first needs to be broken down to form soil. It is true to say that weathering and the formation of soil provide an excellent example of the wonders of nature.

In order to make this sediment and sedimentary rock, several steps are required:

- Weathering – Breaks pre-existing rock into small fragments or new minerals
- Transportation of the sediments to a sedimentary basin.
- Deposition of the sediment

- Burial and Lithification to make sedimentary rock.

Each Step in the process of forming sediment and sedimentary rocks leaves clues in the sediment. These clues can be interpreted to determine the history of the sediment and thus the history of the Earth.

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Soil profile and components of soil

Soil profile

In pedology, the age of the soil is the stage of soil development irrespective of the time taken. Thus, *a young soil* means the soil where the factors of soil formation and pedogenic processes are still operative and changing the properties of soil in the profile and the processes have not made a distinct impression on the soil profile. The horizons are riot well demarcated. A *mature soil* represents a steady state in respect of the parent material. Time factor has no relevance discernible. In young soil, clay from primary minerals is still being actively formed, whereas after the soil reaches its maturity. In mature soil, the different genetic horizons are clearly in mature soil the clay is more or less in equilibrium with the primary minerals. Further, in nature soils, clay content increases with depth of profile, accumulating at an intermediate depth, whereas in young soils, clay content decreases with depth. If the soil solum is removed by erosion or deposited over by a fresh transported parent material, a new cycle of soil formation takes place over the buried soil.

Soil morphology is the description of the soil body, its appearance, features, and general characteristics as expressed in the profile of a soil. The morphology of the soil is expressed by number, kinds and arrangements of the different horizons and their observable and measurable characteristics.

A soil horizon is "a layer of soil, approximately parallel to the soil surface, with characteristics produced by soil forming processes". Soil horizons extend in space, horizontally, laterally and vertically as soil is a three-dimensional component of the landscape. An individual soil body may be bounded laterally by other soil bodies or by non-soil materials. A soil individual is a natural unit in the landscape characterized by position, size, slope, profile and other features.

Soil profile is studied in the field from a freshly exposed pit. A pedon is the smallest volume that can be recognized as a soil individual and "has the smallest area for which we should describe and sample the soil to represent the nature and arrangement of its horizons and variability in other properties that are presented in the sample. A pedon is comparable to a unit cell of a crystal. It has three dimensions. Its lowest limit is the somewhat vague limit between the soil and not-soil below. Its lateral dimensions are large enough to represent the number of any horizons and variability that may be present. The area of a pedon ranges from 1 to 10 m^2, depending on the variability in the soil.

A soil profile is a vertical section of the soil. It allows you to examine the layers of the soil from the surface down to the rock or sediment from which the soil was formed (parent material). In the inland vegetable-growing environment, most soils have parent material consisting of sediments or soil particles carried into the area by wind or water.

Soils develop in parent material from the time of its deposition under the influence of local climate, topography, and biota. The process of soil development is often referred to as soil weathering. Over time, a number of environmental forces act to create distinct layers or horizons parallel to the soil surface. This occurs through the differential downward movement of materials, such as organic matter or clay particles. The movement and accumulation of materials at depth affects soil texture, structure, and/or color. These are three properties that are useful for distinguishing horizons. For example, accumulation of clay affects texture and structure (e.g. Bt) and an accumulation of organic matter affects color (e.g. A, Bh). However, these are not the only soil properties used to distinguish horizons. For example, the depth to parent material (C) in a calcareous till is best determined by testing for the presence of carbonates.

Thus, the concept of pedon includes the vertical and lateral Extent of soil, whereas that of a profile does for the vertical extent only. A. group of similar pedons that are bounded on all sides by 'non-soil' or by pedons of unlike character is called a *polypedon.*

The profile characteristics studied in the field consist of locating the soil horizons, based on colour differences. Where vertical colour differentiation is not possible, horizons are differentiated on the basis of variations in other soil characters. Each of these horizons is then described in terms of thickness, colour (Munsell notations), texture, structure, consistence, pH, carbonate, clay film, roots, krotovinas, pores, wetness, presence of mottlings and concretions etc. Besides genetic soil horizons, many soils may have layers of soil inherited from parent material or deposition of soil from other source. The external soil characteristics studied are form, linearity, and per cent slit gradient of slope, erosion, drainage condition and groundwater level. To make precise differentiation among soil horizons and among the soil groups, the field data on soil morphology are supported by measurements in the laboratory of selected soil properties, viz. mechanical composition, bulk density, permanent wilting point, coefficient of linear extensibility (COLE), pH, cation exchange capacity and exchangeable cations, base saturation, calcium carbonate, electrical conductivity of saturation extract of soil (for total soluble salts), organic carbon, mineralogical composition. All these data are used in interpreting the soil forming processes which have acted over many years in shaping the characteristic genetic soil horizons.

It may be emphasized that profile studies are the first step in understanding soil genesis and also the basis of soil classification.

Soil horizons

The layers in the soil are called horizons. The soil horizons depict the history of soil formation. Of the several horizons, the master horizons are the results of the fundamental soil forming processes, viz. accumulation of humus, eluviation, and illuviation. These are designated by the capital letters 0, A, E, B, and C. 0 represents organic horizon at the surface; A, E, B and C are the mineral horizons. These horizons overlie the bed rock from which the soils have been formed.

Soil master horizons

Soil horizons are horizontal bands or layers in the soil profile. The main horizons, called master horizons, are O, A, E, B, C and R.

O horizon (surface organic litter)

This is the layer of organic matter sitting on top of the soil. It tends to be deepest in undisturbed forest environments. `O' is the organic horizon of mineral soil formed from the organic litter derived from plants and animals and deposited on the surface or at any depth beneath the surface in buried soils. This horizon is often black or dark brown in color, because of its organic content. The organic horizons do not include soil horizons formed by illuviation of organic material or by the decomposing roots below the surface. Some soils consist entirely of material designated as O horizons or layers. A horizon formed by illuviation of organic material into mineral subsoil (e.g. Bh) is not an O horizon, though some horizons formed in this manner contain much organic matter.

a Highly decomposed organic material of unidentifiable origin.

e Organic material of intermediate decomposition; identifiable; fragmented.

i Slightly decomposed organic material; identifiable; slightly fragmented.

A horizon: The A horizon may be seen in the absence of the O horizon, usually known as the topsoil. It is the top layer soils for many grasslands and agricultural lands. Typically, they are made of sand, silt and clay with high amounts of organic matter. This layer is most vulnerable to wind and water erosion. It is also known as the root zone. Mineral horizons that formed at the surface or below an O horizon and (1) are characterized by an accumulation of humified organic matter well mixed with the mineral fraction and not dominated by properties characteristic of E or B horizons (defined below) or (2) have properties resulting from cultivation, pasturing, or similar kinds of disturbance. If a surface horizon has properties of both A and E horizons but the feature emphasized is an accumulation of humified organic matter, it is designated an A horizon.

p disturbance of the surface layer by plowing, pasturing, or similar uses. A disturbed organic horizon is designated Op. A disturbed mineral horizon, even though clearly once a E, B, or C horizon, is designated Ap.

A1 horizon (topsoil)

This is the surface soil, referred to as topsoil. It has the most organic matter and biological activity of any of the horizons. The decayed organic matter (humus) darkens the soil colour.

A2 horizon (topsoil)

This layer is not present in all profiles. It frequently has a pale, bleached appearance and is poorly structured. Bleaching is an indication of periodic water logging often due to formation of a 'perched' water table above a relatively impermeable subsoil.

E horizon:

`E' horizon is usually lighter in color, commonly near surface, below '0' or 'A' horizon, and above 'B' horizon, but the symbol `E' can be used for eluvial horizon or parts of the 'B' horizon. It is often rich in nutrients that are leached from the top A and O horizons. It has a lower clay content and is common in forested lands or areas with high quality O and A horizons.

`E' horizon is the mineral horizon in which the main feature is the loss of silicate clay, iron, aluminium or some combination of them, leaving a concentrate of sand and silt particles and exhibiting obliteration of all or most of the original rock structure.

`E' horizon is usually, but not necessarily, lighter in colour than the underlying 'B' horizon. In some soils, the colour is that of the sand and silt particles, but in many soils, coatings of iron oxides or other compounds mask the colour of the primary particles. It is most commonly differentiated from an overlying horizon by its lighter colour and has less organic matter than the 'A' horizon. `E' horizon is differentiated from an underlying B-horizon in the same sequum by colour of higher or lower chroma or both, by coarse texture, or by a combination of these properties.

B horizon (subsoil)

The B-horizon has some similarities with the E-horizon. It is also called the illuviation zone because of the accumulation of minerals. This horizon frequently has more clay than topsoil. In clay soils, the difference in clay content between the A and B horizons is less than those for other soils, such as the red brown earths, where the topsoil is loamy or sandy.

Mineral horizons that have formed below an A, E, or O horizon and are dominated by one or any combination of the following: (i) illuvial accumulation of silicate clay, iron, aluminum, humus, etc. alone or in combination; (ii) a residual concentration of sesquioxides of silicate clays, alone or mixed, that has formed by means other than solution and removal or carbonates or soluble salts; (iii) coatings of sesquioxides adequate to give conspicuously darker, stronger or redder colour than the overlying and underlying horizons in the same sequum *(*sequum is an eluvial horizon and its subjacent B horizon, if one is present), but without apparent illuviation of iron and not genetically related to the B horizon that meets the requirements of 1 or 2 in the same sequum; or (iv) an alteration of materials from its original conditions in sequums lacking conditions defined in 1, 2 and 3 that obliterate original rock structure, that form silicate clays, liberate oxides, or both, and that form granular, ,blocky, or prismatic structure if textures are such that volume changes accompany changes in moisture.

h Illuvial accumulation of organic matter. Accumulation of illuvial, amorphous, dispersible organic matter -sesquioxide complexes if the sesquioxide component is dominated by aluminum, but is present only in very small quantities. The organosesquioxide material coats sand and silt particles or may occur as discrete pellets. In some horizons, coatings have coalesced, filled pores, and cemented the horizon. The symbol "h" is also used in combination with "s" as "Bhs" if the amount of sesquioxide component is significant but value/chroma of the horizon are approximately 3/3 or less. “Bh” and “Bhs” horizons usually have hues 7.5 YR or redder.

s Illuvial accumulation of sesquioxides and organic matter. “s” is used if both the organic matter and sesquioxide components are significant and the value/chroma of the horizon is more than 3/3. The symbol may also be used in combination with "h" as described above.

t Accumulation of silicate clay that either has formed in the horizon or has been moved into it by illuviation. The clay can be in the form of coatings on ped surfaces or in pores, lamellae, or bridges between mineral grains.

w Slight accumulation of material, giving rise to a change in color and removal of carbonates. Characteristic of *weakly* developed young soils.

C horizon (weathering rock)

This layer may be very deep, and may not be present in the root zone of many vegetable-growing soils.It is mainly made up of broken bedrock and no organic material. It has cemented sediment and geologic material. There is little activity here although additions and losses of soluble materials may occur. The C horizon is also known as saprolite.

Horizons, excluding hard bedrock, that are little affected by pedogenic processes and lack properties of O, A, E, or B horizons. Most are mineral layers, but limnic layers, whether organic or inorganic, are included. The material of C layers may be either like or unlike that fromwhich the solum presumably formed. A C horizon may have been modified even if there is no evidence of pedogenesis. Some soils form in material that is already highly weathered, and such material that does not meet the requirements of A, E, or B horizons is designated C. Changes not considered pedogenic are those not related to overlying horizons. ‘C’ is a mineral horizon or layer, excluding bed rock, that is either like or unlike the material from which the solum is presumed to have formed.

R Layers: Hard Bedrock. Granite, basalt, quartzite and indurated limestone or sandstone are examples of bedrock that are designated R. The bedrock of an R layer is sufficiently coherent when moist to make hand digging with a spade impractical, although it may be chipped or scraped with a spade.

The master horizons may not be uniform throughout the thickness (depth) in the characters by which they have been designated and may be subdivided to indicate the deviations. The subdivisions are indicated by placing Arabic numerals after the capital letter, such as, 01, 02, Al, A2, Bl, B2, etc. A secondary Arabic number is used to' indicate further subdivision, viz. A 11, Al2, A21, etc.

Subordinate distinctions within master horizons In addition to the above designations, the following symbols (lower cases) are used as suffixes to designate specific kinds of master horizons and layers Symbol 'a' is used with '0' to indicate the most highly decomposed state of organic materials; 'b' in mineral soils to indicate identifiable buried horizon; 'c' to indicate a significant accumulation of cemented concretions, or of nodules; `d' to indicate naturally occurring or man-made unconsolidated sediments or materials with high bulk density; `e' with '0' to indicate organic materials of intermediate decomposition; T to indicate that the horizon or layer contains permanent ice; `g' to indicate that either iron has been reduced or removed during soil formation or that saturation with stagnant water has preserved a reduced state; 'h' with 'B' to indicate the accumulation of illuvial, amorphous, dispersible organic matter sesquioxide complexes; T with '0' to indicate the least decomposed organic materials; 'k' to indicate accumulation of alkaline earth carbonate, commonly calcium carbonate; 'm' to indicate continuous or nearly continuous cementation; 'n' to indicate accumulation of exchangeable sodium; 'o' to indicate residual accumulation of sequioxides; `p' to indicate disturbance of the surface layer by mechanical means; 'q' to indicate accumulation of secondary silica; 'r' with 'C' to indicate layers of soft bedrock; 's' with 'B' to indicate the accumulation of illuvial, amorphous, dispersible organic matter sesquioxides complexes; 'Bs' to indicate the presence of sesquioxides; 't' to indicate accumulation of silicate clay either by illuviation into the horizon or by formation and-subsequent translocation ,within the horizon or both; 'v' to indicate the presence of iron-rich, humus-poor reddish material (plinthite) that is firm or very firm when moist and that hardens irreversibly when exposed to atmosphere and to repeated wetting and drying; 'w' with 'B' to indicate development of colour and structure; 'x' to indicate genetically developed firmness, brittleness or high bulk density, these features are characteristic of fragipans; 'y' to indicate accumulation of gypsum; 'z' to indicate accumulation of salts more soluble than gypsum.

In some cases, the B horizon is absent due to mixing of the A and B horizons; such profiles have an AC horizon. If the A horizon or even part of the B horizon is removed by erosion (discussed in the next chapter), the soil profile is truncated.

Descriptions of Black soil *(Typic Chromustert,* Location: Indore, M.P.) is given, below.

Horizon	*Depth and Description*
Ap	0-0.11 m; dark greyish-brown (2.5Y4/2, D) tovery dark greyish-brown (2.5Y3.5/2, M) clay; moderate medium subangular blocky structure; firm, sticky and plastic; many fine roots inside peds; medium tubular pores; pH 8.0; clear smooth boundary.
Al2	0.11-0.29 m; dark greyish-brown (2.5Y4/2,D) tovery dark greyish-brown (2.5Y3.5/2,,M) clay; moderate medium subangular blocky structure; hard, firm, sticky and plastic; many fine roots inside peds; fine and tubular pores; pH 8.1; clear smooth boundary.

A13 0.29..0.54 in; very dark greyish-brown to darkgreyish-brown (2.5Y3.5/2D) clay; moderate medium angular blocky structure with slickensides and shiny pressure faces; hard, firm, sticky and plastic; few fine roots; pH 8.1; diffuse smooth boundary.

A14 0.54-0.95 m; very dark greyish brown to darkgreyish-brown (2.5Y3.5/2, D&M) clay; intersecting slickensides forming large parallelepipeds with long axes tilted 40° to 45° from the horizontal that break into strong coarse angular blocks with shiny pressure faces; very hard, very firm, very sticky and very plastic; few fine roots; fine irregular pores; slightly effervescent; pH 8.1; gradual smooth boundary.

A15 0.95-1.19 m; very dark greyish-brown to darkgreyish-brown (2.5Y3.5/2, D&M) clay; intersecting slickensides forming large parallelepipeds with long axes tilted 30° from horizontal that break into strong coarse angular blocks with shiny pressure faces; very hard, very firm, very sticky and very plastic; few fine roots; fine irregular pores; slightly ;effervescent; pH 8.1; gradual smooth boundary.

A16 1.19-1.47 m; dark greyish-brown (2.5Y4/2, D) tovery dark greyish-brown (2.5Y3.5/2, M) clay; intersecting slickensides forming large parallelepipeds with long axis tilted 35° from the horizontal with shiny pressure faces; very hard, very firm, very sticky and very plastic; few fine roots; fine irregular pores; slightly effervescent; pH 8.2; clear smooth boundary.

AC 1.47-1.60 m+; very dark greyish-brown to darkgreyish-brown clay; intersecting slickensides forming medium parallelepipeds tilted 35° from the horizontal that break into strong coarse angular blocks with shiny pressure faces; very hard, very firm, very sticky and very plastic; fine irregular pores; strongly effervescent; pH 8.2.

The soils have developed on basaltic alluvium. The $CaCO_3$ content of the AC horizon is 14.9 per cent; the slickensides and strong coarse angular blocky structure are due to strong swelling and shrinking of montmorillonitic clays; there is not much difference in the subhorizons of the A horizon; the genesis of the black soils is characterized by the process of pedoturbation that leads to haploidization of the profile. These deep black soils exhibit evidence of appreciable vertical mixing within the profiles caused by shrinking and swelling which results cracking due to changes in water content. In many profiles, the C horizon is observed and is characterized by weathering rocks (parent material).

'A' (Eluvial) Horizons: This 'A' horizon is present at or near the surface and it is characterized as zones of 'washing out' or maximum leaching. This horizons can be divided into three specific horizons as follows :

'B'(Illuvial) Horizons: This horizons are the zone of 'washing in' or accumulation of materials such as iron and aluminium oxides and silicate clays, from the above horizons or even from the below horizons in arid conditions as calcium carbonate, calcium sulphate and other salts during evaporation. This horizons sometimes are referred to as the 'Sub soil' where it may not be considered as the plough layer. It can be divided into three specific horizons as follows

'C' Horizon: It is the unconsolidated material underlying the Solum (A plus B horizon). It may or may not be the same as the parent material from which the Solum formed. This horizon also considers as outside the zones of major biological activities and is very little affected by Solum forming processes. The upper portion of the C horizon may sometimes be considered as the Solum since continually weathering and erosion are going on.

SURFACE SOIL VS. SUB-SOIL

Surface Soil	Sub Soil
1. It is completely weathered.	1. It is partially weathered.
2. Surface soil is dominated by finer particles like silicate clays.	2. Sub-soil is dominated by quartz particles and other coarse fragments of minerals.
3. Surface soil is porous and friable.	3. The sub-soil is more massive and compact.
4. Aeration status of surface soil is good and exchange of gases between atmosphere and soil air takes place.	4. Aeration status of sub--soil is very poor and hence exchange of gases is very much limited.
5. The number and activity of soil microorganisms is very high.	5. The microbial population and their activity is very low.
6. Relatively higher organic matter content due to presence of higher biomass on the soil surface.	6. Due to lack in plant and animal residues in the sub-soil, the amount of organic matter is very low.
7. Due to presence of high organic matter content the colour of surface soil is deep brown or dark.	7. The colour of sub-soil is light and sometimes may be light yellowish colour depending on the nature and kinds of unweathered materials.
8. It is fertile and most of the essential plant nutrients are present.	8. It is less fertile, very few essential plant nutrients are present;
9. Surface soil has no hard pan.	9. Sub-soil sometimes has hard pan.
10. It has good physical management condition because of surface soil.	10. It has poor physical condition.
11. Cation exchange capacity is very high.	11. Cation exchange capacity is low.

Components of soil

Soil provides anchorage to roots enabling plants to stand erect; it acts as a storehouse of water and nutrients for uptake by plant roots, it provides space for air and aeration which create a healthy environment for the biological activity of soil organisms.

It may be of interest to distinguish between a soil and soil. A soil is studied as a natural body from the point of view of pedology, and as part of the landscape. Soil is a material whose physical, chemical mineralogical and biological characteristics are studies in relation to plant growth or to any other use.

Soil is composed of partly weathered, un weathered, and transformed products of rocks and rock minerals and organic matter the soil particles are present partly as individual and partly as aggregates or ‘peds’ the organic matter is often firmly combined with mineral particles forming aggregates which are of various sizes and shapes, just as the interparticle pores.

Soils are applied solely to those superficial or nearly superficial horizons of rocks, that have been more or less modified naturally by the interaction of water, air and various kinds of organisms, either living or dead; this being reflected in a certain manner in the composition, structure and colour of such formations. Where these conditions are absent, there are no natural soils, but either artificial mixtures or rock. (*Dokuchaev*)

Soil is a natural body developed by natural forces acting on natural materials. It is usually differentiated into horizons from minerals and organic constituents of variable depth which differ from the parent material below in morphology, physical properties and constituents, chemical properties and composition and biological characteristics. (*Joffe and Marbut*)

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. (*Buckman and Bardy*)

Soil physics is that branch of soil science which deals with the mechanical behavior of the soil mass, i.e. the physical properties of soils as well as the measurement and control of physical processes that take place in and through the soil. Soil Chemistry deals with the chemical composition and properties of soil and describes the chemical processes taking place in the soil and describes the chemical processes taking place in the soil. Soil biology deals with soil ecology – the organisms and their role in biological transformation in the soil. Soil mineralogy deals with the minerals (primary rock minerals and secondary minerals) present in soil and their contribution to the chemistry, physics, biology and fertility deals with the nutrient status or ability of soil to supply nutrients for plant growth under favorable environmental conditions such as light, temperature, and physical conditions of soil. Soil Genesis and Classification (Pedology) deals with weathering of rocks and minerals, factors and processes of soil formation, and classification of soils in a recognized system. Soil survey is the systematic examination of soils in the field and laboratories, their description and classification, the mapping of kinds of an area, and also the interpretation of soils according to adaptability to various crops and their productivity under different management system. Soil Technology is an applied science and deals with the principles and practices of soil erosion and conservation, and management of problem soils, viz. saline, sodic (alkali), acid, waterlogged and other degraded soils.

Soils consist of four major components viz. (i) mineral matter, (ii) organic matter, (iii) water and (iv) air. All these components cannot be separated with much satisfaction because they are present very intimately mixed with each other. The mineral matter forms the bulk of soil solids and a very small amount of the soil solids occupied by organic matter.

Soil is made up of solid, liquid and gas components:

- the solid part consists of mineral particles and organic matter
- the liquid part is water and nutrients
- the gas part is air.

The solid components are minerals derived originally from weathering rock and organic materials derived from plants and microorganisms. The liquid component of the soil is made up of water, with varying amounts of nutrients and other soluble substances dissolved within it. The water and nutrients are used by plants to grow. Water may be lost by evaporation to the atmosphere, or by deep drainage through the soil. Water that is drawn out of the soil by plants and released into the atmosphere is called transpiration.

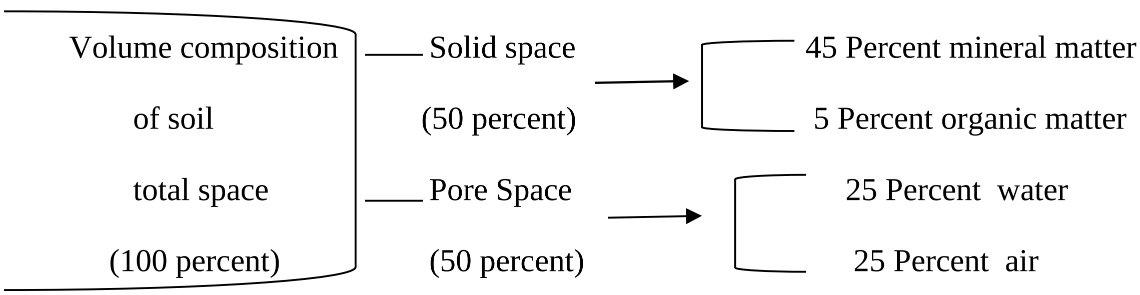
The gas component of the soil refers to air. Soil is generally porous, containing many air spaces. Oxygen in the air is required in the soil for the growth of most plants. When the soil becomes saturated with water, with no air left in the pores, the soil is said to be waterlogged.

Concept of soil

In the organic matter portion of the soil, about half of the total matter comprised of the dead remains of the soil life in all stages of decomposition and the remaining half of the organic matter consists of plant roots, bacteria, earthworms, algae, fungi, nematodes, actinomycetes and many other living organisms.

Volume composition of Soil

The volume composition of soil in optimum condition for the crop growth are as follows :



Soil contains about 50 percent solid space and 50 percent pore space. The total solid space of the soil is occupied by mineral matter and organic matter by about 45 percent and 5 percent respectively. The total pore space of the soil is occupied by air and water on 50:50 basis i.e. in this case 25 percent air and 25 percent water. The proportion of air and water will vary under natural conditions depending upon the weather and environmental factors. So it must be emphasized that the above four major components of the normal soil exist mainly in an intimately mixed condition which encourages various reactions within and between the groups and gives optimum condition for the crop growth.

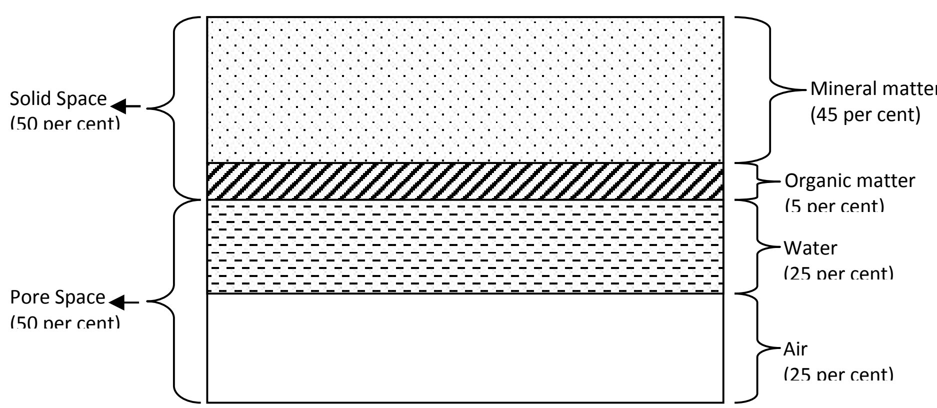


Fig. Volume composition of soil suitable for plant growth. The amount of air and water will fluctuate depending on the weather and other factors.

A. SOLID PHASE

Soil material less than 2 mm size constitutes, according to international convention, the soil sample, the rest of the soil matrix being rejected as unimportant.

The solid phase thus obtained is broadly composed of inorganic and organic constituents. Soils having more than 20 percent of organic constituents are arbitrarily designated organic soils. Where inorganic constituents dominate, they are called mineral soils. The majority of the soils of India are mineral soils.

i) Inorganic Constituents

The inorganic constituents which form the bulk of the solid phase of soil consist of silicates, both of primary and secondary origin, having a definite chemical composition and a well defined crystalline structure, a soil may also contain a certain proportion of carbonates, soluble salts, and free oxides of iron, aluminium and silicon, in addition to some amorphous silicates.

Primary minerals

Primary minerals found in rocks are the original source of all primary minerals found in soils. The most abundant are quartz and feldspars with relatively small proportions of pyroxenes, amphiboles, olivines, micas, etc, the primary minerals in soil are mostly concentrated in the coarse fraction.

Secondary minerals

Under conditions of weathering, the primary minerals are broken down to small fragments and even to molecular species such as silica, alumina, iron oxide, etc. the latter are capable of being synthesized into structurally different silicates which are called the secondary minerals. They constitute the most active ingredient of soils with respect to most of the chemical, physical, and mineralogical properties. The fraction with particles less than 2 microns (0.002 mm) is arbitrarily called the clay fraction which possesses colloidal properties.

The soil clay fraction may be composed of, in addition to secondary minerals, simply called clay minerals, hydrated iron and aluminium oxide minerals, and amorphous minerals; the secondary minerals are dominant in the majority of soil clays. The clay minerals are aluminosilicate in chemical composition and have crystalline structure. The oxide and hydroxide minerals constitute a sizable fraction of the soils of humid subtropical and tropical regions, and probably account for variable proportions of iron and aluminium in those soils. The principal forms of amorphous minerals in soils are oxides and hydroxides of iron, aluminium and silicon and do not constitute significant proportions of soil clays except in highly weathered soils allophone, a prominent member of this group, has been reported in soils of volcanic origin .

Calcium carbonate

Carbonates in soil are mostly of calcium with occasional occurrence of dolomite. Carbonates may be derived from the parent rock of may be formed in soil by interaction of calcium released during weathering with the carbon dioxide of biological origin because of low solubility, carbonates of calcium and magnesium may persist even in the soils of humid regions. Sparingly soluble carbonate is commonly absent in soils having pH less than 7.0 soils having a high content of calcium carbonates are called calcareous. The calcium carbonate may be present in pulverized form or as concretions of varying sizes. The pH of such soil is in the range 8.0-8.5.

Soluble salts

Soluble salts are released from rocks during weathering and in course of soil formation. In high rainfall regions, most of the soluble salts are leached down to lower depths. In regions of low rainfall, in soils of low lying areas, or irrigated soils not having adequate drainage, the soluble salt content of soil may gradually rise so as to limit plant growth. The soluble salt content of soil at which damage to plant growth may occur usually varies from 0.1 to 0.2 per cent on a dry soil basis. Such soils are classified as saline. If the salinity is measured conductometrically, as is more easily done, it is expressed in dSm^{-1}. Extracted and measured under specified conditions salinity above 4 dSm^{-1} is harmful. Cations commonly found in soluble salts are calcium, magnesium, sodium and potassium, while the anions are chloride, sulphate, carbonate and bicarbonate. In specific situations, nitrates and borates are also present.

Free oxides of silicon, iron and aluminium

In the course of weathering and soil formation, oxides of iron, aluminium and silicon are formed which remain in the soil as such and/or get coated over soil particles. They can be removed by suitable chemical treatments.

ii) Organic matter in soils

Soil organic matter exists as partly decayed and partially synthesized plant and animal residues. Such organic residues are continually being broken down as a result of microbial activity in soil and due to constant change it must be replenished to maintain soil productivity. The organic matter content in a soil is very small and varies from only about 3 to 5 percent by weight in a top soil. In addition to partly decayed plant and animal residues, soil organic matter contains living and dead microbial cells, microbially synthesized compounds and derivatives of these materials produces as a result of microbial decay.

Organic matter is a store house of nutrients in soil. Besides these, organic matter is responsible for most desirable surface soil structure, promotes a greater proportion of larger pore sizes, improves water holding capacity and also aeration status of the soil.

It is a major source of nitrogen, 5-60 percent of the phosphorus and perhaps about 80 percent of the sulphur. Besides these it can also supply different trace element like boron, molybdenum etc. to soil which are essential for the plant growth. Organic matter is the main source of energy for soil micro-organisms.

Organic matter acts as a chelate. A chelate is any organic compound that can bound to a metal by more than one bond and form a ring or cyclic structure by that bonding. Due to chelate formation between organic matter and various metals, the availability of those metallic elements will be increased to the plants through increasing their mobility in soils, organic matter contributes to the cation-exchange capacity in soils. Organic matter reduces soil erosion, shades the soil and keeps the soil cooler in very hot weather and warmer in winter.

iii) Living Organisms

Soil is the habitat for enormous number of living organisms. Some of these are visible to the naked eye, whereas others are of microscopic dimensions. Roots of higher plants—soil macroflora—belong to the first group whereas bacteria, fungi, actinomycetes and algae—soil microflora—belong to the latter group. The soil microflora are most abundant. A gram of fertile soil contains billions of these microorganisms. The live weight of the microorganisms may be about 4000 kg per hectare and may constitute about 0.01 to 0.4 per cent of the total soil mass. Significant among the soil microfauna are protozoa and nematodes.

B. LIQUID PHASE

Forty to fifty per cent of the bulk volume of the soil body is generally occupied by voids or soil pores, which may be completely or partially filled with water. A considerable part of the rain which falls on soil is absorbed by the soil and stored in it to be returned to the atmosphere by direct evaporation or by transpiration through plants. The same is the fate of irrigation water. The soil acts as a reservoir for supplying water to plants for their growth. The soil water keeps salts in solution which act as plant nutrients. Thus, the liquid phase is an aqueous solution of salts.

When all the soil pores are completely filled with water or aqueous solution, the soil is said to be saturated. But this stage is transient under field conditions unless there is standing water very near the surface. Water starts draining off immediately from the bigger pores first; after a few hours (say 24 hours of water saturation stage), the downward flow of water is almost negligible and water is retained in the soil. Up to a certain limit, this water is utilized by plants. The pores which are drained of water are simultaneously filled with air.

C. GASEOUS PHASE

The air-filled pores constitute the gaseous phase of the soil system. The volume of the gaseous phase is thus dependent on that of the liquid phase. At any stage the sum of the volumes of the liquid and gaseous phases remains constant for a particular soil. The nitrogen and oxygen contents of soil air are almost the same as that of the atmospheric air but the concentration of carbon dioxide is much higher. Too high a concentration of carbon dioxide in soil air may be toxic to plant roots, the gaseous phase supplies oxygen for root respiration which finally liberates carbon dioxide. Gaseous exchange between soil air and atmospheric air ensures fresh supply of oxygen, and thereby prevents carbon dioxide toxicity.

The three phases of the soil system have definite roles to play. The solid phase provides mechanical support for and nutrients to the plants. The liquid phase supplies water and along with it dissolved nutrients to plant roots. The aeration need of plants is satisfied by gaseous phase. The soil's function to sustain plant growth is thus shared complementarily by its three phases.