LECTURE NOTE

SOS 211

# PRINCIPLES OF SOIL SCIENCE

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## UNIT 1: DEFINITION OF SOIL

There have been several conceptions held about soil in the historic past. This has led to several definitions of soil by different people at various times. Some of the several definitions range from very simple definitions to very professional definitions such as the following:

1 ***Soil*** *is a thin layer of material on the Earth's surface in which plants have their roots. It is made up of many things, such as weathered rock and decayed plant and animal matter. Soil is formed over a long period of time.*

2 ***Soil*** *is the unconsolidated mineral or organic material on the immediate surface of the Earth that serves as a natural medium for the growth of land plants.*

3 *The unconsolidated mineral or organic matter on the surface of the Earth that has been subjected to and shows effects of genetic and environmental factors of: climate (including water and temperature effects), and macro- and microorganisms, conditioned by relief, acting on parent material over a period of time. A product-soil differs from the material from which it is derived in many physical, chemical, biological, and morphological properties and characteristics.*

4. *Soil is a natural body comprised of solids (minerals and organic matter), liquid, and gases that occurs on the land surface, occupies space, and is characterized by one or both of the following: horizons, or layers, that are distinguishable from the initial material as a result of additions, losses, transfers, and transformations of energy and matter or the ability to support rooted plants in a natural environment.*

Some of the concepts that have affected the definition of soil in the past includes:-

- Soil as a thin mantle over the land surface
- Soil as a medium for plant growth
- Soil as a basic matter of the universe
- Soil as a mantle of loose and weathered rock
- Soil as an organized natural bodies

Also, the definition of soil varies with the profession and perception of the person defining soil. What a soil is to civil engineers is different from the definition of soil by geologists, geomorphologists, archeologists and soil scientists.

However, among the different definitions of soil in the historic past, two have stood the test of time. These are soil as a medium for plant growth and soil as organized natural bodies.

The concept of soil as a medium for plant growth must have been one of the first held by man. When man began to grow his food rather than gather it, the nature of soil assumed a direct bearing on his welfare. Man then realized that the soil underfoot was a medium for plant growth, something in which seed could be sown and from which plant could be produced to provide food, if all went well. This concept regards the soil as a medium for plant growth, both as a substrate providing mechanical support and as store house for essential plant nutrients.

Soil, in terms of its morphological characteristics, is defined as unconsolidated surface material forming natural bodies made up of mineral and organic materials and the living matter within them. Soil is a dynamic entity with material continually and simultaneously added, removed, and transformed. Its formation begins with a parent material derived from either the underlying rock or material transported from somewhere else to its present site.

It is mainly the combined effects of climate and living matter that convert a material to a soil. For example, in temperate rainy environments, moisture and dense vegetation may lead to deep, richly organic soils. In deserts, with the lack of moisture and subsequent vegetation, soils may be thin and remain highly mineral. Human disturbances, such as dwellings, agricultural practices, grave sites, and garbage dumps, may also affect soils, giving them other unique characteristics. Soil, in terms of its morphological characteristics, is defined as unconsolidated surface material forming natural bodies made up of mineral and organic materials and the living matter within them. Soil is a dynamic entity with material continually and simultaneously added, removed, and transformed. Its formation begins with a parent material derived from either the underlying rock or material transported from somewhere else to its present site.

**Soil Composition**

While a nearly infinite variety of substances may be found in soils, they are categorized into four basic components: minerals, organic matter, air and water. Most introductory soil textbooks describe the ideal soil (ideal for the growth of most plants) as being composed of 45% minerals, 25% water, 25% air, and 5% organic matter. In reality, these percentages of the four components vary tremendously. Soil air and water are found in the pore spaces between the solid soil particles. The ratio of air-filled pore space to water-filled pore space often changes seasonally, weekly, and even daily, depending on water additions through precipitation, throughflow, groundwater discharge, and flooding. The volume of the pore space itself can be altered, one way or the other, by several processes. Organic matter content is usually much lower than 5% in Nigeria (typically 1% or less). Some wetland soils, however, have considerably more organic matter in them (greater than 50% of the solid portion of the soil in some cases).

## Soil Genesis and formation

### Factors of soil formation

The five soil forming factors are: parent material, topography, climate, biological activity, and time. Soil formation begins with a parent material derived from weathering of either the native rock or material transported to the site. The concerted effect of climate and biological activity then transforms parent material by producing the physical and chemical energy to alter minerals and vertically redistribute material through the soil profile. The effect of climate and biological activity is modified by topography.

### Parent material

Parent material is the initial mineral substance that forms a soil. It is derived from the weathering of rocks and may reside at the site of its origin or be transported from somewhere else to its current location. A soil formed from parent material found at the site of its origin is called a residual or sedentary soil. Bedrock weathering in place produces a stony, massive material called saprolite. As physical and some chemical weathering occur, the saprolite becomes denser than the underlying bedrock. The texture and original rock structure remain, but the material is soft enough to dig with a hand shovel. As chemical weathering converts primary minerals to secondary minerals, particles are redistributed vertically. As material is both added and removed, a soil develops. A residual soil will retain many of the characteristics of the underlying bedrock. Also the texture, mineralogy, pH, and other characteristics of the soil may be a direct result of the saprolite below.

Material can be eroded from one place and transported to another where it becomes parent material for a soil at the new site. Often weathering occurs before the material is transported to the new site. In this case, the soil may have few features in common with the underlying rock. Transported material can bury an existing soil at the new site. Once a depositional episode is completed, time zero for the new soil's formation begins. Several forces can supply energy for the transportation of parent material: ice, wind, water, and gravity.

***Ice***

Glacial deposits occur at the front and sides of advancing ice. Normally this material is poorly sorted with respect to particle size. Because ice melts from the bottom, this is also true of material deposited under a glacier. Also, material can be deposited as outwash in the glacier's melt-water.

Soils formed from glacial deposits vary in composition depending on the rock type over which the glacier traveled. Since glaciers advance and retreat with time, the composition and depositional environment of the parent material can be quite complex.

Overall, the texture of soil produced in glacial deposits reflects the mode and distance of transport and the type of rock scoured. Shale and limestone scouring tends to produce a soil with relatively more clay and silt-sized material. Igneous and metamorphic rocks produce mostly sandy soils. Deposits beneath the ice usually result in finer textured, denser materials, whereas outwash and front and side deposits are generally coarser.

***Wind***

Wind deposits two major types of material: eolian sands and loess. Clay-sized material (< 0.002 mm) tends to bind together in aggregates too large to be eroded by wind.

Eolian sands are windblown deposits of material predominantly greater than 0.05 mm (0.05 to 2 mm) in diameter. Most of this material moves in a series of short-distance jumps called saltation. Eolian deposits may move several kilometers from the source.

Material adhering to saltating sand particles and material deposited as an aerosol are the sources of clay in eolian sand. Normally this material has a narrow textural range and is deposited on the leeward side of valleys or bodies of water.

Loess, which is windblown silt-sized material (0.002 to 0.05 mm), once airborne, can travel several hundred kilometers before deposition. The texture of loess usually does not vary in a vertical direction, but tends to thin with horizontal distance from the source.

Windblown material tends to have sharp edges, a conchoidal shape, and surface etching. In contrast, material deposited by water tends to have rounded edges and a polished surface. Careful observation under a hand lens can shed light on the environment present at deposition.

***Water***

An alluvial or stream-borne deposit occurs in floodplains, fans, and deltas. Because fast-moving water picks up debris, a river meandering downstream will undercut the outer bank of each bend. Water moves slower around the inner bank than the outer bank and therefore loses energy. Thus, coarse material settles out, forming a bar over the inner bank. As water levels rise during floods, the stream overflows its channel and spills over onto the floodplain.

Typically, alluvial deposits are characteristic of the decrease in energy during deposition. Where the stream overflows its bank, the energy is still relatively high; only deposits of coarse material occur, forming a levee. On the far side of a levee, moderate energy is available, and silty material settles.

On the floodplain, water velocity and its corresponding energy is low, and clay settles. Because bars form under moderate energy, this type of sorting does not occur on the plain. However, a floodplain may surround a bar. As the distance from the channel increases, the material's texture becomes finer, and the thickness of the deposit decreases.

Alluvial fans form where water in a channel, carrying sediments downhill, experiences an abrupt reduction in slope. The stream energy is reduced quickly, and material settles. This also occurs where a narrow valley opens onto a wide flat. Fans have a cone shape, widening in the downslope direction. Channels shift easily in fan deposits, and sediments are reworked over time. The texture of a fan becomes finer with distance from its apex. Normally fans in humid areas are not as steep and cover a much larger area than those in arid regions.

Marine and lacustrine deposits form in low-energy environments under inland seas and lakes. These sediments are typically coarse near the shore and finer toward the middle of the lake or sea. Several shoreline features can be associated with inland water bodies, including deltas, sand dunes, and beaches. Deltas are essentially alluvial fans with their sediments deposited underwater. As lakes dry, evaporite minerals form. Under other conditions, eolian sediments can fill in the lakebed. Such soils have a finer texture and occupy lower sections on the landscape.

Soils formed in shoreline deposits have a coarser texture and occupy higher landscape positions. In lakebeds with a very low influx of sediments, organic substances dominate the sediments, and peats form.

***Gravity***

Colluvium or hillslope sediments result from the force of gravity and runoff moving downslope. This material may be deposited in catastrophic events, such as mudslides, or by very slow but persistent processes, such as slope wash or surface creep. As viewed from the crest of a hilltop, sediments thicken, and the clay content increases on the downslope.

**Topography (relief)**

Topographic relief, or the slope and aspect of the land, has a strong influence on the distribution of soils on a landscape. Two aspects of topography that influences soil formation are the altitude and the slope. Position on a slope influences the soil depth through differences in accumulation of erosion debris. Slope affects the amount of precipitation that infiltrates into soil versus that which runs off the surface. Aspect, or the direction a slope is facing, affects soil temperature. In northern hemisphere sites, south-facing slopes are warmer than those facing north. Differences in moisture and temperature regimes create microclimates that result in differences in vegetation with aspect. Differences in weathering, erosion, leaching, and secondary mineral formation also can be associated with relief.

Increase in altitude leads to decrease in ambient temperature and consequently leading to decrease in soil temperature. An increase of 1000m in altitude leads to a decrease of about 6℃ in ambient temperature. This change in temperature creates a micro-climatic condition that differs from the immediate environment. This also creates some unique conditions for the formation of soils that differs from those of the immediate environment.

**Climate**

Climate arguably has the greatest effect on soil formation. It not only directly affects material translocation (leaching or erosion, for example) and transformation (weathering), but also indirectly influences the type and amount of vegetation supported by a soil. The two most important aspect of climate that has direct bearing on the process of soil formation are precipitation (total amount, intensity and distribution) and temperature (soil temperature). Precipitation is the main force in moving clay and organic matter from the surface to a depth within the profile. When a soil is at field capacity, the addition of more water will result in drainage either downward or laterally. Drainage water carries with it dissolved and suspended clay particles and soluble minerals that collect at a new location within the soil profile. As a result, soils often show an increase in clay with depth resulting in an accumulation of clay and some mineral elements at certain depth of the soil. While the total amount of precipitation affect the amount of dissolved substances passing through the profile, the intensity of precipitation (amount of rainfall per unit time) affects the erosive potentials of the rain. Erosion affects the process of soil formation by reducing the effective solum depth in the upper and middle slope of the toposequence while increasing the soil depth at lower slope and valley bottom. Differences in rainfall distribution pattern accounts for regional variation in soil characteristics. These variations lead to zonation of soil types.

Temperature affects the rate of biochemical and biophysical reactions taking place in the soil environment. As we know, the rate of reaction is directly proportional to the soil temperature. Most soil reactions are enzymatic reaction depending mainly on temperature. There are optima temperatures for the soil reactions above or below which these reactions will be negatively affected. The rate of chemical weathering as well as biological decomposition of plant and animal remains in the soil environment is determined by the amount of soil moisture and soil temperature. Diurnal and seasonal changes in temperature cause particles to expand and contract unevenly, breaking them apart. Heat and moisture are active agents of chemical weathering, the conversion of one mineral into another.

Climate affects the type and amount of vegetation in a region. A warm, humid climate produces the most vegetative growth; however, microbial decomposition is also rapid.

The net effect is that tropical and subtropical soils are generally low in organic content. In contrast, organic matter tends to be highest in a cool damp environment where decomposition is slow.

Temperature and the amount of water moving through a profile affect all of the following:

- the amount and characteristics of organic matter;
- the depth at which clay accumulates;
- the type of minerals present;
- soil pH (humid climates tend to produce more acidic soil than do arid climates);
- soil color;
- iron, aluminum, and phosphorus distributions within a soil profile; and
- the depth to calcium carbonate and/or salt accumulation.

**Biological activity**

Biological activity and climate are active forces in soil formation. Soil pedogenesis involves a variety of animals, plants, and microorganisms. Ants, earthworms, and burrowing animals, for example, mix more soil than do humans through plowing and construction. Plant roots remove mineral nutrients from subsoil and redeposit them at the surface in leaf litter. Growing roots open channels through soil where rainwater can wash clay and organic matter down along these channels. Soil microbes decompose plant and animal debris, releasing organic acids. This biochemical activity is the catalyst for a great deal of the oxidation/reduction and other chemical reactions in soil.

The distribution of organic matter in a forest soil is different from that of grassland. The surface soils of forests tend to have concentrated organic matter, which quickly decreases with depth. Grassland soils tend to accumulate organic matter to a greater depth than do forest soils. It is important for pedologist to note that the dark staining from the humic fraction of organic matter can persist in a buried soil. Thus, ancient buried surface soils may be recognized in the field by color alone.

The distribution of iron and aluminum throughout a profile also differs between forest and grass land soils. In forests, due to the greater rainfall, clays and organics drain downward, leaving behind resistant minerals. As a result, iron and aluminum in B horizons in forest soils are found in higher concentrations than in grassland soils.

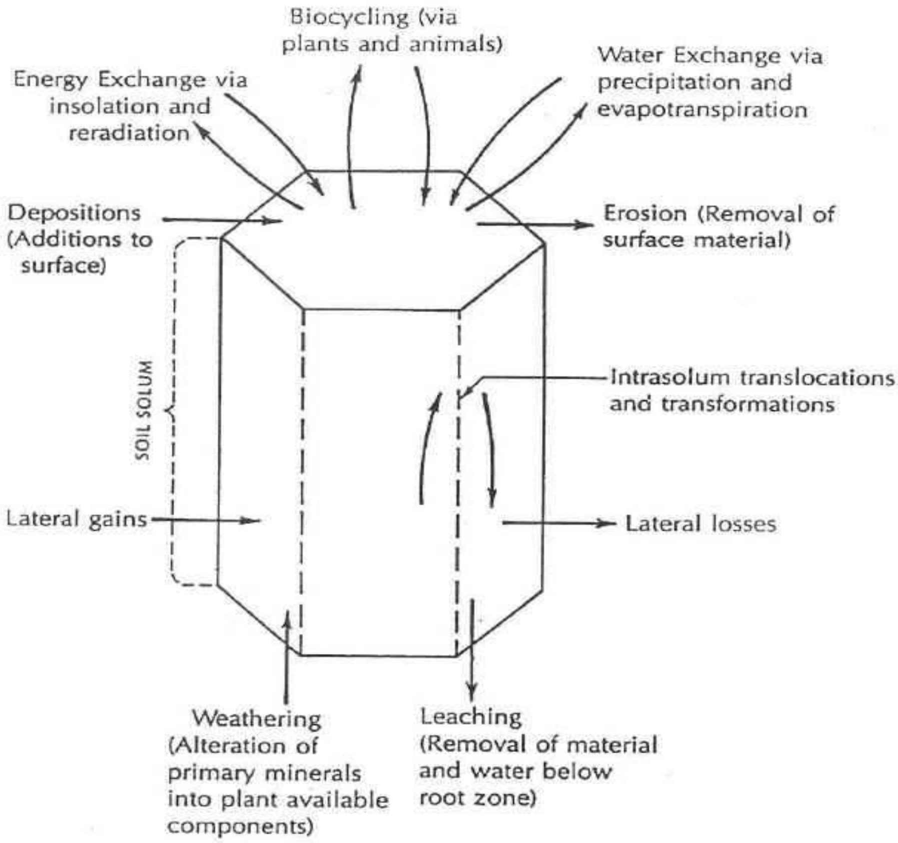
**Time**

Soils develop over time. Soil formation is a dynamic process, where a steady state is slowly approached but only rarely reached. The rate at which a soil forms is related more to the intensity of other soil forming factors than to chronological age.

**Soil Formation Processes**

Soil development begins with a parent material that has a surface layer altered by vegetation and weathering. For example, a young Coastal Plain soil has relatively uniform material throughout, and is altered only by a dark-stained surface layer that has been formed by vegetation. A more mature soil, on the other hand, shows evidence of the removal and transport of surface-layer clay to a subsurface layer called the B horizon. In an even older soil, chemical weathering and leaching have removed silicon, causing a change in the suite of clay minerals. A senile soil is excessively weathered and dominated by very resistant iron and aluminum oxide minerals. The rate that a young Coastal Plain soil becomes a senile soil depends not on its chronological age but on how rapidly minerals are transported and transformed within the profile.

Human activity frequently alters the process of pedogenesis. Once human activity ends, soil formation can continue as before if no radical change in the soil-forming factors occurred in the interim. Because fine material leaches selectively faster than coarse material, differences between human-altered and undisturbed soils in the ratio of fine to coarse clay may be apparent in a relatively short span of time (one hundred years in a humid environment).




Schematic representation of the solum of a pedon as an open system.

The processes of soil formation has been summarized into four major processes and represented schematically in the above figure. The four processes are Addition, Removal or subtraction, Transfer or Translocation and Transformation or Synthesis. These processes take place simultaneously but at different rates. Equilibrium is rarely attained because the processes are dynamic. The resulting soil reflects the most predominant of these processes. Thus a soil that suffers erosion loses or leaching losses may have low level of soluble elements like calcium, Magnesium, potassium and sodium. Continuous addition of plant or animal residue may on the other hand leads to accumulation of organic matter, creating a unique soil known for example as organic soil. There can be movement of materials in and out of the soil. Dissolved minerals and clay can be translocated from the top soil to the subsoil, while burrowing animals can remove soils from the subsoils to the top and vice versa. Weathering of minerals leads to the formation of new minerals. For example, the weathering of talc, may lead to the formation of smetite in areas with impeded or poor drainage. The transformation process will lead to the formation of new products.

History of Soil Science

## UNIT 2: BASIC PRINCIPLES OF SOIL SURVEY AND CLASSIFICATION

***Soil survey***

Soil survey is a branch of soil science which involves the identification of the different types of soil in a given landscape and the location of their distribution to scale on a map. In addition, soil survey provides information on the quality of the land in terms of their response to management and manipulation.

From this definition, it is clear that soil classification is a branch of soil survey and the unit of classification is the taxonomic unit or mapping unit or pedon. A taxonomic class depicts the properties of a soil profile as given in the profile description and analyses.

***Mapping Unit***

A mapping unit is a geographical unit and it is an area of land within which the greater proportion is occupied by the taxonomic class after which it is named. For example, if about 85% of the soil within a mapping unit is occupied by a soil whose property is that of Ibadan series, the soil will be named as Ibadan series.

**Principles of soil survey**

The principles of survey can be discussed under five points

***A soil survey must have an objective.*** The objective or aim of soil survey must be defined before the commencement of the survey. It may be wide ranging or it may be narrow and specific.

***A soil survey is not the only basis for decision on land use and management, it is only an aid***

Decisions on land management are usually influenced by economic considerations, social and institutional factors, often by existing legal land rights and sometimes by political constraints.

***Land resources do not consist of soils alone***

The potential of land to support crops depends on climate as much as on soils, and whenever soil-water relationship can be advantageously modified. Other land resources include vegetation, water resources, social and institutional factors.

***A soil map must show soils.*** The map produced by a survey is a soil map if mapping units are based specifically on soil profile. If on the other hand, it is primarily a map of land form units with soils being added to the legend, it is a geomorphological map.

***Soil map and report are complementary.*** The products of a soil survey include a soil map and survey report; neither is more important than the other because they are mutually indispensible.

**Type of Survey**

Soil survey can be classified using the following criteria

Purpose of survey

Regularity of observation

Based on scale of mapping

***Classification by purpose of survey***

Based on the purpose of survey, there are two types of survey. These are general purpose and special purpose survey.

**A general purpose soil survey** is one that is done mainly to add to the already existing inventory of soil information. This commonly found in the national survey of each country, e.g. the USDA, FMAWR. The information may not be needed at the time of survey but such a survey is done for record purpose.

**A special purpose soil survey** is done for specific purpose in mind, e.g. survey for irrigation or survey for citrus plantation.

**Based on regularity of observation**, three kinds of surveys have been distinguished: - free survey, rigid grid and flexible grid.

In **free survey**, there is no rigid pattern of observation. The surveyor uses the field features such as change in vegetation, topography, slope and even change in sound to movement to observe soil and to locate soil boundaries. And in most modern soil survey involving 5000 ha and above, this is usually the type of survey methodology adopted.

In **rigid grid survey**, examinations of the soil are done at regular and pre-determined interval. It is normally used when detailed information is required, e. g. mapping the soil of a research station or mapping for irrigation. Usually, the points of observation are at the intersection of the two regularly placed vertical and horizontal lines.

**Flexible grid survey method** is a compromise between the free and rigid grid methods of survey. In this system of survey, the number of observation is fixed but the location of the observation points are not pre-determined and can be fixed at will.

**Based on the scale of mapping**, there are seven kinds of surveys:- compilation, integrated survey, exploratory survey, reconnaissance survey, semi-detailed survey, detailed survey and intensive survey.

**Compilation:** These are soil maps produced by abstraction from other soil surveys. And where they exist they are filled by inferences. The scale is usually at 1: 100,000 or smaller. Many national soil maps of many countries are produced in this way.

**Integrated survey:** This is also known as land system survey. It is based on mapping the total physical environment and in fact land forms are mapping unit. Soils are an important but usually not a defining property of the mapping unit. The scale is 1: 250,000 or smaller.

**Exploratory survey:** Exploratory surveys are not survey proper. They are usually rapid road traverse made to provide modicum of information about the area that are otherwise unknown. Scale of exploratory survey varies from 1: 2,000,000 to 1,500,000.

**Reconnaissance survey:** These are mostly based on remote sensing especially Area Photo Imagery (API). They are the smallest scale of survey where the whole area is still covered. The scale is usually 1:250,000 although smaller scales have been used.

**Semi-Detailed survey:** In a semi-detailed survey, we have a combination of remote sensing and field work. Mapping units are usually soil association. Scale of mapping varies from 150,000 to 100, 000.

**Detailed survey:** Detailed surveys are executed through field examination with pre-determined numbers of observation points and or spacing. These kinds of surveys are usually employed for small area and for special purposes. Scale of observation varies between 1: 10,000 and 1: 25,000. Mapping unit are usually soil series.

**Intensive survey:** Intensive survey rigid grid approach, i.e. number of observation and spacing of observation are pre-determined. Mapping units are soil series and phase of soil series. Scale of mapping varies from 1: 1,000 to 1: 10,000 or even larger. They are usually experimental station surveys.

## Principles of classification

• Why do we classify?

**Why we classify**

- The purpose of any classification is so to organize our knowledge that the properties of objects may be remembered and their relationships may be understood most easily for a specific objective.
- Classification helps us deal with complexity. There are too many objects to consider individually. If we can find some common properties or behaviour between them, we can make meaningful classes.
- Classification also help to simplify our decision-making.
- Classification help us to exchange scientific findings internationally
- To provide a basis for research and experimentation
- To understand relationships among individuals of the population

The process involves formation of classes by **grouping the objects** on the **basis of their common properties**. The properties chosen as the basis for grouping are known as differentiating characteristics. The differentiating characteristics chosen for any classification must:-

a) be a property of the object to be classified
b) be important for the purpose of the classification
c) be associated with other characteristics (accessory or covarying characteristics) which are also important for the purpose of the classification

We classify **individual** objects, for example soil profiles, by grouping them into **classes**, for example soil series. These classes then form other objects that can in turn be classified into still more general classes, for example, reference soil groups. This is a **hierarchical** classification, and is common in soil science.

The characteristic used for classification of soils are those of the soil profiles and include the following:

1. Number of horizons in the profile
2. Colour of various horizons with special emphasis on the surface one or two
3. Texture of each horizon
4. Structure of the horizons
5. Relative arrangement of horizons
6. Thickness of horizons
7. Thickness of the true soil (profile)
8. Chemical composition of horizons
9. Character of the soil material [alluvial, loess, sand]
10. Geology of the soil material [parent material]

**Major ways of classifying soils**

There are various ways to organise a soil classification. A major distinction is between **natural** and **technical** approaches:

• **Natural** soil classifications group soils by some intrinsic property, behaviour, or genesis of the soils themselves, without reference to use. Examples of natural classification include grouping of soil by **ecologic region**, e.g. “prarie soils”, “boreal soils”, grouping by **presumed genesis**, i.e. the development pathway of the soil profile (These are called **genetic** soil classifications) and grouping by **similar properties.**

**Technical** soil classifications group soils by some properties or functions that relate directly to a proposed use or group of uses. Examples of technical classification includes:-

• Hydrologic response
• Suitability classes (FAO Framework for Land Evaluation)
• Land Use Capability (USDA LCC)
• Fertility Capability Classification (FCC)
• Engineering group

**Principles of classification**

1. Principle of **Purpose.** The reasons for wanting to organize soil knowledge.
2. Principle of **Domain.** The universe of objects relevant to the purpose.
3. Principle of **Identity**. The individual members of the domain are defined and named.
4. Principle of **Differentiation.** The protocol-guided hierarchical structure of a system with categories, and classes within categories.
5. Principle of **Prioritization.** The priority of knowledge by sequencing categories and sequencing classes within categories.
6. Principle of **Diagnostics**. The quantification and use of soil properties, sets of properties, and selected features (diagnostics) that provide objectivity.
7. Principle of **Membership.** Class membership for individuals based on quantified class limits and described central tendencies.
8. Principle of **Certainty.** The recognition that change is inevitable and the driving force continual testing of a system.

## UNIT 3: SOIL SURVEY INFORMATION AND LAND USE PLANNING

One of the motives behind soil survey was the recognition that the productive capacity of the land, as measured by the crop yield varies.

***Land*** comprises the physical environment, including climate, relief, soils, hydrology and vegetation, to the extent that these influence potential for land use. It includes the results of past and present human activities.

***Planning*** is the process of allocating resources, including time, capital, and labor, in the face of limited resources, in the short, medium or long term, in order to produce maximum *benefits* to a defined group. Although individuals plan for the future, by 'planning' in the context of land evaluation we understand some form of collective activity, where the overall good of a group or society is considered.

***Land use planning*** is the process of allocating uses to land areas, and resources to those uses.

The function of land use planning is to guide decisions on land use in such a way that the resources of the environment are put to the most beneficial use for man, whiles at the same time conserving those resources for the future. This planning must be based on an understanding both of the natural environment and of the kinds of land use envisaged. Land evaluation is concerned with the assessment of land performance when used for specified purposes. It involves the execution and interpretation of basic surveys of climate, soils, vegetation and other aspects of land in terms of the requirements of alternative forms of land use. To be of value in planning, the range of land uses considered has to be limited to those which are relevant within the physical, economic and social context of the area considered, and the comparisons must incorporate economic considerations.

## UNIT 4: SOIL COLLOIDS AND SOIL REACTION

- Next to photosynthesis and respiration, no process in nature is more vital to plant and animal life than the exchange of ions between soil particles and plant roots.
- These cation and anion exchanges occur mostly on the surfaces of the finer or colloidal fractions of both the inorganic and organic matter (clay and humans).
- Colloids are substances whose particle size is about 1 to 1000nm when they are mixed with another substance, usually air or water.
- Colloids are action sites for chemical reaction, microscopic, large surface area. The larger the surface area, the better they are for chemical reaction.
- Molecules of some compounds can come within the colloidal range but most colloids consist of aggregate of molecules. Colloids are so ubiquitous in nature and so distinctive that they have common names as fog, smoke, aerosol, foam, emulsion, soil and clay. All are small particles suspended in a fluid. as

### General properties of soil colloids

- **Size**
- **Surface area**
- **Surface charges**
- **Adsorption of cations and water**

### Types of soil colloids

There are four major types of colloids present in soil

1) Layer silicate clays

2) Iron and Aluminum oxide clays

3) Allophane and associated clays

4) Humus

(Generally 1, 2, 3 are inorganic while 4 is organic colloids)

**Sources of charges on soil colloids**

There are two major sources of charges on soil colloids:

1) Hydroxyls and other such functional groups on the surfaces of the colloidal particles that by releasing or accepting $H^+$ ions can provide either negative or positive charges.

2) The charge imbalance brought about by the isomorphous substitution in some clay structures of one cation by another of similar size but differing in charge.

**Permanent charges**

- **Negative charges**

A net negative charge is found in minerals where there has been an isomorphous substitution of a lower charged ion (e.g. $Mg^{2+}$ for a higher-charged ion (e.g. $Al^{3+}$).

- **Positive charges**

Isomorphous substitution can also be a source of positive charges if the substituting cation has a higher charge than the ion for which it substitutes.

**pH- dependent charges**

- **Negative charges**

The pH-dependent charges are associated primarily with hydroxyl (OH) groups on the edges and surfaces of the inorganic and organic colloids. The OH groups are attached to iron and/or Al in the inorganic colloids (e.g. Al-OH) and to the carbon in CO groups in humus (e.g. –CO-OH). Under moderately acid conditions, there is little or no charge on these particles, but as the pH increases, the hydrogen dissociates from the colloid OH group, and negative charge result.

**Positive charges**

Under moderate to extreme acid soil conditions, some silicate clays and Fe, Al oxides may exhibit net positive charges. The exposed OH groups are involved. In this case, however, as the soils becomes more acid, (protonation), the attachment of $H^+$ ion to the surface OH groups takes place.

**SILICATE MINERAL CHEMISTRY**

The silicate minerals are responsible for the important, physical and chemical properties of most soils. Silicate minerals characteristically contain Si, $O_2$ and Al.

**Silicon**

It makes up of 27.6% of the Earth crust, second to $O_2$. Si compound make up of the framework for most soils except tropical soils. It is amphoteric and usually slightly acidic, forming weak acid.

**Definition of clays**

Clays are the active mineral portion of soils dominantly colloidal and crystalline. The crystalline nature of clays is such that they have definite repeating arrangement of atoms which they are composed of. Majority are made of planes of $O_2$ atoms with Si and Al atoms holding the $O_2$ together by ionic bonding.

**Classification of clays**

Clays are usually given group names based on their structure or on purely chemical composition. There are 3 groups.

1) **Silicate clays: -** These are crystalline clays e.g. Montmorillonite, illite, vermiculite, kaolinite, chlorite. Each crystalline clay is like a particular deck of cards. Each card represent a layer each of which is an exact replication of each other layer.

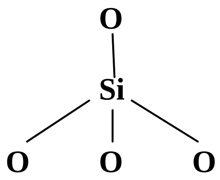
2) **Amorphous clays:-** These are non-crystalline, which have silica, they are mixtures of Si and Al that have not formed well oriented crystals but sometimes have high cation or anion exchangeable capacity.

3) **Sesquioxides:-** These consists of groups of Fe, Al and Ti oxides clays. They are present in condition where there is excessive leaching caused by rainfall and sometimes intensive weathering of minerals in humid warm climate. They can be crystalline or armorphous.

**Structures of layer silicate clay**

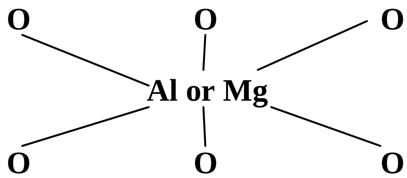
This implies the basic building blocks of clays. All soil clays are formed from the same 2 basic structural units. It is the way these 2 basic building units are put together that gives the soil clay distinctly different properties. They are:

1) **Silica tetrahedron:-** This is a silica dominated sheet is a unit composed of one silicon atom surrounded by four oxygen atoms.



$SiO_4$

2) **Aluminum and/or Mg octahedron:-** In this unit, an Al or Mg is surrounded by 6 oxygen atoms or hydroxyl groups, the center of which define the apices of an 8-sided solid. .



$Al_2O_6$ or $Mg_3O_6$

**MINERALOGICAL ORGANIZATION OF SILICATE CLAYS**

On the basis of the number and arrangement of tetrahedral (silica) and octahedral (Al-Mg) sheets contained in the crystal units or layers, silicate clays are classified into two different groups, 1:1 – type minerals and 2:1 – type minerals.

**1:1 type minerals**

The layer of the 1:1 type minerals are made up of one tetrahedral (silica) sheet and one octahedral (alumina) sheet hence the terminology 1:1 type crystal. Kaolinite is the most prominent member of this group, others are halloysite, nacrite and dickite.

**Characteristics of kaolinite**

1) It has strong H-bonding
2) It does not allow water to penetrate between the layers and have almost no swelling
3) It has low cation exchangeable capacity.
4) Kaolinite exhibits less plasticity (capacity to be molded), stickiness, cohesion, shrinkage or swelling.

5) Kaolinite containing soils make good bases for road beds and building foundations.

**2:1 type minerals**

The crystal unit (layers) of these minerals are characterised by an octahedral sheet sandwiched between two tetrahedral sheets. Four general groups have this basic crystal structure. Two of them, smectite and vermiculite (expanding – type) and the other two fine-grained (illite) and chlorite (non expending).

**Expanding minerals**

- **The smectite group**

**Characteristics of smectites**

1) High plasticity and cohesion
2) Their marked swelling when wet and shrinkage on drying
3) Has high CEC
4) Permeability to water is low.

- **Vermiculites**, these are also 2:1 type minerals, an octahedral sheet being found between two tetrahedral sheets. In most soil verticulites, the octahedral sheet is aluminum dominated (dioctahedral), although Mg-dominated (trioctahedral) vermiculites are also found.

- **Non-expanding minerals**

  Micas and chlorites are the types of minerals in this group.

- **Muscorite and biotite** are examples of unweathered micas often found in sand and silt separates.

- **Soil chlorites** are basically Fe-Mg silicates with some Al present.

**Soil Reaction (Acidity, Alkalinity)**

The degree of acidity or alkalinity is an important variable that affects all soil properties (chemical, physical and biological).

- Soil acidity is then total amount of acid present in the soil. The soil reaction is expressed as the soil pH, this is the measure of the relative acidity and alkalinity of the soil
- **Active** acidity is that measured by the soil pH while the
- **Reserve** acidity is that left within the soil microcell, it is usually measured by titrating the soil solution with a base.

**Causes of soil acidity:-**

1) Leaching loss of bases like Ca, Mg, etc.
2) Application of acid-forming fertilizers e.g. urea, $NH^{4+}$ based fertilizers
3) Acid rain
4) Decomposition of organic matter, $CO_2$ is evolved, it mixed with soil water to form weak carbonic acid ($H_2CO_3$)
5) Hydrolysis of Al. $Al^{3+} + 3H_2O \quad Al(OH)_3 + 3H^+$

**Importance of soil pH in crop production**

1) It is useful in determining the availability of plant nutrients e.g. P is fixed by Al and Fe oxides at low pH, at high pH it is fixed by Ca. Therefore, P is available maximally at near neutral pH.
2) pH influences the availability in toxic amounts minerals and elements that may reduce crop growth (At low pH, Fe and Mn are present in toxic amount in soil).

3) It influences the population and activities of beneficial microbe.

**Lime requirement ((LR)**

Lime requirement is the amount of liming material required to bring about a desired pH change. (i.e., amount of lime required to raise a soil from one pH to a desired pH value). LR is determined by (1) the change in pH required (2) the buffer capacity of the soil (3) chemical composition of the liming material (4) finess of the liming materials.

**Methods of determining lime requirements**

1) Field plot techniques (apply rates, plant and monitor for best yield and best rat performance
2) Titration with a base (soil solution with a base)
3) Incubation studies (8 weeks with different rates of lime test for best pH
4) Use of buffer like woodruff buffer, Adams and Evans, etc.

## UNIT 5: ESSENTIAL NUTRIENTS IN PLANT NUTRITION

There are 17 nutrient elements that are essential and are classified into 4 categories

i) Structural components of the plants viz **C, H, O**.

ii) Major nutrient elements also known as primary nutrients viz **N, P, K**

iii) Secondary nutrient elements viz **Ca, Mg, S** (S can be a major nutrient in some ecology as savanna e.g. 20-10-10, 5 S - 2 Zn

This underlines the complexity in sulphur

- $(NH_4)_2SO_4$, Bordeaux mixture ($CuSO_4$), SSP (21% P, 9 % S)

iv) Micronutrients these are important but needed in small quantity they act as enzyme system and cofactors viz **Fe, Mn, Cu, B, Zn, Mo, Cl, Co**

v) Others, they have been established to be very useful to plants e.g. **sodium (Na)** important to tomato

**NUTRIENT ABSORPTION BY PLANT ROOTS**

- Root interception,
- Mass flow,
- Diffusion process,

## UNIT 6: SOIL ORGANIC MATTER

### INTRODUCTION

Soil organic matter is the organic component of the soil and it includes all parts of living and dead plants and animals, micro-and macro-organisms and products of decaying processes that occur in the soil. The dark colouration of certain soils is attributed to the presence of organic matter because dark coloured colloidal humus compounds are able to coat mineral particles of soil; hence the darker the soil, the more organic matter it is likely to contain. In addition to clay minerals in the soil, organic matter is a major source of plant nutrient elements. The greatest amount of organic matter in the soil resides in the top soil. The organic matter of most soils ranges between 1-5% mostly in the top 25cm of soil, and the concentration reduces with depth except, relatively in cases in which deep ploughing is being used to incorporate organic materials into the soil.

**Definition:** Soil organic matter (SOM) could be defined as any material produced originally by living organisms (plant or animal) that is returned to the soil and goes through the decomposition process.

### Composition of Soil Organic Matter

About 75% of green tissue is made up of water while 90% of the remaining dry matter is made up of carbon, oxygen and hydrogen. Nitrogen and other mineral elements constitute the remainder of organic matter. The major source of soil organic matter (plant tissue) is made of very complex substances such as carbohydrates (Sugar, starch, hemicellulose, cellulose, pectiles, muscilages) lignins, proteins (soluble proteins and crude proteins), fats (oil), waxes, tannin, resins, pigments and organo-mineral compounds. The largest percentage of soil organic matter is made of lignins and proteins. Lignin builds up as the plant ages and it is resistant to decomposition.

**Sources of Soil Organic Matter**

There are two main sources of organic matter in soils and these include:

(i) Plant sources: These are the most prevalent and they include dead and decayed plant roots, leaf droppings, crop residues, green manures and dead and decayed "above ground" parts of plants.

(ii) Animal sources: These form the next most important source of soil organic matter. They include all residues of animals and micro-organisms, domestic wastes, animal faeces, animal feeds, and animal manures.

**Classification of soil organic matter**

For practical purposes, organic matter may be classified into (a) aboveground and (b) belowground fractions.

(a) Aboveground organic matter comprises plant residues and animal residues; Organic matter existing on the soil surface as raw plant residues helps protect the soil from the effect of rainfall, wind and sun. Removal, incorporation or burning of residues exposes the soil to negative climatic impacts, and removal or burning deprives the soil organisms of their primary energy source.

(b) Belowground organic matter consists of living soil fauna and microflora, partially decomposed plant and animal residues, and humic substances. Organic matter within the soil serves several functions. From a practical agricultural standpoint, it is important for two main reasons: (i) as a "revolving nutrient fund"; and (ii) as an agent to improve soil structure, maintain tilth and minimize erosion.

**Importance of Soil Organic Matter**

Organic matter is so important to the soil that it has been described as the life blood of the soil. Its importance is enumerated as follows:

1) It is a storehouse of plant nutrients.

2) The stable organic fraction (humus) adsorbs and holds nutrients in a plant available form. Hence, it contributes to the cation exchange capacity of the soil.

3) It improves soil physical conditions.

4) It provides medium for microbial growth and activities.

5) Humus adds substantially to the buffering capacity of soils making it less amenable to pH changes by bases or acids.

6) Organic acids released during decomposition of the soil organic matter aid in the process of rock mineral weathering.

**Decomposition of Soil Organic Matter**

When plant residues are returned to the soil, various organic compounds undergo decomposition.

**Decomposition** is a biological process that includes the physical breakdown and biochemical transformation of complex organic molecules of dead material into simpler organic and inorganic molecules ones by the activities of microorganisms such as bacteria, fungi, actinomycetes, algae, and protozoa.

In the decomposition process, different products are released which include carbon dioxide (CO2), energy, water, plant nutrients and re-synthesized organic carbon compounds. Successive decomposition of dead material and modified organic matter results in the formation of a more complex organic matter called humus. This process is called humification. Humus is a by-product of organic matter decomposition. It is resistant to further decomposition and is the source of nutrient storage capacity. In the formation of soil humus, there is a rapid decomposition of the water soluble constituents: sugars, organic acids, amino acids, lipids, and nucleotides. SOM is frequently said to consist of **humic substances** and **nonhumic substances**.

**Humic substances** are series of relatively high-molecular-weight, brown to black colored substances formed by secondary synthesis reactions. It comprises of humic acid, fluvic acid and humins.

**Nonhumic substances** are compounds belonging to known classes of biochemistry, such as carbohydrates, lipids and amino acids.

Decomposition of organic matter is largely a biological process that occurs naturally. The rate at which the organic matter decomposes in the soil is determined by some major factors.

**Factors Affecting the Rate of Organic Matter Decomposition**

i) The quality of organic material such as the type of plant material, age of the plant and the chemical composition

ii) The physical environment which could be categorized into two:

a) Soil factors such as aeration, temperature, moisture, pH, and fertility status

b) Climatic factors such as rainfall and temperature

iii) Population of soil microorganisms such as bacteria, fungi, actinomycetes and protozoa

**Mineralization of Organic Matter**

This is the process involved in the release of plant nutrients from organic matter. Most of the soil nitrogen, phosphorus and sulphur are present in the organic forms which are only converted to the mineral forms, utilizable by plants, through the mineralization process.

Mineralization of organic matter to release mineral nutrients is a two step process, namely:

- **i.** **Aminization** which is the decomposition of organic matter by heterotrophic bacteria to release amino acids and amides.
- **ii.** **Amonification** which is the release of ammonium ion from amino acids and amides. Amino acids + amides heterotrophic bacteria $NH_4^+$

The ammonium ion ($NH_4^+$) further undergoes Aminoacid amides heterotrophic bacteria oxidation process as a result of participation of special purpose bacteria in another two-step process called **nitrification.**

### Maintenance of Soil Organic Matter

The maintenance of the organic matter in soils used for agricultural production is an important practice. Where the rate of addition is less than the rate of decomposition, soil organic matter declines. Conversely, where the rate of addition is higher than the rate of decomposition, soil organic matter increases. The term 'steady state' describes a condition where the rate of addition is equal to the rate of decomposition. For adequate maintenance of soil organic matter, the rate of addition must be equal to the rate of decomposition i.e. a steady state condition must be maintained. The practices involved in the maintenance of soil organic matter include:

i) Addition of new organic materials: This is an essential part of good soil management practice. It involves the addition of bulky manures, such as farmyard green manures, compost and processed animal wastes at least once a year depending on the intensity of cultivation.

ii) Sound cropping system that reduces the intensity of cultivations and keeps the soil protected e.g. cover cropping and good crop rotation.

iii) Green manuring: This is the practice of enriching the soil by turning under soil green tender plants, usually legumes grown on the field or brought from outside.

iv) Management of crop residues: Crop residues provide varying amounts of organic carbon when incorporated into the soil or used as mulch.

## UNIT 7: TYPES AND ACTIVITIES OF SOIL ORGANISMS

### INTRODUCTION

All the organisms living within the soil are collectively termed **soil life** or **soil biota. Soil organism** is any organism inhabiting the soil during part or all of its life. Soil organisms range in size from microscopic cells that digest decaying organic material to small mammals that live primarily on other soil organisms. They play an important role in maintaining fertility, structure, drainage, and aeration of soil. They also break down plant and animal tissues, releasing stored nutrients and converting them into forms usable by plants. They are the life force of soil. More living organisms occur in soil than in all other ecosystems combined. The living portion of soil is a diverse and dynamic collection of organisms, from types that you can easily see with an unaided eye down to creatures that you can observe only by using a high-powered microscope.

**Classification of Soil Organisms**

The soil organisms are classified into two broad groups, these include:

1. Soil flora – subdivided into:

(a) microflora size range 1-100 micrometres, e.g. bacteria, actinomycetes, fungi and algae

(b) macroflora: size range 20 mm upwards, e.g. roots of higher plants

2. Soil fauna – subdivided into:

(a) Megafauna: size range 20 mm upwards, e.g. moles, rabbits, and rodents.

(b) Macrofauna: size range 2–20 mm, e.g. woodlice, earthworm, beetles, centipedes, slugs, snails and ants.

(c) Mesofauna: size range 100 micrometer - 2 mm, e.g. tardigrades, mites and springtails.

(d) Microfauna: size range 1-100 micrometres, e.g. protozoa, nematodes and rotifers.

**Bacteria**

Bacteria are single-celled microbes that are so abundant that a square inch of soil contains millions of these microorganisms. Bacteria primarily act as decomposing agents and usually break down organic material in its initial stage of decomposition due to high moisture levels conducive for their growth. Other nitrogen- fixing bacteria help in converting nitrogen gas into simpler forms that can be consumed by plants.

Some common soil bacterial are the species of Pseudomonas, Arthrobacter, Achromobacter, Bacillus, Clostridium, Micrococcus, Flavobacterium, Chromobacterium and Mycobacterium. Chemosynthetic autotrophic bacteria present in the soil are the species of Thiobacillus, Ferrobacillus, Nitrosomonas and Nitrobacter.

**Fungi**

Fungi are microscopic cells made up of spores, hyphae and gills. They are aerobic and largely distributed in forests. These organisms benefit the soil as they function as decomposers and also act as soil binders, making the earth's water retention more efficient. Aside from its ability to break down complex dead organisms, fungi also thrive by having a mutual relationship with plants.

Some important soil inhabiting microfungi are the species of Aspergillus, Botrytis, Cephalosporium, Penicillium, Alternaria, Monilia, Fusarium, Verticillium, Mucor, Rhizopus, Pythium, Cunninghamella, Chaetomium and Rhizoctonica. Some microfungi, such as species of Alternaria, Aspergillus, Cladosporium and Dematium, are helpful, are helpful in the preservation of organic materials in the soil.

**Actinomycetes**.

A large number of actinomycetes are particularly abundant in the soil rich in decomposed organic materials; species .of Streptomyces, Micromonospora and Nocardia are some common actinomycetes occurring in soils. They are responsible for the characteristic musty or earthy smell of a freshly ploughed field. They are capable of degrading many complex chemical substances and thus play an important role.

**Algae**.

Many microalgal forms occur on the surface of moist soils, where sufficient light is available. The growth of microalgae is helpful for soil conservation and in improving soil structure. In paddy fields, blue-green algae play a significant role in nitrogen fixation.

Species of Chlorella, Chlorococcum, Protosiphon, Aphanocapsa, Anabaena, Chroococcus, Nostoc and Scytonema are some common microalgae present in the soil

**Protozoa**

Protozoans are single-organisms slightly larger than microbes that are organized into three general categories: cilliates, amoebas and flagellates. The protozoans main diet consists of both dead and living bacteria thus controlling its rapid increase in population. Like the bacteria, it also releases excess nitrogen only this time in the form of ammonia. Protozoans are helpful in maintaining equilibrium of the microbial flora in the soil. Some important protozoans present in the soil are species of Allantion, Biomyxa, Nuclearia, Trinema, Balantiophorus,Colpoda, Gastrostyla, Oxytricha, Pleurotricha and Vorticella.

**Nematodes**

Nematodes are a group of tiny roundworms that demonstrate the wide diversity and the inextricable food web that exists in a healthy soil. Most soil nematodes eat bacteria, fungi, protozoa, and other nematodes, making them important in nutrient cycling. Others are plant parasites and cause disease symptoms such as malformed or dwarfed plants, or root structures with deformities such as galls and cysts. The root knot nematode, for instance, stimulates parasitized plants to form root galls. The galls choke off the flow of water and nutrients to the above-ground portion of the plant. Plants infected by root gall nematodes may live through the season but crop yields will be dramatically reduced.

The following shows the approximate numbers of organisms (per gram) commonly found in the microbiota:-

| Organism | Estimated number/gram |
|---|---|
| Bacteria | 3 000 000 - 500 000 000 |
| Actinomycetes | 1 000 000 - 20 000 000 |
| Fungi | 5 000 - 900 000 |
| Algae | 1 000 - 500 000 |
| Protozoa | 1 000 - 500 000 |

**Activities of Soil Organisms**

Healthy soil is a jungle of rapacious organisms devouring everything in sight (including each other), processing their prey or food through their innards, and then excreting it. The activities of these organisms have been categorized into two, namely, beneficial and detrimental activities.

**A) Beneficial Activities**

1. Nutrient cycling.
2. Enhancing soil structure, which improves water and air movement.
3. Controlling disease and enhancing plant growth.

**1. Nutrient cycling**

Soil organisms continually transform nutrients among many organic and inorganic forms. (Organic compounds contain carbon. Inorganic compounds do not.) Plants primarily need simple inorganic forms of each nutrient. Soil organisms create many of these plant-available nutrients and help store nutrients in the soil as organic compounds. Cycling of nutrients involves the following transformation processes:

- **decomposition**: turning organic compounds into other organic compounds
- **mineralization**: turning organic matter into inorganic compounds that may be used by plants
- **immobilization**: turning inorganic compounds into organic compounds. Farmers depend on bacteria for one more transformation:
- **mineral transformation**: turning inorganic matter into other inorganic compounds

**Bacteria Involved in Mineral Transformations**

Bacteria that perform mineral transformations are important in nitrogen cycling and these include the following:

i) Nitrogen fixing bacteria: The roots of legumes host nitrogen-fixing bacteria that convert large amounts of dinitrogen ($N_2$) from the atmosphere into forms that plants can use. Some nitrogen-fixing bacteria live free in the soil.

ii) *Nitrifying bacteria* convert ammonia ($NH_3$) into nitrate ($NO_3^-$).

iii) *Denitrifying* bacteria convert nitrate into gases that are lost into the atmosphere. These species are anaerobic so denitrification occurs only in places in the soil where there is little or no oxygen.

Other soil bacteria are important for similar mineral transformations of sulfur, iron, and manganese.

## 2. Forming soil structure

Most crops grow best in crumbly soil that roots can easily grow through and that allows in water and air. Soil organisms play an important role in the formation of a good soil structure.

As the soil heats up, fungi grow long filaments called hyphae that surround soil particles and hold them together in soil aggregates. Some bacteria produce sticky substances that also help bind soil together.

Many soil aggregates between the diameters of 1/1000 and 1/10 of an inch (the size of the period at the end of this sentence) are fecal pellets. Arthropods and earthworms consume soil, digest the bacteria, and excrete a clump of soil coated with secretions from the gut. As beetles and earthworms chew and bury plant residue and burrow through the soil, they aerate the soil and create nutrient-lined channels for roots and water to move through.

**3. Controlling disease and enhancing growth**

Soil organisms have many methods for controlling disease-causing organisms. Protozoa, nematodes, insects, and other predatory organisms help control the population levels of their prey and prevent any single species from becoming dominant. Some bacteria and fungi generate compounds that are toxic to other organisms. Some organisms compete with harmful organisms for food or a location on a root.

In addition to protecting plants from disease, some organisms produce compounds that actually enhance the growth of plants. Plant roots may excrete compounds that attract such beneficial organisms.

**B) Detrimental Activities**

1. Some cause plant diseases e.g. fusarium wilt caused by fungus attack.
2. Some cause root damage e.g. root knot nematode.
3. Some cause tuber destruction e.g. yam beetles in the soil.

**Factors Affecting Distribution, Activity and Population of Soil Microorganisms**

Soil microorganisms (Flora & Fauna), just like higher plants depends entirely on soil for their nutrition, growth and activity. The major soil factors which influence the microbial population, distribution and their activity in the soil are

1. Soil fertility

2. Cultural practices

3. Soil moisture

4.Soil temperature
5. Soil aeration

6. Light

7. Soil PH (H-ion Concentration)

8. Organic matter

9. Food and energy supply

10. Nature of soil and

11. Microbial associations.

All these factors play a great role in determining not only the number and type of organism but also their activities. Variations in any one or more of these factors may lead to the changes in the activity of the organisms which ultimately affect the soil fertility level. Brief account of all these factors influencing soil organisms and their activities are given as follows:

## UNIT 8: ORGANIC AND INORGANIC FERTILIZERS

### What is a fertilizer?

A fertilizer is any material, organic or inorganic, natural or synthetic, which supplies plants with one or more of the nutrient elements required for normal growth and development. Fertilizers are of two types namely organic and inorganic. The primary nutrients supplied by fertilizers are nitrogen, phosphorus and potassium. Their concentration in a fertilizer is expressed as percentage of N, $P_2O_5$ and $K_2O$.

**Inorganic (or mineral) fertilizers** are fertilizers mined from mineral deposits with little processing (e.g., lime, potash, or phosphate rock), or industrially manufactured through chemical processes (e.g., urea). Inorganic fertilizers vary in appearance depending on the process of manufacture. The particles can be of many different sizes and shapes (crystals, pellets, granules, or dust). Inorganic fertilizer could be classified into three based on the nutrient composition as follows:

1. **Straight fertilizers**: These are fertilizers which contain and supply one or single nutrient element only. They could be nitrogenous, phosphatic or potassic fertilizers supplying nitrogen, phosphorus or potassium, respectively.

a) Nitrogenous fertilizers: Nitrogen is the first fertilizer element of the macronutrients usually applied in commercial fertilizers. Nitrogen is very important nutrient for plants and it seems to have the quickest and most pronounced effect. In the case of nitrogenous fertilizers, nitrogen may be in the ammoniacal, nitrate (or a combination thereof) or amide form.

**Nitrogenous fertilizer - Source of Nitrogen**

| **Name of fertilizers** | **Percentage of Nitrogen** |
|---|---|
| Ammonium Sulphate | 20.6-21.0 |
| Urea | 44.0-46.0 |
| Ammonium Chloride | 25+ |
| Ammonium Nitrate | 32-35 |
| Ammonium Sulphate Nitrate | 2.6 |
| Calcium Ammonium Nitrate (CAN) | 25.0 |
| Sodium Nitrate | 16.0 |
| Calcium Nitrate | 15.6-21.6 |
| Potassium Nitrate | 13.0 |
| Calcium cynamide | 212.0 |

b) Phosphatic fertilizers: Phosphorus is the second fertilizer element and it is an essential constituent of every living cell and for the nutrition of plant and animal. It takes active part in all types of metabolism of plant. Phosphate present in phosphatic fertilizers may be in the water soluble form or citrate soluble form. That portion of phosphate which is soluble in water is called water soluble phosphate and that which is not soluble in water but in 2 per cent neutral ammonium citrate solution is called citrate soluble phosphate. The sum of water soluble and citrate soluble values is termed as available phosphates.

**Phosphatic fertilizer – Source of phosphorous**

| **Name of fertilizers** | **Percentage of $P_2O_5$** |
|---|---|
| Single Superphosphate | 16.1-20+.0 |
| Double Superphosphate | 30.1-35.0 |
| Triple Superphosphate | 45.0-50.0 |
| Basic Slage (India) | 3.0-8.0 |
| Dicalcium Phosphate | 35.0-40.0 |
| Rock Phosphate | 20.0-25.0 |

c) Potassic fertilizers: Potassium is the third fertilizer element. Potassium acts as a chemical traffic policeman, root booster, stalk strengthener, food former, sugar and starch transporter, protein builder, breathing regulator, water stretcher and as a disease retarder but it is not effective without its co-nutrients such as nitrogen and phosphorus.

**Potassic fertilizer – Source of potassium**

| **Name of fertilizers** | **Percentage of $K_20$** |
|---|---|
| Murate of potash | 50.0-60.0 |
| Potassium sulphate | 48.0-52.0 |

2. **Complex/Compound fertilizers**: These are fertilizers which contain two or more nutrient elements usually combined in a homogeneous mixture by chemical interaction. Complex NPK fertilizers have the advantage of having each nutrient in each granule. Examples of complex fertilizer are listed in the following table.

**Complex fertilizers**

| **Material** | **Total Nitrogen (N)** | **Neutral ammonium citrate soluble phosphate ($P_2O_5$)** | **Water soluble phosphate ($P_2O_5$)** | **Water soluble potash ($K_2O$)** |
|---|---|---|---|---|
| **Ammonium Phosphate** | | | | |
| 11-52-0 | 11.0 | 52.0 | 44.2 | |
| 18-46-0 | 18.0 | 46.0 | 41.0 | |
| **Ammonium Phosphate Sulphate** | | | | |
| 16-20-0 | 16.0 | 20.0 | 19.5 | |
| 20-20-0 | 20.0 | 20.0 | 17.0 | |
| 18-9-0 | 18.0 | 9.0 | 8.5 | |
| **Ammonium Phosphate Sulphate Nitrate** | | | | |
| 20-20-0 | 20.0 | 20.0 | 17.0 | |
| **Nitrophosphate** | | | | |
| 20-20-0 | 20.0 | 23.0 | 12.0 | |
| 23-23-0 | 23.0 | 23.0 | 18.5 | |
| **Ammonium Nitrate Phosphate** | | | | |
| 23-23-0 | 23.0 | 23.0 | 20.5 | |
| **Urea Ammonium Phosphate** | | | | |
| 28-28-0 | 28.0 | 28.0 | 25.2 | |
| 24-24-0 | 24.0 | 24.0 | 20.4 | |
| 20-20-0 | 20.0 | 20.0 | 17.0 | |
| **Potassium Nitrate (cystalline/prilled)** | | | | |
| 13-0-45 | 13.0 | | | 45.0 |
| **Mono Potassium Phosphate** | | | | |
| 0-52-34 | | | 52.0 | 34.0 |

3. **Fertilizer blends or mixed fertilizers:** These are fertilizers formed by physically blending mineral fertilizers to obtain desired nutrient ratios. Two or more of the separate

fertilizer carriers or straight fertilizers are mixed to obtain the desired nutrient ratios. Examples are NPK 15-15-15, NPK 20-10-10 etc.

**Common Terms used in Fertilizer**

**1. Fertilizer Grade:** This is the numbering system of a particular element in the mixture or the compound. It is usually written in real figures for mixed or compound fertilizers. It is often expressed in a set of three numbers e.g. 15-15-15 indicating manufacturer's guarantee of the percentage of N, $P_2O_5$ and $K_2O$. When an element is missing. it is represented as zero.

**2. Fertilizer Ratio:** This is the relative proportion or ratio of two or more nutrient elements in fertilizer grade e.g. NPK 10-10-10 has a ratio of 1:1:1. This ratio is obtained by dividing the fertilizer grade figures by a factor that produces the smallest possible whole numbers.

| Grade | Ratio |
|---|---|
| 5-10-10 | 1-2-2 |
| 3-9-9 | 1-3-3 |
| 4-8-12 | 1-2-3 |

**3. Fertilizer Material or Carrier**: This is a material which contains at least one plant nutrient.

**4. Filler:** This is a material added to a mixed fertilizer to make up weight requirements in a ton (1000 kg). Examples are sand, soil, coal powder, ground lime etc. Example: ton of 0-8-8

| | |
|---|---|
| add 0-20-0 superphosphate | 400 kg |
| add 0-0-60 muriate of potash | 133.5 kg |

| | |
|---|---|
| filler | 466.5 kg |
| total | 1000 kg or 1 ton |

**Advantages and Disadvantages of Inorganic Fertilizers**

| Advantages | Disadvantages |
|---|---|
| • Works immediately | • Leaching occurs beyond plant's rooting zone |
| • Contains all necessary nutrients that are ready for use | • Too much may burn and kill plants |
| • Affordable | • Some are not affordable |
| • Convenient to use, it is easy to apply | • Accumulation of toxic wastes |

**Major limitations of Inorganic Fertilizers**

1. As inorganic fertilizers are both powerful and take effect too quickly, they can burn and totally destroy plants when applied excessively.

2. Excessive use of inorganic fertilizers can also kill earthworms and microorganisms in the soil that help in the plants' growth.3. The nitrates contained in some inorganic fertilizers can actually pollute groundwater that we use for drinking.

4. Some inorganic fertilizers may contain wastes that went through a recycling process. As such, they may have in them lead or other heavy-metal residues which can be taken in by growing plants and which, in turn, we eventually consume as food.

5. When applied excessively or too liberally, inorganic fertilizers can be washed and transported by rain into water sources (such as rivers and lakes) and end up polluting them. If this happens, it may result to an increase in growth of several aquatic plants which can then substantially lessen the supply of oxygen in water and kill fish.

6. It requires high purchasing power

7. Availability is an obstacle, especially in remote areas

**Organic fertilizers** are natural materials of either plant or animal origin, including livestock manure, green manures, crop residues, household waste, compost, and woodland litter. Organic fertilizers include both plant and animal bi-products. They are slow acting. Organic nitrogen fertilizers include oil cakes, fish manure, dried blood from slaughter houses etc., where as organic phosphorus fertilizers are from bone meal and organic potassium from cattle dung ash, wood ash, leaf mould, tobacco stems and water hyacinth.

**Organic fertilizers are categorized into two:**

1. **Bulky:** This consists of the slow acting organic manures with large quantities of organic matter. Examples are Cattle, Sheep Poultry, Pig, Goat, Horse manures, Compost, Green Manures, and Sewage Sludge.
2. **Concentrated:** This consists of the quick acting organic manures with small quantity of organic matter. Examples are Groundnut cake, Castor cake, Bone meal, Blood meal, Horn meal, Wood ash, Cotton and Linseed Meal.

**Specific properties of organic fertilizers**

Organic nutrient sources are highly heterogeneous and vary in quality and quantity. The quality aspect is important in determining the nutrient release potential of the organic fertilizer. Microorganisms that decompose organic fertilizers use the carbon in such materials as an energy source for growth. Required in even bigger quantities by microorganisms for growth and reproduction is nitrogen (N). Commonly available materials are often particularly low in N content. For organic fertilizers with low N contents (such as cereal straw and most smallholder farmyard manures), microorganisms themselves will consume much of the available N for their own growth. Consequently, insignificant amounts of N will be released for the crop. Thus, on their own, poor quality materials have limited potential to enhance productivity.

**Advantages of Organic Fertilizers**

1. Organic fertilizers mobilize existing soil nutrients, so that good growth achieved with lower nutrient densities while wasting less. By their nature, they increase physical and biological nutrient storage mechanisms in soils, mitigating risks of over-fertilization.

2. They release nutrients at a slower, more consistent rate, helping to avoid a boom-and-bust pattern.

3. They help to retain soil moisture, reducing the stress due to temporary moisture stress.

4. They improve the soil structure.

5. They help to prevent topsoil erosion (responsible for desertification and the Dust bowl.

Organic fertilizers also have the advantage of avoiding certain problems associated with the regular heavy use of artificial fertilizers:

6. The necessity of reapplying artificial fertilizers regularly (and perhaps in increasing quantities) to maintain fertility.

7. Extensive runoff of soluble nitrogen and phosphorus leading to eutrophication of bodies of water (which causes fish kills).

8. Costs are lower for if fertilizer is locally available.

9. Organic fertilizer nutrient content, solubility, and nutrient release rates are typically much lower than mineral (inorganic) fertilizers.

**Disadvantages of Organic Fertilizers**

Organic fertilizers have the following disadvantages:

1. Generally require large amounts to have desired effects.

2. As a dilute source of nutrients when compared to inorganic fertilizers, transporting large amount of fertilizer incurs higher costs, especially with slurry and manure.

3. The composition of organic fertilizers tends to be more complex and variable than a standardized inorganic product.

4. Improperly-processed organic fertilizers may contain pathogens from plant or animal matter that are harmful to humans or plants. However, proper composting should remove them.

5. More labor is needed to compost organic fertilizer, increasing labor costs. Some of this cost is offset by reduced cash purchase.

6. Unavailability of seed for green manures is one of the major limitations.

7. Green manures must occupy land at a time when other food crops could be grown.

**Methods of Fertilizer Application**

Fertilizers can be applied to soil before seeds are sown, at the time of planting and while the plants are growing. Fertilizers can also be added to the hole when transplanting vegetables, flowers, trees, shrubs and other plant types. The method of fertilizer application to be used is dependent upon the following factors:

i) Type of plant being fertilized

ii) Type of soil,

iii) Type of fertilizer, and

iv) Size of the area that needs fertilizing.

The following methods are adopted to apply fertilizers-

**A) Application of fertilizer in solid form**

**1. Broadcasting:** This type of application method basically refers to the spreading of the fertilizer uniformly over the entire area. This is usually done with a spreader of some sort.

**2. Band Placement:** This is a method in which fertilizer is placed in a band about 5 cm to the sided of the plant. Inserting or drilling or placing the fertilizer below the soil surface by means of any tool or implement at desired depth to supply plant nutrients to crop before sowing or in the standing crop is called placement.

**3. Drilling:** This is a method where fertilizer is applied with a drill at the same time as the seed is sown.

**4. Side Dressing:** This is a method in which the fertilizer is placed either in a continuous band 4-5 cm deep near the crop or in between the plants in a row.

**B) Application of fertilizer in liquid form**

1. Foliar Application
2. Starter solution
3. Application through irrigation water

**5. Foliar Application:** This refers to the spraying on leaves of growing plants with suitable fertilizer solutions. These solutions may be prepared in a low concentration to supply any one plant nutrient or a combination of nutrients.

**6. Starter Solutions:** This is a method where solutions of fertilizers, generally consisting of N, $P_2O_5$, $K_2O$ in the ratio of 1: 2: 1 and 1: 1: 2 are applied to young vegetable plants at the time of transplanting. These solutions are known as 'Starter Solutions'. They are used in place of the watering that is usually given to help the plants to establish. Only a small amount of fertilizer is applied as a starter solution.

**7. Application through irrigation water:** This is a method where fertilizers are allowed to dissolve in the irrigation stream and the nutrients are carried into the soil in solution. This saves the application cost and allows the utilization of relatively inexpensive waters.

## UNIT 9: SOIL TEXTURE AND SOIL STRUCTURE

### SOIL TEXTURE

Soil texture is the relative proportion of various soil separates in a soil. It is usually expressed on percentage basis.

Soil separates are group of soil particles of given size range i.e. different size of particles which together make up a given soil.

The main textural classes are sand, silt and clay. These textural classes may be modified by addition of suitable adjective based on relative amount of each separate that make up the soil e.g.

Loam: Soil material with clay, silt and sand in close proportion (e.g. 7-27% clay; 28-50% silt and <50% sand).

Loamy sand: Materials with about 80-90% sand.

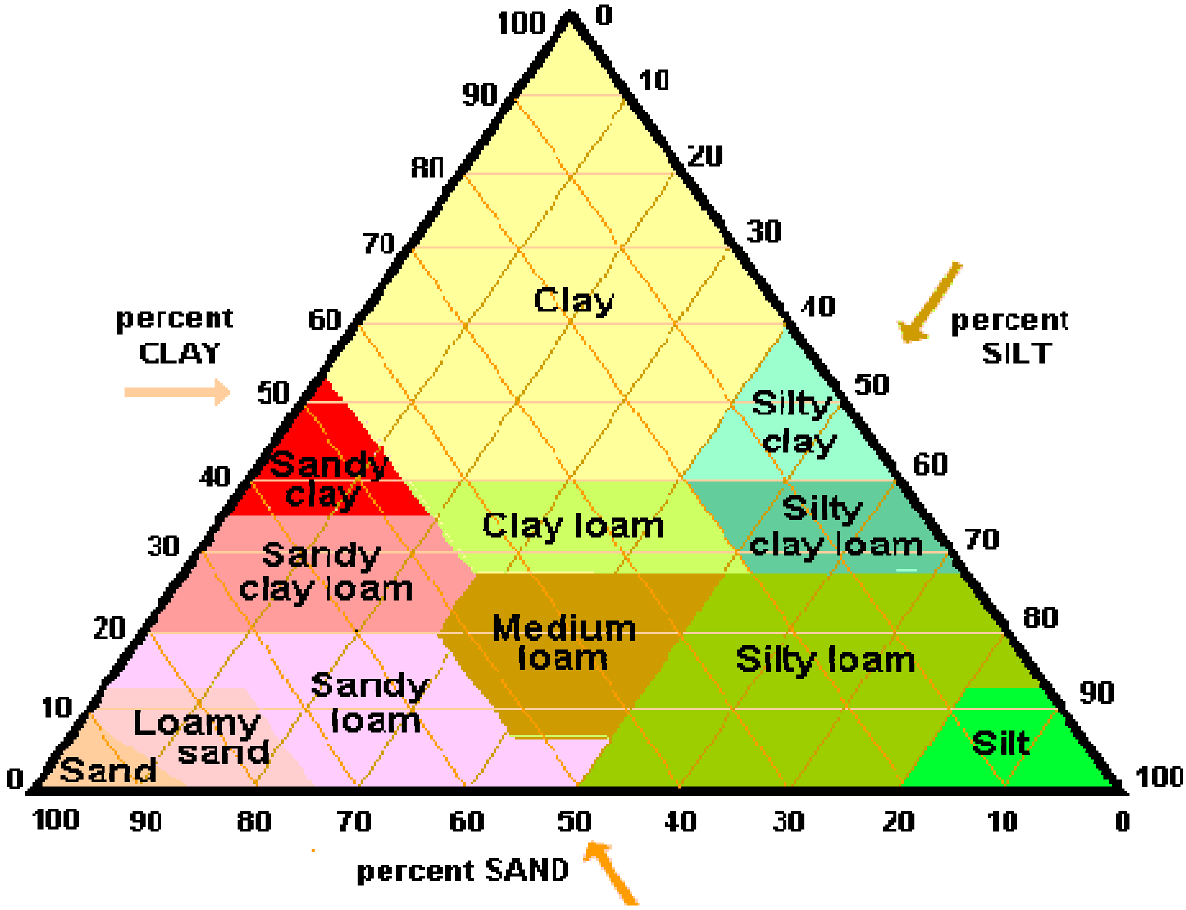
Sandy loam: <7% clay; <50% silt; about 52% sand.

Other modifications include silty loam, sandy clay loam, clay loam, gravelly loamy sand etc.

**Determination of Soil Texture**

Soil texture may be determined on the field by textural feel and in the laboratory by soil mechanical analysis or soil particle size distribution. The mechanical analysis in the laboratory may be carried out either by Pipette or hydrometer method.

After the proportion of each of the soil separates are determination, the textural class of the soil is identified using a USDA Soil Textural Triangle. The sides of the soil texture triangle are scaled for the percentages of sand, silt, and clay.




**Soil texture triangle**

**Systems of soil particle size classification**

There are two widely used systems of soil classification. These are: United State Department of Agriculture (USDA) and International Soil Science Society (ISSS)

USDA Classification system

| Fraction | Diameter (mm) |
|---|---|
| Very coarse sand | 2.00 – 1.00 |
| Coarse sand | 1.00 – 0.50 |
| Medium sand | 0.50 – 0.25 |
| Fine sand | 0.25 – 0.10 |
| Very fine sand | 0.10 – 0.05 |
| Silt | 0.05 – 0.002 |
| Clay | <0.002 |

ISSS Classification system

| Fraction | Diameter (mm) |
|---|---|
| Coarse sand | 2.00 – 0.2 |

| | |
|---|---|
| Fine sand | 0.2 – 0.02 |
| Silt | 0.02 – 0.002 |
| Clay | <0.002 |

Generally

Materials : >20 mm diameter – stone
20-2 mm diameter – gravel
<2mm diameter – Fine earth (soil)

## SOIL STRUCTURE

Soil structure is the arrangement of soil particles to form peds. Or, the arrangement of primary particles into secondary particles (aggregate).

Each individual unit of soil is called a ped.

**Classification of soil structure**

There are three basic groups of classification

1. Classification based on shape of aggregate

   (i) Simple structure: this includes (a) Single grain and (b) Massive structure

   (ii) Compound structure: under this we have:

      Spheroidal (Granular, crumb)

      Block-like (Blocky; sub-angular blocky)

      Prism-like (Prismatic; columnar)

      Platy – flat, plate like. These are soil found in compacted soils.

2. Classification based on size and shape of pores

   Coarse pore – >200 µm

   Medium pore – 200 - 20 µm

   Fine pore – 20 - 2 µm

   Very fine pores - <2 µm

3. Classification based on grade

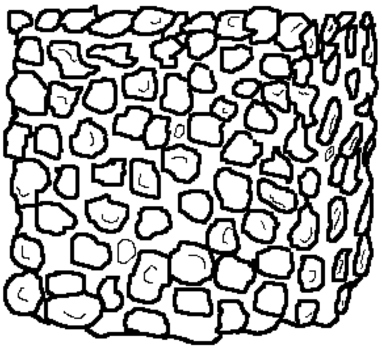
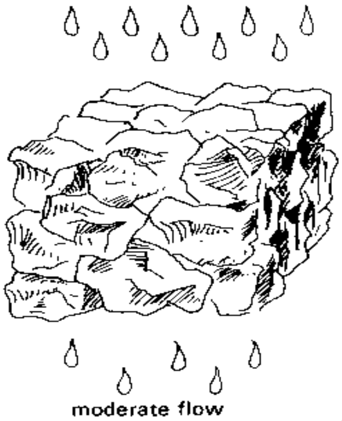
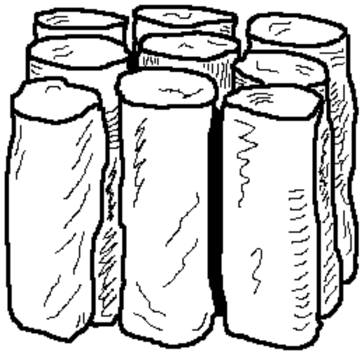
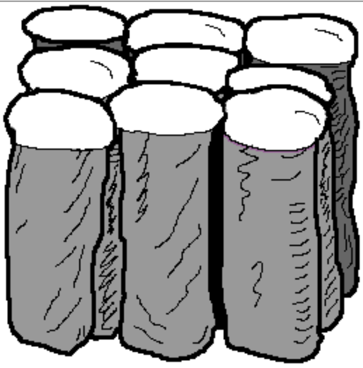
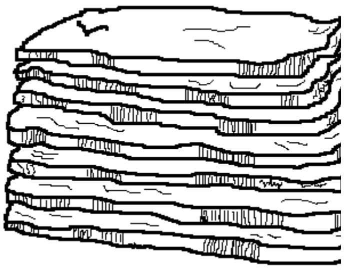
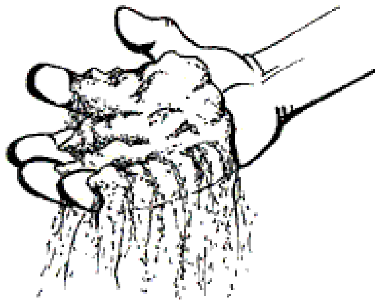
Poor e.g single grain structure

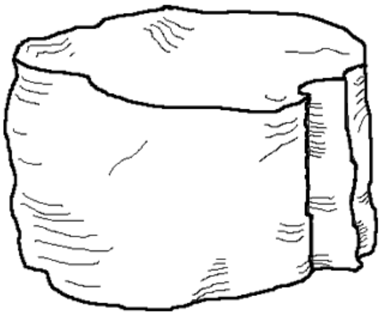
Weekly developed: contains high level of sand and silt

Well developed: contains some amount of binding agents

Strongly developed: contains high level of binding agents e.g. soil Organic matter.

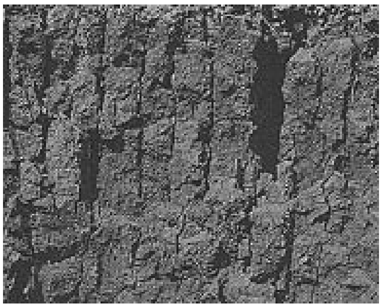
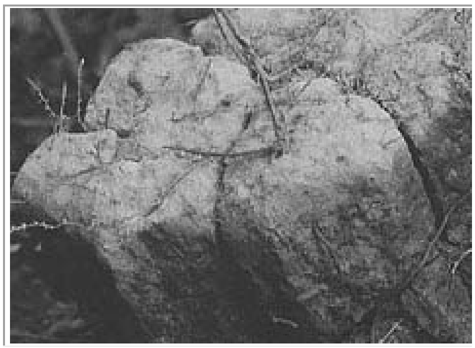
## Pictorial Description of Soil Structure

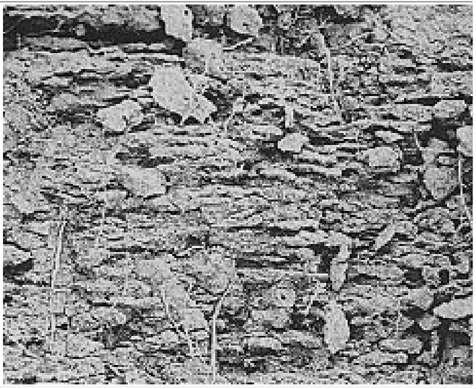
| | | |
|---|---|---|
|  |  |  |
| **Granular**: Resembles cookie crumbs and is usually less than 0.5 cm in diameter. Commonly found in surface horizons where roots have been growing. | **Blocky**: Irregular blocks that are usually 1.5 - 5.0 cm in diameter. | **Prismatic**: Vertical columns o soil that might be a number of cm long. Usually found in lower horizons. |
|  |  |  |
| **Columnar**: Vertical columns of soil that have a salt "cap" at the top. Found in soils of arid climates. | **Platy**: Thin, flat plates of soil that lie horizontally. Usually found in compacted soil. | **Single Grained**: Soil is broke into individual particles that d not stick together. Always accompanies a loose consistence. Commonly found in sandy soils. |



**Massive**: Soil has no visible structure, is hard to break apart and appears in very large clods.

**Images of the different soil structures are shown below.**

| | | | |
|---|---|---|---|
| **Granular** |  | **Blocky** |  |
| **Prismatic** |  | **Columnar** |  |

| | |
|---|---|
| **Platy** |  |

**Structureless:**

| | | | |
|---|---|---|---|
| **Single grained** |  | **Massive** |  |

**Importance of soil structure**

- ❖ It affects water and nutrient holding capacity of the soil
- ❖ It affects germination and root growth and development
- ❖ It affects water retention and transmission of fluid in soil
- ❖ It affects soil aeration
- ❖ It influences soil thermal properties

## UNIT 10: SOIL MANAGEMENT

Soil management refers to the practices adopted for a particular soil, such as methods of cultivation, erosion control measures, fertilizer practices and pest control.

Soil management should include a practice of suitability classification where various farm activities (such as cropping, grazing, shelter belts, woodlots and irrigation) are assigned to the most suitable soil unit.

### TILLAGE PRACTICES

Tillage is a physical /mechanical manipulation of the soil for the purpose of crop production.

Tillage affects soils structure, soil water conservation, weed infestation, rate of decomposition of soil organic matter, population of soil fauna, soil temperature, seed germination, seedling emergence, crop growth and yield.

**Types of tillage**

There are three basic types of tillage

**1. Zero tillage**: this involves planting on a piece of land without the use of any farm machinery such as tractor; plough. Under zero tillage weeds are destroyed with the aid of herbicides before planting.

<u>Advantages of zero tillage</u>

i. maximum soil erosion control

ii. soil moisture conservation

iii. minimum fuel and labour cost.

iv. promotes soil carbon and nitrogen sequestration

**2. Minimum tillage:** this involves the use of primary tillage implements such as plough for soil preparation before planting. It is also called reduced tillage.

Advantages of minimum tillage

i. less erosion control

ii. well adapted for lighter or medium textured, well-drained soil

iii. excellent incorporation of plant materials

**3. Conventional tillage:** this involves the use of primary tillage implements such as plough followed by the use of secondary tillage implement such harrow or ridger.

Advantages of conventional tillage

i. excellent control of weeds

ii. provides ease of seed planting

iii. seed germination or seedling emergence is faster

**SOIL WATER MANAGEMENT**

The rapidly increasing urban population and development with limited water supply has led to increasing competition for water between urban users and agriculture. This calls for urgent need for proper management of available water to agriculture.

There are 3 basic approaches to soil water management

1. Conservation of natural precipitation

2. Addition of water to supplement the amount of natural precipitation

3. Removal of water from wet land

**Conservation of natural precipitation:** these practices are important in areas with large water deficit and are designed to increase the amount of water that enters the soil and to make efficient use of this water. These practices are popular in Sub-humid and Arid regions. These practices include vegetative cover, contour tillage, terraces, application of organic manures, fallowing etc.

## IRRIGATION

Irrigation is the artificial supply of water to the crops to supplement rainfall

**Methods of irrigation**

i. Flood irrigation

ii. Furrow irrigation

iii. Sprinkler irrigation

iv. Drip irrigation

TYPES OF IRRIGATION

Flood irrigation

Furrow irrigation

Sprinkler irrigation

Drip Irrigation

## DRAINAGE

Drainage or dewatering is the removal of excess water that has accumulated on the soil surface.

### Types of drainage

1. Surface drainage: collection and removal of water from the soil surface through open ditches.

2. Subsurface drainage: installation of drainage ditches under ground with the aid of a trenching machine. It is usually laid around 1 m depth to the soil surface.

*Drainage trencher installing subsurface pipe drains*

## SOIL EROSION CONTROL

Soil erosion is the wearing away of the soil surface either by water or by wind

**Types of water erosion**

i. Splash erosion

ii. Sheet erosion

iii. Rill erosion

iv. Gully erosion

**Control of water erosion**

1. Agronomic practices: these include vegetative cover, cropping systems (e.g. mixed cropping, strip cropping, intercropping and contour cropping).

2. Engineering practices:

Contour bounding: making embankment with a narrow base at intervals across the slope and along the contour.

Gully plugging: this done with live edges, earth, sand bags, brick masonry and boulders.

Small gully can be controlled by clearing, levelling and constructing diversion/check bunds and disposal of excess runoff at the end of the bounds into grassed slope.

**Wind erosion**

This is the movement of soil and loss by the action of wind.

**Control of wind erosion**

i. Construction of windbreak and shelterbelts

ii. Cropping system e.g. cover cropping, strip cropping

iii. Residue of crop left over following harvest

iv. Avoidance of overgrazing

v. Vegetative cover.