COURSE CODE: *SOS 211*

COURSE TITLE: *Principles of Soil Science*

NUMBER OF UNITS: *2 Units*

COURSE DURATION: *Two hours per week*

COURSE DETAILS:

Course Coordinator: Dr. Adeniyi Adebowale Soretire *B. Agric., M. Agric., PhD*
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COURSE CONTENT:

Definition of soil; soil genesis and formation. History of Soil Science; Basic principles of soil survey and classification. Soil survey information and land use planning. Soil colloids and soil reaction; Soil nutrients and mineral nutrition of plants. Soil organic matter; types and activities of soil organisms. Organic and inorganic fertilizers; nutrient management. Soil texture and soil structure. Soil management: tillage practices; soil water management; irrigation; drainage and soil erosion control.

COURSE REQUIREMENTS:

This is a compulsory course for all students in the Agricultural Colleges of the University. In view of this, students are expected to participate in all the course activities and have minimum of 70% attendance to be able to write the final examination.

READING LIST:

1. Brandy, M.C. and Wil, Ray R. The Nature and Properties of Soils 12th ed. New Jersy: Prentice Hall.
2. Robert E. White. Principles and Practice of Soil Science: The soil as a Natural Resource, Willey-Blackwell, 2005.
3. Singer, M.J. and Munns D.N. Soils: An Introduction. 4th Edition. New Jersey: Prentice Hall, 1999.

LECTURE NOTES

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.*
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.*
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.*

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.

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 Genesis and formation

Factors of soil formation

The five soil forming factors are: parent material, topography, climate, biological activity, and time.

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.

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.

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).

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.

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.

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.

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.

Principles of soil survey

The principles of survey can be discussed under five points

A soil survey must have an objective. A soil survey is not the only basis for decision on land use and management, it is only an aid

Land resources do not consist of soils alone

A soil map must show soils.

Soil map and report are complementary.

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.

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.

In **rigid grid survey**, examinations of the soil are done at regular and pre-determined interval. **Flexible grid survey method** is a compromise between the free and rigid grid methods of survey.

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. The scale is usually at 1: 100,000 or smaller.

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. 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). 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. 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. 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.Scale of mapping varies from 1: 1,000 to 1: 10,000 or even larger.

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.

- 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 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 organize 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. 2)** Principle of **Domain. 3)** Principle of **Identity**. 4) Principle of **Differentiation. 5)** Principle of **Prioritization. 6)** Principle of **Diagnostics**. 7) Principle of **Membership. 8)** Principle of **Certainty.**

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.

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.

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

Why plan land use?

- To provide maximum *economic benefit* to the individual land owner or operator (e.g. farm planning)
- To prevent or solve *conflicts* between individuals and other individuals or with the needs and values of society as a whole.

Land evaluation is only part of the process of land use planning. Its precise role varies in different circumstances. In the present context it is sufficient to represent the land use planning process by the following generalized sequence of activities and decisions:

a) recognition of a need for change; b) identification of aims; c) formulation of proposals, involving alternative forms of land use, and recognition of their main requirements;
   d) recognition and delineation of the different types of land present in the area;
e) comparison and evaluation of each type of land for the different uses; f) selection of a preferred use for each type of land; g) project design, or other detailed analysis of a selected set of alternatives for distinct parts of the area; g) decision to implement; h) implementation; monitoring of the operation.

History of soil Science

Possibly the oldest written observations on soils and agronomy are to be found in Jewish culture – the Old Testament of the Bible and the Talmud – much of which were evidently passed down in the folklore of a largely agricultural population (Hillel, 1991).

The selection of the best soils followed naturally. The three geographic regions noted above are (a) The Mesopotamian plains between the Tigris and Euphrates, (b) the Nile Valley, and (c) the Indo-Gangetic plains of present-day India and Pakistan.

Curiously enough, it was the economic incentives that spurred the feudal owners of Russia's great landed estates and opened the door to the age of Dokuchaev and the introduction of science into soil studies (Evtuhov in Warkentin, 2006) and the development of soil classification. First scientists The first and unquestionable "father of soil science" (Warkentin, 2006) was V. V. Dokuchaev who was linked to the Russian Academy of Science (originally in St. Petersburg), but who was first approached by the big landowners who wanted to improve the economic viability of their territories. In this way he traveled widely with a background knowledge derived from the German schools of geochemistry. The year 1899 marked (a) the first textbook of soil science (Pochvovedenie by N. M. Sibirtzev), which contained a synthesis of Dokuchaev's ideas about classification of soils and their genetic history; and also (b) the first appearance of a soil science journal, with the same name Pochvovedenie (edited by P. V. Ototski, followed later by A. A. Yarilov). This journal played a major role in the beginnings of soil science, although this leading role was lost during the secretive and xenophobic conditions of Soviet hegemony. Dokuchaev was responsible for the introduction of many of the basic terms. A mineralogist by training, he created the genetic and zonal approach, as well as the concept of the soil profile. The first textbook, by N. M. Siburtzev (1890–1900), as noted above, expanded the terminology, introducing what were originally folk terms such as Podzol and Solonetz. Siburtzev became the first professor of pedology. The year 1899 also marks a milestone for soil science in the United States when through its Department of Agriculture it initiated the systematic mapping of soils (later to become the Soil Survey Division). Gradually the development of the U.S. Soil Taxonomy was expanded to embrace more genetic and landscape concepts (for example, the "andisols" and their volcanic connections). Robert V. Ruhe (1919–1993) pioneered the idea of soil geomorphology (Ruhe, 1965). After this, according to Yaalon (1997), "modern soil research took off at an accelerated rate". Yaalon submitted that there have been essentially three paradigm leaps in the history of soil science: a. Liebig's mineral theory of plant nutrition in the 1840s.

In England, an independently wealthy English gentleman, Sir John Bennet Lawes and his assistant Henry Gilbert, established the Rothamsted Experimental Station at Harpenden, some 50 km N of London in 1843. Their objective was to try out all sorts of crops, fertilizers and synthetic "weather" conditions, so that they could positively recommend certain procedures and materials of benefit for agriculture in general. Rothamsted investigated at a "hands-on" scale the science of soil physics, soil chemistry and soil biology. It had more in common with the Germanic centers of soil investigation, and less with the mapping programs of Russia and the U.S. One of their distinguished researchers was H. L. Penman (1909–1976) who presented to the Royal Society of London, a paper on "Natural evaporation from open water, bare soil, and grass" with an equation that was later adopted by the Food and Agricultural Organization of the United Nations.

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.

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. 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.
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 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. They are:

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

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. .

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 swelling3) 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
- **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
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 (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

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 and 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. In addition to clay minerals in the soil, organic matter is a major source of plant nutrient elements. 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.

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:** They include all residues of animals and micro-organisms, domestic wastes, animal faeces, animal feeds, and animal manures.

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 by the activities of microorganisms.

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.

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. 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^+

Maintenance of Soil Organic Matter

The maintenance of the organic matter in soils used for agricultural production is an important practice. The practices involved in the maintenance of soil organic matter include: i) Addition of new organic materials 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 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.

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. Some common soil bacteria 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. 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. 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, etc.

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.

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: 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. **mineral transformation**: turning inorganic matter into other inorganic compounds.
2. Enhancing soil structure, which improves water and air movement.
3. Controlling disease and enhancing plant growth.

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 8. Organic matter 9. Food and energy supply 10. Nature of soil and 11. Microbial associations.

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 fertilizer could be classified into three based on the

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. In the case of nitrogenous fertilizers, nitrogen may be in the ammoniacal, nitrate (or a combination thereof) or amide form. Examples are Ammonium Sulphate, Urea, Ammonium Chloride, Ammonium Nitrate, Calcium Ammonium Nitrate (CAN) etc.

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. Examples are Single Superphosphate, Double Superphosphate, Triple Superphosphate, Basic Slag, Dicalcium Phosphate and Rock Phosphate.

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. Examples are Murate of potash and Potassium sulphate.

2. **Complex/Compound fertilizers**: These are fertilizers which contain two or more nutrient elements usually combined in a homogeneous mixture by chemical interaction. Examples are Ammonium Phosphate, Ammonium Phosphate Sulphate, Ammonium Phosphate Sulphate Nitrate, Nitrophosphate, Urea Ammonium Phosphate, Mono Potassium Phosphate etc.

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.

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.

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.

Advantages and Disadvantages of Inorganic Fertilizers

Advantages and Disadvantages of Inorganic Fertilizer

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

ORGANIC FERTILIZERS

These 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 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.

Advantages of Organic Fertilizers

(1) Organic fertilizers mobilize existing soil nutrients, so that good growth achieved with lower nutrient densities while wasting less. (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. (6)The necessity of reapplying artificial fertilizers regularly 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. (5) More labor is needed to compost organic fertilizer, increasing labor costs. (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. 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.

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.

5. Foliar Application: This refers to the spraying on leaves of growing plants with suitable fertilizer solutions.

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.

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.

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.

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

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.

Importance of soil structure

1) It affects water and nutrient holding capacity of the soil (2) It affects germination and root growth and development 3) It affects water retention and transmission of fluid in soil
   1) It affects soil aeration 5) 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.

Advantages of zero tillage

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

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

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

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.

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.