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 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
- **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,