CHAPTER

1

Concept of Soil

Soil is one of the three major natural resources, alongside air and water. It is one of the marvelous products of nature and without which there would be no life. Soil is the unconsolidated or loose covering of fine rock particle that covers the surface of earth. The word soil is derived from a Latin word '*solum*' which means floor.

Soil may be attributed to different concepts and viewpoints. To the farmers soil is the habitat for plants which provide food and fiber to man and animals. Thus, they require to pay due attention to sustain its properties leading to better crop growth. To the highway engineers, the soil is the material on which a roadbed is to be placed. If the characteristics of the soil are not suitable, then it must be replaced with rock and gravel. To the homemakers, the soil is used for erecting wall of the house either in the form of mud or brick (also made from soil). To the clay modelers, it is the basic material which is molded to get different shape of the clay models. To the economists, the soil is synonymous to land consisting of soil, hydrology, climate, vegetation and other physical attributes which affect its use. Unfortunately, to most of us, soil is considered as natural dustbin to dump all types of wastes including the polluting materials also.

1.1 WHAT IS SOIL?

To define soil is not an easy task owing to its complexity and heterogeneity. The concept of soil has been changing from time to time with accumulation

of more and more data and knowledge ever since it has been considered as scientific entity. Glimpse of such development is shown below.

Whitney (1892) conceived soil as a nutrient bin, i.e. all soils were considered to be naturally enough in nutrients for satisfactory plant growth and the texture of soil provided a direct index to moisture and temperature conditions important to plant growth.

Hilgard (1892) viewed soil as more or less a loose and friable material in which plants, by means of their roots, find a foothold for nourishment as well as for other condition of growth.

Dokuchaev (1900) defined soil as a natural body composed of mineral and organic constituents, having a definite genesis and a distinct nature of its own.

Jenny (1941) considered soil as a naturally occurring body that has been evolved owing to combined influence of climate and organisms, acting on parent material, as conditioned by relief over a period of time.

Joffe (1949) conceived soil as a natural body of mineral and organic constituents, differentiated into horizons of variable depth, which differs from the materials below in morphology, physical make up, chemical properties and composition, and biological characteristics.

Ruffin (as quoted by Simonson, 1968) considered soil as a mixture of earth's uppermost mantle of weathered rock and organic matter.

According to the Glossary of Soil Science Term (Soil Science Society of America, 1987), "soil is

(i) 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.

(ii) 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".

According to Soil Taxonomy (second edition), 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.

Considering the all above definitions of soil as well as their limitations one generalized definition may be put forth: *'Soil is a dynamic three dimensional natural body of the landscape developed from weathering of rocks through various pedogenic processes, consisting of mineral and organic constituents, possessing a definite set of physical, chemical and biological properties, having a variable depth covering the surface of earth and providing a medium for growth of the terrestrial plant'.*

Many a time students get confused with the two terms **'land'** and **'soil'** as synonymous. Practically, land is a broader term which in addition to soil includes climate, hydrology, vegetation, relief. Besides productivity of the soil, the value of land depends on its location, size, distance from the market, etc.

1.2 APPROACHES OF SOIL STUDY

Two basic concepts of soil have evolved through more than two centuries of scientific study. One treats soil as a natural body, weathered and synthesized product in nature while other treats soil as a medium for plant growth.

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

(B) ***Edaphological Approach*: Edaphology** (derived from Greek word *edaphos*, means soil or ground) is the study of soil as habitat for living things, especially plants. Edaphologists consider the various properties of soil in relation to plant production. At the same time, they must determine the reasons for variation in the productivity of soils and find means for their improvement.

1.3 FUNCTIONS OF SOIL

The soils in any part of the world are used to play five functions:

(a) Medium for Plant Growth

Soil mass provides physical support to the terrestrial plant, anchoring the root system against its fall over by strong wind or heavy snow. Soil through its pore space provides thorough passage

for entry of fresh O_2 for respiration of plant roots and release of CO_2 produced thereby. Within the pore spaces soil holds water which can be utilized by plant roots needed for nutrient transport, photosynthesis and other activities. Soil, being a reservoir of mineral nutrients supports plant growth. Soil acts as a natural purifier against different toxins released by plant roots and microorganisms or may be accumulated due to human activities. Soil temporarily holding these toxins on its surface or within the pore space transforms them to some insoluble forms or volatilizes as gases.

(b) Regulator of Water Supply

The quantity and quality of water in different water bodies and in the underground aquifer are regulated by the soil through which the water travels. During movement through the soil profile the soil cleanses and purifies the contaminated water by removing pollutants and killing detrimental organisms.

(c) Recycler of Organic Residues

The most important function performed by the organisms present in the soil is the decomposition of organic wastes; otherwise we would have to walk on a thick layer of undecomposed plant and animal residues. During decomposition process nutrients in organic form present in the organic residues are converted into inorganic form which is taken up by the plant for their growth and development. Since animals are directly or indirectly depend on the plant for food, thus the nutrition of all the living organisms in the world is very much related to the recycling of organic wastes.

(d) Habitat for Soil Organisms

Soil is not merely a pile of weathered rock and dead debris; rather it is the home for billions of organisms of diversified nature. These organisms are the component of ecosystem and agents for number of transformations occurring in the soil.

(e) Engineering Medium

Soil plays an important role as engineering medium, not only as a building material in the form of mud wall or bricks but provides the base for virtually every road, dam, etc. that we build. Reliable construction on soils and with the soil materials requires sufficient knowledge about diversified physical properties, such as swelling-shrinkage behaviour, shear strength, bearing strength and stability, etc.

1.4 SOIL AS ENVIRONMENTAL INTERFACE

Soil is a three dimensional natural body. Its importance derives largely from its role as an interface between the worlds of rocks and mineral (the **lithosphere**), air (the **atmosphere**), water (the **hydrosphere**) and living organisms (the **biosphere**). Environments where all these four worlds interact are often the most complex and productive part on earth (Figure 1.1). The soil or **pedosphere**, is the unique example of such environment.

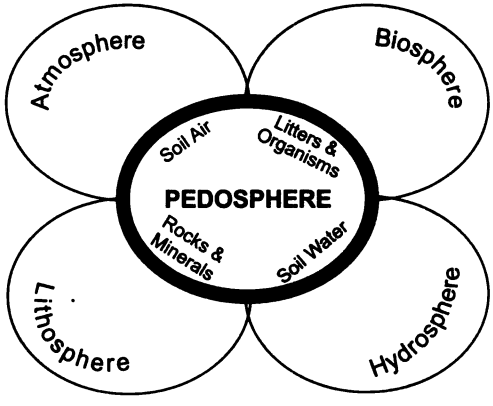

Figure 1.1 The pedosphere in association with lithosphere, atmosphere, biosphere and hydrosphere.

1.5 COMPOSITION OF SOIL

Soil is a three phase system: solid, liquid and gaseous phase excluding the condition when soil is completely frozen or dry, then soil becomes two phase system, i.e. solid and gaseous phase. Again, solid phase is composed of two components, namely inorganic or mineral component and organic compoment. The relative proportions of these four components greatly influence the behaviour and productivity of soil. The relative proportion (volume basis) of four components in a loam surface soil is shown in the Figure 1. 2. Although a handful of soil seems to be solid thing, but in ideal condition its 50% volume should be occupied by pore space filled with air and/or water. Of the 50% soil volume occupied by solid material, mineral matters which are derived from weathering of rocks in the earth-crust contribute 45% and rest 5% by organic matter in an ideal soil.

The spaces between the particles of solids, i.e. **pore space** are the room and passage where air and water may circulate, roots grow and microorganisms can live. As plant roots require both air and water, under

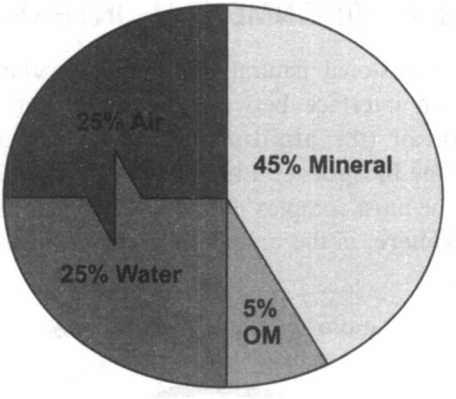

Figure 1.2 Volume composition of a loam surface soil.

optimum condition of growth for most of the plants 50 % pore space (or 25% of total soil volume) should be occupied by air and 50% should be filled up by water. The proportion of air and water may vary depending upon the moisture status of the soil. Under waterlogged condition proportion of water is more; on the other hand, under drought condition proportion of air is more than the ideal situation.

(a) Mineral (Inorganic) Component of Soil

Soils (except organic soil) consist of mostly the mineral particles of extremely variable size and composition. Large size soil particles like, stones, gravels and coarse sands are often the aggregates of several different minerals. But smaller size particles are mostly made up of a single mineral.

Minerals that have persisted with little or no change in composition as they were extruded in molten lava are known as **primary mineral** (quartz, feldspars, mica, *etc*) which are usually predominant in sand (2 to 0.05 or 0.02 mm diameter) and silt (0.05 or 0.02 to 0.002 mm diameter) fractions. On the other hand, the minerals which are formed by breakdown and weathering of less resistant minerals as soil formation proceeds are called **secondary mineral,** *viz*, silicate clays, oxides of iron and aluminium. These are mostly predominant in clay fractions (<0.002 mm diameter). The inorganic minerals in the soil are the original source of most of the chemical elements essential for plant growth.

(b) Soil Organic Matter

Soil organic matter consists of a whole range of organic (carbonaceous) substances including partially decomposed to

completely decomposed plant and animal remains, living organisms and organic compounds produced by soil organisms as their cell components or by-product of metabolic processes.

The remains of plants, animals and microorganisms are continuously broken down by the other microorganisms with the synthesis of new compounds and removal of major part of carbon as CO_2. Thus, continuous replenishment is necessary to maintain the soil organic matter status. Though, organic matter constitutes a small fraction of total mass of a typical soil, its influence on soil properties and consequently on plant growth is far greater than its contribution to the weight of soil. Soil organic matter is a major source of plant nutrients like nitrogen, phosphorus, sulphur and some micronutrients. Organic matter is the food that supplies carbon and energy to many soil organisms. It also increases the plant available water content of soil.

(c) Soil Water

Water is essential for the survival and growth of plants and soil organisms. Water is held within the soil pores with varying degrees of tenacity depending upon the size of the pore and amount of water present. The attraction between solid surface and water greatly restricts the movement of water.

Soil water that contains number of dissolved organic and inorganic substances is synonymous to **soil solution**. The soil solution supplies elements that are essential for plant growth. Under the influence of concentration gradient nutrient ions are released by exchange process from the inorganic and organic colloidal (particles having diameter <0.001 mm) surface to soil solution, from where these are taken up by the growing plants.

The concentration of H^+ and OH^- ions in soil solution which is ascertained by measuring pH, is important as it governs the solubility, and in turn the availability of several essential nutrients to plant. The pH by definition is the negative logarithm of activity of H^+ ions in the solution. Numbers of chemical and biological reactions are regulated by the soil pH.

(d) Soil Air

In a typical soil, approximately half of the total soil volume is constituted by pore spaces of variable sizes, which are filled with either air and/or water. At any instant, the air occupies those pore spaces which are not filled with water. Thus, the air content is

inversely related to the water content of soil. As the soil drains after a heavy rain or irrigation due to gravity or evaporation or plant use, at first large pores are to be filled with air, followed by medium-sized pores and finally small pores.

Diffusion of air (O_2) from atmosphere to soil is vital for respiration of plant roots. If diffusion of air is impeded due to water stagnation over the soil surface by heavy rain or excess irrigation, the CO_2 concentration will increase and O_2 level in soil will decrease which is undesirable for growth of most plants.

The composition of soil air differs from atmosphere air. Usually soil air contains higher amount of CO_2 and moisture (except in very dry soil) and lesser amount of O_2 than atmosphere air. The composition of soil air varies greatly from place to place owing to variable local demand of different gases by plant roots and microbes.

1.6 THE SOIL PROFILE AND ITS LAYERS

Soil scientists often dig a large hole, called a **soil pit**, usually several meters deep and about a meter wide, to expose horizons for study. The vertical section exposing a set of layers in the wall of soil pit is termed a **soil profile** and the individual layers are regarded as **horizons** (Figure 1.3). Soil profile tells one much about the environment and history of a region. For example, soils developed in a dry region will have different horizons from those developed in a humid region. Horizons within a soil may vary in thickness and have somewhat irregular boundaries, but generally parallel to the land surface.

The material of unconsolidated debris overlying the hard, unweathered rock (**bed rock**) is known as **regolith**. The whole regolith is not equally exposed to air, water, solar radiation and living organisms. Since the weathering of the regolith occurs first at the surface, i.e. soil-atmosphere interface, the uppermost layer has been changed the most, while the deepest layer is very much similar to the original regolith, which is referred to as the soil's **parent material**.

In undisturbed ecosystem, say forest, the organic materials received in the form of leaf fall, plant and animal residues tend to accumulate on the surface. The fresh, partially and completely decomposed organic material together form an organic layer at the surface is designated as the **O horizon.**

The topmost mineral horizon formed at or near the surface (just below O horizon) is regarded the **A horizon** which is dominated by mineral particles

but is darkened by the accumulation of organic matter moving along with the percolating water. In some soils, the upper layers may lose some of their clay, oxides of iron and aluminium with consequent increase in the concentration of quartz in sand and silt fractions. These layers usually occur just below A horizon, are designated **E** (eluvial or washing out) **horizon.**

The layers underlying O and A horizons contain less amount of organic matter but may accumulate considerable amount silicate clay, iron and aluminium oxides washing down from upper horizons. These underlying horizons are referred to **B horizon or Illuvial** (washing in) **horizon.**

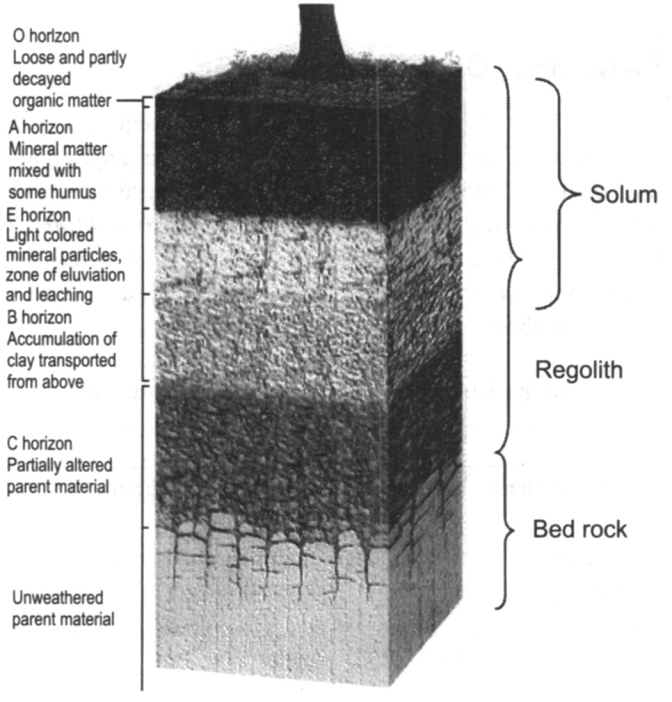

Figure 1.3 Relative positions of solum, regolith and bed rock

Plant roots and microorganisms extending below B horizons may cause biochemical weathering of regolith and help in the formation of **C horizon (parent material)**, the least weathered part of soil profile. Horizons (A and B horizon) above the parent material are collectively referred to as **solum.**

Underlying C horizons, there is consolidated bed rock from which the adjacent overlying horizons are formed, is designated **R** (in Roman numeral it denotes lithologic discontinuity).

1.7 SURFACE SOIL AND SUBSOIL

The organic matter-enriched A horizon present at the soil surface is known as **surface soil** or **top soil**. When a soil is ploughed, then upper 15cm surface soil is called the *plough layer* (or the *furrow slice* if moldboard plough is used). In cultivated soils, majority of plant roots can be found in this part.

The relatively compact soil layers underlying the surface soil are referred to **subsoil**. The characteristics of subsoil horizons can affect the land use. Much of water and sometimes considerable amount of some nutrients needed by plant remain stored in subsoil.

1.8 BRANCHES OF SOIL SCIENCE

Soil is a material whose physical, chemical, biological and mineralogical properties are studied in relation to plant growth or any other use; thus emerged the different branches of soil science. These are *Soil Fertility, Soil Chemistry, Soil Microbiology, Soil Physics, Soil Mineralogy, Soil Conservation (Soil Technology), Soil Genesis and Classification (or Pedology),* and *Soil Survey.* The scope of each of these cannot be exactly defined because of their overlapping domains.

Comparison between surface soil and subsoil

Surface Soil	Subsoil
It is completely weathered layer	1. Usually weathering status advances up the layer.
2. Surface soil contains higher amount of organic matter	2. Organic matter content decreases down the layer
3. Due to presence of high organic matter the colour of the soil is dark	3. Light colour due lack of organic matter
4. Surface soil is porous and fertile	4. Sub-soil is relatively compact and less fertile
5. Microbial population and activity are maximum	5. Less microbial population and activity
6. It does not contain any hard pan	6. It may contain hard pan or impervious layer
7. Aeration status is good	7. Aeration status decreases down the layer
8. Highest amount of plant roots is available in this layer	8. Lesser amount of plant roots are there.

(a) Soil Fertility
It deals with the nutrient supplying properties of a soil under favourable environmental conditions and physical condition of soil. It deals not only with the supply of nutrient by the soil but the ways by which nutrients are lost from the soil and methods by which nutrient supplying capacity can be restored or improved.

(b) Soil Chemistry
It deals with the chemical composition, chemical properties and different chemical reactions taking place in the soil.

(c) Soil Physics
This branch of soil science deals with the study of soil physical properties as well as regulation of physical processes taking place in and through the soil.

(d) Soil Mineralogy
Soil mineralogy deals with the minerals (primary and secondary) present in soil and their relation to the physics, chemistry, biology and fertility of soil.

(e) Soil Conservation (or Soil Technology)
It is the division of soil science dealing with the protection against soil loss by erosion or against chemical deterioration (saline, alkali, acid, waterlogged and other degraded soil) practices and land use.

(f) Soil Genesis and Classification (Pedology)
It deals with the weathering of rocks and minerals, factors and processes of soil formation and classification of soils in a recognized classification system.

(g) Soil Survey
Soil survey encompasses the morphological examination of soil in the field and laboratory, description, classification and mapping for interpretation of soil according to its adaptability for crop production under various management systems. Soil survey is important for any country as it provides the inventory of its soil resources.

SUGGESTED READINGS

Joffe, J.S. (1949) "*Pedology*" New Brunswick, New Jersey, Pedology Publications.
Simonson, R. W. (1968) Concepts of Soil. *Adv. Agron.* 20: 1-47.