1.0 Introduction

What is soil?

Soil is the upper most layer of earth crust, and it supports all terrestrial life. It is the interface between the lithosphere and atmosphere, and strongly interacts with biosphere and the hydrosphere. It is a major component of all terrestrial ecosystems, and is the most basic of all natural resources. Most living things on earth are directly or indirectly derived from soil.

Soil is the unconsolidated material at the earth's surface that serves as a medium for plant growth, regulator of water regime, environmental filter and functions as supporting medium. It is a dynamic 3-phase system comprised of solids, liquids and gases.

What is Soil Physics?

Soil physics is the application of principle of physics to the characterization of soil properties and the understanding of soil processes involving the transport of matter and energy.

Soil physicists are generally concerned with heat and mass transport in soil. Subject they considered frequently include: soil aeration, soil temperature and soil water. These are described in both static and dynamic terms.

Static parameters:

- Soil porosity
- Water content
- Degree of saturation
- Void ratio
- Bulk density

- Particle density
- Soil water potential, i.e. the potential energy of water

Dynamic parameters:

Mass and energy transport in soil are described using:

- Darcy's law for water
- Fourier law for heat
- Fick's law for gas

Each of these laws states that a flux density of heat or substance is proportional to a driving force. The driving are:

- Water potential gradient for water flow
- Temperature gradient for heat flow
- Concentration gradient for gas diffusion

What are the major roles of Soil physicist?

Although soil physicists still must remain concerned about the physical environment of plants, conservation of resources against degradation and pollution problems by agricultural and non-agricultural agents have become the responsibilities of soil physicist too. Soil physicist must be concerned with flow and transport processes in the zone between the soil surface and groundwater table, i.e. the VADOSE ZONE. So, soil physicist are increasingly becoming participants in global-scale hydrologic research cooperating with hydrologists, climatologists, geologists and other scientists who study soil from non-agricultural point.

1.1 Soil Components

The four major components or constituents of soil are:

a). Mineral matter, b). Organic matter, c). Water and, d). Air

1.2 Soil Phase

Phase is portion of a system with definite geometrical boundaries and uniform properties.

Soil has three major phases:

- Solid phase
- Liquid phase
- Gaseous phase

Solid phase: Solid phase is the most dominant with great influence over the behaviour of other two phases. The solid phase is the soil matrix or skeleton of the soil. It is the product of weathering of parent rocks/materials and materials which they contain. The solid phase consists of mineral matter and decomposed or decomposing organic matter of all shapes, sizes and arrangement.

Liquid phase: This is primarily water, i.e. soil solution containing various ions such as Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, NO_3, SO_4^{2-}, etc.

Gaseous phase: This is the soil air. It composed of N_2, O_2, CO_2 and H_2O (vapour) mainly. Other gases in the atmosphere are also present in the soil. Others also like CH_4, H_2S which are by-products of impeded drainage condition could be found in the soil.

2.0 SOLID PHASE

2.1 Surface Relationship

Soil specific surface is used to describe the extent of the surface of the dispersed soil system. It is defined as the sum of the surfaces of constituent dispersed soil particles referred to unit mass or unit volume of the soil. Specific surface is a geometrical concept which is strongly dependent on the degree of dispersion of the soil, i.e. soil texture. Thus,

Specific surface of soil (A_m) or (A_v):

$$= \frac{total\ surface\ area\ of\ soil}{Mass\ or\ Volume\ of\ soil} = \frac{A_S}{M_S\ or\ V_S}$$

Units: $A_m = A_s/M_s$ (cm^2/g) or (L^2/M)

$A_v = A_s/V_s$ (cm^2/cm^3)

The relationship between A_m and A_v:

From $\rho_s = M_s/V_s$

$M_s = \rho_s V_s$

$\therefore A_m = A_s/ \rho_s V_s$

$= A_s/V_s \times 1/\rho_s$

$= A_v/\rho_s$

where ρ_s = average density of soil particle i.e. 2.65 g cm^{-3}

NOTE: Most soil physical and chemical reactions occur at the surface, and the amount of these reactions is directly proportional to the specific surface.

Factors influencing specific surface:

- Size

- Shape
- Mineralogy of the soil or material

(a) Particle Size:

Side of cube (cm)	**NO. of Particles in $1cm^3$**	**Surface of single particle (cm^2)**	**Total (cm^2)**	**Specific surface of 1 g particle where** ρ_s = 2.65 g cm^{-3}
1	1	6	6	A_m = $6cm^2$/2.65 g = 2.26 cm^2/g
10^{-1}	10^3	6 x 10^{-2}	60	2.26 x 10 cm^2/g
10^{-5}	10^{15}	6 x 10^{-10}	6 x 10^5	2.26 x 10^5 cm^2/g

(b) Particle Shape:

(i) Sphere with diameter d:

$$A_v = A_s/V_s$$

Area of sphere = $4\Pi r^2 = \Pi d^2$ Note: $r^2 = (d/2)^2 = d^2/4$

Volume of sphere = $4/3\,\Pi r^3 = \Pi d^3/6$

$A_v = \Pi d^2/(\Pi d^3/6)$

$= 6/d$

$A_m = A_v/\rho_s$, and assume $\rho_s = 2.60$ g cm^{-3}

$A_m = 2.3/d$

(ii) Cube of edge L:

$A_v = 6L^2/L^3 = 6/L$

$\therefore A_m = 2.3/L$

2.2 Soil Texture

Definition: Soil texture is relative proportion of different sized groups in the soil on percentage basis. It describes the sand, silt and clay composition of a soil.

Soil Textural Class: Grouping based on relative proportion and specifically on % sand, silt and clay in given soil sample. The class name essentially describes the separate which most influence the sample physical/chemical/biological properties.

2.3 Soil Structure

The term structure relates to the arrangement of primary soil particles into groupings called AGGREGATES or PEDS. The pattern of pores and peds defined by soil structure greatly influence water movements, heat transfer, aeration and porosity in soils.

Types of Soil Structure:

Different types of structural peds in soils occur within horizons of soil profile. Soil structure is characterized in terms of shape (type or form), size and distinctiveness (grade) of the peds.

GRADE: Describes the distinctiveness of the peds (differential between cohesion within peds and adhesion between peds). It relates to the degree of aggregation or the development of soil structure. In the field a classification of grade is based on a finger test (durability of peds) or a crushing of a soil sample.

FORM: Is classified on the basis of the shape of peds, such as spheroidal, platy, blocky, or prismatic. A granular or crumb structure is often found in A horizons, a platy structure in E horizons, and a blocky, prismatic or columnar structure in Bt horizons. Massive or single-grain structure occurs in very young soils, which are in an initial stage of soil development. There may two or more structural arrangements occurring in a given profile. This may be in the form of progressive change in size/type of structural units with depth (e.g. A horizons that exhibit a progressive increase in size of granular peds that grade into subangular blocks with increasing depth) or occurrence of larger structural entities (e.g. prisms) that are internally composed of smaller structural units (e.g. blocky peds).

The four principal shape of soil structure are: (i) Spheroidal; (ii) Blocklike; (iii) Prismlike; and (iv) Platy.

(i) Spheroidal: We have (a) Granular structure and (b) crumb structure. The granular structure consists of spheroidal peds or granules that are usually separated from each other in loosely packed arrangement. When the spheroidal peds are porous, they are classified as **crumbs.**

(ii) Blocklike: Blocky peds are irregular, roughly cubelike in shape and range from about 5 to 50 mm across. When the edges of the blocks are sharp and the rectangular faces are distinct, the subtype is referred to as **angular blocky.** When the corners are round and the edges are sharp, then it is called **subangular blocky.**

(iii) Prismlike: This has two sub-types namely (a) Columnar and (b) Prismatic.. Columnar structure has pillars with distinct, rounded top and this is especially common in subsoils high in Na^+. When the tops are of the prisms are relatively angular and flat horizontally, the structure is designated as Prismatic.

(iv) Platelike: Platy structure is characterized by relatively horizontal peds or plates and may be found in both surface and subsurface horizons. The horizontal axes are longer than vertical, i.e. horizontal cleavage planes predominate.

3.0 Soil Consistency

Definition: Soil consistency describes the state of the soil, i.e. solid, plastic and liquid states.

OR:

- Ability of soil to keep its place or maintain its form when stress is applied.
- Soil consistence (or consistency) refers to the manifestations of the physical forces of cohesion and adhesion acting within the soil at a range of soil moisture contents.

Adhesion refers to the attraction between dissimilar objects, i.e. to the attraction of water to the soil solids. While cohesion is attraction between similar objects, i.e. bonding between soil particles. Cohesive forces in soil are due to attractive forces between the particles.

These forces are due to physicochemical mechanisms including:

- van der Waals forces
- Electrostatic attraction between negatively charged clay surfaces and positively charged clay edges

- Cationic bridges,
- Cementing effects of humic substances and salts, and
- Surface tension of water

Soil consistence encompasses several attributes including friability, tilth, plasticity, stickiness, and resistance to compression.

4.0 Soil Strength and Compaction

Soil strength is an important soil physical property, with numerous applications to agronomy and engineering. Important agronomic applications are those related to impacts of crusting and compaction on plant growth and agronomic yield.

Surface crust / seal

Soil crust or surface seal, refers to the thin dense layer on the soil surface characterized by low porosity, high density, and low permeability to air and water. Crusting is a soil surface phenomena caused by susceptibility of aggregates at the soil-air interface to disruptive forces of climatic elements (the impact of raindrops) and perturbations caused by agricultural practices (e.g., tillage, traffic and trampling action of livestock or humans). Slaking, deflocculation, or dispersion of aggregates on rapid wetting or submersion in water, is attributed to numerous factors including the effect of entrapped air, predominance of Na^+ on the exchange complex, and weak aggregate strength caused by low level of soil organic matter content and weak ionic bonds.

Crusting has adverse impacts on seedling emergence and growth. Preventative measures are based on strategies of enhancing aggregation, improving soil structure, and minimizing the disruptive effects of raindrop impact.

Hardsetting

"Hardsetting" refers to a process in which soils set hard into a structureless mass following drying. When dry and set hard, these soils have a high bulk density, high penetration resistance, high strength, and are difficult to plow or dig. Hard setting soils have a narrow range of workable soil moisture content.

Hardsetting soils have a weakly developed structure characterized by: (i) low aggregation, (ii) aggregates prone to slaking and dispersion, (iii) low infiltration rate, and (iv) high runoff and erosion.

There are some soil attributes that make it susceptible to hardsetting. Hardsetting soils have textural properties ranging from loamy sand to sandy clay, low swell-shrink capacity, low soil organic matter content, and predominantly low activity clays.

Hardsetting behavior has numerous limitations with regards to timings of cultivation, restricted root growth, and poor yield. Management of hardsetting soils involve techniques that improve aggregation and aggregate strength. These techniques include use of residue mulch, no-till or conservation tillage, cover crops, etc.

Stress-strain relationship

Soil strength is the soil's ability to bear or withstand stress without collapsing or deforming excessively. Soil strength is attributed to forces of cohesion and adhesion and varies with soil moisture content. When subjected to external force or stress (i.e., force per unit area), soil undergoes different types of deformation or strain.

Soil Porosity

Soil porosity refers to the relative volume of voids or pores, and is therefore expressed as a fraction or percent of the total volume or of the volume of solids. Soil porosity can be expressed as, *Total porosity;* Air-*filled porosity*