

SS-301 INTRODUCTION TO SOIL SCIENCE 3(2-1)

Course for Mid Examination

- Introduction to earth, soil and disciplines of soil sciences
- Introduction to environment, environmental sciences and its components; lithosphere, hydrosphere, atmosphere and biosphere
- Soil forming rocks and minerals: types and their formation
- Weathering: Definition, agents and classification
- Parent materials: Definition and types
- Soil formation: Definition, specialized soil development processes and factors

Course for Final Examination

- Soil profile: Definition and description
- Soil physical properties; soil texture, soil structure and significance of these
- Soil bulk density, particle density and significance
- Soil porosity, aeration and significance
- Soil temperature, consistency and significance
- Introduction to soil and land capability classification

Course for Practical Examination

- Experiment: Method of soil sampling, preparation, labeling and storage
- Experiment: Preparation of Saturated Soil Paste
- Experiment: Determination of Soil Saturation Percentage
- Experiment: Determination of Soil water content
- Experiment: Determination of Soil Texture with different method
- Experiment: Determination of soil bulk and particle density
- Experiment: Method of water sampling, preparation, labeling and storage
- Experiment: Determination of Electrical Conductivity (EC)
- Experiment: Calculation of Total Soluble Salts (TSS) or Total Dissolved Solids (TDS) in Irrigation Water
- Experiment: Determination of SAR and RSC
- Experiment: Determination of cations and anions
- Experiment: Interpretation of results and report writing

INTRODUCTION TO EARTH, SOIL AND DISCIPLINES OF SOIL SCIENCES

SOIL SCIENCE

Soil is the unconsolidated upper part of the earth's crust which serves as a natural medium for the growth of plants. It is dynamic in nature and composed of mineral and organic materials, water, air and living forms (plants and animals) that support plant growth.

For agriculturist **soil** is a habitat for plants. However, there are different concepts and viewpoints regarding soil in various scientific disciplines.

For instance, what a soil scientist considers **soil**, a civil engineer may call it **earth** or foundation material for constructing roads and buildings; and an economist may call it **land**.

In any ecosystem, whether your backyard, a farm, a forest, or a regional watershed, soils have six key roles to play:

1. Soil supports the growth of higher plants mainly by providing a medium for plant roots and supplying nutrients.
2. Soil properties are the principal factor controlling the fate of water in hydrological system
3. Soil functions as nature's recycling system.
4. Soils provide habitats for living organisms.
5. Soils markedly influence the composition and physical condition of the atmosphere.
6. In human-built ecosystem, soil plays an important role as engineering medium/materials.

Soil Science is a branch of science/agriculture that deals with soils as a natural resource on the surface of earth. It includes the study of soil formation, classification and the physical, chemical, biological and fertility properties of soils in relation to their management for growth of plants and sustaining a clean environment.

BRANCHES/DISCIPLINES OF SOIL SCIENCE

Soil Chemistry: It is the study of chemical composition of a soil and the chemical reactions occurring in the soil.

Soil Genesis: It deals with the study of mode of origin of the soil in relation to soil forming processes and factors.

Soil Classification: It is the study of systematic arrangement of soils into groups or categories on the basis of their characteristics.

Soil Physics: It deals with the physical properties of a soil and physical processes occurring in the soil.

Soil Fertility: It deals with the ability of the soil to supply nutrient that are essential for plant growth.

Soil Microbiology: It is the study of micro-organisms inhabiting the soil, their functions and activities in relation to plant growth and environmental health.

Soil Mineralogy: It is the study of minerals occurring in the soil.

Soil Salinity: It is the study of salt affected soils, their effects on plant growth, their management and amelioration/reclamation.

Soil Survey: It is the systematic examination, description, classification and mapping of soils in a specific area.

Soil Morphology: It is the branch of soil science that deals with the visual observations of morphological features of a soil.

INTRODUCTION TO ENVIRONMENT, ENVIRONMENTAL SCIENCES AND ITS COMPONENTS; LITHOSPHERE, HYDROSPHERE, ATMOSPHERE AND BIOSPHERE

ENVIRONMENTAL SCIENCE

Environment is all the external factors that affect an organism or group of organisms during its lifetime.

Environmental science is an interdisciplinary field that integrates physical and biological sciences to the study of the environment, and the solution of environmental problems.

BRANCHES OF ENVIRONMENTAL SCIENCE

Atmospheric Sciences: It studies the Earth's gaseous outer layer with relation to other systems. e.g. greenhouse gas phenomena

Environmental Ecology: It studies the interaction of populations with the environment.

Environmental Chemistry: It is the study of chemical alterations in the soil, water and air environments and their remediation.

Environmental Microbiology: It is the study of the composition and physiology of microbial communities and their transformation processes in the environment.

Further Reading:

Brady, N.C. and R.R. Weil. 2008. The Nature and Properties of Soils, 14th Ed. Prentice Hall, NJ, USA.

FOUR SPHERES OF EARTH

The area near the surface of the earth can be divided up into four inter-connected "geospheres:" the lithosphere, hydrosphere, biosphere, and atmosphere. Scientists can classify life and material on or near the surface of the earth to be in any of these four spheres.

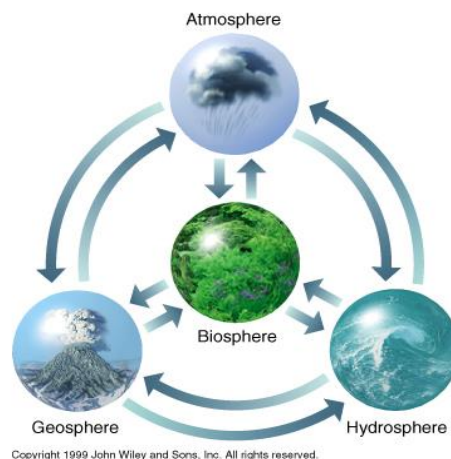


Figure 1

Lithosphere (Geosphere)

The lithosphere is the solid, rocky crust covering entire planet. This crust is inorganic and is composed of minerals. It covers the entire surface of the earth. The lithosphere is also called as Geosphere.

Hydrosphere

The hydrosphere is composed of all of the water on or near the earth. This includes the oceans, rivers, lakes, and even the moisture in the air. Ninety-seven percent of the earth's water is in the oceans. The remaining three percent is fresh water; three-quarters of the fresh water is solid and exists in ice sheets.

Biosphere

The biosphere is composed of all living microorganisms. Plants, animals, and microorganisms are all part of the biosphere.

Atmosphere

The atmosphere is the body of air which surrounds our planet. This gaseous envelop is most dense at sea level and rapidly decreases with increasing altitude. It is an important geological agent. It acts as a thermal blanket, captures heat and supply snow and rain water.

The air of our planet is about 78% nitrogen and about 21% oxygen; the small amount remaining is composed of carbon dioxide (0.03%) and other gasses such as neon, helium, krypton, xenon, water vapours, dust particles and hydrocarbons etc.

Earth's cycles and spheres are interconnected (Figure 1). All four spheres can be and often are present in a single location. The importance of soil as a natural body derives in large part from its role as an interface between the above four spheres of earth. This interface where the worlds of rock (lithosphere), air (atmosphere), water (the hydrosphere), and life (biosphere) all meet, is termed as **pedosphere** or soil. For example, a piece of soil will of course have mineral material

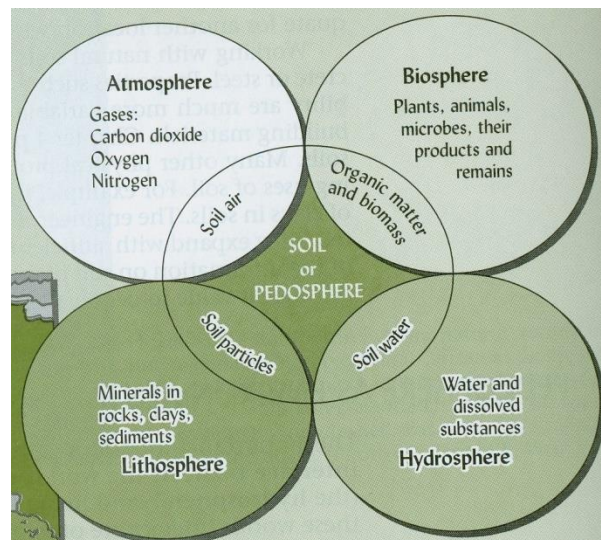


Figure 2

from the lithosphere.

Additionally, there will be elements of the hydrosphere present as moisture within the soil, the biosphere as insects and plants, and even the atmosphere as pockets of air between soil pieces (Figure 2).

Further reading: Brady, N.C. and R.R. Weil. 2008. The Nature and Properties of Soils, 14th Ed. Prentice Hall, NJ, USA.

SOIL FORMING ROCKS AND MINERALS: TYPES AND THEIR FORMATION

MINERALS AND ROCKS

Minerals and rocks are the most common material of the earth. This section briefly describes the definition of mineral and rock, and types of minerals and rocks.

Mineral

Mineral is a natural inorganic substance of definite chemical composition and generally with a definite crystal form. All minerals except water and mercury are solids at normal temperature.

Types of Minerals

1. Primary minerals: Minerals that have not been altered chemically since deposition and crystallization from molten lava.

Examples: Quartz, feldspar, mica etc.

2. Secondary minerals: Minerals resulting from the decomposition of a primary mineral or from the re-precipitation of the products of decomposition of primary minerals.

Examples: Calcite, gypsum, dolomite etc.

ROCKS

Rock is defined as a natural aggregate of one or more minerals to form an appreciable part of the solid portion of the earth.

Types of Rocks

The rocks are classified into three types according to their origin

1. Igneous rocks
2. Metamorphic rocks
3. Sedimentary rocks

1. Igneous rocks

Rocks formed by the cooling and solidification of extremely hot molten material (lava) are called igneous rocks.

Geologists consider that igneous rocks were the first rocks formed on the earth whereas sedimentary and metamorphic rocks originated from igneous rocks.

The word igneous is derived from a Latin word meaning fire, which provides a clue to the origin of the rocks. Many areas of the earth contain points of weakness in the crust, and sometimes the molten material within the earth forces its way through these points of weakness and appears on the surface. Once the molten material has escaped from the conditions of high temperature and pressure which exist under the surface, it begins to cool down. Eventually the flowing material slows down, comes to a stop and solidifies and becomes a solid igneous rock.

The characteristics of igneous rocks are determined by the composition of the original material from which it was formed.

EXAMPLES: Granite, Gabbro and Basalt.

2. Sedimentary rocks

Sedimentary rocks are formed from the layers of accumulated sediments.

Pre-existing rocks of any group (igneous, metamorphic and sedimentary) are broken down by the continuous process of weathering to form debris known as sediments. The process continues over millions of years and the early sediments are gradually buried and more sediment accumulates. The accumulated sediment is finally compacted through the weight of the sediment layers one above the other, the water squeezes off and the minerals become cemented.

In the process of sedimentary rocks formation, layers of sediments are built up layer by layer. Layering is therefore a fundamental characteristic of these rocks. Each layer is separated

from the one above and the one below by a line of demarkation known as bedding plane. This generally represents the sudden change in the grain size or in the composition of the sediment being laid down.

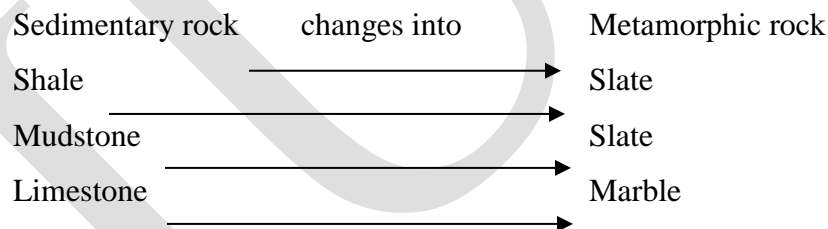
EXAMPLES: Shale, mudstone and limestone.

3. Metamorphic rocks

Meta means change and Morph means shape or form. Therefore, metamorphic rocks are those rocks which are formed due to change in shape of pre-existing igneous or sedimentary rocks under very high temperature and pressure. The process of change is called metamorphism. Under extremes of heat and pressure, physical and chemical changes occur in pre-existing rocks and this process of metamorphism generally occurs deep within the earth's outer layers. Because of this, most metamorphic rocks are revealed after a considerable amount of erosion has taken place.

Both sedimentary and igneous rocks can be changed into new rock types by the process of metamorphism.

FOR EXAMPLE: The metamorphic rock slate is derived from sedimentary shales and mudstone whereas sedimentary limestone can be metamorphosed into marble.



WEATHERING: DEFINITION, AGENTS AND CLASSIFICATION

WEATHERING

Weathering is a process in which different physical and chemical changes are produced in rocks at or near the earth's surface by atmospheric agents. There are two basic weathering processes.

1. **Mechanical/Physical weathering (disintegration):** It causes decrease in size of rocks and minerals without appreciably affecting their chemical composition.

- 2. Chemical weathering (decomposition):** It is a process in which chemical changes take place in rocks and minerals. In this process soluble materials are released, new minerals are synthesized and some resistant products remain as such.

Mechanical/Physical Weathering (Disintegration)

Temperature

Rocks heat up during the day and cool down at night, causing alternate expansion and contraction of their constituent minerals. As some minerals expand more than others, temperature changes set up differential stresses that eventually cause the rock to crack apart. Further the outer surface of a rock is often warmer or colder than the inner resulting in the peeling away of outer layers. This process is called **exfoliation**.

Abrasion by Water, Wind, and Ice

When flowing water is loaded with sediments, it has tremendous cutting power. These sediments colloid with each other and breakdown into smaller particles. The rounding of riverbed rocks and beach sand grains is an evidence of the abrasion that accompanies water movement.

Wind-blown dust and sand can break down rocks by abrasion in certain arid regions. In glacial areas, huge moving ice masses carrying soil and rock fragments, grind down rocks in their path and carry away large volumes of material.

Action of Microorganisms, Plants and Animals

Lower plants like mosses, lichens grow on exposed rocks, catch dust particles, accumulate organic matter and encourage further plant growth. Pressure by roots of higher plants assist disintegration by opening up spaces for the penetration of water which may freeze and expand later.

Burrowing animals such as earthworms, ants and rodents and also hooved animals through their action contribute slowly to the disintegration of rocks. Humans accelerate the slow process of physical weathering by ploughing and cultivating.

Chemical Weathering (Decomposition)

Hydration: It is the addition of water molecule in chemical combination with a mineral to form hydrated compounds. Hydrated minerals are more prone to decomposition due to their increased volume which makes it softer and more stressed.

Hydrolysis: In hydrolysis reactions, water molecules split into their hydrogen and hydroxyl components and the hydrogen often replaces a cation from the mineral structure.

Dissolution: Water dissolves many minerals by hydrating the cations and anions until they become dissociated and surrounded by water molecules. These dissolved minerals are converted into solution form which permits greater chemical changes than could occur in an unionized (generally solid) state.

Acid reactions: Weathering is accelerated by the presence of acids, which increase the activity of hydrogen ions in water. Soils contain stronger acids, such as nitric acid (HNO_3), sulfuric and (H_2SO_4), and many organic acids like carbonic acid. Hydrogen ions are also associated with soil clays. Each of these sources of acidity is available for reaction with soil minerals resulting in enhanced weathering.

Oxidation-reduction: Minerals that contain iron, manganese, or sulfur are especially susceptible to oxidation-reduction reactions. The variation in oxidation-reduction ability cause weathering.

The various chemical weathering processes occur simultaneously and are interdependent.

PARENT MATERIALS: DEFINITION AND TYPES

PARENT MATERIALS

Unconsolidated product of weathering from which soil develops is called parent material.

Generally there are two groups of parent materials, i.e. sedimentary and transported. The transported materials are further subdivided according to transporting agency and place of deposition.

A. Sedimentary or Residual: The parent material formed in place and still at the original site.

B. Transported: The parent material carried and deposited by various transporting agencies.

1. By gravity- Colluvial
2. By water- Alluvial
3. By ice- Glacial
4. By wind- Eolian

The nature and properties of parent material together with climate are the most important factors affecting the kind and quality of soils. So to understand soils we must know the sources of parent material, mechanisms of weathering and transporting agencies.

A. Sedimentary or Residual Parent Material

This material develops in place from the rocks, generally by long and intense weathering. In warm humid climate, it is well oxidized and leached of basic cations (Na, K, and Ca). It has red and yellow colors due to oxidation of iron. In cooler and drier climates, weathering is less intense; leaching of basic cations does not take place. In Pakistan pothohar plateau is covered with such materials. The nature of these materials depends upon the nature of rocks from which these materials have formed.

B. Transported Materials

1. Colluvial deposits:

A material transported by gravity that has been deposited at the base of foothills or mountains. These deposits are extremely variable in composition. Soils developed from these parent materials may be coarse and stony because physical rather than chemical weathering is dominant. This material has good drainage.

2. Alluvial deposits:

The material which has been transported/deposited by river and streams is termed as alluvium.

Alluvial soils are finely layered to great depths, which shows marked changes horizontally. This is somewhat sandy near river bank to clayey away from river bank. These soils are generally level, fertile and highly productive, however if clayey there may be drainage problem.

3. Glacial deposits

This refers to all the materials of glacial origin, whether deposited directly by the ice or by associated water. It consists of heterogeneous mixture of debris, varying in size from coarse fragments to clay particles.

4. Eolian deposits

These are materials carried and deposited by wind. Such windblown materials are differentiated into loess, sand dunes, adobe and volcanic ash depending upon the type of original material that was subjected to such actions.

a. Loess

It is generally silty in nature with some sand and clay. Mostly Pakistani soils are alluvial in nature; however some soils are formed from loess. Loess generally forms productive soils and these soils are quite open and porous.

b. Sand dunes

This is the sandy materials carried and deposited by wind. The coarse particles deposit near the source and accumulate in the form of sand dunes.

c. Adobe

It is similar to loess but calcareous in nature.

SOIL FORMATION: DEFINITION, SPECIALIZED SOIL DEVELOPMENT PROCESSES AND FACTORS

SOIL GENESIS / SOIL FORMATION

It is mode of origin of soil. Soil formation means both the production of parent material and soil profile development. The process of weathering and soil profile development occur simultaneously.

The formation of soil happens over a very long period of time. It may take thousands of years. Soil is formed as results of weathering of rocks and minerals. The surface rocks break down into smaller pieces through a process of weathering and is then mixed with organic matter. Over time this creates a thin layer of soil and then lower plants grow and soil development is enhanced. Later on higher plants grow and attract animals. When the plants and animals die, their bodies decay/decompose. Decaying matter makes the soil thick and rich. This continues until soil is fully developed.

Factors of Soil Formation

1. Parent material

Parent material is the unconsolidated initial material from which soils develop. The nature of parent material greatly influences soil characteristic. Parent material influence soil formation by its following properties/characteristics:

- a. rate of weathering
- b. the nutrients
- c. the particle size

For example sandstones give rise to sandy and shale's to clayey soils. The less the soil developed the grater will be the effect of parent material on the soil properties.

Parent material also influences the quantity and type of clay minerals present in soil profile. Soil developed from potassium rich parent material may have illite as the dominant clay mineral.

2. Climate

Climate is the average weather conditions at a particular place over a period of time as determined by temperature, precipitation, wind velocity and other morphological factors.

Climate is the dominant factor of soil formation because of the effects of:

- temperature
- rainfall
- wind

These sub-factors affect the rate of chemical, physical and biological processes that are responsible of soil development. The biochemical changes are sensitive to temperature. These changes are favored by temperature range of 20-30°C. Temperature also influences the organic matter content of the soil. Decomposition of organic matter is more at higher temperatures. That is why organic matter is generally low in soils of dry regions like Pakistan.

Moisture is another important factor in soil formation. Rainfall is the major source of moisture. In areas receiving low rainfall, there is shallow accumulation of carbonates in the soil, in humid areas, acid soils are developed under conditions of intense weathering and leaching. Erosion caused by water may remove upper fertile portion of soils and may deposit

it at some other places. A soil is said to be developed when it has detectable layers (horizons), such as accumulated clays, organic colloids, or soluble salts that have been moved by water.

Wind can affect soil development through erosion as it may decrease the depth of soil developed and may damage the vegetation. In sandy areas like Cholistan the destructive effects of winds are more pronounced.

Climate also influences the natural vegetation. In humid regions, high rainfall provides an environment favorable for the growth of trees. In contrast, grasslands are dominant with native vegetation in semi arid regions and shrubs of various kinds in arid areas. In these areas the vegetation is not dense enough to protect soil from wind and water erosion.

3. Living organisms

The activities of living plants, animals and the decomposition of their wastes and residues have marked influence on soil development. Soil organisms play a major role in soil profile differentiation through

- Organic matter accumulation
- Profile mixing
- Nutrient cycling
- Soil structure stability

Burrowing animals such as moles, earthworms, ants, and termites are highly important when they exist in large numbers. Soils having large numbers of these animals have fewer but deeper horizons because of the constant mixing within the soil profile. Microorganisms present in the soil attack plant and animal residues producing organic materials. These microorganisms along with an abundance of plant roots help to bind soil particles into stable aggregates. Similarly, certain microorganisms can fix atmospheric nitrogen into compounds useable by plants.

4. Topography

Topography is the difference in elevation or slope between the uplands and low lands of a valley or it is the earth's surface contour.

Topography of a land can hasten or delay the work of climatic forces. In smooth and flat surfaces excess water is removed less rapidly than in areas of steep slopes. Soils having steep

slopes encourage natural erosion of the soil surface which reduces the possibilities of the development of a deep soil. On the other hand, if water remains available for part or all of the year on gentle slopes there will be more vegetation and organic matter accumulation resulting in the development of a deep soil profile.

Topography also determines the type and amount of vegetation. e.g. in northern hemisphere, higher plants and more vegetation is present on north facing slopes but scarce and small shrubs are present on the south facing slopes.

5. Time

The time required for a soil to develop the distinct layers (horizons) depends upon all other factors of soil formation (climate, nature of parent material, living organisms and topography). Horizons tend to develop more rapidly under warm, humid and forested conditions where there is enough water to move clay, humus and other colloids downward. Under ideal conditions, recognizable soil profile may develop within 200 years, under less favorable conditions, the time may extend to several thousand years.

Basic Processes of Soil Formation

During soil formation, the unconsolidated weathered material under goes many changes. These changes are brought about by variations in the four basic soil forming processes. These four basic processes often referred as soil forming or Pedogenic processes. They are responsible of soil formation under all kind of environments. These processes are

1. Addition

Inputs of materials to the developing soil profile from outside sources are considered additions. For example, fallen plant leaves, twigs, dust, animal dung, salts or silica dissolved in groundwater and deposited near or at the soil surface when rising water evaporates.

2. Losses

Materials are lost from soil profile by leaching to groundwater, erosion of surface material, or other forms of removal. Leaching causes the loss of water and dissolved substances such as salts or silica, weathered from parent materials. Grazing of animals or harvest by people can remove large amounts of both organic matter and nutrient element.

3. Transformation

It involves the physical or chemical modification of soil constituents i.e some materials are broken down and others are synthesized. For example, weathering of primary minerals results in disintegration and alteration of various kinds of silicate clays. As primary minerals decompose, the decomposition products recombine to form new minerals which include additional type of silicate clays and hydroxides of iron and aluminum. The decomposition of organic residues gives rise to organic acids, humus and other products

4. Translocation

It involves the movement of inorganic and organic material laterally within a horizon or vertically from one horizon up or down to another. Water, either percolating down with gravity or rising up by capillary action is the most common translocation agent. The material moved within the profile includes dispersed clay particles, dissolved salts and dissolved organic substances.

Soil organisms also play a major role in translocation of soil material e.g. Incorporation of surface organic matter into A and B horizons by certain earth worms, transport of B and C horizon to the surface by termites and rodents.



Fig. 1: Sketch of a typical soil profile showing different master horizon.

SOIL PROFILE: DEFINITION AND DESCRIPTION

SOIL MORPHOLOGY

Soil morphology is the visual observation of morphological features of soil i.e. soil color, texture and structure of horizons and arrangement of these horizons in the soil profile. This can be studied in the field by the naked eye (macromorphology), with the aid of hand lens and binocular stereoscope (mesomorphology), with the electron microscope (micromorphology).

Soil Profile

A vertical section of the soil showing different layers (horizons) and extending into the C-horizon or parent material (R layer).

Horizon

A layer of soil, approximately parallel to the soil surface, having different properties and characteristics from adjacent layers below or above it.

Description of a Typical Soil Profile

A common sequence of horizons within a profile comprises of five master soil horizons, i.e., O, A, E, B and C. Distinctions within these master horizons are designated by the subscripts to indicate subordinate distinction within the master horizons and layers e.g., A_p, B_t, etc.

Different master horizons or layers that might occur in a soil profile are described briefly in the form of a diagram.

O Horizon (Organic): The O horizon is comprised of organic material that forms above the mineral horizon. This result from litter derived from dead plants and animals. O horizon usually occurs in forested areas and is generally absent in grassland regions.

A Horizon: Mineral horizon that forms at the surface or below an O layer. A horizon shows one or more of the followings:

1. An accumulation of humified organic matter intimately mixed with the mineral fraction results darker in color than that of the lower horizons
2. Not dominated by characteristics/properties of the E or B horizons.
3. Have properties resulting from cultivation, pasturing or other similar kinds of disturbance.

E Horizon:

1. Mineral horizon from which silicate clay, iron, aluminum or some combination of these have been eluviated (leached).
2. Sand and/or silt sized quartz or other resistant minerals remain there and become concentrated.
3. An E horizon is generally lighter in color than the A horizon and is found below the A horizon.

Eluviation: It is the movement of materials out of a portion/layer of soil profile as in E horizon.

B Horizon:

1. Horizon that forms below an O, A or E horizon and shows illuviation (accumulation) of material from above E horizon.
2. In humid regions, B horizon shows the accumulation of Fe/Al oxides, silicate clays and humus.
3. In arid and semiarid regions, calcium carbonate and calcium sulfate and other salts may accumulate in B horizon.

Illuviation: It is the movement of materials into a portion/layer of soil profile as in B horizon.

C Horizon:

1. Unconsolidated material underlying the solum (A, E & B horizons).
2. Mineral horizon or layer (not bedrock) relatively unaffected by pedogenic processes, and lacking the properties of O, A, E, or B horizons.
3. May be like or unlike the parent material from which solum of soil develops.

R Layer (Bedrock): It is of hard bedrock, not practically diggable with a spade and shows no or little evidence of weathering.

Transitional Horizons

Transitional horizons are layers of the soil between two master horizons. These exhibit properties of both the master horizons e.g. AB and BA.

SOIL CLASSIFICATION/TAXONOMY

SOIL CLASSIFICATION

Some sort of grouping is necessary to study any heterogeneous mass in nature. It is especially true for soils as they vary greatly from place to place. **Soil Classification** is the systematic grouping of soils into various categories based on mainly morphological, mineralogical and some chemical characteristics. **While Soil Taxonomy** is the science that deals with laws and principles of soil classification.

Categories of Soil Classification

There are six categories of classification.

These are 1) order 2) suborder 3) great group 4) subgroup 5) family 6) series.

- 1) Orders (12)
- 2) Suborders (54)
- 3) Great Groups (211)
- 4) Subgroups (1,100+)
- 5) Family (7,000+)
- 6) Series (a lot!)

Order is the most generalized category. All soils in the world fit into one of the twelve orders. The names of orders and their significant features are given below.

1. Aridisols: Soils of dry regions
2. Entisols: Recently formed soils
3. Inceptisols: Moderately weathered soils
4. Alfisols: High base status soils
5. Mollisols: Dark organic soils
6. Vertisols: Shrinking and swelling dark clay soils
7. Ultisols: Low base status soils (Acid soils)
8. Oxisols: Highly weathered soils
9. Spodosols: Soils, with subsoil accumulations of humus and sesquioxides
10. Andisols: Generally soils of volcanic origin
11. Histosols: Organic soils
12. Gelisols: Frozen soils

The extent of six orders which occur in Pakistan is as under:

Aridisols > Entisols > Inceptisols > Alfisols > Vertisols.

Suborder

Grouped by similarities in soil formation such as wetter/dryer soil, colder/warmer soil, etc.

Great Groups

Based on differences between soil horizons

Sub Groups

Describes a profile characteristic, wetness, sand

Family

Based on soil properties that affect management and root penetration, such as texture, temperature and depth

Series

Named from the town or landscape feature near where the soil was first recognized (Lester = Lester Prairie, MN. Other examples = Clarion, Nashwauk, Milaca, Port Byron, Zimmerman. Le Sueur for Le Sueur County, MN.)

SOIL PHYSICAL PROPERTIES; SOIL TEXTURE, SOIL STRUCTURE AND SIGNIFICANCE OF THESE

PHYSICAL PROPERTIES OF SOILS

The soil properties that we can see or feel which are relatively more permanent than chemical properties are called physical properties of soil. Such properties are difficult to change. Soil physical properties include texture, structure, particle and bulk density, porosity, air and water content, consistency (strength), color and temperature.

Soil Texture

It refers to the relative proportions of the three primary soil separates (sand, silt, and clay).

Soil separates and their diameter ranges

International Society of Soil Science (ISSS)	
Soil separate name	Diameter range (mm)
Coarse sand	2.0-0.2
Fine sand	0.2-0.02
Silt	0.02-0.002
Clay	Less than 0.002

Significance of soil texture

Texture is important because it will, in part determine the ease of tilling the soil, the amount of aeration (necessary for root growth), water intake rates (absorption) and water storage in the soil. It also influences soil fertility. For example, a fine textured clayey soil is difficult to till, has poor aeration for good root growth, difficult to wet and difficult to drain but it can retain more nutrients and water. A coarse sandy soil is easy to wet, easy to drain and easy to till, has good aeration but loses more plant nutrients by leaching.

Soil Structure

The term structure relates to the clustering (grouping) or arrangement of primary soil particles into secondary particles or units called peds or aggregates e.g. Plate like, Block like and Granular.

Importance of soil structure

Soils with good physical condition (tilth) are important to good yield. The formation and maintenance of stable aggregates is the essential feature of soil tilth. The rate of water infiltration, water-holding capacity, heat transfer, aeration, porosity and root development are greatly influenced by soil structure. For instance, both granular and single-grain (structure less) soils have rapid infiltration rates, prismatic and blocky soils had medium rates and platy and massive soil conditions have slow infiltration rates.

Aggregated soil is generally the most desirable condition for plant growth, particularly in the critical early stages of germination and seedling establishment. The continued existence of large pores in the soil depends on the stability of the aggregates.

SOIL BULK DENSITY, PARTICLE DENSITY AND SIGNIFICANCE

Particle Density

Particle density of soils refers to the ratio of total mass of the solid particles to their total volume excluding pore spaces (between particles). In technical work, its units are mega-grams per cubic meter (Mg/m^3) or grams per cubic centimeter (g/cm^3) or kilogram per cubic meter (kg/m^3).

Particle density for most mineral soils usually varies between 2.60 and 2.70 Mg/m^3 . However, the standard value used in calculations is 2.65 Mg/m^3 if actual particle density is not known.

Bulk Density

It is defined as the mass of dry soil solids per unit bulk volume. Bulk volume means the volume of the soil particles plus pore space. So the density for a volume of soil as it exists naturally is called bulk density. The value is expressed in Mg/m^3 or g/cm^3 or kg/m^3 ($1 g/cm^3 = Mg/m^3$).

Significance of bulk density

1. The bulk density of soil is used for estimating the mass of a volume of a soil too large to weigh. For example, the average weight of soil for a hectare or acre area per unit depth is calculated by multiplying the soil volume by its bulk density.
2. It is needed for converting water percentage by weight to content by volume.
3. It is also used for calculating porosity when the particle density is known.
4. It can indicate the differences in compaction of a given soil resulting from heavy tillage equipment on wet clayey soil.
5. Plant roots of field crops are hindered by soils high in bulk density but to varying degrees.

SOIL POROSITY, AERATION AND SIGNIFICANCE

Pore Space

The pore space of a soil is the portion of soil bulk volume occupied by soil pores (or by air and water). So it consists of that portion of the soil volume not occupied by solids, either mineral or organic).

Importance

The micro pores are generally filled with water in a moist soil and there is slow movement of air and water into or out of the soil. On the other hand, the macro pores allow the ready movement of water and air, thus, the movement of water and air through a sandy soil is rapid due to the dominance of the macro pores, even though total porosity is relatively lower. Clayey soils, particularly those without good structure allow relatively slow air and water movement despite having large total pore space. In these soils, the dominating micro-pores generally remain full of water. However, improvement in structure can promote aeration by increasing the proportion of macro-pores. Therefore, the pore size distribution is more important rather than the volume of total pore space.

Soil Aeration

It is the process by which air in the soil is replaced by air from the atmosphere (gaseous exchange). The rate of aeration depends mainly on the volume and continuity of air-filled pores within the soil.

Composition of soil and atmospheric air

In a well-aerated soil, the soil air is very similar in composition to the atmospheric air above the soil. However, poorly aerated soils generally contain a much higher percentage of CO₂ and a correspondingly lower percentage of O₂ than the atmospheric air above the soil. Atmospheric air has about the following composition of the important gases in soils:

Dinitrogen (N₂) = 79.0%, oxygen (O₂) = 20.95%

Carbon dioxide (CO₂) = 0.03%

Water vapor or relative humidity = 20-90%. Soil air is different from atmospheric air as it has lower oxygen content (14-20%) and relative humidity (95-99%). Plant roots and micro-organisms take oxygen from soil air and release carbon dioxide into it.

Significance

The oxygen contents are the most important for plant growth as are needed for respiration (necessary for life and growth). Except rice, most plants need oxygen to be present in the pores where roots are growing. So the rate at which soil oxygen exchanges with atmospheric oxygen ODR (oxygen diffusion rate) is important.

Organic matter decomposition by soil microorganisms also uses oxygen in soils, when there is little oxygen in soil anaerobes start working and anaerobic microorganisms produce gases (other than CO₂) such as Nitrous oxide (N₂O), methane CH₄) and H₂S. These gases are harmful and are source of pollution.

SOIL TEMPERATURE, CONSISTENCY AND SIGNIFICANCE

Soil Temperature & Significance

The temperature of a soil influences plant growth and crop yields as it generally influences date of planting, germination and number of days for a crop to mature. For every 10C in the temperature, the rate of chemical reaction is doubled. The sub-soil temperature is less variable than the air and surface soil temperatures.

There is a base temperature for different species below which germination of seedling does not occur. The activity of soil microorganisms is affected by soil temperature. Each type of microorganisms flourishes best at a certain optimum temperature. The decomposition of organic matter is also depending on soil temperature.

Factors influencing heat absorption include soil color, water contents, mulches, vegetative cover and soil slope as well as its direction.

SOIL CONSISTENCY

Resistance of soil material to crushing (rupture)

OR its ability to be molded or changed in shape.

- It indicates the degree of cohesion and adhesion of the soil mass at various water contents
- Soil consistency is usually described at three soil water levels:
wet, moisture & dry
- Importance:
 - Soil tillage & compaction by farm machinery
 - Useful in estimating the soil's flow or support strength under applied forces (building weight, vibration of road traffic)

INTRODUCTION TO SOIL AND LAND CAPABILITY CLASSIFICATION

Land Capability Classification

Land capability class categorizes the productive potential of the soil. The classes generally range from class 1, the best land for agricultural production, to class VIII, the least productive.

In general, class I through class IV are for row crop production, and V through VIII are not suitable for row crop production for various reasons.

Irrigated land

Class I land

Flawless agricultural land, suitable for orchards and all climatically adapted crops except rice. It gives high response to good management and inputs

Class II land

Has a minor limitation or limitations, which make its net production potential about 25% less than that of class I land.

Class III land

This class has moderate limitations and moderate agricultural potential

Class IV land

Having low agricultural potential, this is economically marginal land

Grazing and forest land

Class V is nearly level,

This includes good forest or grazing land. The soils are nearly level, deep but stony and in some places somewhat imperfectly drained.

Class VI is just a more serious version of V.

This includes moderate forest or range land. The land has minor limitations for grazing but non for forestry.

Class VII has some severe limiting properties.

This includes poor forest or range land. It has severe limitations both for grazing and forestry.

None-Agricultural land (Recreation)

Class VIII has one or more extreme limitations.

This land has no potential for cultivation, forestry or grazing because of very severe limitations imposed by soil erosion (e), excessive wetness (w), shifting sand (s), severe salinity/sodicity (a) plus lack of porosity, unstable soil (x), very arid climate (c), or ice / glacier cover (z)

PRACTICAL COURSE SS-301

Experiment: Method of soil sampling, preparation, labeling and storage

Experiment: Preparation of Saturated Soil Paste

Experiment: Determination of Soil Saturation Percentage

Experiment: Determination of Soil water content

Experiment: Determination of Soil Texture with different method

Experiment: Determination of soil bulk and particle density

Experiment: Method of water sampling, preparation, labeling and storage

Experiment: Determination of Electrical Conductivity (EC)

Experiment: Calculation of Total Soluble Salts (TSS) or Total Dissolved Solids (TDS) in
Irrigation Water

Experiment: Determination of SAR and RSC

Experiment: Determination of cations and anions

Experiment: Interpretation of results and report writing

EXPERIMENT: METHOD OF SOIL SAMPLING, PREPARATION, LABELING AND STORAGE

Objectives

- a. To evaluate fertility status of soil
- b. To assess salinity/sodicity status of soil
- c. To monitor contamination of soil
- d. To assess physical, chemical and biological properties of a soil.

Pre-sampling Requirements

1. Before sampling be sure to have

- a. Map of the sampling site
- b. Cropping history of the sampling site
- c. History of fertilizer/amendment applications
- d. Field notebook and marker

2. Tools for soil sampling

- a. Sampling bags
- b. Buckets
- c. Augers/soil sampler

Method of sampling

1. Collect randomly 4 to 5 samples from the soil at specific depth (e.g. 0-15 cm and 15-30 cm depth) depending upon the purpose of analysis.
2. Remove large stones, sticks and vegetation from the samples
3. Combine these 4-5 samples of same depth by mixing the soil and make one composite sample for each depth.
4. Bring the sample to the lab

Sample size

Approximately 1 kg composite sample is sufficient.

Sample preparation

1. Air dry the samples
2. Grind the samples if needed
3. Sieve the soil through 2 mm sieve

Sample labelling

A label should have the following information.

1. Date of collection
2. Depth of collection
3. Name of the collector
4. Geographical information of the sampling area

Sample storage

The labelled samples should be stored at 4 °C in a refrigerator.

EXPERIMENT: PREPARATION OF SATURATED SOIL PASTE

Apparatus

Beaker and spatula

Procedure

Take 250 g of soil sample in a beaker. Add sufficient amount of distilled water to moisten the soil while stirring with spatula. Continue to add water and stir until the soil is just saturated.

Saturated soil paste should fulfill the following criteria.

1. Water should not stand on the surface of soil paste
2. The soil paste should look as a homogenous mixture of soil and water
3. Paste should glisten as it reflects light
4. Paste flows slightly when the container is tilted
5. Paste slides freely and cleanly off the spatula
6. It should not stiffen markedly or lose its glistening appearance on standing

Significance

1. Saturated soil paste is prepared to determine the soil pH
2. It is used to get saturated soil extract for chemical analysis e.g. E_{Ce}
3. Saturated soil paste is also used to determine the saturation percentage of a soil

EXPERIMENT: DETERMINATION OF SOIL SATURATION PERCENTAGE

Apparatus

Weighing balance, china dish, oven

Procedure

Transfer 50 g of the saturated soil paste to a tarred china dish and weigh. Dry it in an oven at 105 °C till a constant oven-dry weight. Remove the china dish from the oven and cool it in a desiccator. Weigh the china dish with dried soil and note the loss in weight.

Calculations

Weight of china dish	=	A g
Weight of china dish + paste	=	B g
Weight of china dish + paste after oven drying	=	C g
Loss in weight	=	(B-C) g
Weight of oven dry soil	=	(C-A) g
Saturation percentage	=	$\frac{(B-C)}{(C-A)} \times 100$

EXPERIMENT: DETERMINATION OF SOIL WATER CONTENT

Apparatus

- Electric oven with thermostat.
- Desiccator.

Procedure

- ✓ Weigh 10 g air-dry soil (< 2-mm) into a previously dried (105°C) and weighed metal can with lid.
- ✓ Dry in an oven, with the lid unfitted, at 105°C overnight.
- ✓ Next day, remove from oven; fit the lid, cool in a desiccator for at least 30 minutes and re-weigh.

$$\% \text{ Soil moisture content} = \frac{\text{Weight of wet soil (g)} - \text{Weight of dry soil (g)}}{\text{Weight of dry soil (g)}} \times 100$$

EXPERIMENT: DETERMINATION OF SOIL TEXTURE

Texture: It refers to the relative proportions of the three primary soil separates (sand, silt, and clay). There are four different methods for determination of soil texture

- A. Feel touch method
- B. Gravitational Method
- C. Saturation percentage method
- D. Hydrometer Method

A. Feel touch method

In this method, soil sample is felt between the fingers and thumb and following classes can be determined

- i. Sand
- ii. Silt
- iii. Clay

i. Sand

If soil is gritty & non sticky in moist condition then it is sand

ii. Silt

If soil is little gritty or flour like & non sticky in moist condition then it is called silt

iii. Clay

If soil between finger and thumb is talc & sticky when wet, it is clay

B. Gravitational Method

In this method, soil sample is passes through different size of sieves and following classes can be determined

- i. Sand
- ii. Silt
- iii. Clay

In this method dry soil sample is passes through 2 mm sieve (Sieve of 2 mm mesh size)

Then pass through sieve of 0.05 mm

Then pass through sieve of 0.002 mm

i. Sand

The material left over on 0.05mm sieve is claimed as sand

ii. Silt

The material left over on a sieve of 0.002mm is called silt

iii. Clay

The portion of soil which is passes through the sieve of 0.002mm is known as clay particle

C. Saturation percentage method

If Saturation percentage is less than 30%:	Sandy Soil
If Saturation percentage is 30-45%:	Loam Soil
If Saturation percentage is 45-60%:	Clayey Loam
If Saturation percentage is more than 60%:	Clayey Soil

D. Particle size analysis of a given sample of soil by hydrometer method

Principle

Particle size analysis is carried out to determine soil texture which is a physical property of soil and express the relative proportion of the various soil separates like sand, silt and clay. The analysis usually involves sedimentation, sieving, micrometry, or combination of these methods.

To separate particles or to measure particle densities at a certain depth in a suspension of soil in water requires knowledge of settling rates of different sized particles. Stokes's law provides basis for this type of analysis (theoretical basis). The law simply balances the downward force due to gravity with the resisting force due to buoyancy (Surface, friction and solution movements). It is assumed that smooth rigid particles are settling in acquiescent (non –turbulent) viscous fluid of known density and viscosity.

According to Stoke (1851), the movement of particles in a fluid depends upon:

- (a) Viscosity of the fluid
- (b) Radius of the particles
- (c) Force of gravity
- (d) Density of soil particles and fluid (medium)

According to Stokes law

Velocity of fall is proportional to square of the radius of particles.

$$V \propto r^2$$

Where V is the velocity of fall in cm/s

r is the radius of a particle

K is constant

The equation for Stoke's law is:

$$V = \frac{2}{9} \frac{[d_1 - d_2]}{n} g r^2$$

Where V= velocity of fall (m s^{-1})

d_1 = density of particles (Mg m^{-3}) or g cm^{-3}

d_2 = density of medium (Mg m^{-3})

g= acceleration of particles (cm s^{-2})

r= radius of particles (m)

n= viscosity of medium (dyne sec cm^{-2})

Hydro meter methods for the determination of soil texture

1. Weigh quantity of air dry soil that contains 40 g of dry soil
2. Take 100 gram of soil if soil class is estimated to be sand
3. Transfer the soil sample into 400ml beaker, add 40ml of 2% sodium hexametaphosphate (NaPO_3)₆ solution
4. Then add 150 ml distilled water in the beaker
5. Stir the contents of beaker with glass rod and let the mixture stand for overnight (at least for 18hrs)
6. Transfer the mixture to dispersion cup and wash the beaker in the cup with distilled water
7. Be sure that every soil particle has been removed from the beaker and transferred to the cup.

8. Fix the cup to an electric stirrer and run it for a period of time depending upon the estimated soil class (6 minutes for sands, 10 minutes for sandy loams and 15 minutes for all other classes).
9. Wash the contents of the dispersion cup into a 1000ml graduated cylinder having 36 ± 2 cm heights. Place the hydrometer in the cylinder and add distilled water to make up to the volume upto mark.
10. Remove the hydrometer from the cylinder and shake the content of the cylinder from bottom to the top by means of a metal plunger (during the mixing process, do not bring the base of plunger too close to the top of the water column or force it down through the column too vigorously , otherwise splashing will result).
11. When a uniform suspension is obtained, remove the plunger from the cylinder but carefully and start counting time as the plunger leaves the suspension surface.
12. Insert the hydrometer quickly but carefully and steadily with the fingertip at first to hasten attainment of an equilibrium position.
13. Record the hydrometer reading (top of the meniscus) after exactly 40 seconds (USDA and 4 minutes to ISSS) along with the temperature reading. Move the hydrometer up and down in the suspension to displace soil particles which have settled on it and then remove it from the cylinder.
14. After 2hrs record the second hydrometer reading along with the temperature (with thermometer).

Temperature correction

Since the hydrometer is calibrated at a temperature of 68 F (20°C) , the reading obtained at the temperature must be corrected. Add 0.2 to the observed hydrometer reading for every one degree rise in temperature from 68 F and subtract 0.2 from the observed hydrometer reading for every one degree fall in temperature from 68F.

In case Celsius thermometer is used, then add 0.36 to the observed hydrometer for every one degree rise and subtract 0.36 from every degree fall in temperature.

Classification of soil separates

USDA system after 40 seconds and International System 4 minutes reading will indicate Silt +Clay and after 2hrs, it will be Clay.

Calculations

The hydrometer scale indicates gram of suspended material per 1000ml of water at 68 F. in this exercise, the volume of water in the suspension was 800 ml. The amount of a soil separates in a given soil sample can be calculated as:

Total Suspended material (g) = (CHR g * 800 ml /1000ml)

Total suspended material (%) = Total suspended material g *100)/weight of soil (40g)

= CHR (g) *(800ml/1000ml)*(100/40 g)

= 2CHR

USDA

Observed hydrometer reading for 40 seconds =

Observed temperature for 40 seconds =

Corrected hydrometer reading for 40 seconds (CHR1) =

Observed hydrometer reading for 2 hrs =

Observed temperature reading for 2 hrs =

Corrected hydrometer reading for 2 hrs (CHR2) =

% (silt + clay) = 2CHR1

% Clay = 2CHR2

% silt = % (Silt + Clay) – (% Clay)

% Sand = 100- % (Silt + Clay)

By use of International soil triangle, textural class of given soil sample can be calculated

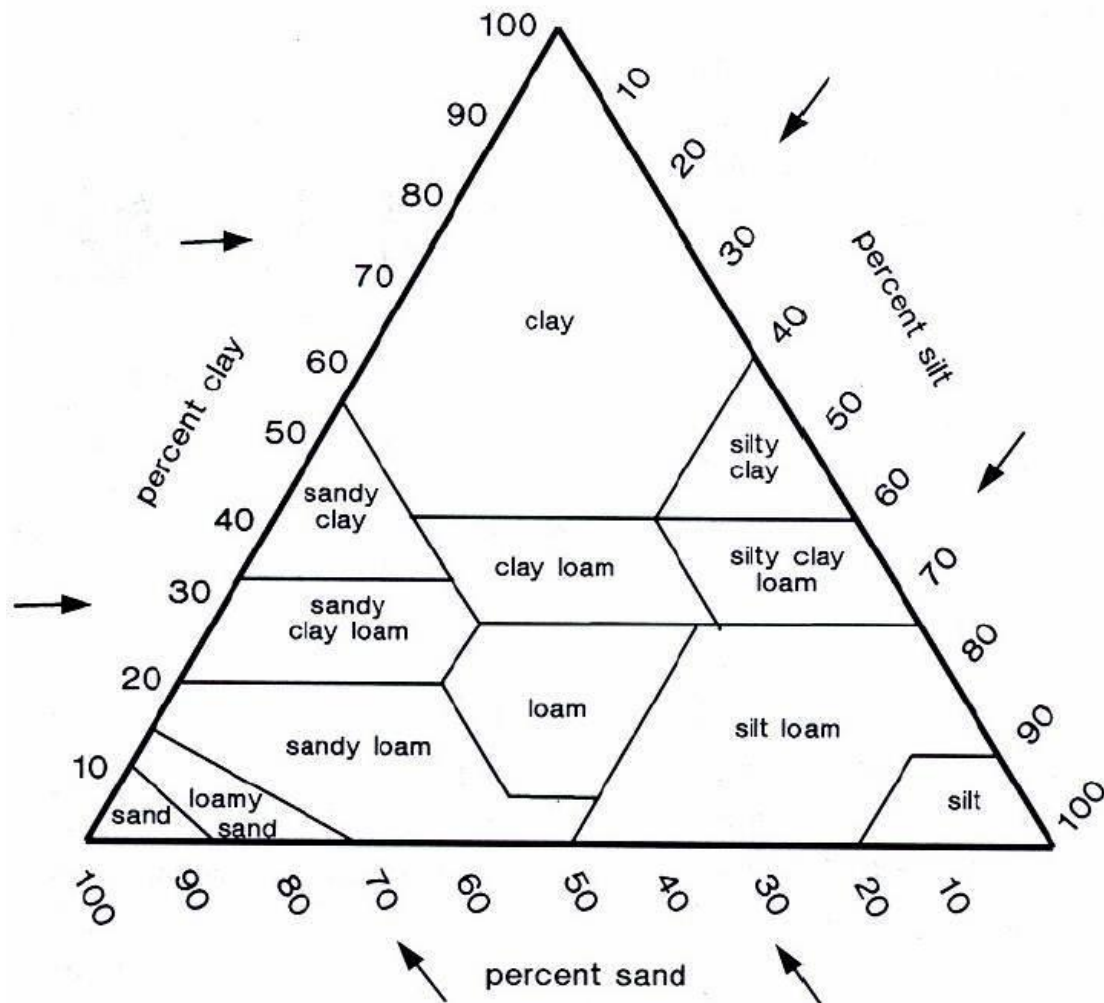


Fig. USDA International Soil triangle

EXPERIMENT: DETERMINATION OF BULK DENSITY OF GIVEN SOIL

SAMPLE BY CORE METHOD

Bulk Density

It is defined as the mass of dry soil solids per unit bulk volume. Bulk volume means the volume of the soil particles plus pore space.

Principle

Soil bulk density is the mass (on oven dry basis) per unit volume of soil in its natural undistributed state. Its value is expressed in g cm^{-3} and may be between 1.0 and 1.8 for mineral soils.

Procedure

A sample of known volume is used. It consists of metal cylinder which is pushed in to soil, removed and volume is calculated. Determination of bulk density is simply a matter of drying the contents of the sampler completely to tarred dish and dry in a oven at 105°C till constant oven dry weight is observed.

Calculation:

Volume of sample (Volume of the sampler) = $V \text{ cm}^3$

$$V = \pi r^2 h$$

$$\pi = 3.14$$

r = radius of the cylinder

h = length of portion of cylinder which contains soil sample

$M \text{ (g)}$ = weight of the oven dry material contained in it

$$D_b = (M/V) \text{ g cm}^{-3}$$

Where

D_b = Bulk Density

g cc^{-1} = g per cubic centimeter

EXPERIMENT: DETERMINATION OF PARTICLE DENSITY OR SPECIFIC DENSITY

Particle or specific density:

Particle or specific density is the ratio of the mass of soil particles and their volume. The particle density is an important property needed for many other soil physical measurements, e.g., the determination of the particle-size distribution requires knowledge of the particle density. For soils, it is often sufficient to assume a particle density of 2.65 g cm^{-3} ; however, when high accuracy is needed, or non-silicate minerals are present, the particle density should be determined by measurement.

The determination of the particle density is based on displacement of water by solid particles (Archimedes' Principle). The measurements are simple and can be made very accurately. More details can be found in Blake and Hartge (1986b) and (ASTM, 2000).

Equipment and Supplies

- ✓ 100 mL volumetric flask
- ✓ Stopper for flask
- ✓ Balance 0.01 g accuracy
- ✓ Water bath to control temperature
- ✓ Bunsen burner
- ✓ Thermometer
- ✓ Oven
- ✓ Volumetric Flask Method

Procedures

- ✓ Weigh the dry volumetric flask.
- ✓ Determine the air-dry water content of the soil sample by oven-drying an aliquot, or use oven-dry soil.
- ✓ Weigh out about 50 g of soil into the volumetric flask. Record the exact amount of soil within 0.05 g accuracy.
- ✓ Fill volumetric flask about half full with distilled water. Boil water and soil with a Bunsen burner to remove entrapped air, but be careful not to boil too much so that soil does not spill out.

- ✓ Cool flasks in water bath and fill flask with distilled water to the mark.
- ✓ Insert stopper and let temperature equilibrate in the water bath.
- ✓ Dry outside of flask and weigh flask.
- ✓ Empty flask and fill with distilled water to the mark. Weigh flask with water.

Calculation

The particle or specific density of soil is calculated as follows:

$$P_s = \frac{M_s}{(M_s + M_w) - M_{ws}}$$

Where P_w is the density of water at the temperature observed, m_s is the mass of oven-dry soil, m_w is the mass of water in flask without soil, and m_{ws} is the mass of water and soil in the flask. (All masses are masses without the mass of the flask itself.)

EXPERIMENT: METHOD OF WATER SAMPLING, PREPARATION, LABELING AND STORAGE

Objectives

2. To assess the quality of irrigation water and its effects on soil
3. To evaluate the suitability of water for crop use
4. To know the nature, type and amount of salts present in the water
5. To recommend suitable measures for using available water

Methods of sampling

1. Sample should be true representative of the water to be analysed
2. If new tubewell is being installed, water sample should be collected from every 50 feet depth
3. In case of existing tubewell, it should be run for 15-20 minutes before taking the sample. Sample should be collected from the discharge pipe and not from the water channel
4. Samples from the canals, rivers and streams should be taken from running water. The properties of samples may vary due to the following factors.
 - Depth of sampling
 - Rate of flow of water

- Distance from the bank
 - Time of the year (season)
5. It is best to take an integrated sample from top to bottom of the water body

Sample size

Analysis of water for irrigation purpose requires at least one liter of water.

Sample labelling

Samples should be labelled with:

1. Name of canal / stream/ tubewell/tap water
2. Date of collection
3. Depth of collection
4. Name of the collector
5. Geographical information of the sampling area

Sample storage

1. Clean plastic/glass bottles should be rinsed two to three times with water to be collected
2. Fill the bottle up to the top and cap tightly
3. The bottles should not be washed with any detergent
4. Sample should be refrigerated and analysed as quickly as possible so that chemical changes during storage can be minimized
5. Sample should be analysed preferably within seven days of collection

EXPERIMENT: DETERMINATION OF ELECTRICAL CONDUCTIVITY (EC)

Principle

Electrical conductivity of a soil extract or water sample is measured by using EC meter. Electrical conductivity meter measures the electrical conductance of any solution containing inorganic soluble salts.

In general more the salts present in water/soil extract more will be the intensity of current passing through it and more the electrical conductance and vice versa.

Procedure

1. Standardization
2. Actual Measurement

1. Standardization

The instrument must be standardized with 0.01N KCl (0.7456 g KCl L⁻¹) solution. The EC of this standard solution will be 1.4118 dS m⁻¹ at 25 °C. Dip the electrode of EC meter in 0.01 N KCl solution. Before dipping, it is rinsed with the standard solution 2 to 3 times. The modern EC meters measure EC at 25 °C automatically. Calculate the cell constant by the formula given below:

$$K = 1.4118 \text{ dS m}^{-1} / \text{Observed EC (dS m}^{-1}) \text{ of solution}$$

2. Actual Measurement

Rinse the electrode of the EC meter with distilled water. Dry it gently with tissue paper and dip in the soil extract or water sample. Record the reading and its unit when it becomes stable. Calculate the corrected EC if the cell constant is not one using the following relationship.

$$\text{Corrected EC} = K \times \text{EC of water} \\ (\text{dS m}^{-1})$$

If there is soil sample than soil extract of the soil saturated paste is taken with the use of suction pump,

If suction pump is not available than make soil and water suspension (1:10) and filter it with the filter paper.

EC of Soil and water suspension (1:10) is divided by 1.33 to get E_{Ce}

Units of EC

The standard units of EC are dS m^{-1}

$$\mu\text{S cm}^{-1} = \text{dS m}^{-1} \times 1000$$

Criteria for the Fitness of Irrigation Water

- ✓ Fit water if $\text{EC} \leq 1150 \mu\text{S cm}^{-1}$
- ✓ Marginal water if $\text{EC} = 1150 \text{ to } 1450 \mu\text{S cm}^{-1}$
- ✓ Unfit water if $\text{EC} \geq 1450 \mu\text{S cm}^{-1}$

Criteria for the Fitness of Soil

- ✓ If $\text{ECe} \leq 4000 \mu\text{S cm}^{-1}$ ----- Normal Soil
- ✓ If $\text{ECe} = 4000 \text{ to } 8000 \mu\text{S cm}^{-1}$ ----- Saline Soil (Only salt tolerance species)
- ✓ If $\text{EC} > 8000 \mu\text{S cm}^{-1}$ Extremely Saline Soil (Only kallar grass etc)

EXPERIMENT: CALCULATION OF TOTAL SOLUBLE SALTS (TSS) OR TOTAL DISSOLVED SOLIDS (TDS) IN IRRIGATION WATER

Principle

The determined electrical conductivity (EC) is multiplied with an appropriate factor i.e., 10 to estimate the total dissolved solids or total soluble salts.

For example:

$$\text{Observed EC of irrigation water} = \text{EC dS m}^{-1}$$

$$\text{TSS or TDS in irrigation water (me L}^{-1}\text{)} = \text{EC} \times 10$$

Note:

The factor is appropriate for irrigation waters having EC in the range 0.1 to 4.0 dS m^{-1} . For higher values, consult the graph given in the USDA, hand book No. 60.

Criteria for the Fitness of Irrigation Water

1. TSS less than 15 me L^{-1}

$$\text{where TSS (Total soluble salts)} = \text{EC} \times 10$$

2. RSC less than 2.25 me L^{-1}

$$\text{where RSC (Residual Sodium Carbonate)} = (\text{CO}_3 + \text{HCO}_3) - (\text{Ca} + \text{Mg})$$

Criteria for RSC

Fit water if RSC less than 1.25 meq/L

Marginal fit water if RSC equal 1.25 meq/L to 2.5 meq/L

Unfit water if RSC more than 2.5 meq/L

3. SAR less than 10 (mmol L⁻¹)^½

where SAR = Sodium Adsorption Ratio =
$$\frac{\text{Na}}{\sqrt{\frac{\text{Ca} + \text{Mg}}{2}}}$$

and the units of Na and Ca + Mg are me L⁻¹

Criteria for SAR

Fit water if SAR less than 6

Marginal fit water if SAR equal to 6-10

Unfit water if SAR more than 10

Significance

A water sample is said to be unfit for irrigation if any of the above parameters is equal or more than the prescribed limits.

EXPERIMENT: DETERMINATION OF CATIONS AND ANIONS IN IRRIGATION WATER SAMPLE

CATIONS

Determination of Calcium and Magnesium ($\text{Ca}^{+2} + \text{Mg}^{+2}$)

Principle:

Calcium and magnesium in irrigation water is determined by titrating against 0.01N EDTA solution using EBT indicator in the presence of buffer

Procedure:

- ✓ Take 10 ml of irrigation water sample in conical flask
- ✓ Add 10-15 drops of buffer solution in the conical flask (mixture of weak acid and base NH_4OH and NH_4Cl)
- ✓ Add 2-3 drops of Erio-chrome black T (EBT) indicator
- ✓ Reddish pink (wine red) color will appear
- ✓ Titrate against 0.01 N Ethylene diamine tetra acetate or ethylene tetra acetic acid di-sodium salt (EDTA) solution upto blue green color from reddish pink (wine red).

Calculations:

Volume of irrigation water taken = 10 ml

Volume of EDTA used = *R ml

10 ml of irrigation water contain ($\text{Ca}^{+2} + \text{Mg}^{+2}$) = R ml X (Normality of EDTA used) me

1000 ml of irrigation water contain ($\text{Ca}^{+2} + \text{Mg}^{+2}$) = R ml X 0.01 X 1000/10

R me L^{-1}

*R is the supposed value in all the anions and cations calculations

Determination of Sodium (Na^+)

Sodium is determined by flame photometry. As this introductory class has not the skill to operate this instrument

Principle:

Sodium can be determined by difference method

Calculation:

$\text{Na}^+ \text{ me } \text{L}^{-1} = \text{TSS} - (\text{Ca}^{+2} + \text{Mg}^{+2})$

ANIONS

Determination of Carbonates (CO_3^-)

Principle:

Carbonates can be determined by titrating against (0.1 N) H_2SO_4 using phenolphthalein as an indicator

Procedure:

- ✓ Take 50 ml irrigation water sample in flask
- ✓ Add 2-3 drops of phenolphthalein, if no color appear carbonates are absent but if pink color develop, carbonates are present
- ✓ Titrate against 0.1 N sulphuric acid (H_2SO_4) to colorless end point
- ✓ Save the flask along with its contents for bicarbonates and chlorides determination

Calculations:

Volume of irrigation water taken = 50 ml

Volume of H_2SO_4 used = R ml

Actual volume of H_2SO_4 used = $2 \times R$ ml

50 ml of irrigation water contain $(\text{CO}_3^{2-}) = 2R \text{ ml} \times (\text{Normality of } \text{H}_2\text{SO}_4 \text{ used}) \text{ me}$

1000 ml of irrigation water contain $(\text{CO}_3^{2-}) = 2R \text{ ml} \times 0.1 \times 1000/50$

R me L^{-1}

Determination of Bicarbonates (HCO_3^-)**Principle:**

Bicarbonates can be determined by titrating (0.1) against standard H_2SO_4 using methyl orange as an indicator

Procedure:

- ✓ To the same conical flask (after the end point of for carbonates)
- ✓ Add 3 drops of methyl orange
- ✓ Titrate against 0.1 N sulphuric acid (H_2SO_4) to pinkish yellow end point
- ✓ Save the flask as such for chloride analysis

Calculations:

Volume of irrigation water taken = 50 ml

Actual volume of H_2SO_4 used = Volume used for bicarbonates - Volume used for carbonates

Suppose it is = R ml

50 ml of irrigation water contain $(\text{HCO}_3^-) = R \text{ ml} \times (\text{Normality of } \text{H}_2\text{SO}_4 \text{ used}) \text{ me}$

1000 ml of irrigation water contain (HCO_3^-) = $R \text{ ml} \times 0.1 \times 1000/50$

R me L⁻¹

Determination of Chlorides (Cl^-)

Principle:

Chloride can be determined by titrating against standard silver nitrate (AgNO_3) solution using potassium chromate (K_2CrO_4) as an indicator

Procedure:

- ✓ To the same conical flask (after the end point of for carbonates and bicarbonates)
- ✓ Add 3 drops of potassium chromate
- ✓ Titrate against 0.05 N Silver nitrate (AgNO_3) solution upto brick red precipitate/ color

Calculations:

Volume of irrigation water taken = 50 ml

Volume of AgNO_3 used = R ml

50 ml of irrigation water contain (Cl^-) = $R \text{ ml} \times (\text{Normality of } \text{AgNO}_3 \text{ used}) \text{ me}$

1000 ml of irrigation water contain (Cl^-) = $R \text{ ml} \times 0.05 \times 1000/50$

R me L⁻¹

Determination of Sulphate (SO_4^-)

Principle:

Sulphate can be determined by difference method

Calculation:

Sulphate (SO_4^-) me L⁻¹ = TSS - ($\text{Ca}^{+2} + \text{Mg}^{+2}$) - Cl^-