Soil texture

Soil texture refers to the relative proportion of particles or it is the relative percentage by weight of the three soil separates viz., ***sand, silt and clay*** or simply refers to the size of soil particles.

It is often thought of as the fineness or coarseness of soil particles determined by the percentages of sand, silt, and clay in the surface layer of soil. Soil particle size is important because it affects the water-holding capacity and workability of soil.

Sand, the larger particles in a soil, can be seen with the naked eye. Soils with a high percentage of sand are infertile because they do not provide nutrients to growing plants. Sandy soils dry out quickly and are droughty.

Silt particles are between sand and clay particles in size. Until they weather to fine-sized particles, they provide few nutrients for growing plants. After rainfall, topsoil with a high percentage of silt tends to run together and forms a surface crust. Silt type soils erode very easily.

Clay, the smallest of the soil particles, holds soil nutrients, influences soil acidity, and holds more moisture than sand or silt. Clay particles are microscopic in size; their expansion and contraction depend on the amount of moisture present. In presence of water, a film of moisture separates clay particles; as the moisture evaporates and the soil becomes dry, the soil contracts and leaves cracks in the ground. Clay soils dry out slowly and become cloddy unless properly managed. The size limits of these soil particles (separates) have been established by various organizations.

Naming soil separates:

There are a number of systems of naming soil separates. And they are as follows;

(a) The American system developed by USDA

(b) The English system or British system (BSI)

(c) The International system (ISSS)

(d) European system

I) USDA: United States Department of Agriculture

Soil separates	***Diameter (mm)***
Clay	< 0.002 mm
Silt	0.002 – 0.05
Very Fine Sand	0.05 – 0.10
Fine Sand	0.10 – 0.25
Medium Sand	0.25 - 0.50
Coarse Sand	0.50 - 1.00
Very Coarse Sand	1.00 – 2.00

ii) BSI: British System

Soil separates	**Diameter (mm)**
Clay	< 0.002 mm
Fine Silt	0.002 – 0.01
Medium Silt	0.01 – 0.04

Coarse Silt	0.04 – 0.06
Fine Sand	0.06 - 0.20
Medium Sand	0.20 - 1.00
Coarse Sand	1.00 – 2.00

iii) ISSS: The International System

Soil separates	***Diameter (mm)***
Clay	< 0.002 mm
Silt	0.002 – 0.02 mm
Fine sand	0.02 – 0.2 mm
Course sand	0.2 – 2.0 mm

IV) European System

Soil separates	***Diameter (mm)***
Fine clay	< 0.0002 mm
Medium clay	0.0002 – 0.0006
Coarse clay	0.0006 – 0.002
Fine silt	0.002 - 0.006
Medium silt	0.006 - 0.02
Coarse silt	0.02 - 0.06
Fine sand	0.06 - 0.20
Medium sand	0.20 - 0.60
Coarse sand	0. 60 - 2.00

Particle Size Analysis

Sieves can be used to separate and determine the content of the relatively large particles of the sand and silt separates. Sieves, however, are unsatisfactory for the separation of the clay particles from the silt and sand. Thus hydrometer was preferred.

The hydrometer method is an empirical method that was devised for rapidly determining the content of sand, silt, and clay in a soil.

In the hydrometer method a sample (usually 50 grams) of air-dry soil is mixed with a dispersing agent ***(such as a sodium pyrophosphate solution)*** for about 12 hours to promote dispersion. Then, the soil-water suspension is placed in a metal cup with baffles on the inside, and stirred on a mixer for several minutes to bring about separation of the sand, silt, and clay particles.

The suspension is poured into a specially designed cylinder, and distilled water is added to bring the contents up to volume.

The soil particles settle in the water at a speed directly related to the square of their diameter and inversely related to the viscosity of the water.

A hand stirrer is used to suspend the soil particles thoroughly and the time is immediately noted. A specially designed hydrometer is carefully inserted into the suspension and two hydrometer readings are made.

The sand settles in about ***40 seconds*** and a hydrometer reading taken at 40 seconds determines the grams of silt and clay remaining in suspension. Subtraction of the 40-second reading from the sample weight gives the grams of sand. After about ***8 hours,*** most of the silt has settled, and a hydrometer reading taken at 8 hours determines the grams of clay in the sample.

(See Figure 3.2). The silt is calculated by difference: add the percentage of sand to the percentage of clay and subtract from 100 percent.

The following calculation example is very helpful;

PROBLEM: Calculate the percentage of ***sand, clay, and silt*** when the ***40-second*** and ***8-hour*** hydrometer readings are ***30*** and ***12***, respectively; assume a ***50*** gram soil sample is used:

$$\frac{\text{Sample weight} - \text{40-second reading}}{\text{Sample weight}} \times 100 = \%\text{sand}$$

$$\frac{50\ g - 30\ g}{50\ g} \times 100 = 40\%\ \text{sand}$$

$$\frac{\text{8-hour reading}}{\text{sample weight}} \times 100 = \%\ \text{clay}$$

$$\frac{12\ g}{50\ g} \times 100 = 24\%\ \text{clay}$$

100% - (40% + 24%) = 36% silt.

After the hydrometer readings have been obtained, the soil-water mixture can be poured over a screen to recover the entire sand fraction. After it is dried, the sand can be sieved to obtain the various sand separates.

Importance of Soil Texture.

Presence of each type of soil particles makes its contribution to the nature and properties of soil as a whole;

- Texture has good effect on management and productivity of soil. Sandy soils are of open character usually loose and friable.
- Such type of the texture is easy to handle in tillage operations.
- Sand facilitates drainage and aeration. It allows rapid evaporation and percolation.
- Sandy soils have very little water holding capacity. Such soils cannot stand drought and unsuitable for dry farming.
- Sandy soils are poor store house of plant nutrients
- Contain low organic matter
- Leaching of applied nutrients is very high.
- In sandy soil, few crops can be grown such as potato, groundnut and cucumbers.
- Clay particles play a very important role in soil fertility.
- Clayey soils are difficult to till and require much skill in handling. When moist clayey soils are exceedingly sticky and when dry, become very hard and difficult to break.
- They have fine pores, and are poor in drainage and aeration.

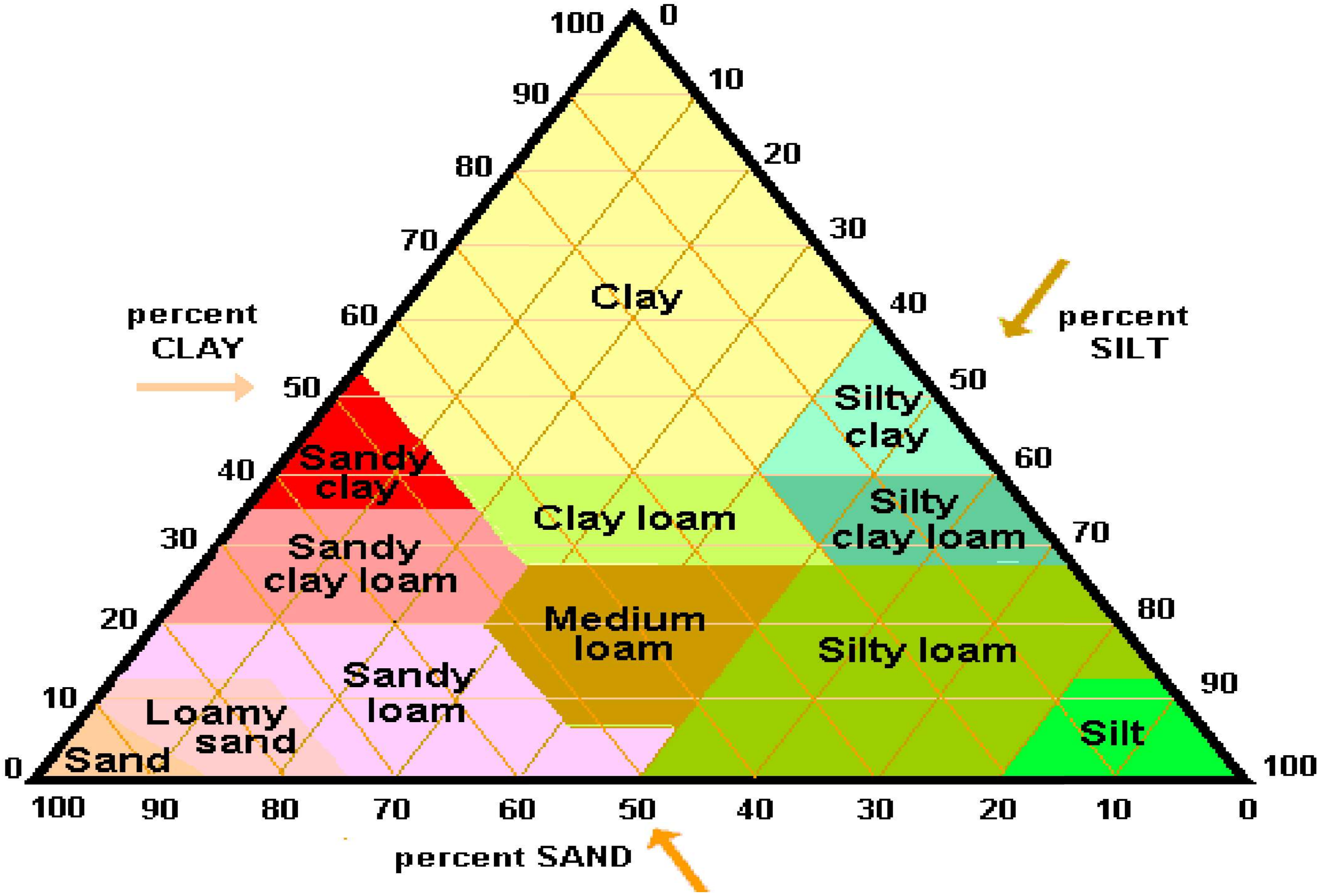

Fig 1: 12 major textural classes.

Soil Textural Classes:

Once the percentages of sand, silt, and clay have been determined, the soil can be placed in one of ***12*** major textural classes.

The texture of a soil is expressed with the use of class names. The sum of the percentages of sand, silt, and clay at any point in the triangle is ***100***. A soil containing equal amounts of sand, silt, and clay is ***a clay loam***.

Naming the soil gives an idea not only of the textural composition of a soil but also of its various properties in general.

On this basis, soils are classified into various textural classes which are following in detail;

Sand - Soil material that contain 85% or more of sand and a percentage of silt plus 1 ½ times the percentages of clay not exceeding 15.

Loamy Sand- Soil material that contains at the upper limit 85 to 90% sand, and the percentage of silt plus 1 ½ times the percentage of clay is not less than 15; at the lower limit it contains not less than 70 to 85% sand, and the percentage of silt plus twice the percentage of clay does not exceed 30.

Sandy Loam- Soil material that contains either 20% clay or less and the percentage of silt plus twice the percentage of clay exceeds 30, and 52% or more sand; or less than 7% clay, less than 50% silt, and between 43% and 52% sand.

Loam- Soil material that contains 7 to 27% clay, 28 to 50% silt, and less than 52% sand.

Silt Loam- Soil material that contains 50% or more silt and 12 to 27% clay (or) 50 to 80 percent silt and less than 12% clay.

Silt - Soil material that contains 80% or more silt and less than 12% clay.

Sand Clay Loam – Soil material that contains 20 to 35% clay, less than 28% silt and 45% or more sand.

Clay Loam- Soil material that contains 27 to 40% clay and 20 to 45% sand.

Silty Clay Loam – Soil material that contains 27 to 40% clay and less than 20% sand.

Sandy Clay- Soil material that contains 35% or more clay and 45% or more sand.

Silty Clay- Soil material that contains 40% or more clay and 40% or more silt.

Clay- Soil material that contains 40% or more clay, less than 45% sand, and less than 40% silt.

Determining Texture by the Field Method

When soil scientists make a soil map, they use the field method to determine the texture of the soil horizons to distinguish between different soils.

When investigating a land-use problem, the ability to estimate soil texture on location is useful in diagnosing the problem and in formulating a solution. A small quantity of soil is moistened with water and kneaded to the consistency of putty to determine how well the soil forms casts or ribbons (plasticity). The kind of cast or ribbon formed is related to the clay content and is used to categorize soils as loams, clay loams, and clays.

If a soil is a loam, and feels very gritty or sandy, it is a sandy loam. Smooth-feeling loams are high in silt content and are called silt loams. If the sample is intermediate, it is called a loam. The same applies to the clay loams and clays. Sands are loose and incoherent and do not form ribbons.

SOIL STRUCTURE.

Soil structure is referred to as the arrangement of the soil particles. Sand, silt, and clay particles are typically arranged into secondary particles called *peds,* or *aggregates.*

Soils with good structure contain a large number of crumbs or aggregates, which indicates good tilth.

Good soil structure permits deep root penetration and a large particle area from which plants can secure nutrients.

Types of Soil Structure.

Soil peds are classified on the basis of shape. The four basic structural types are *spheroid, platelike, blocklike, and prismlike.* These shapes give rise to *granular, platy, blocky, and prismatic* types of structure. Columnar structure is prismatic-shaped peds with rounded caps.

Soil structure generally develops from material that is without structure. There are two structureless conditions, the first of which is sands that remain loose and incoherent. They are referred to as ***single grained***.

Second, materials with a significant clay content tend to be ***massive*** if they do not have a developed structure. Massive soil has no observable aggregation or no definite and orderly arrangement of natural lines of weakness. Massive soil breaks up into random shaped clods or chunks.

Note that each horizon of the soil has a different structure. This is caused by different conditions for structure formation in each horizon.

The **A** horizon has the most abundant root and small-animal activity and is subject to frequent cycles of wetting and drying. The structure tends to be ***granular.***

The **Bt** horizon has more clay, less biotic activity, and is under constant pressure because of the weight of the overlying soil. This horizon is more likely to crack markedly on drying and to develop either a ***blocky or prismatic*** *structure*.

The development of structure in the ***E*** horizon is frequently weak and the structure hard to observe. In some soils the E horizon has a weakly developed ***platy*** structure.

Here, the four basic structural types are defined in detail;

Plate-like (Platy):

In this type, the aggregates are arranged in relatively thin horizontal plates or leaflets. The horizontal axis or dimensions are larger than the vertical axis. When the units/ layers are thick they are called *platy*. When they are thin then it is l*aminar*. Platy structure is most noticeable in the surface layers of virgin soils but may be present in the subsoil. This type is inherited from the parent material, especially by the action of water or ice.

Prism-like (prismatic).

The vertical axis is more developed than horizontal, giving a pillar like shape. Vary in length from 1- 10 cm. commonly occur in sub soil horizons of Arid and Semi-arid regions. When the tops are rounded, the structure is termed as columnar when the tops are flat / plane, level and clear cut – prismatic.

Block like (blocky).

All three dimensions are about the same size. The aggregates have been reduced to blocks .Irregularly six faced with their three dimensions more or less equal. When the faces are flat and distinct and the edges are sharp angular, the structure is named as *angular blocky*. When the faces and edges are mainly rounded it is called *sub angular blocky*. These types usually are confined to the sub soil and characteristics have much to do with soil drainage, aeration and root penetration.

Spheroidal (granular).

All rounded aggregates (peds) may be placed in this category. Not exceeding an inch in diameter. These rounded complexes usually loosely arranged and readily separated. When wetted, the intervening spaces generally are not closed so readily by swelling as may be the case with a blocky structural condition. Therefore in sphere-like structure, infiltration, percolation and aeration are not affected by wetting of soil. The aggregates of this group are usually termed as *granular* which are relatively less porous. When the granules are very porous, it is termed as *crumb*.

This is specific to surface soil particularly high in organic matter/ grass land soils. Classes of Structure: Each primary structural type of soil is differentiated into 5 size classes depending upon the size of the individual peds.

Grade and Class:

Complete descriptions of soil structure include:

Type which refers to the shape of the soil aggregate e.g. granular, platy, crumb, etc.

Class refers to the size of the peds e.g. fine, medium, coarse, etc.

Grade describes how distinct and strong the peds are.

Grades indicate the degree of distinctness of the individual peds. It is determined by the stability of the aggregates. Grade of structure is influenced by the moisture content of the soil.

Grade also depends on organic matter, texture etc. Four terms commonly used to describe the grade of soil structure are:

1. ***Structureless***: There is no noticeable aggregation, such as conditions exhibited by loose sand.

2. ***Weak Structure***: Poorly formed, indistinct formation of peds, which are not durable and much un aggregated material.

3. ***Moderate structure***: Moderately well-developed peds, which are fairly durable and distinct.

4. ***Strong structure***: Very well formed peds, which are quite durable and distinct.

For naming a soil structure the sequence followed is *grade, class and type*; for example *strong coarse angular blocky, moderate thin platy, weak fine prismatic.*

The terms commonly used for the size *classes* are

1. Very fine or very thin.
2. Fine or thin.
3. Medium.
4. Coarse or thick.
5. Very coarse or very thick.

Factors Affecting Soil Structure:

The development of structure in arable soil depends on the following factors:

1. Climate

Climate has considerable influence on the degree of aggregation as well as on the type of structure. In arid regions there is very little aggregation of primary particles. In semi-arid regions, the degree of aggregation is greater.

2. Organic matter

Organic matter improves the structure of a sandy soil as well as of a clay soil. In case of a sandy soil, the sticky and slimy material produced by the decomposing organic matter and the associated microorganism cement the sand particles together to form aggregates. In case of clayey soil, it modifies the properties of clay by reducing its cohesiveness. This helps making clay more crumby.

3. Tillage

Cultivation implements break down the large clods into smaller fragments and aggregates. For obtaining good granular and crumby structure, optimum moisture content in the soil is necessary. If the moisture content is too high it will form large clods on drying. If it is too low some of the existing aggregates will be broken down.

4. Plants, Roots and Residues

Excretion of gelatinous organic compounds and exudates from roots serve as a link. Root hairs make soil particles to cling together. – Grass and cereal roots vs other roots.

Pressure exerted by the roots also held the particles together

Dehydration of soil - strains the soil due to shrinkage

- result in cracks
- lead to aggregation
- Plant tops and residues
- shade the soil
- Prevent it from extreme and sudden temperature and moisture changes and also from rain drop impedance.

Plant residues – serve as a food to microbes – which are the prime aggregate builders.

5. Animals

Among the soil fauna small animals like earthworms, moles and insects etc., that burrow in the soil are the chief agents that take part in the aggregation of finer particles.

6. Microbes

Algae, fungi, actinomycetes and fungi keep the soil particles together. Fungi and actinomycetes exert mechanical binding by mycelia, Cementation by the products of decomposition and materials synthesized by bacteria.

7. Fertilizers

Fertilizer like Sodium Nitrate destroys granulation by reducing the stability of aggregates. Few fertilizers for example, CAN help in development of good structures.

8. Wetting and drying

When a dry soil is wetted, the soil colloids swell on absorbing water. On drying, shrinkage produces strains in the soil mass gives rise to cracks, which break it up into clods and granules of various sizes.

Soil Consistence

Soil consistence is defined as "the resistance of a soil at various moisture contents to mechanical stresses or manipulations".

It combines both the 'cohesive' and 'adhesive' forces, which determine the ease with which a soil can be reshaped or ruptures.

Soil consistence is described at three moisture levels namely; *wet, moist' and dry'*.

1. Wet soils: Consistency is denoted by terms stickiness and plasticity.

Stickiness is grouped into four categories namely i) *non sticky, ii) slightly sticky, iii)sticky and iv)very sticky*.

Plasticity of a soil is its capacity to be moulded (to change its shape depending on stress) and to retain the shape even when the stress is removed. Soils containing more than about 15% clay exhibit plasticity –

Pliability and the capacity of being molded. There are four degrees in plasticity namely *i) non plastic, ii) slightly plastic, iii) plastic and iv) very plastic.*

2. Moist soil: Moist soil with least coherence adheres very strongly and resists crushing between the thumb and forefinger. The different categories are

i. Loose-non coherent

ii. Very friable - coherent, but very easily crushed

iii. Friable - easily crushed

iv. Firm - crushable with moderate pressure

v. Very firm - crushable only under strong pressure

vi. Extremely firm - completely resistant to crushing. (type and amount of clay and humus influence this consistency)

3. Dry soil: In the absence of moisture, the degree of resistance is related to the attraction of particles for each other. The different categories are

i) Loose - non coherent

ii) Soft - breaks with slight pressure and becomes powder

iii) Slightly hard - break under moderate pressure

iv) Hard - breaks with difficulty with pressure

v) Very hard - very resistant to pressure

vi) Extremely hard - extreme resistance and cannot be broken.

Density and weight relationship

Two terms are used to express soil density. Particle density is the average density of the soil particles, and bulk density is the density of the bulk soil in its natural state, including both the particles and pore space.

Particle Density.

The weight per unit volume of the solid portion of soil is called *particle density*. Generally particle density of normal soils is *2.65 grams per cubic centimeter*. The particle density is higher if large amount of heavy minerals such as magnetite, limonite and hematite are present in the soil. With increase in organic matter of the soil the particle density decreases.

Particle density is also termed as *true density*.

Table Particle density of different soil textural classes:

Textural class	**Particle density (g/ cm)^3**
Coarse sand	2.655
Fine sand	2.659
Silt	2.798
Clay	2.837

Bulk Density.

The oven dry weight of a unit volume of soil inclusive of pore spaces is called *bulk density.* The bulk density of a soil is always smaller than its particle density. The bulk density of sandy soil is about 1.6 g / cm^3 , whereas that of organic matter is about 0.5. Bulk density normally decreases, as mineral soils become finer in texture. The bulk density varies indirectly with the total pore space present in the soil and gives a good estimate of the porosity of the soil. Bulk density is of greater importance than particle density in understanding the physical behavior of the soil. Generally soils with low bulk densities have favorable physical conditions.

Bulk density of different textural classes:

Textural class	**Bulk density (g/cc)**	**Pore space (%)**
Sandy soil	1.6	40
Loam	1.4	47
Silt loam	1.3	50
Clay	1.1	58

Factors affecting bulk density:

1. Pore space

Since bulk density relates to the combined volume of the solids and pore spaces, soils with high proportion of pore space to solids have lower bulk densities than those that are more compact and have less pore space. Consequently, any factor that influences soil pore space will affect bulk density.

2. Texture

Fine textured surface soils such as silt loams, clays and clay loams generally have lower bulk densities than sandy soils. This is because the fine textured soils tend to organize in porous grains especially because of adequate organic matter content. This results in high pore space and low bulk density. However, in sandy soils, organic matter content is generally low, the solid particles lie close together and the bulk density is commonly higher than in fine textured soils.

3. Organic matter content

More the organic matter content in soil results in high pore space there by shows lower bulk density of soil and vice-versa.

Soil pore space and porosity.

Soil porosity refers to that part of a soil volume that is not occupied by soil particles or organic matter.

The pore space of a soil is the space occupied by air and water. The amount or ratio of pore space in a soil is determined by the arrangement of soil particles like sand, silt and clay. In sandy soils, the particles are arranged closely and the pore space is low. In clay soils, the particles are arranged in popous aggregates and the pore space is high. Presence of organic matter increases the pore space.

Factors influencing pore space.

Soil texture

Sandy surface soil:	35 to 50 %
Medium to fine textured soils:	50 to 60 %
Compact sub soils:	25 to 30%

Crops / vegetation.

Some crops like blue grass increases the porosity to 57.2% from the original 50% .Cropping reduces the porosity as cultivation reduces the organic matter content and hence decrease in granulation. Virgin soils have more pore space.

Continuous cropping reduces pore space than intermittent cropping. More the number of crops per year, lesser will be the pore space particularly macro pores. Conservation tillage and no tillage reduces porosity than conventional tillage

Size of pores

1. Macro pores (non-capillary pores): diameter >0.05 mm

2. Micro pores (capillary pores): diameter < 0.05 mm

In macro pores, air and water moves freely due to gravitation and mass flow. In micro pores, the movement of air and water is very slow and restricted to capillary movement and diffusion.

Sandy soil have more macro pores and clay soils have more micro pores. So in sandy soils, water and air movement is rapid due to macro pores though the pore space is higher and in clay soils the air and water is slower due to micro pores though the total pore space is higher.

Loamy soils will have 50% porosity and have equal portion of macro and micro pores.

Significance and manipulation of soil porosity:

The bulk density and pore space are inter related. Development of low bulk density values also means the development of large amount of pore spaces. In nature, low bulk density values are usually found in soils with high organic matter contents. High biological activities are necessary for formation and large accumulation of organic matter. Together with the effect of soil organisms, the high humus content will encourage aggregation, increasing in this way soil porosity, and thereby decreasing bulk density values. The cultivation effect of the soil macro and micro fauna produces an intricate system of macropores, which is a major factor for lowering the bulk density of soil. Continuous cropping is noted to decrease the amount of organic matter in soils, and is expected to decrease soil aggregation. Tillage by ploughing is designed to increase the pore space in soils, but is infact decreasing organic matter. To alleviate these problems conservation tillage and no tillage have been introduced. Though many claimed that this increased the organic matter, the later have not always increased the total pore space.

Calculations of bulk density, particle density and porosity.

- **Bulk density.**

Is the mass of soil per unit bulk volume of dry soil:

$$\text{Bulk density} = \frac{M_s \text{ or weight of dry soil} = g}{V_b \text{ volume of dry soil} \quad = cm3}$$

Where M_s is mass of soil, V_b is natural volume or bulk volume.

Problem One:

Weight = 2.66 grams

Volume = 2 cubic centimeters

B.D?

$$\text{Bulk density} = \frac{\text{Ms or weight of dry soil} = g}{\text{Vb volume of dry soil} \quad = cm3}$$

$$= \frac{2.66 \text{ g}}{2 \text{ cc}}$$

$$= 1.33 \text{ g/cc}$$

Problem Two:

If the soil in core weighs 600 grams over dry and the core has a volume of 400 cm^3 , calculate the bulk density?

$$\text{Bulk density} = \frac{\text{Ms or weight of dry soil} = g}{\text{Vb volume of dry soil} \quad = cm3}$$

$$= \frac{600 \text{ g}}{400 \text{ cm}^3}$$

$$= 1.5 \text{ g cm}^3$$

- **Particle density.**

$$\text{Particle Density} = \frac{\text{Weight of Soil Mass}}{\text{Volume of Solids Only}}$$

Problem One:

Weight of Soil Mass = 2.66 grams

Volume of Solids Only = 20 cubic centimeter

Particle Density?

$$\text{Particle Density} = \frac{\text{Weight of Soil Mass}}{\text{Volume of Solids Only}}$$

$$= \frac{2.66\ g}{20\ cm^3}$$

$$= 0.133 g/cm^3$$

- ***Porosity.***

$$\textit{Porosity} = \frac{\textit{Pore Volume (Vp)}}{\textit{Total volume (Vt)}} \times 100$$

Problem One.

A 500 cm3 oven dry core has a bulk density of 1.1 g/cm3. The soil core is placed in a pan of water and becomes water saturated. The oven dry soil and water at saturation weigh 825 grams. Calculate the total soil porosity?

$$Porosity = \frac{\underline{Pore\ Volume\ (Vp)}}{Total\ volume\ (Vt)} x100$$

Weight of oven dry soil= $500cm^3$ **x** 1.1g/cm3
=550g

Weight of water in saturated core= 825g-550g
=275g

$$\frac{275\ cm^3\ \text{pore volume}}{500cm^3\ \text{soil volume}} \mathbf{x} 100 = 55\%$$

Soil Color:

Soil color indicates many soil features. A change in soil color from the adjacent soils indicates a difference in the soil`s mineral origin (parent material) or in the soil development. Soil color varies among different kinds as well as within the soil profile of the same kind of soil. It is an important soil properties through which its description and classification can be made.

Soil color is inherited from its parent material and that is referred to as lithochromic, e.g. red soils developed from red sandstone. Besides soil color also develops during soil formation through different soil forming processes and that is referred to as acquired or pedochromic color, e.g. red soils developed from granite or schist.

Factors affecting soil color:

There are various factors or soil constituents that influence the soil color which are as follows:

- Organic matter: soils containing high amount of organic matter show the color variation from black to dark brown.
- Iron compounds: soil containing higher amount of iron compounds generally impart red, brown and yellow tinge color.
- Silica, lime and other salts: Sometimes soils contain either large amounts of silica and lime or both.

  Due to presence of such materials in the soil the color of the soil appears like white or light colored.

- Mixture of organic matter and iron oxides: Very often soils contain a certain amount of organic matter and iron oxides. As a result of their existence in soil, the most common soil color is found and known as brown.
- Alternate wetting and drying condition: During monsoon period due to heavy rain the reduction of soil occurs and during dry period the oxidation of soil also takes place. Due to development of such alternating oxidation and reduction condition, the color of soil in different horizons of the soil profile is variegated or mottled. This mottled color is due to residual products of this process especially iron and manganese compounds.

- Oxidation-reduction conditions: when soils are waterlogged for a longer period, the permanent reduced condition will develop. The presence of ferrous compounds resulting from the reducing condition in waterlogged soils impart bluish and greenish color.

Therefore, it may be concluded that soil color indirectly indicative of many other important soil properties. Besides soil color directly modify the soil temperature e.g. Dark colored soils absorb more heat than light colored soils.

Determination of soil color:

The soil colors are best determined by the comparison with the Munsell color.

This color chart is commonly used for this purpose. The color of the soil is a result of the light reflected from the soil. Soil color rotation is divided into three parts:

Hue - it denotes the dominant spectral color (red, yellow, blue and green).

Value - it denotes the lightness or darkness of a color (the amount of reflected light).

Chroma - it represents the purity of the color (strength of the color).

The Munsell color notations are systematic numerical and letter designations of each of these three variables (*Hue, Value and Chroma*).For example, the numerical notation 2.5 YR6/6 suggests a hue of 2.5 YR, value of 5 and chroma of 6.

The equivalent or parallel soil color name for this Munsell notation is `red`.

Significance of Soil Color:

Many people have a tendency to equate black colored soils with fertile and productive soils. Broad generalizations between soil color and soil fertility are not always valid. Within a local region, increases in organic matter content of surface soils may be related to increases in soil fertility, because organic matter is an important reservoir of nitrogen.

Subsoil colors are very useful in predicting the likelihood of subsoil saturation with water and poor aeration.

Gray subsoil color indicates a fairly constant water-saturated condition. Such soils are poor building sites because basements tend to be wet and septic tank filter fields do not operate properly in water-saturated soil. Installation of a drainage system is necessary to use the soil as a building site successfully.

Sub soils that have bright brown and red colors are indicative of good aeration and drainage. These sites are good locations for buildings and for the production of tree fruits. Many landscape plants have specific needs and tolerances for water, and aeration and soil color are a useful guide in selection of plant species.

Alternating water saturation and drying of the subsoil, which may occur because of alternating wet and dry seasons, may produce an intermediate color situation. During the wet season, iron is hydrated and reduced, and during the dry season the iron is dehydrated and oxidized. This causes a mixed pattern of soil colors called *mottling*. Mottled-colored B horizons are indicative of soils that are intermediate between frequent water saturation and soils with continuous well-drained conditions.

Soil temperature

Soil temperature is an important plant growth factor like air, water and nutrients. Soil temperature affects plant growth directly and also indirectly by influencing moisture, aeration, structure, microbial and enzyme activities, rate of organic matter decomposition, nutrient availability and other soil chemical reactions.

Specific crops are adapted to specific soil temperatures. Apple grows well when the soil temperature is about 18°C, maize 25°C, potato 16 to 21°C, and so on.

Heat Balance of Soils

The heat balance of a soil consists of the gains and losses of heat energy. Solar radiation received at the soil surface is partly reflected back into the atmosphere and partly absorbed by the soil surface.

A dark-colored soil and a light-colored quartz sand may absorb about *80* and *30* percent of the incoming solar radiation, respectively. Of the total solar radiation available for the earth, about *34* percent is reflected back into space, *19* percent is absorbed by the atmosphere, and *47* percent is absorbed by the land.

Heat is lost from the soil by:

- Evaporation of water,
- Radiation back into the atmosphere,
- Heating of the air above the soil, and
- Heating of the soil.

For the most part the gains and losses balance each other. But during the daytime or in the summer, the gains exceed the losses, whereas the reverse is true for nights and winters.

The amount of heat needed to increase the temperature of soil is strongly related to water content. It takes only 0.2 calories of heat energy to increase the temperature of 1gram of dry soil 1°C; compared with 1.0 calorie per gram per degree for water. This is important in the temperate regions where soils become very cold in winter and planting dates in the spring depend on a large rise in soil temperature. In general, sandy soils warm more quickly and allow earlier planting than do fine-textured soils, because sands retain less water and heat up faster.

Factors affecting soil temperature.

The average annual soil temperature is about 1°C higher than mean annual air temperature. Soil temperature is influenced by climatic conditions. The factors that affect the transfer of heat through the atmosphere from sun affect the soil temperature also.

Environmental factors.

Solar radiation: The amount of heat received from sun on Earth's surface is 2 cal $Cm^{-2} min^{-1}$. But the amount of heat transmitted into soil is much lower. The heat transmission into soil depends on the angle on incident radiation, latitude, season, time of the day, steepness and direction of slope and altitude. The insulation by air, water vapour, clouds, dust, smog, snow, plant cover, mulch etc., reduces the amount of heat transferred into soil.

Soil factors.

a) Thermal (Heat) capacity of soil: The amount of energy required to raise the temperature by 1°C is called heat capacity. When it is expressed per unit mass (Calories per gram), then it is called as specific heat.

The specific heat of water is 1.00 cal g^{-1} where the specific heat of a dry soil is 0.2 cal g^{-1}.

Increasing water content in soil increases the specific heat of the soil and hence a dry soil heats up quickly than a moist soil.

b) Heat of vaporization: The evaporation of water from soil requires a large amount of energy, 540 kilocalories kg^{-1} soil.

Soil water utilizes the energy from solar radiation to evaporate and thereby rendering it unavailable for heating up of soil. Also the thermal energy from soil is utilized for the evaporation of water, thereby reducing the soil temperature.

This is the reason that surface soil temperatures will be sometimes 1 to 6°C lower than the sub-surface soil temperature. That is why the specific heat of a wet soil is higher than dry soil.

c) Thermal conductivity and diffusivity: This refers to the movement of heat in soils. In soil, heat is transmitted through conduction. Heat passes from soil to water about 150 times faster than soil to air. So the movement of heat will be more in wet soil than in dry soil where the pores will be occupied with air. Thermal conductivity of soil forming materials is 0.005 thermal conductivity units, and that of air is 0.00005 units, water 0.001 units. A dry and loosely packed soil will conduct heat slower than a compact soil and wet soil.

d) Biological activity: Respiration by soil animals, microbes and plant roots evolve heat. More the biological activity more will be the soil temperature.

e) Radiation from soil: Radiation from high temperature bodies (Sun) is in short waves (0.3 to□2.2) and that from low temperature bodies (soil) is in long waves (6.8 to 100□) Longer wavelengths have little ability to penetrate water vapour, air and glass and hence soil remains warm during night hours, cloudy days and in glass houses.

f) Soil color: Color is produced due to reflection of radiation of specific wavelengths. Dark colored soils radiate less heat than bright colored soils. The ratio between the incoming (incident energy) and outgoing (reflected energy) radiation is called albedo. The larger the albedo, the cooler is the soil.

Rough surfaced soil absorbs more solar radiation than smooth surface soils.

$$\text{Albedo} = \frac{\text{Reflected energy}}{\text{Incident energy}}$$

g) Soil structure, texture and moisture: Compact soils have higher thermal conductivity than loose soils. Natural structures have high conductivity than disturbed soil structures. Mineral soils have higher conductivity than organic soils.

Moist soil will have uniform temperature over depth because of its good conductivity than dry soils.

h) Soluble salts: Indirectly affects soil temperature by influencing the biological activities, evaporation *etc*.