Understanding the Physical Characteristics of Soil

Sonali Patel, Ashish Kumar Dash, Poonam Priti Pradhan

Soil is a living, dynamic, polyphasic system composed of solids, water, and air. The physical characteristics of soil plays a fundamental role in regulating different soil processes that support crop growth, soil health, and environmental sustainability. Soil physical characteristics such as texture, structure, bulk density, porosity, consistency etc govern water infiltration, movement, retention and availability to the plant, aeration, root growth, root penetration, nutrient availability, and resistance to degradation processes. Soil texture as determined by hydrometer method indicate the relative proportions of primary soil particle such as sand, silt, and clay which provides the basic framework influencing water-holding capacity and permeability. Soil structure evaluated through aggregate stability influences the size as well as continuity of soil pores, infiltration, and resistance to erosion. Plant root growth, gas exchange in soil and soil water dynamics directly influenced by two important key indicators i.e. bulk density and porosity mediated through soil compaction and pore geometry of soil. Soil consistency is the physical manifestation of cohesive and adhesive forces reflects the soil's resistance to deformation under varied moisture conditions. Surface crusting, a manifestation of structural breakdown, restricts seedling emergence and infiltration, thereby increasing runoff and soil loss. Soil colour, evaluated through standard colour charts i.e. Munsell's soil colour chart provides valuable insights regarding organic matter content, drainage conditions, and mineral composition.

Keywords: *Soil texture, Soil structure, Porosity of soil, Soil compaction, Bulk density, Particle density*

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Publisher: Cornous Publications LLP, Puducherry, India.
Elements of Soil Science and Recent Advances
Editor: Dr. Manik Chandra Kundu
ISBN: 978-81-986832-4-3
DOI: https://doi.org/10.37446/edibook222025/118-132

Scientific assessment and precise management of the above-mentioned physical characteristics facilitate the efficient management of runoff, erosion, water, as well as nutrient losses, and land degradation. Therefore, understanding different soil physical characteristics are essential for sustainable crop production, improvement of soil health and eco-friendly environment.

Introduction

Soil is a dynamic, three-phase and living system formed through the weathering of rocks into parent materials mediated by different biological and environmental processes. The physical characteristic provides a suitable and effective environment within which chemical and biological processes operate in order to regulate plant growth and ecosystem functioning. Soil physical characteristic influences the relative proportion of primary soil particles, their arrangement, individual particle size distribution, and interaction between the soil particles and pores. These parameters play a decisive role in determining soil behavior under natural and managed conditions. Under such circumstances, the soil's physical characteristics govern its response to external forces that influence various processes. Manifestation of most of the physical characteristics are slow to change but these are degraded significantly because of inappropriate land use along with management practices. Characterization of different soil physical properties are highly essential for identification of different crop specific as well as region specific production constraints along with the identification of appropriate sustainable management interventions for soil and crop. Characterization of different soil physical properties are influenced by accurate evaluation and scientific assessment which improves the soil compactness, soil structure, optimization of pore space distribution along with pore geometry, reduction of soil crusting, improvement of water as well as nutrient efficiency. Improvement of crop performance in terms of production and productivity along with environmental quality can be manipulated by integrating all these above-mentioned properties. Concise Information regarding the soil physical characteristic, their evaluation should be provided for the improvement of different soil and crops. Therefore, the basic objective of this chapter is to provide a comprehensive overview of the major soil physical characteristics, such as densities, soil texture, soil structure, soil crusting, and soil colour, with their methods of evaluation, which improve the soil water dynamics, root growth, crop productivity, and sustainable soil management.

Physical characteristics of soil

The composition of soil significantly alters the physical characteristics of a soil, such as structure, and porosity, which indirectly affects the flow of water and air inside the soil along with the soil's functionality. On the other hand, physical characteristics of soil influence the water availability, water storage capacity and nutrient availability. All these characteristics affect the usefulness of soils for different processes along with the type of crop grown in a given area. In a similar vein, the physical attributes of the soil directly mediate the ability of the soil to support plants, as well as the movement, storage, retention, and availability of water and nutrients to plants, ease of root penetration, and flow of heat and air, all of which have an indirect impact on the chemical and biological properties of the soil. Some of important physical characteristics of soil relevant to its use as a medium for plant growth are disused below.

Soil texture

One of the most significant physical characteristics that may significantly impact other soil parameters is soil texture. The average size of mineral soil particles varies widely. They are categorized into three classes, such as sand, silt, and clay, and are referred to as either primary particles or textural fractions or soil separates or fundamental particles. The percentage of primary soil particles, such as sand, silt, and clay, on a weight basis is known as soil texture. The mechanical composition of soil and the word "soil texture" are often used interchangeably. It is regarded as a static characteristic as it is very difficult to increase the amount of particular primary particle to change the soil texture. The texture of a soil in the field is not readily subject to change, so it is considered a permanent soil attribute (Brady and Weil 2007). Since “these components of soil are largely unalterable, there’s not much can be done to change this property.” (Gershuny 1993). Berry et al. (2007, 2) indicated that “It is very impractical (expensive) and thus ill-advised to modify a soil’s texture.” Estimating soil texture is a fundamental practice universally applied by soil scientists to classify and understand the behaviour, health, and management of soil systems. Soil texture greatly affects crop production, land use, and management and it is directly related to water as well as nutrient retention along with availability. Soil texture is also helpful for drainage depending upon their pore geometry as well as aeration capacity for good root growth along with plant growth.

Classification of different primary soil particles

Primary soil particles having size more than 2 mm in diameter are not considered in soil texture, although in certain cases they may affect some of the soil properties such as hydraulic conductivity, water retention. The texture of the soil, such as clay, loam, sandy loam, or other textural groupings is indicated by the relative amounts of different sizes of particles in the soil and it is mainly due to weathering which is the physical and chemical degradation of rocks and minerals. Materials will weather at different rates due to these variations in composition and structure, which will alter the soil's texture. For instance, shale, a quickly weathered rock, generates clay-rich soils, whereas granite, a slow-weathering rock, forms sandy, coarse soils. In contrast to clay soils, which are more challenging to cultivate due to their high water-holding capacity, sandy soils are droughty and have a low water-holding capacity. Two organisations classify primary soil particles, depending on their respective sizes, i.e. the United States Department of Agriculture (USDA) and the International Society of Soil Science (ISSS) were renamed as the International Union of Soil Sciences (IUSS), presented in Table 1. The particles having the size more than 2 mm are classified as gravel having average size of 2-4 mm, pebbles having size of 4-76 mm, cobbles having size of 76-250 mm, stones having size of 250-600 and boulders having size of >600 mm. While comparatively inert sand and silt fractions show chemical and physical activities to a lesser degree, clay is a surface-active fraction with a high level of chemical and physical activity. The clay is thought of as the flesh of the soil, while the sand and silt are referred to as the skeleton of the soil. The soil matrix is made up of all three sections, including the pore space.

Table 1. Soil classification system of different soil particles according to their sizes

United States Department of Agriculture (USDA)		International Society of Soil Science (ISSS)	
Particle	**Maximum Diameter (mm)**	**Particle**	**Maximum Diameter (mm)**
Very coarse sand	2.0-1.0	Coarse sand	2.0-0.2
Coarse sand	1.0-0.5	Fine sand	0.2-0.02
Medium sand	0.5-0.25	Silt	0.02-0.002
Fine sand	0.25-0.10	Clay	<0.002
Very fine sand	0.10-0.05		
Silt	0.05-0.002		
Clay	<0.002		

Practical implications of soil texture

Soil texture is one of the most basic physical properties of soil [Adhikari et al., 2013; Fernandez-Illescas et al., 2001]. The composition and content of coarse and fine particles can affect the hydraulic characteristics of water retention, availability and conductivity in soil, as well as heat transfer and heat capacity [Safari et. al. 2012; Shwetha and Varija, 2015; Abu-Hamdeh, 2003]. Soil texture can also affect evaporation and infiltration rates [Liu et al., 2020; Lehmann et al., 2018]. Studies have shown that the spatial heterogeneity of a soil's texture is responsible for the spatial variation of moisture, which further increases the differences in the spatial distribution of moisture over time [Srivastava et al., 2020; Famiglietti et al., 2008]. Soil texture also has a close relationship with soil carbon stocks [Plante et al., 2006; Hamzehpour et al., 2019; Liao et al., 2013; De Carvalho et al., 2003]. Therefore, soil texture is an important parameter for land surface process models, hydrological models, and atmospheric models [Wang et al., 2012; Braud et al., 2010]. Soil texture influences the global and regional issues such as climate change, soil degradation, water resource management, environmental pollution, agriculture, and sustainable development. Soil texture indicates the relative proportions of sand, silt, and clay which facilitates irrigation water along with drainage and gaseous exchange through aeration which are critical for agriculture and cation exchange capacity affecting nutrient management and management of sustainable soil health through microbial population and activity. Integration of all these above information affects land, nutrient and nutrient management for sustainable production.

Textural classes

According to the feel method, soils may be classified into three major textural groups: sandy, loamy, and clayey. Textural class refers to the overall textural categorization of a soil with relation to the relative proportion of its sand, silt, and clay content. Textural class describes the physical, chemical, and biological characteristics of soils in addition to their textural composition. As shown in the textural triangle (Figure 1), soils are categorised into twelve textural classes based on the quantitative measurement of their sand, silt, and clay concentrations. Altogether there are 12 textural classes of soil as determined quantitatively by mechanical analysis method. These 12 textural classes are presented in table 2 as per the fractional composition of soil. Such as Sandy, Sandy loam, Sandy clay, Sandy clay loam, Silty, Silty Loam, Silty clay, Silty Clay Loam, Loamy, Loamy sand, Clayey, Clayey loam.

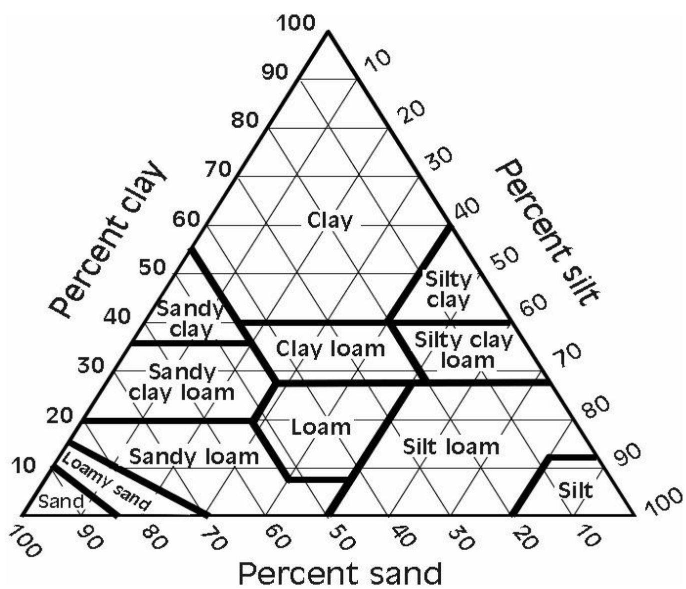

Figure1. Textural triangle diagram according to ISSS system of classification of soil particles (Fundamental of Soil Science, The Indian Society of Soil Science, 2009)

Table 2. Soil Texture in relation to the basic Soil Textural class (USDA classification)

Textural group	Texture	Textural class
Sandy	Coarse	Sandy
		Loamy sand
Loamy	Moderately coarse	Sandy loam
	Medium	Loamy
		Silty loam
		Silty
	Moderately fine	Sandy clay loam
		Silty clay loam
		Clay loam
Clayey	Fine	Sandy clay
		Silty clay
		Clay

Characteristics of broad soil groups

1. Characteristics of sandy soils

Sandy soils are classified into two textural classifications, sandy and loamy sand, and typically include more than 70% sand and less than 15% clay. Because they need less draft (power) for various field activities, these soils are sometimes referred to as light soils. Sandy (coarse texture) soil is loose and gritty, with low organic matter content, poor water and nutrient availability capacity, no swelling or shrinking, high water absorption capacity due to high infiltration rate, high nutrient and pollutant leaching capacity, and high aeration.

2. Characteristics of loamy soils

Sandy loam, loamy, silty loam, sandy clay loam, silty clay loam, clayey loam, and silt are the seven sub textural classifications that make up the loamy soils. Typically, loamy soil is the mixture of sand, silt and clay separates in equal proportions. The soil which is classified as sandy loam soil indicated that the soil is loamy in which proportion of sand is comparatively more. From an agricultural perspective, loamy soils are the most advantageous because they can retain more water and nutrients than sandy soil, and they have superior drainage, aeration, and tillage qualities than clayey soils.

3. Characteristics of clayey soils

The percentage of clay in a clayey soil should be at least 35%. These soils are further categorized using three textural classifications. The textural class is either sandy clay, silty clay, or clay if the percentage of clay is greater than 40%, depending on the quantities of sand and silt. Because of their poor infiltration capacity, clayey or fine-textured soils hold more water, become plastic and sticky when wet, and become hard and cohesive when dry. Because it requires more energy for cultivation, this soil is known as heavy soil. Percolation, saturation hydraulic conductivity, and infiltration rate are all lower in clayey soil than in sandy soil.

Qualitative estimation of soil texture

There are different methods used for determining soil texture. The Robinson's pipette method otherwise known as international pipette method is considered to be an exact and precise method. This method is time consuming and tedious for which it is not very suitable for routine analyses (Gee & Or, 2002). Bouyoucos

(1936) proposed an alternative analytical method *i.e.* hydrometer method which is simpler, quicker but less accurate than that of the international pipette method. Both methods are based on Stokes' law (Jury & Horton, 2004), which establishes a relationship between particle size and the terminal velocity which indirectly influences the rate of sedimentation. Thus, particles are assessed by their settling velocities from soil water that can be used to quantify particle size. In the international Pipette method, the particles in the suspension are measured as they move through the maze of solids of a known volume. In the methodology proposed by Bouyoucos, the size of the solids in the suspension is estimated from the density of the solution measured using the hydrometer. The Pipette method and the method proposed by Bouyoucos differ in the treatment of the samples before sedimentation. The Pipette method recommends the destruction of the soil organic matter (SOM) in the sample, whereas the Bouyoucos method does not recommend this pre-treatment (Bouyoucos, 1962).Another important difference between these two techniques is that the clay fraction determination is performed following two hours of sedimentation using the Bouyoucos method (Gee & Or, 2002), whereas in the Pipette method, the length of the clay fraction determination is dependent on the temperature of the solution and frequently exceeds two hours.

Soil structure

The arrangement of soil particles into bigger clusters, referred to as aggregates or "peds," is known as soil structure. (Figure 2). The size, shape, and arrangement of solids and voids, as well as the continuity of voids and their ability to hold and transfer fluids, make up soil structure. (Lal, 1991). Aggregation is the process of flocculation in which the soil particles are coming closer to each other for enhancing the stability of soil particles due to the presence of cementing agent.

Importance of soil structure

Soil structure is made of aggregated particles that differ, and they are presented as soil organic matter (Carter, 2004). Soil pores are filled with air, water, and nutrients and can be used by microbiota, plants, and animals for their growth and development. Soil structure is important for soil function and improvement in it represents an increase in soil quality, whereas the soil structure can be determined through aggregate stability, porosity, bulk density, and water infiltration.

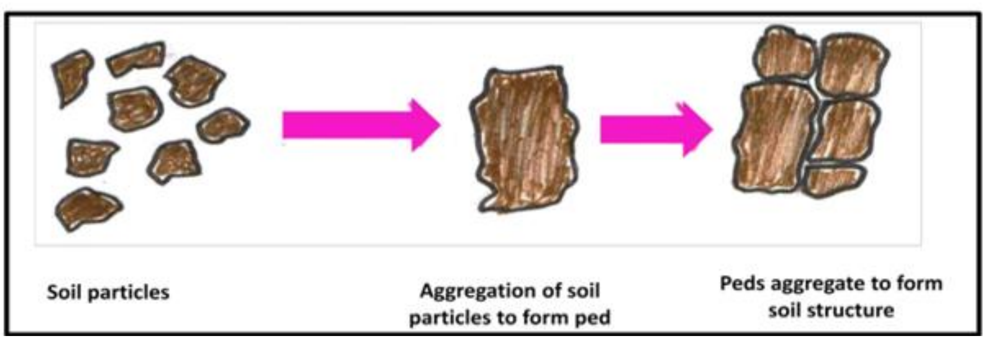

Figure 2. Formation of soil structure by aggregation

Formation of soil structure (soil aggregation)

Soil aggregation may be considered as flocculation plus which involves two processes viz. flocculation of the particles and cementation of the particles in presence of organic acids, polyuronide, polysaccharides.

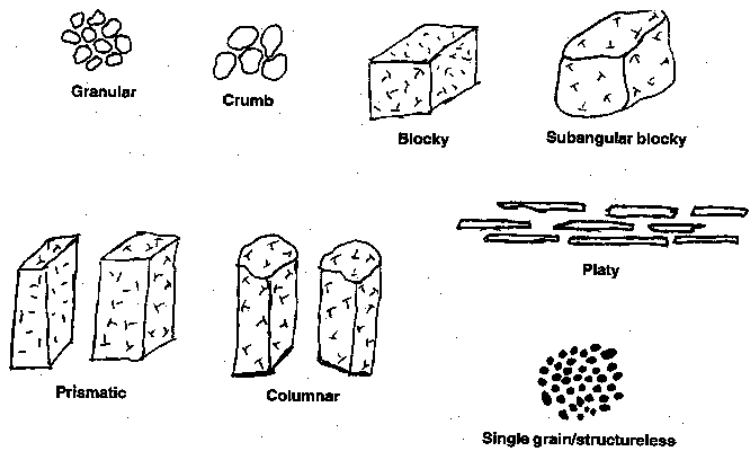

Figure 3. Types of soil structure

The processes that facilitate the flocculation of particles are:

a) Alternate wetting and drying
b) Freezing and thawing
c) Decaying organic matter
d) Activity of roots, small animals, and bacteria and
e) Soil tillage.

Classification of soil structure:

Based on several criteria, soil structure may be divided into many groups.

Classification based on the shape and arrangement of aggregates

- **Platy:** Platy peds have a flattened top and are longer horizontally than vertically, measuring between 1 and 10 mm. The A-horizon of forest soils and lake sedimentation is where they are mostly found.

- **Prism like:** Aggregates that resemble prisms are longer vertically (10–100 mm) and bigger horizontally. There are two subgroups within this group: (a) Prismatic and (b) Columnar. Prismatic structures have flat tops, whereas columnar structures have rounded tops. This kind of soil structure is often seen in the B horizon of soil with high sodium and clay content.

- **Block like block**: Blocky structures are imperfect cubes (5–50 mm). This group has two subgroups viz. angular blocky having sharp edges whereas sub-angular blocky have rounded edges. This type structure normally observed in the B-horizon where clay accumulation takes place with poor water infiltration.

- **Sphere like Spheroid:** Spherical polyhedrons (1–10 mm) that resemble spheres are most often observed in the A-horizon with presence of organic matter. Spherical polyhedrons (1–10 mm) that resemble spheres are most frequently observed in the A-horizon when organic matter is present. Granular and Crumb are the two subgroups of these types of structures. For soil aggregates, crumb structures are more porous than granular structures, which are less porous.

Classification based on the size of the soil aggregates

(a) Very fine or very thin: The size of very fine aggregates are <1 mm for platy and spherical, <5 mm for blocky and <10 mm for prism like structure.
(b) Fine or thin: The sizes of fine or thin aggregates are 1–2 mm for platy as well as spherical, 5–10 mm for blocky, 10–20 mm for prism like structure.
(c) Medium: The sizes of medium aggregates are 2–5 mm for platy as well as granular, 10–20 mm for blocky and 20-50 mm for prism like structure.
(d) Coarse or thick: The size of coarse or thick aggregates are 5–10 mm for platy as well as granular, 20–50 mm for blocky and 50–100 mm for prism like structure.
(e) Very coarse or very thick: The size of very coarse or very thick aggregates are >10 mm for platy as well as granular, >50 mm for blocky and >100 mm for prism like structure.

Classification Based on the grades

Aggregates' grade indicates the level of development or cementation that provides them their strength and stability. Basing upon the grade, the soil aggregates can be classified as follows:

(a) Structure less: These types of soils are neither aggregated nor the soil is entirely cemented together to form one big mass or aggregates.

(b)Weak: Weak grade indicates the aggregates are fall apart into the individual particles with slightest applied forces.

(c) Moderate: In undisturbed soil, aggregates are indistinguishable; however, upon removal from the profile, they split into aggregates, fragmented aggregates, and unaggregated material. These types of aggregates are considered ideal for crop growth point of view.

(d) Strong: Aggregates are distinct, durable and well formed with more cementation which do not break easily.

Relationship with volume and mass of soil:

Soil mass is expressed as 2.24×10^6 kg ha^{-1} for 15 cm soil depth. The mass and volume of the soil is related through the density of soil. Density is the weight pen unit volume of a substance. It is expressed as gram per cubic centimeters or pound per cubic feet or mega gram per cubic meter (Mg m^{-3}). Two density measurements like particle density and bulk density are common for soils. There are some of the established relationships existing between the volume and the mass of the soil on the basis of three phases which are discussed below.

Density

Density is defined as mass per volume as per the classical physics. In case of soil basically there are two type of densities prevail taking into consideration of solid, liquid as gases phase of soil. These two types of densities are follows

1) Particle density

The oven dry mass of a specific soil particle divided by the total volume of soil solids alone is known as soil particle density. In other words, it is the weight of a soil particle per unit volume of that soil solid particle only. It is otherwise known as true density. In most mineral soils, the average particle density varies between 2.6 and 2.7 g/cm^3 (Mgm^{-3}), with the mean particle density value of 2.65g/cm^3(Mgm^{-3}) whereas the mean particle density of organic matter is about 0.8 g/cm^3.
Particle density can be expressed as follow

$$\text{Particle density (P.D.)} = \frac{Mass\ of\ oven\ dry\ soil}{Volume\ of\ soil\ excluding\ pore\ space}$$

2) Bulk density

The bulk density of the soil is defined as the oven dry mass per unit volume of total soil which includes both the soil solids and the pore space inside the soil. Bulk density is important because it largely influences the porosity of a soil. Bulk density is otherwise known as apparent density. Bulk density indicates the amount of void space i.e. volume of water and air space which indirectly affects the infiltration rate, water holding capacity, ease to cultivate, saturated hydraulic conductivity and aeration capacity of soil. Fine sands, silt loams, and silty clay loams typically have bulk densities of 1.5, 1.35, and 1.25 g/cm3, respectively. Bulk density can be determined by the following relationship.

$$\text{Bulk density (B.D.)} = \frac{Mass\ of\ oven\ dry\ soil}{Volume\ of\ soil\ including\ pore\ space}$$

For a particular soil, the bulk density is less than that of the particle density.

Soil porosity

The portion of the bulk volume of soil that is not filled by solid particles, such as organic or mineral materials, but rather by gases or water, is referred to as porosity, also known as the amount of pore space. The total pore space in a typical medium-textured soil is around half of the soil volume. The typical pores are categorised as follows because the size of the pores within the soil varies significantly. (a) Cryptopores: These are the tiniest holes, measuring less than 0.1 µm, that retain water excessively tightly. (b) Ultra micropores: When the soil reaches field capacity, air frequently fills (d) micropores (>75 µm), which are plant-sized holes that store water in ultra-microspores and (c) mesopores (0.1-75 µm). In general soil pores are two types i.e. macro pores and micropores which influenced by soil texture.

Clay soils have more micro pores (small size pores) having more total pore space on the other hand; sandy soils contain more macro pores (large sized pores) with less. By rearranging the particles and increasing the void space, tillage or intercultural action might temporarily increase the total number of pores. The distribution of pore sizes in the soil enhances plants' indirect access to water and air, improving aeration and nutrient movement from the soil.
The formula porosity is expressed as follow

$$\text{Total Porosity (f)} = \frac{Volume\ of\ pore\ space}{Total\ volume\ of\ soil}$$

$$\text{Total Porosity (\%)} = [1 - \frac{Bulk\ density}{Particle\ density}]\ x\ 100$$

Soil compaction

Soil compaction is one of the dynamic characteristics linked to increased pressure and moisture content of soil. The ability of the soil to withstand cohesive and frictional pressures is known as soil strength, or load-bearing capacity. Frictional forces cause soil particles to slide over one another, while cohesive forces destroy the ties between soil particles. (McKenzieet al. 2002). When the soil is dry, its strength is at its highest, and it quickly declines as the soil moisture content rises. The term "compaction" influenced by the reduction in soil volume brought on by an applied force that raises the soil's bulk density. The bulk density may rise to a depth of at least one foot due to compaction brought on by implement movement. A traffic pan may result from "smearing," which is the breakdown of soil structure brought on by soil shearing. Figure 1 explains the idea of compaction in the creation of a tillage pan. Generally, root penetration is reduced with soil bulk densities higher than 1.7 to 1.8 g/cm^3.

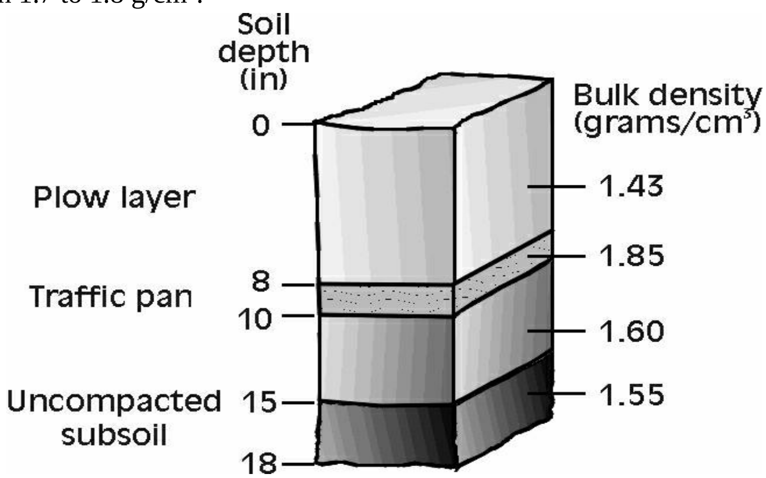

Figure 4. Effects of traffic and tillage on bulk density (Yonts, D., Benham, B.)

Causes of soil compaction

Soil compaction is most often seen when heavy machinery or agricultural implements pass over the soil surface due to mechanization. Soil types also have an influence on compaction depending on their moisture level and organic matter contents in soil. Organic matter contents in soil facilitates the reduction of soil volume which indirectly increases the bulk density which leads to compaction. Similarly grazing also leads to compaction due to trampling by cattle.

Effects of soil compaction

Soil compaction has far-reaching implications as it affects most of the processes in soil. On the agricultural point of view, the compacted soil increases the likelihood of aeration problems that reduces the root growth of plants. The flow of water as well as nutrients may drastically reduce and impact crop and harvest schedules. Plants and animals aren't the only ones who need nutrition; soil does as well. If the soil isn't fed properly, it cannot feed roots properly. When a root tries to make its way through soil and reaches a depth it can no longer push through, it will grow in horizontally resulting in a pancake effect. This stunts the growth of the plant and minimizes its ability to draw water and nutrition from the soil. Crop yields may be drastically reduced due to soil compaction. The structure of the soil is another essential factor in the effects of compaction.

When soil structure is destabilized, compaction from external pressure is easier to achieve. Soils subject to heavy traffic are slower to warm when compared with less compacted soils.

Water Holding Capacity

Every soil has a property to retain water in its pores and on aggregate surfaces. This capacity varies from soil to soil and is strongly correlated with the soil's texture and pore size distribution. Because of their limited water-holding capacity and inability to retain a large number of macropores, coarse-textured soils are sometimes referred to as "thirsty soils." Conversely, fine-textured soils may store more water because they have more small pores.

Soil consistency

Friable consistency relates to the moisture content where the field can be cultivated in order to get a good seed bed for good crop growth. This condition may differ from the type of soil or their texture. In addition to its resistance to rupture and deformation, consistency is the soil's capacity to adhere to itself or other objects due to cohesion and adhesion forces, respectively. During crop growth, this dynamic feature helps determine the kind of tools and cultivation technique. Consistency is interactive physical manifestation of the amount of water present in the soil as well as type and amount soil solids. In dry soil, the cohesive force is more between soil solids which makes the soil hard consistency or harsh consistency. In moist condition soil water content increases the adhesive force between solid particles and liquid particles (soil water) whereas the cohesive force between solid particles leads to friable consistency. Increase in moisture content leads to plastic consistency. In this consistency soil will behave like plastic with increasing soil moisture the cohesive forces between soil solid will decreases whereas adhesive forces between soil solid and liquid will increase where the soil will deform easily and it will not come to its original position. Lastly with further addition of moisture leads to saturated moisture content where soil will behave as semi-fluid or soil may flow under pressure which is characterised as sticky consistency. This consistency is not suitable for the growth of most of the crops except rice.

Importance of soil consistency

Soil consistency depends on the texture, nature and amount of inorganic and organic matter, structure and moisture content etc., With decreasing moisture content, the soils loose their stickiness and plasticity and become friable and soft and finally when dry become hard and coherent. The characteristics of harsh consistency (Dy soil) is loose, soft, slightly hard, hard, very hard, extremely hard; friable consistency (moist soil) is loose, very friable, friable, firm, very firm, extremely firm; Characteristics of plastic consistency (wet soil) is non sticky, slightly sticky, sticky, very sticky; non plastic, slightly plastic, plastic, very plastic and characteristics of sticky consistency is weakly cemented, semi fluid with respect to agriculture point of view on the other hand, soil consistency is useful for determining the ability of soil to support buildings and roads. More precise measures of soil strength are often made prior to construction.

Soil colour

Soil colour is an ocular property by which one has to view the soil with some of its characteristic features. Soil mineralogy, organic matter concentration, drainage conditions, and oxidation level all affect colour. Soil colour may be used to identify boundaries within a soil profile, expose the origin of a soil's parent material, and indicate wetness in addition to being a qualitative means of assessing various soil attributes. Soil colour may be studied using the Munsell soil colour chart. Soil colour variations result from the existence of different minerals, which are impacted by diverse chemical and biological weathering processes. While manganese, sulphur, and nitrogen may create black minerals, iron makes secondary minerals that are yellow or red in colour and organic matter breaks down into black and brown compounds. Presence of oxygen i.e. aerobic conditions results in uniform or gradual colour changes, while reducing environments anaerobic condition result in rapid colour flow with complex, mottled patterns and points of colour concentration. Soil colour as per Munsell colour notation can be studied with three components such as Hue, Value and chroma. Hue indicates the basic colour (Red, Yellow etc.) of rainbow. Value indicates the lightness or darkness of a given colour can be expressed as 5YR6/7 where 5YR is hue reading and numerical 6 is assigned for value and numerical 7 is assigned for chrome reading.

Factors affecting soil colour and its importance

Soil colours are mostly affected by pedogenic processes in soils, mineral composition, element concentration, organic matter content and moisture content. Soil colour reflects different soil properties, involvement of different soil processes influencing different important diagnostic feature for soil horizon delineation and soil classification. When a soil horizon has more than one color, the dominant color by volume is the matrix color. The quantity of soil organic matter as well as iron oxides influences soil colour the most. Organic matter darkens the soil, while iron oxides produce a range of soil colours that are dependent on the oxidation state of the iron. The most widely used method for determining soil colours is the comparison of soil samples with the colour chips in the Munsell soil colour charts. In the Munsell colour system, colour is expressed in terms of hue (basic colour), value (lightness or darkness), and chroma (intensity of basic hue). Color determinations are applied to air-dried bulk soil samples; but more elaborate color-determination schemes have also been advocated. Because most of the colour of a bulk soil sample is due to the clay fraction, which contains clay particles intimately bound to soil humus (forming the clay–humus complex) and clay particles coated with iron oxides, some forensic soil analysts have suggested basing colour determinations on the clay fraction of the soil. Other forensic soil analysts have proposed determining the colors of the soil sample after air-drying, wetting, organic matter removal, iron oxide removal, and ashing.

Conclusion

Land suitability for sustainable crop production depends upon the physical characteristics of soil such as texture, structure, bulk density, particle density, porosity, and soil consistency. All these parameters collectively influence the behavior of soil with respect to crop production and plant growth. These properties influence the soil aggregation, the air and water movement inside the soil, effective root penetration and stable environment for soil microbes along with their biological activity. The capacity of the soil can be increased manifold to function as a productive medium when these characteristics are studied in combination with other properties rather than isolation. Soil compaction is directly affected by bulk density and particle density which indicates pore space availability in soil for root expansion and higher production. Similarly, porosity affects the water movement and drainage. Infiltration rate, aeration, and nutrient availability are mainly influenced by soil texture, whereas soil structure affects the aeration, permeability, hydraulic conductivity and mechanical stability. Soil consistency and soil color provide valuable information about moisture content, organic matter content, and mineralogical composition of soil. These physical characteristics of soil provide information regarding the type of tillage implements used and its intensity along with quantity and type of organic matter added, irrigation scheduling as well as crop rotation. All this above-mentioned information indirectly enhances soil fertility, improve water-use efficiency, erosion prevention and long-term soil health improvement. Therefore, the study of soil physical characteristics plays an important role in managing crop productivity through effective agronomical practices, adoption of suitable cropping systems, management of organic carbon along with biological environment of soil for economically, ecofriendly and sustainable crop production.

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