



SOIL HEALTH AND PLANT NUTRITION

The soil is a natural resource which is intensively utilized for crop production. It acts as primary medium for crop growth and sustenance. Plant obtains their food materials and water from soil. It also provides mechanical support to crops. Soil is also living place of numerous other living organisms like algae, bacteria, fungi, virus, etc. These organisms help in plant nutrition and protect the environment. Therefore, soil is called as soul of infinite life. So you can understand how soil plays a critical role in agriculture. As the cultivable land is decreasing day-by-day due to increased population, we need to manage the soil more efficiently for food production. This requires scientific knowledge about soil. In this lesson, we will study about fundamental principles about soil and its management.



LEARNING OUTCOMES

After studying this lesson, the learner:

- summarizes the importance of soil in agriculture and human life;
- explains how a soil is originated from parent rocks;
- supports the farmers to manage the soil sustainably for crop production; and
- discusses the techniques for protection of soil from erosion and degradation.

5.1 SOIL AS A NATURAL BODY FOR PLANT GROWTH

Soil is a precious natural resource that supports outdoor plant growth. It is a thin-layer 3-dimensional polyphasic dynamic natural body on upper portion of the earth's crust which supports plant growth. It is called polyphasic system because soil contains solid, liquid and gaseous phases. Millions and millions of micro organisms are residing

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in soil; therefore, it is considered as a living body. They help in nutrient transformations for the support of plant growth. For this reason, Franklin Roosevelt (32nd President of USA) said ‘*A nation that destroys its soils destroys itself. Forests are the lungs of our land, purifying the air and giving fresh strength to our people*’. Soils have developed over a long period of time in a place through natural processes, following natural laws, under natural conditions and from natural materials. That’s why soil is considered as a natural body.

5.2 COMPONENTS OF SOIL

Soil is a thin-layer material on upper portion of the earth’s crust present in between bedrock and air. An ideal soil consists of mineral matters (45%), organic matter (5%), soil air (~25%) and soil water (~25%).

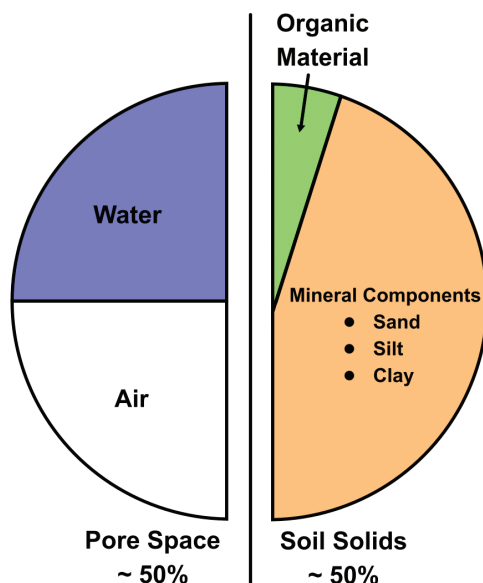


Fig. 5.1: Components of soil

5.2.1 Mineral Matter

Major part of solid portion of the soil is mineral matter. It includes sand, silt and clay. It is composed of primary and secondary minerals. Primary minerals like quartz, mica and feldspar are similar to soil parent materials, whereas secondary minerals such as silicate clay, limonite, haematite are originated from primary minerals. The primary minerals dominate in the coarser fraction of soils. The secondary minerals are prominent in the fine soil particles, especially in clay fraction. The size of these particles does have much effect on the properties of soil.

5.2.2 Organic Matter

Soil organic matter includes the decomposed organic materials, partially decomposed and partially synthesized plant and animal residues in the soil. They are continuously decomposed by microbial action. Plant residues are the primary source of organic matter in soil and animal residues are secondary source.

Mineral matter and organic matter of soil are the inorganic and organic constituents, respectively. Soils having more inorganic constituents are called mineral soils. The majority of the soils of India are mineral soils. If more than 20% of constituents in soil are organic, then such soils are referred as organic soils.

5.2.3 Soil Water

The pore space of soil is occupied by water and air, their content in soil is inversely proportional to each other. Optimum content of soil water is helpful in plant growth. Soil water acts as solvent for nutrients/salt and it helps to transport nutrient from soil to plant roots.

5.2.4 Soil Air

A part of the soil pore space not occupied by soil water is filled up by air. The composition of soil air is similar to atmospheric air, viz. nitrogen, oxygen, carbon dioxide, inert gases and water vapour. But soil air has higher concentration of CO₂ (0.25%) than atmospheric air (0.03%). This is due to continuous respiration of plant root and soil microorganisms. Gaseous exchange process between soil air and atmospheric air ensures fresh supply of oxygen and prevent carbon dioxide toxicity in soil.



INTEXT QUESTIONS 5.1

1. Major components of soil are,, and
2. Soils having more inorganic constituents are called
 - a. Organic soil
 - b. Mineral soil
 - c. Humus soil
 - d. None of these



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3. Soil pore spaces are filled with and

5.3 SOIL HORIZONS AND PROFILE

A soil horizon is a layer of soil approximately parallel to the ground surface. It has distinct characteristics from its adjacent soil horizon. These distinct soil properties are produced by the action of soil forming process. The soil horizons tell much about the history of soil formation. Each soil has unique combination of soil horizons. In general, a soil consists of six horizons which are designated as 'O', 'A', 'E', 'B', 'C' and 'R'.

- O-horizon:** This is top most horizon dominated by organic matter. O-horizon is mostly found in forest areas where continuous addition of dead plant and animal occurs.
- A-horizon:** This horizon is found below 'O' horizon where soil mineral matter and organic matter are intimately mixed. It is also called mineral horizon.
- E-horizon:** It is eluvial or washed out horizon. Silicate clay, iron and aluminium present in this region are washed out from this horizon. As a result, only sand and silt particles are present here.
- B-horizon:** It is illuvial or washed in horizon where material washed from E horizon are deposited here. Hence it is known as zone of accumulation.
- C-horizon:** This horizon has been least affected by soil forming processes and lacks the properties of O/A/E/B horizon.
- R-layer:** This is strongly cemented bed rock. Such bed rocks may be granite, basalt, quartzite, etc. Above horizons overlie the bed rocks from which soil have been formed.

Soil profile is a vertical section of soil from ground surface to parent material or to a considered depth (1.5 m) showing various soil horizons.



INTEXT QUESTIONS 5.2

- What is soil horizon?
- A soil horizon dominated by organic matter is designated as
 - O horizon
 - A horizon
 - E horizon
 - C horizon



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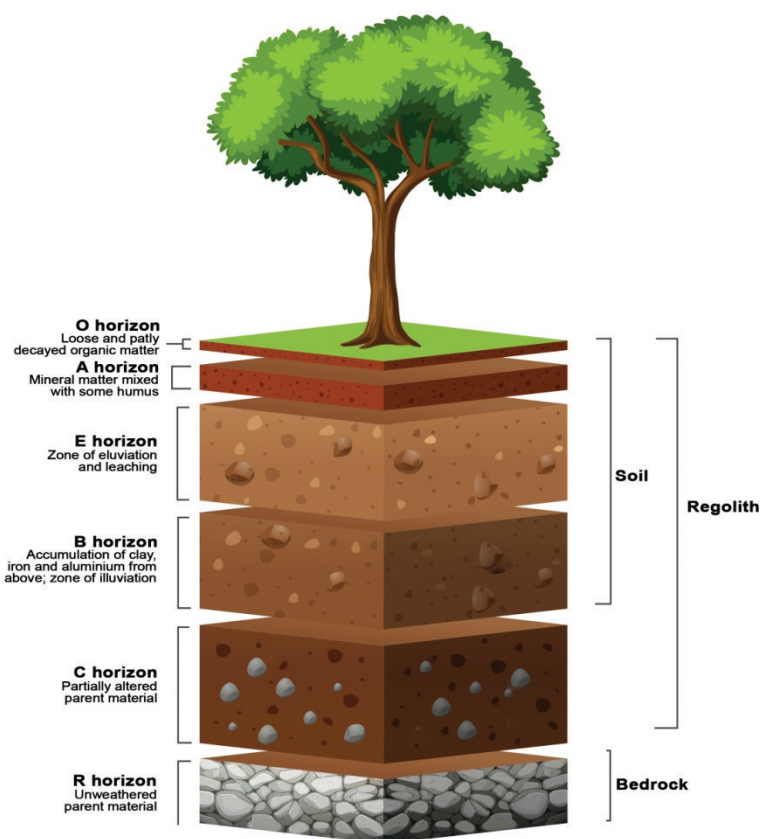


Fig. 5.2: Sequence of soil horizons

5.4 WEATHERING AND SOIL FORMATION

Soil is formed through the process of weathering. The hard consolidated rocks are transformed into soil through combined action of water, wind or organic matter decomposition. Generally, a soil is formed through two different stages

1. **1st stage:** Weathering where hard consolidated rocks are transformed into loose materials.
2. **2nd stage:** Conversion of loose materials into soil

5.4.1 Weathering

Weathering is physical disintegration and chemical decomposition of rocks and minerals. Through this process rocks are broken down into smaller fragments. Further, these small fragments undergo chemical changes to form new minerals. A weathering is of three types

- A. Physical Weathering:** Through this mechanical process, huge mass of rocks

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are disintegrated into smaller pieces. The agents of physical weathering are temperature, wind, water, ice and pressure.

- B. **Chemical Weathering:** In this process, rocks and minerals combine with water (H_2O), carbonic acid (H_2CO_3), hydroxyl ions (H^+ or OH^-) or undergo oxidation-reduction reaction. As a result, some minerals are disappeared, some are altered or new minerals are formed.
- C. **Biological Weathering:** Actually, this is physical and chemical weathering caused by biological organisms. Growing plant root exert tremendous pressure on rock and widens the cracks and crevices. Plant root also releases CO_2 which combine with water to form carbonic acid. This acid then initiates the process of chemical weathering.

5.4.2 Factors of Soil Formation

At any place of the world, at least five factors work simultaneously to produce soil. These factors are soil forming factors e.g. **climate, living organisms, parent material, relief or topography** and **time**. American soil scientist H. Jenny (1941) had described how a soil is formed through interaction of soil forming factors. Therefore nature of soil is the result of collective action of these five factors. It is important to note that all of these factors work simultaneously to produce soil.

Let's discuss these factors in this section.

- 1) **Climate:** Climate is most influential factor of soil formation. Rainfall and temperature are major component of climate that affects physical, chemical and biological processes of profile development and soil formation. Precipitation results addition to and loss from parent materials. For every $10^\circ C$ rise in temperature, the rate of biochemical reactions doubled. Thus, it accelerates decomposition of organic matter and weathering process.
- 2) **Parent Materials:** Parent material refers to unconsolidated material from which soil develops. Jenny defined parent materials as 'the state of soil system at time of zero soil formation'. These are formed due to the process of weathering or by transportation and deposition from other places. Physical, chemical and mineralogical characteristics of parent materials have a significant effect on soil formation. Parent material decides texture, pH, lime and salt-content and mineralogical composition of a soil.



- 3) **Topography:** Topography is mainly defined on the basis of elevation and slope of land surface. Topography modifies climate and vegetation, and very often, has a direct effect on soil formation. Sloping and undulating lands have very thin soil horizon. This is because most of the water is lost through runoff and lack of availability of water to pass through soil profile. Therefore, soils on flat/smooth land surface are deeper and have luxuriant vegetation as it permits more percolation, less runoff and soil erosion. In southern hemisphere, north facing slopes get more sunlight, therefore, are warmer and drier than south facing slopes. Hence, they are more productive.
- 4) **Living Organisms:** Living organisms are various plant and animal species present in the soil profile. Through their various activities, they help to form soil. For example, plant roots penetrate parent materials in the search of nutrients. When such roots die, they create passages for movement of water and favourable environment for other biological species. Plant roots also release CO₂ and organic acids which solubilize the minerals. Earthworms ingest the soil and excrete them in granular form. Activity of human also effects soil formation.
- 5) **Time/age of Soil:** The period for which the parent material is exposed to weathering is called time. In other word, it is the period from the start of soil development to present stage. Soil formation is very slow process. It takes thousands of years for development of an inch of soil. A soil body at any point of time reflects impression of soil forming factors in its profile development. Soil maturity measured in terms of profile development. Mature soil means it has a fully developed soil profile. A young soil means factors of soil formations are still operative and changing soil properties in profile, and profile development has not completed.

5.4.3 Soil Forming Processes

Soil formation leads to formation, transformation and rearrangement of soil materials in soil horizons. Soil forming processes are very complex in nature. Many dynamic chemical and biological reactions operate simultaneously during soil formation. Four basic processes that take place during soil formations are

- I. **Gain or addition** to the soil
- II. **Loss** from the soil
- III. **Transformation (conversion):** Transformation takes place through chemical weathering. Here, primary minerals are converted into secondary minerals and

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organic residues are transformed into humus by humification process.

- IV. **Translocation (migration):** In translocation, materials like clay, organic matter or hydrous oxides are transported with water by the process of leaching, percolation or run off.

**INTEXT QUESTIONS 5.3**

1. Weathering is process of transforming soil into hard mass of rocks (True/False).
2. Chemical weathering occurs through
 - a. Water
 - b. Carbonic acid
 - c. Hydroxyl ions
 - d. All of these
3. Enlist the factors of soil formation.
4. The basic processes of soil formation are,, and

5.5 PROPERTIES OF SOIL

Soil is regarded as living material. Therefore it possesses various physical, chemical and biological properties. These properties are the result of soil forming processes. As the factors of soil formation vary from place to place, soil properties also change with them. Let's discuss some of the important soil properties in this section.

5.5.1 Physical Properties of Soil

Physical soil properties include texture, structure, density, porosity, temperature, colour and water content.

i. Soil Texture

Soil texture refers to relative proportion of sand, silt and clay in soil. It is an important soil property which gives an idea about other soil properties like water holding capacity, bulk density, and nutrient retention, etc. Texture is a permanent property of soil which can't be changed easily. Soil particles can be differentiated into various groups based on their size.

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Table 5.1: Dimension/size of different soil particles

Particle group	Diameter (mm)
Clay	Less than 0.002 mm
Silt	0.002-0.02 mm
Fine sand	0.02-0.2 mm
Coarse sand	0.2-2 mm

Based on relative percentage of soil particles (sand, silt and clay), soils are classified into various textural classes. These classes are represented through textural triangle.

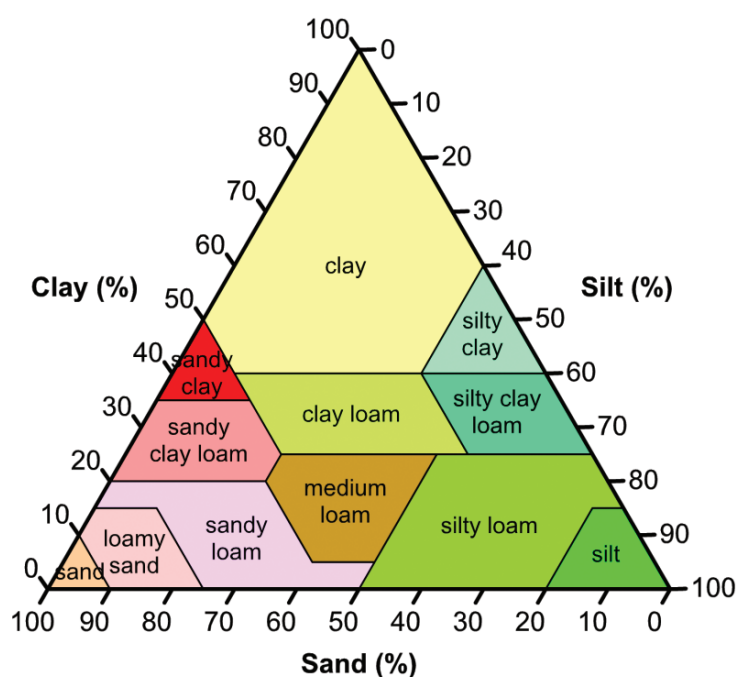


Fig. 5.3: Textural triangle

Texture of soil can be determined by laboratory methods or by feeling the soil in between thumb and forefingers. Sands feel gritty while silt feels like flour or talcum powder. Clay particles are hard when dry and exhibit stickiness when wet.

ii. Soil Structure

Under natural condition, primary soil particles (sand, silt, clay) do not exist freely. They are bonded together into aggregates through some cementing agents.

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These aggregates are called secondary particles. Arrangement of primary particles and their aggregates into certain definite pattern is called soil structure. Natural aggregate of soil is called peds. Soil structures are classified into four types based on their shapes.

Table 5.2: Brief description of soil structures

Type of Structure	Description
Plate like	This structure has flattened compressed appearance. Here horizontal dimension is more developed than vertical dimension.
Prism like	The soil particles are arranged along a vertical line resembling a prism. Here vertical dimension is more developed than horizontal dimension.
Block like	Structural units appear like a block where all of the three dimensions are of about same size.
Spheroidal/sphere like	The sizes of structural units are small and spherical. They may be porous or non-porous. Porous spheroidal structure called crumb is ideal for satisfactory crop growth.

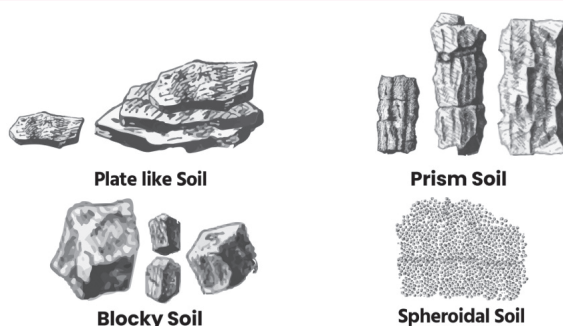


Fig. 5.4: Different types of soil structure

iii. Porosity

Porosity is the percentage of soil volume occupied by pore spaces. Pore spaces in soil are that portion of soil volume which is not occupied with soil solids (mineral matter + organic matter). Generally, an ideal soil has 50% solid space and 50% pore space. At field condition pore spaces are filled with water and air. Therefore, it indirectly affects crop growth. If good proportions of pore



spaces are not maintained in soil, plant may suffer from aeration and water availability. Two types of pore are found in soil viz. macro and micro pore.

- ❖ **Macro Pore:** These are large pores having diameter more than 0.06 mm. Water and air can easily pass through macro pores. Sandy soils have large number of macro pores.
- ❖ **Micro/capillary Pore:** They are smaller sized pore with diameter less than 0.06 mm. Micro pores play critical role in plant water availability. Generally, clay soil has greater proportion of capillary pore. However, movement of water is limited through these pores.

iv. Density

Can you recall the formula of density from your science book? It is mass per unit volume of a substance. Density of soil is expressed in gram per cubic centimeter (g/cm^3) or mega gram per cubic meter (Mg/m^3). There are two types of density of a soil a) particle density and b) bulk density.

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

- ❖ **Particle Density:** As the name indicates, it is the density of soil solid (mineral matter + organic matter) only. Hence, particle density is the ratio of mass of soil solid and volume of soil solid. It is also known as true density of soil.

$$\text{Particle density} = \frac{\text{Mass of soil solid}}{\text{Volume of soil solid}}$$

- ❖ **Bulk Density:** In the previous section, you found that apart from solid part, soil also has substantial pore spaces. These pore spaces occupy large portion of soil volume. When we include this pore volume in calculation of density, it becomes bulk density of soil. Bulk density is defined as mass of soil solid per unit volume of soil (including pore spaces). Generally bulk density of soil is lower than particle density.

$$\text{Bulk density} = \frac{\text{Mass of soil solid}}{\text{Volume of soil solid} + \text{volume of soil pore space}}$$

v. Soil Water

Water is a universal solvent for all the nutrients present in soil. Several organic and inorganic substances, plant nutrients are dissolved in soil water; therefore it is called soil solution. Soil water helps plant to absorb essential nutrients from their root zone. Important physiological processes of plant and soil organisms are also controlled by soil water. Generally, water is held in between pore spaces

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and on the surfaces of soil particles. Rainfall and snow fall are the major sources of soil water. After rainfall, the fate of water in soil is presented as follows

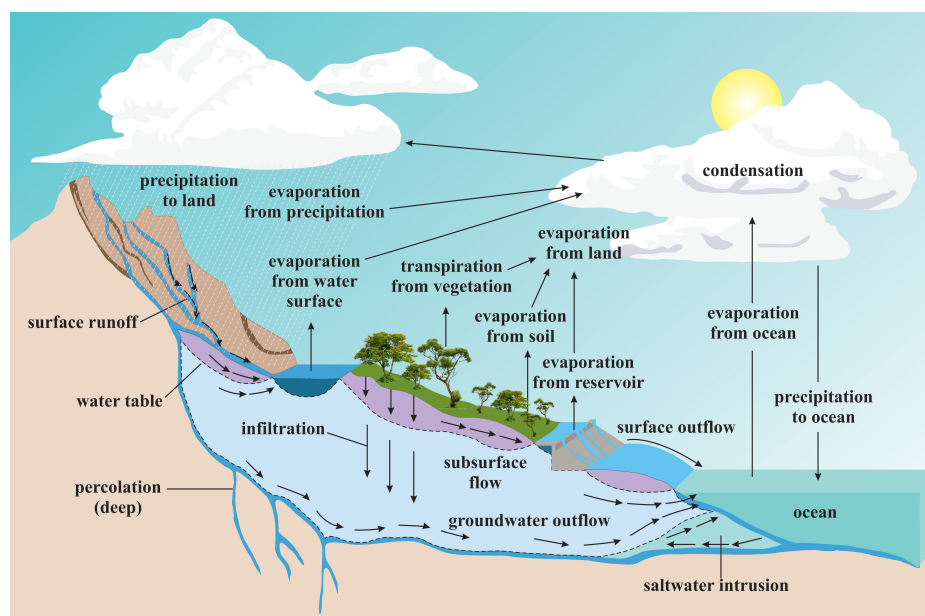


Fig. 5.5: Movement of water between soil, atmosphere and ocean

vi. Soil Colour

Colour of soil is the first criteria through which human can identify the soils. Globally, soils are found in various colours like red, yellow, brown, black or white. Colour of soil is determined by the parent material from which it develops, mineral composition, organic matter and water content. If a soil has high organic matter and water content, it is darker in colour.

vii. Soil Temperature

Optimum soil temperature is essential for seed germination, root growth and microbial activity. Solar radiation is the main source of heat energy in soil. As solar radiation cannot reach uniformly to all the places, place-to-place variations exist in soil temperature. Generally, soil temperature is highest during afternoon, while it is lowest in the morning just before the sun rise. Generally, dark coloured soil absorbs more heat and it has higher temperature than light coloured soil.



INTEXT QUESTIONS 5.4

1. The size of clay particles is
 - a. $> 2 \text{ mm}$
 - b. $0.002 - 0.02 \text{ mm}$



- c. 0.02 – 0.2 mm
 - d. < 0.002 mm
2. The relative proportion of sand, silt and clay in soil is called
 - a. Soil structure
 - b. Soil texture
 - c. Soil consistency
 - d. Soil water
3. Soil structure which is ideal for plant growth
 - a. Platy
 - b. Crumby
 - c. Blocky
 - d. Prismatic
4. Which type of soil absorbs more heat?



ACTIVITY 5.1

Collect the soil from different areas from your locality. Carefully observe whether these are same in colour or different. Add few drops of water to these soils. Describe how colour changes with addition of water.

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5.5.2 Chemical Properties of Soil

Soils differ very much in their chemical composition due to nature of rocks from which they are formed. Moreover, different soil types have different plant nutrient availability. It is very important to know about the chemical properties of soil to successfully grow a crop. Let's discuss some of these properties in detail.

i. Soil Reaction or pH

Soil pH is a measure of acidity or alkalinity present in a soil. It is the most important chemical property of soil which governs availability of nutrients and activity of biological organisms. pH is defined as negative logarithm of hydrogen ion activity in soil solution. In other words, it is concentration of H^+ or OH^- ions in soil solution. When concentration of H^+ ion is higher than OH^- ion, then soil is called acidic and when concentration of OH^- ion is higher than H^+ ion, then soil

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is called basic/alkaline; at equal concentration of H^+ and OH^- ion, soil is said to have neutral pH. Neutral pH is considered ideal for crop cultivation as most of the nutrients are in available form in this pH range.

Generally, soil acidity or alkalinity is expressed through pH scale which extends from 0 to 14. pH 7 is considered as neutral while below 7, it is acidic and above 7, it is alkaline.

Table 5.3: pH rating of soil

Soil rating	pH range
Extremely acidic	<4.5
Very strongly acidic	4.5-5.0
Strongly acid	5.1-5.5
Moderately acid	5.6-6.0
Slightly acid	6.1-6.5
Neutral	6.6-7.3

ii. Electrical Conductivity

Electrical conductivity (EC) refers to total amount of soluble salts present in the soil solution. If a soil has higher soluble salt content, then it is said to have higher electrical conductivity and vice-versa. It is expressed as dS/m (deci Siemens per metre) or mmho/cm (milimho per centimeter). Based on pH and electrical conductivity, soils are classified into various groups.

Table 5.4: Classification of soil based pH and electrical conductivity

Soil type	pH	EC (dS/m)
Saline soil	< 8.5	> 4
Alkali soil	> 8.5	< 4
Saline-alkali soil	> 8.5	> 4

iii. Presence of Soil Colloids

Soil particles which has diameter between 1 μm to 1 nm are considered as soil colloids. Soil colloids have unique properties like large surface area, high electric

charge, cohesion and adhesion. These colloids are the most reactive part of soil. Therefore, presence of colloids in a soil imparts peculiar characteristics like high water holding capacity, greater nutrient content, better soil structure and infiltration. Colloids in soil can be classified into two types – inorganic and organic.

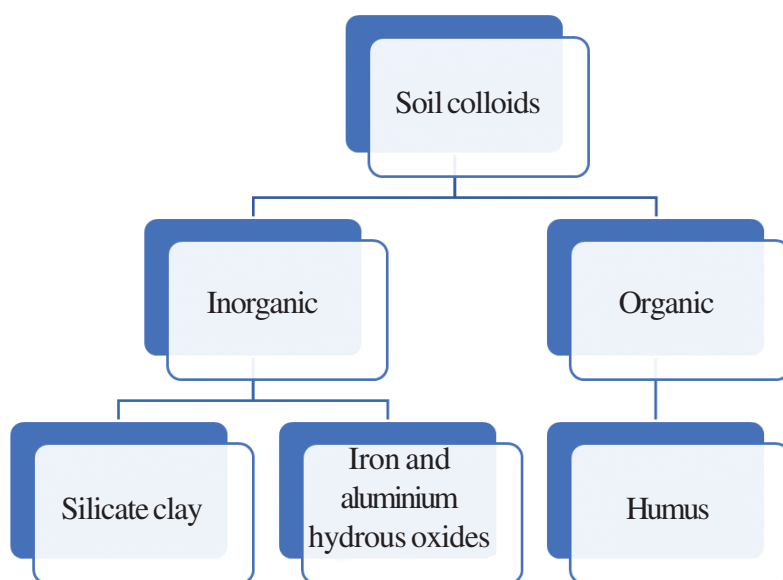


Fig. 5.6: Classification of soil colloids

Silicate clays: These are soil clay particles of colloid size dimension. Silicon is the basic structural element of these colloids. One clay particle is composed of many layers like a deck of cards. Based on arrangement of layers, silicate clays are further classified into several groups. Example of such silicate clays are Kaolinite, Montmorillonite and Illite.

iv. Soil Organic Matter

Soil organic matter consists of decomposing plant and animal residues. Additionally, it includes dead and living microbial cells along with their synthesized products. The residues of organic matter left after microbial decomposition is called humus. In nature, humus is structureless, dark brown to black materials. Organic matter is the principle source of organic carbon in a soil. These are store house of plant nutrients. They improve soil structure, aeration, biological activity and water movement in soil. Overall, organic matter improves physical, chemical and biological properties of the soil.

v. Presence of Plant Nutrients

There are seventeen (17) nutrients essential for plant growth. These nutrients



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are present in soil solution. Source of these nutrients is primarily parent materials from which soil is developed. Through the process of weathering, nutrients are released from rocks and minerals and become available for plant uptake.

vi. Cation and Anion Exchange

Soil colloidal particles possess electric charge (both positive and negative charge) on their surface; however negatively charged soil colloids are dominant in soil. Plant nutrients are present in soil in cationic or anionic form. When a positively charged cation comes in contact with negatively charged clay particle, it is adsorbed on the surface of particle due to electrostatic attraction force. The phenomena of cation exchange is basically process of exchanging cation present in soil solution with those present of soil surface. Cation exchange capacity (CEC) indicates quantitative measure of soil's ability to retain cations. A soil having high organic matter content or Montmorillonite type clay mineral has high cation exchange capacity. In general, fertile soils are those soils which have higher cation exchange capacity. In similar way, anion exchange happens when negatively charged anion is attracted by positively charged clay particles.

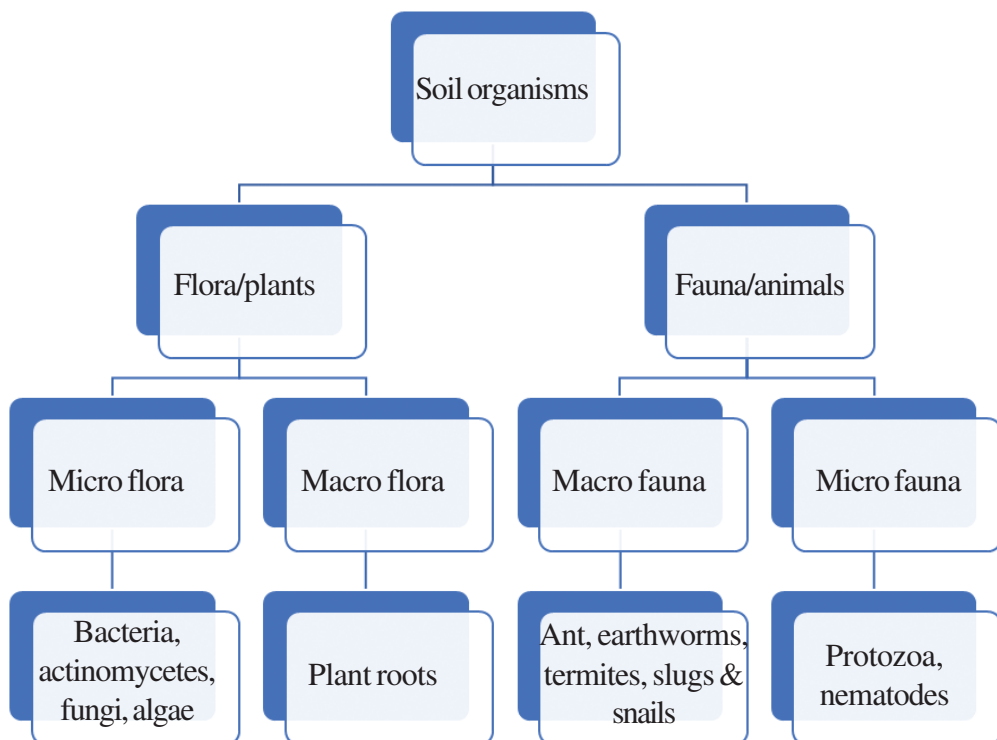
5.5.3 Biological Properties of Soil

Fig. 5.7: Classification of soil organisms

A variety of organisms inhabit the soil. These organisms perform several critical functions in soil like organic matter decomposition, nitrogen fixation, nitrification, denitrification, nutrient transformation and biocontrol of plant pathogens. Soil biological properties indicate how well soil is suited as a habitat to microbes. Soil microbes are classified in following way

Functions of Soil Organisms

- i. **Organic Matter Decomposition:** It is a process through which carbon present in organic matter is converted into CO_2 . Microbes degrade organic matter for their own sustenance.
- ii. **Mineralization:** Through this process, unavailable forms of nutrients are converted into plant available forms. For example, microbes like *Bacillus megaterium* solubilize the phosphate ions from insoluble compounds like calcium phosphates.
- iii. **Nitrogen Fixation:** It is a biological process by which certain bacteria and algae convert atmospheric nitrogen (N_2) into ammonia (NH_3) with the help of enzyme nitrogenase. Legume plant has special type of bacteria (*Rhizobium*) in their root nodule which can fix atmospheric nitrogen.
- iv. **Nitrification:** It is basically mineralization process of nitrogen. Here organic nitrogenous compounds are converted into nitrate ions (NO_3^-) by nitrifying bacterias like *Nitrosomonas* and *Nitrobacter*.
- v. **Denitrification:** Through this process, bacteria like *Pseudomonas*, *Bacillus* can convert ammoniacal (NH_4^+) or nitrate ions (NO_3^-) present in soil into gaseous form of nitrogen like NO , N_2O , N_2 . This is a harmful process as nitrogen is lost from a soil system.



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INTEXT QUESTIONS 5.5

1. When concentration of H^+ ions are higher than OH^- ions in soil solution, then soil is

a. Saline	b. Alkaline
c. Acidic	d. Neutral

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2. What are soil colloids?
3. Give one example of 2:1 type clay mineral.
4. Quantitative measure of soil's ability to retain cations is called
5. The process of converting atmospheric nitrogen into ammonia is called
 - a. Nitrification
 - b. Denitrification
 - c. Nitrogen fixation
 - d. Ammonification

5.6 SOIL FERTILITY AND PLANT NUTRITION

Nutrients are the chemical compounds required by organisms for growth and metabolism. Plant nutrients are present in soil in varying quantities. The inherent capacity of soil to provide plant nutrients in adequate amount and in a proper balance is termed as soil fertility. Therefore, a fertile soil is expected to produce abundant crop under suitable environment.

There are seventeen elements which are considered as essential for plant. Apart from them, there are other nutrients which are beneficial to selected plants only. Hence they are termed as beneficial elements. You will learn more about these nutrients in lesson 7 'Nutrient, water and weed management'. Here, we will discuss some important terms related to plant nutrition.

- A. Deficient:** When the concentration of an essential element is low enough to limit yield severely and distinct deficiency symptoms are visible, then that element is said to be deficient. Extreme deficiencies can result in plant death. With moderate or slight deficiencies, symptoms may not be visible, but yields will still be reduced.
- B. Insufficient:** When nutrient concentration in plant is below the desired level which is required for optimum yield, but distinct deficiency symptoms are not visible, the element is said to be insufficient.
- C. Sufficient:** Nutrient content at which plant produces optimum yield.
- D. Toxic:** When the concentration of essential or other elements is higher than required, then nutrient is said to be toxic. Toxic elements reduce plant growth and yield.



- E. **Luxury Consumption:** It is a condition when a plant takes up excess amounts of nutrients beyond their sufficient concentration. At luxury consumption plant does not produce any toxicity symptoms.
- F. **Critical Range:** The nutrient concentration in the plant below which a yield response to added nutrient occurs. Critical level or ranges vary among plants and nutrients but occur somewhere in the transition between nutrient deficiency and sufficiency.

5.6.1 Mechanisms of Nutrient Transport from Soil to Plant

A. Passive Absorption of Mineral Ions

Through this mechanism, plant cells absorb minerals without any use of metabolic energy. It may be achieved by some of physical process like diffusion, mass flow and contact exchange or root interception.

B. Active Absorption of Mineral Ions

An active absorption is a process where nutrient uptake by plant requires the use of metabolic energy. This energy is mainly derived from ATP (Adenosine triphosphate) formed during photosynthesis. Here absorption takes place against the concentration gradient.

5.6.2 Factors Affecting the Availability of Nutrients

Availability of nutrients to plant is a complex process. The various soil factors affect the plant growth in different manners. Soil pH, CEC, organic matter content, oxidized and reduced condition of soil, soil texture, structure, soil moisture content and soil composition, etc. are the major factors responsible for nutrient uptake. Although farmers are unable to manage all of these factors; however they can modify many of these factors in their advantage.

1) Soil pH

Different nutrients have different optimal pH ranges for absorption by plants. Soil acidity or alkalinity can affect the solubility and availability of certain nutrients.

2) Cation Exchange Capacity (CEC)

CEC refers to the soil's ability to hold and exchange cations (positively charged ions). Soils with higher CEC can retain more nutrients, making them available to plants over time.

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3) **Soil Texture**

The texture of the soil (sand, silt, clay) can influence nutrient availability. Sandy soils drain quickly, which may result in leaching of nutrients, while clayey soils may retain nutrients and make them available to plant roots for longer period of time.

4) **Organic Matter**

The presence of organic matter in soil enhances its fertility. Organic matter contributes to nutrient retention and microbial activity, which influences the breakdown of organic materials into forms that plants can absorb.

5) **Soil Moisture**

Presence of sufficient moisture in soil is important for plant nutrition. If a soil is dry, there will be no water to transport nutrients from other places of soil to plant root zone. As a result plant will not get optimum amount of nutrients.

Understanding and managing these factors are essential for optimizing nutrient availability in agricultural practices. Soil testing and proper nutrient management practices can help ensure that plants receive the nutrients they need for healthy growth.

**INTEXT QUESTIONS 5.6**

1. How many elements are considered essential for plant growth?
2. When the concentration of an elements is high enough to reduce plant growth and yield, then element is said to be
 - a. Deficient
 - b. Sufficient
 - c. Toxic
 - d. Insufficient
3. Movement of nutrients ion form the zone of higher nutrient concentration to the zone of lower nutrient concentration is termed as
 - a. Diffusion
 - b. Mass flow
 - c. Contact exchange
 - d. Root interception
4. Soils with higher CEC retain less amount of nutrients (True/False).



5.7 SUSTAINABLE SOIL MANAGEMENT

Soil is essentially a non-renewable resource. Approximately, 400 years are required for the formation of one cm soil. If the soil is not managed properly, its performance will decline over the time. Intensive agriculture, urbanization, and climate change have negative effect on soil health. We have to use this precious natural resource carefully to meet the needs of the present without compromising the ability of future generations to meet their own needs. The sustainable soil use means using the soil in a way that builds healthy soil, reduces erosion, and minimizes the need for chemical inputs which are environmentally degrading in nature.

5.7.1 Threats to Soil Sustainability

Some agricultural practices place a significant pressure on the environment, especially soil health. The result of such pressure includes soil erosion, organic carbon loss, nutrient imbalances, multiple nutrient deficiency, acidification, soil contamination, water logging, compaction, acidification, salinization, and loss of biodiversity. Unsustainable soil management practices can release excess greenhouse gases like carbon dioxide (CO_2), methane (CH_4). It further contributes to the global warming and climate change.

- 1) Excessive use of agro-chemicals (fertilizer or pesticides) results in toxicity of soil. These chemicals harm microbial biodiversity present in the agro-ecosystem. Such unscientific use of synthetic chemicals also makes the ground water contaminated and the soil acidic or alkaline resulting nutrient deficiency.
- 2) Heavy use of agricultural machinery on soil creates tremendous pressure on soil. Subsequently, soil is compacted and plant root will not be able to penetrate.
- 3) Excessive tillage operation is also injurious to soil health. It destroys the soil structure and decomposes soil organic matter very rapidly.
- 4) If irrigation water carries excessive salts, it will make the soil saline.
- 5) Sometime proper drainage of water is not available on land. Then water is impounded for a longer period of time which will create anaerobic condition. Prolonged anaerobic condition kills the aerobic microorganisms.
- 6) Soil erosion is the removal of the upper layer of soil which is most fertile. Exposure of soil to strong winds, heavy rains, and flowing water, human activities like farming and land clearing make soil vulnerable to erosion.

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- 7) Stubble burning is a practice of setting on fire the straw stubble (*parali*) that is left on the land after harvesting of grains of paddy. This is done with an aim of removing agricultural waste from the field and prepares the land for the next cultivation. Burning paddy straw radiates heat that kills fungus and bacteria that is essential for soil fertility. The smoke dispersed due to burning caused irritation to eyes, breathing difficulties and lung diseases.

5.7.2 Practices for Sustainable Soil Management

Healthy soils support diverse range of organisms, as they provide sufficient nutrients, aeration and water holding capacity. Adopting sustainable agricultural practices can enhance soil carbon content and help offset greenhouse gas emissions. Traditional agricultural practices, such as crop rotation, inter cropping, mixed cropping, organic farming, and natural farming have holistically aimed at maintaining soil fertility.

- a) **Integrated Nutrient Management (INM):** It is the combined application of chemical fertilizers along with organic fertilizers. Organic fertilizers include farm yard manure (FYM), compost, vermin-compost, bio-fertilizer, green-manure crop and other decomposable materials. Maintenance of soil fertility and balanced supply of plant nutrients are the major objectives of INM.
- b) **Judicious use of fertilizer:** Farmers often tend to use excess amount of fertilizers for crop production. Judicious use of fertilizer means supply of all the essential nutrients as per the need of crops. Basic tip to achieve this is to follow the '4Rs' principle during fertilizer application. This principle recommends to use fertilizer at
 - ❖ Right time
 - ❖ Right place
 - ❖ Right rate
 - ❖ Right source
- c) **Reduced/minimum Tillage:** Reduced tillage is a common sustainable soil management technique. In this technique, only those tillage operations are performed which are absolutely necessary for crop production. This has several benefits like keeping soil structure intact, increasing organic matter and supporting microorganisms and reducing soil erosion/runoff.



- d) **Use of Cover Crops:** Generally, crop fields are left empty in between crop growing seasons. Growing of cover crop during this gap period protect the soil from erosion. They recycle the nutrients present in soil which would otherwise wash off with rain during off-season period. Generally, grasses with shallow fibrous root system are preferred as cover crop. When ploughed and incorporated within soil, they act as manure for subsequent crops.
- e) **Use of Green-manure Crops:** Green manure crops are those crops grown for the purpose of improving soil fertility and organic matter content. They differ from cover crops as the later is grown to protect soil only. During decomposition, green-manure provides fresh, easily decomposable organic material as a food to soil microorganisms. Consequently, soil microbial activity and physico-chemical properties are improved. In India, *Dhaincha* (*Sesbania aculeata*) and Sunhemp (*Crotolaria juncea*) are widely used as green manure crop.
- f) **Better Crop Rotation:** Crop rotation is the process of changing the crops that are cultivated in a field in a specific order that varies with the growing seasons. To stop soil from being depleted and to use fewer pesticides and fertilizers, it is essential to switch to crops with different nutritional profiles and disease and insect pressures. Additionally, it can increase soil organic carbon, increase soil fertility, and improve biodiversity.

For example, you may plant legume crops after planting rice or wheat which take up lot of nutrients from soil. Legumes fix nitrogen in the soil and improve fertility.

- g) **Avoid using Bad Quality Irrigation Water:** All irrigation waters contain some amount of salt. But, we should carefully choose those waters which have lower level of soluble salts to prevent the development of soil salinity. Water should also be free from any toxic metals, compounds and plant pathogens.

Therefore sustainable soil management is really necessary as everybody's life depends on healthy soil. It is the cornerstone of productive agriculture and food production.



INTEXT QUESTIONS 5.7

1. What is soil erosion?
2. Which types of crops are preferred as cover crops?

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3. '4R' principle is application of fertilizers at,, and
4. Make a list of sustainable soil management practices.

**ACTIVITY 5.2**

You may have seen that some kitchen wastes are generated daily at your home. Often these are dumped at other place or collected by some people. You can use biodegradable wastes like left over vegetable, fruits, food materials for making organic fertilizer. This is also a way of sustainable management of resources. Follow the process given below to make your home made organic fertilizer.

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- 1) Dig a pit of 12-14 inches deep at your backyard or you may take a container with hole beneath it.
- 2) Collect the vegetable and fruit wastes from your kitchen and put them inside the pit/container.
- 3) Add brown materials like dried leaves, cocopeat or handful of soil.
- 4) You can spray some water if wastes are excessively dry.
- 5) You may provide microbes to these wastes for quick decomposition. For this you may add cow dung and/or earthworms.
- 6) To provide oxygen, you may make perforated holes in the container or churn the waste once in every four days.

Cover your pit/container appropriately so that rain water cannot enter in it. Your compost will be prepared within 2-3 weeks. Composting is like the art of cooking and is completely subjective. There is no hard and fast rule regarding the quantity of waste, dry leaves or the size of the container.

**WHAT YOU HAVE LEARNT**

- Soil is a 3-dimensional, polyphasic, dynamic natural body on upper portion of



the earth's crust which supports plant growth.

- An ideal soil has four components *viz.* mineral matter (45%), organic matter (5%), soil air (~25%) and soil water (~25%).
- A soil horizon is a layer of soil approximately parallel to the ground surface. The distinct properties of a soil horizon are produced by the action of soil forming process. Basic soil forming processes include gains, losses, translocation and transformation.
- Soils are formed through the process of weathering. The process of soil formation is controlled by five major factors (climate, parent material, living organisms, topography and time).
- Being a natural living body, soil has several physical (soil structure, texture, water, air, temperature, colour), chemical (pH, electrical conductivity, organic matter, soil colloids, plant nutrients) and biological (plant roots, bacteria, actinomycetes, virus, algae, fungus) properties.
- Soil fertility is defined as the inherent capacity of soil to provide nutrients and water for plant growth and development. Plants take up nutrient from soil through the process of diffusion, mass flow and contact exchange.
- Soil is the key to agriculture and food production. Soil health should be maintained by adopting sustainable management practices like integrated nutrient management (INM), careful fertilizer application, use of cover crop, green-manure crop, crop rotation, reduced tillage, etc.



TERMINAL QUESTIONS

1. What is the difference between soil horizon and soil profile? Discuss major soil horizons found in a soil profile.
2. 'Soil is a living body' – justify the statement.
3. Illustrate various types of soil structures along with their brief description.
4. Why presence of soil colloids is important for crop production?
5. Write short note on the following topics
 - a. Soil porosity
 - b. Cation exchange capacity (CEC)
 - c. Soil pH
 - d. Soil fertility
6. Do you think presence of organic matter is important for soil? Write your answer with suitable explanation.

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7. Differentiate between bulk density and particle density.
8. Compare the terms 'deficient', 'sufficient', 'toxic' and 'luxury consumption'.
9. Explain the mechanisms through which plant takes up nutrient from soil.
10. Suppose you are an agriculture officer in block. In your area, farmers often come to you and complain about poor yield of crops due to poor soil nutrient content. What practices would you recommend as an agriculture expert to them?

**ANSWERS TO INTEXT QUESTIONS****5.1**

1. Mineral matter, organic matter, soil water and soil air
2. Mineral soil (option b)
3. Water and air

5.2

1. A soil horizon is a layer of soil approximately parallel to the ground surface.
2. 'O' horizon

5.3

1. False
2. All of these (option d)
3. Climate, parent material, organisms, time, topography
4. Gain, loss, transformation, translocation

5.4

1. < 0.002 mm (option d)
2. Soil texture (option b)
3. Crumbly (option b)
4. Dark coloured soil

5.5

1. Acidic (option c)
2. Soil particles having diameter between 1 μm to 1 nm are called soil colloids.

3. Montmorillonite
4. Cation exchange capacity
5. Nitrogen fixation (option c)

5.6

1. 17
2. Toxic (option c)
3. Diffusion (option a)
4. False

5.7

1. Soil erosion is the removal of the upper layer of soil
2. Shallow rooted grass species
3. Right time, right place, right rate, right source
4. Integrated nutrient management (INM), judicious use of fertilizers, use of cover crop, green manure crop, crop rotation, reduced tillage

GLOSSARY

Aerobic and anaerobic condition: When oxygen is present in environment, then condition is called aerobic. If O_2 is not present, then condition is anaerobic.

Mineral: Mineral is an inorganic body, produced by the process of nature, usually having a definite chemical composition. It will have crystalline structure if they are formed under favourable condition,

Rocks: Rocks are basically aggregation of several minerals.

Tillage: Tillage is a mechanical process that prepares soil for planting and cultivation. It involves digging, stirring, and overturning the soil to achieve a desired condition.

SUGGESTED READINGS

1. *Introduction to Soil Science*, e-KrishiShiksha, Agricultural Education Division, Indian Council of Agricultural Research, New Delhi (<https://ecourses.icar.gov.in/>).

*Notes*

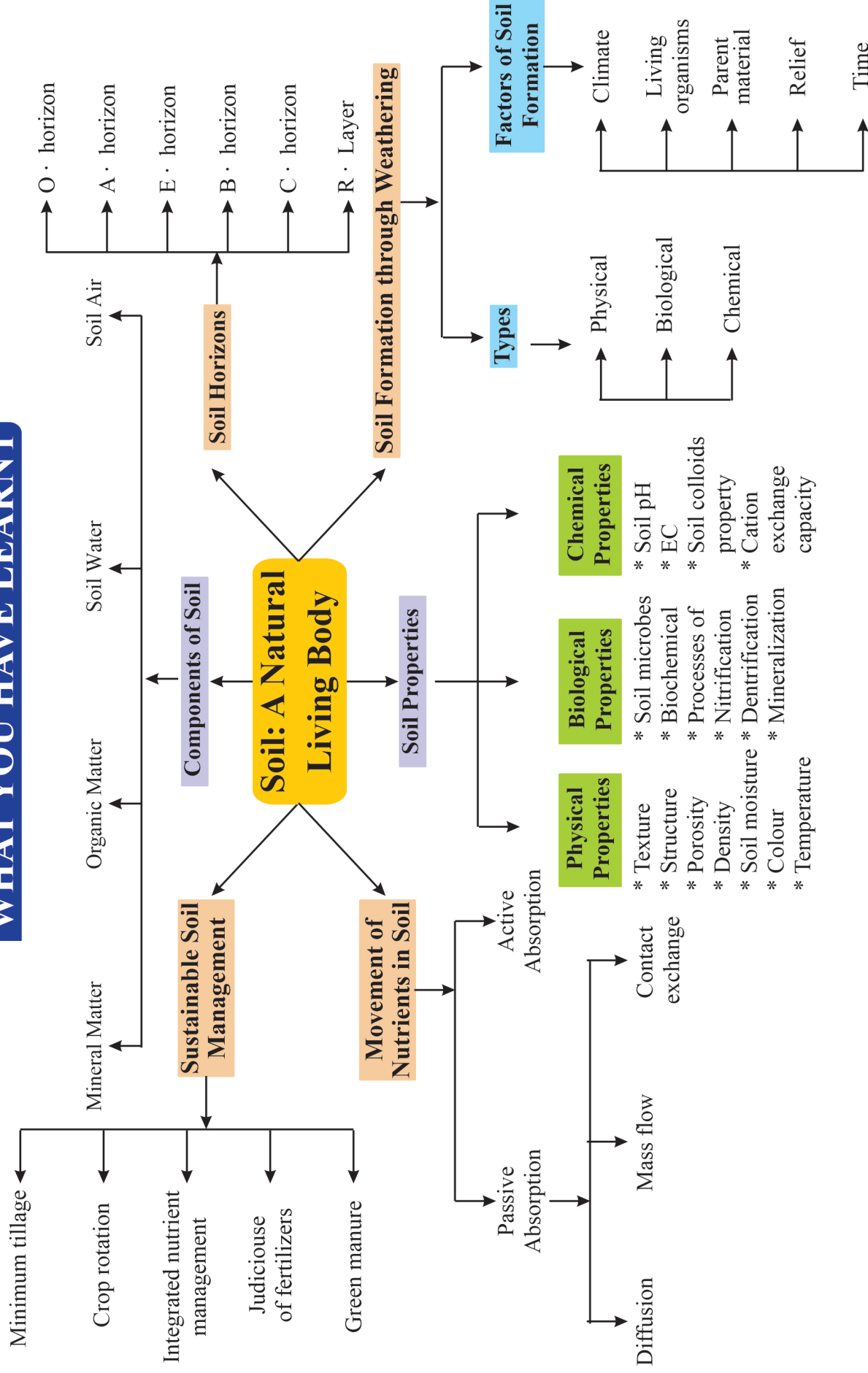
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2. Das, D. K. (2022). *Introductory Soil Science*, Kalyani Publishers, Ludhiana.
3. *Soil Science: An Introduction*, (2015). Indian Society of Soil Science, New Delhi.
4. *Fundamentals of Soil Science*, (2012). Indian Society of Soil Science, New Delhi.
5. Brady, N. C. & Weil, R. R. (2008). *The Nature and Properties of Soils*, Upper Saddle River, NJ: Prentice Hall.

WHAT YOU HAVE LEARNNT





NOTE

This image shows a blank sheet of white paper with horizontal grey ruling lines. In the top-left corner, there is a small graphic of a notepad with three lines and a pencil resting on it. The rest of the page is empty, with no handwriting or other markings.