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An estimated 70 percent of the earth's surface is covered with water, while the remaining 30 per cent constitutes land. The layer of the earth that is composed of soil and is influenced by the process of soil formation is called pedosphere. But what exactly is soil and what is soil made of? What is Soil? Technically, the soil is a mixture that contains minerals, organic matter, and living organisms. But broadly speaking, soil can refer to any loose sediment. Moreover, there are many types of soil that are distributed around the world and these are generally classified into the following: Clay Soil Sandy soil Loamy Soil Silt Soil Typically, the soil consists of 45% minerals, 50% empty spaces or voids and 5% organic matter. Furthermore, soil performs many important functions such as: Providing a growth medium for the plants Acts a modifier of the earth's atmosphere One of the most crucial components of the biosphere Provides habitat for organisms Also Read: Soil Teeming How is Soil Formed? Soil is formed by weathering of rocks. Solid rock can weather away in one of the three ways into the soil, namely: Mechanical Weathering Chemical Weathering Biological Weathering Mechanical Weathering This is commonly observed near the surface of the earth. Also called physical weathering, as this process is influenced by physical forces such as wind, water and temperature. Chemical Weathering As the name suggests, chemical weathering occurs when rocks are broken down by chemical reactions. Often, such types of weathering can change the chemical composition of the soil. Biological Weathering Though not an actual weathering process, living organisms weaken and subsequently disintegrate rocks, often by initiating mechanical or chemical weathering. For instance, tree roots can grow into cracks in the rock, prying them apart and causing mechanical fractures. Microorganisms can secrete chemicals that can increase the rock's susceptibility to weathering. Also Read: Soil Profile Composition of Soil The soil is composed of different components: 5% organic matter, 45% minerals, 20-30% different gases and 20-30% water. Therefore, the soil is known as a heterogeneous body. Given below is the composition of soil in detail: Organic Matter Organic substance is found in very small amounts in the soil. Plants and animals are the main sources of organic matter. Depending upon the decomposition stage, the organic matter is of the following three types: Completely decomposed organic matter Partially decomposed organic matter Undecomposed organic matter Minerals Minerals are an important element of the soil. These are solid components composed of atoms. These occur naturally and have a fixed chemical composition. Olivine and feldspar are the main minerals present in the soil. Gaseous Components The air-filled pores of the soil contain the gaseous components. Nitrogen and oxygen present in the pores is generally the atmospheric air fixed by the microorganisms. However, the composition of carbon dioxide is higher due to the gas produced by microorganisms present in the soil. Water The soil dissolves the minerals and nutrients in the water and transports it to different parts of the plants. These are essential for the growth and development of the plant. Importance of Soil Soil is an important element essential for the survival of living organisms. The importance of soil is mentioned below: The fertile soil helps in the growth and development of the plants. The plants thus produced are healthy and provide food, clothing, furniture, and medicines. It supports many life forms including bacteria, fungi, algae, etc. These microbes, in turn, maintain environmental balance by retaining the moisture and decaying the dead organisms. The topsoil supports certain life activities such as reproduction, hatching, nesting, breeding, etc. of a few organisms. The organic matter present in the soil increases the fertility of the soil which is responsible for the growth of the plants. It also contains certain minerals and elements that are necessary for the plants to carry out their cellular activities. Soil is used for making cups, utensils, tiles, etc. The contents in the soil such as gravel, clay and sand are used in the construction of homes, roads, buildings, etc. Useful mineral medicines such as calcium, iron, and other substances such as petroleum jelly for cosmetics are extracted from the soil. The soil absorbs the rainwater. This water is evaporated and released into the air during sunny days, making the atmosphere cooler. Also Read: Mineral Riches In The Soil Thus we see how the soil is formed, what it is composed of and how it is important to different life forms. To know more about soil, its formation, composition and importance (along with other important concepts such as soil pollution), download BYJU'S – The Learning App. Put your understanding of this concept to test by answering a few MCQs. Click 'Start Quiz' to begin! Select the correct answer and click on the "Finish" buttonCheck your score and answers at the end of the quiz Visit BYJU'S for all Biology related queries and study materials 0 out of 0 arewrong 0 out of 0 are correct 0 out of 0 are Unattempted View Quiz Answers and Analysis Soil is a complex natural resource that plays a vital role in supporting life on Earth. It acts as a medium for plant growth, a habitat for various organisms, and a crucial component of the Earth's ecosystem. Understanding soil composition and types is essential for sustainable agriculture, land management, and environmental conservation. This article delves deeper into the components of soil, the different soil types, their properties, and the factors influencing their formation. Soil composition structure labeled educational scheme vector illustration. Land mixture components explanation with minerals, air, water and organic matter percentage pie diagram as earth description. Soil is composed of several key components, each contributing to its overall characteristics and functions. The primary components of soil include: Mineral particles are the primary constituents of soil, making up approximately 45% of its volume. These particles originate from the weathering of rocks and can vary in size, shape, and mineral content. The three main categories of mineral particles are: Sand Size: Coarse particles ranging from 0.05 mm to 2 mm in diameter. Characteristics: Sand has a gritty texture, high permeability, and excellent drainage capabilities. It retains little moisture and nutrients, making it less fertile compared to other soil types. Advantages: Sand warms quickly in the spring and is easy to work with. It is ideal for crops that require good drainage and can tolerate drier conditions, such as root vegetables (e.g., carrots, potatoes). Size: Medium-sized particles measuring between 0.002 mm and 0.05 mm. Characteristics: Silt has a smooth texture and retains moisture and nutrients better than sand. It holds water well but can become compacted, leading to reduced aeration. Advantages: Silty soils are often fertile and support a variety of crops, including grains (e.g., wheat, barley) and vegetables. Size: Fine particles smaller than 0.002 mm. Characteristics: Clay particles are very small and flat, which leads to a dense, sticky texture when wet. Clay has a high cation exchange capacity (CEC), allowing it to retain nutrients and water effectively. Advantages: Clay is rich in nutrients and can support crops that require more moisture, such as rice and certain fruit trees. However, it can pose challenges for drainage and aeration, especially when compacted. Organic matter, comprising about 5% of soil composition, is made up of decomposed plant and animal materials, as well as living microorganisms. This component is critical for several reasons: Nutrient Supply: Organic matter releases essential nutrients as it decomposes, providing a continuous supply of food for plants and soil organisms. Soil Structure: It improves soil structure by binding soil particles together, creating aggregates that enhance porosity and aeration. Moisture Retention: Organic matter increases the soil's water-holding capacity, helping to retain moisture during dry periods. Microbial Activity: A diverse community of microorganisms thrives in organic matter, contributing to nutrient cycling, disease suppression, and soil health. Soil water, or soil moisture, constitutes approximately 25% of soil composition. Water plays several critical roles in soil: Dissolving Nutrients: Water acts as a solvent for nutrients and minerals, making them available for plant uptake. Supporting Organisms: Soil organisms, including roots, bacteria, and fungi, rely on moisture for survival and function. Influencing Soil Properties: The amount and availability of water in soil can impact its physical and chemical properties, including texture, structure, and nutrient availability. Soil air occupies about 25% of the soil volume. The composition of soil air differs from atmospheric air, primarily due to the biological activity occurring within the soil: Oxygen Levels: Soil air typically has lower oxygen concentrations than atmospheric air, especially in waterlogged soils. Oxygen is essential for the respiration of plant roots and soil organisms. Carbon Dioxide: Soil air often contains higher levels of carbon dioxide due to the respiration of organisms, which can affect soil chemistry and pH. Nutrient Cycling: The exchange of gases in soil air influences various biochemical processes, including nutrient cycling and organic matter decomposition. Soil is home to a vast array of organisms, including bacteria, fungi, protozoa, nematodes, earthworms, insects, and larger animals. These organisms perform essential functions in the soil ecosystem: Decomposition: Soil organisms break down organic matter, recycling nutrients back into the soil. Soil Structure Formation: Earthworms and other burrowing organisms create channels in the soil, improving aeration and drainage. Nutrient Cycling: Microbial activity enhances nutrient availability by converting organic and inorganic forms of nutrients into plant-accessible forms. Disease Suppression: A diverse microbial community can help suppress soil-borne diseases, promoting plant health. Soils can be classified into several types based on their physical and chemical properties, as well as their formation processes. Understanding the characteristics of each soil type is crucial for effective land management and agricultural practices. Below are some major soil types: Composition: High in sand particles with low clay and silt content. Texture: Gritty and coarse. Properties: Well-drained and warm, but low in nutrients and moisture retention. Best Uses: Ideal for growing root crops and certain grains. Requires regular fertilization and irrigation. Composition: Predominantly silt particles with a balanced mix of sand and clay. Texture: Smooth and silky. Properties: Fertile, retains moisture well, but can become compacted. Best Uses: Excellent for grains, vegetables, and other crops that prefer moist conditions. Composition: High clay content with low sand and silt. Texture: Dense and sticky when wet, hard and compacted when dry. Properties: Retains moisture and nutrients well but has poor drainage and aeration. Best Uses: Suitable for crops that require consistent moisture, such as rice and some tree fruits. Composition: A balanced mixture of sand, silt, and clay (approximately 40% sand, 40% silt, and 20% clay). Texture: Soft, crumbly, and well-structured. Properties: Excellent drainage, nutrient retention, and moisture availability. Best Uses: Ideal for a wide variety of crops, including fruits, vegetables, and ornamental plants. Composition: High organic matter content and moisture retention. Texture: Dark, spongy, and often acidic. Properties: Rich in nutrients, but may require liming to neutralize acidity. Best Uses: Suitable for acid-loving plants, such as blueberries and certain ornamental species. Composition: High concentrations of soluble salts. Texture: Can vary, but often compacted and poorly drained. Properties: Poor for most crops; salt can hinder plant growth and reduce yields. Best Uses: Some salt-tolerant crops (e.g., barley, certain grasses) can thrive in these conditions. Composition: Contains high levels of calcium carbonate, making it alkaline. Texture: Can range from gritty to smooth, depending on particle size. Properties: Well-drained, but may be low in nutrients; some crops may struggle in alkaline conditions. Best Uses: Suitable for alkaline-loving plants like lavender, thyme, and some fruit trees. Soil formation is a complex process influenced by several factors, leading to the development of various soil types over time. The primary processes involved in soil formation include: Soil forms from the weathering of rocks (parent material), which can occur through physical, chemical, and biological processes: Physical Weathering: The breakdown of rocks into smaller particles through mechanical forces such as wind, water, ice, and temperature changes. Chemical Weathering: The alteration of minerals in rocks due to chemical reactions, often involving water and atmospheric gases (e.g., oxygen, carbon dioxide). Biological Weathering: The breakdown of rocks and minerals by living organisms, such as plant roots, fungi, and bacteria, which produce organic acids that aid in mineral dissolution. As plants and animals die and decompose, organic matter accumulates in the soil. This process is crucial for building soil fertility and enhancing its structure. Microbial activity in the soil plays a key role in breaking down organic matter and recycling nutrients. Leaching is the process by which water-soluble substances, including nutrients and minerals, are washed out of the soil profile. This process can lead to nutrient depletion in the upper soil layers, especially in sandy soils. Leaching is influenced by rainfall, soil permeability, and vegetation cover. Soil profiles develop distinct layers, known as horizons, over time. These horizons vary in color, texture, composition, and nutrient content. The main soil horizons include: O Horizon: The top layer, rich in organic matter (humus) and living organisms. It is usually dark in color and contributes to soil fertility. A Horizon (Topsoil): The uppermost mineral layer, containing a mix of organic matter and minerals. It is fertile and supports most plant growth. E Horizon: A leached layer, often lighter in color, where minerals and nutrients have been washed away. B Horizon (Subsoil): The layer below the topsoil, rich in minerals leached from the upper layers. It may be less fertile than the topsoil. C Horizon: Composed of weathered parent material, this layer is less affected by soil-forming processes. R Horizon: The bedrock layer beneath the soil. Figure 2: A brief overview of how soil is formed, including its soil forming factors, the diverse soil processes, a conceptual soil profile and the average composition and formation time of soil (modified after FAO, 2015).The Tor Exhumation Approach – A New Technique to Derive Continuous In-Situ Soil Erosion and Surface Denudation Models – Scientific Figure on ResearchGate. Available from: [accessed 31 Oct 2024] Understanding soil composition and types is crucial for effective agricultural practices and ecological conservation. Here are some implications for both fields: Crop Selection: Different soil types support different crops. Understanding soil characteristics allows farmers to select the right crops for their soil conditions, leading to higher yields and sustainable practices. Soil Management: Knowledge of soil composition helps in managing soil health through practices such as crop rotation, cover cropping, and organic matter addition. Fertilization: Soil testing can determine nutrient needs, allowing for targeted fertilization to improve soil fertility without overapplying, which can lead to environmental pollution. Habitat Preservation: Healthy soils support diverse plant and animal life. Protecting soil health contributes to ecosystem resilience and biodiversity. Erosion Control: Understanding soil types and their erosion susceptibility can inform land management practices to prevent soil loss and degradation. Water Quality: Healthy soils filter pollutants and improve water quality in surrounding ecosystems. Sustainable land management practices help maintain this vital function. Soil is a complex and dynamic resource that plays a crucial role in supporting life on Earth. Understanding soil composition and types is essential for effective land management, sustainable agriculture, and ecological conservation. By recognizing the importance of soil health and promoting practices that enhance soil quality, we can ensure the continued productivity of this vital resource for future generations. Effective soil management not only supports agricultural productivity but also plays a critical role in maintaining ecological balance and protecting our environment. Soils are dynamic and diverse natural systems that lie at the interface between earth, air, water, and life. They are critical ecosystem service providers for the sustenance of humanity. The improved conservation and management of soils is among the great challenges and opportunities we face in the 21st century. Soil is... a Recipe with Five Ingredients Soil is a material composed of five ingredients — minerals, soil organic matter, living organisms, gas, and water. Soil minerals are divided into three size classes — clay, silt, and sand (Figure 1); the percentages of particles in these size classes is called soil texture. The mineralogy of soils is diverse. For example, a clay mineral called smectite can shrink and swell so much upon wetting and drying (Figure 2) that it can knock over buildings. The most common mineral in soils is quartz; it makes beautiful crystals but it is not very reactive. Soil organic matter is plant, animal, and microbial residues in various states of decomposition; it is a critical ingredient — in fact the percentage of soil organic matter in a soil is among the best indicators of agricultural soil quality ((Figure 3). Soil colors range from the common browns, yellows, reds, grays, whites, and blacks to rare soil colors such as greens and blues. Figure 1Relative sizes of sand, silt, clay. Figure 2A Vertisol high in shrink-swell clay showing cracks formed during a dry period. Figure 3This soil from Iowa is dark due to high organic matter content; combined with high plant-available, water-holding capacity due to a high silt concentration. Soils with these characteristics are present in parts of the United States, Russia, and South America, making them among the great grain-producing regions of the world. You may be surprised to hear "dirt" described as "big". However, in the late 1800's soil scientists began to recognize that soils are natural bodies with size, form, and history (Figure 4). Just like a water body has water, fish, plants, and other parts, a soil body is an integrated system containing soil, rocks, roots, animals, and other parts. And just like other bodies, soil systems provide integrated functions that are greater than the sum of their parts. Figure 4A soil body with contrasting and interacting soil horizons. One is usually able to distinguish different layers within soils, called soil horizons (Figure 5). These horizons interact with each other, and therefore cannot be considered as independent, although they can be very different from each other. There is great complexity and diversity in soil horizons, but in general the surface horizons are dynamic and rich in life and organic matter. Below the surface horizons, one often finds more stable horizons that are formed through a diverse suite of soil formation processes, such as bright white horizons formed through the removal of clays or deep-red, low-fertility horizons formed through millions of years of weathering (Figure 6). Below these horizons, soils transition into layers that are only partially affected by soil formation and ultimately into unaltered layers of parent material. Figure 5A soil from Alaska showing distinct horizons resulting from both soil formation processes and periodic deposits of volcanic ash.Figure 6A highly weathered soil that is red due to the high content of iron oxide minerals.The lateral extent of a soil can be difficult to define because adjacent soils can have sharp to gradual transitions. Soil bodies can be conceptualized and mapped at different scales, for example for an individual property or an entire watershed. The characterization and delineation of soil bodies forms the basis of most soil mapping systems (Figure 7). Figure 7Block diagram showing distribution of soil bodies across a landscape. Soils are... Young to Very, Very OldIt can be difficult to say exactly when some soils were born, but we can say that while some are young, many are very old. The oldest soils on earth may be in Australia, where stable land forms have allowed some soils to age several million years. New soils are born with every landslide, volcanic eruption, or glacial retreat. Soils change over time through a host of biological, chemical, and physical processes. Horizons form, minerals and rocks weather, nutrients leach, and plant communities change. Soil scientists have learned to predict the current stage of these processes if given five key pieces of information about the soil's history — the five factors of soil formation — climate, organisms, topography, parent material, and time (Jenny 1941). Soils are... DiverseThe variety of soil formation processes operating on different parent materials under different climatic, topographic, and biological conditions over varying periods of time gives rise to the vast diversity of soils on earth. Soil formation creates a dizzying array of soil horizons; here are just a few examples: Plinthite — which hardens irreversibly upon repeated wetting and drying (Figure 8a). Sulfidic — a horizon containing pyrite which, upon exposure to oxygen, can produce so much sulfuric acid that it kills plants and can cause fish kills (Figure 8b). Petrocalcic — in which so much calcium carbonate is accumulated that it literally forms a rock-like layer in the middle of a soil (Figure 8c). Soil scientists capture this vast diversity through systems of soil classification. The U.S. system, called Soil Taxonomy (soils.usda.gov/technical/classification/taxonomy/), groups soils into 12 broad orders at the most general level, and more than 19,000 soil series at the most detailed level (Ahrens & Arnold 1999). The International Union of Soil Sciences has developed a system called the World Reference Base, which has 32 Reference Soil Groups (. Figure 8(a) Plinthite in an eastern Nicaragua rainforest with distinct areas of red iron oxide concentrations. Soils with plinthite must be managed carefully because they harden irreversibly if they are exposed to repeated wetting and drying. (b) A soil showing subsurface horizons darkened by the black mineral pyrite (FeS2), which oxidizes to release sulfuric acid and iron — the iron has precipitated in the red layers. (c) Soil showing a petrocalcic horizon, in which so much calcium carbonate has precipitated that a soil horizon has become cemented. These master horizons may then be further annotated to give additional information about the horizon. Horizons are first assigned to one of the following master horizons as designated by a single capital letter: O - Horizon containing a high percentage of soil organic matter. A - Horizon darkened by the accumulation of organic matter. E - Horizon formed through the removal (eluviation) of clays, organic matter, iron, or aluminum. Usually lightened in color due to these removals. B - Broad class used for subsurface horizons that have been transformed substantially by a soil formation process such as color and structure development; the deposition (illuviation) of materials such as clays, organic matter, iron, aluminum, carbonates, or gypsum; carbonate or gypsum loss; brittleness and high density; or intense weathering leading to the accumulation of weathering-resistant minerals. C - A horizon minimally affected or unaffected by the soil formation processes. These master horizons may then be further annotated to give additional information about the horizon. Lower case letters can be placed as suffixes following the master horizon letter to give additional information about soil characteristics or soil formation processes. For example, the lower case "t" on the B horizon in Figure 9 indicates that the horizon is characterized by illuvial clay accumulation. Multiple letters can be used — Figure 8c depicts a Bkm horizon meaning that it is cemented (m) by illuvial carbonates (k). Numbers placed before the master horizon name (e.g., 2Bt) indicate a difference in parent material; numbers placed at the end of a horizon name are used to subdivide horizons that have the same designation but are different in some way (e.g., a red Bt1 over a yellow Bt2). Figure 9Example soil with designations that communicate the soil formation processes occurring in each horizon. Soils are... Biological BlissIf you like life, you'll love soils. There are a host of small, medium, and large organisms that live in soils, including mammals, birds, insects, and protozoa. But the greatest biodiversity lies in the soil microbes — the bacteria, fungi, and archaea (Figure 10). A teaspoon of rich soil can contain one billion bacteria. We actually know very little about the diversity of soil microbes, partially because they are so diverse, but also because we have not been able to culture the vast majority of these organisms in the lab. Soil microbiologists are applying advanced molecular techniques to understand the diversity and function of soil microbes. It is an exciting field of exploration with new biological taxa frequently being discovered. Figure 10Arbuscular mycorrhizal fungi are among the most critical soil organisms, they form symbiotic associations with roots that helps many plants species to thrive. This spore of the arbuscular mycorrhizal fungus Acaulospora scrobiculata has been broken open, allowing the lipid contents to spill out (the liquid in the lower right). The outermost layer of the cell wall is ornamented like a golf ball. Soils are the primary provider of nutrients and water for much of the plant life on earth. There are 18 elements considered essential for plant growth, most of which are made available to plants through root uptake from soils (Brady & Weil 2007). Soils retain nutrients by several mechanisms. Most nutrients are dissolved in soil water as either positively or negatively charged ions; soil particles are also charged and thereby are able to electrically hold these ions. Soils also hold nutrients by retaining the soil water itself. Arguably the greatest of all the ecosystem services provided by soils is the retention of water — without soils our land would be little but rocky deserts. Plants use much more water than one might think because they are constantly releasing water into the atmosphere as a result of transpiration, which is a component of the process of photosynthesis. Clay and silt particles are the primary mineral components in soils that retain water — these small particles slow the drainage of water and, like a sponge, physically hold water through capillary forces. Clay provides such strong force that plants can't pull all the water away from it, which makes silt particles the ultimate ingredient for plant-available water storage — they hold large quantities of water but also release it to plant roots (Figure 3). Soils are... Clay FactoriesAmong the most important functions performed by soils is to provide the ideal conditions for clay synthesis. Clays are important because they are often active, which is a general term soil scientists use to describe how chemically reactive a particle is with ions, water, and other particles. These reactions are critical for the provision of many ecosystem services. Clays are often the most active mineral particles because they have unique chemical characteristics and also because they have so much surface area — clays can have 10,000 times the surface area of sand of the same weight (Brady & Weil 2007). All this surface area makes clays a hot spot for chemical reactions. Soils are... Service ProvidersSoils are the among the great ecosystem service providers on earth (Haygarth & Ritz 2009) (Figure 11). They store and provide water for plants. They prevent floods by transferring water slowly to streams and groundwater. They filter and remediate pollutants. They cycle and recycle nutrients and wastes — transforming them into biologically available forms, storing them away for later use, and preventing their leaching to ground and surface waters. Soils provide habitat for a vast diversity of life. They take up and release important gases, including oxygen and greenhouse gases, a service called gas regulation. Many of these ecosystem services are being lost through the degradation and loss of soils. The conservation, restoration, and optimization of ecosystem services provided by soils is among the great challenges for humanity in the 21st century. Figure 11Soils as ecosystem service providers.2013 Redrawn with permission Unfortunately many human activities degrade and pollute soils, lessening the ecosystem services provided by soils and making some soils and their runoff water harmful to our environment and human health. Erosion is among the great causes of soil degradation as essential topsoil is lost at rates far greater than it can be replaced (Figure 12a, 12b); this sediment is also among the greatest pollutants of water bodies. Salinization and desertification are major causes of soil degradation in arid areas. Salinization is the buildup of salts in soils to a point that they destroy the physical and chemical properties of soil and make it impossible for plants to take up water from the soil. Salinization is often associated with improper irrigation. Desertification is caused by a combination of climate changes and human-induced soil degradation (such as through overgrazing). Figure 12(a) Soil in central Iowa with dark, organic-matter-rich topsoil. Iowa's average topsoil depth decreased from 35-45 cm to 15-20 cm during the 20th century due to farming. (b) Severe gully erosion in western Iowa.Soils have a great capacity to filter and remediate pollutants, but applications of pollutants to soils often exceed this capacity. When we apply excess nutrients to soils, particularly nitrogen and phosphorus, we make these soils sources of nutrient pollution to water bodies. These nutrients can cause eutrophication — a process of excess algal growth that leads to oxygen depletion. We also apply many synthetic organic chemicals, metals, and radioactive materials to soils that can damage ecosystems and can have serious human health effects. The clean-up of soils is among the great efforts being conducted by soil scientists around the world. Soils are... HomeThe phrase "to be on a nation's soil" is used as a poetic means to express our connection to country, to home. Soils give us a sense of place in our environment, a sense of geography. Our language abounds with phrases such as being "grounded" and "down to earth". Although we seldom consider the role of soils in our day-to-day lives, we have an intrinsic understanding that soils are home. Soils are... a ProfessionWhile many people work with soils — from farmers, to gardeners, to construction workers — some people make soil science a career. Soil scientists work in a variety of fields — space exploration, archeology, insurance, defense, engineering, and yes, agriculture. Soil science professional societies have been established in nations throughout the world. The Soil Science Society of America is among the largest ( ). Many of these organizations are represented in the International Union of Soil Sciences ( ). Soil scientists are trained to understand how the basic concepts of chemistry, biology, and physics operate within the diversity of soils, and to apply this knowledge to address problems related to soil behavior and management. People drawn to this profession tend to have a love and respect for soils rooted in appreciation of their complexity, importance, and beauty. Back to Resources Soils provide water, air, nutrients, and mechanical support for plants. Soils also tie up, filter, and break down natural and man-made toxins. Soils sustain all life on Earth and might be the most important, neglected, and least understood resource in the landscape. Soil problems such as compaction, low fertility, poor drainage, and thin topsoil, can cause stress, poor growth, and decline in our garden and landscape plants. The native topsoil has been removed from many urban and suburban soils. These soils are often compacted and low in organic matter. Poor soil management and misuse of fertilizers contribute to surface and groundwater pollution. It's our job to protect and improve our soils so they can nourish future generations of plants and animals - including humans! What you should know about soil Soil is a natural resource and a living ecosystem (the "living skin of the earth"). Soils sustain all life on earth and filter and break down natural and man-made toxins. Soils provide water, nutrients, and support, along with oxygen for the plant's root growth. Soils have four main components: mineral particles (sand, silt, and clay), organic matter, water, and air. There are many different types of soil in Maryland. You may have several types even in a small yard! Healthy soils grow healthy plants that keep people healthy. Information found on this page. Soil texture Nearly all soils in Maryland contain a combination of sand, silt, and clay particles. Soil texture is determined by the relative amounts of these three types of particles and doesn't change over time. Soil texture is determined by the parent material (rocks from which the soil formed), climate, slope, and other factors. Texture determines, in large part, how the soil feels and behaves. Sand particles are the largest (0.05-2 mm) and can be seen without a magnifier. Silt particles (0.002-0.05 mm) are next in size, followed by clay particles that are 1,000 times smaller than sand particles (< 0.002 mm) and can only be seen with an electron microscope. Too much clay in the soil can make it difficult to manage. But clay plays a positive role in holding and protecting organic matter particles. Also, clay's enormous surface area carries negative charges that hold positively charged nutrients (e.g., calcium, magnesium, potassium, ammonium) used by plants and soil microbes. You can roughly determine your soil's texture by the "feel method" or the "jar test." Some soil testing labs will conduct a "mechanical analysis" (for an additional fee) to identify soil texture. You can determine your specific soil type through the U.S.D.A.'s Web Soil Survey. Photo: Melissa L. Wilson, Ph.D. Credit: USDA-NRCS Bozeman, Montana The soil triangle shows the 12 textural classes of soils. In the example below, the soil has 25% sand, 10% clay, and 65% silt, giving it a silt loam texture. Pore space One half of the volume of most soils is composed of solids (sand, silt, clay, and organic matter) and the other one half is composed of pores--spaces between solid particles, that are filled with air, water, roots, microorganisms, earthworms, and other soil animals. Healthy soils have a large number of pore spaces of varying sizes that allow for the free movement of water, air, and growth of plant roots, soil microbes, and animals. In the diagram below we can imagine that rain fell two or three days ago. Most of the pore spaces would have been filled with water. Gravity carries excess water down through the soil profile. The water in the diagram is held on, and between, soil and organic matter particles and is available for uptake by plant roots. Photo: Melissa L. Wilson, Ph.D. You may have seen soils with a high percentage of clay draining very slowly after a thunderstorm. The tiny clay particles are packed closely together which slows the movement of water. Soils with a lot of clay are also more susceptible to compaction from foot traffic, vehicles, and machinery, further slowing the movement of water and air into (infiltration) and through (percolation) the soil. Soils with a high percentage of sand drain quickly after a thunderstorm, carrying nutrients from fertilizers and organic matter down through the soil and out of the root zone of plants. As a result, plants growing in sandy soils often require more frequent watering and fertilizing. This chart shows how soil texture affects water, air, and nutrients in the soil   Sands, sandy loams and loamy sands(coarse-textured soils Loams, silt loams, silts and all the clay loams(medium-textured soils) Clay, silty clay, sandy clay, clay loam and silty clay loam(fine-textured soils) Water and nutrient holding capacity low moderate high Infiltration and drainage fast moderate slow Leaching potential high moderate low Aeration good moderate poor Credit: Melissa L. Wilson, Ph.D., and Patricia Steinhilber, Ph.D. Soil structure Soil structure describes the way that particles fit together and form small clumps, called aggregates. Roots, fungal hyphae (thread-like growths), and sticky substances produced by soil microbes and plant roots hold and "glue" clay and silt particles into aggregates. Very small microaggregates combine to form macroaggregates. Earthworms and small soil animals also contribute to aggregation by burrowing and producing fecal pellets. The topsoil of a healthy soil should have a crumb-like structure with ½ of the volume made up of different size pores. Soil structure can be improved over time by increasing the amount of organic matter in the soil. Organic matter Photo: Melissa L. Wilson, Ph.D. and Patricia Steinhilber, Ph.D. Soil organic matter is made up of living, dead, and decomposing organisms within and on top of the soil. These include plants (leaves, stems, roots), earthworms and other soil animals, and microorganisms. Organic matter accounts for a relatively small part of soil (1%-5% by weight) but is critically important to soil health because it supports the soil food web that drives the biochemical action in the soil. Organic matter exists on a continuum from living organisms to "protected organic matter" (formerly described as humus) which is made up primarily of dead microbial cells found inside small soil crumbs (microaggregates) or attached to clay particles. The "protected organic matter" in the graphic accounts for about 75% of total soil organic matter. It's made up mostly of dead soil microbes that are protected from further decomposition because of their location and attachment to clay particles. Once plants and animals die, their tissues ("residues and by-products" in the graphic above) are shredded, chewed, and digested by huge populations of soil animals and microbes (fungi and bacteria). This leads to the release of nutrients, like potassium and nitrogen, that plants can use. In the process nutrients, once part of organic compounds in the living organisms are converted through biochemical processes into inorganic forms used by plants and microbes. Organic Matter and Soil Amendments   The soil food web On first glance, soil may appear dense, dead, and deserted. But it's actually teeming with life. Soils are home to thousands of different species of soil -animals, including tiny mites, nematodes, springtails, and earthworms, as well as bacteria and fungi. A teaspoon of soil can contain several billion microorganisms! All of these life forms occupy particular positions (trophic levels) in the soil ecosystem. Organic matter feeds the soil food web with larger animals consuming smaller ones. Living plant roots leak sugars and other compounds that support huge populations of bacteria and fungi in the root zone. Roots and microbes release sticky substances that help form stable aggregates, giving the soil a crumb-like structure. "Soil is a living factory of macroscopic and microscopic workers who need food to eat and places to do their work". Source: USDA-NRCS, USDA, National Resources Conservation Service Additional resources Soil Texture "Feel Method" Washington State University video - Determining Soil Texture by Hand University of California-Davis video - Soil Texture by Feel University of Kentucky - (PDF) Determining Soil Texture by Feel Soil Texture "Jar Test" Method Clemson University - Soil Texture Analysis "The Jar Test" University of California - (PDF) Sedimentation Test of Soil Texture   Author, Jon Traunfeld, HGIC Director, and Extension Specialist, Fruits and Vegetables. Still have a question? Contact us at Ask Extension. Home » Agricultural Microbiology Soil is a biologically active porous medium that is present on the uppermost layer on the uppermost layer of the Earth's crust formed by weathering processes under various influences. Soil acts as a substratum for life on Earth that serves as a reservoir of water and nutrients, a medium for the breakdown of organic materials, and as a participant of various biogeochemical cycles. The soil in any particular area evolves through a series of weathering processes that are influenced by biological, topographical, climatic, and geological factors. As studies on agriculture and geology have increased, the soil is now considered a complex, dynamic, biogeochemical system that is vital to the life cycles of various land vegetation and soil-inhabiting organisms. Soil is one of the most important elements of an ecosystem as it contains both biotic and abiotic components. Figure: Soil Profile and Soil Horizon. Created with BioRender.com. What is Soil moisture? Soil moisture is the volumetric water content of soil held within the spaces the soil particles or soil aggregates. Soil moisture is of two types; surface soil moisture is the water present on the upper layer of soil, whereas root zone moisture is the water available to plants, generally present within the soil. The moisture of the soil is considered an indicator of the quality of soil and the fertility of the soil. What is Soil gas? Soil gases are different types of gases that are present within the pores between soil particles or soil aggregates. The gases found in soil include carbon dioxide, oxygen, and nitrogen. Other atmospheric gases include methane and radon. Pores in the soil are filled by gases after the water present in such pores are evaporated absorbed by the root. In the case of environmental contaminants, soil gas might include gases diffused from landfill wastes, mining activities, and petroleum products. What is the Soil matrix? Soil matrix refers to all the solid particles found in soil that include the soil particles, organic matter, and other inorganic materials. The soil particles might either be sand, silt, or clay, the composition of which might differ from one type of soil to another and the location. Organic matter found in the soil matrix is humus which is the final stage of degradation of dead plants and animals. Humus might even form organic colloids with water and other inorganic substances. The soil matrix determines various physical and chemical properties of soil like water retention capacity, nutrient content, and pH. Composition of Soil Figure: Composition of Soil. Image Source: Professor Patricia Shapley, University of Illinois. Soil is composed of various factors like air, water, minerals, and different living and non-living organic compounds. The entire composition of soil can be classified as biotic and abiotic components; the abiotic component includes the non-living things of soil while the biotic component includes the living organisms. In general, the abiotic component of the soil accounts for about 40-45% of the soil volume followed by air and water that occupy 25% each with 5% covered by living things. The exact composition of the soil, however, might vary from place to place with the existing rocks of the area and the climate. Other factors like the quantity of vegetation, soil compaction, and water retention capacity also influence the composition of the soil of a particular area. The inorganic part of the soil is composed of rocks that are slowly broken down into smaller particles that might vary in size. The organic component of soil is called the humus, which is made up of living organisms like insects or microorganisms (dead or alive) and dead animals and plants in varying stages of decay. Properties of Soil The properties of soil are determined by the composition of the soil, depending on different amounts of biotic and abiotic components. The combinations of these components determine the physical and chemical properties of soil. A. Physical Properties The physical properties of soil include the following: a. Soil Texture Soil texture refers to the size of the soil particles that is dependent on the relative proportions of mineral components like sand, silt, and clay. Soil texture is further influenced by soil porosity, infiltration, and water retention capacity. The texture of soil differs with soil type; sandy soil feels gritty, silt feels smooth, and clay is sticky and mouldable. b. Soil Structure The textural components of soil, including sand, silt, and clay might result in aggregates as a result of their clumping. The aggregates further clump together to form peds. Information on the structure of soil gives information on the soil texture, matter content, and biological activity. Soil structure is influenced by physical processes that might be improved or destroyed by the choice of farming practices. c. Soil Density The average soil particle density ranges from 2.60 to 2.75 grams per cm3, which usually remains unchanged for a given soil. The soil particle density is lower for soils with high organic matter content and higher for soil with higher mineral content. Soil particle density is different from soil bulk density which is always less than soil particle density. Soil density usually depends on the soil texture and structure and the composition of the soil. d. Soil Porosity Soil porosity is defined by the number of pores present within the soil. The porosity of soil is determined by the movement of air and water within the soil. Healthy soils usually have more number of pores between and within soil aggregates, whereas poor quality soils have few pores or cracks. Soil porosity is influenced by soil texture and structure. The pore size in soil affects the ability of plants and organisms to access water, oxygen, and other gases and minerals. e. Soil consistency Soil consistency refers to the ability of the soil to stick to itself or other objects and to resist deformation and rupture. Three moisture conditions define soil consistency; air-dry, moist, and wet. The consistency of dry soil ranges from loose to hard, whereas that of wet soil ranges from non-sticky to sticky. Soil consistency is an important property that determines the ability of soil to support buildings and roads. f. Soil Colour Soil color is determined primarily by the organic composition of the soil. Soil color is one of the factors that help in the prediction of other soil characteristics within a soil profile. Observation of soil color is a qualitative means of measuring organic, iron oxide, and the clay contents of the soil. Besides, soil color is also influenced by the mineral content of the soil as the color might change as a result of oxidation of degradation. B. Chemical properties a. Cation exchange capacity (CEC) Cation exchange capacity is the maximum amount of total cations that a soil sample is capable of holding at a given pH. The cation exchange capacity of the soil is taken as an indicator of soil fertility, nutrient retention, and the ability of soil to protect groundwater from cation contamination. b. Soil pH The reactivity of soil is expressed in terms of the soil pH, which determines the acidity and alkalinity of the soil. It is the measure of the hydrogen ion concentration in the aqueous solution of soil which ranges between 3.5 to 9.5. Usually, soils with high acidity contain higher amounts of aluminum and manganese, and soil with higher alkalinity has a higher concentration of sodium carbonate. In terms of soil fertility, agricultural production tends to be more in acidic soil. c. Soil salinity Salts in the soil are transported from salt tables in water resources that then accumulate due to evaporation. Salinization of soil also occurs during irrigation processes from drainages. The salt accumulation affects the degradation of organic matter in soil and the vegetation on the soil. The most common salts that are present in soil include magnesium sulfate, potassium sulfate, and carbonates. Types of Soil Figure: Four major types of soil. Image Source: Wilson Bros Gardens. Soil, in general, is classified into four different types depending on its composition and the size of particles. The four types of soil are: A. Sandy Soil Sandy soil is a type of soil that contains a higher proportion of sand and less clay. Sandy soil is light, dry, and warm that tends to be more acidic than other types of soil. Because the size of the sand particle is larger than other particles, they have low water retention capacity and fewer nutrients. The lack of enough moisture and nutrients makes the soil less suitable for crop production. However, the soil can be made suitable by adding organic matter to increase water and nutrient content. B. Clay Soil Clay soil is a type of soil that is comparatively heavy as it has higher water retention capacity and a higher concentration of nutrients. The soil is made up of over 25% clay particles that are smaller in size and thus hold a large amount of water. Clay soil drains water slowly and thus takes longer to warm up in the summer without drying out. However, because it is a heavy and dense type of soil, it doesn't provide space for plant roots to flourish. C. Silt Soil Silt soil is a light soil with a higher fertility rate with soil particles that are large than clay but smaller than sand. The soil is smooth and of fine quality that holds water better than the sandy soil. The soil can also be easily transported by moving currents, and it is found near water bodies. Silt soil is considered the best type of soil for agricultural practices as it has sufficient nutrients and enough moisture for plant growth. D. Loam Soil Loam soil is a mixture of sand, silt, and clay soil that combines the properties of all three types of soil to make it more fertile. The soil has enough pores as well as water retention capacity to promote crop production. The level of calcium and pH of loam soil is also of the appropriate amount due to the presence of inorganic matter. Functions of Soil Soil is the medium for plant growth as it provides an anchor for plant roots and acts as a water holding tank for necessary moisture. The degradation of plant and animal matter, i.e. the release and the binding of nutrients and trace elements, is one of the most important functions of soil organisms. Soil absorbs the water during rainfall and snowfall, which creates a pool of available water for plants and soil organisms. The absorbed water also moves downward through the soil profile towards the water bodies, thus acting as a regulator for water supplies. Soil is an essential part of biogeochemical cycles, where it allows the cycling of different organic and inorganic compounds from the atmosphere to the soil and back. Soil is a habitat for soil organisms as it provides necessary nutrients and water to living beings. Soil acts as the base for building homes, roads, and buildings, acting as a landscape or engineering medium. Soil provides the raw material for different purposes like clay for ceramic production.
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