

Understanding Soil Properties

Soils are dynamic, complex systems of inorganic, organic and biotic components that have the capacity to support plant life. Soils are classified on the basis of their chemical and physical properties. These properties include texture, structure, color and the nature and properties of soil horizons.

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Key Concepts

- Soils are dynamic systems composed of organic, inorganic and living components.
- Soils are classified according to measurable and observable properties.
- Key physical characteristics of soils are texture, bulk density and porosity, all of which influence nutrient and water dynamics in the soil.
- Key chemical properties of soils include acidity (pH), cation exchange capacity (CEC), base saturation, organic matter content and nutrient availability.
- Soils are a slowly renewable natural resource that is being degraded worldwide due to erosion, desertification, salinization and overuse.
- Understanding, interpreting and managing soil properties can result in improved soils, more efficient nutrient utilization, improved plant performance and promotes conservation, land stewardship and sustainable practices.

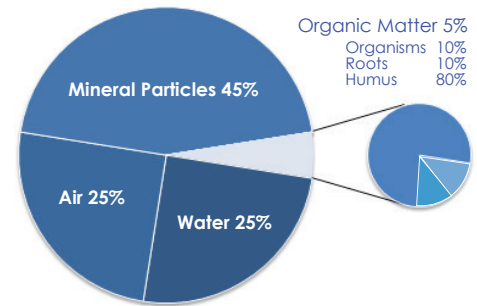


A. Reviewing Soil Composition and Profile

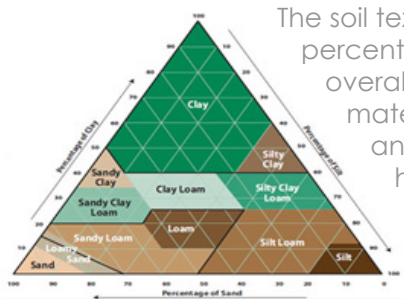
What are soils made of?

The ideal soil contains 25% air, 25% water, 45% minerals as sand, silt and clay, and 5% organic matter. A soil with this composition would be easy to cultivate, stable, fertile and capable of supporting a diverse range of plant and microbial life.

It's important to know what type of soil you're dealing with in order to ensure the most accurate results possible. The following information will help you determine what type of soil you have.



An easy way to help determine what type of soil you have is to simply feel it to determine texture and thus what the primary makeup of the soil is. Grab a baseball size portion of the soil in your hands and wet the soil with water, working the moist soil with your hands. The stickier it is, the more clay there is. The soapier the soil feels the higher the silt content. Grittiness is indicative of sand.



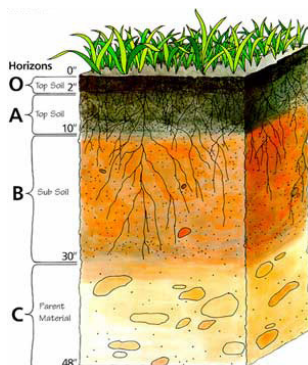
The soil texture triangle shows the 12 major soil texture classes and what percent of each type soil makes them up. The type of soil with the best overall properties is loamy soil. It contains a balance of all three soil materials—silt, sand and clay—plus humus. Loam is dark in color and is mealy—soft, dry and crumbly—in your hands. It has a tight hold on water and plant food but it drains well, and air moves freely between soil particles down to the roots. The feel test for loam yields a smooth, partly gritty, partly sticky ball that crumbles easily.

What is soil profile?

A soil profile is a vertical section through the soil that extends to or into less weathered parent material. Soil profiles are divided into horizons. Each horizon is a layer within the soil profile that has distinct characteristics, such as color, texture or structure; that differ from the layer above or below it.

As soil develops, it forms layers. The layered structure is called a soil profile, and each layer is a soil horizon. The top layer, called the O horizon, is a thin layer of mostly dead plant matter. Under it is a layer rich in humus and minerals, called the A horizon. The A and O horizons together are also called topsoil.

Under the topsoil, there is often a zone of leaching. As rainwater percolates through the soil, it washes down material from the layers above - dissolved calcite, iron oxides (gives soil color), clay minerals, products of humus decay - leaving behind pale sandy material. The B horizon is where all the stuff leached from above ends up. Also called the zone of accumulation, it's a place that tends to be clayey. It's a place where clays can compact to the point of making a layer impermeable to water, called hardpan. Acids and salts can also accumulate in the B horizon, which reduce plant growth.



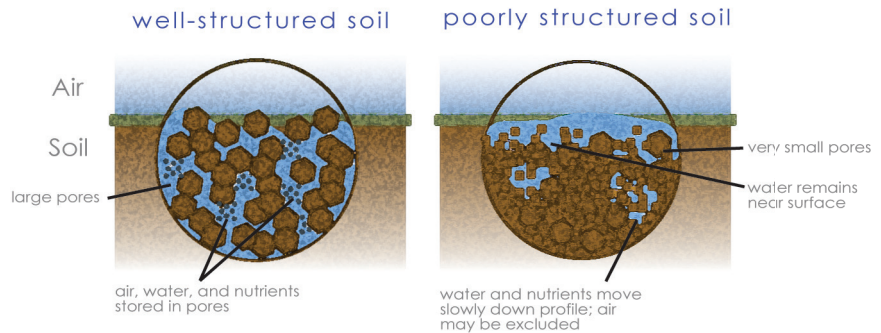
The C horizon is a zone filled with large chunks of parent rock in the process of weathering. This zone is just above the R horizon, or bedrock.

B. Two Soil Properties that Influence Soil Fertility and Plant Growth

1. Physical, or the texture and structure of the soil

What is soil structure?

Soil structure has a major influence on soil behavior. A 'well structured' soil has plenty of living spaces, storage spaces, doorways, and passages (for utilization by water, gases, nutrients, roots and a vast array of organisms). Only about 50% of soil is solid material. The remainder is pore space. It is in these spaces that the action happens. Soil structure is the arrangement of pores and fissures (porosity) within a matrix of solid materials (soil particles and organic matter). The solid materials bond and aggregate to give the pores and fissures. The quantity, distribution and arrangement of pores determines water holding capacity, infiltration, permeability, root penetration, and respiration.



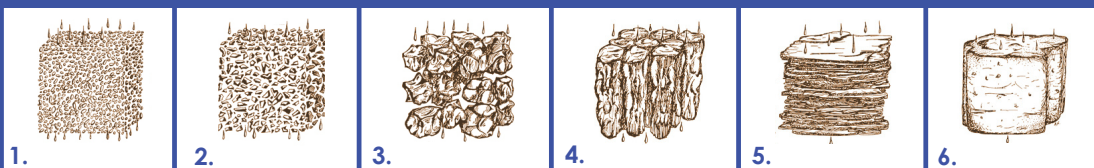
The diagram demonstrates how solids and pores might arrange in soil to give a porosity of 50%. Small pores within the aggregates provide storage and refuge. The larger pores (and fissures) between the aggregates are the pathways for liquids, gases, roots and organisms.

What types of soil structure are there?

Soil material fits and binds together in many different ways. With some, the bonding is very weak, in others very strong. With some, the size of aggregates is very fine, in others coarse and large. With some the aggregates are dense containing few pores, in others quite open with plenty of pores.

Six Broad Categories of Soil Structure

1. **Granular** (high permeability)
2. **Aggregated** (high permeability)
3. **Blocky** (moderate permeability)
4. **Columnar/prismatic** (moderate permeability)
5. **Platy** (low permeability)
6. **Massive** (low permeability)



Why is soil structure so important?

Soil is like a city. The structure and layout of both determine how things happen, the rate at which they happen, and the capability to keep them happening. The following characteristics are used to help evaluate the ability of any soil to perform well (or otherwise):

- Porosity (to represent aeration, water storage capacity, plant wilting point and drainage)
- Permeability (to represent infiltration, drainage and respiration)
- Bonding and aggregation (to represent how the solids group together and the construction materials used)
- Soil strength (to represent toughness and resilience of structures)
- Friability, tillage and trafficability (to represent how soils behave with mechanical disturbance)



2. Chemical, which affects both the fertility of the soil and its physical properties

What are the chemical properties of soils that are important to plant growth?

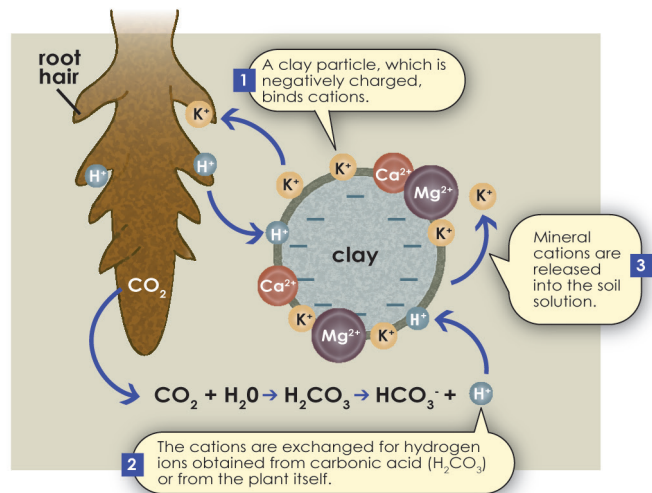
- Nutrient availability and cation exchange capacity, which affect the soil's inherent fertility and its ability to hold nutrients.
- The chemical characteristics of the soil solution, which affect pH and salinity.
- The sodicity of the soil, which affects soil stability.

What is nutrient availability and cation exchange capacity?

Nutrients become available to plants as minerals in the soil solution, or once released from soil reserves by root acids and microbial enzymes. Soluble nutrients can move to the root zone as plants take in water. In the soil, the larger portion of plant nutrients is bound up in complex compounds that are unavailable to plants. The smaller portion is in simpler, more soluble forms, which are useable by plants. The complex compounds are gradually changed into the simpler compounds by chemical weathering. Thus, the fertility of a soil depends in part on how easily

the complex compounds can be changed to the simpler forms. This is referred to as the availability of a nutrient. Plant nutrients are composed of single elements (for example, phosphorus (P)) or compounds of elements (for example, ammonium nitrate (NH₄NO₃)). In either case, the nutrients are all composed of atoms.

Most of the soil nutrients that a plant takes up must be in a soluble form (in other words, mixed with water). When an atom is in water, it usually becomes electrically charged and is called an ion. An ion with a positive electrical charge is called a cation. An ion with a negative electrical charge is called an anion. Cations include sodium (Na⁺), potassium (K⁺), calcium (Ca⁺⁺), magnesium (Mg⁺⁺) and aluminium (Al⁺⁺⁺). Anions include chloride (Cl⁻), nitrate (NO₃⁻), sulfate (SO₄⁻⁻), carbonate (CO₃⁻⁻) and borate (BO₂⁻⁻). One plus sign or one minus sign means an ion has one positive or negative electrical charge. Two or more plus or minus signs means an ion has two or more positive or negative charges. More positive charges mean an increasing ability to bond with a negatively charged surface. More negative charges mean an increasing ability to bond with a positively charged surface.



The cations and anions can be:

- Absorbed (taken up) by plant roots
- Leached from the soil via the soil water
- Adsorbed (attached) to the surfaces of negatively and positively charged soil particles

The soil's capacity to adsorb nutrients in the form of cations is called its cation exchange capacity (CEC). Cation exchange capacity is measured by a soil test.

The cations are held on the surface of soil minerals and organic matter and within the crystalline framework of some clay minerals. The greater the particle surface area available to adsorb cations the higher the soil's fertility.

Thus, soil texture has an effect on soil fertility because of the sizes of the particles that make up the various soil texture classes; and so does the amount of organic matter.

Soils with a high clay or organic matter content provide a much greater surface area for cations to adsorb onto. As long as the nutrient cations and anions are adsorbed onto the soil particles, they cannot be absorbed by plants or leached from the soil. However, they are not held too tightly and can be exchanged with other ions of a like charge that are in the soil solution. Once the nutrients are in the soil solution, they can be absorbed by the plant's roots or lost to leaching.

Particle	Sq. cm/gram
Coarse sand	23
Fine sand	90
Very fine sand	230
Silt	450
Clay	around 8,000,000
Organic matter (humus)	around 8,000,000

In order to release a cation held on an exchange site, some other material must first dislodge or replace it. This is known as Cation Exchange. Plants roots produce organic acids, or exudates, which act as a lubricant for the root, a food source for microbes and provide hydrogen ions. This hydrogen is used to drive the cation exchange process; both plants and microbes employ the technique of cation exchange to release nutrients from the soil. It has been estimated that up to 95% of a plants mineral nutrition goes through the exchange process.

The relative amount of each nutrient on the exchange sites is measured to determine base saturation. This term is used to indicate nutrient balance and the effects of each element on the exchange process. When any one element dominates the exchange sites, nutrient

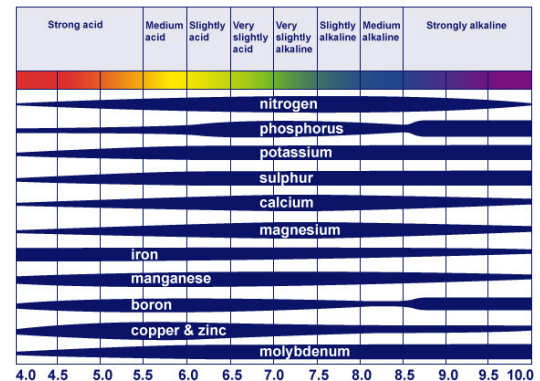
imbalances, antagonistic lock-up and genuine deficiencies can occur. The ratio of one element to another is far more important than levels of available or total nutrients.

Cation exchange and base saturation also determine the pH of the soil, and should always be measured before any form of fertilizer or lime is applied. Cation exchange provides a convenient means of storing nutrients as they are released from soil reserves, before they are needed by the plant. Without this, available nutrients would be washed away. The exchange process also gives plants a means of controlling nutrient uptake, via root exudates and beneficial microbes, creating a supply-and-demand situation.

What are the chemical characteristics of the soil solution, which affect pH and salinity?

Soil water is the water (H₂O) held within the soil pores. Soil solution is the soil water together with its dissolved salts (cations and anions). The soil solution is the medium by which most soil nutrients are supplied to growing plants. It also has a role in soil salinity and pH.

Soil salinity - an increased concentration of salts in the soil solution. In general, as soil moisture is reduced, especially by evaporation, the concentration of soluble salts of sodium, calcium, magnesium, and potassium in the soil solution increases. These salts may already be present in the soil solution or they can be carried upward from the ground water by capillary action if the water table rises.

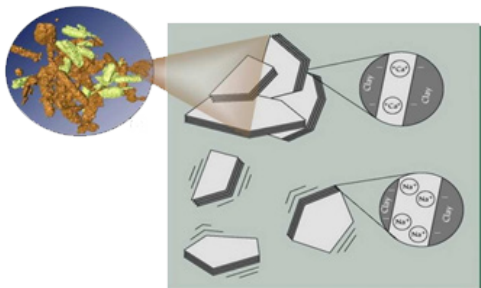


The concentration of soluble salts can become so high as to interfere with the growth of plants. Soils that have a salt concentration in the surface soil that is sufficient to interfere seriously with the growth of plants are called saline soils. Salinity can occur on dryland farms and on irrigated farms. The salinity that occurs is the same in either case, only the initiating causes and management methods may be different and is measured in soil tests.

Soil pH - the soil solution can be neutral, acid, or alkaline. This is called the soil pH. The pH measures the concentration of positively charged hydrogen ions (H⁺) in the soil solution on a logarithmic scale ranging from 0 to 14. When a soil solution contains more H⁺ ions, it is acidic. When there are fewer H⁺ ions, the soil solution is alkaline. The level of acidity or alkalinity in a soil affects the availability of soil nutrients.

What is the sodicity of the soil, which affects soil stability?

The sodicity of the soil refers to the amount of exchangeable sodium cations compared to other cations adsorbed onto the soil. A soil with 6% or more of its exchangeable cations as sodium is called a sodic soil. Excessive exchangeable sodium can cause clay particles to disperse when in contact with water.



Sodic soils have poor structure and disperse readily when wet. Seedlings have difficulty penetrating a drying dispersed surface, and their roots have difficulty penetrating into the soil, with consequent poor germination and survival. The dispersion is caused by weak positive charges, such as sodium.