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Unit Guide 2023 - 2024

The Interaction of Soil Environments and Woody Plants

LO 2 Understand the importance of the differing quantities of water found in a soil

2.1 Describe how water moves within the soil

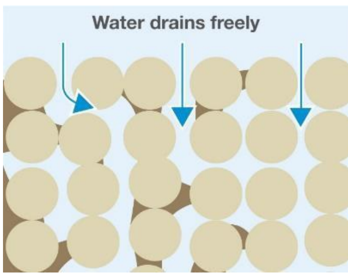
Plants must have an adequate supply of water and nutrients to thrive. Water carries nutrients and gases to plants through the soil.

There are three main outcomes for the water that reaches the soil surface: (a) flow over its surface to reach the streams, lakes, and rivers; (b) entering the soil and partially filling pores from which position it provides water for plant roots and ultimately for the above ground parts of plants; and (c) passing straight down through the soil, into the aquifers and rock bodies below.

Concepts of water retention and movement presented apply to all soils.
Mineral soil particles are a combination of sand silt and clay size soil particles as well as organic matter. The proportion of small, medium, and big soil particles (clay, silt, and sand, respectively) in each soil mass is referred to as the soil's texture. Sand or loamy sand, for instance, is a coarse soil. Loam, silt, or silt is a medium soil. Sand, silty clay, or clay is a fine soil.

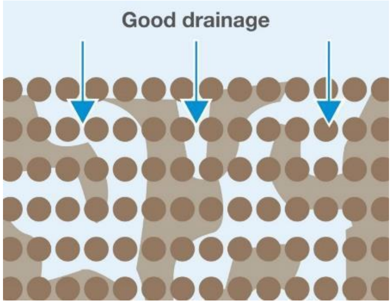
Sand

- Largest soil particle at 0.06–2 mm
- Large air spaces between particles
- Free circulation of air and good drainage
- Warms up quickly in spring and has a long growing season
- Drought-sensitive, often acidic
- Weak structure, so may slump or cap
- Prone to compaction by deep cultivation or harvesting in wet weather
- Can suffer from runoff and erosion by water and wind



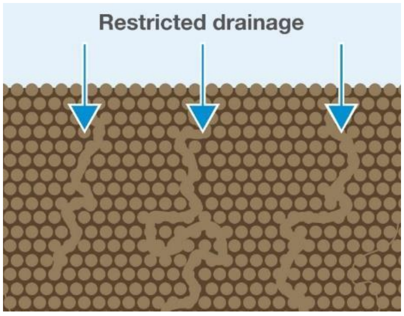
Silt

- Smaller than sand, but bigger than clay, at 0.002–0.06 mm
- Air spaces and water channels are more restricted than in sandy soils
- Fertile, well-drained and holds more moisture than sandy soils
- Easy to cultivate, except in dry conditions, but easily compacted
- Prone to capping, so needs careful management
- Damaged when worked or grazed in wet conditions

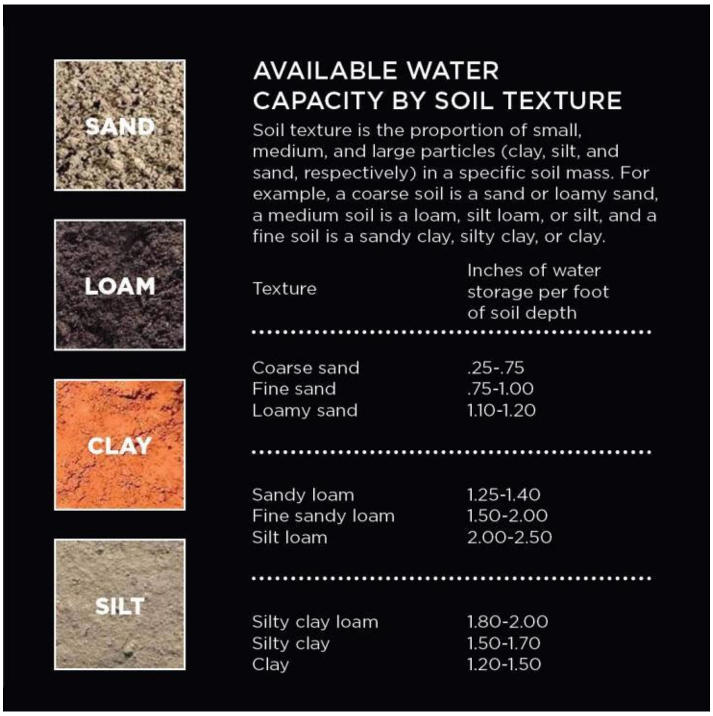


Clay

- Smallest particle at less than 0.002 mm
- Restricted air and water movement, so can lie wet for long periods
- Contains high levels of nutrients if drainage is adequate
- Easily compacted if poached while wet
- Bakes hard in dry conditions
- Unsuited to ploughing in spring if subsoil remains wet
- May crack in dry or frosty conditions, which can alleviate compaction



Soil porosity describes the amount of macro- and micropores in the soil. These pores exist in gaps where soils particles come together. The macropore space in a sand-dominated soil, where the particles are larger, would be much more than the micropore space in a clay-dominated soil, where particles are smaller and held together tightly. Water will move in and out of these pores if they are connected to one another. These pores also allow water to enter the soil surface through infiltration, where it starts moving both laterally and vertically.

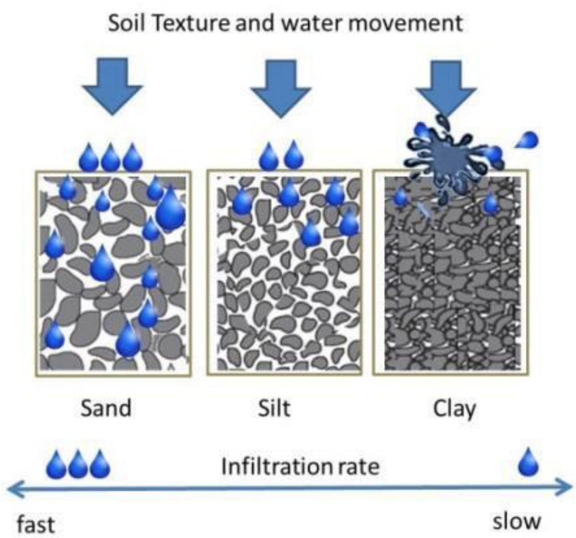


There are at least seven different flows that are important in transferring the precipitation that has fallen on the land into the drainage network.

1. Interception: the retention of water by plants and soils which is subsequently evaporated or absorbed by the vegetation.
2. Infiltration: the process by which water soaks into, or is absorbed by, the soil.
3. Percolation: like infiltration, but a deeper transfer of water into permeable rocks.
4. Throughflow: the lateral transfer of water downslope through the soil
5. Groundwater flow: the very slow transfer of percolated water through permeable or porous rocks.
6. Surface runoff: the movement of water that is unconfined by a channel across the surface of the ground (overland flow).
7. River or channel flow: takes over as soon as the water enters a river or stream; the flow is confined within a channel.

The passage of water and air through the soil is referred to as permeability, and it is significant because it has an impact on the amount of nutrients, moisture, and air available for plant uptake in the root zone. The quantity of air and moisture which can move through the most impermeable layer in the top (100 cm) of the effective root zone at any given time determines how permeable a soil is.

High soil permeability means that the pore space in the soil is well-connected and that the pores are found throughout the soil. Beach sand is highly permeable.
Soils with low permeability may have several pores but those pores may not be connected. Or there may be very few pores. However, once water reaches pores in low-permeability soils, it must move down the soil profile via **gravity** or laterally via **capillary action**. Water will move laterally in the soil profile if there is enough pore space in that soil. This movement is aided by the capillary action of water in small spaces. The water will bind to the edges of the pores and slowly move laterally and even upward if the voids are small enough. You might see a puddle of water in this instance.



Two primary forces govern water movement through soils, gravitational forces, and capillary forces.

(1) Gravitational force or gravity tension: When the soil is wet, the flow of water due to gravity is extremely noticeable, and the direction of such flow is normally downhill, but some lateral flow occurs. The principal conduits for gravity flow are the macropores.

(2) Capillary force or capillary tension: Water is kept in the soil by surface forces in capillary voids and around soil particles. The force of surface tension causes water to move in unsaturated soil conditions. Once the flow caused by

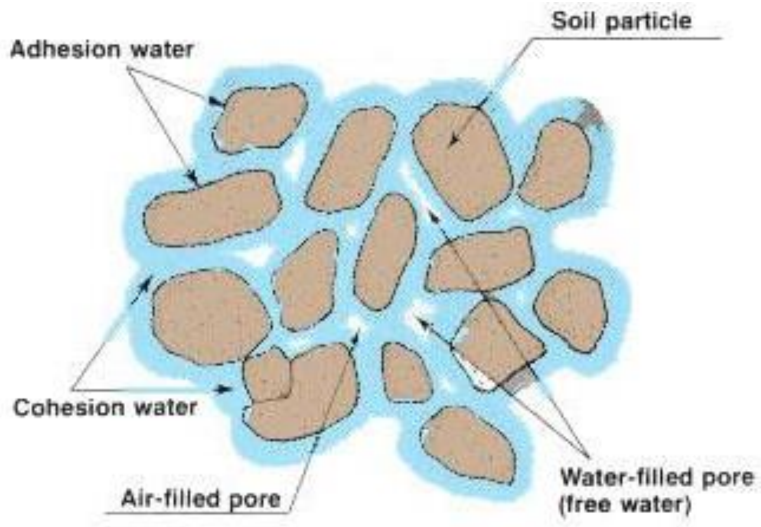
gravity has stopped, water travels in the form of a thin, capillary film from a wet zone to a dry region via micropores. The surface tension, or capillary tension, is responsible for water capillary flow in all directions, from low to high tension.

(3) Vapour tension: If the soil is not waterlogged, water vapour may migrate in a very small amount from more heated soil layers to cooler soil layers, particularly when the temperature difference between them is significant.

(4) Osmotic pressure: Water moves due to differences in the osmotic pressure of the soil solution. The scenario is only found in saline soil with high salt levels.

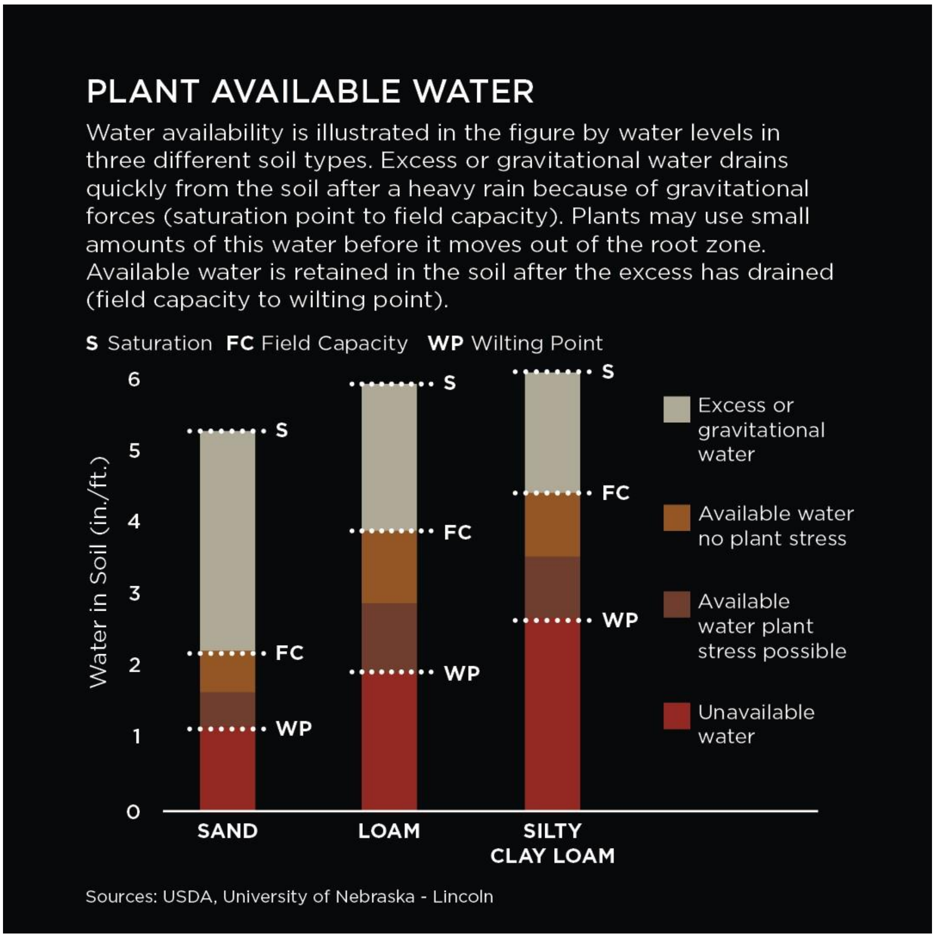
Water that enters in the soil is retained by means of the following three forces:
The attraction of water molecules to their solid surfaces (the attraction of distinct substances to each other) is referred to as the **force of adhesion**. Due to the force of adhesion, water molecules attach to the surface of soil particles, generating a thin film of water that is tightly wrapped around the soil particles. The more surface area the soil particles have, the more surface area the water film retains.
Cohesion force: attraction between comparable molecules with similar properties the attraction of water molecules to one another is referred to as cohesion. When more water is added to damp soil, the cohesive force is activated, and newly added molecules are drawn to already existing water molecules. This causes the water film around the soil particles to thicken.
Soil colloids (clay or humus particles): Soil colloids, such as clay or humus particles, help to retain water in the soil. Imbibitional moisture refers to the water retained in the soil as a result of this process.

Moisture retention varies according to soil type. Fine-textured soils with greater aggregation and more organic matter, or humus, hold significantly more water than coarse-textured, single-grained soils with low organic matter.



Water that is permanently bound to soil particles and is not available to plants is called **bound water**.
Most of the water available to plants is capillary water, which slowly becomes more difficult to extract from the soil as the soil dries until the point has been reached that all the capillary water has been used and only bound water remains. As water drains from field capacity through gravitational action, it is available to plants, but generally this water is available for only a short time after saturation. Water molecules are adsorbed to the soil particles and held in pore spaces, the smaller the pore, the more tightly the water is held. As a soil is depleted of its available water, the remaining water is held more tightly. We are often interested in knowing how tightly the water is being held in the soil because this gives us an idea of how easily a plant might retrieve it and often gives us an idea how much water is in the soil. When all the available water has been removed from the soil where plants could absorb it, the soil is said to have reached the permanent wilting point. At this point, if soil moisture is not replenished, plants will probably die. Water is also present in the soil as vapor. The RH of the pore spaces in soil is above 99% even at the

permanent wilting point. This water vapor is important for plant growth. In a soil near field capacity, only 10% of the seed's surface is in contact with liquid water. It is more important to ensure that soil moisture losses are minimized during germination by covering the seeds adequately with either soil, mulch, or both.

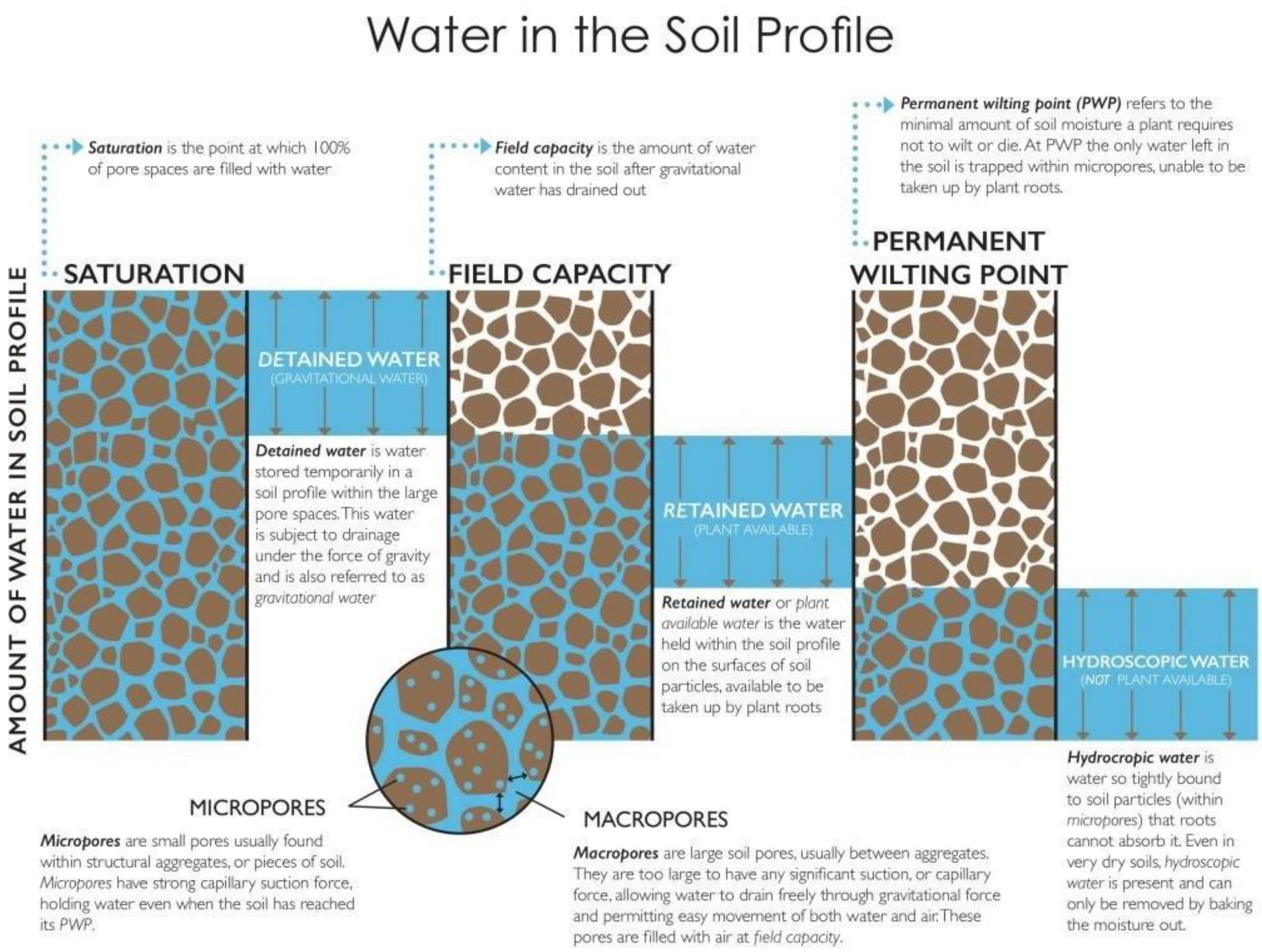


The table shows how much soil texture influences water availability. Although sandy soil can quickly rehydrate, it cannot hold as much water as soils with heavier textures. Because fine soils with narrow pore spacing hold water more tightly than coarse soils with wide pore spacing, the wilting point rises as texture thickens.

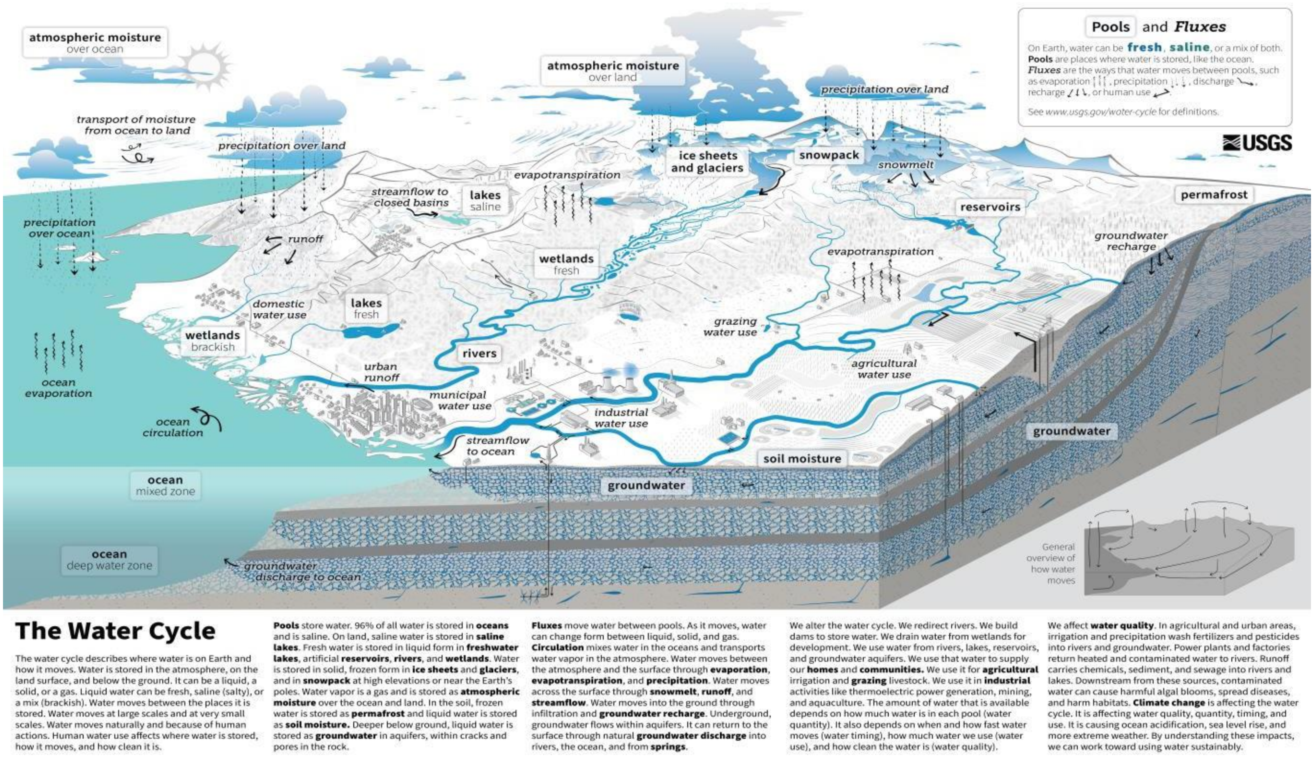
When all the soil pores are full of water, the soil is said to be saturated. The percentage of porosity is equal to the water content of the soil at saturation. Field capacity is the amount of water in the soil after it has been saturated and has been given time to drain properly for 24 to 48 hours. Gravity's pulling power on the water causes free drainage to happen. When water stops draining, we can be certain that a force other than gravity is keeping the remaining water in the soil. The soil water content when plants have drawn all the water they can is known as the permanent wilting point. A plant will wilt and not recover if it reaches its irreversible wilting point. Unavailable water is soil water content that is tightly bound to soil particles and aggregates and cannot be retrieved by plants. This water is stored in the form of films that cover soil particles.

These words describe soil from its wettest to its driest state. Several names are used to characterise the water contained between these various water contents. Gravitational water is the quantity of water held by the soil between saturation and field capacity. Water holding capacity is the amount of water held in the soil against gravity, or the total volume of water in the soil at field capacity. The quantity of water held between field capacity and wilting point is referred to as plant available water or available water capacity.

The total quantity of water stored in each soil volume at a particular moment is measured as volumetric water content. It includes all possible water, including gravitational, accessible, and unavailable water.



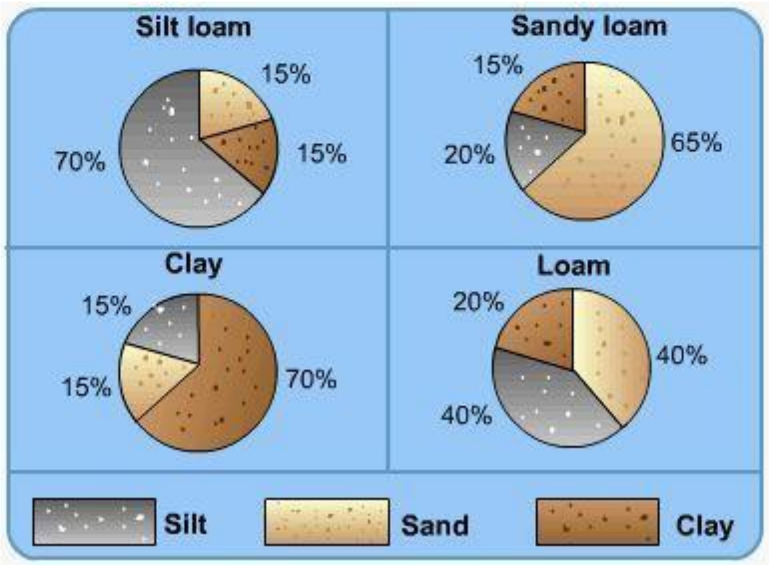
Plant available water is that portion of the water holding capacity that can be absorbed by a plant. Generally, plant available water is 50 percent of the water holding capacity.



2.2. Identify how pore size affects water retention in a soil

All soils contain mineral particles, organic matter, water, and air. The combinations of these determine the soil's properties – its texture, structure, porosity, chemistry, and colour.

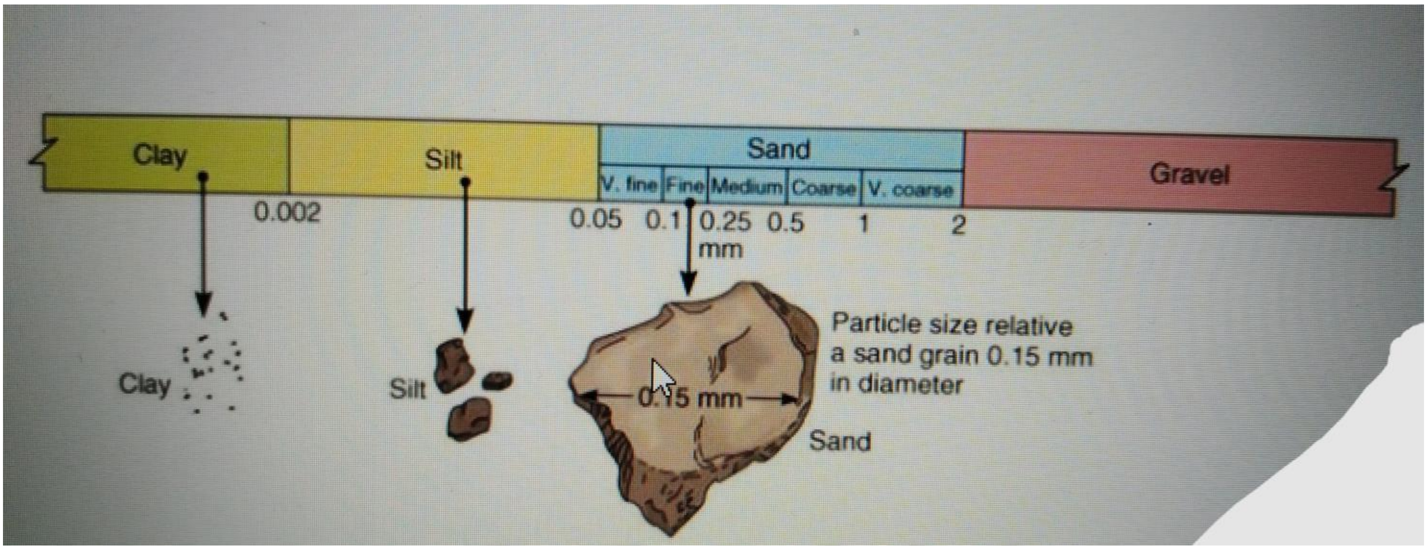
Soil combinations



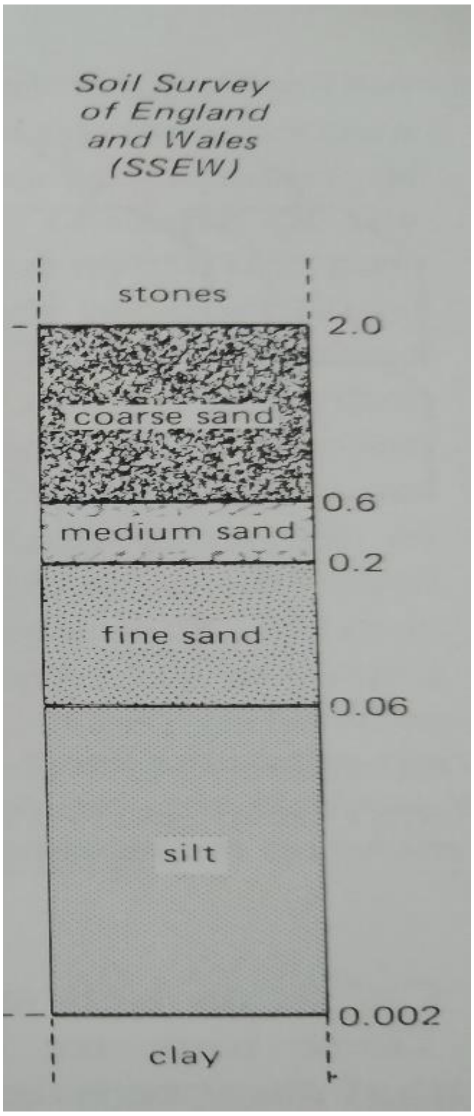
The **texture of soil** refers to the sizes of the solid particles composing the soil. The sizes range from gravel to clay**.** The proportions of the different sizes present vary from soil to soil and from layer to layer.
The types of pore spaces that exist in a soil are directly influenced by its structure. In coarse-textured soils, pores can be categorised as **macro-pores** that exist between aggregates or individual grains. In addition to offering space for roots and other soil-dwelling creatures, macro-pores easily permit the circulation of air and water.
Micro-pores can be found within or inside aggregates of clay-size particles. Because they are too small to enable significant air movement, micro-pores are typically filled with water. Since water moves slowly via micropores, some of the water that soil colloids tightly hold onto is unavailable to plants.
Large "aeration and drainage" pores and small "water-retention" pores are typically in balance in well-aggregated clay soils. Small or medium-sized aggregates with lots of pores both inside and between aggregates are a sign of a healthy soil structure. Soil texture affects the water holding capacity, nutrient retention, nutrient fixation, drainage, compressibility, and aeration of the soil.

- Sand: Particle Size – diameters between 0.05 and 2 millimetres.
- Silt: Particle Size – diameters between 0.002 millimetres to 0.05 millimetres.
- Clay: Particle Size – diameters less than 0.002 millimetre

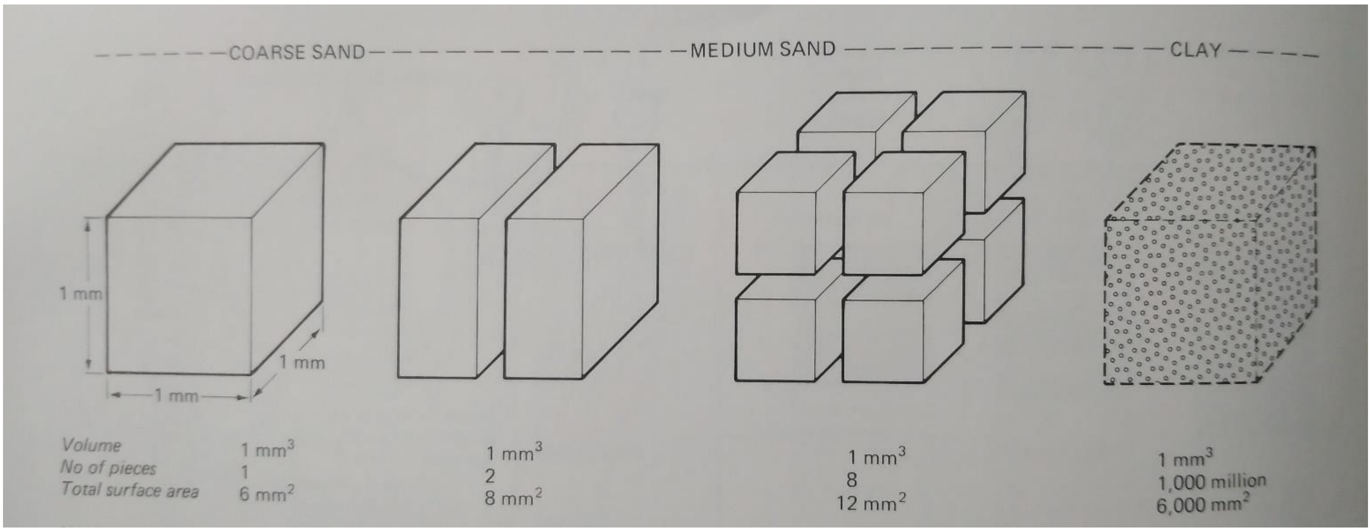
Rocks larger than 2 millimetres are regarded as pebbles, gravel, or rock fragments *and technically are not soil particles.*



One of the major particle size classification system in use today is the SSEW (Soil Survey of England and Wales).



The particles with a diameter of less than 2 mm are regarded as soil. Sometimes, the silt and clay particles are referred to as "fines." Quartz is the primary component of sand. The particles range in morphology from sharp and gritty sand to more rounded, worn grains. Most of the sand granules lack cohesiveness and are chemically inert, neither releasing nor retaining plant nutrients. The size of the particles is crucial because sand's impact on the soil is primarily physical. The **surface area** of a given amount of sand increases as the particle size and volume of individual grains shrink. Since sand granules lack pores, their ability to retain water is directly correlated with the size of their surface areas. Since water cannot pass through openings smaller than 0.05 mm in diameter, it is easy to observe that coarse and fine sands have extremely different drainage properties. Soils with a high proportion of coarse sand are often devoid of contaminants. Because of this, soils with a high proportion of coarse sand tend to drain freely yet retain little water, whereas soils with a high proportion of unaggregated fine sand retain a lot of water against gravity. Roots can easily extract the water that is retained on all sand particles.

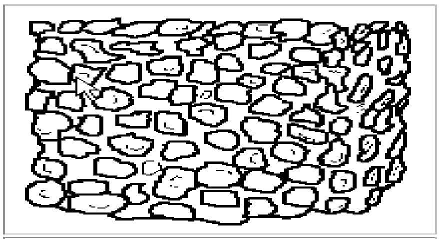
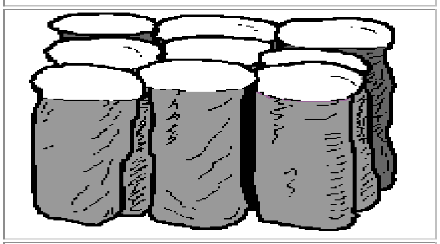
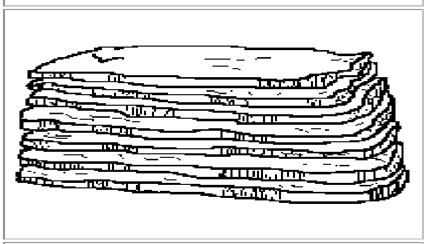
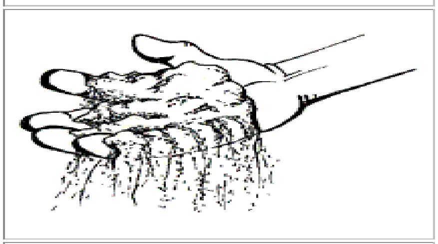


The **surface area** of a given amount of sand increases as the particle size and volume of individual grains shrink.

Surface area of soil particles
The effect of sub-dividing a cube corresponding in size to a grain of coarse sand. The same volume of medium sand is made up of over eight times more pieces which have a total surface area more than double that of coarse sand. It requires over a thousand million of the largest clay particles to make up the volume of one grain of coarse sand and their surface area is approximately one thousand times greater.

Soil structure describes the way the sand, silt, and clay particles are clumped together. Organic matter (decaying plants and animals) and soil organisms like earthworms and bacteria influence soil structure.
Clays, organic matter, and materials excreted by soil organisms bind the soil particles together to form **aggregates**. Soil structure is important for plant growth, regulating the movement of air and water, influencing root development, and affecting nutrient availability.
Good quality soils are friable (crumbly) and have fine aggregates so the soil breaks up easily if you squeeze it. Poor soil structure has coarse, very firm clods or no structure at all.

Examples of soil structure types:

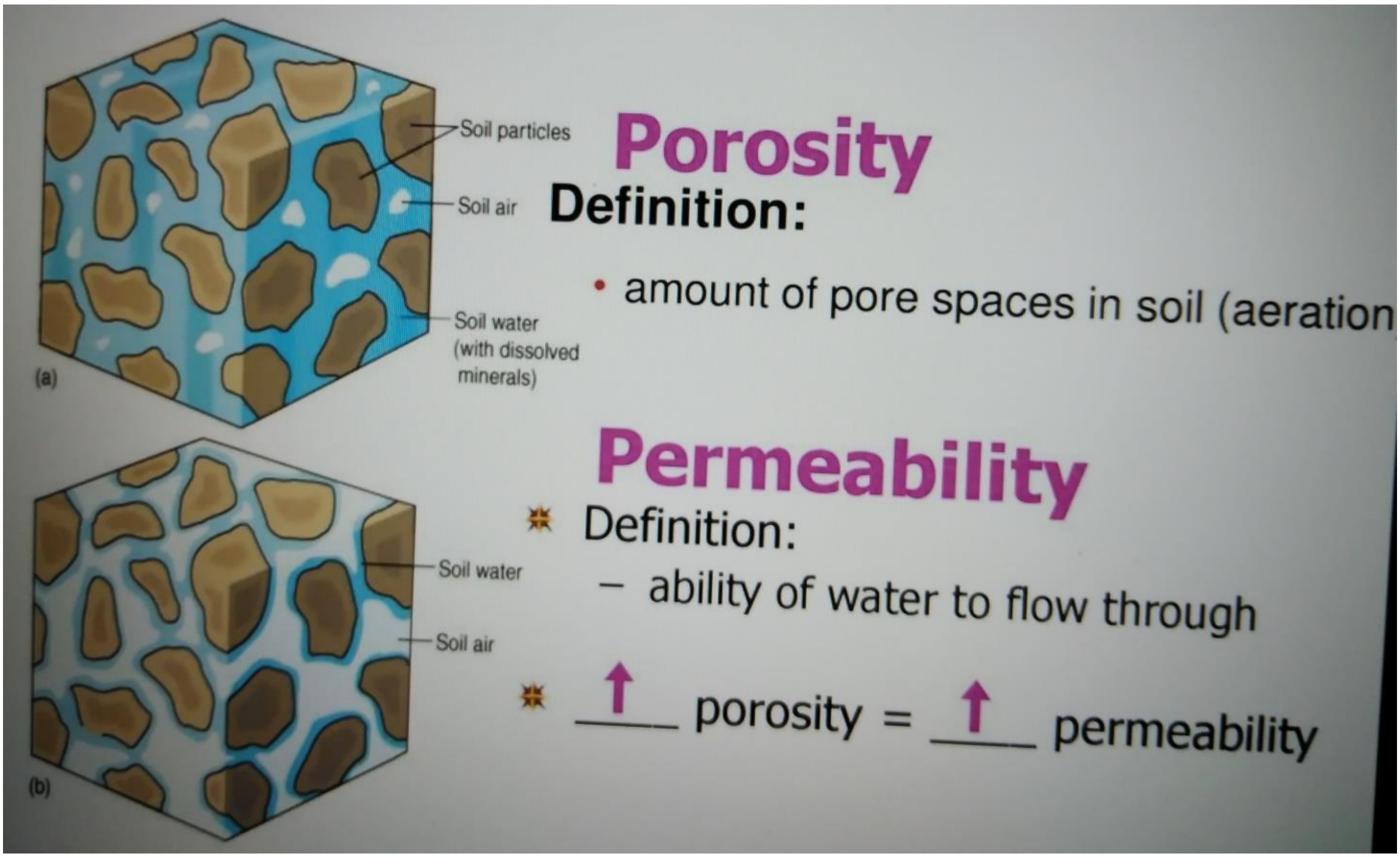
		
Granular: Resembles cookie crumbs and is usually less than 0.5 cm in diameter. Commonly found in surface horizons where roots have been growing.	**Blocky**: Irregular blocks that are usually 1.5 - 5.0 cm in diameter.	**Prismatic**: Vertical columns of soil that might be a number of cm long. Usually found in lower horizons.
		
Columnar: Vertical columns of soil that have a salt "cap" at the top. Found in soils of arid climates.	**Platy**: Thin, flat plates of soil that lie horizontally. Usually found in compacted soil.	**Single Grained**: Soil is broken into individual particles that do not stick together. Always accompanies a loose consistence. Commonly found in sandy soils.

GOOD CONDITION VS = 2
Soil dominated by friable, fine aggregates with no significant clodding. Aggregates are generally sub-rounded (nutty) and often quite porous

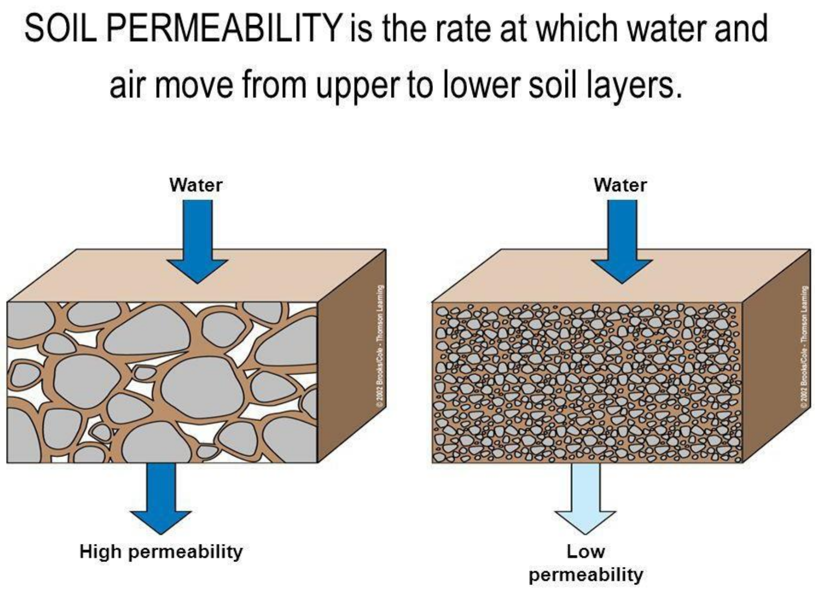
MODERATE CONDITION VS = 1
Soil contains significant proportions (50%) of both coarse clods and friable fine aggregates. The coarse clods are firm, sub-angular or angular in shape and have few or no pores

POOR CONDITION VS = 0
Soil dominated by coarse clods with very few finer aggregates. The coarse clods are very firm, angular or sub-angular in shape and have very few or no pores

Structural characteristics of soil:



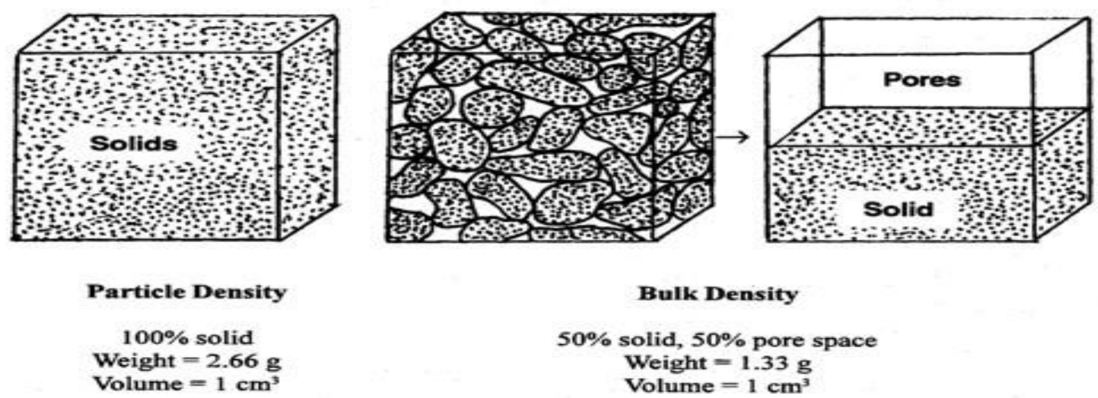
- **Permeability** – The ease with which liquids/gases can pass through rocks or a layer of soil is called permeability. It depends on the size, shape, and packing of particles. It is usually greatest in sandy soils and poor in clayey soils.



- **Porosity** –Soil porosity is usually divided into Air-Filled Porosity and Water-Filled Porosity.
  Porosity or pore space refers to the volume of soil voids that can be filled by water and/or air. It is inversely related to bulk density
  A straightforward formula is used as follows:
  Soil Porosity = (1 - (Bulk Density ÷ Particle Density)) x 100. This will indicate the percentage of the soil that contains pores.

Soil weight is most often expressed on a soil volume basis rather than on a particle basis. **Bulk density** is defined as the dry weight of soil per unit volume of soil. Bulk density considers both the solids and the pore space; whereas, particle density considers only the mineral solids.

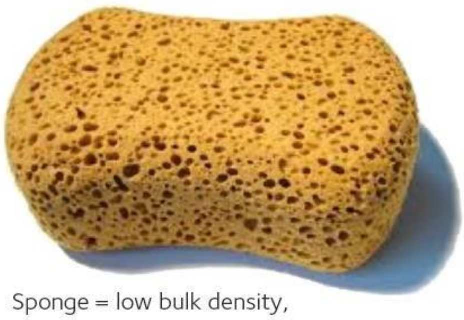
The difference between bulk density and particle density.



- The volume of water which can be held within the soil is called its porosity. It is expressed as a ratio of the volume of voids (pores) to the total volume of the material.

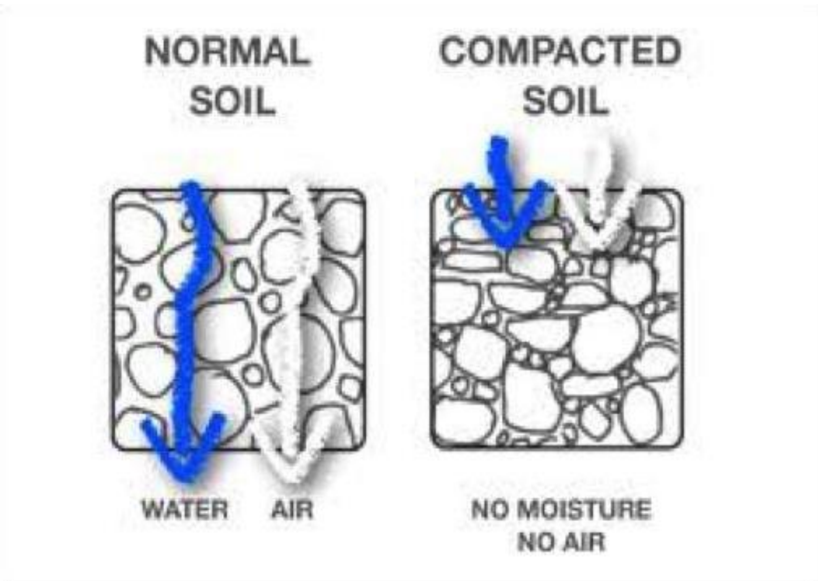
Total porosity	35%-55%	The total amount of pores within the soil
Air Filled Porosity	15%-30%	The amount of air-filled pores within the soil
Capillary Porosity	15%-25%	The amount of water filled pores within the soil, where the water is available for use by the plant.

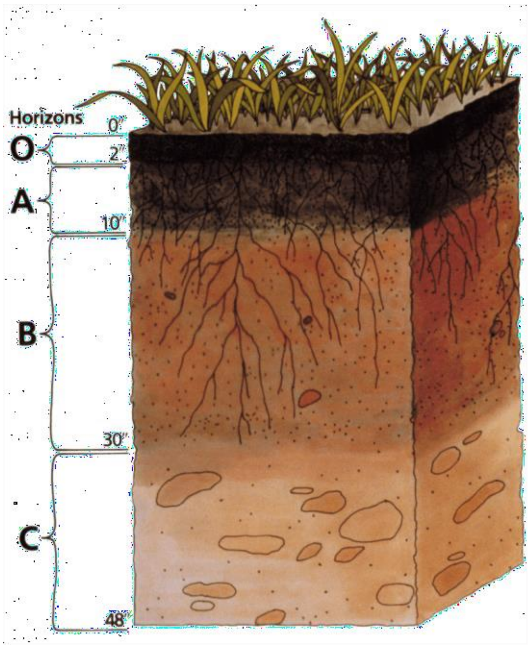
Brick = high bulk density, low pore space



Sponge = low bulk density, high pore space

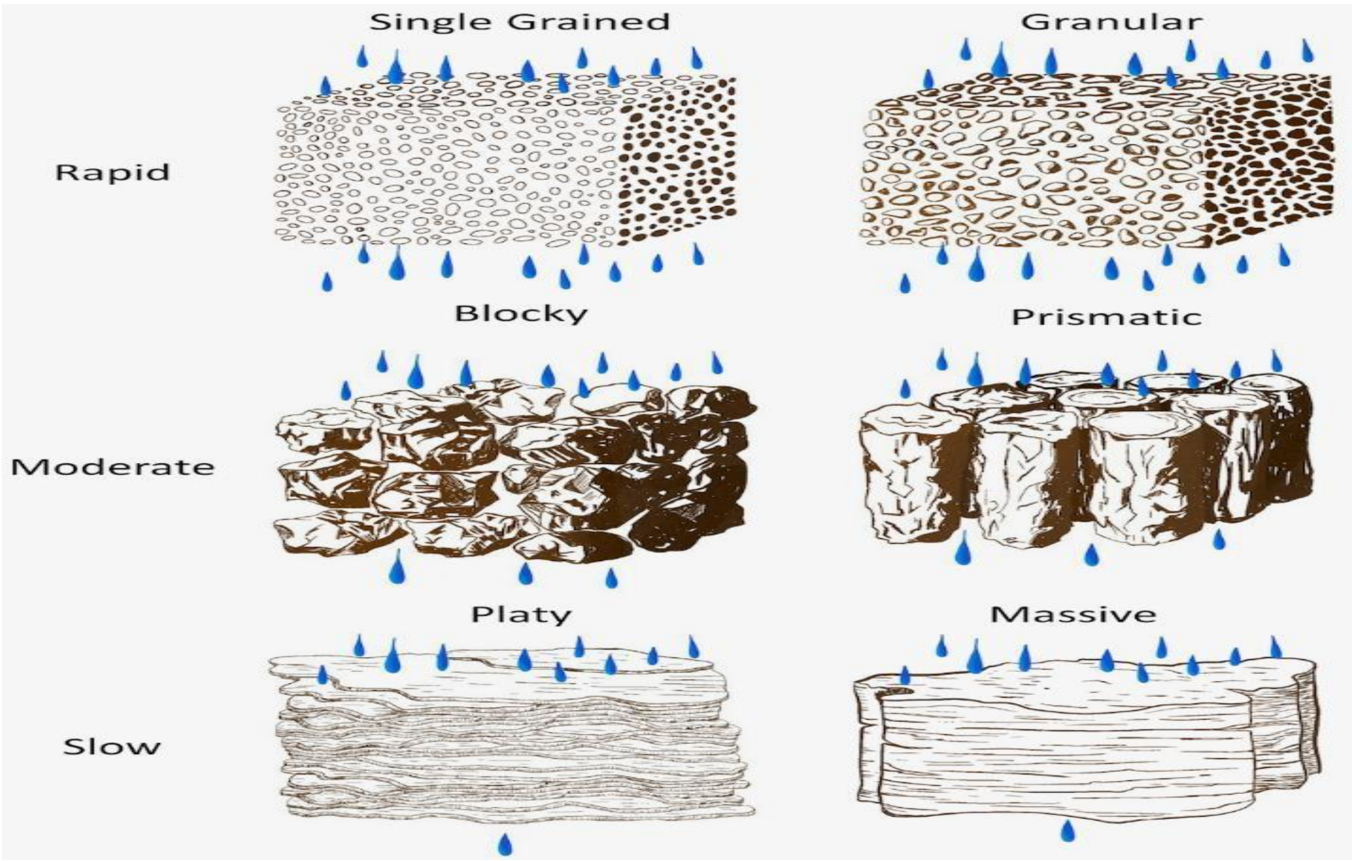
Loose, rich in organic matter, well aggregated and porous soils have a low bulk density. Sandy soils on the other hand have relatively high bulk since the sand particles can interlock to form a more solid mass with little pore space. This translates into sandy soils being easily compacted.
Bulk density then is an indicator of a common soil health problem that we've all encountered at some point – **compaction.** Compaction affects infiltration, rooting depth, water holding capacity, soil porosity, the availability of plant nutrients, and the activity of soil microbes.



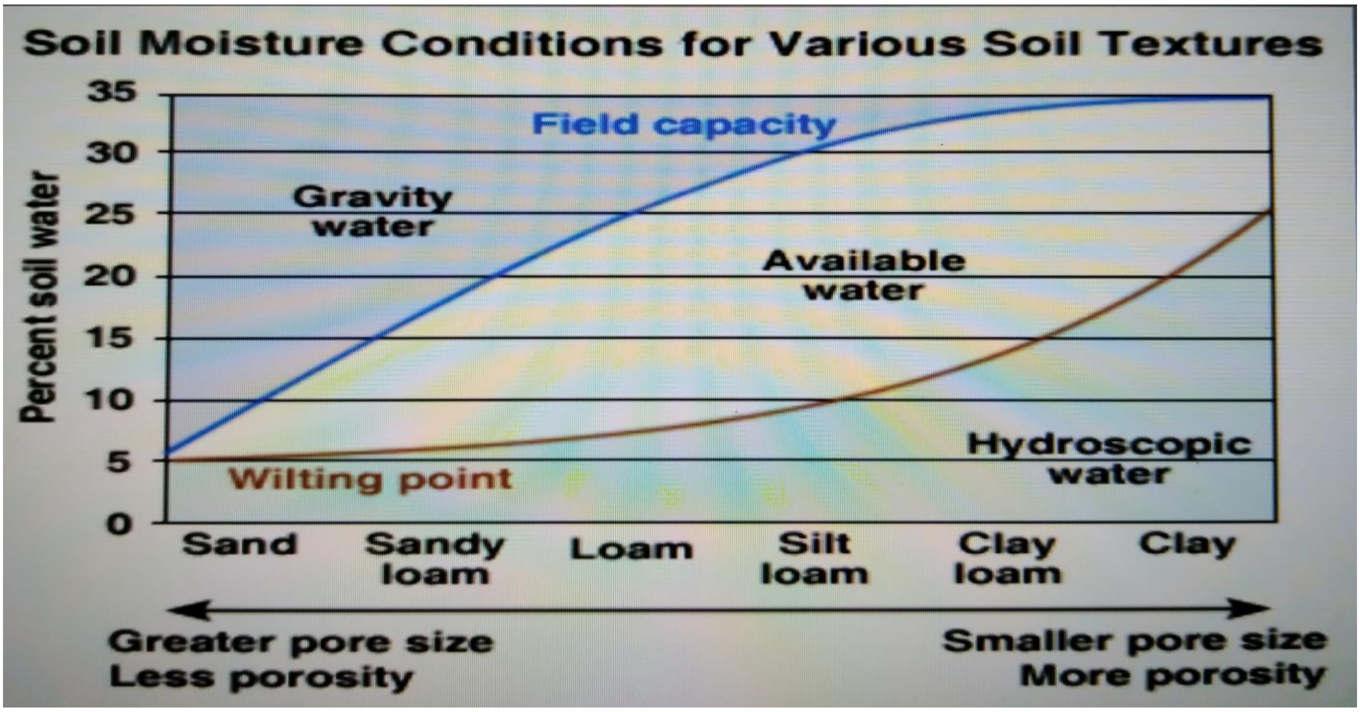


Weathering of minerals in the A horizon commonly produces clay minerals and these clays are transported downward, accumulating in the B horizon. Clays tend to reduce the porosity and permeability of soil material and many types of clays can absorb water like tiny sponges; this absorption causes them to swell and further reduce the porosity and permeability. This leaves the A horizon with a higher porosity and the B horizon with a relatively smaller porosity and reduced permeability, with helps to effectively retain water in the soil for use by plants.

Water movement as affected by type (shape) of aggregates.



The rate of water infiltration, water retention, aeration, and drainage are only a few of the significant soil qualities that are directly influenced by soil structure, which also has an impact on the size of pores. Water can pass slowly through pores in soils with enormous structure or platy aggregates, whereas it moves quickly in soils with granular aggregates and single grains.



Water molecules are held in the soil by the force of **cohesion**. This is the force that exists between molecules of the same substance. The molecules are attracted to each other and cling together. The force of cohesion is responsible for the surface tension of water. It is also responsible for the capillary action of water in the soil. The force of adhesion is the force that exists between molecules of different substances. The water molecules are attracted to the soil particles and cling to them. This is what gives water its **adhesive properties**. The force of adhesion is responsible for the ability of water to wet the soil and to form a film on the surface of the soil. The forces of cohesion and adhesion work together to keep water molecules in the soil. The molecules are attracted to each other and to the soil particles. They cling to each other and to the soil particles. This prevents the water molecules from moving out of the soil.

Of the water entering a soil profile, some will be stored within the rooting zone for plant use, some will evaporate and some will drain away from the plant root zone. Plant available water is the difference between field capacity (the maximum amount of water the soil can hold) and the wilting point (where the plant can no longer extract water from the soil) measured over 100 cm or maximum rooting depth. Beyond the wilting point there is still water in the soil profile, however it is contained in pores that are too small for plant roots to access. Soil texture, soil structure and plant rooting depth are the crucial factors in determining the amount of water available for plants to access.

Taking all these factors into account, the reason why the pore size affects the soils' capability to retain water is because pores of varying sizes will allow different the transit and/or retention of gases and moisture. The amount of water that a soil can hold is highly correlated with the size of its particles; because clay soils tend to have finer particles than sand does, clays tend to hold more water overall. Sands, on the other hand, facilitate easier water transportation through the profile. The kind of clay, the amount of organic matter, and the structure of the soil all impact soil water retention. Clay type, organic content, and soil structure also influence soil water retention.

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