SUBJECT- ENVIRONMENTAL SCIENCE

SEMESTER – 2nd SEMESTER (CC4)

TEACHER- SHRAMANA ROY BARMAN

TOPIC- SOIL DEGRADATION AND CONSERVATION

Soil, the biologically active, porous medium that has developed in the uppermost layer of Earth's crust. Soil is one of the principal substrata of life on Earth, serving as a reservoir of water and nutrients, as a medium for the filtration and breakdown of injurious wastes, and as a participant in the cycling of carbon and other elements through the global ecosystem. It has evolved through weathering processes driven by biological, climatic, geologic, and topographic influences.

Soil formation results from its disintegration or weathering of parent rock by physical, chemical or biological agents. As a result, small particles called regoliths are formed. Regoliths under the influence of other pedogenic processes finally develop into mature soil.

(a) Physical Weathering:

When climatic agents such as temperature, water, ice and gravity change the rocks in regoliths but do not cause any chemical transformation of rocks, the process is called as physical weathering. It occurs in deserts, at high altitudes and latitudes specially at places where sparse vegetation grow over the rocks.

(b) Chemical Weathering:

Chemical transformation of parent mineral occurs to form new mineral complexes. Water is the most potent weathering agent. Soluble rocks like gypsum, lime stone and those with a calcareous content gets weathered by the solvent action of water.

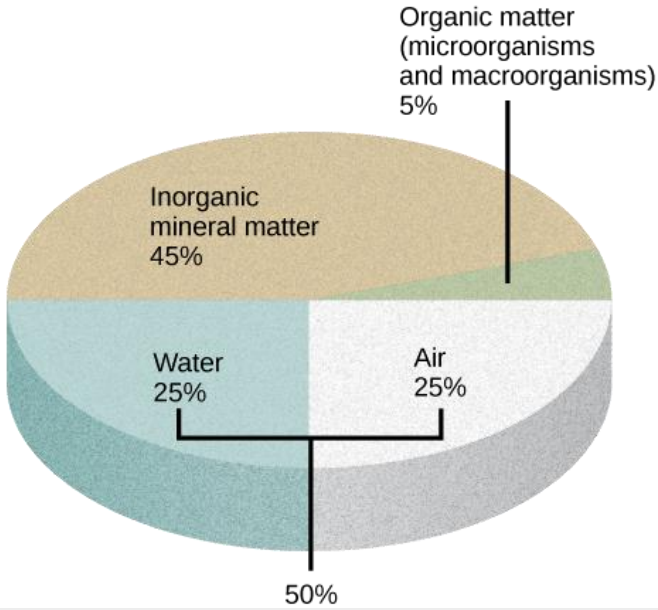
(c) Biological Weathering:

Certain organisms like bacteria, protozoans, fungi and nemetodes as well as lichens and mosses colonize the rocks and transfer it into a dynamic system storing energy and synthesizing organic material. Their activities change the physical structure of the rock.

Weathered rocks are changed into regoliths that are again changed into soil. Thus weathered material undergoes a number of complex processes collectively known as pedogenesis. Pedogenesis is by and large a biological phenomenon. During this process living organisms such as bacteria, algae, fungi and lichens, insects and molluses contribute to different geochemical, biochemical and biophysical reactions.

These activities convert the weathered earth crust into true soil consisting of mineral matrix in association with a variety of organic compounds supporting rich population of micro organisms. The processes, being continuous, keep on adding to the developing soil, organic matter and materials in the form of layers. Therefore, the soil when fully developed can be observed having a number of horizons, starting from surface to downwards. These horizons make a soil profile.

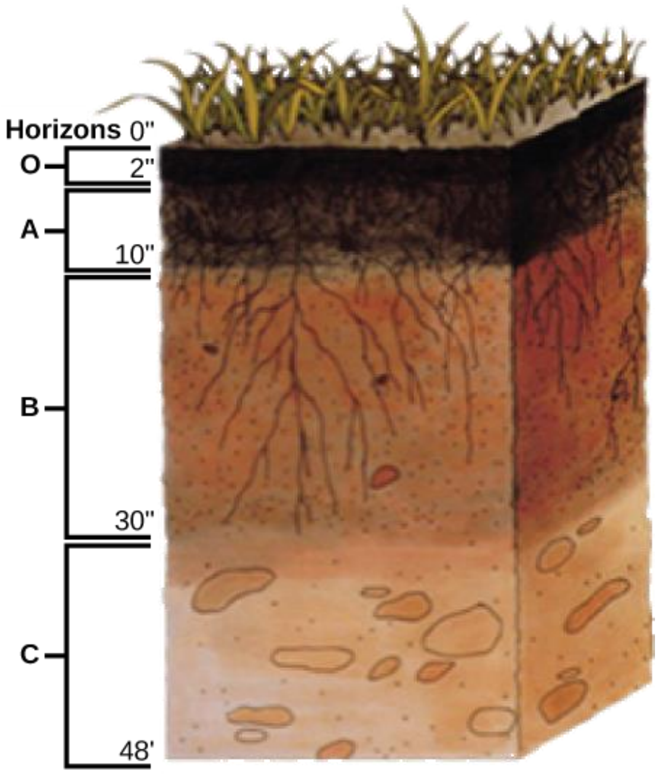
Soil consists of these major components:



Components of soil: The four major components of soil are shown: inorganic minerals, organic matter, water, and air.

- inorganic mineral matter, about 40 to 45 percent of the soil volume
- organic matter, about 5 percent of the soil volume
- water, about 25 percent of the soil volume
- air, about 25 percent of the soil volume

Soils are named and classified based on their horizons. The soil profile has four distinct layers:



Soil profile: This soil profile shows the different soil layers (O horizon, A horizon, B horizon, and C horizon) found in typical soils.

1. The O horizon has **freshly-decomposing organic matter**, **humus**, at its surface, with decomposed vegetation at its base. Humus enriches the soil with nutrients, enhancing soil moisture retention. **Topsoil**, the top layer of soil, is usually two to three inches deep, but this depth can vary considerably. For instance, river deltas, such as the Mississippi River delta, have deep layers of topsoil. Topsoil is rich in organic material. Microbial processes occur there; it is responsible for plant production.
2. The A horizon consists of a **mixture of organic material with inorganic products of weathering**; it is the beginning of true mineral soil. This horizon is typically darkly colored because of the presence of organic matter. In this area, rainwater percolates through the soil and carries materials from the surface.
3. The B horizon, or **subsoil**, is an accumulation of mostly **fine material** that has moved downward, resulting in a dense layer in the soil. In some soils, the B horizon contains nodules or a layer of calcium carbonate.
4. The C horizon, or soil base, includes the parent material, plus the organic and inorganic material that is broken down to form soil. The parent material may be either created in its natural place or transported from elsewhere to its present location. Beneath the C horizon lies bedrock.

Soil Erosion

It is a process in which the top fertile layer of soil is lost. Due to soil erosion, the soil becomes less fertile. The top layer of soil is very light which is easily carried away by wind and water. The removal of topsoil by the natural forces is known as soil erosion.

Even though erosion is a natural phenomenon, human interference into natural systems have created erosion that is much higher than the average geological erosion rate. Erosion is a threat to sustained agricultural production. When soils are left bare even for a short period (such as when fields are tilled for planting), the soil can be picked up and moved. These bare soil drops are exposed to the energy of the raindrops and wind. The finer particles of soil are eroded first, taking with them most of the natural fertility and production potential. However, with plant cover, the roots bind the soil particles together and lesson erosion.

The process of soil erosion is made up of three parts:

Detachment: This is when the topsoil is actually "detached" from the rest of the ground.

Movement: This is when the topsoil is relocated to another area.

Deposition: Where the topsoil ends up after this process.

Types of soil erosion:

1. Natural or geological or normal soil erosion:

When the top soils are gradually removed under normal conditions of physical, biotic and hydrological equilibrium it is called normal erosion. Sometimes, it is also called geological erosion it take place steadily slowly which developed the present topographic feature like valley, plains, stream, channel etc. It is very slow process in which complete equilibrium is maintained between soil removing and soil forming processes. The normal erosion tends to produce wavy or undulating land surface with alternating ridges and depressions. This is accomplished chiefly by means of slow migration of soil particles from soil surface in successive rains. In arid region, wind during the long dry season is an important factor for normal erosion. Nature requires, on an average, about 1000 years building up 2.5cm of top soil, but wrong farming methods may be take place only a few years to erode it from lands of average slope.

2.Accelerated soil erosion:

It occurs due to disturbance in natural equilibrium by the activity of men and animal through land mismanagement, destruction of forests, over grazing etc. When the removal of soil does not keep harmony with the soil formation and it is much faster than the latter, it is called accelerated soil erosion.

Agencies or mechanism of soil erosion:

a. Water erosion

b. Wind erosion

c. Glacial erosion

d. Sea waves

e. Biotic erosion

A. Water erosion:

Process of water erosion:

Soil erosion caused by rainfall is the application of energy from two distinct sources namely

(i) the falling rain drops and

(ii) the surface flow.

The energy of falling raindrop is applied vertically from above, whereas that of surface flow is applied more or less horizontally along the surface of the ground. The chief role of the falling of rain drop on ground is to detach soil particle, whereas that of the surface flow is to transport the soil. The falling of raindrop also makes a major contribution to the movement of the soil on unprotected sloping lands during the period of heavy impact storms, by splashing large quantities down slope.

Soil erosion caused by water can be distinguished in different forms, viz

(1) Splash Erosion: Remove of soil particles due t rain drops is called splash erosion.

(2) Sheet Erosion: Sheet erosion means removes a thin uniform covering of top productive/surface soil from large areas, often from field, more or less, during every rain which produces a run-off.

(3) Rill Erosion: **Rills** are shallow drainage lines less than 30cm deep. They develop when surface water concentrates in depressions or low points through paddocks and erodes the soil

(4) Gully Erosion: It is more prominent type of erosion in which heavy rainfall, rapidly running water and transporting water may result in deeper cavities or grooves called gullies. Gullies may be V shaped or U shaped unstable channels that have been cut more than 30 centimetres deep into the ground. Gullies cut the large fields into small fragments and, in course of time, make them unfit for cultivation uncultivable.

(5) Ravine Erosion: **Ravines** are erosion landforms that are narrower than a canyon. **Ravines** are typically classified as larger in scale than gullies, although smaller than valleys.

(6) Landslides or slip erosion: This type of soil erosion is caused by heavy rainfall and it occurs in sloppy lands, such as mountains and hilly areas with slope is >20%. In this type of erosion when the running water percolates through the crevices of rocks great masses of soils and loose rocks lying on the steep slopes slip downward.

(7) Stream-Bank Erosion: On the banks of swollen rivers it is most active. During the rainy season when fast running water streams take turn in some other directions, they cut the soil and make caves in the banks. As a result of this, quite often large masses of soils become detached and washed away from the banks and are deposited at places in course of streams

Wind erosion:

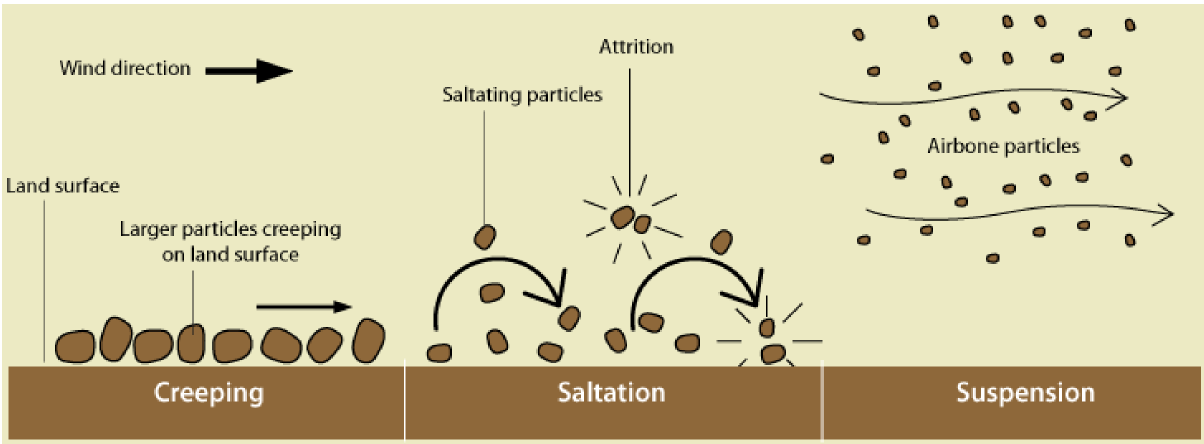
Wind erosion takes place normally in arid and semi arid areas devoid of vegetation, where the wind velocity is high. The soil particles on the land surface are lifted and blown off as dust storms. When the velocity of the dust bearing wind is retarded, coarser soil particles are deposited in the form of dunes and thus fertile lands are rendered unfit for cultivation. In other place, fertile soil is blown away by winds and the subsoil is exposed, as a result the productive capacity of the soil is considerably reduced.

Movement of soil particles in wind erosion is initiated when the pressure by the wind against the surface soil grains overcomes the force of gravity on the grains. Wind is responsible for three types of soil movement in the process of wind erosion. They are known as

(i) Saltation : In **saltation**, fine soil particles are lifted into the air by the wind and drift horizontally across the surface increasing in velocity as they go. Soil particles moved in this process of **saltation** can cause severe damage to the soil surface and vegetation. After being pushed along the ground surface by the wind, the particles leap almost vertically in the first stages of saltation.

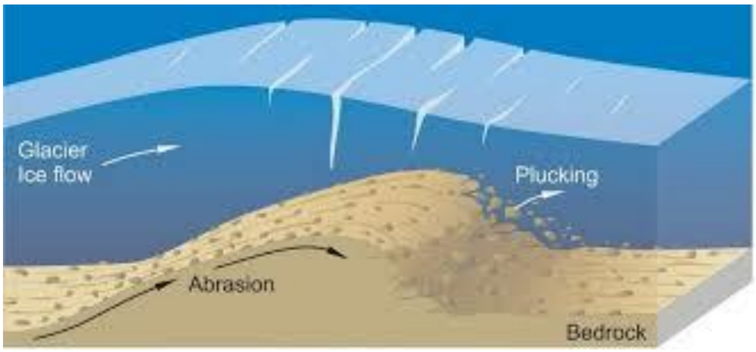
(ii) Suspension: Movement of fine dust particles smaller than 0.1 mm diameter by floating in the air is known as suspension. Soil particles carried in suspension are deposited when the sedimentation force is greater than the force holding the particles in suspension.

(iii) Surface Creep: Soil particles, larger than about 0.5 mm in diameter but smaller than 3.0 mm, are too heavy to be moved in saltation but rolled along the surface by the pressure of wind and hitting during saltation.



Glacial erosion: Like flowing water, flowing ice erodes the land. It also can deposit the material elsewhere. Glaciers cause erosion in two main ways: plucking and abrasion.

- Plucking is caused when sediments are picked up by a glacier. They freeze to the bottom of the glacier and are carried away by the flowing ice.
- Abrasion occurs when glaciers scrape over the Earth's surface. The ice sheet acts like sandpaper. The ice contains sediments and rocks frozen in the ice. The rocks and sediment grind away as the glacier moves. They wear away rock. They may also leave scratches and grooves in them. Scientists use these grooves to learn about the direction the glacier has moved.



Sea waves:

Waves are the major cause of erosion along the coast. Waves shape the coast through erosion by breaking down rock and moving sand and other sediment.

One way waves erode the land is by impact. Large waves hit rocks with lots of force. The energy in waves can break apart rocks. Over time waves make small cracks bigger. Eventually the wave causes the rock to chip off. Waves can also erode rock by abrasion. As a wave comes to shallow water it picks up sediment. Once the wave crashes against land the sediment wears the rock down.
As a wave approaches land it usually changes direction due to the way the wave drags on the bottom. When these waves change direction they can create a headland. A headland is a part of the shore that sticks out into the ocean. The headland sticks out from the shoreline because it is made from harder rock than the rest of the coast, making the shore erode before the headland.

Biotic agencies causing soil erosion:

1. Excessive grazing, deforestation, undesirable forest biota, and mechanical practices by man are important factors which cause soil erosion. Deforestation is the commonest factor which is responsible for soil erosion.

2. Grazing is yet another destructive biological factor for the soil erosion. Cattle and sheep during the summer graze the forest vegetation and make the soil bare.

3. Shifting cultivations. Shifting cultivations are usually noted in the mountains which are geographically young and degraded into soil easily and the whole of the land is covered with a thick mantle of tropical forest vegetation. The removal of the forest or bush cover by felling and burning for shifting cultivation and the resulting exposure of the bare soil to rams and sun, cause enormous soil losses especially on hill slopes. Both surface layer of the soil and large quantity of plant nutrients are washed away under the influence of intense rainfall. Shifting cultivation is a major problem in the hilly areas of Assam, Manipur, Tripura, Arunachal Pradesh, Nagaland and Orissa. Fields on steep slopes are cultivated and top soil is washed away by rains. The loss of soil is too much and the fields become uncultivable.

4. Forest fires are responsible for burning down forest trees on huge scale.

5. Faulty agricultural methods—Sometimes farmers do not care towards leveling and terracing of their upland fields. Rainfall washes away the top soil and results in erosion.

6. Over-grazing by cattle causes removal of vegetation cover of the soil.

Soil Degradation

Soil degradation is defined as a change in the soil quality status resulting in a diminished capacity of the ecosystem to provide goods and services for its beneficiaries. Soil degradation is a nebulous term suggesting that the capacity of a soil to perform selected specified service(s), such as growing crops, has been diminished. The concept seems rather simple, but quantifying degradation has been very challenging and creates uncertainty.

Soil degradation includes

- loss of organic matter
- fertility decline
- soil acidity or alkalinity
- structure decline (includes soil compaction and surface sealing)
- soil contamination (including effects of toxic chemicals and pollutants).
- erosion,
- salinization (due to freshwater removal),
- soil loss following erosion after deforestation or overgrazing,
- "**compaction and crusting** (of soils), [which] can be caused by cattle trampling," and
- **water logging** with impaired water movement.

It was estimated in 1991 that there was 1.96 billion ha of land globally with soil degradation caused by human activity. Soil degradation is made up of the following

- overgrazing, 679 million ha globally
- deforestation, 579 million ha globally
- agricultural mismanagement, 552 million ha globally
- overexploitation, 133 million ha globally

These elements contribute to a significant amount of soil quality depreciation annually. Excessive soil degradation thus gives rise to immediate and long-term impacts which translate into serious desertification. Desertification is defined by the United Nations (1980) as "diminution or destruction of the biological potential of the land which can lead ultimately to desert-like conditions."

While soil degradation may occur naturally, it has been highly exuberated by anthropogenic activities. Besides, climate change combined with human activities continues to worsen soil degradation. With the objective of understanding the distinct nature of soil quality decline, here are the causes, effects, and solutions of soil degradation.

Causes of Soil Degradation

Physical Factors

There are several physical factors contributing to soil degradation distinguished by the manners in which they change the natural composition and structure of the soil. Rainfall, surface runoff, floods, wind erosion, tillage, and mass movements result in the loss of fertile top spoil thereby declining soil quality.

All these physical factors produces different types of soil erosion (mainly water and wind erosion) and soil detachment actions, and their resultant physical forces eventually changes the composition and structure of the soil by wearing away the soil's top layer as well as organic matter. In the long-term, the physical forces and weathering processes lead to the decline in soil fertility and adverse changes in the soil's composition/structure.

Biological Factors

Biological factors refer to the human and plant activities that tend to reduce the quality of soil. Some bacteria and fungi overgrowth in an area can highly impact the microbial activity of the soil through bio-chemical reactions, which reduces crop yield and the suitability of soil productivity capacity. Human activities such as poor farming practices may also deplete soil nutrients thus diminishing soil fertility. The biological factors affect mainly lessens the microbial activity of the soil.

Chemical Factors

The reduction of soil nutrients because of alkalinity or acidity or water logging are all categorized under the chemical components of soil degradation. In the broadest sense, it comprises alterations in the soil's chemical property that determine nutrient availability. It is mainly caused by salt buildup and leaching of nutrients which corrupt the quality of soil by creating undesirable changes in the essential soil chemical ingredients. These chemical factors normally bring forth irreversible loss of soil nutrients and productivity capacity such as the hardening of iron and aluminum rich clay soils into hardpans.

Deforestation

Deforestation causes soil degradation on the account of exposing soil minerals by removing trees and crop cover, which support the availability of humus and litter layers on the surface of the soil. Vegetation cover primarily promotes thee binding of the soil together and soil formation, hence when it is removed it considerably affects the capabilities of the soil such as aeration, water holding capacity, and biological activity.

When trees are removed by logging, infiltration rates become elevated and the soil remains bare and exposed to erosion and the buildup of toxicities. Some of the contributing activities include logging and slash and burn techniques used by individuals who invade forest areas for farming, rendering the soils unproductive and less fertile in the end.

Misuse or excess use of fertilizers

The excessive use and the misuse of pesticides and chemical fertilizers kill organisms that assist in binding the soil together. Most agricultural practices involving the use of fertilizers and pesticides often entail misuse or excessive application, thereby contributing to the killing of soil's beneficial bacteria and other micro-organisms that help in soil formation.

The complex forms of the fertilizer's chemicals are also responsible for denaturing essential soil minerals, giving rise to nutrient losses from the soil. Therefore, the misuse or excessive use of fertilizers increases the rate of soil degradation by destroying the soil's biological activity and builds up of toxicities through incorrect fertilizer use.

Industrial and Mining activities

Soil is chiefly polluted by industrial and mining activities. As an example, mining destroys crop cover and releases a myriad of toxic chemicals such as mercury into the soil thereby poisoning it and rendering it unproductive for any other purpose. Industrial activities, on the other hand, release toxic effluents and material wastes into the atmosphere, land, rivers, and ground water that eventually pollute the soil and as such, it impacts on soil quality.

Altogether, industrial and mining activities degrade the soil's physical, chemical and biological properties.

Improper cultivation practices

There are certain agricultural practices that are environmentally unsustainable and at the same time, they are the single biggest contributor to the worldwide increase in soil quality decline. The tillage on agricultural lands is one of the main factors since it breaks up soil into finer particles, which increase erosion rates. The soil quality decline is exuberated more and more as a result of the mechanization of agriculture that gives room for deep plowing, reduction of plant cover, and the formation of the hardpan. Other improper cultivation activities such as farming on steep slope and mono-cropping, row-cropping and surface irrigation wear away the natural composition of the soil and its fertility, and prevent soil from regenerating.

Urbanization

Urbanization has major implications on the soil degradation process. Foremost of all, it denudates the soil's vegetation cover, compacts soil during construction, and alters the drainage pattern. Secondly, it covers the soil in an impermeable layer of concrete that amplifies the amount of surface runoff which results in more erosion of the top soil. Again, most of the runoff and sediments from urban areas are extremely polluted with oil, fuel, and other chemicals. Increased runoff from urban areas also causes a huge disturbance to adjacent water sheds by changing the rate and volume of water that flows through them, and impoverishing them with chemically polluted sediment deposits.

Overgrazing

The rates of soil erosion and the loss of soil nutrients as well as the top soil are highly contributed by overgrazing. Overgrazing destroys surface crop cover and breaks down soil particles, increasing the rates of soil erosion. As a result, soil quality and agricultural productivity is greatly affected.

Effects of Soil Degradation

Land degradation

Soil quality decline is one of the main causes of land degradation and is considered to be responsible for 84% of the ever diminishing acreage. Year after year, huge acres of land lost due to soil erosion, contamination and pollution. About 40% of the world's agricultural land is severely diminished in quality because of erosion and the use of chemical fertilizers, which prevent land from regenerating. The decline in soil quality as a result of agricultural chemical fertilizers also further leads to water and land pollution thereby lowering the land's worth on earth.

Drought and aridity

Drought and aridity are problems highly influenced and amplified by soil degradation. As much as it's a concern associated with natural environments in arid and semi-arid areas, the UN recognizes the fact that drought and aridity are anthropogenic induced factors especially as an outcome of soil degradation. Hence, the contributing factors to soil quality decline such as overgrazing, poor tillage methods, and deforestation are also the leading causes of desertification characterized by droughts and arid conditions. On the same context, soil degradation may also bring about loss of biodiversity.

Loss of arable land

Because soil degradation contributes to land degradation, it also means that it creates a significant loss of arable land. As stated earlier, about 40% of the world's agricultural land is lost on the account of soil quality depreciation caused by agro-chemicals and soil erosion. Most of the crop production practices result in the topsoil loss and the damage of soil's natural composition that make agriculture possible.

Increased flooding

Land is commonly altered from its natural landscape when it rids its physical composition from soil degradation. For this reason, the transformed land is unable to soak up water, making flooding more frequent. In other words, soil degradation takes away the soil's natural capability of holding water thus contributing to more and more cases of flooding.

Pollution and clogging of waterways

Most of the soil eroded from the land together with the chemical fertilizers and pesticides utilized in agricultural fields are discharged into waterways and streams. With time, the sedimentation process can clog waterways, resulting in water scarcity. The agricultural fertilizers and pesticides also damage marine and freshwater ecosystems and the limits the domestic uses of the water for the populations that depend on them for survival.

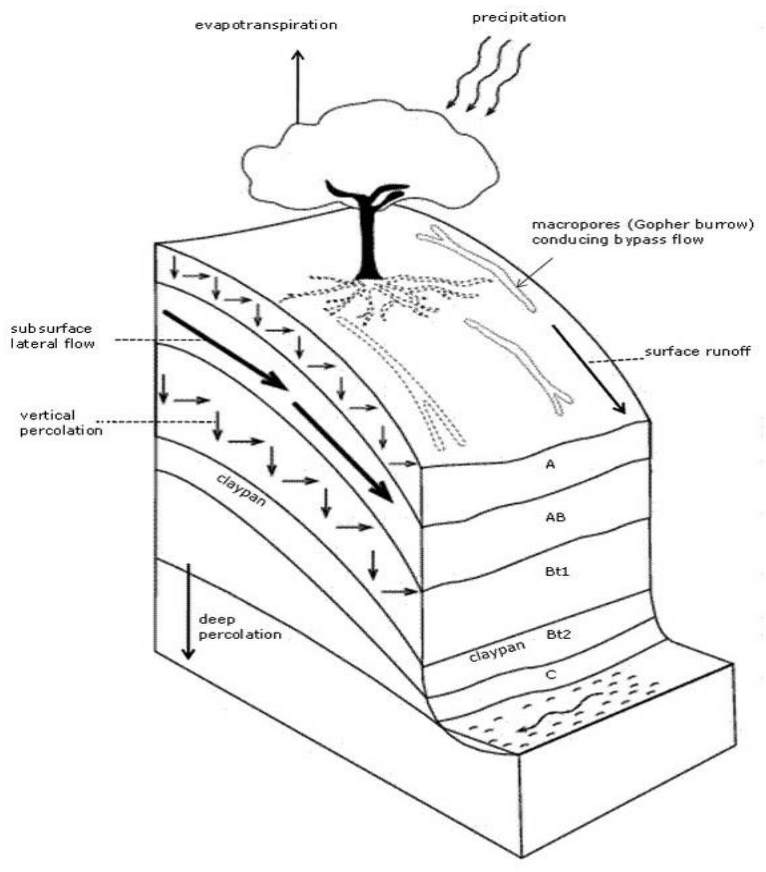
The capacity of soil to regulate the terrestrial freshwater supply is a fundamental ecosystem service. Water percolating through soil is filtered, stored for plant utilization, and redistributed across flow paths to groundwater and surface water bodies. As such, the sustainability of water resources (considering both quantity and quality) is directly influenced by soil. Thus, most aspects of terrestrial- and freshwater aquatic-life depend on hydrologic processes in soil.Water dynamics in soil are governed by many factors that change vertically with depth, laterally across landforms and temporally in response to climate.

Storage, Flow and Potential Energy

Stored water in soil is a dynamic property that changes spatially in response to climate, topography and soil properties, and temporally as a result of differences between utilization and redistribution via subsurface flow. Changes in soil moisture storage can be generalized with a mass balance equation as a result of the difference between the amount of water added and that which is lost.

Change in soil moisture storage = inputs - outputs

Water content increases (positive change in storage) when inputs including precipitation or irrigation exceed outputs. Water content decreases (negative change in storage) when outputs such as deep percolation, surface runoff, subsurface lateral flow, and evapotranspiration (ET) exceed inputs.



Conceptual diagram of a soil profile illustrating the multiple flow paths through which water moves through soil.

Water storage and redistribution are a function of soil pore space and pore-size distribution, which are governed by texture and structure. Generally speaking, clay-rich soils have the largest pore space, hence the greatest total water holding capacity. However, total water holding capacity does not describe how much water is available to plants, or how freely water drains in soil. These processes are governed by potential energy. Water is stored and redistributed within soil in response to differences in potential energy. A potential energy gradient dictates soil moisture redistribution and losses, where water moves from areas of high- to low-potential energy.

Macropore: Pores ranging in size from >5000 to 75 µm.

Micropore: Pores ranging in size from 30-75 µm.

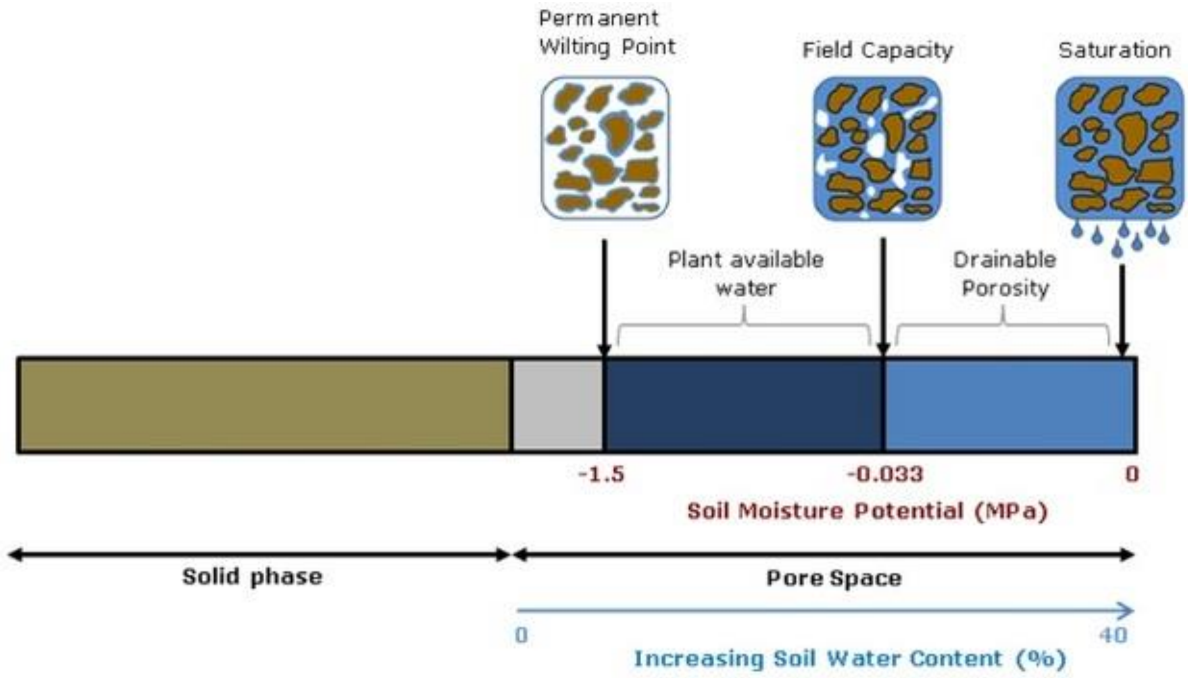
Mesopore: Pores ranging in size from 5-30 µm.

Three soil moisture states:-

- **Saturation-**The soil water content at which all pore space is filled with water corresponding to a water potential of 0 MPa.
- **Field Capacity:-** The soil water content after three days of drainage of a saturated soil. Described quantitatively as the soil water content after saturated soil is exposed to a suction pressure (e.g., drying by water removal) of -0.33 MPa
- **Permanent Wilting Point:-** Water content at which soil has dried to the point that plants begin to wilt. Described quantitatively as the soil water content after saturated soil is exposed to a suction pressure (e.g., drying by water removal) of -1.5 MPa.

They are used to describe water content across different water potentials in soil and are related to the energy required to move water (or extract water from soil). When the soil is at or near saturation the direction of the potential energy gradient is downward through the soil profile or laterally down slope. This mechanism of flow by the force of gravity occurs mainly in macropores. As the soil dries, field capacity is reached after free drainage of macropores has occurred.

As water content decreases, soil matric potential decreases, becoming more negative, and as a result, water is held more strongly to mineral surfaces due to cohesive forces between water molecules and adhesive forces associated with water and mineral particles (capillary forces). Water held between saturation and field capacity is transitory, subject to free drainage over short time periods, hence is it is generally considered unavailable to plants. This free water is termed **drainable porosity**. In contrast, much of the water held at field capacity is available for plant uptake and use through evapotranspiration

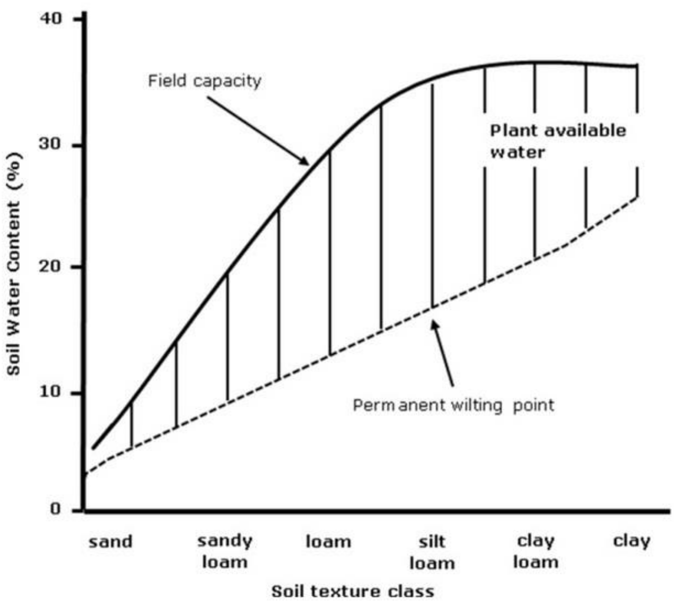


Water content and water potential at saturation, field capacity and permanent wilting point. The difference in water content between field capacity and permanent wilting point is plant available water. Drainable porosity is the amount of water that drains from macropores by gravity between saturation to field capacity typically representing three days of drainage in the field.

The point at which matric forces hold water too tightly for plant extraction (-1.5 MPa) is termed the **permanent wilting point**. The amount of water held between field capacity and permanent wilting point is considered **plant available water** (PAW). Water held between these two states is retained against the force of gravity, but not so tightly that it cannot be extracted by plants. Mesopores and micropores supply most plant available water. Water held at potentials below permanent wilting point (< -1.5 MPa) is not available for use by most plants because it strongly adheres to mineral particles. Water held at permanent wilting point is associated with partially filled micropores and hydrated surfaces of soil particles.

Influence of Texture and Structure

Differences in soil properties (texture and structure) affect the water content at saturation, field capacity, and permanent wilting point. Texture and structure determine pore size distribution in soil, and therefore, the amount of PAW.



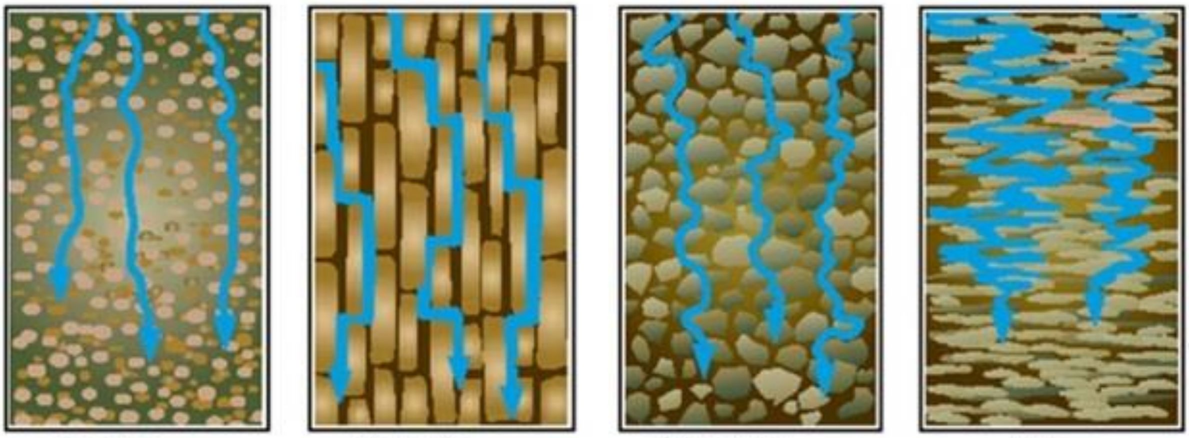
- Coarse textured soils (sands and loamy sands) have low PAW because the pore size distribution consists mainly of large pores with limited ability to retain water.

- Although fine textured soils have the highest total water storage capacity due to large porosity values, a significant fraction of water is held too strongly (strong matric forces/low, negative water potentials) for plant uptake.

- Loamy textured soils (loams, sandy loams, silt loams, silts, clay loams, sandy clay loams and silty clay loams) have the highest PAW, because these textural classes give rise to a wide range in pore size distribution that results in an ideal combination of meso- and micro-porosity.

Soil structure can increase PAW by increasing porosity. Soil depth and rock fragment content also affect water holding capacity because bedrock and rock fragments are assumed to be unable to hold plant available water and/or accommodate plant roots.

Water movement in soil is closely linked with storage because water potential is a function of water content . Water flow is also influenced by texture and structure, and other factors such as the layering of soil profiles. The rate of water flow is a function of the potential energy gradient and the ease with which water is transmitted through soil is **termed saturated hydraulic conductivity**. Clay-rich soils have low saturated hydraulic conductivity due to a highly tortuous (complex) flow path. Conversely, sandy soils have larger pores and lower tortuosity that facilitate rapid water flow.



Water movement through different soil structure shapes

Drainage

The ease with which water drains from soil is equally as important as storage. For example, most terrestrial plants need to assimilate oxygen through roots, but oxygen is scarce in saturated soils. Moreover, microbial decomposition of organic matter is greatest (by orders of magnitude) under aerobic conditions. Poorly drained soils have limitations for a variety of land use practices. The recognition of poor drainage in soils is also used in wetland delineation efforts.

Drainage capacity can be identified through careful observation of soil properties. Poorly drained soils result in episodes of prolonged saturation, while excessively drained soils commonly experience water deficits. Soils that are saturated at times when the system is above biological zero (> 5° C) often develop redoximorphic features

Redoximorphic features (redox features): Soil features associated with prolonged or seasonal wetness that result from reduction and oxidation of iron and manganese.

The most common redoximorphic features in soil are iron and manganese concentrations and iron depletions. These features arise through microbial decomposition of soil organic matter under anaerobic conditions. Anaerobic conditions arise because the diffusion of oxygen in saturated soil is very slow and does not keep up with oxygen demands of aerobic respiration by microbes. When oxygen is depleted, facultative microbes utilize iron (Fe^{3+}) and manganese (Mn^{4+}) as terminal electron acceptors to make energy. In doing so, these elements are reduced and become soluble in soil solution. As water mobilizes these soluble constituents they eventually encounter air (e.g., in root channels or other macropores) where they oxidize and re-precipitate as iron and manganese concentrations. Iron concentrations are usually rust colored, red or orange. Manganese concentrations are gunmetal blue, almost black.

Timing of Inputs

The amount and timing of precipitation ultimately governs soil moisture content, availability and flow. The temporal nature of moisture dynamics dictates ecosystem response and land-use decisions. Soil moisture regimes are used in Soil Taxonomy to describe annual variability in moisture as dictated by climatic factors and indirectly by soil and landscape factors. There are five general soil moisture regimes: aquic, udic, xeric, ustic, and aridic. These moisture regimes have detailed definitions. General working definitions are described below.

Aquic - poorly drained soils that are saturated when the soil temperature (at 50 cm) is above biological zero (>5°C). These soils typically display evidence of prolonged saturation in the form of redoximorphic features in the root zone.

Udic - soils typical of humid or tropical environments that receive an even distribution of precipitation throughout the year. Soils are never dry for as long as 90 cumulative days or 60 consecutive days following summer solstice.

Ustic - soil moisture conditions intermediate between aridic and udic and typical of semiarid, tropical and monsoon climates, where soil is moist during part or all of the growing season followed by a prolonged dry season at some point in the year.

Xeric - a soil moisture regime with wet winters and dry summers typical of Mediterranean type climates.

Aridic - a soil moisture regime that is dry (low plant available water) for most times of the year.

Soil moisture regimes serve as a broad scale planning tool to inform a variety land use decisions related to the hydrologic cycle such as, regions suitable for groundwater banking, dryland agriculture, summer fallow, or requiring irrigation technology, engineering considerations, and drainage infrastructure. These decisions cannot be made from climatic conditions alone. Soil moisture regimes are more useful in this type of decision making because it accounts for how soil properties (such as PAW) affect moisture dynamics within the soil profile.

Summary

Water storage dynamics and flow facilitate the four basic soil forming processes: translocations, transformations, additions and losses of soil constituents in a soil profile. These processes determine the chemical, morphological and physical properties of soil such as the variation of texture with depth. Hydrological processes active in soil contribute to weathering processes, and indicators of these processes are preserved by the soil profile in the form of observable and measurable soil characteristics.

Although climatic factors ultimately control plant-water relationships, soils regulate water acting as a sponge to hold water against gravitational forces in plant available form. Soil properties such as texture and structure govern pore size distribution, which dictates total water storage, available water holding capacity, and water movement in soil. While it is generally not feasible to modify soil texture to improve plant-water relationships, soil structure can be enhanced by adding organic matter to promote more meso- and macro-porosity, which increases plant available water holding capacity and helps to promote free drainage. An understanding of soil water relationships is fundamental to most land use decisions.

Prevention of Soil Moisture loss

The main objective of soil moisture conservation is to minimize the amount of water lost from the soils through evaporation (water loss directly from the soil) and transpiration (water loss occurring through the plants) – or combined, the evapotranspiration. Preserving soil moisture is important means to maintain the necessary water for agricultural production, and also helps minimize irrigation needs of the crops. This is especially important in areas where rainwater and/or groundwater resources for irrigation are scarce or decreasing due to climate change or other causes.

Implementation

There is a variety of methods that can be used to conserve soil moisture. Most of these are relatively low cost and complexity approaches, primarily relying on the presence of required materials and technical capacity locally. Many of the methods rely on providing some kind of cover for the soil to minimize evapotranspiration and direct soil exposure to heat and sun. Generally, most methods used for soil quality improvement and conservation, will also yield benefits to soil moisture conservation. Examples of methods for reducing excess soil moisture loss include following:

- **Spreading manure or compost over the soil** – this minimizes evapotranspiration and also provides valuable nutrients to the soil through processes of decomposition

- **Mulching** – mulch is a layer of organic (or inorganic) material that is placed on the root zone of the plants. Examples of mulch materials include straw, wood chips, peat. Inorganic mulch in form of plastic sheeting is also used. Mulching is most suited for low to medium rainfall areas, and less suited for areas with very wet conditions.

- **Conservation tillage** – reducing or, in extreme cases, completely eliminating the tillage to maintain healthy soil organic levels which increases the soils capacity to absorb and retain water. Conservation tillage is a specific type of such approach where crop residue is left on the soil to reduce evapotranspiration, and protect soil surface from wind, sun and heavy rain impacts.

- **Crop rotation** – growing different types of crops every season helps improve soil structure and thus water holding capacity. Examples include rotating deep-rooted and shallow rooted crops that make use of previously unused soil moisture, as plants draw water from different depth levels within the soil. Crop rotation may also improve soil fertility and help control pests and diseases.

- **Green manuring** – growing of plant materials with the sole purpose of adding to the soil for improved organic matter and nutrients. The improved soil quality then also improves water retention capacity.

- **Deep tillage** – suited for some areas and soils, deep tillage can help increase porosity and permeability of the soil to increase its water absorption capacity.

- M**ixed cropping** and interplanting - cultivating a combination of crops with different planting times and different length of growth periods.

- **Contour ploughing** – by ploughing the soil along the contour instead of up- and downward slopes, the velocity of runoff is reduced, creating even barriers, and more water is retained in the soils and distributed more equally across the cropland.

- **Strip cropping** - growing erosion permitting crops and erosion resisting crops in alternate strips. Other soil moisture conservation techniques may include rainwater harvesting to minimize runoff and collect water for use on site. For more technologies on this see technology sheet Rainwater harvesting for infiltration.

Environmental Benefits

- The benefits of many soil conservation methods, depending on the material used, may also include better control of weeds, provision of additional nutrients to the soil, soil temperature control and protection of soil surface from the impacts of heavy rain and wind.
- Active reuse of waste organic materials also reduces waste management needs, returning the residue crops and plants to the soil through decomposition. Socioeconomic Benefits
- Potential to reduce water irrigation needs, increase crop productivity and improve soil quality

- By extension, reduced irrigation needs may also reduce the costs and energy requirements of water pumping for irrigation.

Advantages:
- Improved soil moisture goes hand in hand with improved soil quality thus potentially improving harvest and reducing soil degradation
- Opportunities for using existing waste materials may considerably reduce costs and needs for waste handling
- Many soil conservation methods are relatively low cost and complexity approaches, primarily relying on the presence of required materials and technical capacity locally
- May create new income and synergies between different crop variety farmers (e.g. using palm oil production residues for mulching).