

SOIL

Soil refers to the top most material on the earth's surface and constitutes the outer most layer of the earth's crust. It is made up of weathered rock particles and decayed plant and animal matter. Soil provides a medium for the plant roots to grow. The nature of the soils depends on the rocks from which they were formed as well as the environmental conditions and various soil forming processes.

Constituents of Soil

- (i) Inorganic matter (rock particles).
- (ii) Organic matter/humus (decayed plants and animal matter).
- (iii) Living organisms such as bacteria, worms, and insects.
- (iv) Water/moisture. (v) Air/gases.

Soil basically results from the breakdown of parent rock through weathering processes i.e. physical and chemical weathering lead to the decomposition and disintegration of rock into soil. The weathered material may then be modified by other soil forming processes to give a wide range of soil types.

The soil that has been formed may combine with organic matter to give an ideal soil type. Soil formation has been as a result of a wide range of conditions.

FACTORS AFFECTING SOIL FORMATION

1. Nature of the parent material/parent rock.

The parent rock material is the rock material that breaks down into rock particles and may influence the nature of the soil in terms of fertility, mineral composition, depth, colour and the final soil profile. Parent rock may be hard or it may be soft.

Hard parent rock is normally resistant to weathering and as a result skeletal soils are formed. On the other hand, relatively soft rocks are easily broken down into soil particles and the results into a higher rate of soil formation.

The parent rock structure may be characterized by joints or lines of weakness or may be just a block of massive rock. Well-jointed rocks are susceptible to weathering and easily break down to give rise to soil particles. On the other hand, massive rocks may not easily allow agents of weathering to penetrate and therefore there is a low rate of weathering and soil formation.

The colour of the parent rock also influences the rate at which soil is formed. This is because light coloured or shiny parent rock may be more resistant to weathering. On the other hand, dark coloured rocks absorb heat, expand and later contract leading to the break down of rocks through the weathering process of thermal expansion or exfoliation.

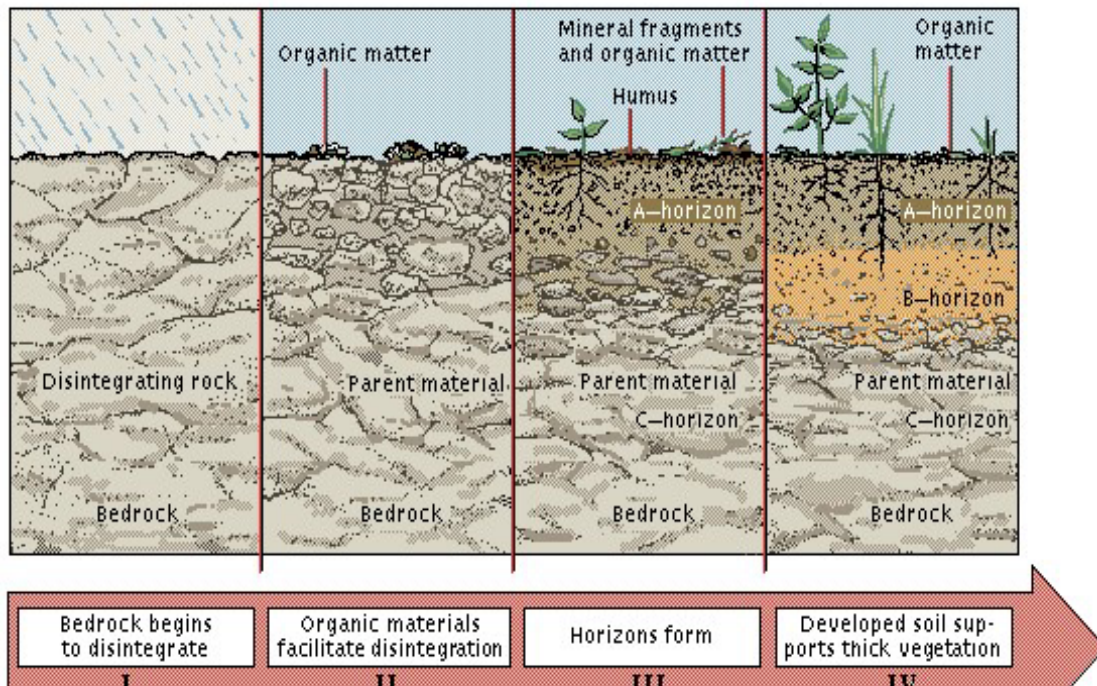
This therefore means that with the dark colored rock soil formation is faster.

The mineral composition of the parent rock determines the nature of the soil nutrients or soil fertility. Rocks of limestone nature will give rise to soils that are rich in lime. In addition, mineral composition may determine the nature and rate of chemical decomposition of the rocks.

Porosity or permeability of the parent rock may also determine the rate of soil formation. Porous rocks allow in the agents of weathering such as moisture and air, which accelerate the chemical break down of rocks into soil.

On the other hand, non-permeable rocks may lead to the formation of thin soils because of the low rate of soil formation.

Stages of soil formation



2. Climate

Climate influences soil formation through its role in weathering that leads to the formation of soil. In areas of heavy rainfall adequate moisture is provided for the process of chemical weathering. In addition, in the desert areas soil formation through physical weathering processes like exfoliation are common.

High temperatures accelerate chemical weathering leading to high rate of soil formation unlike in areas of lower temperatures where soil formation through chemical weathering is limited.

In very cold regions like mountain tops, the nature of soil formation is through physical weathering processes like frost action or freeze and thaw. Climate also determines the nature of vegetation and animal life that consequently contribute to the soil formation through the addition of humus.

3. Living Organisms/Biota

These include bacteria, insects, mammals (animals), human beings and plants. Bacteria play an important role in the breakdown of rocks through complex processes. Organisms such as

earthworms, termites also play an important role in the breakdown of rocks into simple or smaller substances that constitute soil. Rodents e.g. rats, moles, squirrels etc physically breakdown rocks as they dig holes into the ground.

Man also influences soil formation through activities like mining/Quarrying and digging. As a result, masses of rock are physically weathered by man to produce soil. On the other hand, plant roots physically break rocks as they grow into the ground. Plant roots also secrete substances that chemically decompose rocks to produce soil.

Plant leaves or branches may fall down and decay to form humus that is added to the soil through the soil forming processes of Humification and consequently mineralization. That is why in areas of thick vegetative cover the soils are rich in organic content while in desert areas or areas of limited vegetation cover the soils have limited humus

4. Relief

Relief influences soil formation through erosion and deposition. The nature of the relief influences the rate and nature of the soils formed. Steep slopes are easily eroded and this implies that the weathered material on the steep slope soils tend to be skeletal because of erosion.

However the rate of soil formation is high because erosion exposes the parent rock to further weathering. On the other hand, in the gentle slopes, soils tend to be deep, mature and with a well-developed profile. In the lowlands or flatlands where rainfall is high leaching takes place and may lead to the formation of Laterite soils that are poor in terms of plant nutrients.

5. Time

This refers to the duration of the interaction of soil forming processes and factors. Soil formation requires adequate time, time is important in that the nature of the soils depends on how long the processes and factors have been interacting.

If a parent rock has been exposed to the weathering processes for a long time, soil formation will

complete as compared to a parent rock exposed for a relatively shorter period.

SOIL PROFILE

This refers to the vertical arrangement of the various soil layers from the top layer down to the parent rock or bottom layer. It is a vertical section through the soil horizons extending into the parent material or the bedrock. It describes the sections down wards through the soil which comprises of differing characteristics in terms of texture, colour, mineral composition, ratio of combination of organic and inorganic matter, hardness and rate of weathering.

The different layers are referred to as horizons.

Soil horizon is a well-defined layer within the soil profile parallel to the local round surface.

There are four main horizons namely: A horizon, B horizon, C horizon and D horizon. Each horizon has different physical and chemical properties, which result from various soil forming processes such as weathering, introduction of humus and movement of minerals.

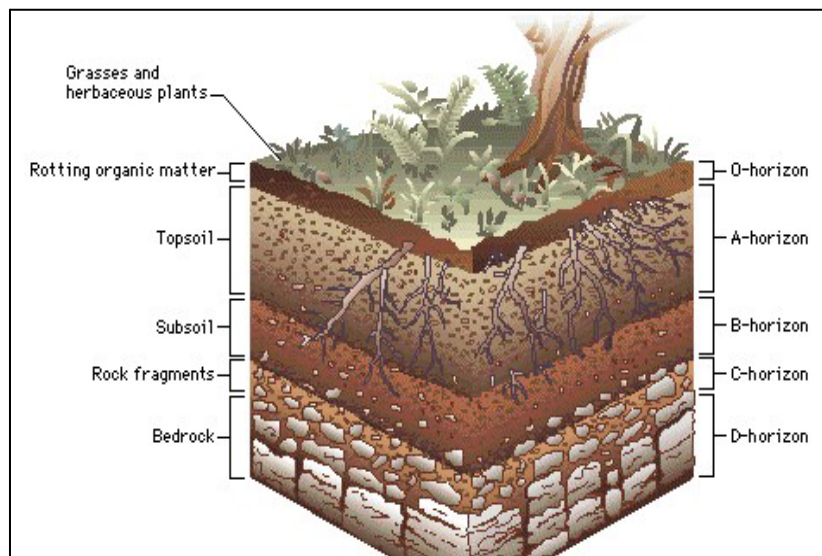
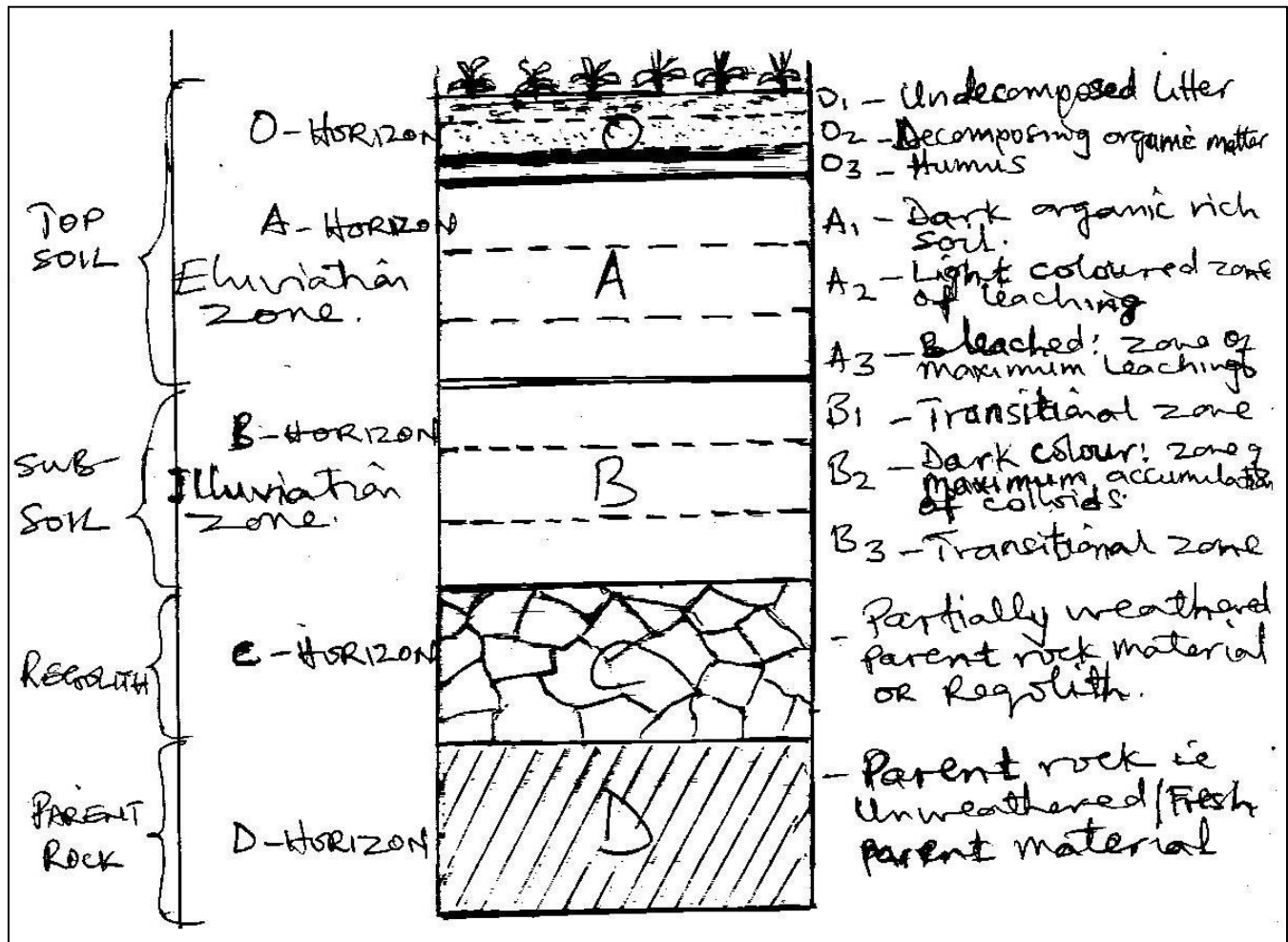


Diagram of an Idealised Soil Profile



O-HORIZON

This is the top most/ surface layer of the soil comprising of organic matter. The constituents of this layer include un-decomposed litter, decomposing organic matter and humus.

A-HORIZON

This is also known as the topsoil and it is rich in organic matter which organic matter accounts for the dark colour. Leaching and Eluviation may at times impoverish the topsoil.

B-HORIZON

This is known as the sub soil. Nutrients removed from the A horizon through leaching and

Eluviation accumulate or are deposited in this horizon. The process of plant nutrients precipitating or accumulating in this horizon is known as illuviation.

This horizon may also be characterized by hard pans due to the accumulation of large quantities of clay and other nutrients.

C-HORIZON

This consists of partially weathered rock, this is because weathering and other soil forming processes may not effectively operate at this depth.

D-HORIZON

This consists of the solid parent rock or unweathered rock or fresh parent material. It is also known as the bedrock. It has no soil particles but has potential for future soil formation.

Soil profile development

The nature of the soil profile may be such that it is fully developed or partially developed implying that soils may be deep or skeletal or soils of medium depth. Soil profile development is influenced by a number of factors namely:

1. Nature of the parent rock

The parent material is the nature of rock upon which weathering and other soil forming processes operate to create to create soil. In the first place the parent material provides the basis for soil profile development. It influences soil profile development in the following ways;

- (a) Hard or resistant rocks lead to the development of thin soils i.e. with poorly developed profiles. On the other hand softer rocks are easily weathered and acted upon by other soil forming processes leading to the formation of deep soils with a well-developed profile.
- (b) The rocks with lines of weakness or joints have facilitated weathering and other soil forming processes leading to the formation of fairly deep soils. Such soils normally lead to a welldeveloped soil profile.
- (c) Young parent material has led to poorly developed soil or poor soil profile while older rocks

have had enough time to be weathered and to develop into well-developed soil profiles.

- (d) Permeable or porous rocks have enabled the easy infiltration of agents of weathering resulting into deep weathering and consequently deep soils with a well-developed profile unlike impervious rocks.

2. Climate

Rainfall and temperature determine the nature and rate of weathering and soil forming processes. Climate also determines the growth of plants and animals that contribute to the soil profile through weathering and through the addition of humus. Therefore, different climatic conditions influence soil profile developments differently.

In areas where the climate enhances weathering and other soil forming processes there is a well-developed soil profile.

3. Living organisms

Vegetation provides the needed organic matter for the soils therefore a well-vegetated area has a better-developed soil profile. In addition, animals influence the mechanical break down of rocks therefore contributing to soil profile development.

Man's activities such as cultivation, mining, construction tend to physically weather rocks thereby contributing to the development of soil profile therefore areas of abundant biodiversity have a well developed soil profile as compared to those with limited biodiversity.

4. Topography/Relief

The nature or shape of the earth's surface influences soil profile development. Highly or steeply sloping areas tend to have less developed soil profiles unlike areas of gentle slopes. This is because the rate of erosion is greater on the steep slopes and this removes the topsoil resulting into shallow or skeletal soils. On the other hand, in the gently sloping lands and generally flat lands, soil profile tends to be more developed i.e. there are deep soils.

5. Time

It takes time for the soil profile to be fully developed. A typical or well developed profile of soil

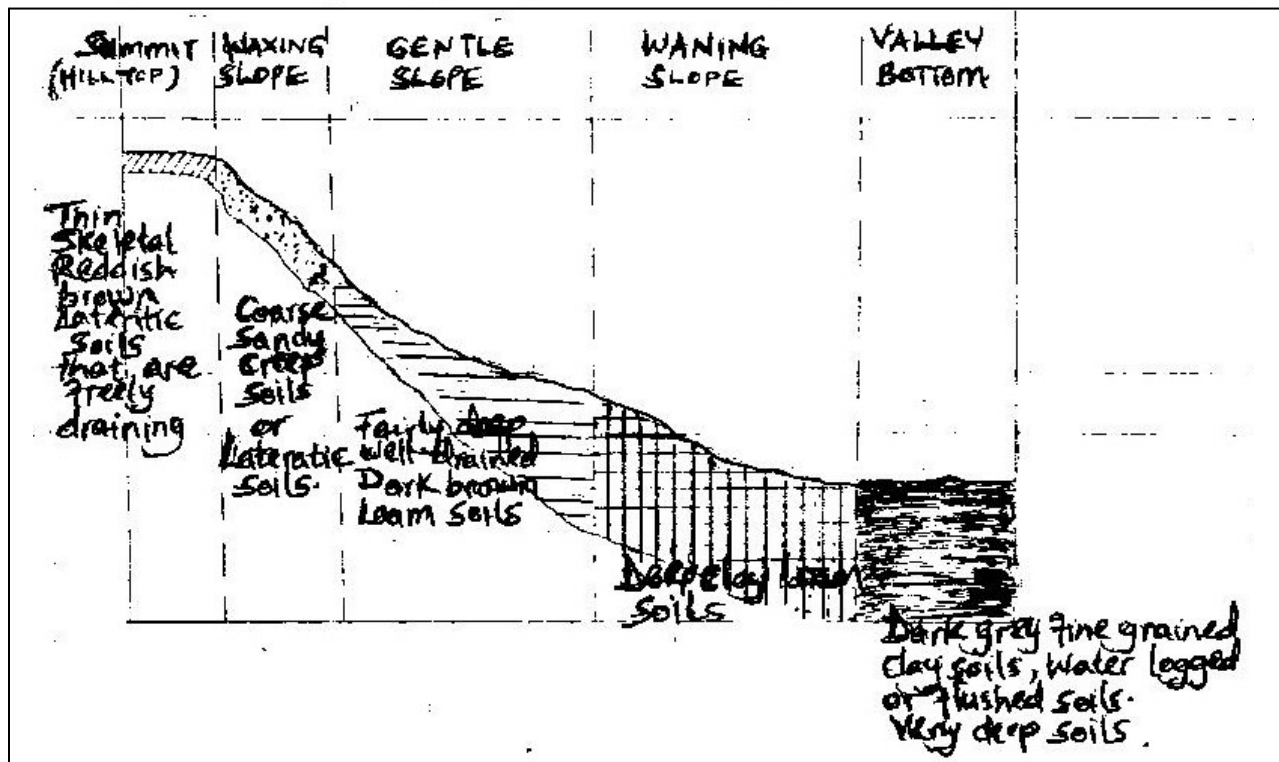
must have undergone adequate time, therefore the longer the time to which the rocks are exposed to weathering and other soil forming processes, the more the developed profile. Young rocks normally yield skeletal soils i.e. with poorly development profile.

SOIL CATENA

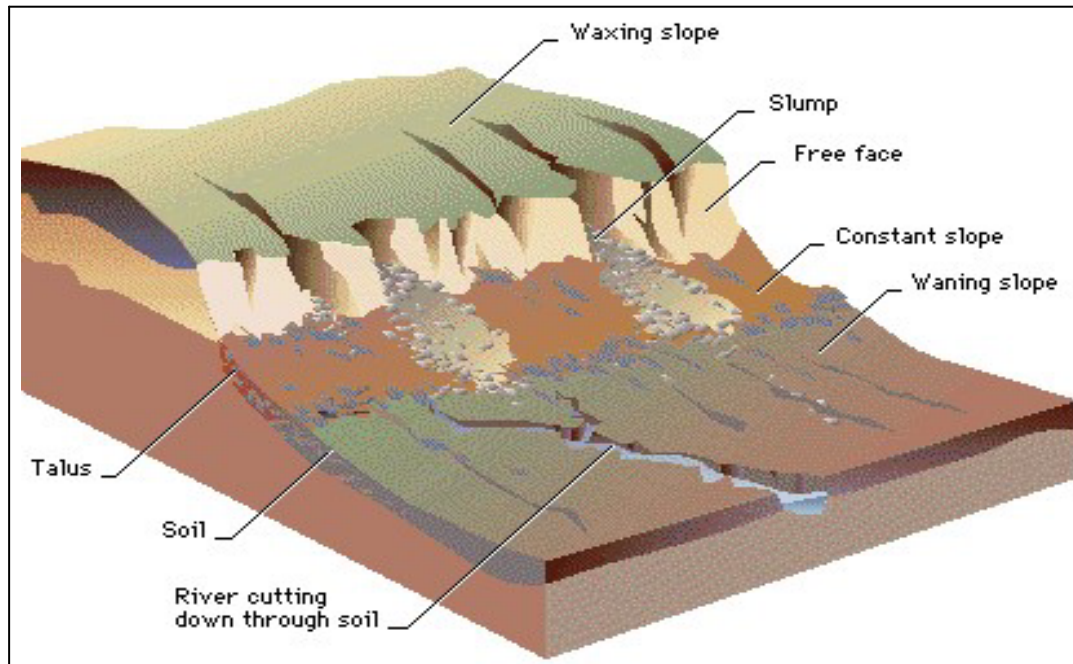
This is the successive arrangement or sequence of arrangement of differing soil types along the slope from the hill top (summit) to the valley bottom.

This sequence varies with relief and drainage though it may be derived from the same parent material e.g. the soils at the valley bottom are likely to be different from those of the hill top. Soil catena may be due to factors like relief, climate, living organisms and time.

Diagram illustrating soil Catena .



Profile of a slope



The factors influencing the development of soil catena:

Relief: which is the physical appearance (morphology) of the landscape affects or influences the development of soil catena in such a way that differences in relief affect the nature or soil type due to the fact that they influence erosion, deposition and human activities.

- Hill tops have lateritic capping with the resultant thin/ skeletal soils.
- The very steep slope/free face hardly has any soil i.e. has bare rock.
- The waxing slope/ convex slope is characterised by coarse, stony, creep soils due to erosion.
- The waning slope is fairly deep with clay loam soils.
- The low lying area/ valley bottom has fine particles of clay. It is deep and poorly drained. It is generally a zone of deposition or illuviation i.e. zone of accumulation.

The steep slope encourages erosion and hence has shallow soils. The gentle slopes are well drained and experience some down slope translocation of soil particles while the valley bottom

experiences deposition hence accounting for the deep soils.

Climate: Influences the development of soil catena in the following ways:

- Heavy rainfall encourages erosion on the upper slopes (waxing slope) and deposition on the lower slopes and valley bottom.
- Heavy rainfall also encourages leaching leading to the development of lateritic soils along the waxing slope.
- Heavy rainfall also leads to flooding in the valley bottom and lower slopes resulting into clayey water logged soils.

Living organisms: These include plants, animals and man.

- Well vegetated areas lead to development of the loamy soils or those with adequate humus especially on the middle and lower slopes.
- Forested slopes check on the rate of soil erosion hence influencing the depth of the soil.
- Man's activities like deforestation and cultivation encourage erosion thereby leading to thinner soils especially on the steeper slopes while on the other hand encouraging deposition on the lower slopes and the valley bottom.

Nature of the parent rock: The differences in the soil types along the slope could be as a result of them having developed from different parent materials.

Time: The development of soil catena needs ample time. The processes involved take long and therefore the longer the geological time scale, the more developed of soil catena of an area.

SOIL TEXTURE

Soil texture refers to the size of soil particles. These particles may be classified as gravel sand, silt and clay. Soil particles like gravel have a coarse texture while particles like clay have a very fine texture. Soil that is commonly referred to as sand may include silt and clay. That is why we may have sandy loam soils, silty loam soils and clay loam soils. Soil texture is important in that it

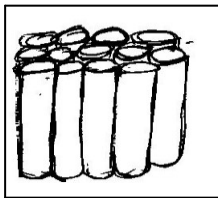
determines the water transmission capacity and the water retention properties of the soil.

SOIL STRUCTURE

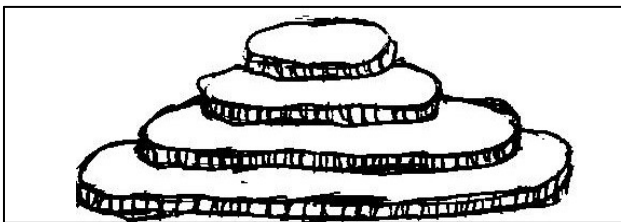
This refers to how soil particles are held together into large pieces or aggregates. Tiny particles or organic matter and mineral substances in solution known as colloids hold soil particles together. Soil structure may be derived from the fact that soil grains or mineral particles are grouped together in various ways.

The different types of soil structure include the following;

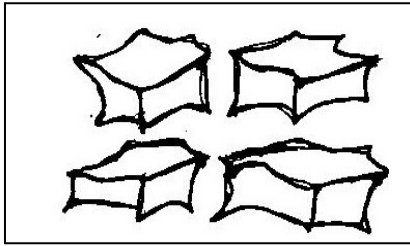
1. **Prismatic structure;** this is where mineral particles are grouped together in form of vertical long prisms or columns. These allow free vertical movement of soil water.



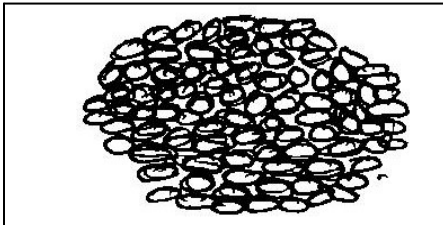
2. **Platy structure;** this is where the soil particles are arranged in flat thin horizontal layers. Such a structure hinders plant root development and the vertical water movement.



3. **Blocky structure;** this is where the soil is made up of sharp edged irregular blocks. This allows both vertical and horizontal movement of soil water.

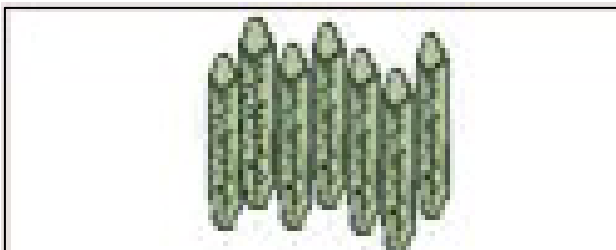


4. **Granular and Crumb structure;** this is where rounded or spherical soil particles are grouped in loosely arranged aggregates. Granular structure is normally located in the top soils and soils of granular structure are normally porous.



5 **Columnar structure:**

This is a column – like structure with rounded caps and sides. The particles tend to fit closely together. It is common in the B and C horizons and mostly found in alkaline and desert soils.



SOIL PH

This refers to the measure of the concentration of hydrogen ions in a solution. It is therefore the degree of acidity or alkalinity of soil. High concentration of hydrogen ions means the soil is acidic and low concentration means the soil is alkaline. The decay of organic matter increases the acidity of soils. On the other hand, bases like calcium, sodium, potassium, make the soils more alkaline. The PH scale that measures from 1-14 is used to estimate the degree of acidity or alkalinity.

A PH of 7 is neutral. If it is below 7 the soil is said to be acidic and if it is above 7 the soil is said to be alkaline.

Soil PH determines the mineral contents that will remain in the topsoil after others have been leached. This is because most minerals dissolve under acidic conditions. It therefore implies that leaching is more in acidic soil than in alkaline soils. In relation to human activities like agriculture, soil PH determines whether the farmer should add humus or lime to the soils so as to produce good agricultural soils.

PROCESSES OF SOIL FORMATION AND SOIL PROFILE DEVELOPMENT 1.

Weathering

This is the physical disintegration or chemical decomposition of rocks. Rocks break down through various physical and chemical processes leading to soil formation.

High rate of weathering result into deep and mature soils meaning that with high rates of weathering, a mature soil profile is easily reached.

In the tropics weathering under hot humid conditions has led to deep Latosols and tropical black earths. Weathering under humid temperate conditions have led to the development of deep podsols (poorly drained soils found in the temperate regions) and brown earths. In areas of seasonal rainfall deep chernozem soils have developed while in semi-arid regions, deep chestnut, coloured soils have developed.

Weathering in high latitude climatic zones has yielded deep and mature tundra and arctic soils.

On the other hand areas of more resistance to weathering have lead to shallow soils or soils of poorly developed profile. Such include the recent volcanic soils, mountain soils, glacial soils and marine soils.

2. **Laterisation:**

This involves weathering under hot and damp conditions followed by leaching within the tropics to form Laterite. Silica is leached out of the A-Horizon leaving behind iron and alluminium compounds. Laterisation leads to the formation of a stratified profile consisting of an indurated zone known as duricrust.

Laterisation may also be described as the process by which silica is leached out and iron and alluminium compounds become concentrated in the A-horizon due to leaching and consequent drying. This gives rise to Laterite soils. Such soils that have been formed from weathered material that has not been fully leached are referred to as Latosols.

Laterite is usually reddish brown colour and it tends to be sticky when wet i.e. it is plastic or cohesive. They tend to harden when exposed to the dry atmosphere. In East Africa,

Laterite is commonly known as murram. In the process of the formation of Laterite soils, it is important to note that iron and alluminium compounds do not dissolve easily and therefore get concentrated on the top soil.

In the first place, the alluminium and iron compounds form small stones or gravel on the top or within of the weathered material known as Laterite gravel. After sometime the Laterite gravel is cemented together to form Laterite. It is important to note that the formation of Laterite is favoured by some conditions which include the following;

- (a) Heavy rainfall that encourages chemical weathering and consequent leaching of silica.
- (b) High temperatures to encourage deep chemical weathering.
- (c) Clearing of vegetation (deforestation) i.e. man's influence that exposes the soil to the full force of rain and heat.
- (d) Dry conditions that then enable the Laterite to harden.

It is important to note that Laterite can form from any type of soil.

Latosols

These are zonal or lateritic soils formed in humid tropical regions. They tend to be reddish brown in colour; are free-draining; have an acid reaction; and are rich in hydroxides of iron and aluminium or manganese. They result from deep weathering of rocks in tropical climates.

The high temperatures and high rainfall plus free drainage cause deep chemical disintegration or decomposition and rapid removal of silica and bases through leaching leaving a concentration of oxides of iron and aluminium. The texture varies from clay to loamy sand. There are five (5) divisions of Latosols namely:

- (i) Weathered ferrallitic soils.
- (ii) Ferruginous soils.
- (iii) Leached ferrallitic soils.
- (iv) Basisols.
- (v) Humic Latosols.

Importance of Laterite

Laterite has both positive and negative importance.

Positive importance (Uses)

- (i) Laterite is used for brick making for construction purposes i.e. it has promoted the

brick making industry.

- (ii) It is used for road making i.e. the construction of good murram roads.
- (iii) Hardened Laterite provides a firm foundation for construction of buildings and other structures.
- (iv) It may result into possible deposits of bauxite thereby encouraging mining.

Negative importance

- (i) Laterite soils lack a variety of plant nutrients and may not sustainably support plant growth.
- (ii) Laterite encourages soil erosion due to the low infiltration capacity.
- (iii) Laterite is hard and difficult to work and therefore may hinder agricultural mechanisation.

3. Leaching

Leaching refers to the removal of solvable mineral nutrients by water from the upper layers of the soil profile to the underlying ones i.e. minerals like salt and carbonates dissolve in water in the top soil and move in solution form to the sub soil. Leaching results into an impoverished A-horizon.

4. Eluviation

This involves the movement of soil material in solution or suspension form from one place to another within the soil. This movement can be horizontal or vertical. Eluviation is commonly referred to as the movement in form of colloids or suspension. Eluviation generally leads to the development of an impoverished A- horizon i.e. the top soil is impoverished of soil nutrients.

5. Illuviation

This is the precipitation and accumulation of the leached and eluviated material in the B-horizon of the soil profile i.e. eluviated material and leached materials concentrate in the B-horizon. Illuviation is responsible for the B₂ layer (darker colour zone) where maximum

accumulation of colloids takes place.

6. Humification

Is the process through which organic matter is decomposed to form humus that is then mixed with the inorganic content. It is common in wet, warm and densely vegetated areas such as equatorial or moist tropical regions. This process influences the development of the A₀ and A₁ layers of the A-horizon or the O-Horizon.

7. Mineralization

Occurs under extreme conditions in which decomposition of organic matter may extend further than Humification. Organic matter is further broken down into basic parts or components e.g. carbon dioxide, water and Silica. This greatly influences the formation of the A-horizon.

8. Calcification

Is a soil forming process, which takes place in dry or arid areas as a result of upward movement of capillary water with dissolved nutrients through capillary attraction moves from the lower parts of the soil the top or surface. This process is common in areas of limestone geology on East Africa. The soils formed comprise of a lot of calcite or calcium compounds. Calcification leads to the development of shallow soil profiles.

9. Gleization/ Gleying

This soil forming process occurs in climatic environments where there is impeded drainage i.e. where there are swamps or wetlands. Usually the process leads to the development of hydromorphic soil. In addition, the oxygen deficient conditions of water- loggedness leads to the reduction of ferric oxide to ferrous oxide giving a grey colour. Such soils are intrazonal hydromorphic soils with poorly developed profiles.

10. Podsolization.

This process occurs under cool moist climatic conditions i.e. temperate climatic conditions.

It involves the removal of iron and aluminium oxides known as sesquioxides due to intense leaching especially where soils are sandy or well drained. It results into soils with an impoverished A-horizon.

11. Salinization

Is the process by which soils are enriched with salt. This is due to evaporation from the soil surface which draws up soils in solution by capillary movement. Salinization may also be induced by man through intense irrigation. It gives rise to saline top soils (intrazonal soils of high salt concentration especially in the semi-arid areas. Salinization gives rise to a poor A-horizon.

12. Chelluviation

This is the process that involves chemical bonding of metallic ions and organic matter. In this case when organic matter decomposes it releases chelating agents (organic acids) that attack rocks thereby producing iron, aluminium and magnesium compounds which then move downwards affecting soil movement or development. It normally results into rich nutrient A-horizon soils.

13. Lessivage

Is the process of soil formation especially the breakdown of peds where clay particles are carried downwards from the upper soils in suspension form leading to an impoverished A-horizon and hard pans in the B-horizon?

Classification of soils

Soils may be classified as zonal, intrazonal soils and azonal soils.

Zonal soils

These are soil types largely resulting from the climatic factors, which contribute to soil forming processes. They are well developed or mature soils with well-developed profiles due to prolonged action of climate and vegetation. They develop under conditions of good

soil drainage i.e. under well drained soils. The soils develop on gently sloping or rather flat landscapes. They develop from parent rocks that are neither very acid nor very alkaline. Zonal soils are mainly categorized into two groups namely;

- (a) **Pedocals:** These are soils with a high calcium carbonate content that tend to develop under conditions of low rainfall e.g. chernozems, chestnut or brown soils, sierozems etc.
- (b) **Pedalfers:** These are soils with a high content of aluminium and iron i.e. they are rich in aluminium and iron and have low calcium carbonate content mainly due to leaching. Such soils include podsoles, the Latosols and prairies soils. Generally, types of zonal soils tend to be restricted to certain latitudinal regions. The resultant type of zonal soils is closely related to the nature of weathering that takes place under a specific type of climate for instance;
 - (i) In low latitude areas/ tropics, the hot humid conditions give rise to Latosols and tropical black earths (Basisols).
 - (ii) In mid latitude climates, humid conditions are associated with the development of podsoles and brown earths.
 - (iii) In areas of seasonal rainfall chernozem soils develop e.g. on the Canadian prairies.
 - (iv) Semi-arid conditions and arid conditions yield chestnut colored soils.
 - (v) High latitude climates lead to the development of Tundra and arctic brown soils.

Azonal soils

These are young soils without a clear soil profile; they have not been exposed to soil forming processes for long so as to develop mature characteristics. They tend to be skeletal with an underdeveloped soil profile.

They also tend to show characteristics of their original parent rock material. They are derived from unconsolidated material such as alluvium, sand and volcanic ash. Examples of azonal soils include the mountain soils, alluvial soils, marine soils, glacial soils, wind-blown soils and recent volcanic soils.

Factors influencing the formation of azonal soils

- Weathering of the parent rock leads to the formation of screes on the mountain slopes. These soils normally show characteristics of their original parent material and resist change.
- Volcanic activity leading to the extrusion and deposition of lava resulting into the formation lava/ash soils, cinder and pumice.
- Erosion, transportation and deposition through agents such as.
 - Wave action leading to formation of mudflat soils/marine clays.
 - Wind action leading to the formation of windblown soils like sand sheets, sand dunes and loess.
 - Glacial action (fluvio-glacial action) resulting into the formation of fluvio-glacial soils such as tills, outwash sands and gravel as well as resorted clays (Deposited in glacial lakes).
 - River action leading to the formation of alluvial soils.
- Climate influences azonal soil formation in the following ways:
 - Heavy rainfall results into river floods that lead to the formation of alluvial soils in the lower course.
 - High rainfall causes erosion on steep slopes and deposition in the lowlands leading to the formation of alluvial soils.
 - Temperature changes on the mountain slopes influences physical weathering consequently leading to the formation of rock screes.
- Relief: The nature of relief influences erosion of screes on the mountain slopes and their subsequent deposition hence forming new soils.
- Human activities like quarrying and mining lead to the breaking of parent rock into simpler particles leave alone dumping of rock waste material leading to the formation of azonal soils. In addition, deforestation, bush burning and overgrazing expose the parent rock to weathering processes that lead to the formation of young soils.
- Time lapse: Azonal soils are immature soils and this mainly depends upon the short period of time entailed in their course of formation.

Intrazonal soils

These are mature soils that result from particular conditions or constituents. They are not therefore restricted to latitudinal zones like the zonal soils.

They are developed under special prevailing conditions as a result of local factors such as relief and the parent material.

Examples of intrazonal soils include; the bog/peat soils (hydromorphic soils), saline soils (halomorphic soils). In addition, there are also soils that develop over calcareous parent material leading to the development of calcimorphic soils. Intrazonal soils also include meadow soils.