SOIL

Definition

- **Soil** is the top most/uppermost layer of loose and unconsolidated materials that overlie the crustal rocks and on which plants grow.
- It is composed of disintegrated rock fragments, mineral particles, humus, water and air
- It is derived from different types of rocks making the earth's crust through the processes of weathering

Composition of Soil

a. **Inorganic matter**: - mainly mineral particles derived from parent rock such as silicates, calcium, sodium, etc.
b. **Humus/soil organic matter**: - is the product of decomposed tissues of animals and plants as well as animal remains
   Humus is important to soils because:
   - It supplies the plants with food and minerals
   - It is fertile and produces high agricultural yields
   - It has high water retention capacity in the soil
   - It promotes the development of a structure that favours circulation of air and water
   - It contributes to further weathering of rock through decomposition
   - It is a source of food for soil microorganisms
c. **Soil water** is dissolved in the minerals
d. **Soil air**: - is contained in the pores and air spaces between the soil particles

Soil forming processes

a. **Through weathering**
   - This involves breaking and disintegration of parent rocks through physical and chemical processes.
   - This (weathering) results to regoliths that are further broken into smaller and finer particles to form soil

b. **Through decomposition of organic matter**
   - This involves the accumulation and decomposition of decaying plants and animal matter on the ground surface
   - This is done through mineralization and humification
   - ***Mineralization*** is the biological and chemical breakdown on dead plant tissues by soil microorganism to produce simple soluble organic substance
   - ***Humification*** involves regrouping of the mineralized materials into large molecules to form humus

c. Through leaching

- Leaching is the removal of soluble mineral matter in solution from the upper layer/horizon to the lower horizons of the soil
- The following leaching processes lead to formation of various types of soils
  - **(i) Eluviation**: - this is the physical or mechanical washing down of fine mineral particles from the upper layer of the soil into the middle and lower layers. These materials are moved in suspension by water percolating downwards
  - **(ii) Illuviation**: - is the deposition or accumulation of the materials that have been washed down from the upper layers to the lower layers through eluviation. It takes place where rainfall is greater than evaporation leading to the redeposition of soil materials that have been leached to the middle layer. Compaction and cementation results into the formation of a hard soil

N/B

Leaching is affected by the following factors

- *Solubility of minerals in the soil*
- *Amount of vegetation cover*
- *Amount of precipitation*
- *Soil porosity*
- *Gradient of slope*

Factors influencing soil formation

a. Nature of parent material

- This determines the rate and type of weathering i.e. some parent materials weather rapidly and form soils fast while others that are resistant to weathering lead to least formation of soils
- It also determines the soil texture and porosity of soil to allow circulation of air and water

b. Climate

- Climatic conditions affect the rate of weathering taking place on a given rock through seasonal variation in rainfall and temperature
- Areas with heavy precipitation (rainfall) are heavily leached and weathered compared to drier areas, they therefore have deep soils
- High temperatures promote rapid faster weathering and chemical changes in the soil. (cold temperatures slow these processes)
- Winds act as agents of soil erosion, blowing fine sand and dust and depositing them far away forming rich fertile soils

c. Living organisms

- Plant roots may penetrate the soil making it to become porous leading to the biological weathering hence formation of soil
- Areas with dense vegetation covers have fertile soils because of the decomposition of the plants' leaves or remains
- Plants' roots improve soil porosity, depth and aeration
- Worms and other burrowing animals mix organic remains with soil mineral components leading to soil formation in the process
- Human activities e.g. mining, quarrying, deforestation, grazing and application of fertilizers may change the nature of soils lead to weathering

d. Topography

- Soils on mountain slopes are heavily leached hence have thin soils
- Plains and valley bottoms have deep soils due to deposition of weathered and eroded materials

e. Time

- Duration taken by soil to form influences its characteristics (depth and maturity).
- Deep and well developed soils take longer time to form.

Properties of soil

a. Soil texture

- This refers to the composition of a particular soil in terms of the size of its particles.
- Soil texture can be coarse with large particles e.g. sandy soils, fine with smooth and small particles e.g. clay soils or loamy i.e. a mixture of particles of different sizes
- Soil texture is important because:
  i. It determines the amount of water available in the soil i.e. coarse gravel has large air spaces and are therefore porous and don't retain water for long/fine gravel have small air spaces and water enters in them at a slower rate. They also hold water for longer
  ii. It influences the ease with which plant roots can penetrate the soil – coarse grained soils are easily penetrated

b. Soil structure

- This refers to the way soil particles are grouped into aggregate compound particles
- It is described from the way the soil particles are joined into groups such as ***Granular/crumb*** (consists of small, soft porous aggregates); ***Platy*** (particles are arranged on top of one another in thin horizontal plates); ***Prismatic*** (aggregates are arranged vertically); ***Blocky*** (irregular pieces of soil with sharp corners and edges).
- Soil structure influences the rate at which soil absorbs water as well as the ease with which soil can be cultivated

c. Soil acidity

- Soils can be acidic or basic/alkaline.
- It changes in moist/humid climates as percolating ground water leaches out soluble minerals.
- The soil then becomes deficit of lime leading to salinity and alkalinity

d. Soil colour

- This is used in describing soil. Soils may be red, brown, yellow or black in colour
- Soil colour is influenced by

  - Type of parent material from which a soil developed.
  - The drainage of the area in which the soil is found.(well drained-red soil, poorly drained-grey/brown/yellow)
  - The content of organic matter present in the soil
  - The extent of leaching.

e. Soil porosity

- This refers to the amount of pore spaces in a soil sample.
- It's determined by soil texture and structure
- It influences soil water retention capacity/drainage.

f. Soil permeability

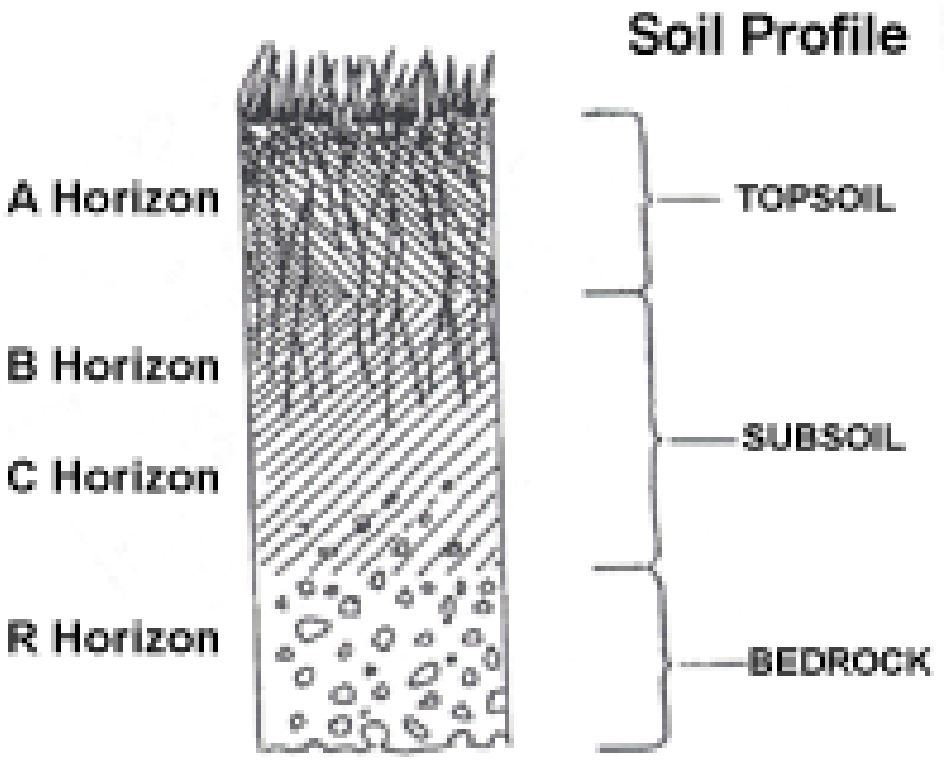
- This refers to the movement of water in the soil. It depends on the soil texture i.e. fine textured soils are impermeable

Soil depth

- This is the mass of a unit volume of dry soil/ the amount of dry soil overlying a parent rock.
- Soil depth is influenced by the following factors;
  i. nature of the bed-rock/ the ease with which it weathers
  ii. the length of time the soil has taken to form
  iii. the vegetation cover existing in the area
  iv. the climate of the place
  v. The rate of weathering of the mineral matter.

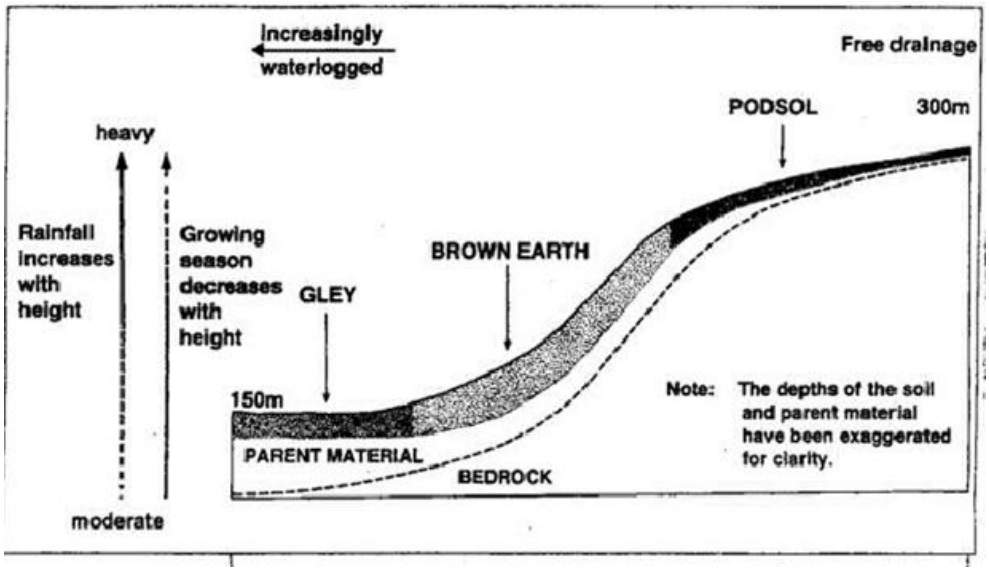
Soil profile

- This is the vertical arrangement of different layers/horizons of soil from the surface to the bedrock



Soil Catena

- This is the arrangement of soil on a mountain or slope from the top to the bottom or the sequence of different soils down a slope
- Soils are derived from the same parent material but vary with relief and drainage
- The mountain top has laterite cap, the slope has light and thin soil and the bottom of the slope has thick deposits of soil



Factors influencing the development of a soil catena

1. **Relief**
   - Slope influences drainage which in turn influences the moisture content of the soil
   - Soils on the upper slopes are generally well drained and thin because of high rate of erosion
   - On the gentle slopes the soil is thick/ deep because the rates of erosion and weathering are balanced. On valley floors the soil may be peat or alluvial due to deposition.

2. **Drainage**
   - The degree of slope and the amount of moisture are the major factors influencing changes along a slope
   - Generally, well drained mature soils are found at the hill tops while thin, stony dry and immature soils are found on the steep slopes. Grey soils (formed through reduction of iron from the red-yellow ferric form to the blue-grey ferrous state under poor drainage) and peat may be found on valley bottoms.

3. **Leaching.**
   - Where percolation of soil solutions tend to be horizontal, soluble salts are removed from the soils of the upper slopes to the lower slopes. Other minerals, humus and clay may be transferred in suspension in the process of ***eluviation***

4. **Transport of debris**.
   - Surface run-off and mass wasting are responsible for the down-hill movement of soil. This results the accumulation of deep soils on the lower gentle slopes. The steep slopes are left with thin, stony and immature soils with little organic matter and moisture called Xeromorphic soils.

Soil Degeneration/deterioration

- This refers to the decline in soil quality/usefulness through changes in its physical, chemical and biological properties.
- Soil degeneration can be physical, chemical or biological

- ***Physical degeneration*** is the decline in the usefulness of soil in which the texture, structure, moisture and quantity of the soil is affected. It is due to the following causes

  - Poor land-use practices such as overgrazing/overstocking
  - Excessive soil erosion due to heavy rainfall
  - Prolonged or excessive drought causes changes in the soil structure, texture and moisture content
  - Over-cultivation
  - Use of heavy farm machineries

- ***Chemical degeneration*** refers to the decline in the usefulness of a soil due to a change in the mineral nutrients and soil pH. It is due to the following causes: -
  - Monoculture
  - Over-cropping
  - Excessive or wrong application of fertilizers
  - Excessive leaching
  - Prolonged drought also leads to accumulation of salts in the top soil

- ***Biological degeneration*** refers to the decline of the organic content of the soil as well as its vegetation cover. This can be due to
  - Overgrazing
  - Deforestation
  - Burning of land
  - Soil water logging.

Soil Erosion

- This is the removal of the top soil by the action of moving water, wind, glaciers, mass movements and human activities

Conditions favouring soil erosion

Natural conditions

1. Length, angle and nature of the slope. Generally steep slopes accelerate erosion
2. Mass wasting especially landslides and soil creep can aid soil erosion
3. Climatic conditions. Arid areas are prone to sheet and wind erosion
4. Nature of the soil texture. Areas with volcanic ash are vulnerable to soil erosion/areas with fine textured soils are easily prone to soil erosion

Human conditions

1. Monoculture/ over-cropping lead to soil exhaustion thus making the soil vulnerable to erosion
2. Overstocking that leads to overgrazing which reduces vegetation cover thus exposing the soil to erosion
3. Ploughing up and down a slope provides channels for surface run-off.
4. Bush fallowing may leave land abandoned or unprotected against erosion.
5. Deforestation and burning of vegetation exposes the soil to agents of erosion
6. Cultivation of crops in marginal areas loosen the soil in the dry seasons resulting in wind erosion
7. Cultivation of steep slopes, catchment areas or along river banks
8. Excavation works trigger off soil erosion.

Types of Soil Erosion

a. Splash Erosion

- This is caused by heavy and sudden rainstorms that hits and loosens unconsolidated particles of soil on the earth's surface
- The impact of the heavy drops throws away or splashes the soil particles

b. Rill Erosion

- The rain water cuts small channels called rills as it flows over the surface.
- It is most prevalent when rainfall exceeds the rate of infiltration

c. Gulley Erosion

- Moving water or glaciers on the surface of the earth surface may cut deep and large channels through widening the existing rills

d. Sheet Erosion

- This is the uniform removal of the top soil by rainwater moving downslope immediately after heavy downpour occurs in a gently sloping area

e. Wind

- Prevailing winds may carry fine soil particles away and deposit them else where

Effects of Soil Erosion

1. Sand eroded from steep slopes is deposited on the river beds and can be harvested for building and construction
2. Soil erosion loosens productive top soils thus lowers agricultural potential of land
3. During soil erosion, rich soils may be deposited e.g. alluvium that create fertile lands for agricultural production
4. Destruction of vegetation cover during soil erosion may lead to aridity and desertification
5. Eroded sediments from farmlands and dumping sites may contain pollutants/agrochemicals that may kill aquatic life if reaches oceans/seas/lakes and river. They also make the water unfit for human consumption
6. Eroded sediments may fill water reservoirs constructed for HEP generation/irrigation thus requiring dredging which is expensive
7. Also eroded alluvial deposits on river beds make the river channel shallower resulting into frequent flooding
8. Soil erosion may destroy structures e.g. buildings, bridges, roads as it weakens their foundations

Significance of soils

1. Soil gives physical support/anchorage for the rooting system/a medium on which plants grow
2. Soil forms habitat for bacteria necessary for breakdown of organic matter into humus.
3. Soils provide mineral elements to plants
4. Soil is a medium through which plants absorb water as soils contain water and air spaces
5. Soils are used in building and construction e.g. clay in making bricks, sand for construction and limestone for cement making
6. Some soils e.g. clay is used in making ceramics such as pots
7. Some soils contain valuable mineral elements e.g. alluvial gold

Classification of soil by order

- Soil order is the grouping of soils according to specific properties and factors such as age, texture, colour and climate
- Based on these, soils are classified as zonal, intrazonal and azonal

1. Zonal soil order

- These result from the prolonged influence of climate and biological factors on soil forming processes.
- Such soils have undergone long time soil formation processes under good drainage
- They are mature soils with well developed soil profiles
- They are further subdivided into the following sub orders

i. Podzols

- These are found in higher latitudes and forested areas which are generally humid with precipitation all year
- Such soils are heavily leached and have low fertility
- They are majorly found in the Scandinavian countries of Europe

ii. Podzolic soils

- These are found in areas with deciduous forests and hot and hot humid climates such as Zaire basin, Kenya highlands.

iii. Tundra soils

- These occur beyond 60^0 north in pole-ward treeless area experiencing tundra climate such as Iceland, Coastal Newfoundland, Northern edge of Europe and Asia
- Such soils are poorly drained given the permafrost conditions and low rates of evaporation
- They consist of bog and hummocky marshlands hence unsuitable for cultivation but can support sparse natural pasture

iv. Latosols

- These form under conditions of high rainfall and temperatures especially areas of basaltic plateaus such as Kericho-Sotik plateau, Uasin Gishu, Trans-Nzoia, Laikipia, Athi- Kapiti plains.
- They are black due to the presence of high content of titanium salts in basalt bedrocks
- Have low organic content; when ploughed it crumbles into dust during dry season or cracks; plastic when wet; heavily leached

v. Pedocals

- These are common in semi-arid and sub humid grasslands.
- They are dark coloured, rich in calcium carbonate and have undergone little leaching
- They are further subdivided into;
  - *Chernozems:* - They are dark coloured top soils with high organic matter content found in semi-arid lands. They are well drained and associated with long-grass vegetation. They have loose crumbled texture and rich in minerals and bases. In Kenya, chernozems are found at the bottom of Nyambene Hills in Meru County
  - *Vertizols:* - are dark, cracking clay soils or black cotton soils; fine textured, plastic and sticky; usually poorly drained and have a high clay content (they are referred to as black cotton soils). They are mainly found in plains, lowlands, plateaus and flooded river valleys. They are suitable for growing cash and subsistence crops e.g. cotton, rice, maize, sorghum. In Kenya, vertizols are found in Machakos, Kitui, Tana River, Kirinyaga, Kano plains, Uyoma Peninsula (Siaya County)

vi. Nitosols

- These are deep, porous and friable soils of the highlands
- They are very fertile hence used to grow a variety of food and cash crops
- In Kenya, they are known as *Kikuyu Red Loam* and are found in the Kikuyu plateau, around Nyeri and Marsabit hills
- They are well aerated, shiny and have a high capacity of moisture storage

vii. Phenozems

- These are dark brown and relatively fertile soils common in the prairies of Canada
- They are generally fertile and have good physical structure
- They are good for growing cereals
- In Kenya, they are found in Narok and Kajiado

viii. Sierozems

- These are soils that form in desert conditions with little seasonal rainfall and high temperatures
- They are mostly found in large parts of northern Kenya.
- They contain very little humus
- They lack distinct profiles and most horizons comprises of fragments of parent rock
- They are rich in calcium carbonate due to excessive evaporation. The salts may harden to form mesas
- They are saline
- They are loose grained and porous with coarse texture

2. Intrazonal soil order

- These are soils formed under poor drainage conditions/systems
- They are further classified into: -

i. Hydromorphic soils

- These are soils formed in waterlogged areas e.g. flat uplands, marshes, bogs and swamps
- In Kenya they are found in Kisii highlands, Lorian, Lotikipi, Yala swamp and parts of Kano plains

ii. Halmorphic Soils

- These are soils formed under arid and semi-arid conditions through the influence of soluble salts (salinisation)
- They are further classified into *solonchak*, *calcimorphic* and *andosols*
  - *Solonchak*: - contain a lot of salts/are saline. They are light coloured and found in depressions in ASALs. They are generally infertile and are poorly drained. In Kenya, they are found in Amboseli, Tana River, North Eastern Kenya and around Lake Turkana
  - *Calcimorphic*: - these are formed by calcification of limestone soils. They are rich in lime. They are mainly found in grassland areas with plenty of humus in the upper zones of the soil profile. They are productive and are used for growing maize and cotton. In Kenya, they are found in North Eastern and Coast Provinces
  - *Andosols*: - are volcanic soils formed from recent volcanic activity. They are highly porous, have high organic matter content and water storage capacity. They are fertile, well drained and support extensive agricultural activities like coffee, wheat, tea and maize growing. In Kenya, they are found on the slopes of Mt. Elgon, Cherangani, Maua Hills, Chyulu, Meru, Embu, Central Province, Kisii, Nyamira, Busia and Upper Rift Valley Province

3. Azonal soil order

- These are young soils that have not undergone full soil formation processes.
- They lack well developed soil profiles due to recent formation
- They are found on steep slopes and areas with poor drainage
- They are further sub grouped into

i. Lithosols

- These are pronounced in slopes that experience excessive erosion and erosive run-off
- Their fertility depends on the parent material
- They are found in high altitude areas of Kenya

ii. Regosols

- Lack genetic horizons developing
- They develop from deep unconsolidated rock or soft material deposits
- They are formed in recent alluvial deposits hence lack distinct profile
- They are common in mountainous parts of Kenya e.g. around Lake Turkana

iii. Alluvial soils

- These are young soils developed from alluvium of recent origin

iv. Mountain soils

v. Arenosols

Management and conservation of soils

Soil management

- This involves controlling the process and activities that would cause deterioration of the soil through measures such as;

Nature of Soil	Management Measure(s)
Acidic soils	Adding agricultural lime to raise their pH level
Saline Soils	Adding good quality irrigation water in sequences to dissolve the accumulated salts
Sodic (Alkaline) Soils	Adding gypsum then good quality irrigation water to leach out the sodium
Deteriorating soil fertility	Application of plant and animal manure
Excessively wet soils	Constructing drainage ditches and shallow waterways to divert the water from the land to natural valleys/reservoirs
Flooded soils	Building dykes, embankments or levees along the river banks
Maintenance of soil texture	Returning crop residue to the soil after harvesting
Eroded Soils	Terracing, construction of water diversion channels upstream, mulching
Soils with poor water retention	Adding humus to the soils

Soil conservation

- This refers to measures that are taken to protect the soil from destruction or intentional planning to make the best use of soil resources while protecting and preserving its quality for sustainable productivity.

Measures of soil conservation

1. *Crop rotation* involves alternate growing of different crops on a given piece of land to prevent/minimize soil exhaustion
2. *Mixed farming* involves integrating animal and crop husbandry. It improves soil fertility as animal waste and plant remain assist in retaining soil fertility
3. *Cover cropping* forms a bumper that reduces the impact of rain-drops; the roots bind the soil firmly.
4. *Mulching*: - involves the use of plant remains are used to cover cultivated ground. It is important because
   - reduces evaporation of water from the soil
   - protects the soil from erosion
   - increases humus content
   - increases the rate of infiltration of water into the soil
   - provides habitat for burrowing animals which churn the soil and increase permeability and aeration
5. *Contour ploughing* i.e. ploughing across the slopes helps to check surface run-off
6. *Strip cropping* involves planting of different crops in narrow alternate belts of land especially on slopes which are too steep to be terraced.
7. *Afforestation* – planting trees where none existed before and *reforestation* – planting trees to replace the cut ones. These trees conserve the soil in the following ways
   - decayed vegetation matter provides humus which binds soil particles together
   - the roots bind soil particles together
   - it increases the rate of infiltration of rainwater, thus reducing surface run-off
   - leaf cover reduces the force of rain drops which would otherwise cause splash erosion
   - vegetation act as wind breakers thus preventing soil erosion
8. *Regulation of livestock numbers* to reduce overgrazing
9. *Bush fallowing*: - cultivating land for a period then allowing it to remain idle without cultivation for some time to help improve the soil quality
10. *Controlling bush fires* that exposes the soil to agents of soil erosion
11. *Intercropping/mixed cropping* i.e. growing two or more crops concurrently on the same piece of land to help improve the soil's nitrogen content
12. *Proper ploughing methods* e.g. digging with a fork jembe/ox plough