SENIOR FIVE TERM 2

TOPIC 2/2: Soil Development and Management

Competency: The learner proposes feasible ways of using and managing soil through gathering and analysing information about soil properties, formation, and quality to promote sustainable development.

Soil is defined as the *biologically active, porous medium formed in the uppermost layer of the Earth's crust*. It is a mixture of **minerals, organic matter, water, air, and living organisms**, serving as the natural medium for plant growth and a key component of ecosystems

Soil According to Geography

(i) **Biologically active medium:** Soil contains microorganisms, fungi, and bacteria that recycle nutrients and sustain plant life.

(ii) **Mixture of components:** It is made up of minerals (sand, silt, clay), organic matter (humus), water, and gases.

(iii) **Uppermost crust layer:** Soil forms at the Earth's surface through weathering of rocks and accumulation of organic material.

(iv) **Dynamic system:** Soil properties change over time due to climate, organisms, relief, and human activity.

(v) **Natural medium for plants:** It provides nutrients, water, and anchorage for vegetation, making it essential for agriculture and ecosystems.

Functions of Soil in Geography

Function	Role	Impact
Plant growth medium	Supplies nutrients, water, and support	Enables agriculture & vegetation
Water regulation	Stores and filters water	Prevents floods & sustains ecosystems
Nutrient cycling	Recycles organic matter	Maintains fertility & biodiversity
Habitat	Home for organisms	Supports ecological balance
Foundation	Base for human structures	Provides stability for settlements
Construction material	Raw material for building material such as bricks and concrete, cement, stones	Strong foundations, good life
Pottery	Clay is used for pots, tiles,	Creation of jobs and useful articles
Minerals	It the source of minerals such as gold, diamond, copper etc.	Raw materials for industrial development and source of revenue and foreign exchange

Negative soil importance

- Dirties clothes, buildings etc.
- Dust damages electronics
- Soft soil hinder construction of roads
- Some soils prevent plant growth.

Components of soil

Mineral matter: Derived from weathered rocks, includes sand, silt, and clay particles that determine soil texture.

Organic matter: Decomposed plant and animal material (humus) that enriches soil fertility and structure.

Water: Occupies soil pores, dissolves nutrients, and makes them available to plants.

Air: Fills spaces between soil particles, providing oxygen for roots and microorganisms.

Living organisms: Microbes, fungi, earthworms, and insects that recycle nutrients and improve soil health.

Soil structure

Soil structure refers to the way soil particles (sand, silt, clay) are arranged and grouped into aggregates. It determines how easily water, air, and roots move through the soil, making it a critical factor for fertility and plant growth.

Features of Soil Structure

- **Arrangement of particles**: Soil particles bind together into clumps called *peds* or aggregates.
- **Types of structure**: Common forms include granular, blocky, prismatic, columnar, and platy.
- **Influence on porosity**: Well-structured soils have pores that allow water infiltration and root penetration.
- **Dynamic nature**: Soil structure changes with cultivation, organic matter input, and environmental conditions.
- **Role in fertility**: Good structure improves aeration, drainage, and nutrient availability.

Soil texture

Soil texture refers to the relative proportions of **sand, silt, and clay** particles in soil. It strongly influences water retention, drainage, aeration, fertility, and how easily soil can be worked.

Table of soil texture

Soil Type	Particle Dominance	Water Holding	Fertility	Workability
Sand	Large particles	Low	Low	Easy
Silt	Medium particles	Moderate	Moderate	Moderate
Clay	Small particles	High	High	Difficult
Loam	Balanced mix	Optimal	High	Easy

Why Soil Texture Matters

- **Water retention**: Clay soils hold water longer, sandy soils dry quickly.
- **Aeration**: Sandy soils allow air circulation; clay soils may suffocate roots.
- **Workability**: Loam is easy to till; clay is heavy and hard to manage.
- **Crop suitability**: Different crops thrive in different textures (e.g., root crops prefer sandy soils).
- **Soil management**: Texture guides fertilization, irrigation, and erosion control strategies.

Water retention and its importance

Soil water retention is the ability of soil to hold water within its pores. It is crucial because it determines how much water is available for plants, influences crop yields, reduces irrigation needs, and supports overall soil health

Soil color and its importance

Soil color is one of the most visible properties of soil. While it doesn't directly affect soil behavior, it provides important clues about **organic matter content, mineral composition, drainage, and fertility.**

Importance of Soil Color

- **Indicator of fertility**: Dark soils often support higher crop yields.
- **Drainage assessment**: Red/yellow soils suggest good drainage; gray/blue soils indicate waterlogging.
- **Environmental monitoring**: Soil color helps identify erosion, pollution, or salinity issues.
- **Soil classification**: Used in pedology to distinguish horizons and soil types.
- **Land management**: Farmers and conservationists use color to guide irrigation, fertilization, and crop selection.

Soil pH and importance

Soil pH is a measure of how acidic or alkaline soil is, ranging from 0–14. It is critical because it controls nutrient availability, microbial activity, and overall plant health**, directly influencing crop yields and ecosystem balance**

Why Soil pH Matters

- **Nutrient availability:**
  - Acidic soils may lock up nutrients like phosphorus.
  - Alkaline soils can reduce availability of iron, manganese, and zinc.
- **Microbial activity:** Beneficial microbes thrive best in neutral to slightly acidic soils, aiding decomposition and nutrient cycling.
- **Plant growth:** Different crops prefer different pH ranges (e.g., blueberries thrive in acidic soils, while most vegetables prefer near-neutral).
- **Disease control:** Proper pH can reduce soil-borne diseases by supporting healthy microbial communities.
- **Soil health:** Balanced pH prevents toxic buildup of aluminum or heavy metals in acidic soils.

Managing Soil pH

- **To raise pH (reduce acidity):** Apply lime (calcium carbonate).
- **To lower pH (reduce alkalinity):** Add sulfur, organic matter, or acid-forming fertilizers.
- **Testing:** Regular soil testing is essential since pH can vary across fields

Soil formation

Soil formation (also called *pedogenesis*) is the process by which rocks and sediments are transformed into soil through the combined action of **parent material, climate, organisms, topography, and time**

Factors of Soil Formation

(i) ***Nature of the parent rock.*** It provides the basis upon which soil forming processes operate. The soil formed possess similar characteristic as those of the parent rock in terms of structure , texture , minerology, porosity, colour etc.

- It is the parent rock which is weathered to produce a particular soil type. E.g. volcanic rocks.
- The parent rock also determines the extent to which the agents of weathering can take place to produce soils: Hard crystalline rocks resist weathering and produce skeletal or thin soils e.g. scree soils on mountains. The soft parent rocks are easily weathered to produce deep and mature soils.

(ii) ***Climate*** influences soil formation through the physical and chemical weathering processes that break down and decompose the parent rocks.

- In dry climates (semi-arid areas) such as Northern Kenya, Central Tanzania, North Eastern Uganda, Physical weathering has produced shallow and infertile soils of azonal nature. On the other hand, chemical weathering processes that occur in the humid areas of East Africa have led to the development of deep fertile soils such as clay, loamy such as Nitisols found in the highland areas of East Africa.
- On other hand, high rainfall totals received in some parts of East Africa encouraged leaching hence formation of Lateritic soils e.g. around lake Victoria shores, dry conditions generally lead to the development of luvisols as in Eastern Kenya.

(iii) ***Relief/ Topography***

- This influences soil formation by forming various slopes that control the rate of erosion and deposition as well the mature soil and soil depth.
- Steep slopes are more susceptible to erosion and rapid transportation resulting into thin skeletal soils although soil formation is rapid due to constant exposure of fresh surface rock to weathering factors, the resultant soils are thin and skeletal due to rapid rates of erosion.

- Gentle/moderate slopes have a relatively slower rate of erosion but encouraged deposition leading to the formation of deep, mature and well drained soils such as loam soils.
- Valleys/flat areas have extensive deposition leading to the development of deep/thick soils found along the Lake Victoria shores, river valleys etc. However, they have limited organic matter due to the poor drainage; in addition the impeded drainage in the valleys leads to partial decomposition that forms grey/gley soils.

(iv) ***Biotic factors.*** This refers to the influence of living organizations in soil formation.

- When plants/vegetation die and rot, they add humus to the soil and produce compounds which may break down complex rocks to form soils.
- Burrowing animals like rabbits and moles, worms, etc. through their passages underground also contribute to the soil formation by allowing air and moisture necessary for chemical weathering.
- Human activities also influence soil formation through physical and chemical means. Through milling and quarrying man accelerates the rate at which rocks are broken down and therefore soil formation through addition of manure, fertilizers etc. man introduces chemicals which help break down rocks and eventually form soils. Industrial pollution also causes acidic rain which is also a contributing factor.

(v) **Influence of time:** Ample time is required to form mature soils. Along time is required for weathering to occur as well as the soil forming processes in order to produce deep mature soils. If time is short, immature, shallow soils will be formed.

Processes of Soil Formation

(i) **Weathering:** Breakdown of rocks into smaller particles (physical, chemical, biological).
(ii) **Accumulation:** Organic matter and minerals build up in soil layers.
(iii) **Leaching:** Movement of dissolved substances downward with water.
(iv) **Transformation:** Chemical changes like oxidation, reduction, and humification.
(v) **Horizon development:** Formation of distinct soil layers (O, A, B, C horizons).

Weathering

Weathering is the natural process that breaks down rocks and minerals into smaller particles through **physical, chemical, and biological mechanisms**, making it the first step in soil formation

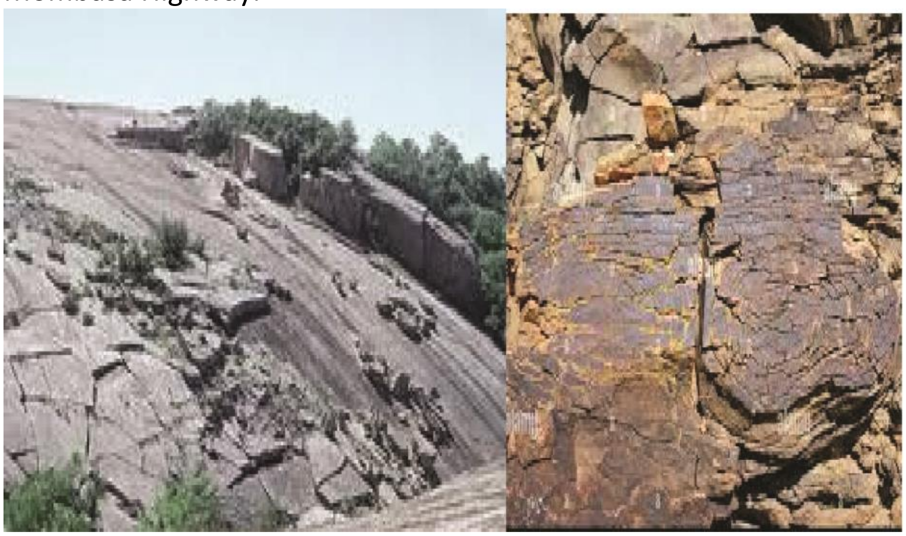
Types of Weathering

Physical weathering:

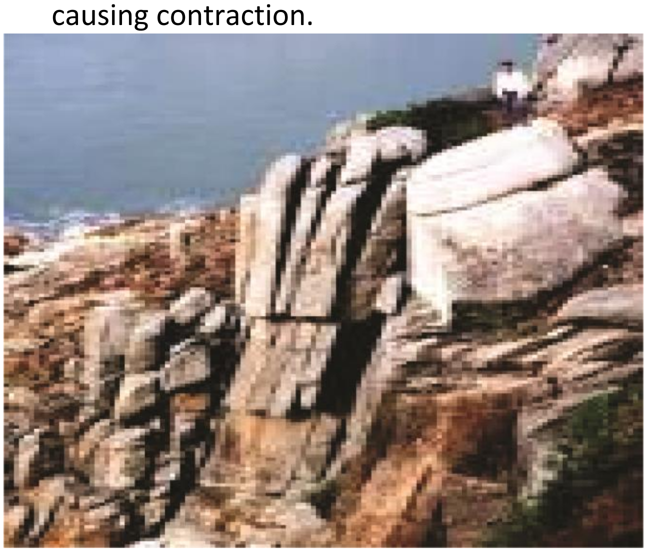
Mechanical breakdown of rocks into smaller fragments without changing composition.

The major processes of physical weathering include;·

- **Exfoliation/onion peeling** which is the peeling off of surface rock layers due to heating during day causing expansion and cooling at night causing contraction. Exfoliated domes in East Africa exist at Mubende and Nakasongola in Uganda, Serengeti etc. outstanding exfoliation domes are the Hells gates at Naivasha and Mubanda rocks along Nairobi-Mombasa Highway.



- **Block disintegration** occur in hot regions and involves breakdown of jointed rocks into rectangular shaped blocks due to heating during day causing expansion and cooling at night causing contraction.

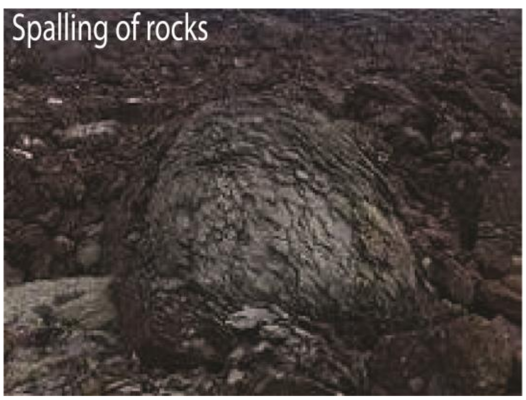


- **Granular disintegration** is a form of physical weathering where a rock breaks into small particles called granules. It is mainly observed in rocks with different colored minerals such granite rocks constitute of mica, quartz and feldspar which have different heat absorption and linear expansivity capacities. Granular disintegration is found at Mubende and Nakasongola in Uganda, Turkana in Kenya, etc.

- **Aridity shrinkage or slaking** occurs on non-porous rocks like clay which absorbs water during rainy season and expands, while during dry season lose water through evaporation and crack. Repeated alternative expansion and contraction eventually cause them to crumble into small elongated pieces. This kind of weathering is common in swamps or areas with clay such as Masai-mara plains in Kenya, Nakasongola and Tororo in Uganda.

- **Frost wedging/Frost** shattering occurs in places where temperature falls below 0^0C such glaciated mountain tops of Kilimanjaro, Kenya and Rwenzori. During day snow or ice melts and water enters into rock cracks. During night water in these cracks solidifies and expands causing pressure that breaks rocks into small pieces.

- **Pressure release/unloading** takes place on granite or metamorphic rocks. Expansion and cracking takes place because large shear stresses under the surface that bends leading to exfoliation of rocks/spalling/sheeting. This form of mechanical weathering can be caused by freezing and thawing, unloading, thermal expansion and contraction, or salt deposition. It common on Nakasongola and Mubende Inselbergs.
  - Unloading/ pressure release while is the process by which newly exposed rock due to mass wasting expand and break due to release of weight caused by pressure.



- **Salt crystallization** which is process where saline solutions in rock cracks and joints begin to crystallize causing stress on the rock resulting into its disintegration

The factors that cause physical weathering

- **Climate**
  - In areas of hot climate such as Turkana region in Northern Kenya, Central Tanzania, during the day it is hot, exposed rocks are heated leading to expansion of the rock, while during the night, temperatures rapidly fall leading to rapid cooling of rock resulting into contraction. Such alternate expansion and contraction of a rock lead to peeling or breaking of the rock through processes like exfoliation, granular disintegration, block disintegration etc.
  - In Semi - Arid areas such as Central Tanzania, during the short rainy season, non-porous rocks like clay absorb water and expand while during the long dry season they lose water and crack resulting into rock disintegration..

- In Semi- Arid areas there is limited cloud cover which leads to temperature fluctuations i.e. hot/very hot during the day, cool/cold during the night leading to expansion and contraction, resulting into breakdown of rocks.
- On high mountains of East Africa, the temperature fluctuations result into frost weathering which is the process by which water collects in cracks during the day and during the night water freezes, volume increases causing pressure and breaking of the rock

- **Nature of parent rock.**
  - Jointed rocks such as limestone in Turkana, Kotido and Moroto areas result into block disintegration when rocks break into rectangular blocks when repeatedly heated or cooled.
  - Mineral composition- Rocks having different minerals absorb heat and lose heat at different rates when heated or cooled respectively resulting into granular disintegration.
  - Color of the rock- dark colored rocks absorb a lot of heat in Semi - Arid areas when heated leading to their disintegration.
  - Differences in rock hardness. Soft rocks such as limestone in semi-arid areas like Turkana, Kotido easily break down when exposed to rapid cooling and contraction due to hot temperatures during day and cold during the night.
- **Relief**
  - Steep slopes tend to experience a lot of soil erosion that expose rocks to process of physical/mechanical weathering.
  - Steep slopes tend to be affected by mass wasting that expose the rock to unloading/pressure release which is in form of mechanical weathering.
  - Limited vegetation cover in semi-arid areas like Turkana, central Tanzania, Moroto exposes the rock to extreme temperature fluctuation resulting into rapid expansion during day and rapid contraction at night leading to rock disintegration.
- **Biotic factors**
  - Movement of heavy animals like elephants, antelopes, zebra in Kidepo National Park lead to breaking of rocks
  - Burrowing animals like squirrels, Hog and insects like locust, termites destroy vegetation thus exposing rocks to physical weathering due to temperature fluctuations.
  - Effects of plants adapted to semi-arid areas like cactus, acacia grow strong roots into and break rocks
  - Human activities such as quarrying cause disintegration of rock
  - Time: the longer the time the more physical weathering occurs.

Chemical weathering

Chemical weathering is the decomposition of rocks due to chemical reaction that takes place between the rock minerals, water and atmospheric gases like oxygen and carbon dioxide causing changes in chemical composition. Chemical weathering dominates areas of heavy rainfall and high temperatures such as L. Victoria basin, Kigezi highlands, Kenya highlands, coastal areas like Mombasa.

Types of chemical weathering

Solution
This is where soluble mineral components in rocks are dissolved by water e.g. rock salts are carried in solution leaving behind joints, cracks/widened hollows in rocks.

Oxidation
This is the reaction between oxygen and mineral components in rocks such as iron, aluminum facilitated by the hot temperatures and existence of water. This has led to the formation of laterites for example on the flat-topped hills of Buganda, Rocks containing Iron (ferrous state) change to ferric state.

Hydrolysis
This is the reaction between the hydrogen ions from water and mineral ions from rocks to form new compounds. It the major process in of decomposition of feldspars in igneous rocks e.g. granite.

Carbonation
This involves rain water dissolving atmospheric carbon dioxide to producing carbonic acid. This reacts with calcium and magnesium carbonates in the rocks to form to form soluble bicarbonates that are lost in solution.

Hydration
This is a process in which certain minerals absorb water and expand causing internal stress and fracturing of the rock. Examples include the conversion of hematite to limonite, mica in sedimentary rocks like sandstone.

Spheroidal weathering
This is the swelling/expansion of the outer shell of a rock mass by penetration of water forcing them to expand, loosen and peel successively away.

Reduction/gleying
It is the removal of oxygen from a substance or addition of hydrogen to it, It occurs in swampy/water logged areas at the shores of lake Victoria. It involves aerobic bacteria absorbing the limited oxygen leaving behind hydrogen that reacts with the rocks to form new compounds i.e. the clay rich rocks turn into blue greyish colour.

Chelation
This involves Base Exchange between plants and rocks which cause chemical changes and rock disintegration.

The factors that favor chemical weathering

Mineral composition of the rock

- Rocks that contain calcium carbonate/limestone dissolve in water that contain carbonic acid e.g. at Tororo in eastern Uganda and Nyakasura
- Rocks like feldspar hydrolyze in water into other compounds such as potassium ions, kaolinite (clay) and silica.
- Rocks that contain iron are oxidized in presence of water and oxygen.

- Rock-salt (halite), gypsum and limestone (including chalk)dissolve in presence of water.
- Igneous rocks are easily hydrated and hydrolyzed because they are composed of silicate minerals, such as quartz and feldspar which readily combines with water.

Nature of rocks

Presence of cracks in jointed rocks increases surface area to agents of chemical reaction
Permeable rocks allow water and oxygen to penetrate leading to hydrolysis and/or oxidation

Climate

- Rainfall provides water for hydrolysis of rocks
- High temperature speeds up chemical reaction in rocks

Relief

- Chemical weathering is dominant on gentle slope and low land because these allows percolation of water in the rocks to allow chemical weathering
- Steep slopes promotes removal of weathered materials by erosion exposing rocks to agents of chemical weathering

Biotic factors

- Plants produce humic acid that facilitate rock decomposition
- Man influences chemical weathering by releasing acidic gases/substances to the atmosphere which cause acidic rain/water. Acidic water promotes hydrolysis of rocks

Time

The longer the time the more physical weathering occurs

Landforms resulting from chemical weathering in East Africa

These include

Stalactite and stalagmite

These are formed through carbonation. Rain water combines with carbon dioxide in the atmosphere to form weak carbonic acid which dissolves calcium carbonate to form calcium bi carbonate. When solution reaches underground cave, calcium carbonate is deposited on roof of the cave to form stalagmite e.g. at Nyakasura in Western Uganda.

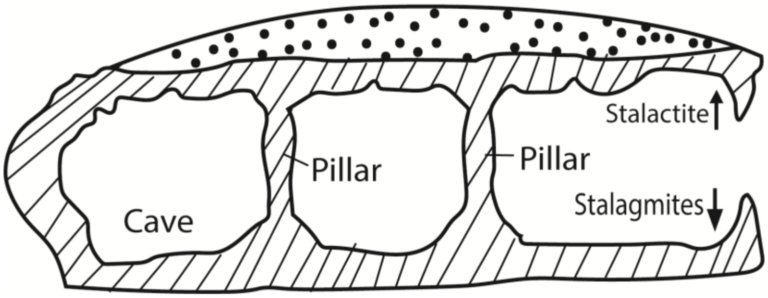
Pillars

These are vertical stands of calcium carbonate formed in underground caves when stalactites and stalagmites continue to grow towards each other and eventually join. Examples arc found at Nyakasura and Tanga.

Caves

A cave is a natural underground space. It is formed when there is chemical dissolution of limestone or dolomite. The rock is dissolved by natural acid in ground water that seeps through the bedding planes, faults and joints.

Cave, pillars,stalactite and stalagmites



Grikes and Clints
Grikes are hollows or depressions while Clints are ridges formed as a result of carbonation. They formed in limestone areas with rocks of different chemical composition. Lime stone is dissolved by acidic rain to form depressions/ hollows called Grikes while dissolved rocks form ridges called Clints/ Limestone pavement.

Grikes/clints

Examples are found on the western side of Tororo rock, Karasuka in Karamoja, Nyakasura etc.

Arenas/Sink holes
A sink hole is a natural depression or hole in earth's surface formed when lime stone is dissolved. It is formed through the processes of removal of soluble rock by percolating water and the collapse of roof cave.

Dolines:
These are larger than sinkholes. These are shallow circular depressions formed either by solution of the surface lime stone or by collapse of underlying caves. In latter case they are called collapse doline.

Polje.
This is an elongated basin having a flat floor and steep walls. The poljes are formed by coalescence of several sinkholes when being formed through carbonation and solution. In some poljes, small residual hills known as hums are formed.

Limestone gorge is deep steep-sided valley formed when acid rain seeps into the cracks in limestone rocks or when a larger river erodes/ weathers soft limestone rocks by solution.

Duricrust is a hard crust (layer) found on the surface formed from mineral precipitation i.e. deposition of insoluble materials from a solution. The most common in East Africa is lateritic duricrust formed when the weathered layer become impregnated with iron solution due to leaching. On removal of top layer laterite hardens into duricrust like on flat topped hills of Buganda/ laterite terms·. , - -·.,._

Tors are landforms created by chemical weathering of a rock along joints followed by removal of the weathered material.

Differences between physical and chemical weathering

- In physical weathering there is no change in the chemical nature of the rocks that are broken into small particles while in chemical weathering there in a change in chemical composition of a rock
- Physical weathering occur in form of block disintegration, exfoliation, granular disintegration, frost weathering while chemical weathering involves decomposition/decay of rocks into new compounds by reactions like oxidation, hydrolysis, hydration etc.
- Physical weathering commonly occur in arid areas with high temperature fluctuation while chemical weathering commonly occur in areas of adequate rainfall
- Physical weathering no new compounds formed while chemical weathering new compounds are formed

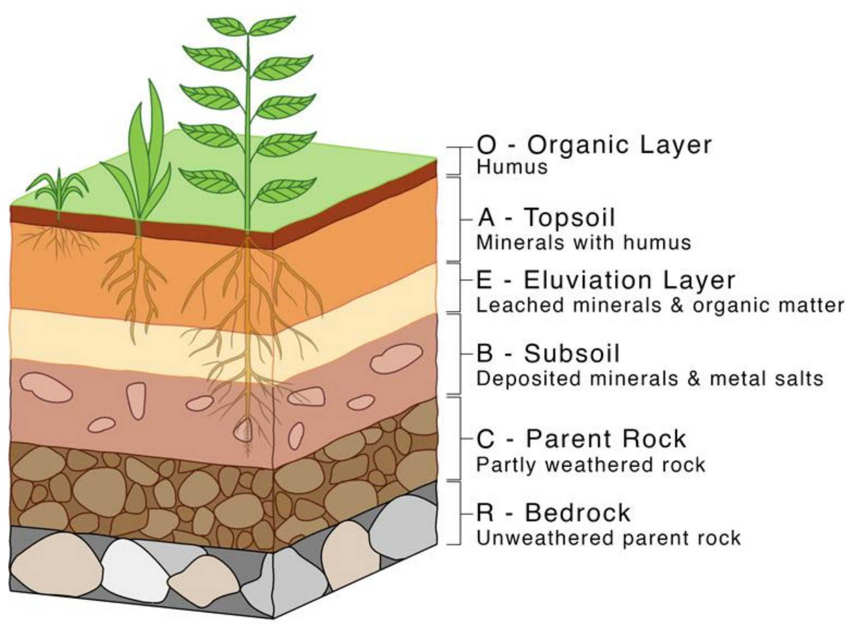
Biological weathering: Breakdown caused by living organisms.

Examples: Plant roots cracking rocks, lichens producing acids, burrowing animals.

Soil Profile

A soil profile is the **vertical section of soil** that shows all its layers (called *horizons*) from the surface down to the parent material. It reveals the history of soil formation and is essential for understanding soil fertility, drainage, and land use.

Soil horizons



Features of soil horizons

(vi) **O Horizon (Organic layer):**

- Composed of leaf litter, decomposed plants, and organic matter.
- Dark in color, rich in nutrients.

(vii) **A Horizon (Topsoil):**

- Mixture of minerals and organic matter.
- Zone of root growth and high biological activity.
- Most fertile layer for crops.

(viii) **E Horizon (Eluviation layer):**

- Light-colored, sandy layer.
- Minerals and nutrients leached downward by water.

(ix) **B Horizon (Subsoil):**

- Zone of accumulation (illuviation).
- Contains clay, iron, and other minerals washed down from above.
- Less organic matter, denser than topsoil.

(x) **C Horizon (Parent material):**

- Weathered rock fragments.
- Little biological activity.
- Source of minerals for upper horizons.

(xi) **R Horizon (Bedrock):**

- Unweathered rock beneath the soil.
- Foundation of soil formation.

Soil Profile Horizons and Their Land Use Implications

Horizon	Characteristics	Land Use Importance
O Horizon (Organic layer)	Rich in decomposed plant material, dark color	Supports forestry, grazing, and organic farming
A Horizon (Topsoil)	Fertile, high biological activity, root zone	Best for crop cultivation and gardening
E Horizon (Eluviation layer)	Leached, lighter color, low nutrients	Often unsuitable for intensive farming, may need fertilization
B Horizon (Subsoil)	Accumulated clay, iron, minerals	Important for water storage; affects deep-rooted crops
C Horizon (Parent material)	Weathered rock fragments	Determines long-term soil fertility and mineral supply
R Horizon (Bedrock)	Solid rock	Limits rooting depth; influences construction and engineering projects

How Soil Profile Influences Land Use

(i) **Agriculture:**
- Thick, fertile A horizons → ideal for farming.
- Shallow soils with exposed bedrock → poor for crops, better for grazing or forestry.

(ii) **Forestry:**
- Deep organic and nutrient-rich layers support tree growth.

(iii) **Construction:**
- Soil depth and stability (B and C horizons) determine suitability for building foundations.

(iv) **Water management:**
- Subsoil layers (B horizon) influence drainage, irrigation, and groundwater recharge.

(v) **Conservation:**
- Soil profiles help identify erosion risks and guide reforestation or terracing.

Key Considerations

- Land use must match soil profile characteristics to avoid degradation.
- Misuse (e.g., farming on shallow or sandy soils) can lead to erosion, nutrient loss, and reduced productivity.
- Sustainable practices (crop rotation, mulching, agroforestry) maintain soil horizons and extend land use potential.

The conditions that influence soil profile development

(i) **Nature of the parent Rock**

- Hard rocks which are not easily weathered such as granite lead to formation of thin soils and poorly developed profiles while soft rocks which are easily weathered such as volcanic ash and limestone lead to the development of a deep soil profile.
- Rocks with joints and cracks are also easily broken down to produce deep/mature soil profiles as compared to those without
- Dark coloured rocks responsive to heat are also easily weathered to produce deep /well developed profiles as compared to light coloured rocks which are difficult to break up.
- Basic igneous rocks which are difficult to weather as well as some sedimentary rocks (composed of previously weathered materials are difficult to breakdown and produce shallow soils in immature/ poorly developed soil profiles.
- Permeable/ porous rocks are easily weathered by chemical processes to produce deep mature soil profile as compared to impermeable rocks which may produce shallow soil profiles etc.

(ii) **Climate**

- It determines the character and rate of weathering.
- In hot humid climates, chemical weathering occurs at a fast rate leading to the formation of deep soils and well developed/ mature soil profiles.
- In hot dry climates physical weathering predominates leading to the formation of thin/ skeletal soils/ azonal soils which do not have well developed profiles.

(iii) **Vegetation**

- Thick vegetation cover decays and leads to the formation of humus which is added to horizon A of the soil profile
- Plant roots also lead to the disintegration of rocks and the formation of soil in a soil profile.
- Forested areas such as Mabira, Kakamaga, Kissi in Kenya therefore tend to have deep soils in well- developed profiles while areas with thin vegetation cover have thin skeletal soils and poorly developed profiles.

(iv) **Drainage**

- Water logged conditions do not allow the easy development of a soil profile such as Lutembe wetlands, Katonga, Awoja wetlands, etc.
- Well drained areas lead to the formation of a well-developed mature soil profile such as areas around L. Victoria

(v) **Human activities**

- Such as mining, quarrying, road construction etc. lead to the breakdown of rocks and the formation of deep soils characteristic of well-developed profiles e.g. mining in

Tororo, cultivation around L. Victoria.

(vi) **Living organisms**

- In the soil such as ants, earthworms and mammals like rats and moles also break down rocks as the construct their passages underground leading to the formation of deep soils and well developed soil profiles

(vii) **Time**

- Ample time is required to the formation of mature, fertile and deep soils in a well-developed soil profile.
- If time is short immature/ azonal soils will formed with poorly developed /shallow soil profiles.

(viii) **Topography.**

- Steep-s lopes are- more susceptible to soil erosion, and thin soil profile
- Gentle slopes - erosion is slower, there is a lot of deposition of soil eroded on steep slopes and water percolates to assist in soil profile development leading to deep, mature soil profile.
- Valleys; lowlands; extensive deposition and percolation of water lead to deep mature soil profiles where there are waterlogged conditions there is immature soil profile.

The Soil Catena

Catena means a chain or connected series

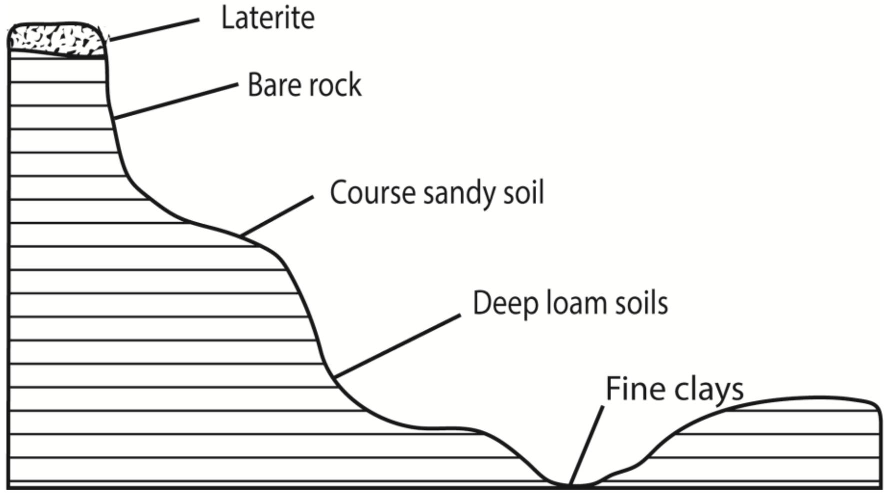
A **soil catena** is the natural sequence of different soil types that occur down a slope, all formed under the same **climate** and from the same **parent material**, but differing because of **topography, drainage, and erosion/deposition patterns**.

Features soil catena

- **Same parent material:** All soils originate from the same rock or sediment.
- **Same climate:** They form under identical climatic conditions.
- **Variation due to slope:** Differences arise from drainage, erosion, and deposition.
- **Linked sequence:** Each soil type is related to the next, forming a chain across the slope.

An example of the soil catena from Buganda shows the following soil types, at the top is laterite/lateritic capping characterized by thin skeletal soils; follwed by a vertical slope/free face with bare rock; followed by concave slope with deep loam soils and lastly in the broad valleys are fine clay soils rich in organic matter.

Buganda's soil catena



The factors which have led to the development of soil catena in East Africa

Relief

The nature of a slope/topography influences the development a soil catena for example in Buganda the hill top/ridge tends to accumulate organic matter that allows formation of an adequate thickness of soil. Steeper slope or crest sections tend to be freely drained, while at the bottom of slopes or toe slopes there is usually higher in moisture content due to poor drainage. Toe slope soils are not only higher in moisture content, but are also known to be richer in clay and organic matter.

Drainage

The moisture content of the soil influences the development of the catena as soil changes along the slope. Well drained mature soils are found on the gentle slope while thin, stony dry, immature soils are found on the steep slopes. Clay/boggy soils are generally found in the valley bottoms where drainage is poor/water logged.

Nature of parent rock

The characteristics of parent rock in terms of hardness, porosity, structure etc. will determine the rate of erosion thereby influencing the type of soil formed downslope. In addition the different soil along the slope could be the result of different parent materials.

Human activities

Man's activities like deforestation, settlement, agriculture etc. result in removal of surface vegetation which encourage erosion on the upper slopes and deposition on the lower slopes.

Vegetation cover

Soil catena development is faster in areas without vegetation cover since the rate of erosion is fast. Thick vegetation slow down the rate of erosion and the rate of soil catena development.

Time

Time is required to form a well developed soil catena

Climate

Heavy rainfall in East Africa in areas around Lake victoria promote leaching leading to the development of lateritic soils at the hill top. **Heavy rainfall** encourage erosion on the upper slopes and deposition on the lowers slopes and valleys. Water logging due to heavy rainfall results in clay soils.

Soil Productivity

Soil productivity refers to the **capacity of soil to support plant growth and yield crops sustainably**. It is a measure of how well soil can provide essential nutrients, water, and a suitable environment for roots and microorganisms.

Differences between soil fertility and soil productivity

Aspect	Soil Fertility	Soil Productivity
Meaning	Ability to supply nutrients	Ability to produce crops/yields
Focus	Nutrient status & soil chemistry	Actual crop output
Nature	Potential property	Realized property
Influenced by	Nutrients, pH, organic matter	Fertility + climate, irrigation, technology, management
Measurement	Soil tests (nutrient levels, pH)	Crop yield per unit area
Example	A soil rich in nutrients but waterlogged (fertile but unproductive)	A soil with moderate fertility but well-managed irrigation (productive)

Key Insight

- **All productive soils must be fertile**, but not all fertile soils are productive.
- Productivity is broader — it includes fertility plus external factors like climate, irrigation, and farming practices.

Factors Affecting Soil Productivity

(i) **Soil fertility:** Availability of nutrients (N, P, K, micronutrients).
(ii) **Soil texture & structure:** Influences water retention, aeration, and root penetration.
(iii) **Soil depth:** Deeper soils allow better root development and water storage.
(iv) **Soil pH:** Controls nutrient availability and microbial activity.
(v) **Organic matter:** Improves structure, water-holding capacity, and nutrient cycling.
(vi) **Moisture & drainage:** Balanced water supply is vital for crops.
(vii) **Biological activity:** Microbes and fauna enhance nutrient cycling and soil health.

Importance of Soil Productivity to Farmers

- **Food security:** Productive soils ensure reliable crop yields, supporting local and global food supplies.
- **Economic stability:** Higher productivity reduces input costs (fertilizers, irrigation) and increases profits.

- **Sustainability:** Maintaining soil productivity through practices like crop rotation and organic amendments prevents long-term degradation.
- **Resilience:** Productive soils buffer against droughts and climate variability by retaining water and nutrients.

Importance of Soil Productivity to Foresters

- **Tree growth:** Soil productivity determines forest health, timber quality, and regeneration capacity.
- **Biodiversity:** Productive soils support diverse plant species, which in turn sustain wildlife habitats.
- **Carbon storage:** Healthy, productive soils enhance carbon sequestration, mitigating climate change.
- **Sustainable forestry:** Productivity guides reforestation, afforestation, and forest management practices.

Importance of Soil Productivity to Environmentalists

- **Ecosystem services:** Productive soils regulate water cycles, filter pollutants, and support biodiversity.
- **Climate regulation:** Soil productivity is linked to carbon cycling and greenhouse gas balance.
- **Land conservation:** Protecting soil productivity prevents erosion, desertification, and land degradation.
- **Human well-being:** Productive soils underpin sustainable development, balancing agriculture, forestry, and conservation needs.

Measures to improve soil productivity

(i) **Add organic matter:** Incorporating compost, manure, or green manure improves soil structure, water retention, and nutrient cycling.

(ii) **Balanced fertilization:** Applying the right mix of macro- and micronutrients prevents nutrient depletion and supports healthy crop growth.

(iii) **Crop rotation:** Alternating crops reduces pest buildup, improves soil fertility, and enhances biodiversity.

(iv) **Cover cropping:** Planting legumes or grasses between main crops prevents erosion, adds nitrogen, and improves soil organic matter.

(v) **Erosion control:** Techniques like terracing, contour plowing, and mulching protect topsoil from being washed away.

(vi) **Irrigation management:** Efficient water use prevents salinization and ensures crops receive adequate moisture.

(vii) **pH adjustment:** Liming acidic soils or adding sulfur to alkaline soils optimizes nutrient availability.

(viii) **Reduced tillage:** Minimizing soil disturbance preserves structure, reduces erosion, and maintains microbial activity.
(ix) **Agroforestry:** Integrating trees with crops improves soil fertility, reduces erosion, and enhances biodiversity.

Soil Degradation

Soil degradation is the **decline in soil quality and productivity** due to natural processes and human activities.

Effects soil degradation

(i) Reduced soil fertility and crop yields.
(ii) Loss of biodiversity and soil organisms.
(iii) Increased flooding and desertification.
(iv) Threats to food security and livelihoods.

Causes of soil degradation

(i) **Erosion:** Loss of topsoil by wind and water.
(ii) **Nutrient depletion:** Continuous cropping without replenishment.
(iii) **Salinization:** Build-up of salts from poor irrigation practices.
(iv) **Acidification:** Excessive use of chemical fertilizers or acid rain.
(v) **Pollution:** Contamination by industrial waste, pesticides, and heavy metals.
(vi) **Deforestation:** Removal of vegetation cover, exposing soil to erosion.
(vii) **Overgrazing:** Livestock pressure reduces vegetation and compacts soil.

Soil Conservation

Soil conservation refers to **practices that protect, maintain, and restore soil health** to ensure long-term sustainability.

Measures for soil conservation

(i) **Afforestation & reforestation:** Planting trees to protect soil from erosion.
(ii) **Contour farming:** Plowing along slope contours to reduce runoff.
(iii) **Terracing:** Creating steps on slopes to slow water flow.
(iv) **Cover cropping:** Growing plants to protect soil between main crops.
(v) **Crop rotation:** Alternating crops to maintain fertility and reduce pests.
(vi) **Organic amendments:** Adding compost or manure to improve soil structure.
(vii) **Mulching:** Covering soil with plant residues to retain moisture and reduce erosion.
(viii) **Controlled grazing:** Managing livestock to prevent overgrazing.
(ix) **Efficient irrigation:** Prevents salinization and waterlogging.

Case study of the nature, causes, effects and control measures soil degradation from a developed country

A strong case study of soil degradation in a developed country is the **Dust Bowl in the United States (1930s)**. It illustrates how poor land management combined with climatic extremes led to massive soil erosion, crop failure, and migration. Control measures like conservation farming, reforestation, and sustainable land management were later introduced to restore productivity.

Case Study: The Dust Bowl (USA, 1930s)

Nature of Soil Degradation

- Severe **wind erosion** stripped away millions of tons of topsoil.
- Vast areas of farmland became barren and unproductive.
- Soil fertility declined drastically, leading to widespread crop failure.

Causes

- **Over-cultivation:** Farmers plowed large areas of prairie grassland for wheat production.
- **Monocropping:** Continuous wheat cultivation depleted soil nutrients.
- **Lack of conservation practices:** No crop rotation, cover crops, or windbreaks.
- **Climatic factors:** Prolonged drought and high winds exacerbated erosion.

Effects

- **Agricultural collapse:** Crop yields dropped sharply, leading to food shortages.
- **Economic hardship:** Thousands of farmers lost livelihoods, triggering mass migration (the "Okie" migration to California).
- **Environmental damage:** Dust storms destroyed ecosystems, reduced biodiversity, and worsened air quality.
- **Social impact:** Rural communities were devastated, increasing poverty and unemployment.

Control Measures

- **Soil Conservation Service (1935):** Established to promote sustainable farming.
- **Contour plowing:** Reduced runoff and erosion.
- **Crop rotation & cover cropping:** Restored soil fertility and organic matter.
- **Shelterbelts (windbreaks):** Trees planted to reduce wind erosion.
- **Reforestation & grass reseeding:** Helped stabilize soils and restore ecosystems.

Case study of the nature, causes, effects and control measures soil degradation from a developing country

A clear case study of soil degradation in a developing country is **Punjab, India**, where intensive agriculture, overuse of chemical inputs, and poor land management have led to severe soil fertility decline, erosion, and salinization. Control measures include crop diversification, organic amendments, and sustainable irrigation practices.

Case Study: Soil Degradation in Punjab, India

Nature of Soil Degradation

- Decline in soil fertility due to nutrient depletion.
- Widespread salinization and waterlogging from excessive irrigation.
- Soil erosion in cultivated areas.
- Loss of organic matter and microbial diversity.

Causes

- **Intensive monocropping:** Continuous wheat–rice rotation depletes nutrients.
- **Excessive chemical fertilizer use:** Leads to soil acidification and micronutrient imbalance.
- **Over-irrigation:** Causes waterlogging and salinity buildup.
- **Deforestation & habitat destruction:** Reduced vegetation cover accelerates erosion.
- **Population pressure:** Expanding agriculture without conservation practices.

Effects

- **Reduced crop yields:** Declining productivity threatens food security.
- **Economic stress:** Farmers face higher costs for fertilizers and irrigation.
- **Environmental damage:** Loss of biodiversity, soil organisms, and increased greenhouse gas emissions.
- **Health impacts:** Contaminated water from fertilizer runoff affects rural communities.
- **Long-term sustainability risk:** Soil degradation undermines agricultural resilience.

Control Measures

- **Crop diversification:** Moving away from wheat–rice monocropping to pulses, oilseeds, and vegetables.
- **Organic amendments:** Use of compost, manure, and green manures to restore fertility.
- **Balanced fertilization:** Incorporating micronutrients and reducing chemical dependency.
- **Efficient irrigation:** Adopting drip irrigation and reducing groundwater overuse.
- **Agroforestry & afforestation:** Planting trees to stabilize soil and improve biodiversity.
- **Government policies:** Soil health cards, subsidies for organic inputs, and awareness campaigns.

Revision questions

1. Examine the weathering processes taking place in East Africa.
   (Define weathering, identify and describe each weathering types, give occurrence of each type of weathering in East Africa))
2. Physical weathering dominates in the arid areas of East Africa. Discuss
   (Define physical weathering, identify arid areas in East Africa, factors that promote the types of physical weathering in East Africa, describe chemical weathering as alternative to physical weathering)
3. (a) Distinguish between physical and chemical weathering
   (Define the terms physical and chemical weathering and then give differences between physical and chemical weathering)
   (b) Describe the factors which have favored chemical weathering in East Africa.
4. Describe the chemical weathering process in humid areas in East Africa
   (Define the term chemical weathering, identify humid areas in East Africa, describe factors that favored chemical weathering, describe chemical weathering processes)
5. Examine the factors that influence the type and rate of weathering in East Africa
   (Define weathering, identify the types of weathering, then explain the factors that influence the type and rate of weathering)
6. To what extend does the rate and character of weathering depend on the nature of rocks?
   (Define weathering, bring out the extent to which the nature of rocks (mineral composition, rock hardness, color of rock, rock joints) influence the character of rate of weathering; discuss the alternative/other factors that affect the rate of weathering as well)
7. (a) distinguish between physical and chemical weathering
   (b) Examine the importance of weathering process on landform formation in East Africa
8. Account for the landform produced by carbonation process in East Africa
9. (a) What is chemical weathering
   (b) Describe the landforms resulting from chemical weathering
10. Examine the weathering processes that take place in the L. Victoria basin of East Africa.
    (Define weathering, identify location of L. Victoria basin, discus both chemical and physical weathering process.

Thank You

Dr. Bbosa Science