DP IB Environmental Systems & Societies (ESS): HL

Your notes

5.1 Soil

Contents

Components & Structure of Soil Systems

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Soil Systems

Soil components

- Soil is made up of a complex mixture of interacting components, including inorganic and organic components, water and air

Inorganic components

- **Mineral matter:**
  - Rock fragments
  - Sand
  - Silt
  - Clay
- These components come from the weathering of parental rock

Organic components

- **Living organisms:**
  - Bacteria
  - Fungi
  - Earthworms
- **Dead organic matter:**
  - Decaying plants
  - Animal remains
  - Animal waste (faeces)

Other components

- **Water**:
  - Essential for chemical reactions and life
- **Air**:

- Oxygen and other gases necessary for organism survival

Soils as systems

- Soils are dynamic systems within larger ecosystems
- As with any system, soil systems can be simplified by breaking them down into the following components:
  - **Storages**
  - **Flows** (inputs and outputs)
  - **Transfers** (change in location) and **transformations** (change in chemical nature, state or energy)

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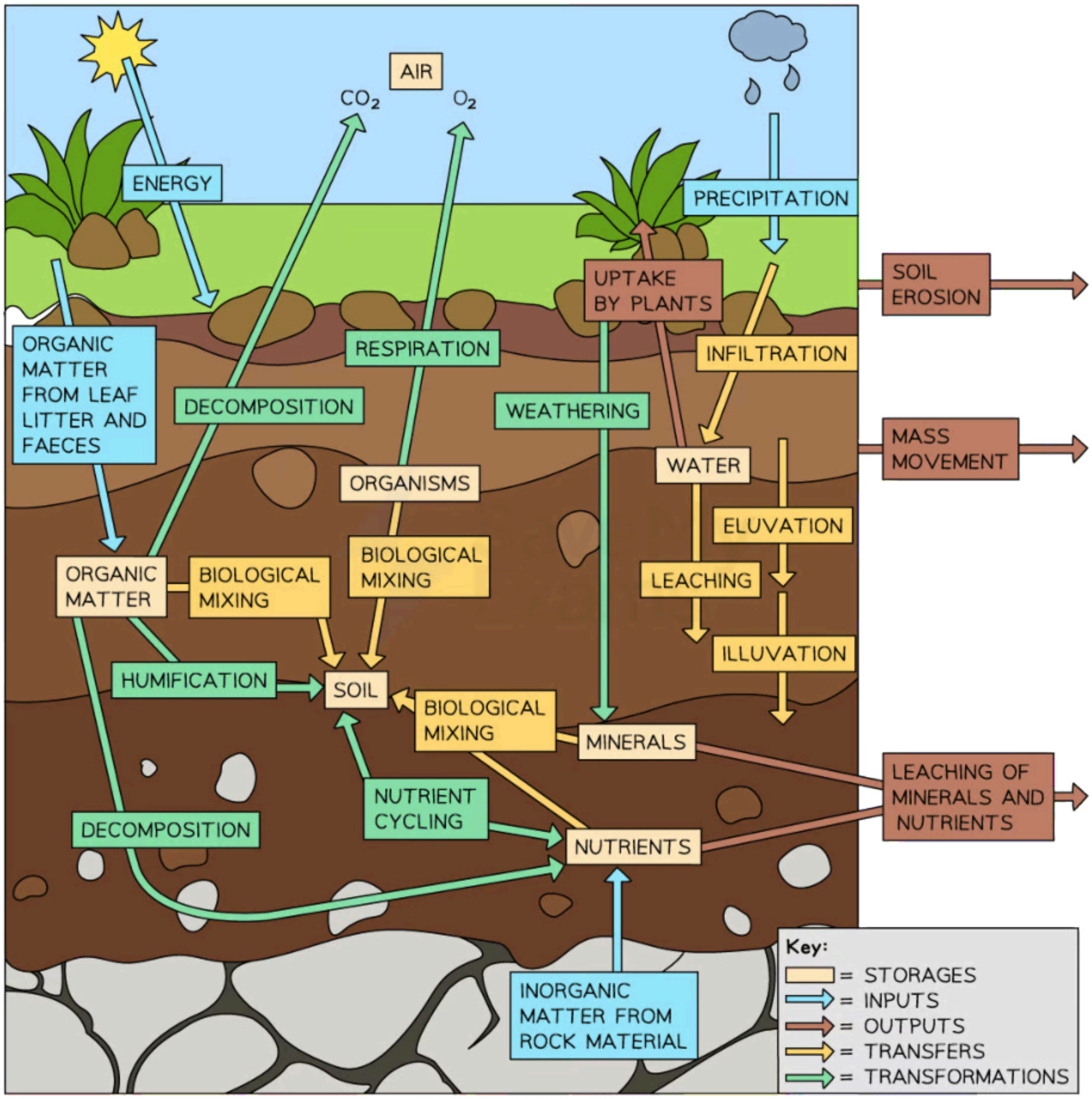

Soils are highly complex, dynamic systems made up of various storages, flows, transfers and transformations

Soil System Storages

Storage	Description

Organic matter	**Accumulation** of plant and animal matter in various stages of decomposition Provides **nutrients**, improves soil **structure** and enhances **water-holding capacity**
Organisms	Includes microorganisms, fungi, bacteria, insects and other living organisms present in the soil They play essential roles in **nutrient cycling**, organic matter **decomposition** and soil structure formation
Nutrients	Elements necessary for **plant growth**, such as nitrogen, phosphorus and potassium Nutrients are stored in the soil and are made available to plants through various biological and chemical processes
Minerals	**Inorganic** components of the soil derived from **weathering of rocks** and minerals Contribute to the physical properties and **fertility** of the soil
Air	Pore spaces within the soil are filled with air, allowing **oxygen** to be available for root **respiration** and microbial activities
Water	Soil acts as a reservoir for water, holding it for **plant uptake** and providing a suitably moist habitat for soil organisms

Soil System Inputs

Input	Description
Dead organic matter	Inputs of plant material (e.g. **leaf litter**) and other organic materials (e.g. dead animal biomass or animal **faeces**) that contribute to the organic matter content in the soil
Inorganic matter from rock material	Contributes to the **mineral composition** of soil, derived from parent materials (e.g. **bedrock**) and the weathering of exposed rock at the soil surface
Precipitation	Rainfall or snowfall that provides water (containing dissolved minerals) to the soil system
Energy	**Solar radiation** and heat influence soil temperature and biological activities

Anthropogenic inputs	E.g. compost, fertilisers, agrochemicals, water from irrigation

Soil System Outputs

Output	Description
Leaching	Loss of **dissolved minerals** and **nutrients** from the soil into streams, rivers, lakes and oceans through **water movement**
Uptake by plants	**Absorption** of **minerals** and **water** by **plant roots** for growth and development
Soil erosion	Removal of soil particles by **water** or **wind**, leading to the **loss of topsoil** and degradation of soil quality
Diffusion and evaporation	Diffusion of gases and evaporation of water from soil

Soil System Transfers

Transfer	Description
Infiltration	Process by which water enters the soil from the **surface**
Percolation	Movement of water **through** the soil and its **layers**, typically **downward** through the soil profile
Groundwater flow	Movement of water through the **subsurface** soil layers, often feeding into **aquifers** and other groundwater reserves
Biological mixing	**Movement** of soil particles and materials by soil organisms, including burrowing animals, earthworms and root growth Contributes to the **mixing** of **organic matter** and **minerals**, enhancing soil structure and nutrient distribution
Aeration	Process by which **air** is **circulated** through and mixed with soil
Erosion	Process by which soil particles are detached and transported by **wind** or **water**

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Leaching	Process in which **minerals** dissolved in water are moved **downwards** or **horizontally** through the soil profile Results in the **loss of nutrients** from the root zone, particularly in areas with **high rainfall** or **excessive irrigation**

Soil System Transformations

Transformation	**Description**
Decomposition	The process of organic matter **breakdown** by **microorganisms**, results in the release of carbon dioxide, water and nutrients Involves the conversion of **complex organic compounds** into **simpler forms**
Weathering	**Physical** and **chemical** processes that break down rocks and minerals into **smaller particles**, contribute to soil formation Includes physical weathering (mechanical breakdown) and chemical weathering (alteration of minerals through chemical reactions)
Nutrient cycling	The cycling of nutrients within the soil-plant system involves uptake, assimilation, release and recycling of elements like nitrogen, phosphorus and potassium Ensures the **availability** and **redistribution** of essential nutrients for **plant growth**
Salinisation	Accumulation of soluble salts in the soil, which can be detrimental to plant growth and soil structure It often results from improper irrigation practices, high evaporation rates, or natural soil mineralisation
Humification	Process of organic matter transformation into **stable humus** It involves the accumulation of complex organic compounds, leading to the dark colouration and **improved water-holding capacity** of soil Contributes to soil fertility and structure

Examiner Tips and Tricks

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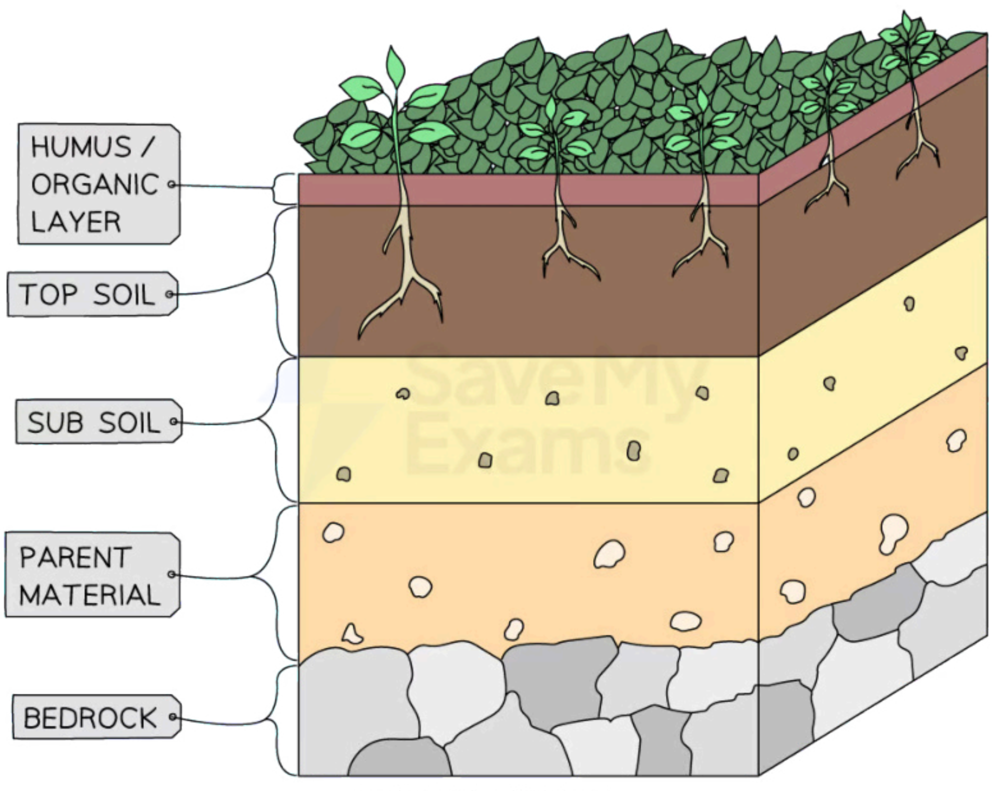
It is important you know the definition of processes like infiltration, percolation, decomposition and salinisation. However, make sure you are also clear on whether these processes are **transfers** or **transformations**.

If the process involves changing location, it is a transfer. Transformations involve a change in chemical nature, state or energy.

Soil Profiles

- Soil profiles develop as a result of long-term interactions within the soil system
- These interactions and processes form **distinct layers** known as **horizons**
- These layers vary in **composition** and **characteristics** from the surface downward
  - This reflects the processes of soil formation over time
- Profiles usually transition from **organic-rich** layers near the **surface** to more **mineral-rich** layers **deeper down**
  - These lower layers generally contain more inorganic material



Soil profiles are formed of different layers (horizons) that develop in soils over time

- The development of soil profiles is influenced by factors such as:
  - Climate
  - Vegetation
  - Parent material
  - Time

Real-world examples

- **Tropical rainforests:**
  - Often have thick, organic-rich top soils due to rapid decomposition and high biological activity
- **Desert regions:**
  - Characterised by shallow, mineral-dominated soils with distinct horizons due to low organic matter input and minimal leaching
- **Peat soils in boreal forests (e.g. Scandinavia):**
  - Soils characterised by thick layers of partially decomposed organic matter (peat)
  - This is due to the cold, wet conditions that slow down decomposition rates, resulting in highly acidic and nutrient-poor soils
- **Prairie soils in the Great Plains, USA:**
  - Soils known for their deep, dark topsoil have developed over millennia
  - This is due to the accumulation of organic matter from grassland vegetation and the semi-arid climate

Examiner Tips and Tricks

You don't need to learn these specific examples, they are just provided here to demonstrate how different factors can affect the soil profiles of different ecosystems.

Just recall that soils have distinct profiles that are composed of individual horizons.

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Functions & Properties of Soils

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Soil Functions

- Soils carry out important functions in **terrestrial ecosystems**
- Soils support plant growth, biodiversity and biogeochemical cycles

Medium for plant growth

- Soils act as a natural seed bank, providing a substrate for germination and root development
- They store water crucial for plant hydration, nutrient uptake and photosynthesis
- They store **essential nutrients** for plants such as nitrogen, phosphorus and potassium
- These essential nutrients support healthy plant growth
    - For example, in the Amazon rainforest, the fertile soils contain high levels of nutrients
    - This allows these soils to support diverse plant life
    - This has led to the Amazon's status as the world's largest tropical rainforest

Contribution to biodiversity

- Soils provide habitats and niches for a wide range of species
- Soil communities support **high biodiversity**, including microorganisms, animals and fungi
    - For example, in the UK, ancient woodlands are rich in soil biodiversity
    - Their soils support rare fungal species that play important roles in nutrient cycling

Role in biogeochemical cycles

- Soils allow the **recycling of elements** essential for life, such as carbon, nitrogen and phosphorus
- Dead organic matter from plants is a major input into soils, where it **decomposes** and **releases nutrients**

Carbon storage dynamics

- Soils can function as carbon sinks, stores, or sources, depending on environmental conditions
- For example, tropical forest soils generally have low carbon storage due to rapid decomposition rates
    - This is because the warm and moist conditions accelerate the decomposition of organic matter by microorganisms

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- This causes carbon to be released back into the atmosphere quickly
- Tundra, wetlands and temperate grasslands can accumulate large amounts of carbon in their soils
    - This is because colder temperatures and waterlogged conditions slow down the decomposition process
    - This allows organic matter to build up in the soil over time without being fully decomposed and released as CO_2

Soil Texture

What is soil texture?

- Soil texture describes the physical make-up of soils
- It depends on the **proportions** of **sand**, **silt**, **clay** and **humus** within the soil
- Soil texture influences various soil properties and plant growth

Components of soil texture

- **Sand:** larger particles that feel gritty
- **Silt:** medium-sized particles that feel smooth
- **Clay:** very fine particles that feel sticky when wet
- **Humus:** organic matter, dark brown or black, crumbly texture from partially decayed plant material

Determining soil texture

- Soil texture can be determined using several methods
- Each method provides insight into:
    - The soil's properties
    - How suitable the soil is for different plants and crops

1. **Using a soil key:**
    - A soil key is a more **systematic** and **detailed** method
    - It uses a step-by-step guide to classify soil texture based on specific criteria
    - The key helps identify the proportions of sand, silt, and clay by guiding the soil tester (the user) through a series of questions or observations
    - It often includes descriptions of soil behaviour when moistened and manipulated

- Soil keys are often used in more **formal** or **scientific settings** where **precise classification** is needed

2. **Feel test:**
    - The feel test is a **simpler** method
    - It involves rubbing moistened soil between the fingers to assess its texture
    - Sand feels gritty, silt feels smooth and clay feels sticky
    - It is a quick, informal assessment that can be done in the field without additional tools
    - The feel test is commonly used by farmers, gardeners, and others needing a **quick assessment**
3. **Laboratory test:**
    - The laboratory test involves mixing soil with water and allowing it to settle into distinct layers
    - This method provides a clear visual representation of the proportions of sand, silt and clay
    - Any large debris like rocks, roots, or organic matter, are first removed from the sample
    - The sample is added to a transparent container
    - Water is added and the container is shaken vigorously
    - The container is left on a flat surface and left undisturbed (e.g. for 24 hours)
    - Silt settles first, then clay, and finally sand
    - The thickness of these layers can be measured to determine their proportions

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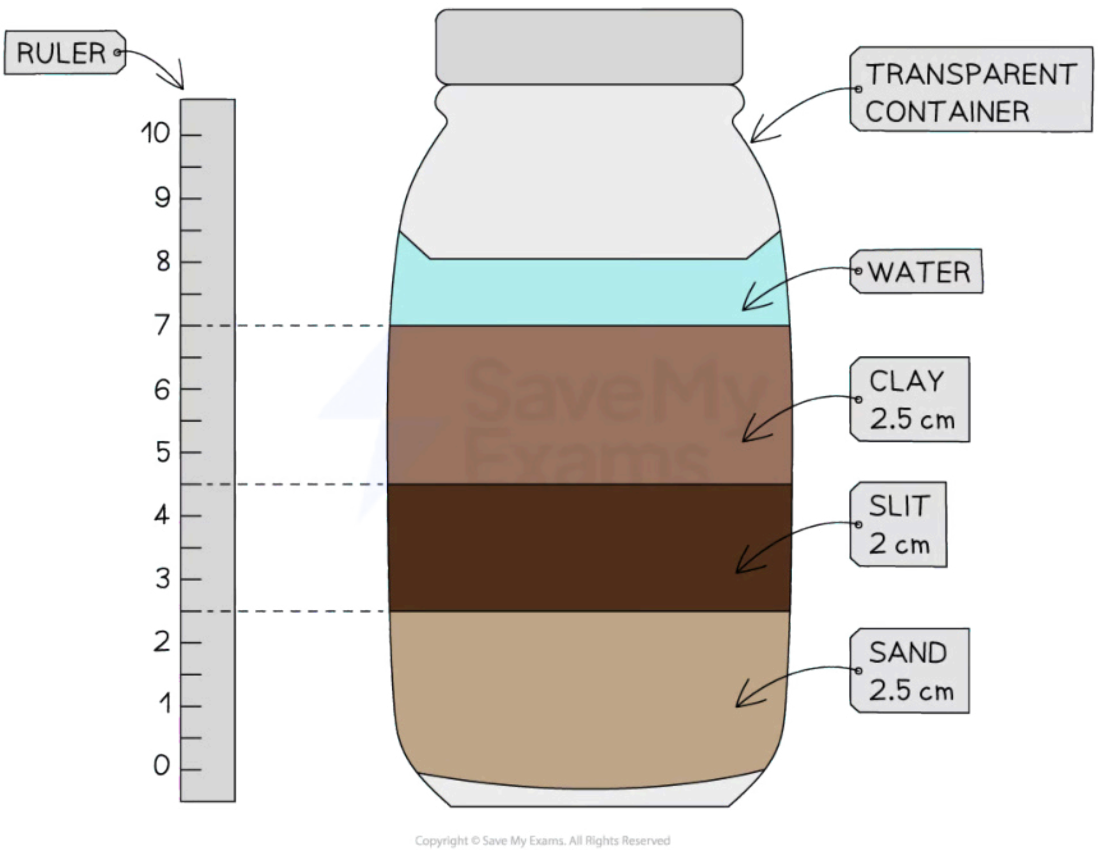

After shaking, soil components settle at different speeds, leading to clear layers that can be measured

- In the example above:
  - The sand layer is 2.5 cm
  - The silt layer is 2 cm
  - The clay layer is 2.5 cm
  - The total thickness is 7 cm
- These measurements can be used to calculate the **percentage** of each soil component:
  - The percentage of sand is (2.5 ÷ 7) × 100 = 35.7%
  - The percentage of silt is (2 ÷ 7) × 100 = 28.6%
  - The percentage of clay is (2.5 ÷ 7) × 100 = 35.7%

Influence of soil texture on primary productivity

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- Soil texture affects primary productivity by influencing:
  - Nutrient availability
  - Water retention
  - Soil aeration
- **Nutrient retention vs. leaching:**
  - Humus contributes significantly to the nutrient content of soils
  - It lies beneath leaf litter and has a loose, crumbly texture
  - It is formed by the partial decay of dead plant material
  - Soils with more humus **retain nutrients better**
  - Less humus means nutrients are more likely to be **washed away**
    - For example, forest floors, like those in the New Forest in Hampshire, UK, have rich humus layers that support diverse plant life
- **Water retention vs. drainage:**
  - Clay and humus-rich soils retain water well
  - **Sandy soils drain quickly** but may not retain enough moisture for some plants
    - For example, sandy soils in East Anglia, UK, require more frequent irrigation for crops
- **Aeration vs. compaction or waterlogging:**
  - Well-aerated soils support **root growth** and **beneficial microbial activity**
  - Clay soils can become compacted, limiting aeration
  - Humus helps improve aeration in clay soils
    - For example, compacted clay soils in urban areas often need organic matter added to improve their structure and aeration

Soil Profiles & Horizons (HL)

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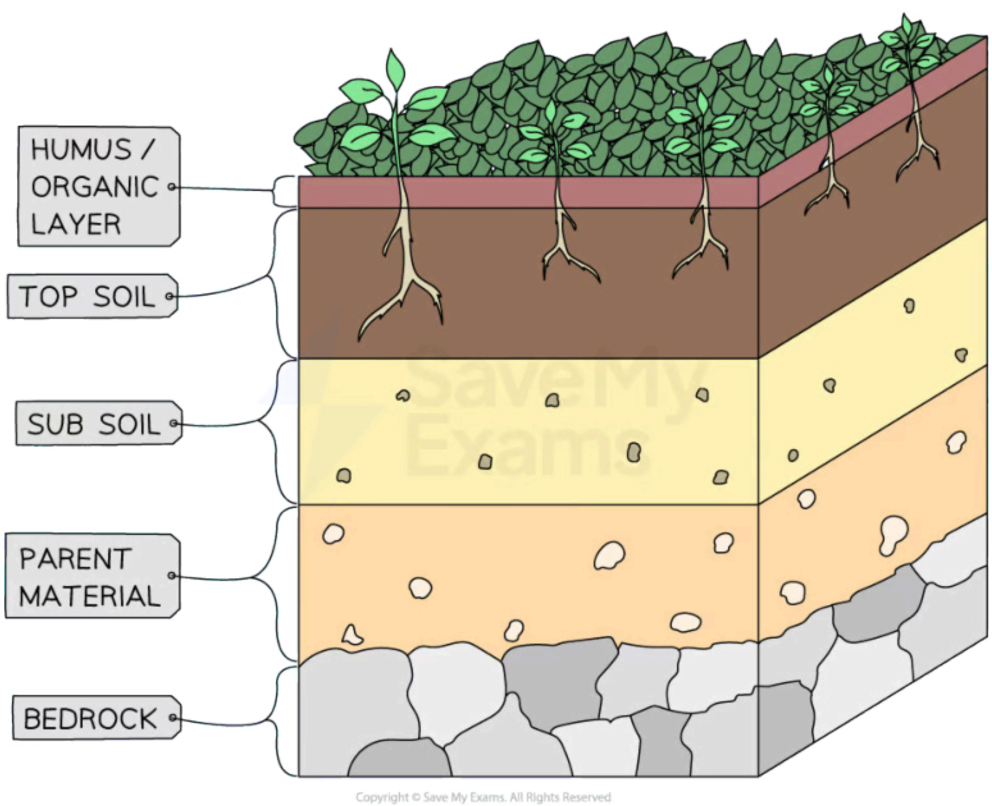
Soil Profiles

- Soils develop a stable, layered structure known as a **profile**
- A soil profile is a **vertical section of soil**
  - It shows distinct layers from the surface down to the underlying rock
- Soil profiles help in **classifying soils** by examining their composition, colour, texture, and structure
  - Soil profiles can provide information about the soil's history, nutrients, and suitability for various uses



Soil profile diagram

Soil profile photograph (Richard Webb, CC BY-SA 4.0)

Layer characteristics

- **Organic material**:
  - The uppermost part of the soil is often rich in decomposed plants and animal material
  - This supports plant growth
- **Mineral content**:
  - Different layers show varying mineral levels, often influenced by water movement
  - Some layers have nutrients while others are nutrient-poor due to leaching
- **Texture and colour**:
  - Soil layers differ in colour and texture, with colours often indicating the presence of certain minerals (e.g., red soils may have high iron content)

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    - Texture varies from sandy to clay-rich, affecting water retention
- **Rock fragments and weathered material**:
    - Deeper layers contain larger pieces of rock and weathered parent material, providing a foundation for the soil layers above

Using soil profiles to understand soil processes

Transfer processes

- **Movement of water and nutrients**:
    - Water carries nutrients downward (leaching) or upwards (capillary action), affecting the nutrient availability in each layer
- **Organic matter movement**:
    - Decomposed organic material often moves downward, enriching the upper soil layers

Transformation processes

- **Decomposition**:
    - Organic matter breaks down, enriching soil with nutrients essential for plants
- **Weathering**:
    - Rock and parent material slowly break down, creating finer particles that contribute to soil formation

Classification of soil types by profile

- Different soil types have distinct profiles, reflecting the climate, vegetation, and biome in which they are found:
    - **Brown earth soils**:
        - Common in temperate deciduous forests
        - These soils are fertile with nutrient-rich upper layers, supporting diverse plant growth
    - **Oxisols**:
        - Found in tropical rainforests
        - These soils have deep, red-coloured profiles rich in iron and aluminium, formed through intense weathering and significant nutrient leaching
    - **Podzols**:
        - Associated with coniferous forests

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    - These soils are acidic with lighter layers, as nutrients are heavily leached out, leading to reduced fertility
  - **Aridisols**:
    - Common in desert biomes
    - These soils contain minimal organic material, with shallow profiles and limited nutrients, often sandy or rocky in texture

Soil Horizons

- Soil profiles are made up of different **horizons** (layers)
- Over a **long period of time**, interactions and processes within the soil system produce these horizons
- Soil profile diagrams provide a visual representation of the horizons present in a soil system
  - There are **six** horizons

O horizon

- The **uppermost layer** is the **O horizon**, also known as the **organic** horizon
- It is composed mainly of organic matter such as leaf litter, decaying plant material and organic debris
- **Dark** in colour due to high organic content
- It is **rich in nutrients**
- It serves as a site for **nutrient cycling** and **organic material decomposition**
- Provides nutrients for **plant growth** and habitat for microorganisms
- Easily eroded by wind and water, especially in disturbed areas such as farmland

A horizon

- The A horizon, also called the **topsoil** or **mixed layer**
- It is a mixed mineral and organic horizon
- Also **dark** in colour due to the accumulation of organic matter
- Essential for plant growth as it contains high levels of organic material, microorganisms, and nutrients
- It provides a favourable environment for **root development**
- Intensive farming can **deplete** or **remove** this layer, increasing the need for **fertilisers** to maintain soil fertility

E horizon

- The E horizon, also known as the **eluvial** or **leached** horizon
- Due to the **downward movement** of water, it is characterised by the **leaching** or **removal** of **minerals** and **nutrients**
- It often appears **lighter in colour** than the surrounding horizons

B horizon

- The B horizon, also called the **illuvial** or **deposited** horizon (sometimes called **subsoil** or **mineral soil**)
- It is the layer where **minerals** and **nutrients** leached from the upper horizons **accumulate**
- It often exhibits different colours, textures, or chemical properties compared to the horizons above and below it
- Higher in clay, iron, and aluminium compounds compared to the upper layers
- Holds water and nutrients that can be accessed by deeper plant roots, but is less fertile than topsoil

C horizon

- The C horizon represents the **weathered parent material** from which the soil has formed
- It is composed of partially weathered rock fragments and may contain **limited organic matter**
- The properties of the C horizon influence the development and characteristics of the upper horizons

R horizon

- The R horizon, also known as **bedrock**
- It is the underlying solid rock that forms the base of the soil profile
- It is often **unweathered**
- It is relatively **unaffected by biological activity** and represents the original geological material from which the soil formed

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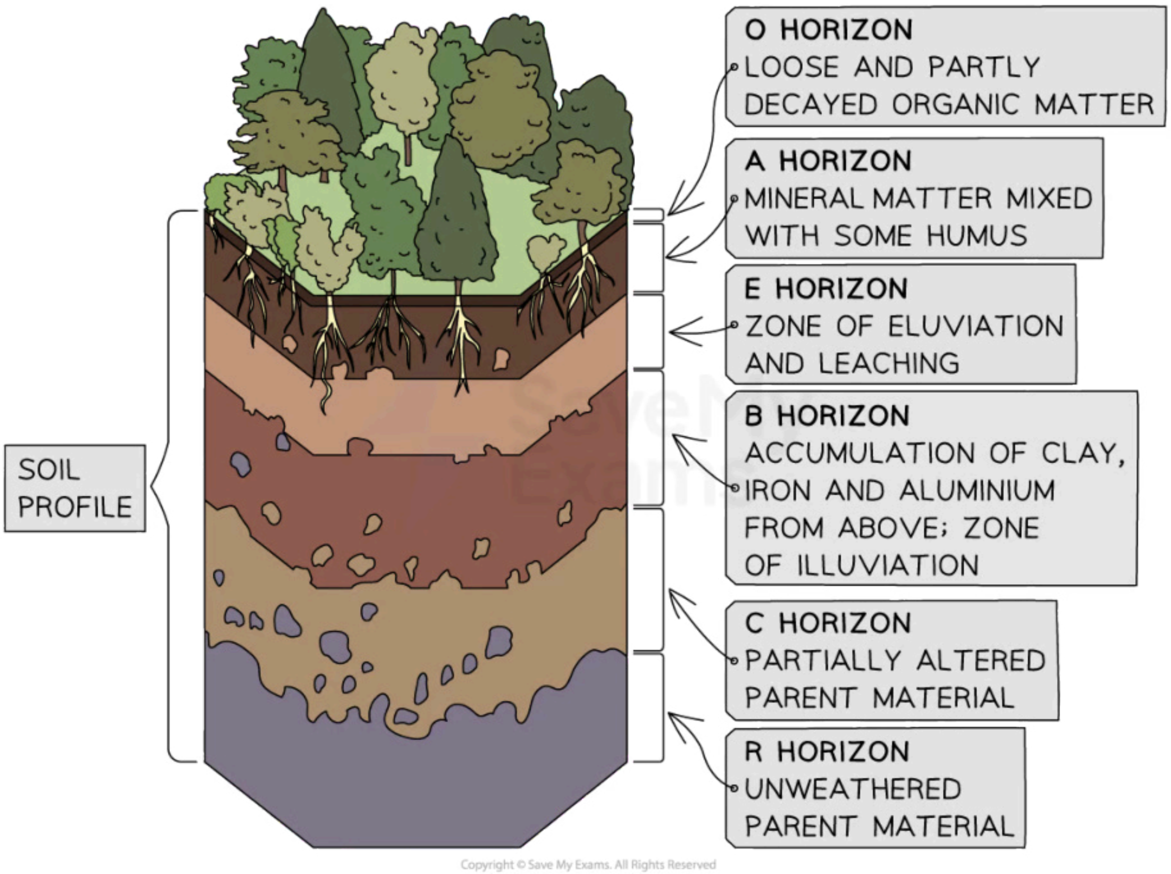
Your notes



A soil profile is a representation of the different horizons present in a soil system

- The distinctive horizons in a soil profile show a **transition** from more organic components in the upper surface to more inorganic components in the layers below
- These layered horizons provide information about the soil's
  - Composition
  - Nutrient content
  - Water-holding capacity
  - Drainage characteristics
- They help scientists, farmers, and land managers understand the **properties** and **fertility** of soils
  - This helps them to make informed decisions regarding land use, crop selection and soil conservation practices

Soil horizons in natural vs. agricultural systems

Natural systems

- In undisturbed soils, **all horizons** (O, A, B, and C) are typically present
- This allows rich, stable ecosystems to develop with diverse plant and animal life

Agricultural systems

- In areas with intensive agriculture, **only B and C horizons** may remain intact due to erosion and loss of topsoil
- **Impact on fertility**:
  - Loss of the O and A horizons reduces soil fertility and requires significant fertiliser use
- **Sustainability concerns**:
  - Removing the organic-rich upper layers leads to long-term soil degradation, requiring careful management to restore soil health
- **Crop rotation and cover crops**:
  - Using cover crops or rotating crops can reduce soil erosion and maintain soil fertility in agricultural systems
- **Reduced tillage**:
  - Minimising tilling helps to maintain soil structure, preserving the O and A horizons and supporting long-term soil health

Examiner Tips and Tricks

The key horizons you should be aware of are: organic layer, mixed layer, mineral soil and parent rock (**O**, **A**, **B** and **C** horizons). Make sure you are clear on the **differences** between these horizons, particularly the organic richness of O and A compared to the mineral-rich B and C.

Factors Influencing Soil Formation (HL)

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Factors Influencing Soil Formation

- There are a number of factors that affect how soil develops, including:
  - Climate
  - Organisms
  - Geomorphology
  - Geology
  - Time

Climate factors

- **Temperature variations**: climate affects soil formation through temperature differences in various biomes
  - **Tropical regions**:
    - High temperatures and humidity promote rapid weathering and decomposition
    - This results in deep, nutrient-rich soils such as oxisols
  - **Temperate regions**:
    - Moderate temperatures and seasonal variations lead to well-defined soil horizons, like those found in brown earth soils
  - **Polar regions**:
    - Cold temperatures slow down biological processes
    - This results in thin, poorly developed soils with limited organic material
- **Precipitation levels**: the amount and intensity of rainfall also influence soil characteristics
  - **High rainfall**:
    - In areas with heavy rainfall, leaching occurs, washing away nutrients and minerals from the topsoil
    - This leads to the formation of acidic soils like podzols
  - **Low rainfall**:
    - In arid regions, evaporation is greater than precipitation

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- This results in soil salinisation and the development of dry, nutrient-poor soils such as aridisols

Organisms

- The presence of plants, animals, and microorganisms significantly influences soil formation
  - **Plants**:
    - Roots help break down parent material and contribute organic matter to the soil, enriching its nutrient content
  - **Soil fauna**:
    - Earthworms and other soil organisms aerate the soil and promote nutrient mixing, enhancing soil fertility
  - **Microorganisms**:
    - Bacteria and fungi decompose organic matter, recycling nutrients and improving soil structure

Geomorphology

- **Landscape features**: the physical features of the landscape affect soil formation and characteristics
  - **Slope**:
    - Steep slopes may lead to soil erosion
    - Gentle slopes allow for deeper soil development
  - **Aspect**:
    - The direction a slope faces can influence temperature and moisture levels, affecting vegetation and soil types
    - For example, south-facing slopes in the Northern Hemisphere receive more sunlight and can support more vegetation than north-facing slopes
  - **Drainage**:
    - Well-drained areas often have drier soils with different characteristics compared to waterlogged regions, which may produce gley soils rich in organic matter

Geology

- **Types of parent material**: the mineral composition of the parent material affects soil characteristics
  - **Calcareous parent rock**:

        - Soils derived from limestone or chalk are often rich in calcium carbonate, leading to fertile, alkaline soils like rendzinas
    - **Volcanic parent rock**:
        - Soils formed from volcanic ash, known as andosols, are typically very fertile due to the presence of minerals and nutrients
- **Weathering processes**: the type of parent rock also influences how soils develop through weathering, erosion, and deposition
    - **Chemical weathering**:
        - Certain rocks, like granite, undergo chemical weathering, leading to the formation of nutrient-rich soils
    - **Physical weathering**:
        - Other rocks, like sandstone, break down through physical processes, resulting in sandy, less fertile soils

Time

- Soil formation is a gradual process that takes time to develop
    - **Soil maturity**:
        - Older soils tend to have well-defined horizons and better-developed characteristics
        - This is due to long-term weathering and biological activity
    - **Young soils**:
        - In contrast, young soils may have less developed horizons and may be less fertile
        - They have had less time for organic matter accumulation and nutrient cycling to occur

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Soil Composition and Properties (HL)

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Soil Composition and Properties

- Soil is a mixture of mineral particles, organic matter, water, and air
  - Mineral particles include sand, silt, and clay
    - These vary in size and chemical properties
  - Organic matter comes from decomposed plants and animals
    - This improves soil fertility
  - Water and air occupy spaces between soil particles
    - This is essential for plant growth and microbial activity

Differences between sand, silt and clay

- **Sand**:
  - Made up of the **largest** soil particles
    - Sand particles are **less than 2 mm** in diameter
    - Derived mainly from quartz
  - Has **low** cation-exchange capacity (CEC)
    - This means it does not hold onto nutrients well
  - Drains quickly due to large particle size
    - This limits its water retention
- **Silt**:
  - Composed of **medium-sized** particles
    - Silt particles are **less than 0.02 mm**
    - Also often derived from quartz
  - Also has a **relatively low CEC** (so holds fewer nutrients)
  - Feels smooth to the touch
  - Retains more water than sand but drains better than clay

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- **Clay**:
  - Contains the **smallest** particles
    - Clay particles are **less than 0.002 mm**
  - Has a **high CEC**
    - This allows it to hold onto and release nutrients like calcium, magnesium, and potassium
  - Has a fine, sticky texture
  - Drains poorly but retains water well

Soil structure

- Soil structure refers to the **arrangement** or **shape** of soil particles
  - Soil structure has a direct impact on primary productivity
- **Clay soils** have a high potential for nutrient exchange due to their large surface area relative to volume
  - However, they tend to become **waterlogged** and are often described as 'cold' or 'heavy'
  - In periods of drought, clay soils can shrink, leading to structural damage (e.g. cracking)
- **Sandy soils** have **excellent drainage** capabilities
  - They are commonly referred to as 'light' soils
- **Silt soils** can be easily **compacted** if ploughed when wet
  - This can negatively affect soil structure and plant growth
- **Loam soils** are a **balanced combination of sand, silt, and clay**
  - They are often considered the **most favourable** for **cultivation**
  - They are easy to work with, drain well, retain moisture and nutrients, and provide good aeration
  - As a result, loam soils have the highest potential for **primary productivity** (plant growth)

Soil Properties Summary Table

	Sand	Loam	Clay
Nutrient status	Poor	Moderate	Good
Water infiltration rate	High	Medium	Low

Water holding capacity	Low	Medium	High
Aeration	Good	Moderate	Poor
Potential to hold organic matter	Low	Medium	High
Ease of working (ease with which soil can be manipulated)	Good	Moderate	Poor

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Soil texture triangles

- A soil texture triangle is a graphical tool used to classify soil types based on their **relative proportions** of **sand**, **silt**, and **clay**
  - The three side of the triangle represent the proportions of the different soil particle sizes: sand, silt, and clay
  - The soil texture triangle allows for easy visualisation and classification of soil types based on their **particle size distribution**
  - By locating the percentage of sand, silt, and clay on the triangle, it is possible to determine the **textural class** of a soil sample (e.g. sandy loam, silty clay, etc.)

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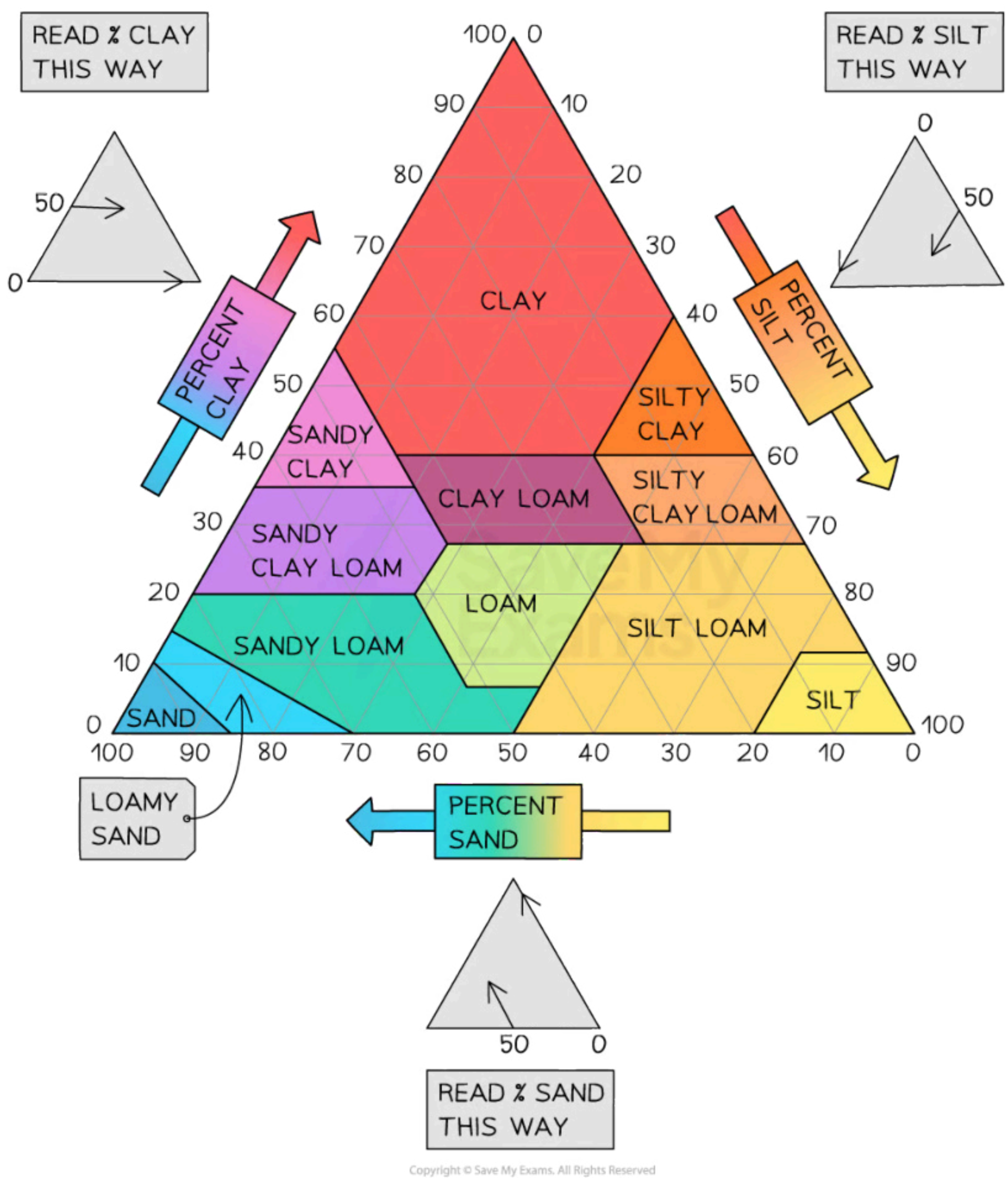


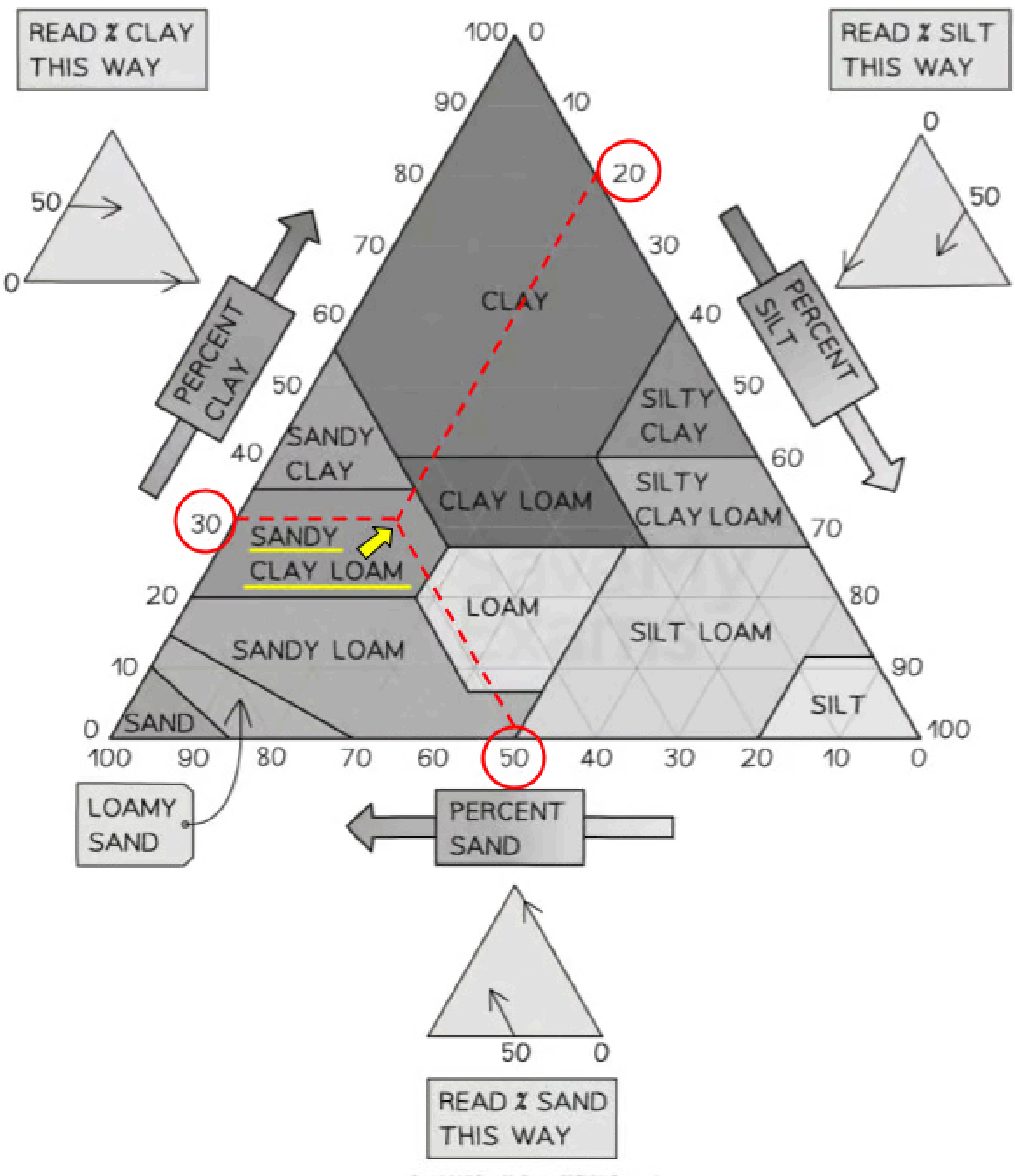
Soil texture triangles are used to classify soil types based on their relative proportions of sand, silt, and clay

Worked Example

A soil sample is found to contain 50% sand, 20% silt and 30% clay. Using the soil texture triangle, determine the textural class of the soil that the sample was taken from.

Answer

The textural class of the soil that this sample was taken from is sandy clay loam.



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Key soil properties

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- **Texture**:
  - Soil texture describes the proportions of sand, silt, and clay
  - This information can help to predict how soil behaves in terms of water and nutrient retention
- **Organic matter**:
  - Organic matter improves soil structure, water-holding capacity, and nutrient availability
  - Healthy soils contain organic matter from decomposing plants and animals, vital for supporting plant growth
- **Water content and infiltration**:
  - Soil water content measures **how much water the soil can hold**, which depends on texture and organic matter
  - Infiltration rate measures **how quickly water enters the soil**, with sandy soils allowing faster infiltration than clay-rich soils
- **Bulk density**:
  - Bulk density measures the mass of soil per unit volume
    - This indicates the level of **compaction**
  - Lower bulk density is ideal for plant growth as it suggests good soil structure and easier root penetration
- **Soil colour**:
  - Soil colour provides clues about its composition and conditions
    - Dark soils are often rich in organic matter, indicating high fertility
    - Red or yellow soils contain iron oxides, indicating good aeration
    - Greyish-blue colours indicate waterlogging
- **pH**:
  - Soil pH measures how acidic or alkaline the soil is, affecting nutrient availability
    - Most plants grow best in neutral to slightly acidic soils (**pH 6–7**)
    - **Acidic** soils (below pH 6) **limit nutrient availability**
    - **Alkaline** soils (above pH 7) often leading to **nutrient imbalances**

Examiner Tips and Tricks

Triangular soil texture graphs are often read **incorrectly**. Remember—the sum of the percentages **must add up to 100%**, so always check this. The diagram above shows how to correctly read off percentages for clay, silt and sand from each of the three axes.

Your notes

Your notes

Soil Carbon Release (HL)

Soil Carbon Release

- Soil is a major carbon store
  - Soils hold approximately twice as much carbon as the atmosphere
- Soils store a significant amount of carbon in the form of **organic material** and **carbon compounds**
  - When soils break down organic matter, carbon is released into the atmosphere as:
    - **Carbon dioxide (CO_2)**
    - **Methane (CH_4)**
  - This carbon release can contribute to global greenhouse gas levels and climate change

Factors that lead to soil carbon release

- **Decomposition**:
  - Microorganisms in the soil decompose organic matter
  - This releases CO_2 when oxygen is available
  - In waterlogged, low-oxygen conditions (such as wetlands), decomposition produces CH_4 instead
- **Impacts of global warming**:
  - Rising temperatures accelerate decomposition
  - This leads to faster release of CO_2 and CH_4
  - This creates a feedback loop where more carbon release leads to more warming, which then increases soil carbon release even further
- **Agricultural practices**:
  - Tilling (turning over the soil) exposes deeper layers to air, increasing decomposition rates and CO_2 release
  - Use of fertilisers and other agricultural chemicals can also increase microbial activity, which increases CO_2 emissions from soil
- **Drainage of wetlands**:
  - Wetlands are important carbon stores

- Draining wetlands for agriculture or development introduces oxygen to previously waterlogged soils
- This exposure speeds up decomposition, releasing CO_2 and CH_4 into the atmosphere

Tipping points in carbon release

- A tipping point in soil carbon release may be reached if rising temperatures lead to rapid and uncontrollable carbon emissions
- Once past this point, the release of carbon can further increase temperatures
  - This could create a self-reinforcing cycle of warming
- For example, **permafrost thawing in the Arctic**:
  - As Arctic temperatures rise, permafrost thaws, releasing both CO_2 and CH_4, which were previously trapped in **frozen soil**
  - Thawing of permafrost is a major concern because it contains large amounts of carbon
  - This amount of carbon could speed up global warming if it enters the atmosphere

Methane clathrates

- Methane clathrates are ice-like structures containing **trapped methane**
  - They are found in permafrost and under the ocean floor
- If temperatures rise enough to **melt** these clathrates, they release large amounts of methane
  - As methane is a very **potent** greenhouse gas, this could **accelerate climate change**

Examiner Tips and Tricks

Make sure you are familiar with the concept of a tipping point and understand how this applies to soil carbon release.