DP IB Environmental Systems & Societies (ESS): SL

Your notes

Introduction to Soil Systems

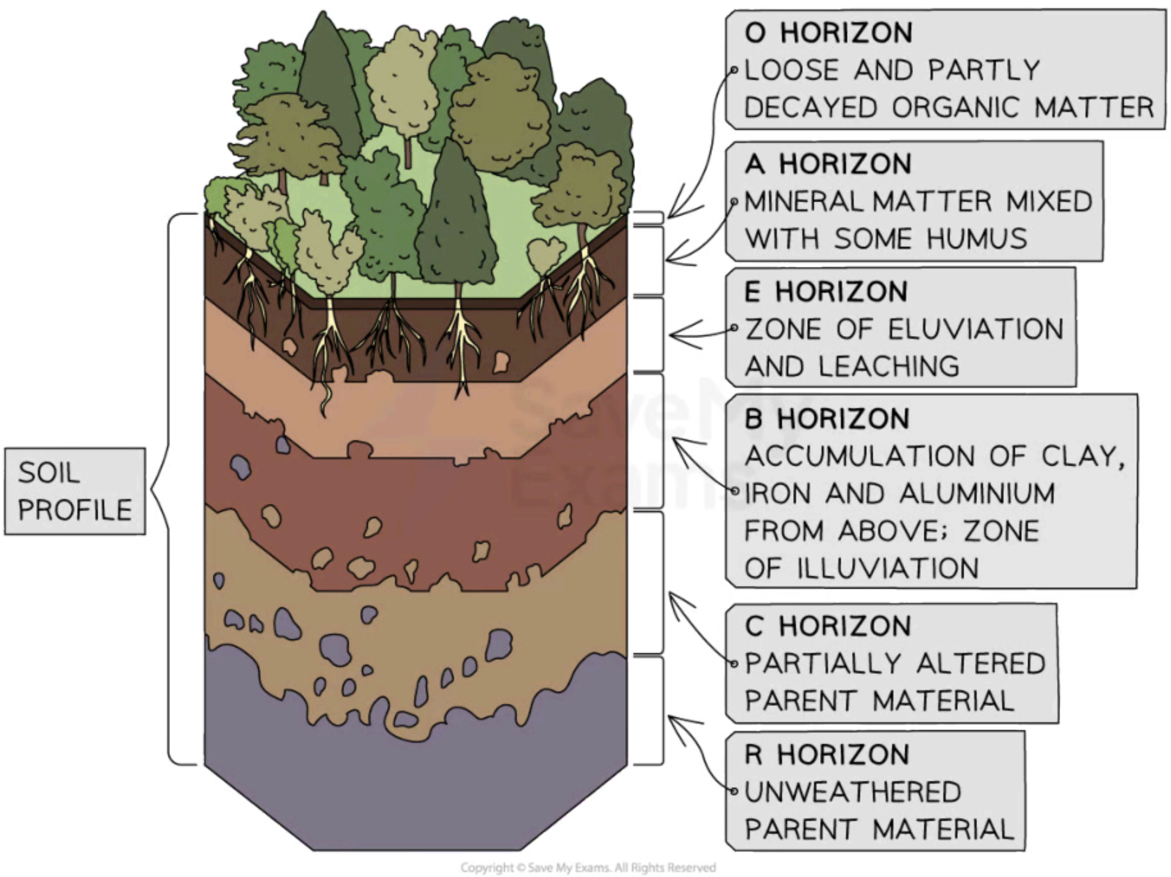
Contents

Soil Profiles

Your notes

Soil Profiles

- Soil profiles provide a visual representation of the different **layers** or **horizons** present in a soil system
  - These horizons reflect the processes and materials that have shaped the soil over time
  - There are **six** main horizons



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

O horizon

- The O horizon, also known as the **organic** horizon, is the uppermost layer

Your notes

  - It is composed mainly of organic matter such as leaf litter, decaying plant material, and organic debris
  - It is **rich in nutrients** and serves as a site for nutrient cycling and **organic material decomposition**

A horizon

- The A horizon, also called the **topsoil**, is a mixed mineral and organic horizon
  - It is usually darker in colour due to the accumulation of organic matter
  - This layer is important for plant growth as it contains nutrients and provides a favourable environment for **root development**

E horizon

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

B horizon

- The B horizon, also called the **illuvial** or **deposited** horizon, 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

C horizon

- The C horizon represents the **weathered parent material** from which the soil has formed
  - It is typically 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**, 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
- These layered horizons in a soil profile provide information about the soil's composition, nutrient content, water-holding capacity, and drainage characteristics

- They help scientists, farmers, and land managers understand the **properties** and **fertility** of soils, enabling them to make informed decisions regarding land use, crop selection, and soil conservation practices

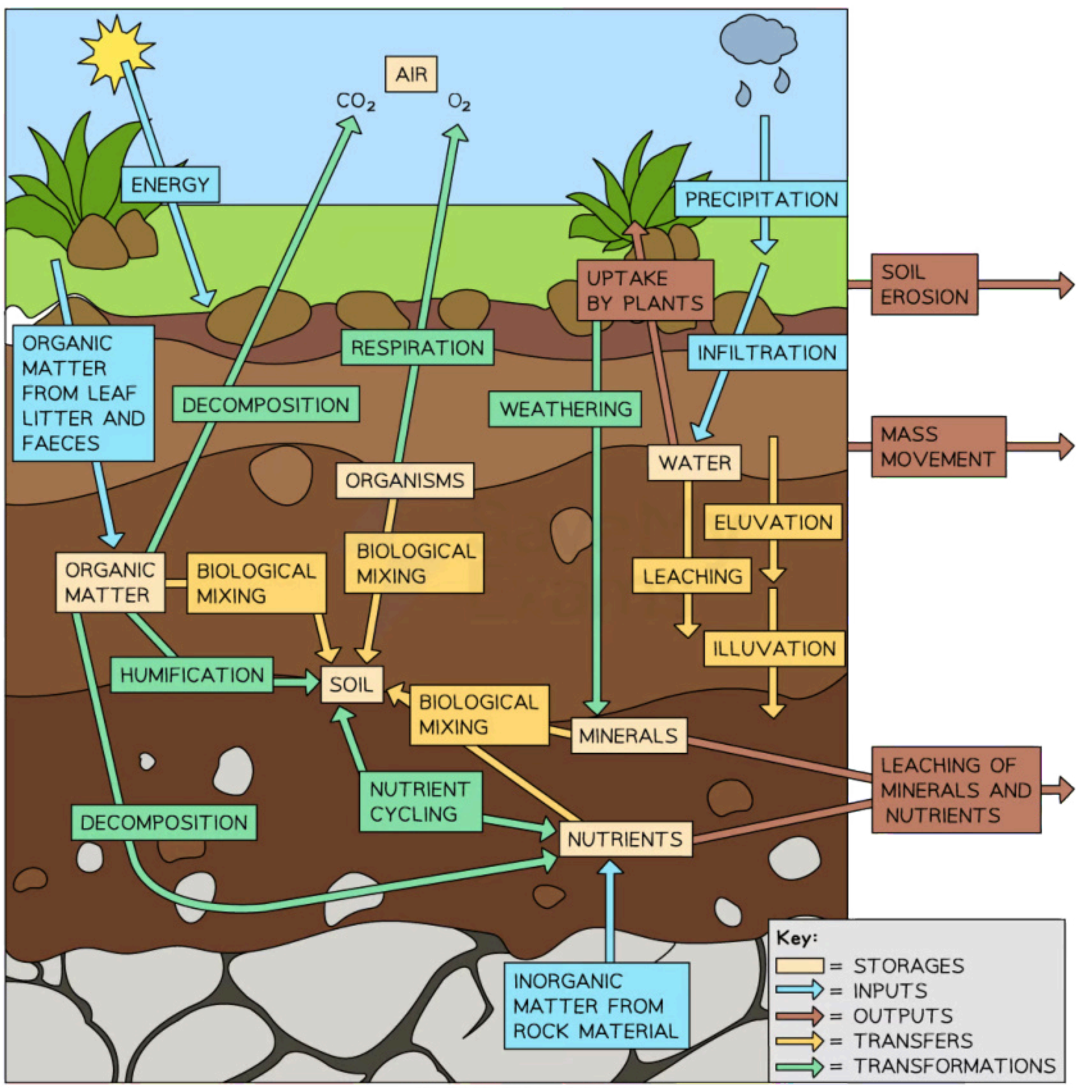
Your notes

Soil Systems

Your notes

Soil Systems

- 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)



Your notes

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

Soil System Storages

Storage	Description
Organic matter	Refers to the **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	Refers to elements necessary for **plant growth**, such as nitrogen, phosphorus, potassium - nutrients are stored in the soil and are made available to plants through various biological and chemical processes
Minerals	Refers to the **inorganic** components of the soil derived from **weathering of rocks** and minerals - they contribute to the physical properties and **fertility** of the soil
Air	The 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
Organic matter	Includes inputs of plant material (e.g. **leaf litter**) and other organic materials (e.g. animal **faeces**) that contribute to the organic matter content in the soil
Inorganic matter from rock material	Represents the **mineral composition** derived from parent materials (e.g. **bedrock**) and the weathering of exposed rock at the soil surface
Precipitation	Rainfall or snowfall that provides water to the soil system

Infiltration	The process by which water enters the soil **from the surface**
Energy	**Solar radiation** and heat influence soil temperature and biological activities

Your notes

Soil System Outputs

Output	Description
Leaching	The loss of **dissolved minerals** and **nutrients** from the soil into streams, rivers, lakes and oceans through **water movement**
Uptake by plants	The **absorption** of **nutrients** and **water** by **plant roots** for growth and development
Mass movement	The **downslope movement** of soil particles due to **gravity**, such as landslides or soil creep
Soil erosion	The removal of soil particles by water or wind, leading to the **loss of topsoil** and degradation of soil quality

Soil System Transfers

Transfer	Description
Biological mixing	The movement of soil particles and materials by soil organisms, including burrowing animals, earthworms, and root growth - it contributes to the mixing of organic matter and minerals, enhancing **soil structure** and **nutrient distribution**
Leaching	The process in which minerals dissolved in water are moved **downwards** or **horizontally** through the soil profile - it can result in the **loss of nutrients** from the root zone, particularly in areas with **high rainfall** or **excessive irrigation**
Eluviation	The removal of fine **particles**, such as clay and dissolved organic matter, from the upper layers of the soil by the **downward movement of water**
Illuviation	The **deposition** of materials, including minerals and organic matter, in **lower soil layers** - it occurs as a result of leaching and eluviation processes, leading to the accumulation of materials in specific horizons

Your notes

Soil System Transformations

Transformation	**Description**
Decomposition	The process of organic matter **breakdown** by **microorganisms**, resulting in the release of carbon dioxide, water, and nutrients - it involves the conversion of **complex organic compounds** into **simpler forms**
Weathering	The **physical** and **chemical** processes that break down rocks and minerals into **smaller particles**, contributing to soil formation - it 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, involving uptake, assimilation, release, and recycling of elements like nitrogen, phosphorus, potassium - ensures the **availability** and **redistribution** of essential nutrients for **plant growth**
Humification	The 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
Mineralisation	The decomposition (i.e. oxidation) of the chemical compounds in organic matter, by which the nutrients in those compounds are released in **soluble inorganic forms** that may be **available to plants** e.g. the conversion of organic nitrogen compounds into inorganic forms, particularly ammonium (NH_4^+) and nitrate (NO_3^-) - it occurs through **microbial activity**, releasing nitrogen for plant uptake and contributing to the **nutrient pool** in the soil

Your notes

Soil Structures & Properties

Soil Structures & Properties

- Soils vary greatly in their structure and properties, with distinct characteristics that influence their ability to promote primary productivity
- Sand, clay, and loam soils differ in their mineral and nutritional content, drainage, water holding capacity, air spaces, biota, and their potential to hold organic matter
- Understanding these soil properties is crucial for comprehending their impact on plant growth, nutrient cycling, and the overall health and functioning of ecosystems

Photo by Dylan de Jonge on Unsplash

Soil is a fundamental component of terrestrial ecosystems, serving as a vital medium for plant growth and supporting the intricate web of life in the natural world

Sand Soils

- **Mineral content**: Dominated by large particles of sand, primarily composed of silica and other minerals
- **Nutritional content**: Typically low in organic matter and nutrients, as sand particles do not have a high capacity for nutrient retention

Your notes

- **Drainage**: Excellent drainage due to the large pore spaces between sand particles, allowing water to move quickly through the soil
- **Water holding capacity**: Low water holding capacity as sand particles have limited ability to retain water
- **Air spaces**: Sand soils have ample air spaces due to the large particle size, facilitating oxygen availability for plant roots and soil organisms
- **Biota**: Generally lower microbial activity and lower diversity of soil organisms compared to other soil types
- **Potential to hold organic matter**: Low potential to hold organic matter, as sand particles do not have strong binding capacity

Clay Soils

- **Mineral content**: Dominated by small clay particles, composed of various minerals such as silicates and aluminum oxides
- **Nutritional content**: Clay soils often have higher nutrient content and cation exchange capacity, allowing them to retain and supply nutrients to plants
- **Drainage**: Poor drainage due to the small particle size and compactness, which limits water movement through the soil
- **Water holding capacity**: High water holding capacity as clay particles have the ability to hold water tightly
- **Air spaces**: Clay soils have fewer air spaces due to the compactness of the particles, leading to limited oxygen availability for roots and soil organisms
- **Biota**: Clay soils can support a diverse range of soil organisms due to their ability to retain water and nutrients
- **Potential to hold organic matter**: High potential to hold organic matter, as clay particles have strong binding capacity and can retain organic compounds.

Loam Soils

- **Mineral content**: Loam soils have a balanced mixture of sand, silt, and clay particles, providing a combination of different mineral compositions
- **Nutritional content**: Loam soils generally have a moderate nutrient content and cation exchange capacity, allowing for adequate nutrient retention and availability
- **Drainage**: Moderate drainage characteristics, providing a balance between water movement and retention
- **Water holding capacity**: Loam soils have a moderate water holding capacity, retaining enough water for plant use while allowing excess water to drain

Your notes

- **Air spaces**: Loam soils have a balanced structure, with sufficient air spaces for root respiration and soil organism activity
- **Biota**: Loam soils support diverse soil biota, including microorganisms, earthworms, and other soil organisms
- **Potential to hold organic matter**: Loam soils have a moderate potential to hold organic matter, as they provide a suitable environment for organic material decomposition and nutrient cycling

Soil Properties Summary Table

Property	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

Primary Productivity of Different Soils

- The **structure** and **properties** of soils directly influence their ability to promote primary productivity:
  - Nutrient content affects the availability of essential elements for plant growth
  - Water holding capacity and drainage characteristics determine the availability of water to plants (water being essential for **photosynthesis**), whilst **preventing waterlogging** (which can be damaging for some plants and therefore lower primary productivity)
  - Air spaces ensure **oxygen availability** for root respiration and soil organisms
  - Biota, including microorganisms, play crucial roles in **nutrient cycling**, organic matter **decomposition**, and symbiotic relationships with plants (e.g. nitrogen-fixing bacteria)
  - The potential to hold **organic matter** influences soil **fertility**, as organic matter provides essential **nutrients** and **improves soil structure**
- The combination of these factors in different soil types determines their suitability for supporting primary productivity, influencing the growth and health of plants and consequently the overall

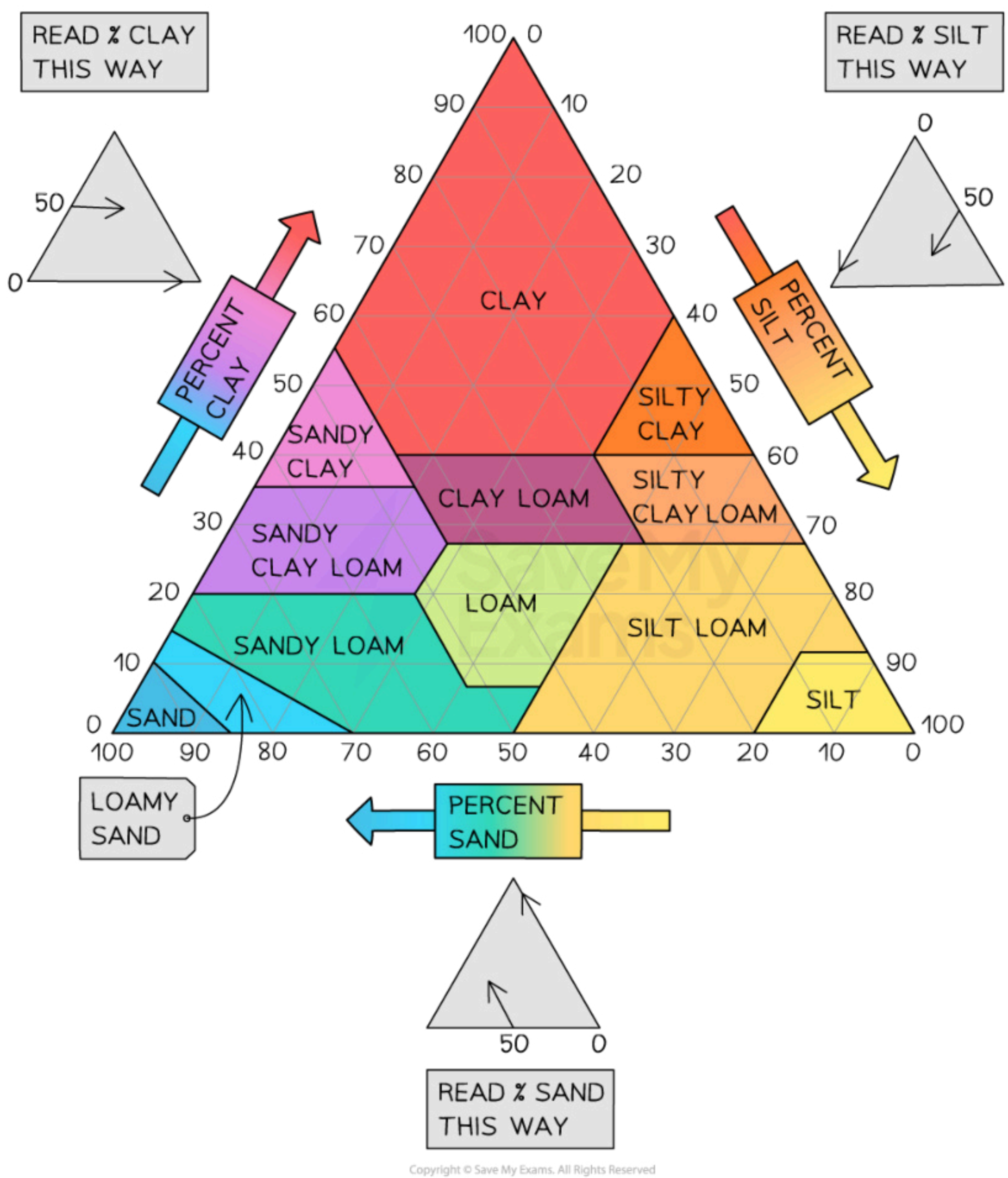
Your notes

functioning of ecosystems

Soil Structure and Texture

- Soil structure refers to the **arrangement** or **shape** of soil particles and has a direct impact on primary productivity
- Soil texture, on the other hand, refers to the **size** of soil particles, with **sand** particles being **less than 2 mm** in diameter, **silt** particles **less than 0.02 mm**, and **clay** particles **less than 0.002 mm**
  - Soil texture is an important characteristic as it influences various soil properties, including moisture content, aeration, nutrient retention, and ease of cultivation and root penetration
- 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 and are commonly referred to as "light" soils
- Silt soils are particularly prone to **compaction** if ploughed when wet, which can negatively affect soil structure and plant growth
- A loam soil, which is a **balanced combination of sand, silt, and clay**, is often considered the **most favourable** for **cultivation**
  - It is easy to work with, drains well, retains moisture and nutrients, and provides good aeration
  - As a result, loam soils have the highest potential for **primary productivity** (plant growth)

Soil Texture Triangles



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

- A soil texture triangle is a graphical tool used to classify soil types based on their **relative proportions** of **sand**, **silt**, and **clay**
  - The triangle is divided into three sections representing 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 a soil sample's percentage of sand, silt, and clay on the triangle, it is possible to determine its **textural class** (e.g. sandy loam, silty clay, etc.)

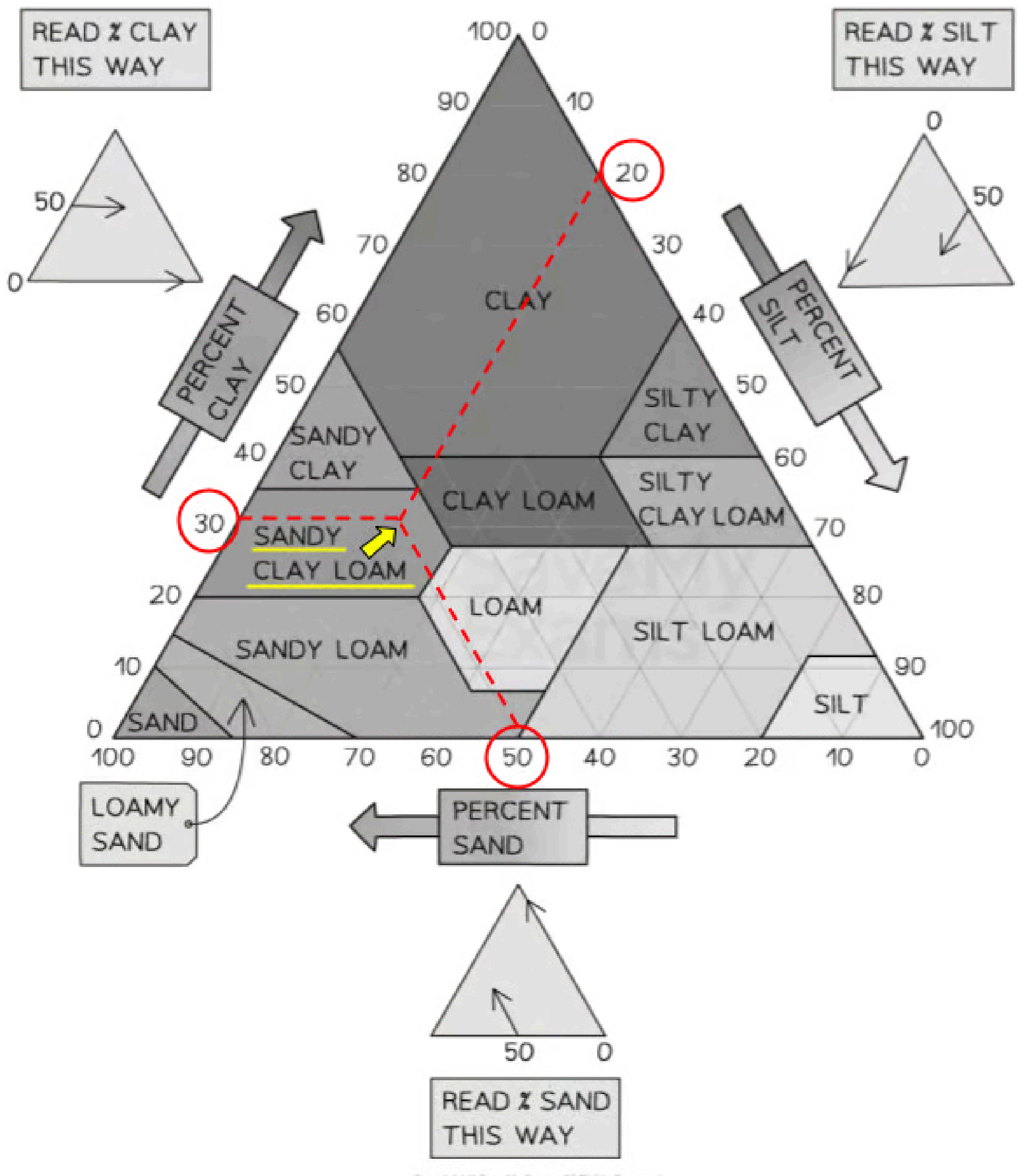
- The soil texture triangle illustrates the differences in composition of soils by showing how the varying proportions of sand, silt, and clay affect soil properties such as moisture retention, drainage, nutrient holding capacity, and workability
    - Soils with higher percentages of sand have **larger particles**, resulting in **good drainage** but **lower water and nutrient holding capacity**
    - Soils with higher percentages of clay have **smaller particles**, which leads to **higher water and nutrient retention** but **slower drainage**
    - Soils with higher percentages of silt have **intermediate** properties, offering a **balance** between drainage and water-holding capacity
- The soil texture triangle provides a practical tool for understanding and classifying soils, aiding in agricultural and environmental management decisions, such as irrigation practices, fertiliser application, and crop selection

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.



Your notes

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