DP IB Environmental Systems & Societies (ESS): SL

5.1 Soil

Contents

Components & Structure of Soil

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)

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**

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

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
- 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

Functions & Properties of Soils

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

- 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

Influence of soil texture on primary productivity

- 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