DP IB Environmental Systems & Societies (ESS): SL

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Soil Degradation & Conservation

Contents

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Soil Ecosystems

Soil Ecosystem Succession

- Soil ecosystems undergo changes over time through a process known as **succession**
- Succession in this context refers to the **predictable sequence of changes** in the **composition** and **structure** of a soil ecosystem
- The process of succession is influenced by factors such as climate, vegetation, and interactions between biotic and abiotic components

Primary Succession

- Primary succession occurs in areas where soil development starts from bare rock where there is no organic matter
- **Pioneer species**, such as lichens and mosses, colonise the bare substrate and begin the process of soil formation
- These pioneer species are well adapted to harsh conditions and can tolerate **low nutrient availability**
- As these pioneer species establish and grow, they begin to break down rocks and organic matter, contributing to the formation of the initial thin, nutrient-poor soil layer
- Over time, the accumulated organic matter and the process of weathering lead to the development and deepening of the soil layer
- This soil can be colonised by herbaceous plants and shrubs - these plants have slightly higher nutrient requirements compared to pioneer species and contribute to the further enrichment of the soil
- As the soil becomes more fertile, it can support the growth of larger plants, such as trees
- The establishment of trees marks the later stages of succession, known as **climax communities**, where the soil ecosystem reaches a **stable state**

Changes in Soil Characteristics

- As succession progresses, there are significant changes in soil characteristics
- Initially, the soil may be nutrient-poor and have a low organic matter content
- However, as vegetation and organic matter increase, the soil becomes enriched with nutrients, organic compounds, and microbial communities

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- The soil **structure** improves, leading to **increased water-holding capacity** and better **nutrient availability** for plant uptake
- Soil pH may also change as different plants and microbes affect nutrient cycling processes
- Additionally, soil erosion becomes less of a risk as the soil becomes more stabilised and protected by vegetation

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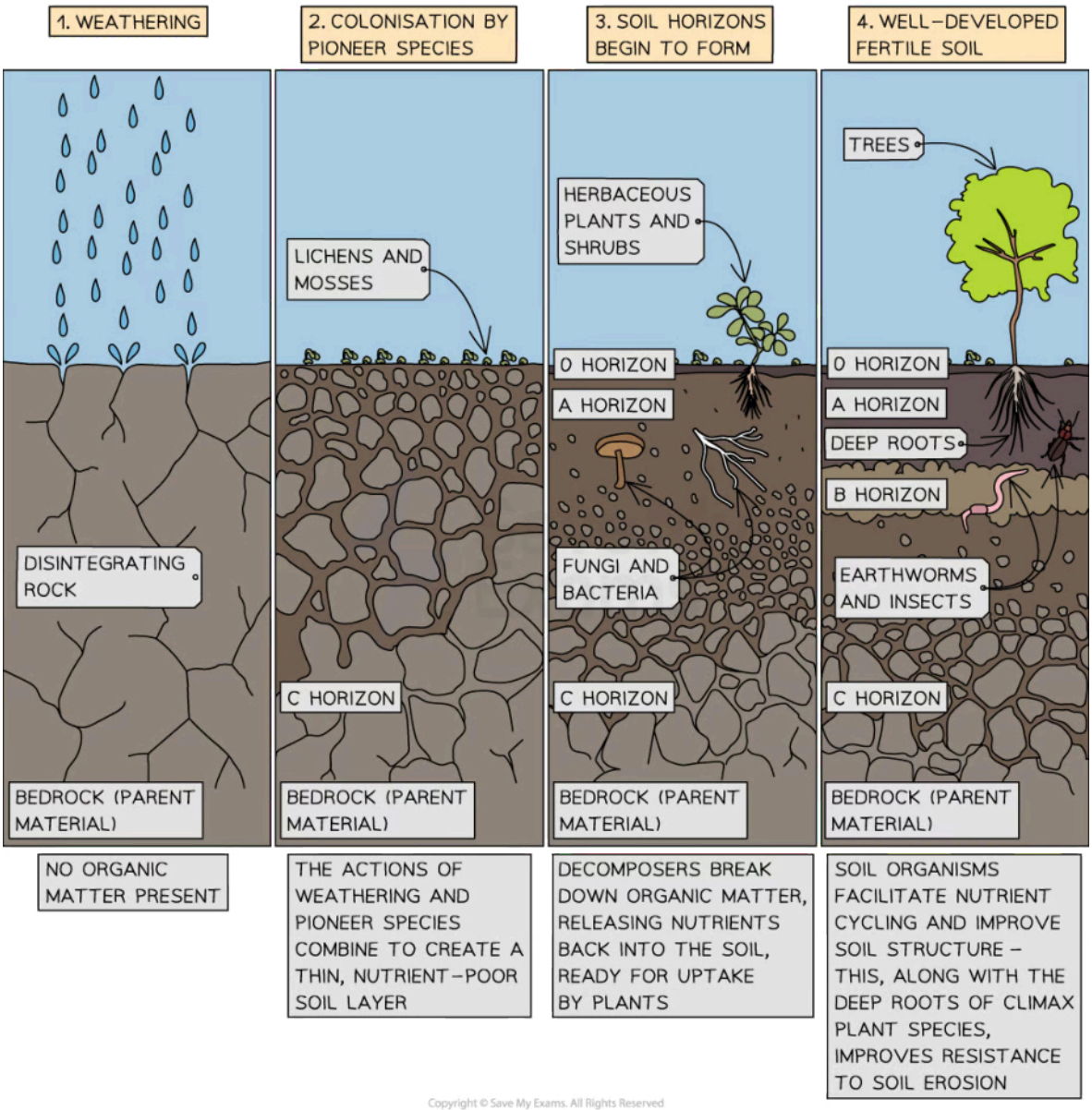

The general process of succession resulting in the creation of new soils

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Fertile Soil and Nutrient Cycles


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- Fertile soil contains a diverse community of organisms, including bacteria, fungi, insects, and earthworms, that play essential roles in maintaining functioning nutrient cycles
- Decomposers, such as bacteria and fungi, break down organic matter, releasing nutrients back into the soil
- Nutrient cycling involves the movement of essential elements, such as nitrogen, phosphorus, and carbon, between living organisms, organic matter, and the soil
- This cycling ensures the availability of nutrients for plants, supporting their **growth** and **productivity**

Resistance to Soil Erosion

- A well-developed and fertile soil ecosystem is resistant to soil erosion (the process by which soil is transported away by wind or water)
- The presence of vegetation, particularly deep-rooted plants, helps to **stabilise** the soil, preventing erosion
- Soil organisms, such as earthworms, contribute to soil structure by creating channels and burrows that **improve water infiltration** and **soil porosity**, reducing the likelihood of erosion
- The organic matter content in fertile soil enhances its ability to **retain moisture**, reducing surface runoff and erosion risks

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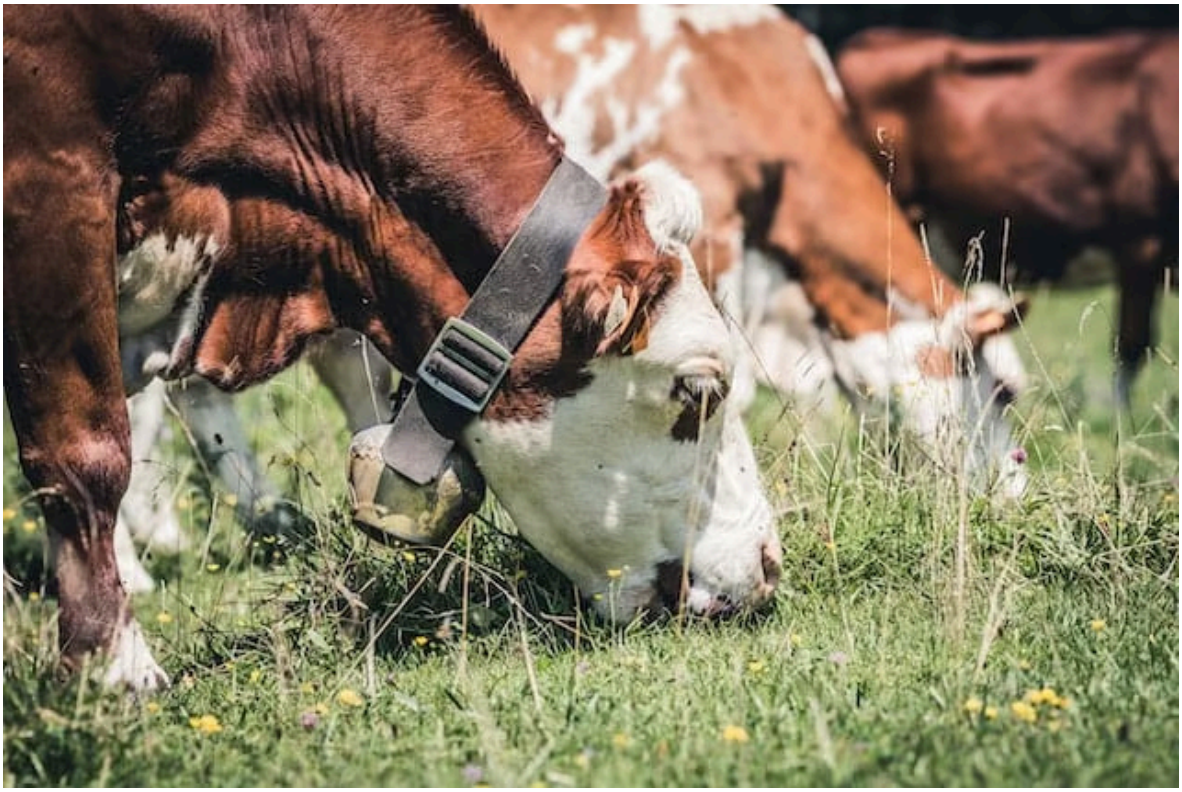
Soil Degradation

Human Activities Reducing Soil Fertility

Deforestation

- Clearing forests for agriculture, logging, or building developments leads to the removal of vegetation cover, exposing the soil to **erosion**
- Without the protection of trees and plants, the soil is more susceptible to **wind** and **water** erosion, leading to the **loss of topsoil**, which is rich in organic matter and nutrients
- Deforestation also **disrupts** the **nutrient cycling** process as tree roots, leaf litter, and decaying organic matter contribute to nutrient replenishment



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Overgrazing by livestock can lead to the degradation of soil fertility

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Intensive Grazing

- Continuous grazing without proper management results in the removal of vegetation, exposing the soil to erosion and **compaction**
- Livestock trampling and excessive grazing pressure can damage the soil structure, **reducing water infiltration** and nutrient availability
- **Nutrient cycling** is also **disrupted** as grazing animals remove vegetation and disrupt the **deposition of organic matter**

Urbanisation

- Urban development involves the conversion of natural or agricultural land into impervious surfaces such as buildings, roads, and concrete
- Urbanisation reduces the amount of vegetative cover, leading to **increased runoff** and soil erosion
- Soil in urban areas often becomes **compacted** due to construction activities, limiting root penetration and nutrient uptake by plants
- Urban areas also tend to have higher pollution levels, such as heavy metals and chemicals, which can negatively impact soil fertility and microbial communities

Agricultural Processes

- Irrigation:
  - Improper irrigation practices, such as excessive or poorly managed irrigation, can lead to soil **salinisation**
  - The accumulation of salts in the soil reduces its fertility and **inhibits plant growth**
- Monoculture:
  - Planting the same crop repeatedly in a field without crop rotation or diversification **depletes specific nutrients** from the soil
  - It can lead to imbalances in nutrient availability and increased vulnerability to pests and diseases
- Excessive fertiliser use:
  - Overapplication of synthetic fertilisers can lead to **nutrient imbalances** and water pollution due to leaching
  - It can also **disrupt** the natural **nutrient cycling** processes in the soil
- Soil erosion:
  - Unsustainable agricultural practices, such as excessive ploughing and inadequate soil conservation measures, can **accelerate** soil erosion

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- Eroded soil loses its fertility as the topsoil, which contains organic matter and nutrients, is washed or blown away
- Commercial industrialised food production systems generally tend to reduce soil fertility more than small-scale subsistence farming methods

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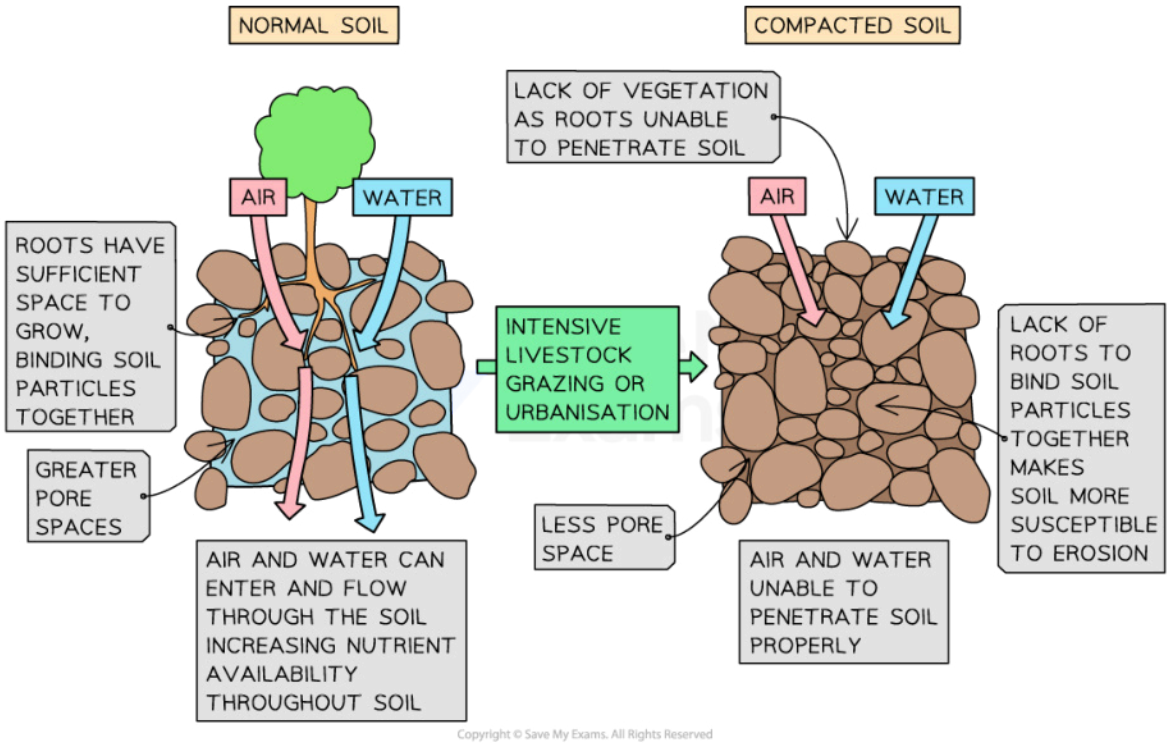

Compaction, caused by various human activities such as livestock grazing or building construction works, has various negative impacts on soil health and fertility

Impacts of Reduced Soil Fertility

Soil Erosion

- Reduced soil fertility can lead to soil erosion through the loss of essential nutrients and organic matter, which provide stability to the soil structure and promote plant growth
  - Without these nutrients, the soil becomes more susceptible to erosion by wind and water
- When soil fertility is low, plants struggle to grow and establish strong root systems
  - This weakens the vegetation cover, making the soil more vulnerable to erosion by wind and water

Toxification of Soil

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- This can occur when certain chemicals or pollutants, such as heavy metals, pesticides, or industrial waste, accumulate in the soil
    - These contaminants can harm soil organisms and disrupt nutrient cycling

Salinisation

- This happens when there is an excessive accumulation of salts in the soil
    - This can occur in arid or semi-arid regions where water **evaporation exceeds precipitation**
    - The salts can inhibit plant growth and **degrade soil fertility**, making it difficult for crops to thrive

Desertification

- This is a process where previously fertile land turns into arid desert-like conditions
    - It can be caused by a combination of factors, including soil degradation, climate change, overgrazing, and deforestation
    - As the soil fertility declines, vegetation cover decreases, exposing the soil to wind and water erosion, ultimately leading to desertification
- Sustainable land management practices, such as agroforestry, rotational grazing, and soil conservation techniques, are essential to mitigate the negative impacts of human activities on soil fertility and maintain productive soils for future generations


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Soil Conservation

- Soil conservation measures play a crucial role in maintaining the **health** and **productivity** of our soils
- As soil fertility declines, various detrimental processes like soil erosion, toxification, salinisation, and desertification can occur, leading to significant environmental and agricultural **challenges**
- Soil conservation measures, including soil conditioners, wind reduction techniques, cultivation techniques, and the avoidance of marginal lands can be used to mitigate soil degradation and preserve the vital characteristics of fertile soils

Soil Conservation Measures

Soil conservation measure	Description	Effect
Soil conditioning: organic materials	Application of organic materials, such as compost or manure, to improve soil structure and nutrient content	Enhances soil fertility, increases water holding capacity, promotes microbial activity, and improves overall soil health
Soil conditioning: lime	Addition of lime to adjust soil pH and reduce acidity	Neutralises soil acidity, improves nutrient availability, and enhances microbial activity, leading to healthier plant growth
Wind reduction: wind breaks	Planting rows of trees or tall vegetation perpendicular to prevailing winds to reduce wind speed and deflect airflow	Provides a physical barrier to wind, reducing soil erosion, protecting crops from wind damage, and creating microclimates that favour plant growth
Wind reduction: shelter belts	Planting multiple rows of trees or shrubs in a staggered pattern to create a windbreak system	Offers effective wind protection by trapping and redirecting wind, reducing soil erosion, protecting crops, and enhancing biodiversity in the surrounding area
Cultivation: terracing	Creating levelled steps on sloped lands to reduce erosion by preventing runoff and promoting water infiltration	Controls soil erosion by slowing down water movement, allowing water to soak into the soil, and minimising soil loss on steep slopes

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Cultivation: contour ploughing	Ploughing parallel to the contour lines of the land instead of up and down slopes	Minimises soil erosion by reducing the length and speed of water flow downhill, preventing gully formation, and promoting water infiltration into the soil
Cultivation: strip cultivation	Planting crops in narrow strips or bands across the slope, leaving natural vegetation between the strips	Reduces soil erosion by trapping water, slowing down runoff, and promoting infiltration while still allowing for crop production in the cultivated strips
Avoiding marginal lands	Refraining from agricultural activities on **marginal lands** with unsuitable soil conditions or high susceptibility to erosion	Protects fragile ecosystems, prevents soil degradation, and avoids the loss of valuable resources by focusing agricultural activities on more suitable and productive lands

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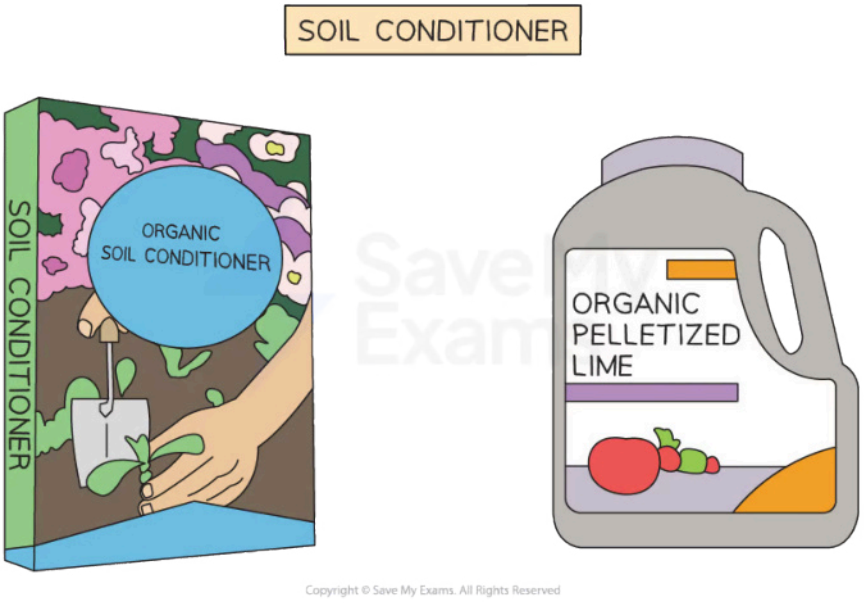
- These soil conservation measures aim to improve soil health, reduce erosion, and promote sustainable land use
- By enhancing soil structure, reducing wind erosion, adopting appropriate cultivation techniques, and avoiding the use of unsuitable lands, these practices help to maintain soil fertility, retain moisture, and protect the soil from degradation, ensuring **long-term productivity** and environmental **sustainability**



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Organic soil conditioners can be used to improve overall soil health, whilst the addition of lime helps to reduce soil acidity

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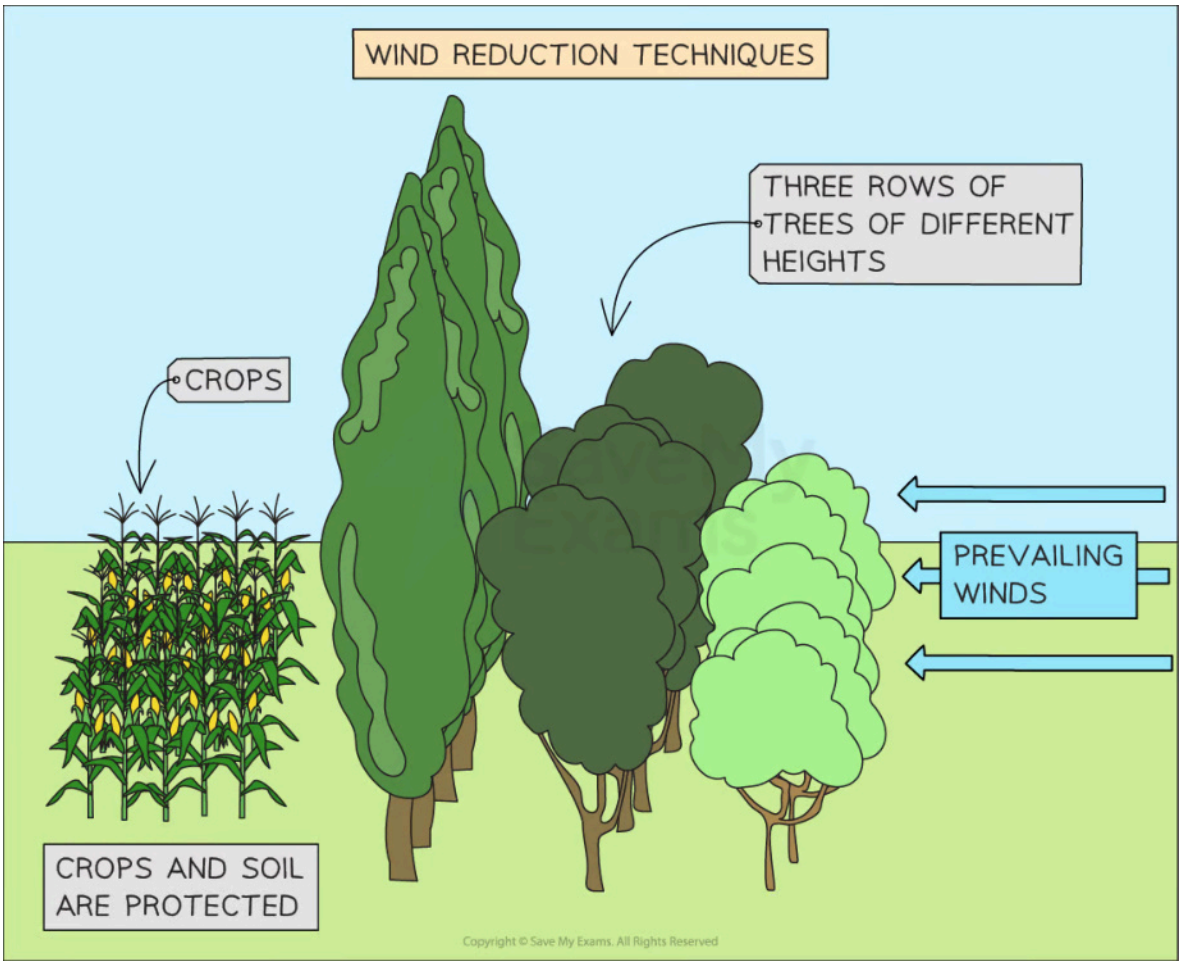

Wind reduction techniques help to minimise soil erosion and protect crops from wind damage

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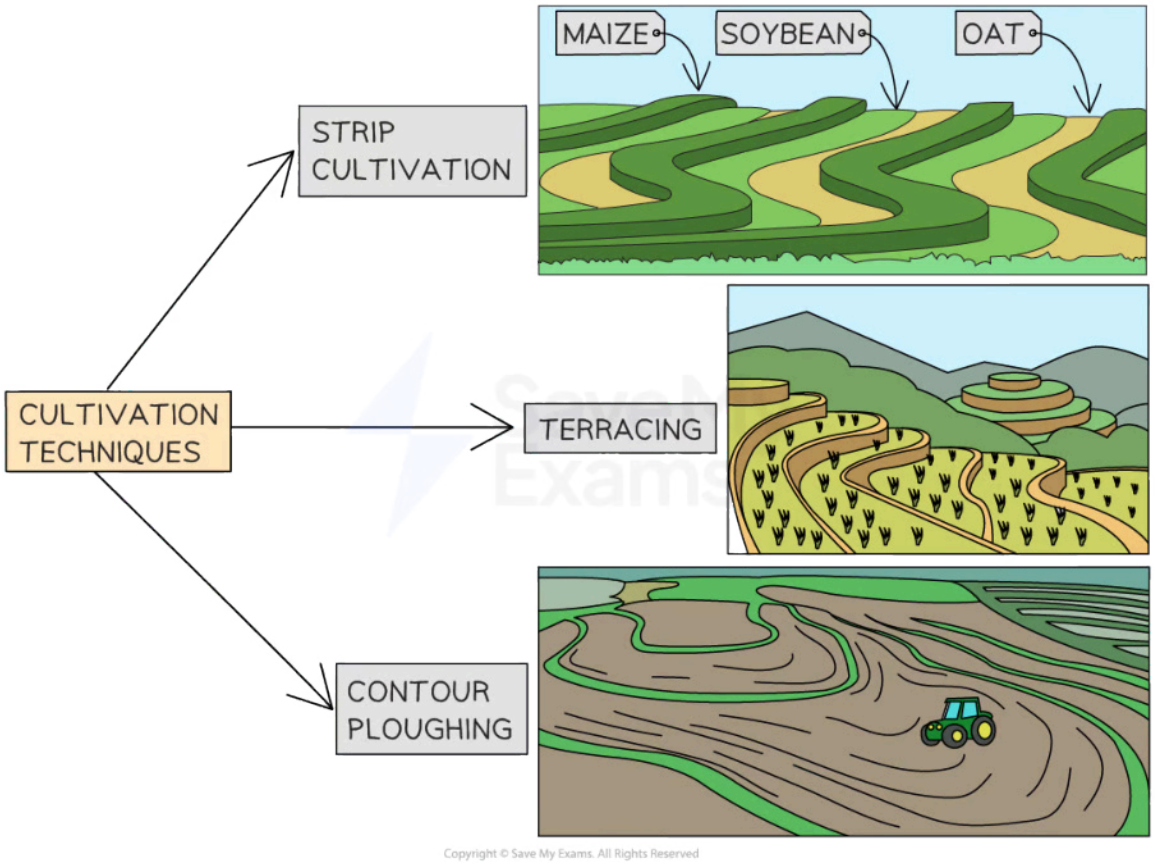

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Strip cultivation, terracing, and contour ploughing all help to conserve soils by slowing the speed of water runoff, which allows water time to infiltrate the soil, minimising soil erosion

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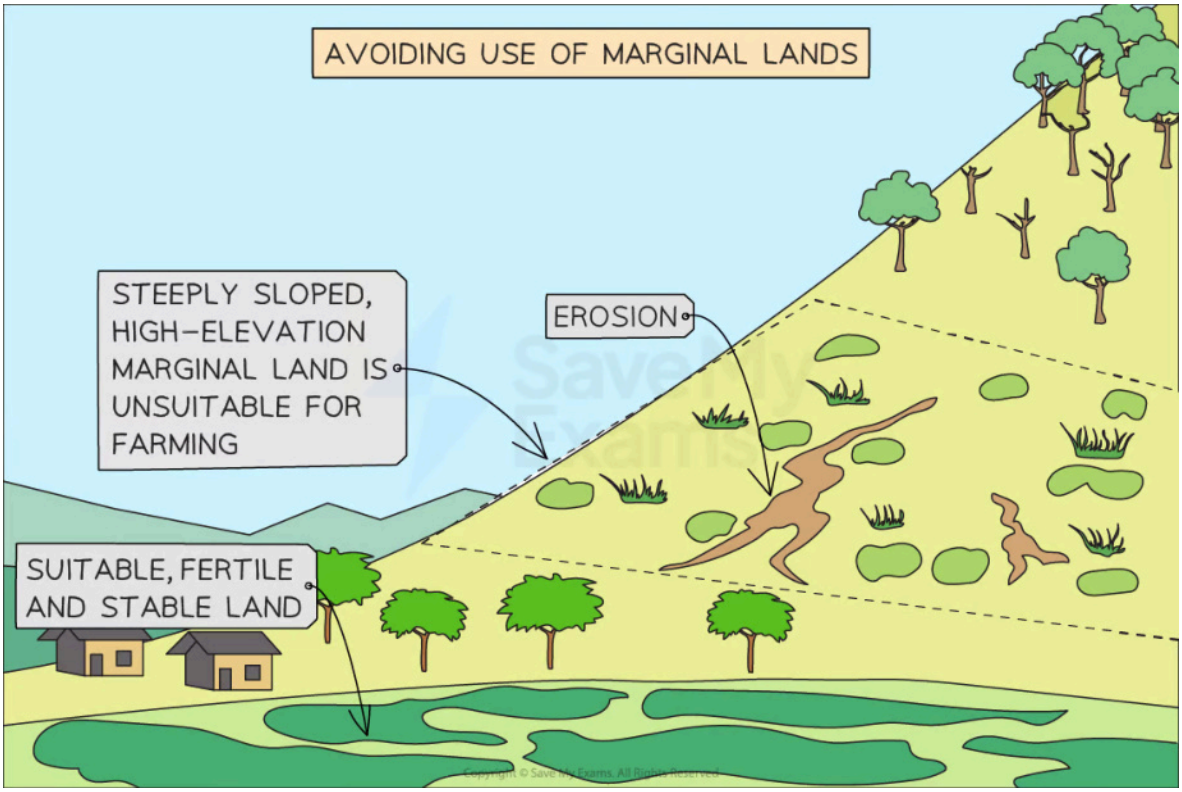

Marginal lands (usually steep land with poor soil structure and low fertility) are already vulnerable to soil erosion, so should not be used for agricultural purposes as this will quickly result in significant soil degradation in these areas

Worked Example

Evaluate the soil management strategies of commercial farming systems and subsistence farming systems.

Answer

Commercial Farming Systems:

Soil management strategies in commercial farming systems typically prioritise high yields and profitability. Intensive tillage methods, such as mechanical ploughing, may be used to prepare the soil for planting, but this can increase the risk of erosion and soil compaction. Synthetic fertilisers are often applied to provide nutrients for crop growth, but excessive use can lead to nutrient imbalances and pollution of water bodies through runoff. Pesticides and herbicides may be utilised

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for pest and weed control, but they can have negative impacts on soil biodiversity and overall ecosystem health. Commercial farming systems use soil conservation measures such as soil conditioning, wind reduction, contour ploughing and generally avoid using marginal lands for agriculture. By focusing on more fertile and suitable lands, commercial farming systems can optimise resource utilisation and minimise negative environmental impacts.

Subsistence Farming Systems:

Subsistence farming systems often rely on traditional practices to enhance soil fertility. Organic materials such as crop residues, animal manure, and compost are commonly used as soil conditioners and fertilisers. These materials help replenish nutrients, improve soil structure, and enhance water-holding capacity. Traditional practices such as slash-and-burn agriculture or shifting cultivation may be used, where farmers clear small plots of land, cultivate them for a few years, and then leave them fallow to regenerate. Crop rotation and intercropping techniques are also often employed to optimise nutrient cycling and maximise yields. Soil conservation measures like terracing and contour plowing may be implemented to control erosion, retain soil moisture, and enhance soil fertility. Subsistence farming systems often make use of marginal lands due to limited access to more fertile areas. These marginal lands may have lower soil fertility and higher erosion risk. However, subsistence farmers often adopt sustainable practices, such as mixed cropping, agroforestry, and crop rotation, to improve soil health and mitigate erosion on these lands. These practices help optimise resource utilisation and enhance food security in challenging environments.


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