DP IB Environmental Systems & Societies (ESS): SL

Your notes

5.2 Agriculture & Food

Contents

Land Use & Agricultural Systems

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Land Use

Land as a finite resource

- Land is limited and cannot be expanded (i.e. it is a finite resource)
- Efficient land use is crucial to meeting growing food requirements
- About 70% of ice-free land is used for agriculture and forestry
    - Agricultural land is used to grow **crops** (arable) and raise **livestock**
- As the human population grows, the demand for food increases
    - This puts **pressure** on available land for food production
- **Urbanisation** leads to the conversion of agricultural land into urban areas
    - This further reduces the availability of land for food production per capita

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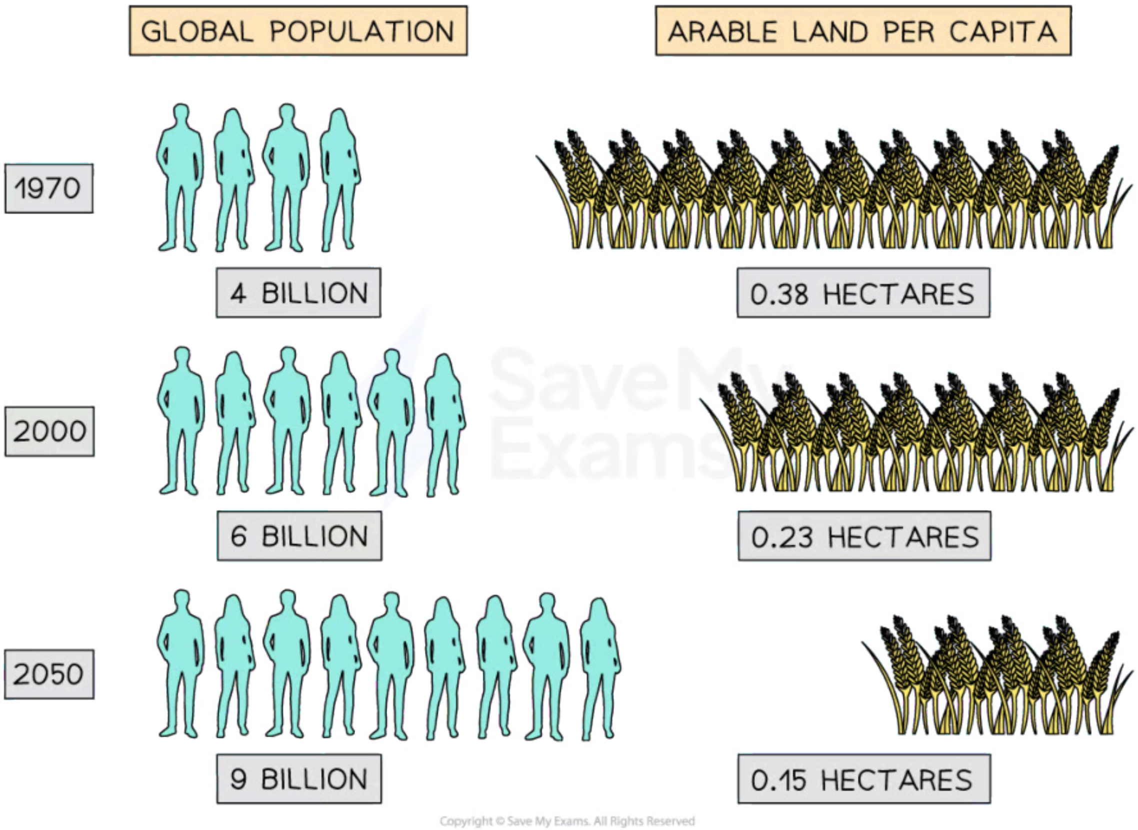

Historical and predicted arable land per capita

Agricultural land use

- Not all land is suitable for crop production
  - land must be **fertile**, **flat**, and have **adequate water supply**
- **Unsuitable land for crops**:
  - Steep slopes:
    - Risk of erosion
    - It is difficult to use machinery
  - Nutrient-poor soils:
    - Cannot support crop growth without significant fertilisation
- These lands are often used for livestock production instead

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    - For example, in the UK, hilly areas like Eryri (Snowdonia, Wales) and the Scottish Highlands are used for sheep grazing due to **unsuitable conditions for arable farming**

Vulnerability of marginalised groups

- **Marginalised groups**:
    - These include:
        - Indigenous peoples
        - Low socio-economic status groups
        - Women farmers
        - People in low-income countries
    - Often have limited access to land and resources
- **Impact of land-use decisions**:
    - Land-use policies can **increase inequalities**
    - Marginalised groups are more vulnerable to changes and restrictions
    - For example, in India, many Dalits (members of a lower caste) face significant barriers to land ownership and agricultural resources
        - This is limiting their ability to improve their economic status and sustain their livelihoods
- **Indigenous peoples**:
    - Indigenous groups often depend on land for their livelihoods
    - **Indigenous land rights** are often **ignored** in favour of large-scale agricultural projects
    - For example, the Maasai in Kenya and Tanzania have faced **land encroachment**
        - This is due to expanding agriculture and tourism projects
        - This is threatening their traditional way of life

Other examples of land-use impacts on marginalised groups

- **Deforestation in the Amazon**:
    - Driven by agricultural expansion
    - It affects Indigenous tribes like the Yanomami
    - Leads to loss of biodiversity and traditional lands
- **Land grabs in Africa**:

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- Foreign investors acquire large areas of land for industrial-scale agriculture
- Displaces local farmers and communities
- Impacts their food security
- **Urban sprawl in China**:
  - Rapid urbanisation consumes agricultural land
  - Affects rural communities' access to arable land

EXAM TIP

Make sure you know the difference between agricultural land and arable land

Agricultural land is used for all types of farming, including both crops and livestock. It includes pastures, orchards, and vineyards.

Arable land is specifically used for growing food crops. It requires fertile soil and suitable conditions for planting.

Key point: all arable land is agricultural land, but not all agricultural land is arable.

Agricultural Systems

Variability in agricultural systems

- **Global variation:**
  - Agriculture systems vary globally due to differences in soil and climate
  - Soils in different biomes support different crop types and productivity levels
- **Soil and climate influence:**
  - Tropical soils may be nutrient-poor, affecting crop choices
    - This **limits** the types of crops that can be grown successfully without heavy fertilisation
    - For example, in Brazil, nutrient-poor tropical soils require heavy fertilisation for crops like soybeans
  - Temperate climates with fertile soils can support **diverse crops**
    - For example, in the UK, temperate climates support a variety of crops like wheat and barley

Classification of agricultural systems

- Agricultural systems can be classified in a number of ways, including:

- **Outputs from the farm system**:
  - **Arable farming**: growing crops (e.g., wheat, rice)
  - **Pastoral/livestock farming**: raising animals (e.g., cattle, sheep)
  - **Mixed farming**: combining crops and livestock
  - **Monoculture**: growing a single type of crop
  - **Diverse farming**: growing multiple types of crops
- **Reasons for farming**:
  - **Commercial farming**: producing food for sale
  - **Subsistence farming**: producing food for the farmer's own use
  - **Sedentary farming**: farmers stay in one place
  - **Nomadic farming**: farmers move with their livestock
- **Types of inputs required**:
  - **Intensive farming**:
    - High inputs of labour, capital and technology
    - E.g. dairy farming in the Netherlands
  - **Extensive farming**:
    - Low input per unit area
    - E.g. sheep farming in Australia
  - **Irrigated farming**:
    - Requires artificial water supply
    - E.g. Central Valley, California: large-scale irrigation systems support the cultivation of crops such as almonds, grapes and tomatoes in this semi-arid region
  - **Rain-fed farming**:
    - Relies on natural rainfall
    - E.g. wheat farming in Canada
  - **Soil-based farming**:
    - Traditional farming in soil

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    - E.g. vegetable farms in the UK
- **Hydroponic farming**:
    - Growing plants without soil, using nutrient solutions
    - E.g. hydroponic lettuce farms or vertical farms in urban areas
- **Organic farming**:
    - Avoids synthetic chemicals
    - E.g. organic tea plantations in India: many use natural fertilisers, compost and biological pest control methods to maintain soil fertility and produce high-quality tea without synthetic pesticides or herbicides
- **Inorganic farming**:
    - Uses synthetic chemicals and fertilisers
    - E.g. large-scale corn farms in the US

Implications of agricultural systems

- **Economic sustainability**:
    - Varies with farming type and market access
    - Monoculture can be profitable but risky due to **crop failure,** e.g. due to disease
    - Diversified farming **reduces risk** and can be more economically sustainable
- **Social sustainability**:
    - Agricultural systems affect community stability and employment in different ways
    - Subsistence farming supports local communities but can limit economic growth
    - Commercial farming can create jobs but may displace small farmers
- **Environmental sustainability**:
    - Intensive farming can lead to **soil degradation** and **pollution**
    - Organic farming promotes **biodiversity** and **soil health**
    - Extensive farming generally has a lower environmental impact

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Make sure you are familiar with the different ways to classify agricultural systems (outputs, reasons and inputs). You need to understand and be able to define agricultural terms like monoculture, subsistence, intensive and extensive farming.

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Traditional & Modern Agricultural Practices

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Traditional Agricultural Practices

Nomadic pastoralism

- Nomadic pastoralism is a form of agriculture where **livestock** is herded to different pastures in a **seasonal cycle**
  - For example, Bedouin tribes in the Middle East traditionally move their camels, goats and sheep across desert regions to find grazing land
- **Characteristics:**
  - Relies on natural pasture and water sources
  - Adapted to **arid** or **semi-arid** environments
  - Minimal permanent settlements
  - **Seasonal changes** control movement

Slash-and-burn agriculture (shifting cultivation)

- Slash-and-burn agriculture is a method of agriculture where forests are cut down and burned
- Crops are grown on the cleared land for a **few years** until the soil is **depleted of nutrients**
  - For example, Indigenous tribes in the Amazon rainforest traditionally practice slash-and-burn to grow crops like cassava and maize
- **Characteristics:**
  - Sustainable in **low-density** populations
  - Allows **regeneration** of forest over time
  - Relies on a rotating cycle of land use

Challenges with traditional practices

- **Environmental impacts:**
  - Deforestation and loss of biodiversity from slash-and-burn
  - Overgrazing and soil erosion can occasionally result from nomadic pastoralism
- **Modernisation and population growth:**

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- Traditional agricultural methods become **unsustainable** as populations grow and land becomes scarce
- Indigenous cultures are increasingly transitioning to more **sedentary lifestyles**
- This leads to **overuse** of land and resources

The Green Revolution

What was the Green Revolution?

- The Green Revolution refers to a series of **research**, **development** and **technology initiatives** that took place between the 1950s and 1960s
  - These initiatives aimed to increase agricultural production and food security globally
- It is also known as the Third Agricultural Revolution

Key initiatives of the Green Revolution

- **High-yielding varieties (HYVs):**
  - Breeding of crops like wheat, rice and maize to produce higher yields
  - E.g. IR8 rice, known as 'Miracle Rice', developed in the Philippines
- **Improved irrigation systems:**
  - Development and expansion of irrigation infrastructure
  - Helped transform arid and semi-arid lands into highly productive agricultural areas
  - E.g. the Indus Basin Irrigation System in Pakistan
- **Synthetic fertilisers:**
  - Use of chemical fertilisers to provide essential nutrients to crops
  - The production of synthetic fertilisers is dependent on nitrogen fixation
    - This means their production relies on fossil fuels
- **Pesticides:**
  - Application of chemical pesticides to protect crops from pests and diseases

Positive consequences of the Green Revolution

- **Increased food production:**
  - Significant increase in crop yields and food availability

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- Helped alleviate hunger and food shortages in many regions
- **Economic growth:**
  - Boosted agricultural economies and increased farmer incomes
  - For example, Mexico became a major wheat exporter due to Green Revolution practices
- **Technological advancements:**
  - Led to further agricultural research and innovation

Negative consequences of the Green Revolution

- **Environmental impacts:**
  - The overuse of chemical fertilisers and pesticides led to **soil degradation** and **water pollution**
  - **Loss of biodiversity** due to intense monoculture practices
- **Economic inequality:**
  - Resulted in greater economic benefits for larger, wealthier farmers compared to small-scale farmers
  - Increased debt for farmers who could not afford new technologies
- **Sociocultural effects:**
  - Displacement and loss of traditional farming practices
  - Increase in **rural to urban migration** due to changes in agricultural labour demands
- **Selective implementation:**
  - The Green Revolution was not universal
  - It did not reach all developing nations
  - Regions without access to necessary resources and infrastructure saw limited benefits

Synthetic Fertilisers & Sustainable Methods

Synthetic fertilisers

- Synthetic fertilisers are chemical compounds applied to soil to supply **essential nutrients** for plant growth
  - Their purpose is to maintain high commercial productivity in intensive farming systems
- **Advantages:**
  - Immediate nutrient supply to crops

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  - Increased crop yields and faster growth
- **Disadvantages:**
  - Soil degradation over time
  - Water pollution from runoff
  - Dependency on fossil fuels for production

Sustainable methods for improving soil fertility

- In sustainable agriculture, there are many alternative methods for improving soil fertility

Sustainable Methods for Improving Soil Fertility

Method	Definition	Benefits
Fallowing	Leaving land uncultivated for a period	Allows soil to **recover** and **regain nutrients** Reduces need for synthetic fertilisers
Organic Fertiliser	Using manure from farm animals or human waste (humanure)	Improves **soil structure** and **fertility** Reduces need for synthetic fertilisers
Herbal Mixed Leys	Planting a mixture of herbs and grasses	Provides **diverse nutrients** to the soil Improves **soil health** and **biodiversity**
Mycorrhizae	Symbiotic fungi that enhance plant nutrient uptake	Increases plant **access to nutrients** Reduces need for synthetic fertilisers
Continuous Cover Forestry	Maintaining a continuous canopy of trees	**Prevents soil erosion** due to root systems binding soil and interception of rain by forest canopy Increases **soil organic matter** and **fertility**
Agroforestry	Integrating trees and shrubs into agricultural landscapes	Improves **soil health** Reduces soil erosion Provides **additional sources of income** (e.g. fruit, timber)

Soil Conservation

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Soil Conservation Techniques

- Soil conservation techniques are used to maintain the **health** and **productivity** of our soils
- As soil **fertility declines**, various detrimental processes can occur, such as:
  - Soil erosion
  - Toxification
  - Salinisation
  - Desertification
- These processes lead to significant **environmental** and **agricultural challenges**
- Soil conservation techniques can be used to:
  - Mitigate soil degradation
  - Preserve the important characteristics of fertile soils
- Soil conservation techniques can be classified in several ways, including:
  1. Techniques that reduce soil erosion
  2. Techniques that increase soil fertility (using soil conditioners)
  3. Cultivation techniques

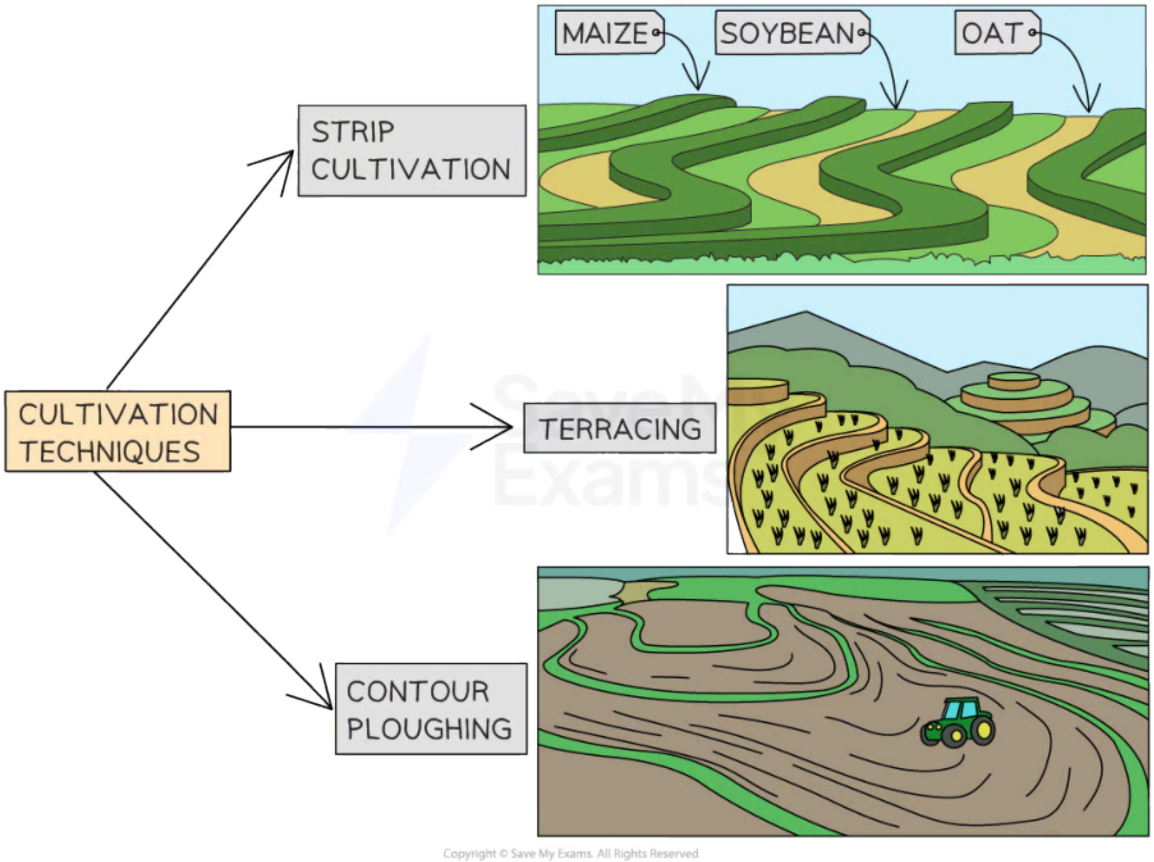
Conservation from Erosion

Soil conservation technique	Type of erosion reduced	Description	Effect
Strip cultivation	Water	Planting crops in alternating strips or bands, leaving natural vegetation between the strips	Reduces soil erosion by trapping water, slowing down runoff and increasing infiltration while still allowing for crop production in the cultivated strips Increases biodiversity

Terracing	Water	Creating levelled steps on sloped lands	Reduces soil erosion by slowing down water movement and increasing infiltration Minimises soil loss on steep slopes
Contour ploughing	Water	Ploughing parallel to the contour lines of the land instead of up and down slopes	Minimises soil erosion by reducing length and speed of water flow downhill Prevents gully formation and increases infiltration
Bunding	Water	Building embankments or barriers along fields	Controls water flow Prevents soil erosion and waterlogging
Drainage systems	Water	Installing systems to manage excess water	Prevents waterlogging Reduces erosion and nutrient loss
Cover crops	Water	Planting crops that cover the soil	Reduces water erosion Improves soil structure
Windbreaks	Wind	Planting trees or hedges to block and reduce wind speed	Provides physical barrier to wind Reduces wind erosion Protects topsoil Protects crops from wind damage
Cover crops	Wind	Planting crops to cover soil	Reduces wind erosion Adds organic matter to soil

Your notes

Your notes



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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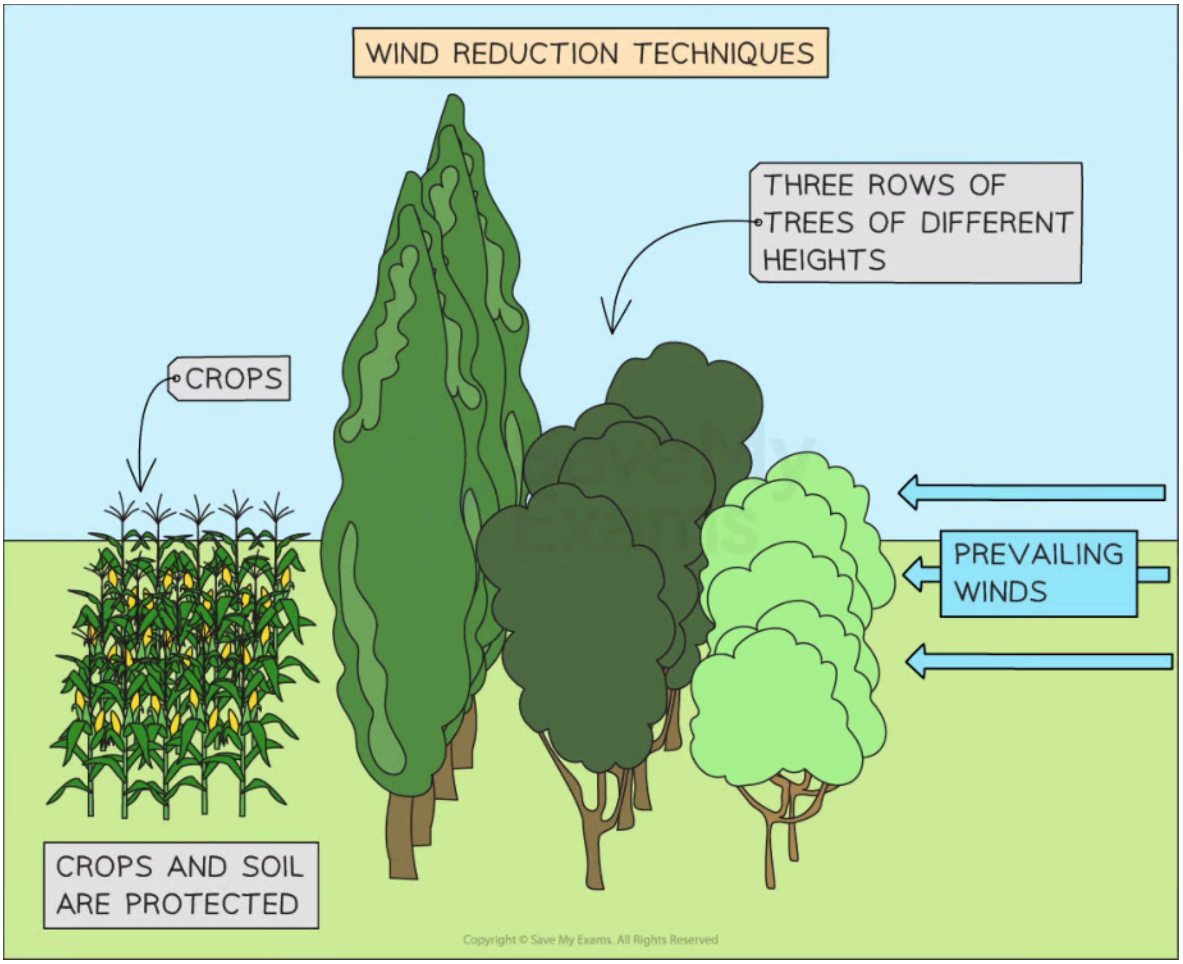
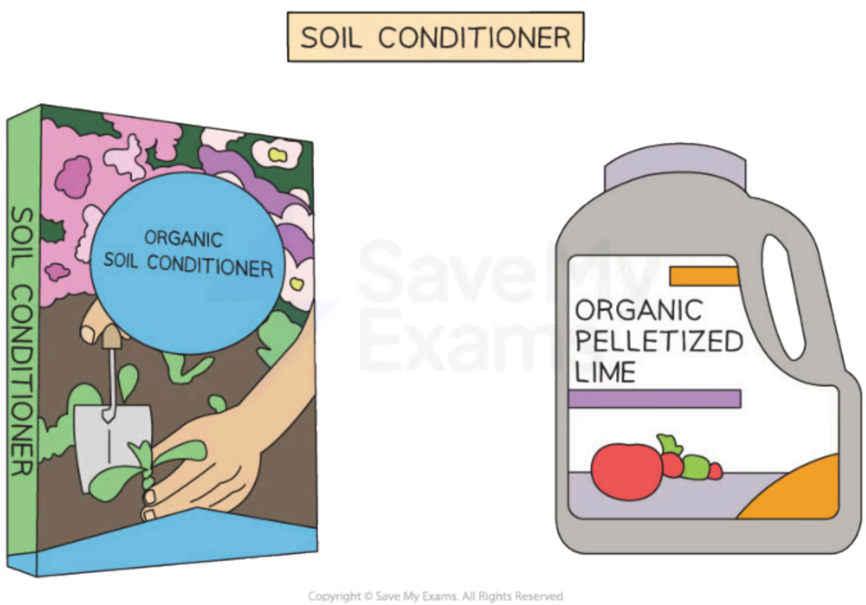


Wind reduction techniques help to minimise soil erosion and protect crops from wind damage

Conservation of Fertility with Soil Conditioners

Soil conservation technique	Description	Effect
Lime	Adding lime to soil	Improves soil pH, reducing soil acidity Enhances nutrient availability Promotes beneficial microbial activity

Compost	Using decomposed organic matter	Enriches soil with nutrients Improves soil structure Increases water-holding capacity Promotes beneficial microbial activity
Green manure	Growing plants (e.g. cover crops) specifically to be ploughed into the soil	Increases organic matter Enhances soil fertility



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

Cultivation Techniques

Soil conservation technique	**Description**	**Effect**
Avoid marginal land	Not farming on land that is vulnerable to erosion or poor in nutrients	Protects fragile ecosystems

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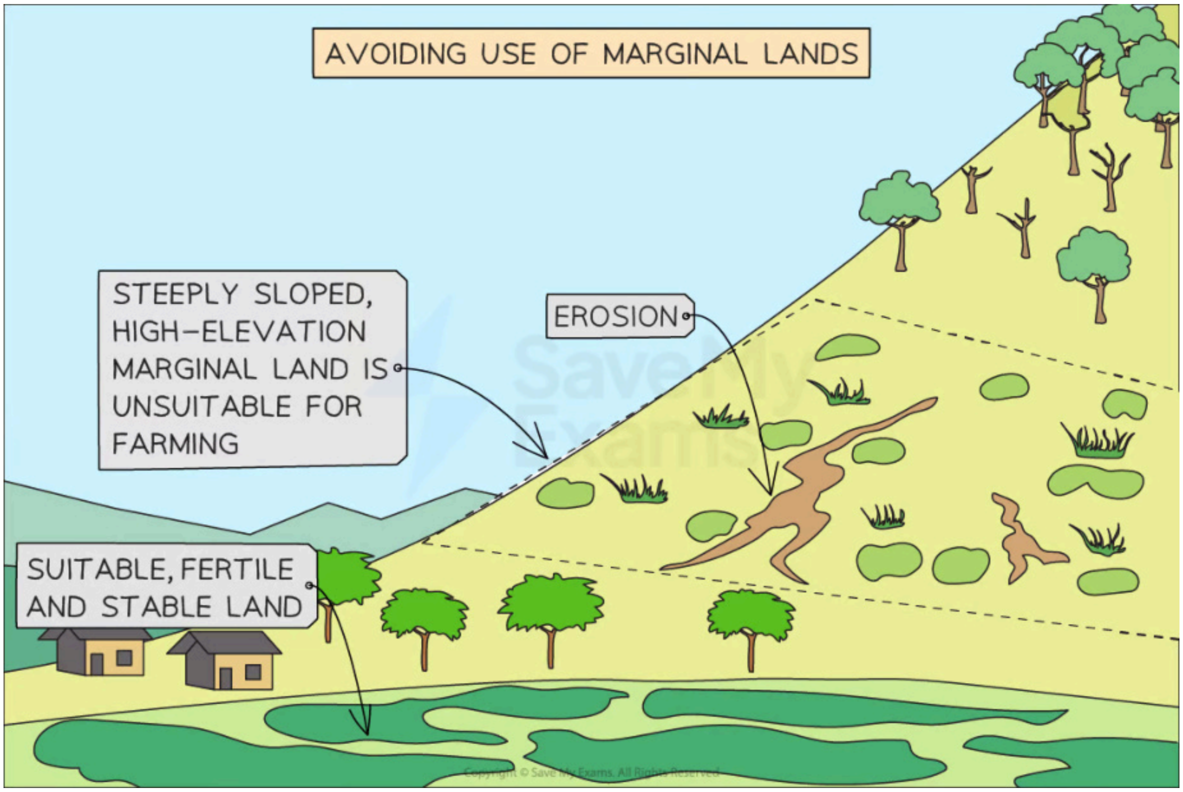
		Prevents soil degradation Maintains soil health
Avoid overgrazing / overcropping	Managing livestock and crop levels to prevent depletion	Maintains soil cover Prevents soil erosion and compaction
Mixed cropping	Growing different types of crops together	Improves soil health Reduces pest and disease issues
Crop rotation	Rotating different crops on the same land	Maintains soil nutrients Reduces disease and pest buildup
Reduced tillage	Minimising ploughing and soil disturbance	Preserves soil structure Maintains moisture levels
Agroforestry	Integrating trees and shrubs into farming systems	Enhances soil structure Provides shade and wind protection
Reduced use of heavy machinery	Minimising the use of heavy equipment on fields	Prevents soil compaction Maintains soil structure



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

EXAM TIP

You should note that many of these techniques help conserve soils in multiple ways. For example, cover crops protect the soil from wind and water erosion, but they can also ploughed into the soil to become green compost.

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Food Security

Food Security

- Food security can be defined as:

When all individuals, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life

Key components of food security

1. **Availability:** ensuring that enough food is **produced** and **supplied** to meet the population's needs
2. **Access:** ensuring that individuals have the resources (economic means) to obtain the food they need (i.e. food is **affordable**)
3. **Use:** ensuring food is used properly alongside a healthy diet, clean water, sanitation and healthcare to achieve **good nutritional health**
4. **Stability:** ensuring consistent and reliable access to food at all times, **without disruptions** from economic or climate-related issues

Regional food security

- **Developed regions:**
  - Generally **high levels** of food security
  - Good infrastructure, economic stability and social safety nets ensure food availability and access
  - Examples: North America, Western Europe
- **Developing regions:**
  - Varying levels of food security, often **lower** than in developed regions
  - Issues include poverty, poor infrastructure and political instability
  - Examples: Sub-Saharan Africa, parts of South Asia, Latin America

Factors affecting food security

- **Economic factors:**
  - Income levels, food prices and employment opportunities impact individuals' ability to purchase food
- **Environmental factors:**

  - Climate change, natural disasters and resource depletion impact food production and availability
- **Social and political factors:**
  - Government policies, conflict and social inequality impact food distribution and access

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Sustainability of Food Production Systems

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Increasing Sustainability of Terrestrial Food Production

- Humans are omnivores, consuming a variety of foods, including:
  - Fungi
  - Plants
  - Meat
  - Fish
- Diets that include more food from **lower trophic levels**, such as plant-based diets, are generally **more sustainable**
  - This is due to their reduced environmental impact

Crop vs. livestock production

- **Yield and cost:**
  - Crops:
    - The yield of food **per unit of land area** is significantly **higher** with crops than with livestock
    - Crop production also has **lower financial costs** associated with it
  - Livestock:
    - Producing food through livestock requires **more land** and **resources**
    - It is usually **more expensive**

Plant-based diets

- Increasing the proportion of plant-based foods in diets can make agriculture more sustainable
- This is because plant-based diets decrease the demand for resource-intensive livestock farming
- **Energy efficiency** is greater in a plant-based diet compared to a meat-eating diet due to several factors:

1. **Trophic levels:**
   - **Energy** is **lost** at each trophic level as it moves up the food chain

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- When we consume plant-based foods directly, we bypass the energy loss associated with raising animals for meat
- By consuming plants (the primary producers) directly, we utilise energy more efficiently

2. **Feed conversion efficiency:**
    - Animals raised for meat require significant amounts of **feed** to grow and develop
    - However, a large portion of the energy from the feed is used for the animals' own **bodily functions** and **metabolic processes**, rather than being converted into **edible biomass**
    - This inefficiency in feed conversion results in higher energy losses when obtaining nutrition from meat
3. **Land use efficiency:**
    - Producing meat requires **vast amounts of land** for grazing or growing animal **feed crops**
    - This land could otherwise be used more efficiently to cultivate plant-based foods directly for human consumption
    - By consuming plant-based foods, we **optimise land use** and reduce the energy required for livestock farming

- By focusing on lower-trophic-level food production, such as promoting plant-based diets, it is possible to:
    - **Maximise food production per unit area**
    - At the same time, mitigating the pressure on land resources

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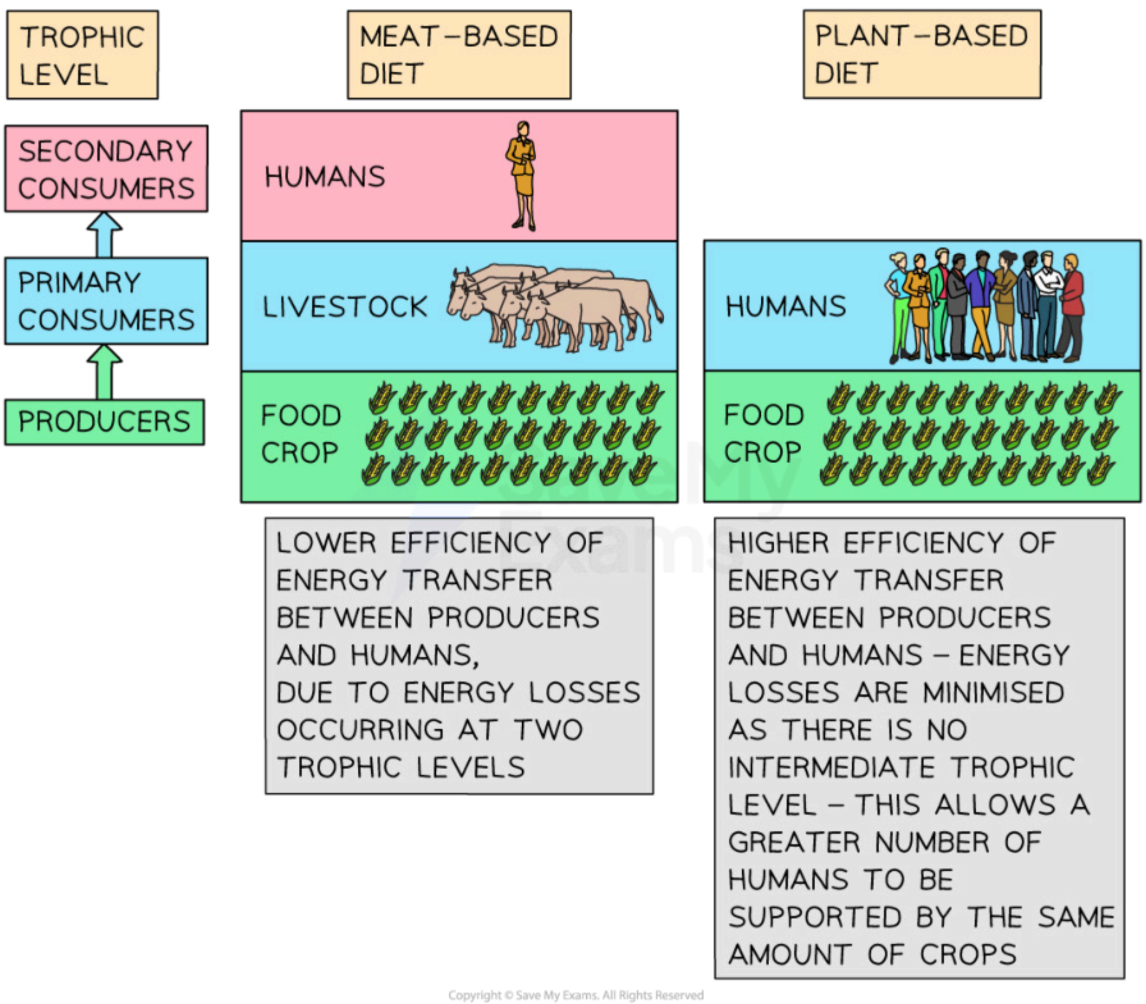

Efficiency of meat-based vs plant-based terrestrial food production systems

Global food production and distribution

- **Current production:**
  - Global agriculture currently produces enough food to feed approximately eight billion people (the global population currently stands at 8.1 billion in 2024)
- Despite this, food is **not distributed equitably** around the world
  - Some regions experience surpluses, while others face severe shortages
- **Food waste:**
  - It is estimated that at least one-third of all food produced is wasted

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    - This can be during:
        - Post-harvest
        - Storage
        - Transport and distribution
- **SDG goal:**
    - The United Nations' Sustainable Development Goal 12 aims to:
        - ***"...ensure sustainable consumption and production patterns."***
    - Target 12.3 within this goal focuses on:
        - Reducing global food waste by **50% per capita** at the retail and consumer levels (i.e. halving global food waste) by 2030
        - By minimising food losses throughout production and supply chains (including post-harvest losses)

Strategies for sustainable food supply

1. **Reducing demand and food waste:**
    - **Encouraging plant-based diets:** shifting towards plant-based diets can reduce the demand for resource-intensive animal products
    - **Improving food distribution systems:** increasing the efficiency of food distribution can help ensure that food reaches those in need and reduce waste. For example:
        - Using refrigerated transport to keep food fresh longer
        - Optimising delivery routes to reduce transport time
        - Collecting and redistributing surplus food to those in need
    - **Educating consumers:** raising awareness about the importance of reducing food waste at the consumer level can have a significant impact
2. **Reducing greenhouse gas emissions:**
    - **Plant-based meat substitutes:** developing and promoting plant-based alternatives to meat can reduce greenhouse gas emissions associated with livestock
        - These products mimic the taste and texture of meat but are made from plants
    - **Low methane rice cultivation:** using rice cultivation practices that produce less methane can help reduce agricultural emissions. For example:
        - Periodically draining and re-flooding rice fields

    - Applying additives that reduce methane emissions
- **Reducing methane release by ruminants:** adjusting livestock diets and using dietary additives like seaweed can lower methane emissions from ruminants

3. **Increasing productivity without expanding agricultural land use:**

- **Extending shelf life:** improving preservation methods to extend the shelf life of food can help reduce waste. For example:
    - Improved packaging
    - Improved refrigeration
- **Genetic modification:** using genetic modification to create crops with increased productivity. For example:
    - Crops that produce higher yields with the same inputs
    - Crops that are more resistant to pests and diseases
- **In-field solar-powered fertiliser production:** using solar energy to produce fertilisers on-site
    - Reduces the need for synthetic fertilisers
    - Reduces reliance on fossil fuels (required for production of synthetic fertilisers)
    - Reduces production and transport costs

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