Dean Close
IGCSE Geography
Revision Guide

1.3 Subject content – Section A

Topic 1: River environments

What students need to learn

Key ideas		Detailed content		
1.1	The world's water supply is contained in a closed system – the hydrological cycle	a)	The hydrological cycle: characteristics, stores and transfers.	
		b)	Features of a drainage basin: source, watershed, channel network, mouth.	
		c)	Factors affecting river regimes: precipitation, including storm hydrographs, temperature, vegetation, land use, water abstraction, dams. (1)	
1.2	Physical processes give rise to characteristic river landforms	a)	Fluvial processes involved in river valley and river channel formation: erosion (vertical and lateral), weathering and mass movement, transportation and deposition, and factors affecting these processes (climate, slope, geology, altitude and aspect).	
		b)	How channel shape (width, depth), valley profile (long and cross profiles), gradient, velocity, discharge, and sediment size and shape change along the course of a named river. (2)	
		c)	How river landscapes change over the course of a river, with distinctive upland and lowland landforms, including the formation of valleys, interlocking spurs, waterfalls, meanders, oxbow lakes, flood plains and levees. (3)	

Case studies of river management in a developed country **and** a developing country **or** an emerging country.

1.3	River environments are of great importance to people and need to be sustainably managed	a)	Uses of water, including agriculture, industry, human hygiene and leisure, and the rising demand for and supply of water: areas of water shortage and water surplus.
		b)	Reasons for variations in water quality, including pollution (sewage, industrial waste, agriculture) and the storage and supply of clean water (dams and reservoirs, pipelines, treatment works). (4)
		c)	Causes of river flooding, including rainfall intensity, seasonal variations in discharge due to monsoons or snowmelt, relief, urbanisation, and the prediction and prevention of flooding. (5)

Integrated skills	
(1)	Draw and interpret storm hydrographs using rainfall and discharge data.
(2)	Use geology maps (paper or online) to link river long profiles to geology.
(3)	Use GIS to map river systems.
(4)	Use different maps (paper or online) to investigate the impact of human intervention.
(5)	Use weather and climate data.

Key ideas	Detailed content
1.1 The world's water supply is contained in a closed system – the hydrological cycle	a) The hydrological cycle: characteristics, stores and transfers. b) Features of a drainage basin: source, watershed, channel network, mouth. c) Factors affecting river regimes: precipitation, including storm hydrographs, temperature, vegetation, land use, water abstraction, dams. (1)

1 River environments

1.1 The hydrological cycle

Characteristics, stores and transfers

The Earth's water is constantly recycled in a **closed system** called the **hydrological cycle**. Figure 1.1.1 shows that water can be held for varying periods of time in a number of **stores**, namely:

- in oceans and seas
- on land as rivers, lakes and reservoirs
- in bedrock as groundwater
- in the atmosphere as water vapour and clouds.

Over 97% of the world's water is stored in oceans and seas. This water is of course saline. Of the rest of the world's water (<3%) which is fresh, just over 2% is held as ice and snow with most of this in Antarctica and Greenland. This is followed by 0.6% as groundwater, and 0.1% in rivers, lakes and surface reservoirs. Only 0.001% is held in the atmosphere at any one time.

Transfers of water occur between stores by the following processes:

- Evaporation
- Precipitation
- **Percolation**
- **Transpiration**
- **Overland flow**
- **Throughflow**
- Condensation
- **Infiltration**
- **Groundwater flow**

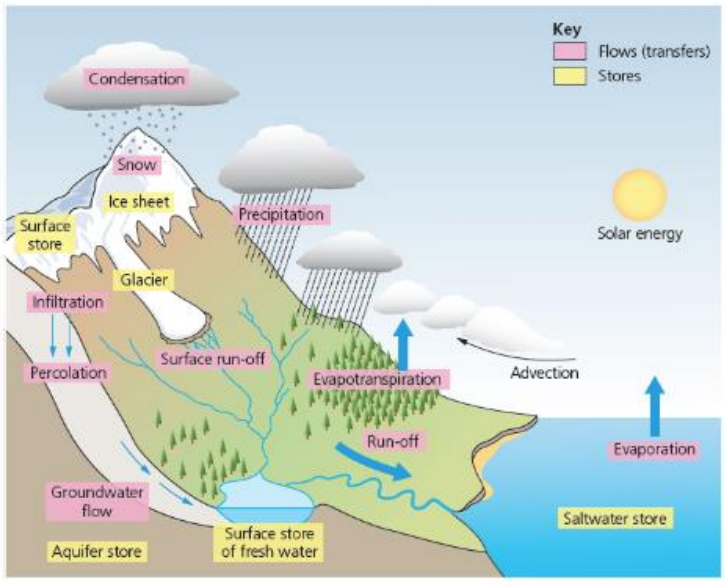


Figure 1.1.1 Processes, stores and transfers in the hydrological cycle

Evaporation, condensation and precipitation

These are the three main processes in the hydrological cycle.

Evaporation takes place mainly from surface water. The energy required comes from the sun's heat and from wind. Large amounts of water evaporated from the seas and oceans are carried by air masses onto land. Evapotranspiration is the combined losses of water from the ground, water bodies and vegetation.

Condensation happens when water vapour is cooled to a level known as the dew point. Condensation forms clouds and can also occur at the surface as fog.

Precipitation occurs when water in any form falls from the atmosphere to the surface. This is mainly as rain, snow, sleet and hail. Thus, water is constantly recycled between the sea, air and land.

Features of a drainage basin

A **drainage basin** is the area drained by a river and its tributaries (Figure 1.1.2). While the global hydrological cycle is a closed system, the hydrological cycle of an individual drainage basin is an open system

as it is open to external inputs and outputs. Drainage basins have a number of distinct features:

- The boundary of a drainage basin is called the **watershed**. This is a ridge of high land that separates one drainage basin from another.
- The point where a river begins is its **source**.
- A river reaches the sea at its **mouth**.
- A tributary joins the main river at a **confluence**.
- A main river and all its tributaries form a **channel network** or river system.

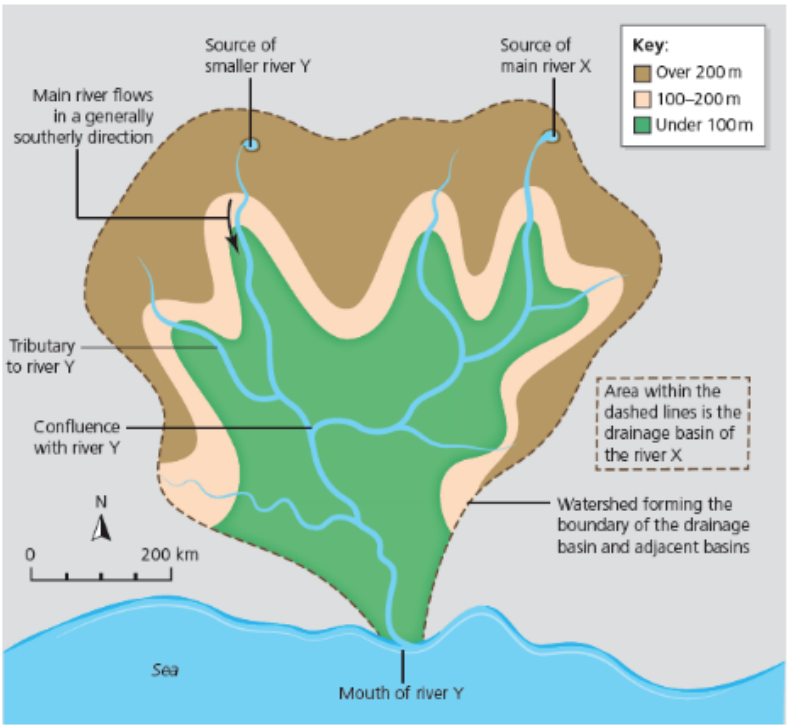


Figure 1.1.2 Features of a drainage basin

EXAM TIP – IF DRAWING A DRAINAGE BASIN – DISTINGUISH BETWEEN FLOWS AND STORES.

Exam tip

Remember that the global hydrological cycle is a closed system as it has no inputs or outputs, but the hydrological cycle of an individual drainage basin is an open system as it is open to external inputs and outputs.

The source of a river

The starting point of a river may be:

- an upland lake
- a melting glacier
- a spring in a boggy upland area
- a spring at the foot of an escarpment.

When small streams begin to flow they act under gravity, following the fastest route down slope. Water is added to them from tributaries, groundwater flow, throughflow and overland flow.

Channel networks

Some main rivers have a large number of tributaries so that no place in the drainage basin is very far from a river. Such an area is said to have a high drainage density. Where a main river has few tributaries, the drainage density is low.

Mouth of a river

Most rivers drain into a sea or ocean, but some drain into lakes which may be far from a coastline. For example, the River Volga, the longest river in Europe, flows into the Caspian Sea.

Factors affecting river regimes

A **river regime** is the variation in the discharge of a river over the course of a year (Figure 1.1.3). The regime of a river is influenced by several factors:

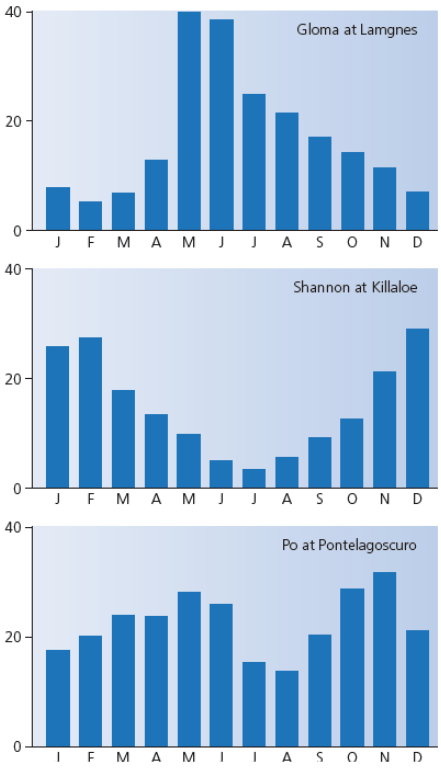


Figure 1.1.3 Three contrasting river regimes for the Shannon, Gloma, and Po

Climate

The most important factor is climate (Figure 1.1.3):

- The river Shannon (Ireland) has a typical temperate regime with a clear winter maximum in discharge, the result of high rainfall beginning in late autumn and subsiding in the spring.
- The river Gloma in arctic Norway has a spring peak associated with snow melt as temperature increases after the cold of winter.
- The river Po near Venice has two main maxima associated with periods of high rainfall in spring and autumn, and spring snowmelt from Alpine tributaries.

For river regimes the type of precipitation occurring is important, e.g. snow in polar and high altitude regions, and thunderstorms with convection rainfall in warm/hot continental interiors in summer. Temperature has a huge effect on evaporation rates – high temperatures lead to more evaporation with less water getting into rivers. However, as warm air can hold more water vapour than cold air, very high precipitation and river discharge can be experienced in hot, moist climates.

Vegetation

- High vegetation cover intercepts more rainfall, increases infiltration and reduces overland flow. Broad-leafed vegetation is particularly effective in this respect.
- In winter deciduous trees lose their leaves and so intercept less rainfall.
- Wetlands can hold water and release it slowly into rivers.

Geology and soils

- Permeable rocks allow the accumulation of groundwater which is gradually released into rivers as **base flow**.
- The more compact the soil surface, the less infiltration and the greater the overland flow.

Land use

- Forested areas are most effective in slowing the movement of water to channel networks. In contrast, run off is much faster in areas lacking in vegetation cover.
- Built environments present the highest levels of impermeability, but urban drainage systems are designed to remove surface water as quickly as possible.

Water abstraction and dams

Water abstraction occurs along most rivers of a significant size. Water is abstracted for human consumption, irrigation and other uses. Abstraction a) directly changes surface water flows and b) indirectly lowers groundwater levels. Dams regulate river flow for the purposes of navigation, irrigation, hydropower production and human water supply. The reservoirs of water held behind dams experience significant evaporation, particularly those in hot, dry climates.

Other factors influencing river regimes

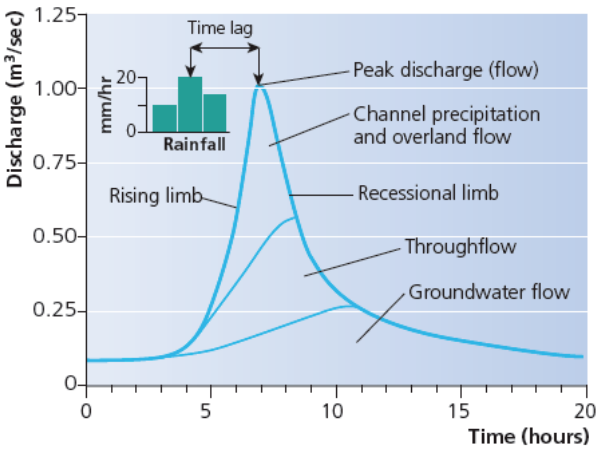
- Drainage basin size and shape: small drainage basins respond most quickly to rainfall events.
- Slopes: steeper slopes create more overland flow.
- Drainage density: basins with a high drainage density respond very quickly to storms.

Storm hydrographs

A **storm hydrograph** (Figure 1.1.4) shows how the discharge of a river varies over a short time period such as 24 hours and usually refers to a single storm (period of rainfall).

- Before the storm begins, water is mainly supplied to the river by groundwater flow (base flow).
- During the storm, some water infiltrates into the local soil while some flows over the surface as overland flow.
- Overland flow, in particular, reaches the river quickly, causing a rapid rise in the level of the river, the rising limb on Figure 1.1.4.
- The peak flow is the maximum discharge of the river as a result of the storm.
- The time lag is the time between the height of the storm and the maximum discharge.
- The recessional limb shows the speed with which the discharge declines after the peak.

The effect of urban development on hydrographs is to increase peak flow and decrease time lag.



Exam tip

Remember that a river regime looks at variations in average discharge over the course of a year, while a storm hydrograph records discharge due to a single storm event.

1.2	Physical processes give rise to characteristic river landforms	a) Fluvial processes involved in river valley and river channel formation: erosion (vertical and lateral), weathering and mass movement, transportation and deposition, and factors affecting these processes (climate, slope, geology, altitude and aspect). b) How channel shape (width, depth), valley profile (long and cross profiles), gradient, velocity, discharge, and sediment size and shape change along the course of a named river 🌍. (2) c) How river landscapes change over the course of a river, with distinctive upland and lowland landforms, including the formation of valleys, interlocking spurs, waterfalls, meanders, oxbow lakes, flood plains and levees. (3)

1.2 Physical processes and river landforms

Fluvial processes and river channel formation

Rivers have played a major part in forming the landscape in drainage basins through the **fluvial** processes of erosion, transportation and deposition. However, two other important landscape processes also operate in drainage basins – weathering and mass movement.

Weathering is the breakdown of rock in situ (not involving movement). For example:

- the freeze–thaw action of physical weathering
- chemical weathering by rainwater, which is slightly acidic, on rocks.

Biological weathering, particularly the root systems of plants and trees gradually breaking rock apart, is also active in drainage basins.

Mass movement is the large-scale movement of weathered material under the influence of gravity. It carries weathered material into rivers which:

- contributes additional material to a river's load
- thereby increasing erosion in the upper course
- and adding to deposition in the middle and lower courses.

The two main types of mass movement in drainage basins are slumping and soil creep.

Energy and processes

- Around 95% of a river's energy is used to overcome **friction**.
- The remaining 5% or so is used to erode the river channel and transport this material downstream. The amount of energy in a river is determined by a) the amount of water in the river and b) the speed at which it is flowing.
- Most friction occurs where the water is in contact with the bed and the banks. Rocks and boulders on the bed increase the amount of friction.

Near the source, rivers channels are shallow and narrow. Also, the beds are often strewn with boulders and very uneven. There is much friction and the water flows more slowly here than further downstream where the channel is a) wider, b) deeper and c) less uneven.

Erosion

There are four processes of **erosion**:

- **Hydraulic action**: the sheer force of river water removing loose material from the bed and banks of the river.
- **Abrasion**: the wearing away of the bed and banks by the river's load.
- **Attrition**: in swirling water, rocks and stones collide with each other and with the bed and banks. Over time the original sharp edges become smooth and the pieces of rock become smaller in size.
- **Solution**: some rocks such as limestone dissolve slowly in river water.

Near the source a river cuts down into its bed, deepening the valley. This is **vertical erosion.** In the middle and lower courses, sidewards or **lateral erosion** is most important. This widens the valley. Most erosion occurs when **discharge** is high and rivers are said to be in flood.

Transportation

There are four processes by which a river can **transport** its **load**: traction, saltation, suspension and solution. Parts of the load which are moved by traction when the discharge of the river is low may be transported by saltation when the discharge is high.

Deposition

Deposition takes place when a river does not have enough energy to carry its load. This can happen when:

- the gradient decreases
- discharge falls during a dry period
- the current slows down on the inside of a meander
- the river enters a lake or the sea.

When a river loses energy, the first part of the load to be deposited is the large, heavy material known as the **bedload**. Lighter material is carried further. The gravel, sand and silt deposited is called **alluvium**. This is spread over the floodplain. The solution load is carried out to sea with much of the clay, the lightest suspended particles.

Channel shape, valley profile, velocity and discharge along the course of the river Tees

The Tees is one of the major rivers in North East England. It drains an area of about 1800 square km. The source of the Tees is on the eastern side of the Pennine mountains. The river flows eastwards to the orth Sea. The Tees exhibits most of the classic ocesses and landforms of the upper, middle and wer courses of rivers. Figure 1.2.1 shows how the ng and cross profiles of the Tees change from source mouth as the river's:

gradient decreases
depth increases
width increases
volume increases
velocity increases
discharge increases
sediment size decreases and shape becomes more rounded.

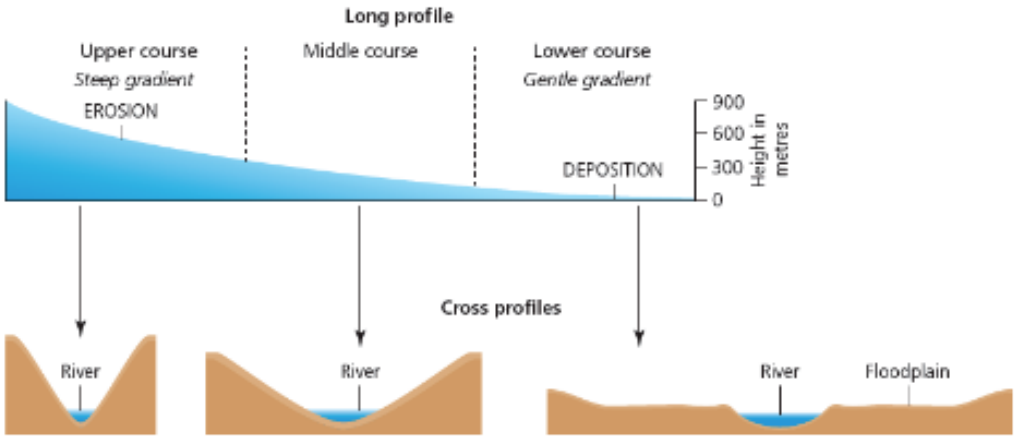


Figure 1.2.1 Long and cross profiles of the river Tees

Upper course

This is mainly an area of moorland where annual precipitation can rise to over 2000 mm per year. The river channel is shallow and narrow. The bed is uneven with sizeable angular boulders in places. There is much friction and the water flows more slowly here than further downstream where the channel is a) wider, b) deeper and c) less uneven.

Vertical erosion has created a steep channel gradient and steep valley sides. Impressive waterfalls are evident along with clear examples of interlocking spurs. High Force is the UK's largest waterfall at 21 metres high. Here a bed of hard rock (dolerite) overlies softer rock (sandstone and shale). As the waterfall has eroded upstream, it has left behind an impressive gorge.

Middle course

Below Middleton-in-Teesdale the valley widens out and the channel slope becomes more gentle. Lateral erosion takes over from vertical erosion, forming distinctive meanders. Good examples can be seen near Barnard Castle. The Tees is joined by important tributaries including the rivers Lune, Balder and Greta. The result is a substantial increase in the volume of water in the river.

Lower course

Here the channel gradient is gentle with the river very close to sea level as it meanders across a fertile clay plain. Deposition is the dominant process. The river has now formed much larger meanders, e.g. near Yarm, across its wide floodplain. Oxbow lakes and levees are clearly evident. The original winding river channel below Stockton has been straightened by artificial cuts to aid navigation. The mouth of the Tees is in the form of a large estuary with mudflats and sandbanks.

Changes in river landscapes over the course of a river

Upland landforms

The characteristic river landforms in upland areas are a steep V-shaped valley, a steep gradient, interlocking spurs, potholes, and waterfalls, rapids and gorges.

Rivers begin to meander in the upper course. Erosion is concentrated on the outside banks of these small meanders. This eventually causes **interlocking spurs** which alternate on each side of the river. These spurs are ridges of high land which project towards a river at right angles.

Where the bed is very uneven, pebbles carried by fast, swirling water can become temporarily trapped by obstacles in the bed. The swirling currents cause the pebbles to rotate in a circular movement, eroding circular depressions in the bed called **potholes.**

- **Waterfalls** occur when there is a sudden change in the course of the river which may be due to differences in rock hardness (Figure 1.2.3).
- Waterfalls can form when the hard rock is horizontal, vertical or dipping upstream. The softer rock is eroded more quickly, causing the hard rock to overhang.
- The undercutting is caused by abrasion and hydraulic action. The overhang steadily becomes larger until a critical point is reached. When this occurs the overhang collapses.
- The rocks that crash down into the plunge pool will be swirled around by the currents. This increases erosion, making the plunge pool deeper.
- This process, beginning with the collapse of a layer of hard rock, will be repeated time after time. As a result the waterfall retreats upstream, leaving behind a steep-sided **gorge**.

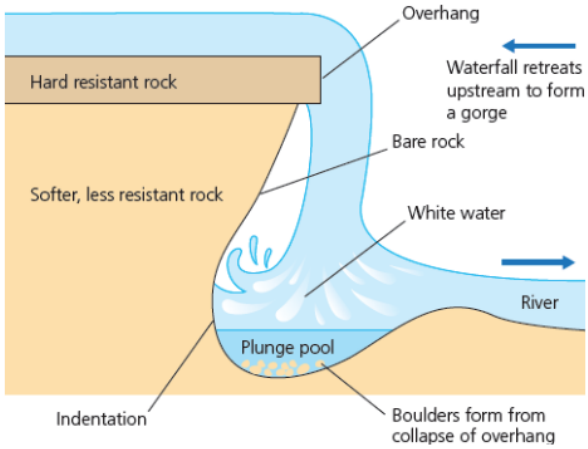


Figure 1.2.3 Formation of a waterfall

Lowland landforms

Meanders and meander migration

The volume of water increases as more tributaries join the main river. **Lateral erosion** takes over from vertical erosion as the most important process (Figure 1.2.4). As a result, meanders become larger. The current is fastest and most powerful on the outside of the meander, particularly on the downstream section. Erosion is relatively rapid. The outside bank is **undercut**. Again the emphasis is on the downstream section. Eventually it collapses and retreats, causing the meander to spread further across the valley. If the meander has already reached the side of the valley, erosion on the outside bend may create a very steep slope or **river cliff**. The current on the inside of the meander is much slower. As the river slows it drops some of its load and deposition occurs. This builds up to form a gently sloping **slip-off slope** (or point bar). Thus, the water is shallow on the inside of the meander and deep on the outside.

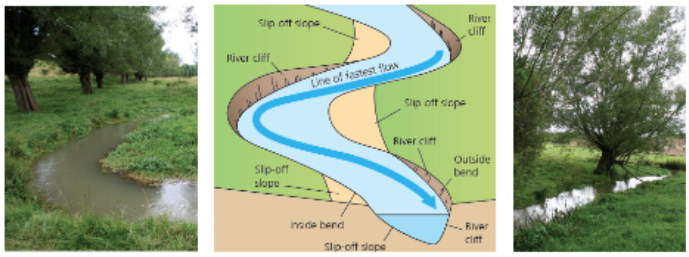


Figure 1.2.4 Cross-section of a meander

Because of the power of lateral erosion in the middle course, meanders slowly change their shape and position. As they push sideways they widen the valley. But they also move or migrate downstream. This erodes the interlocking spurs, giving a much more open valley compared with the upper course.

Meander necks and oxbow lakes

- As a river flows towards its mouth, meanders become more pronounced and the valley becomes wider and flatter.

- As erosion continues to cut into the outside bends of a meander, a **meander neck** may form (Figure 1.2.5). Eventually, when the river is in flood, it may cut right across the meander neck and shorten its course.
- For a while water will flow along both the old meander route and along the new straight course. However, because the current will slow down at the entry and exit points of the meander, deposition will occur.
- After a time the meander will be cut off from the new straight course to leave an oxbow lake.

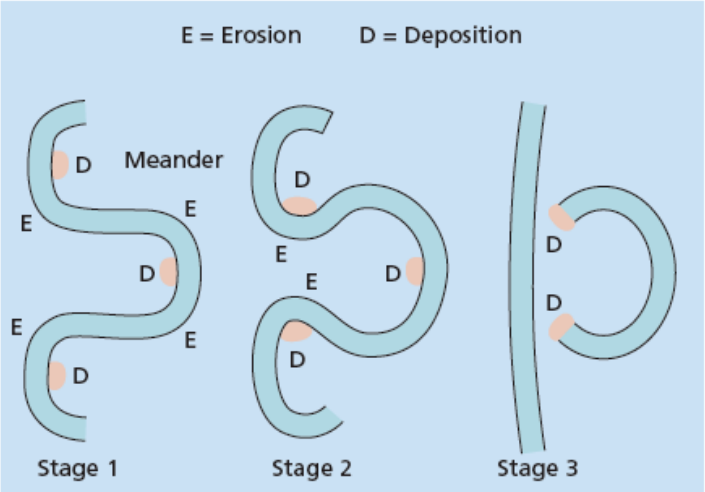


Figure 1.2.5 Formation of an oxbow lake

Floodplains and levees

A floodplain is the area of almost flat land on both sides of a river. It is formed by the movement of meanders explained above. When discharge is high the river is able to transport a large amount of material in suspension. At times of exceptionally high discharge, the river will overflow its banks and flood the low-lying land around it. The sudden increase in friction as the river water surges across the floodplain reduces velocity and causes the material carried in suspension to be deposited on the floodplain. The heaviest or coarsest material will be dropped nearest to the river. This can form natural embankments alongside the river called **levees** (Figure 1.2.6). The lightest material will be carried towards the valley sides. Each time a flood occurs, a new layer of **alluvium** will be formed. This gradually builds up the height of the floodplain.

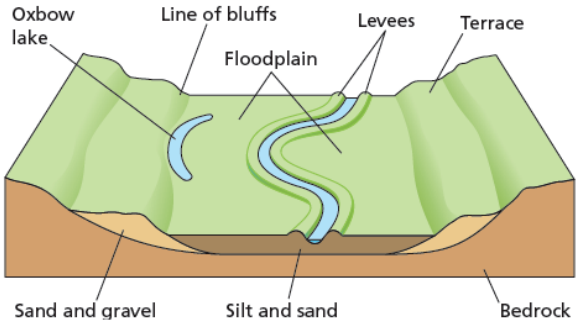


Figure 1.2.6 Cross-section of a river floodplain

Case studies of river management in a developed country **and** a developing country **or** an emerging country.

1.3	River environments are of great importance to people and need to be sustainably managed	a)	Uses of water, including agriculture, industry, human hygiene and leisure, and the rising demand for and supply of water: areas of water shortage and water surplus.
		b)	Reasons for variations in water quality, including pollution (sewage, industrial waste, agriculture) and the storage and supply of clean water (dams and reservoirs, pipelines, treatment works). (4)
		c)	Causes of river flooding, including rainfall intensity, seasonal variations in discharge due to monsoons or snowmelt, relief, urbanisation, and the prediction and prevention of flooding. (5)

1.3 The importance of river environments and their management

Uses of water; rising demand; water shortages

Uses of water

Global water use increased from 1.22 trillion m^3 in 1950 to over 4 trillion m^3 in 2018. This increase was more than twice the rate of population growth. Current global water use by sector is:

- agriculture: 69%
- industry: 19%
- domestic: 12%.

Figure 1.3.1 contrasts water use in developed and developing countries. In developing countries agriculture accounts for over 80% of total water use, with much devoted to **irrigation**. In developed countries the demand for water for leisure activities has risen significantly.

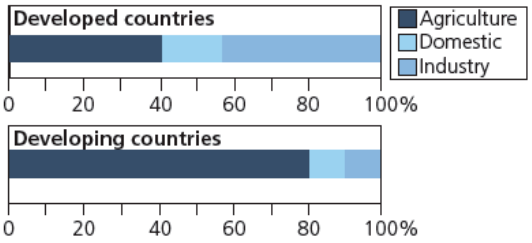


Figure 1.3.1 Water used for agriculture, industry and domestic for the developed and developing worlds

Rising demand for water

Global water use has more than tripled since the 1950s due to:

- population growth
- rising living standards
- changing patterns of food consumption (from grain-based to protein-based diets)
- increasing urbanisation
- higher water demand from industry.

Increasing water supply

The objective in all methods of **water supply** is to take water from its source to the point of usage. In 2015, about 91% of the global population had access to piped water supply, up from 76% in 1990. However, over 660 million people still do not have access to an improved water source. Much of the increase in water consumption has been made possible by investment in water infrastructure, particularly dams and reservoirs. In some countries water is delivered on a daily basis to urban areas that are not yet connected to the mains supply.

Areas of water shortage

Water shortage is most pronounced in the Middle East and North Africa, Central Asia and northern India.

Much of the precipitation that falls to the Earth's surface cannot be captured and the rest is very unevenly distributed. The arid regions of the world cover 40% of the world's land area, but receive only 2% of global precipitation.

Water scarcity is to do with the availability of **potable water**. It is threatening to put world food supplies in jeopardy, limit economic and social development, and create serious conflicts between neighbouring drainage basin countries.

- A country is judged to experience **water stress** when water supply is below 1700 m^3 per person per year.
- When water supply falls below 1000 m^3 per person a year, a country faces **water scarcity** for all or part of the year.

Water depletion hotspots are caused by drought, groundwater depletion, ice-sheet and glacier loss/retreat, surface water loss (the drying of the Aral and Caspian Seas), and the filling of large reservoirs (the Three Gorges Dam).

Water surplus

Water surplus occurs when the demand for water is less than the supply. This situation exists mainly in temperate and tropical wet areas and includes large parts of North America and Western Europe, and the Amazon and Congo Basins.

Countries and regions within countries experiencing water surplus tend to have the following:

- Positive geographical characteristics with regard to water – high rainfall and surface run-off, large stores of surface water and significant aquifers. Moderate rates of evaporation can also play a major role.
- Low population density and effective water management (quantity and quality).

Exam tip

Remember that water supply is water that can be accessed on a regular basis by those people who want to use it. Investment in infrastructure is usually needed for this to happen.

The storage and supply of clean water

Water quality

Reasons for variations in water quality

Water **pollution** comes from a number of sources including:

- contamination by agricultural run-off, particularly from factory farming
- industrial pollution of rivers and other water bodies
- urban run-off carrying pollutants from cars, factories and other sources
- untreated sewage.

Each year, more than 80 per cent of the world's wastewater is released to the environment without being collected or treated. This a) pollutes the environment and b) wastes a renewable resource. While rivers in more affluent countries have become steadily cleaner in recent decades, the reverse has been true in much of the developing world. Rivers in Asia are the most polluted.

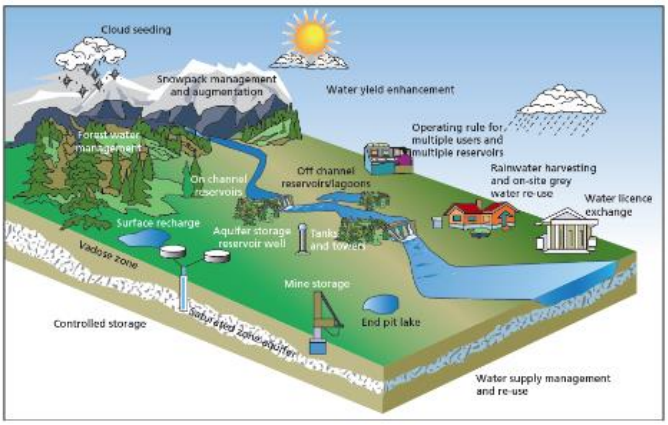


Figure 1.3.2 Alternative water supply and management methods

Dams and reservoirs

- Used to save, manage and prevent the flow of excess water into specific regions.
- 'On channel' **reservoirs** exist where a **dam** has been built across an existing river (Figure 1.3.2).
- 'Off channel' reservoirs usually use depressions in the existing landscape or human-dug depressions to store water.

Globally the construction of dams has declined since the 1960s and 1970s because most of the best sites for dams are already in use or such sites are strongly protected. An alternative to building new dams and reservoirs is to increase the capacity of existing reservoirs by extending the height of the dam.

Wells and boreholes

- **Wells and boreholes** are sunk directly down to the water table.
- **Aquifers** provide about half of the world's drinking water, 40% of the water used by industry and up to 30% of irrigation water.
- About 35% of all public water supply in England and Wales comes from groundwater. Groundwater is even more important in arid and semi-arid areas.

Pipelines

In general, water is redistributed through water networks and grids over longer distances in developed countries than in developing countries because of the high cost of water infrastructure. However, water grids are nowhere near as extensive as power grids. Thus, in many countries there is limited ability to move water from areas of water surplus to areas of water deficit.

Water treatment

- Almost all sources need some degree of **water treatment** to be pure enough for human consumption. Contamination can be caused by both anthropogenic (caused by human activity) and natural contaminants.
- Developed countries use central source treatment systems (treatment works). These involve physical processes such as sedimentation and filtration, and disinfectant processes such as chlorination.
- In developing countries, point-of-use (POU) treatment is also used where treatment works do not exist or lack capacity.
- Groundwater tends to be relatively clean in comparison to surface water.

Well-maintained urban water systems lose between 10% and 30% of the water they transport. However, in developing world cities, up to 70% can be lost.

Relief

Steep slopes encourage rapid run-off. The potential for damage by floodwaters increases exponentially with velocity and speeds above 3 m per second.

Urbanisation

The creation of highly impermeable surfaces increases run-off; a dense network of drains and sewers increases drainage density; natural river channels are often constricted by bridge supports or riverside facilities, reducing their carrying capacity; due to increased storm run-off, many sewerage systems cannot cope with the resulting peak flow.

In addition, impermeable rocks, a high drainage density, lack of vegetation cover and soils with a low infiltration capacity all encourage rapid run-off. Human actions including deforestation and poor agricultural practices can reduce interception and increase run-off.

Flooding

Causes of river flooding

- The primary causes of most floods are external climatic forces. These factors have become more variable and extreme with climate change.
- Secondary **flood** causes tend to be drainage basin specific. Over time the impact of human activity on drainage basins has steadily increased.

Rainfall intensity

Floods in the UK are associated with deep depressions (low-pressure systems) in autumn and winter. They tend to be both long in duration and wide in the area covered.

Seasonal variations in discharge

In India, up to 70% of the annual rainfall occurs in one hundred days in the summer southwest **monsoon**. Melting snow in spring from mountain ranges such as the Himalayas, Rockies and Alps can be responsible for widespread flooding in many countries.

The prediction and prevention of flooding

Prediction

In recent decades, flood forecasting and warning have become more accurate. This is particularly so in developed countries. According to the **US Geological Survey** (USGS), flood prediction requires several types of data:

- the amount of rainfall occurring
- the type of storm producing the precipitation
- the rate of change in the discharge of the river/channel network
- the characteristics of the drainage basin.

The task then is to convey information about the immediacy and severity of the flood risk to people likely to be affected as quickly as possible. For example, using the UK government website (www.gov.uk) and entering the name of a location or postcode, you can check if you are:

- at immediate risk of flooding
- at risk of flooding in the next five days
- in an area that's likely to flood in the future.

This website also provides information on (a) how to plan ahead for flooding, (b) what to do in a flood, and (c) how to recover after a flood.

Prevention

- Traditionally floods have been managed by methods of 'hard engineering' such as dams, reservoirs, levees, straightened channels and flood-relief channels.
- Increasingly 'soft engineering' measures have come to the fore. These techniques focus on working with natural processes and features rather than attempts to control them. They include catchment management plans, river restoration and wetland conservation.
  - **Land-use zoning** can reduce the number of premises and people at risk of flooding.
  - Hazard-resistant design (flood-proofing) includes any adjustments to buildings and their contents that help reduce losses.

Case study

River management in south-western USA

The USA is a huge user of water. The western states of the USA, covering 60% of the land area with 40% of the total population, receive only 25% of the country's annual precipitation. Yet each day the west uses as much water as the east. Water management has been vital to the prosperity of California and other states in this region.

- Over time there has been a huge investment in water transfer schemes. This has benefited agriculture, industry and settlement.
- California has benefited most from this investment in water supply. Seventy per cent of run-off originates in the northern one-third of the state but 80% of the demand for water is in the southern two-thirds. Large amounts of water are transferred from rivers in the north to water bodies in the more heavily populated south for irrigation and urban/industrial use.
- The 2333-km-long Colorado River is an important source of water in the south-west. Over 30 million people in the region depend on water from the river. Major problems over the river's water have arisen because population has increased, along with rising demand from agriculture and industry.
- Major dams along the Colorado include the Hoover Dam and the Parker Dam.
- The $4 billion Central Arizona Project (CAP) is the most recent scheme to divert water from this great river. Completed in 1992, it brings vital water supply to the cities of Phoenix and Tucson. A new source of supply was necessary due to heavy depletion of groundwater resources.
- Resource management strategies include measures to reduce leakage and evaporation losses; recycling more water in industry; charging more realistic prices for irrigation water; extending the use of the most efficient irrigation systems; changing from highly water-dependent crops such as rice and alfalfa to those needing less water.
- Future options include developing new groundwater resources; investing in more desalination plants; constructing offshore aqueducts that would run under the ocean from the Columbia River in the north-west of the USA to California.

There is now general agreement that planning for the future water supply of the south-west should embrace all practicable options.

Case study

River management in China: The Three Gorges Dam

The Three Gorges Dam across the Yangtze River is the world's largest multi-purpose river management scheme. The dam was completed in 2009 and is over 2 km long and 100 m high. The lake impounded behind it is over 600 km long. The Yangtze basin provides 66% of China's rice and contains 400 million people.

The river drains 1.8 million km^2 and discharges 24,000 m^3/second of water annually.

The advantages of the project:

- Flood control protects 10 million people living downstream from the flooding caused by the seasonal nature of the Yangtze River. Downstream cities include Wuhan, Nanjing and Shanghai.
- An electricity-generating capacity of 22,500 MW which supplies Shanghai and Chongqing in particular. It is the largest electricity installation in the world.
- The locks constructed as part of the project allow shipping above the dam. Tourism has benefited from the rapid expansion of cruise ships along the river.
- Supplementing water supply downstream in dry periods to agriculture, industry and domestic supply.

Many disadvantages have been quoted. These include:

- Over 1.25 million people were forced to move to make way for the dam and lake.
- The region is seismically active and landslides are frequent.
- The dam traps silt which gradually reduces the capacity of the reservoir and reduces the fertility of farmland downstream.
- The dam interferes with aquatic life.

Topic 3: Hazardous environments

What students need to learn

Key ideas	Detailed content
3.1 Some places are more hazardous than others	a) Characteristics, distribution and measurement of different types of natural hazards including tropical cyclones, earthquakes and volcanoes. (1) b) Causes of tropical cyclone hazards, including ocean temperature, atmospheric pressure, wind shear and Coriolis force. c) Causes of volcanic and earthquake hazards, including the role of plate boundaries and hotspots. (2)
3.2 Hazards have an impact on people and the environment	a) Reasons why people continue to live in areas at risk from hazard events. b) Some countries are more vulnerable (physically, socially and economically) than others to the impacts of natural hazards. c) The shorter-term and longer-term impacts of **one** earthquake **one** volcano and **one** tropical cyclone hazard (3).

Case studies of hazard management for an earthquake in a developed country **and** a developing country **or** an emerging country.

3.3 Earthquakes present a hazard to many people and need to be managed carefully	a) Preparation for earthquakes (warning and evacuation, building design, remote sensing and GIS). (4) b) Short-term responses and relief (emergency aid, shelter and supplies). c) Longer-term planning (risk assessment, hazard mapping and rebuilding programmes). (5)

Integrated skills	
(1)	Use world maps to show the distribution of different hazards.
(2)	Use a range of different maps to show links between tectonic boundary and hazard type.
(3)	Use social media sources, satellite images and socio-economic data to assess varying impacts.
(4)	Use GIS to investigate preparation for earthquake hazards.
(5)	Use online data sources to research the range of shorter and longer-term responses for a particular earthquake event.

Key ideas	Detailed content
3.1 Some places are more hazardous than others	a) Characteristics, distribution and measurement of different types of natural hazards including tropical cyclones, earthquakes and volcanoes. (1) b) Causes of tropical cyclone hazards, including ocean temperature, atmospheric pressure, wind shear and Coriolis force. c) Causes of volcanic and earthquake hazards, including the role of plate boundaries and hotspots. (2)

3 Hazardous environments

3.1 Natural hazards

Characteristics, distribution and measurement

A natural hazard is defined as an extreme event or condition in the natural environment causing harm to people, properties or livelihoods. Natural hazards only lead to natural disasters because people live in hazardous areas. There are several types of natural hazards.

Tectonic and geological	Climatic and meteorological
Earthquakes	Tropical cyclones
Volcanoes	Drought
Tsunamis	Floods
Landslides	Tornadoes

It is possible to characterise hazards and disasters in several ways:

- **Magnitude**: the size of the event, e.g. the size of an earthquake on the **Moment Magnitude Scale**.
- **Frequency**: how often an event of a certain size occurs. The frequency is sometimes called the recurrence interval – the larger the event, the less frequently it occurs. However, it is the very large events that do most of the damage (to the physical environment, to people, properties and livelihoods).
- **Regularity**: some hazards, such as tropical **cyclones**, are regular, whereas others, such as earthquakes and volcanoes, are much more random.
- **Areal extent**: the size of the area covered by the hazard.
- **Spatial concentration/dispersion** is the distribution of hazards over space, whether they are concentrated in certain areas, such as tectonic plate boundaries,

as an earthquake, to slower timescale events such as tropical cyclones over a period of many days.

- **Duration**: the length of time that a natural hazard exists.

Tropical cyclones (hurricanes)

Tropical cyclones are intense, low-pressure systems that bring heavy rainfall, strong winds and high waves, and cause other hazards such as flooding and mudslides. They are large-scale features with a diameter of up to 800 km and a calm central area, the **eye**. Most hurricanes take place in tropical and sub-tropical regions.

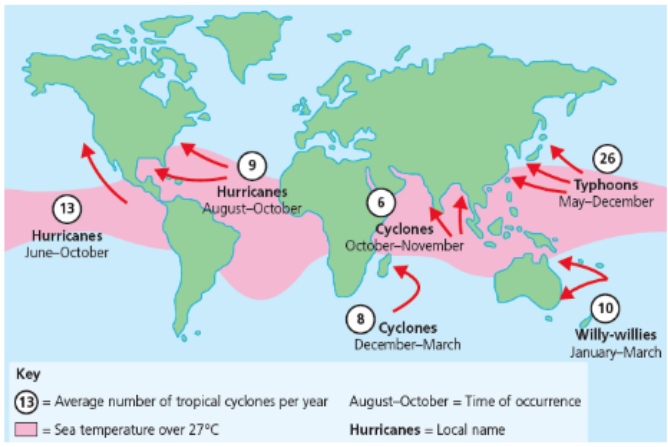


Figure 3.1.1 Distribution of tropical cyclones

Table 3.1.2 The Saffir–Simpson Scale

Hurricane category	Pressure (mb)	Wind speed (kmph)	Approx. storm surge (m)
1	≥980	119–153	1.2–1.5
2	965–979	154–177	1.6–2.6
3	945–964	178–209	2.7–3.6
4	920–944	210–251	3.7–5.5
5	<920	≥252	Over 5.5

Earthquakes

An earthquake is a sudden, violent shaking of the Earth's surface. Earthquakes occur after a build-up of pressure causes rocks and other materials to give way. Most of this pressure occurs at plate boundaries when one plate is moving against another. Earthquakes are associated with all types of plate boundaries. Broad belts of earthquakes are associated with subduction zones, whereas narrower belts of earthquakes are associated with constructive plate margins. Collision boundaries are also associated with broad belts of earthquakes, whereas conservative plate boundaries give a relatively narrow belt of earthquakes.

The **focus** refers to the place beneath the ground where the earthquake takes place. **Deep-focus earthquakes** are associated with subduction zones. **Shallow-focus earthquakes** are generally located along constructive boundaries and along conservative boundaries. The **epicentre** is the point on the ground surface immediately above the focus.

Measurement

The **Richter scale** was developed in 1935 to measure the magnitude of earthquakes. The scale is logarithmic, so an earthquake of 5.0 on the Richter scale is ten times more powerful than one of 4.0 and one hundred times more powerful than one of 3.0. Scientists are increasingly using the Moment Magnitude Scale (M) which measures the amount of energy released and produces figures that are similar to the Richter scale. For every increase of 1.0 on the M scale, the amount of energy released increases by over 30 and an increase of ten times the amplitude recorded by a seismograph.

Table 3.1.3 Annual frequency of occurrence of earthquakes of different magnitude based on observations since 1900

Descriptor	Magnitude (Richter scale)	Average number/years	Hazard potential
Great	>8	1	Total destruction, high loss of life
Major	7.0–7.9	18	Serious building damage, major loss of life
Strong	6.0–6.9	120	Large losses, especially in urban areas
Moderate	5.0–5.9	800	Significant losses in populated areas
Light	4.0–4.9	6200	Usually felt, some structural damage
Minor	3.0–3.9	49,000	Typically felt but usually little damage
Very minor	<3.0	9000/day	Not felt, but recorded

Volcanoes

A volcano is an opening through the Earth's crust through which hot molten **magma** and ash are erupted onto the land as **lava**, ash and cinders. Most volcanoes are found at plate boundaries (constructive and destructive/subduction zones) although some occur over hotspots. About three-quarters of the Earth's 550 historically active volcanoes lie along the Pacific Ring of Fire.

The Hawaii volcanoes are found in the middle of the ocean and occur at a hotspot. A hotspot is a plume of hot material rising from deep within the mantle which is responsible for the volcanoes.

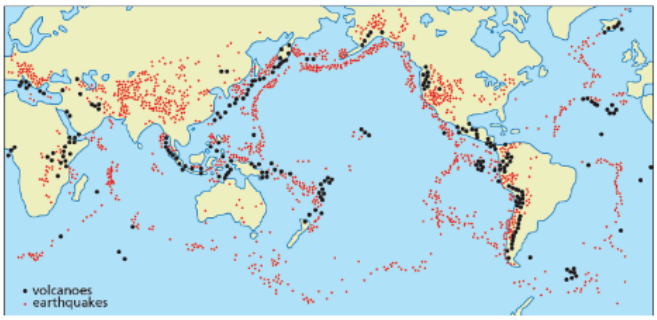


Figure 3.1.2 Distribution of volcanoes and earthquakes

The strength of a volcano is measured by the volcanic explosive index (VEI). This is based on the amount of material ejected in the explosion, the height of the cloud it causes, and the amount of damage. Any explosion above level 5 is very large and violent. A VEI 8 is also known as a supervolcano.

Causes of tropical cyclone hazards

Tropical cyclones develop from low pressure systems. They originate over oceans that have sea surface temperatures of over 27°C in order for sufficient evaporation to occur. They develop away from the Equator as there is insufficient rotation (Coriolis Force) there. For a tropical cyclone to form, lower and upper winds need to be coming from the same direction. This means that vertical wind shear (the change in wind speed and direction with height) is reduced.

Tropical storms bring intense rainfall and very high winds, which may in turn cause storm surges and coastal flooding, and other hazards such as flooding and mudslides. The impact of different strength of tropical cyclones is shown in Table 3.1.5.

Category	Description
Category 1: Winds 119–153 km/h; storm surge generally 1.2–1.5 m above normal	No real damage to building structures. Damage primarily to unanchored mobile homes. Also, some coastal road flooding and minor pier damage.
Category 3: Winds 178–209 km/h; storm surge generally 2.7–3.6 m above normal	Some structural damage to small residences and utility buildings. Mobile homes are destroyed. Flooding near the coast destroys smaller structures, with larger structures damaged by floating debris. Evacuation of low-lying residences close to the shoreline may be necessary.
Category 5: Winds greater than 252 km/h; storm surge generally greater than 5.5 m above normal	Complete roof failure on many residences and industrial buildings. Some small buildings blown over or blown

Volcanic and earthquake hazards

Volcanic hazards occur by constructive and destructive plate margins and near **hot spots**. They do not occur near conservative plate margins or collision zones. The underlying cause of volcanic hazards is the ejection of magma from within the Earth onto the Earth's surface. However, the nature of volcanic eruptions varies. At constructive margins, associated with rising magma within the Earth, the lava is hot and runny and produces less explosive eruptions. In contrast, at destructive plate margins, the lava is acidic and sticky and produces explosive eruptions which can include **pyroclastic flows** and lava flows. Destructive eruptions are more likely to lead to **acidification** and climate change as they put more material into the atmosphere. If volcanic ash mixes with water it can create **lahars** or mudflows. Lava flows at hot spots, e.g. Hawaii, are relatively slow moving but they can burn buildings and vegetation. However, volcanic hazards are only hazards when people are near to volcanoes.

There are a number of **primary hazards** and **secondary hazards** related to volcanic eruptions. The impacts will depend on the magnitude of the event and the population at risk.

Primary hazard	Secondary hazards
Lava flows	Lahars (mudflows)
Ash fallout	Landslides
Pyroclastic flows	Acidification
Gas emissions	Climate change (global cooling)
	Fire

Earthquake hazards

Earthquakes commonly occur at plate boundaries. There is a build-up of pressure as plates move in different directions. The release of pressure results in a sudden movement which is an earthquake. Some earthquakes may be caused by human activity such as mining, building of large dams and the underground testing of bombs.

Primary hazards	Secondary hazard
Ground shaking	Ground failure and soil liquefaction Building collapse Gas leaks and fires Landslides and rock falls Debris flow and mudflow Tsunamis

3.2	Hazards have an impact on people and the environment	a) Reasons why people continue to live in areas at risk from hazard events. b) Some countries are more vulnerable (physically, socially and economically) than others to the impacts of natural hazards. c) The shorter-term and longer-term impacts of **one** earthquake **one** volcano and **one** tropical cyclone hazard (3).

3.2 Hazards have an impact on people and the environment

Reasons why people live in hazardous environments

Why do people often live in hazardous environments?

Natural hazards occur only when people, livelihoods and/or property are at risk. Although some causes of hazards may be tectonic or climatic, it is because people live in such areas that makes them hazardous. If no one was affected, it would not be a hazard.

Why do people live in such places?

- Some people consider that the potential advantages of living in an area outweigh the potential risks.
- Another view is that poor people have little choice in where they live. Hence, poor people live in unsafe areas – such as steep slopes or floodplains – because they are prevented from living in better areas.

For example, deltas provide water, silt, fertile soils and the potential for trade and communications. They may also be subject to tropical cyclones, as shown by the 2020 floods caused by Cyclone Amphan in the Ganges Delta.

Vulnerability to natural hazards

The concept of **vulnerability** includes not only the physical effects of a natural hazard but also the statu of people and property in the affected area. Several factors can increase people's vulnerability to natural hazards.

Economic factors

- *Levels of wealth and development*: These influence building quality. People in high-income countries (HICs) generally have better quality housing than poorer communities in low-income countries (LICs), especially in slum areas.
- *Building styles and building codes*: These affect the safely of buildings. Some countries have a more rigorous enforcement of building regulations, e.g. Japan.
- *Access to technology*: People with access to ICT may have more warnings. Japan sends out text messages to warn people about tsunamis and earthquakes.
- *Insurance cover*: The poor cannot afford insurance cover. To have insurance cover, buildings need to be made hazard-resistant.

Social factors

- *Education*: People with a better education generally have a higher income and can afford better quality housing.
- *Gender*: Many women are carers for their children and/or their parents and they may feel responsible for them following an event.
- *Population density*: Many rapidly growing

Exam tip

Remember that some people are more vulnerable to natural hazards than others – poverty is a major factor which increases risk.

Short-term and long-term impacts

Nepal earthquake, 2015

Short-term impacts

In 2015 there was a 7.8 magnitude earthquake in Nepal.

- There were over 300 aftershocks, some of them reaching magnitudes of over 7.0.
- The main earthquake was a shallow-focus earthquake just 80 km from Kathmandu.
- Rapid population growth in Kathmandu had increased the vulnerability of the area to earthquakes.
- Nearly 9000 people were killed and 20,000 injured.
- Overall, 8 million people were affected.
- Over 600,000 homes were destroyed and over 250,000 homes were damaged.
- Water and electricity were not available in many places following the earthquake.
- The government immediately began to search for people in collapsed buildings.
- Temporary shelters were provided for those made homeless.
- Temporary schools made of bamboo and tarpaulin opened after a month.

Long-term impacts

Longer-term impacts largely related to rebuilding housing.

- One year after the earthquake, towns and villages outside of Kathmandu remained severely damaged with debris present.
- Two years after the earthquake, only 5% of homes had been rebuilt and many school buildings were still only temporary structures.

Volcanic eruptions in Montserrat

Montserrat is a small island in the Caribbean and was affected by volcanic activity between 1995 and 2013.

- In 1997 a pyroclastic flow killed 19 people.
- The largest settlement, Plymouth, with a population of just 4000, was covered in ash and abandoned.
- Other short-term impacts included evacuation and increased unemployment.

Long-term impacts

- Long-term impacts have included the establishment of an exclusion zone, the creation of the Montserrat Volcano Observatory and the development of new infrastructure and buildings in the north of the island, including homes, hospitals, roads and expansion to the island's port.
- Although there was an economic boom in the early 2000s, once those buildings were built many of the jobs disappeared.
- Thus with fewer jobs in construction, a declining tourist sector and rising prices, many Montserratians left the island for a second time.

Hurricane Matthew, September–October 2016

Hurricane Matthew was a Category 5 hurricane that caused significant loss of life and damage in Haiti, as well as widespread damage in parts of the USA.

Table 3.2.3 Impacts of Hurricane Matthew

Country	Fatalities	Missing	Damage (US$ bn 2016)
Haiti	546	128	$2.8
USA	47	0	$10
Other countries	10	0	$3.7
Total	**603**	**128**	**$16.5 billion**

The most significant impacts were felt in Haiti.

- In the short term there was flooding, high winds, telecommunications were disrupted and damage to over 75% of Jérémie, in the west of the country.
- Hurricane Matthew struck Haiti's south coast. About 175,000 people were made homeless. Around 2.1 million people (20% of Haiti's population) were affected by the hurricane.

Long-term impacts

- Long-term impacts included the redevelopment of the area, clean-up and restoration, and the provision of clean water, sanitation and housing.
- Action Aid and World Nation helped provide clean water, sanitation and shelter.
- For those affected by Hurricane Matthew, especially those who lost friends or relatives, the psychological hurt of losing loved ones became a long-term burden.

Exam tip

Remember that the loss of life is often much greater in an LIC, whereas the economic loss is often greater in an HIC.

Case studies of hazard management for an earthquake in a developed country **and** a developing country **or** an emerging country.

3.3	Earthquakes present a hazard to many people and need to be managed carefully	a) Preparation for earthquakes (warning and evacuation, building design, remote sensing and GIS). (4) b) Short-term responses and relief (emergency aid, shelter and supplies). c) Longer-term planning (risk assessment, hazard mapping and rebuilding programmes). (5)

3.3 Earthquakes present a hazard to many people and need to be managed carefully

Preparation

There are many ways to prepare for an earthquake including warning and evacuation, building design, remote sensing and **geographic information systems (GIS)**.

The main ways of dealing with earthquakes include:

- better forecasting and warning
- building design
- building location
- emergency procedures.

There are a number of ways of predicting and monitoring earthquakes. These include:

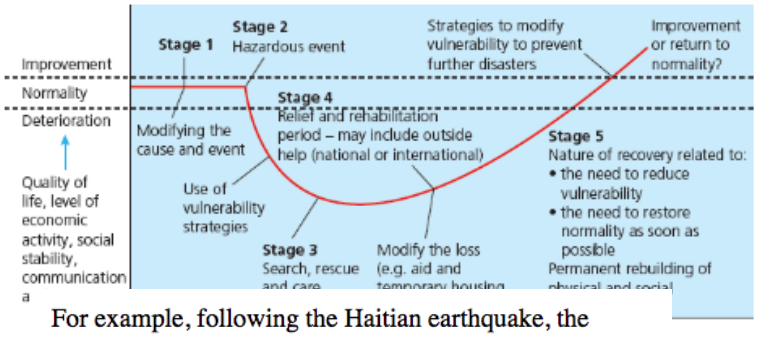
- measurement of small-scale ground surface changes
- ground tilt
- changes in rock stress
- clusters of small earthquakes
- changes in radon gas concentration
- unusual animal behaviour, especially toads.

Buildings can be designed to cope with the shockwaves that occur in an earthquake. For example, single-storey buildings are more suited than multi-story buildings as the potential for swaying is reduced. Some tall buildings may be built with a 'soft-storey' at the bottom, such as a carpark on raised pillars. This may collapse in an earthquake, so that the upper floors sink down onto it, and this cushions the impact. Building reinforcement strategies include building on foundations built deep into the underlying bedrock, and the use of steel frames that can withstand shaking.

Land-use planning is another way of reducing earthquake risk. Densely populated areas and important services such as hospitals and fire services should not be built close to known fault lines.

Remote sensing such as RapidEye and GeoEye satellite data may be used to monitor changes in ground movement. GIS systems may provide data on land use and infrastructure and highlight areas of particular vulnerability.

Short-term response and relief



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For example, following the Haitian earthquake, the Red Cross estimated that 3 million people needed emergency aid. Seven days after the earthquake, the United Nations had delivered food to only 200,000 people. Assistance – in the form of doctors, trained sniffer dogs, and tents, blankets and food – was pledged from other countries. Financial assistance also poured in. The World Bank led with a $100 million commitment. Yet most of this aid arrived too late for the thousands who were trapped in rubble or waiting for treatment for their injuries.

In contrast, following the 2011 Christchurch (New Zealand) earthquake, in which 185 people died, a full emergency management programme was in place within two hours. Rescue efforts continued for over a week, then shifted to recovery mode.

Exam tip

Remember that although the hazard response curve suggests recovery will be complete, in many places, especially in LICs, this does not occur, mainly due to lack of funding.

Longer-term planning

Risk assessment

Risk is the probability of a hazard event causing harmful consequences (losses in terms of death, injuries, damage to property, the economy and the environment). Most of the risk comes from people living in unsafe housing in areas with known fault lines. However, earthquakes can also occur in areas where no fault line was known to exist.

Earthquakes killed about 1.5 million people in the twentieth century, and the number of people at risk appears to be rising. More than a third of the world's largest and fastest-growing cities are located in regions of high earthquake risk, so the problems are likely to intensify.

Hazard mapping

Hazard mapping shows the most likely areas where earthquakes will occur. Most earthquakes are closely linked with the distribution of fault lines, e.g. in western USA the majority of earthquakes occur in a linear distribution following the San Andreas fault line. However, the timing of earthquakes is difficult to predict.

Rebuilding programmes

It is difficult to stop an earthquake from happening, so prevention normally involves minimising the prospect of death, injury or damage by controlling building in high-risk areas, and using aseismic designs.

Following earthquakes there is a need for rebuilding programmes. This varies with the scale of the impacts. For example, following the Christchurch earthquakes it was debated whether the whole city would be removed and rebuilt elsewhere. This was never done and the cost would have been far too expensive, even for a relatively rich country.

Rebuilding in poor countries depends largely on the individuals themselves. Following the Haiti (2010) and Nepal (2015) earthquakes, large-scale rebuilding was needed, but the governments were too poor to undertake such measures. Many households are still living in temporary accommodation years after the events.

One option that has been used is to strengthen existing buildings (retro-fitting) to make them safer in an earthquake. Engineers have created a number of 'safe houses' designs which withstand shaking better than some traditional designs. Safe houses can be built cheaply using straw, adobe and old tyres, and by applying a few general principles, e.g. small windows create fewer weak spots in walls. Compressed bales of straw can be sandwiched between layers of plaster to provide some protection from earthquakes.

2.3 Subject content – Section A

Topic 4: Economic activity and energy

What students need to learn

Key ideas	Detailed content
4.1 The relative importance of different economic sectors and the location of economic activity varies spatially, and changes over time	a) Classification of employment by economic sector (primary, secondary, tertiary and quaternary) and the reasons for the differences in the employment structures in countries at different levels of development (Clark Fisher Model). (1) b) Factors affecting the location of economic activity in each economic sector and how these factors can change over time. c) Reasons for the changes in the numbers of people employed in each economic sector, including the availability of raw materials, globalisation, mechanisation, demographic changes and government policies.
4.2 The growth and decline of different economic sectors has resulted in a range of impacts and possible resource issues	a) Positive and negative impacts of economic sector shifts in a named developed and a named developing or emerging country. (2) b) Informal employment: causes (economic development, rural-urban migration) and characteristics (advantages and disadvantages) in a named megacity. (3) c) Different theories (Malthus and Boserup) are used to explain the relationship between population and resources. (4)

Case studies of energy resource management in a developed country **and** a developing country **or** an emerging country.

4.3 Countries increasingly experience an energy gap and therefore seek energy security by developing a balanced energy mix and sustainable energy use	a) Energy demand and production varies globally and is affected by a range of factors: population growth, increased wealth and technological advances. b) Non-renewable, e.g. coal, oil, natural gas, uranium and shale gas/oil, and renewable sources of energy, e.g. solar, wind, hydroelectric power (HEP), geothermal, biomass, have advantages and disadvantages for people and the environment. c) Energy can be managed in a sustainable way through education, efficiency and conservation (within industry, transport and the home). (5)

What students need to learn

Key ideas	Detailed content
4.1 The relative importance of different economic sectors and the location of economic activity varies spatially, and changes over time	a) Classification of employment by economic sector (primary, secondary, tertiary and quaternary) and the reasons for the differences in the employment structures in countries at different levels of development (Clark Fisher Model). (1) b) Factors affecting the location of economic activity in each economic sector and how these factors can change over time. c) Reasons for the changes in the numbers of people employed in each economic sector, including the availability of raw materials, globalisation, mechanisation, demographic changes and government policies.

4 Economic activity and energy

4.1 Economic sectors and employment

Classifying production into different economic sectors

The wide range of different jobs that people do can be placed into four economic sectors:

- The **primary sector** exploits raw materials.
- The **secondary sector** manufactures primary materials into finished products.
- The **tertiary sector** provides services.
- The **quaternary sector** uses high technology to provide information and expertise.

The **product chain** can be used to show the relationship between the four sectors of employment

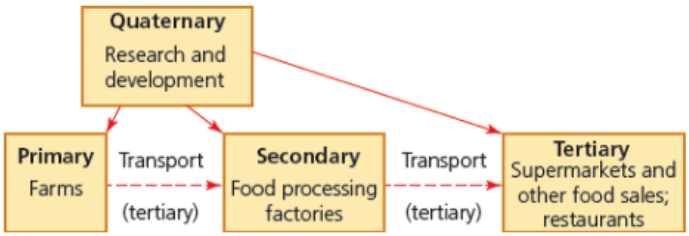

Figure 4.1.1 The food industry's product chain

How employment structure varies and changes over time

As an economy develops, the proportion of people employed in each sector changes (Figure 4.1.2). Countries such as the USA and the UK are '**post-industrial societies**' with most people employed in the tertiary sector.

- In 1900, 40% of employment in the USA was in the primary sector.
- Increasing mechanisation reduced the demand for workers in primary industries.
- As these rural jobs disappeared, people moved to urban areas where the secondary and tertiary sectors were expanding.
- Today only about 2% of employment in the USA is in the primary sector, although production levels are

very high due to a very high level of mechanisation and automation.

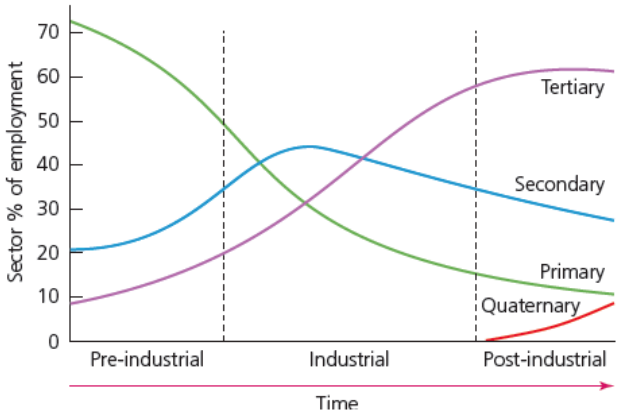

Figure 4.1.2 The Clark-Fisher model

Table 4.1.1 Employment structure of a developing country, an emerging country and a developed country

Country	Primary (%)	Secondary (%)	Tertiary (%)
Australia (*developed*)	4	21	75
Malaysia (*emerging*)	11	36	53
Bangladesh (*developing*)	45	30	25

In manufacturing, robots and other advanced machinery handle assembly-line jobs which once employed large numbers of people. Most manufacturing industries have become more **capital intensive**. Large processing plants can now be run with a relatively small workforce compared to 30 years ago.

The tertiary sector has also changed as computer networks and other technical advances have reduced the number of people required in some occupations. In developed countries employment in the quaternary sector has become more important – a good measure of how advanced an economy is!

Factors affecting the location of economic activity

Table 4.1.2 shows the factors affecting the location of manufacturing industry. These factors can be applied to varying degrees to the other sectors of employment. Changes in the importance of any of these factors can have a big effect on employment in regions and countries.

Physical factors	Human factors
Site: The availability and cost of land. Large factories will need flat, well drained land on solid bedrock. **Raw materials**: Industries requiring heavy and bulky raw materials tend to locate as close as possible to these raw materials. **Energy**: Energy-hungry industries, e.g. metal smelting, may be drawn to countries with relatively cheap hydroelectricity, e.g. Norway. **Natural routeways and harbours**: Many modern roads and railways still follow natural routeways. Natural harbours provide good locations for ports and the industrial complexes	**Capital (money)**: Some areas are more likely to attract investment than others. **Labour**: The quality and cost of labour are most important. The reputation, turnover, mobility and quantity of labour can also be important. **Transport and communications**: Transport costs remain important for heavy, bulky items. Accessibility to airports, ports, motorways etc. may be crucial for some industries. **Markets**: The location and size of markets is a major influence for some industries. **Government influence**: Government policies and decisions

For example:

Primary sector

- Investment in new irrigation projects can extend an area under farming.
- The exhaustion of mineral deposits can shut entire industries such as coal mining.

Tertiary sector

- Improving the accessibility of a central business district (CBD) may attract new businesses.
- Government grants to encourage tourism can help create new jobs.

Quaternary sector

- Higher national investment in science and technology can attract new high-tech industries.
- Improvements in the quality of life in a region will make it more attractive to high tech firms.

Increasingly, manufacturing and large retail companies have located together on **industrial estates** or **business/retail parks**. These are usually located close to good quality transport infrastructure, often in outer suburban or urban fringe locations. The movement of manufacturing and retail outwards from CBDs and inner cities is known as **decentralisation**.

The changing location of manufacturing

Changes in the location of manufacturing industry have occurred at a range of scales:

- The global shift from the developed world to emerging and developing countries.
- The movement from traditional manufacturing areas to higher quality of life regions in developed countries.
- A regional movement from urban areas towards '**greenfield**' rural locations.

Demographic change

Global population has risen from 3 billion in 1960 to

7.8 billion today. Such a large population change has led to a great increase in the demand for goods and services worldwide. At the same time, a growing population has resulted in a larger supply of potential workers. The rate of population change varies from country to country. Other factors to consider include:

- The age structure of a population affecting the size of the working population and the demand for particular goods and services.
- Average disposable income and income distribution.
- Cultural traits affecting demand for different goods and services.

Reasons for change in economic activity

Raw materials

- Farm production can be decimated due to drought, soil erosion and insect plagues.
- The exhaustion of a raw material deposit can cause job losses, not only in mining, but also in local industries using the raw material. Other businesses will suffer as jobs are lost and incomes fall.
- Technological advances can reduce the amount of raw materials required or change the balance between the different raw materials used. Such changes can affect location decision making.

Globalisation

- **Globalisation** is a term that describes increasing global links (economic, cultural and political).
- Until the post-1950 period, industrial production was mainly organised within individual countries. Since then, production has been increasingly divided into different skills that are often spread across a number of countries.
- **Transnational corporations** (TNCs) have increasingly been able to take advantage of lower costs in developing and emerging countries.
- The result is that many of the traditional industries of developed countries such as iron and steel, shipbuilding and textiles have moved on a large scale to **emerging economies** such as China, India and Brazil.
- The large-scale loss of manufacturing employment in developed countries is known as **deindustrialisation**.

The role of technology

Advances in technology have affected all sectors of employment. Large farms can now be run by a small workforce due to advanced mechanisation and automation. The internet has allowed large companies to manage complex operations all over the world. Many jobs in service industries once located in developed countries have been **outsourced** to emerging economies.

Government policy

Governments influence industrial location for economic, social and political reasons. Government at national and regional levels may use grants to attract major international companies. There is a high level of competition both between and within countries to attract inward investment. Examples of major government spending policies include building new high-speed railways and airport expansion. Levels of employment in different sectors can be affected by such decisions.

4.2	The growth and decline of different economic sectors has resulted in a range of impacts and possible resource issues	a) Positive and negative impacts of economic sector shifts in a named developed and a named developing or emerging country. (2) b) Informal employment: causes (economic development, rural-urban migration) and characteristics (advantages and disadvantages) in a named megacity. (3) c) Different theories (Malthus and Boserup) are used to explain the relationship between population and resources. (4)

4.2 The growth and decline of different sectors – impacts and resource issues

Positive and negative impacts of change in economic sectors

Sector shift in the UK

The UK is an example of a developed country in the 'post-industrial' stage of the Clark-Fisher model. The Industrial Revolution began in the UK in the late eighteenth century and then spread to other countries such as Germany and the USA. The number of people working in services in the UK overtook the manufacturing workforce in 1881, over 130 years before this happened in China. Over 80% of the UK workforce is now in the tertiary sector. No region in the country has less than 70% and London has 91%.

- The **City of London** contains one of the greatest concentrations of high-level tertiary industry in the world.
- It is one of the big three financial centres, along with New York and Tokyo.
- Among the important buildings in the City of London are the Bank of England, the London Stock Exchange and Lloyd's of London (insurance).

Table 4.2.1 summarises some of the positive and negative aspects of **sector shift** in the UK.

Positive	Negative
The UK attracts a very high level of foreign direct investment because of its expertise in a wide range of secondary and tertiary industries.	High job losses in traditional secondary industries such as coal, iron and steel, shipbuilding and textiles due to deindustrialisation.
The UK has become one of the world's leading exporters of tertiary products, which creates considerable wealth for the country.	A cycle of deprivation in inner cities and other areas affected by large-scale manufacturing decline.
Low-cost manufactured goods from China and other emerging countries have helped keep inflation low.	A widening gap between a) the highest and lowest paid workers and b) the richest and poorest regions.
Deindustrialisation, with subsequent landscape renewal, has improved environmental conditions in many parts of the UK.	Transnational corporations can move investment away from a country as quickly as they can bring it in, causing loss of jobs and corporation tax.

Sector shift in China

China is an example of an emerging country. Its economy has grown rapidly in the last forty years. Before this time China was largely an agricultural economy. More recently the secondary and tertiary sectors have grown at a very fast rate. China is in the 'industrial' stage of Clark-Fisher model.

Major **economic reforms** introduced in 1978 aimed to:

- rapidly develop manufacturing industry
- extend China's global trade links
- increase the rate of economic growth.

Over 70% of the workforce was employed in agriculture in 1978. By 2018, it was down to 27%. The tertiary sector overtook the secondary sector in 2013. Retailing and tourism are examples of fast-growing tertiary activities in China. China is a) the world's largest manufacturing economy, and b) the world's largest exporter of goods. However, average incomes are still well below developed countries such as the UK.

Case study

Informal employment in a megacity: Mumbai, India

Over two billion people worldwide work in the informal sector. The largest concentrations of **informal sector** work are the **megacities** of developing and emerging countries. Here, levels of unemployment and **underemployment** are often very high.

About 68% of Mumbai's workforce is estimated to work in the informal sector. The population of this huge urban area has grown rapidly. With intense competition for **formal sector** jobs, most people have to look to the informal sector to meet their basic needs. The characteristics of the informal sector are:

- highly labour intensive
- low and unreliable pay
- work often temporary and/or part-time
- poor job security, with an absence of fringe benefits
- poor working conditions and a high exposure to health and safety risks
- high potential for exploitation, especially for children.

The four leading informal sector occupations in Mumbai are domestic workers, home-based workers, street vendors and waste pickers. Other occupations include messengers and repair-shop workers. Over three-quarters of Mumbai's informal workers are in the service sector. Informal manufacturing includes both the workshop sector and the traditional craft sector. A big benefit of the sector is that it provides cheap goods and services for the lower income population in the city.

An often-stated disadvantage of the informal sector to the economy is that it operates outside the tax system. However, most informal workers have incomes below the threshold for paying tax. Most of Mumbai's informal workers live in **slums**. Dharavi is not only Mumbai's largest slum, it is also the biggest in Asia.

India wants to gradually 'transition' informal workers into the formal sector. As this involves such a large number of people, it will be a massive challenge!

Theories used to explain the relationship between population and resources

As a country develops, the highest average living standards mark the **optimum population** in economic terms (Figure 4.2.1). Before that population is reached, a country could be said to be **underpopulated**. As the population rises beyond the optimum, a country can be said to be **overpopulated**.

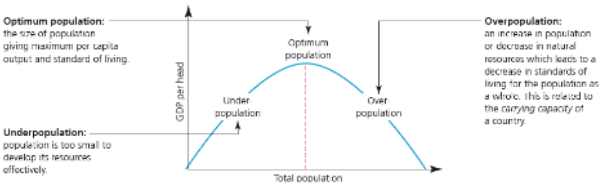

Figure 4.2.1 The optimum population

There are many indications that the human population is pushing up against the limits of the Earth's resources. For example:

- One-quarter of the world's children have protein-energy malnutrition.
- Water scarcity affects every continent.

The most obvious examples of **population pressure** are in the developing world.

The ideas of Thomas Malthus

The Reverend Thomas Malthus produced his *Essay on the Principle of Population* in 1798. He took a pessimistic view about the relationship between population and resources.

- He maintained that while the supply of food could at best be increased by a constant amount in arithmetical progression (2 – 3 – 4 – 5 – 6), the human population tends to increase in geometrical progression (2 – 4 – 8 – 16 – 32).
- In time, population would outstrip food supply until a catastrophe occurred in the form of famine, disease or war.
- These limiting factors maintained a balance between population and resources in the long term.

Malthus could not have foreseen the great advances that were to unfold in the following two centuries. However, today nearly all of the world's productive land is already exploited. Most of the unexploited land is either too steep, too wet, too dry or too cold for agriculture. Modern-day resource pessimists are known as neo-Malthusians. In recent years neo-Malthusians have highlighted:

- the steady global decline in the area of farmland per person
- the steep rise in the cost of many food products in recent years
- the growing scarcity of fish in many parts of the world
- the continuing increase in the world's population.

The resource optimists, such as Danish economist Ester Boserup, believe that human ingenuity will continue to conquer resource problems. They point to:

- the development of new resources
- the replacement of less efficient with more efficient resources
- the rapid development of green technology, with increasing research and development in this growing economic sector.

Case studies of energy resource management in a developed country **and** a developing country **or** an emerging country.

4.3	Countries increasingly experience an energy gap and therefore seek energy security by developing a balanced energy mix and sustainable energy use	a) Energy demand and production varies globally and is affected by a range of factors: population growth, increased wealth and technological advances. b) Non-renewable, e.g. coal, oil, natural gas, uranium and shale gas/oil, and renewable sources of energy, e.g. solar, wind, hydroelectric power (HEP), geothermal, biomass, have advantages and disadvantages for people and the environment. c) Energy can be managed in a sustainable way through education, efficiency and conservation (within industry, transport and the home). (5)

4.3 Energy resource management

Energy demand and resource management

Energy demand and production

- Global energy demand increased by over 60% between 1993 and 2018.
- Fossil fuels dominate the global **energy mix**. Their relative contribution to **primary energy** consumption in 2018 was: oil – 33.6%, coal – 27.2%, natural gas – 23.9%.
- In contrast, hydroelectricity accounted for 6.8%, nuclear energy 4.4% and renewable energy 4.1%.

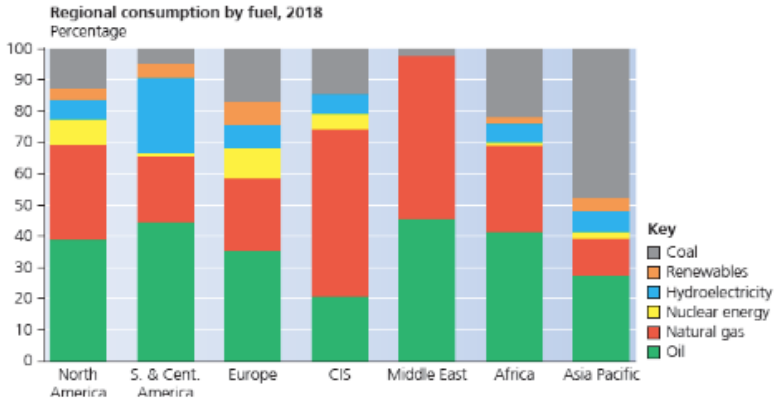

Figure 4.3.1 Regional consumption of fuel by type

National demand is mainly down to:

- the size of a country's population and its rate of growth
- its level of economic development, particularly wealth and level of technology.

Table 4.3.1 shows per capita energy consumption by world region in 2018. Average consumption in North America is 16 times higher than in Africa.

Table 4.3.1 Primary energy consumption per capita, 2018

World region	Per capita energy consumption (GJ), 2018
North America	239.8
South and Central America	56.4
Europe	127.4
CIS	160.9
Middle East	148.5
Africa	15.0
Asia Pacific	60.2
World	76.0

Figure 4.3.2 is a model showing the relationship between resource use in general and the level of economic development. This model applies well to energy consumption. Growth in energy demand is particularly rapid in emerging economies such as China, India and Brazil. The key factor in energy supply is energy resource endowment. However, resources by themselves do not constitute supply. Capital and technology are required to exploit energy resources. In developing countries, about 2.5 billion people rely on fuelwood as their main source of energy. The transition from fuelwood and animal dung to 'higher level' sources of energy, the **energy ladder**, occurs as part of the process of economic development.

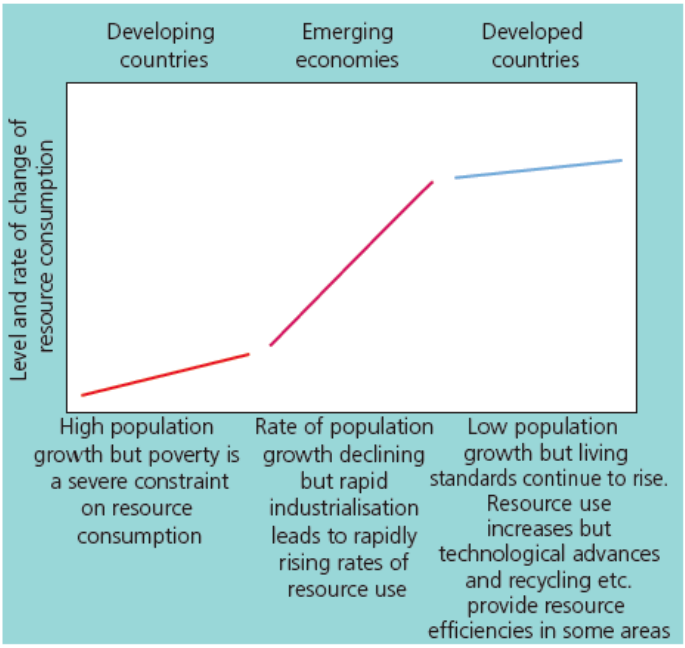

Figure 4.3.2 Model of the relationship between resource use and the level of economic development

The energy gap and energy security

An increasing number of countries are facing an '**energy gap**'. This is the difference between a country's rising demand for energy and its ability to satisfy this demand from its own resources. The International Energy Agency (IEA) defines **energy security** as the '*uninterrupted availability of energy sources at an affordable price*'. Energy security can be affected by a number of factors. Long-term energy security requires careful planning and considerable investment in line with economic development and energy needs.

Energy supply interruption can be caused by a number of factors including:

- natural hazards
- civil disturbance
- geopolitics
- rapid resource depletion
- affordability
- environmental concerns.

Exam tip

The energy ladder is a part of the development process. It requires investment linked to rising standards of living.

Non-renewable and renewable energy resources

Non-renewable sources of energy are the **fossil fuels** and nuclear fuel. Eventually, these resources could become completely exhausted. Fossil fuels are the major source of greenhouse gas emissions. Climate change due to these emissions is the biggest environmental problem facing the planet.

Renewable energy resources cause little or no pollution. Renewable energy includes hydroelectricity, biofuels, wind, solar, geothermal, tidal and wave power. Hydroelectricity is the one renewable source of energy that is sometimes described as a traditional source of energy because water power has been used to generate electricity for over one hundred years.

Non-renewable resources still dominate global energy supply. The challenge is to transform the global energy mix to achieve a better balance between renewables and non-renewables.

Countries are eager to harness renewable energy resources to:

- reduce their reliance on domestic fossil fuel resources
- lower their reliance on costly fossil fuel imports
- improve their energy security
- cut greenhouse gas emissions.

The cost gap with non-renewable energy has narrowed and even closed in some cases. Figure 4.3.3 shows the sharp increase in the consumption of renewable energy (other than HEP) in the last decade. In 2015, this accounted for almost 2.8% of global primary energy consumption. The newer sources of renewable energy making the largest contribution to global energy supply are wind power and biofuels.

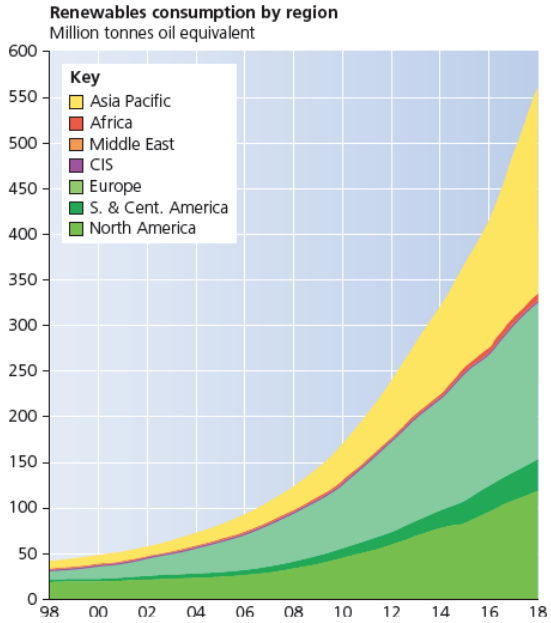

Figure 4.3.3 Renewable energy consumption by world region 1998–2018

Energy sources: Advantages and disadvantages

All sources of energy have advantages and disadvantages. The important issue for each energy source is the balance between the positive and negative factors. Two sources of energy are considered here – **nuclear** and solar. You should be able to produce similar lists or tables for all the other sources of energy as part of your revision programme.

Disadvantages of nuclear power

- Power plant accidents, which could release radiation into air, land and sea.
- Radioactive waste storage/disposal. Most concern is over the small proportion of 'high-level waste'.
- Rogue state or terrorist use of nuclear fuel for weapons.
- High construction and decommissioning costs.
- The possible increase in certain types of cancer near nuclear plants.

Advantages of nuclear power

- Zero emissions of greenhouse gases.
- Reduced reliance on imported fossil fuels.
- Not as vulnerable to fuel price fluctuations as oil and gas.
- In recent years nuclear plants have demonstrated a very high level of reliability.
- Nuclear technology has spin-offs in fields such as medicine and agriculture.

Managing energy resources sustainably

Energy efficiency

Meeting future energy needs while avoiding serious environmental degradation will require increased emphasis on education, efficiency and conservation in all sectors of the economy.

Policies have been developed which include:

- much greater investment in renewable energy
- conservation
- recycling
- carbon credits
- 'green' taxation.

Managing energy supply is often about balancing socio-economic and environmental needs. Many countries are looking increasingly at the concept of **community energy**. Much energy is lost in transmission if the source of supply is a long way away. Energy produced locally is much more efficient. This will invariably involve **microgeneration**.

Table 4.3.3 summarises some of the measures governments and individuals can undertake to reduce the demand for energy and thus move towards a more sustainable situation.

Solar power

Advantages	Disadvantages
A completely renewable resource	Initial high cost of solar plants
No noise or direct pollution	Solar power cannot be harnessed during storms, on cloudy days or at night
Very limited maintenance required	Of limited use in countries with low annual hours of sunshine
Technology is improving and reducing costs	Large areas of land required to capture the sun's energy in order to generate significant amounts of power
Can be used in remote areas where it is too expensive to extend the electricity grid	
A generally positive public perception	

Government	Individuals
• Improve public transport. • Set a high level of tax on petrol. • Set minimum fuel consumption requirements for vehicles. • Congestion charging to deter non-essential car use in city centres. • Encourage business to monitor and reduce its energy usage. • Promote investment in renewable forms of energy. • Pass laws to compel manufacturers to produce higher efficiency electrical products.	• Walk rather than drive for short local journeys. • Buy low fuel consumption/low emission cars. • Reduce car usage by planning more multi-purpose trips. • Use public rather than private transport. • Car pooling. • Use low-energy light bulbs. • Install and improve home insulation. • Turn boiler and radiator settings down. • Wash clothes at lower temperatures. • Purchase energy-efficient appliances.

- The Three Gorges Dam across the Yangtze River is the world's largest electricity generating plant of any kind. This is a major part of China's policy in reducing its reliance on coal.

China's wind power capacity has also grown rapidly in recent years. It is now the largest in the world by a large margin. China plans to have a total renewable capacity of more than 800 GW by 2021 (Table 4.3.4). In 2018, China accounted for 45% of the global growth in renewable power generation. It is now the largest producer of renewable power in the world. However, only

Exam tip

It is easy to think that governments could do much more to conserve energy, but many measures affect individual and family budgets. Governments need to convince people that higher costs are justified.

Case study

Energy resource management in China

China uses more energy than any other country in the world. In 2018, China's main sources of energy were: coal (58.2%), oil (19.6%) and hydroelectricity (8.3%). Chinese investment in energy resources abroad has risen rapidly in order to achieve long-term energy security. In recent years, China has tried to take a more balanced approach to energy supply and to reduce its environmental impact:

- The development of clean coal technology is an important aspect of this approach.
- The further development of nuclear and hydropower is another important strand of Chinese policy.
- China aims to increase the production of oil while augmenting that of natural gas and improving the national oil and gas network. Priority was also given to building up the national oil reserve.
- Total renewable energy capacity in China reached 502 GW in 2015. This included 319 GW of hydroelectricity, 129 GW of wind energy, 43 GW of solar PV and 10 GW of bioenergy.

4.4% of China's primary energy production comes from renewables.

Table 4.3.4 China's projected renewable electricity capacity (GW), 2015–21

	2015	2018	2021
Hydropower	319.4	348.4	368.4
Bioenergy	10.3	14.4	18.4
Wind:	129.3	189.4	257.1
Onshore	128.3	186.8	250.3
Offshore	1.0	2.6	6.8
Solar PV	43.2	104.2	160.2
CSP/STE	0.0	1.5	3.1
Geothermal	0.0	0.1	0.1
Ocean	0.0	0.0	0.0
Total	**502.3**	**557.8**	**807.3**

Case study

Energy resource management in Sweden

Few countries consume more energy per capita than Sweden, but Swedish carbon emissions are very low. In 2018, Sweden's primary consumption energy mix was: oil – 27.6%; natural gas – 1.3%; coal – 3.7%; nuclear – 28.9%; hydro – 26.1%; renewables – 12.3%.

- Hydropower and bioenergy are the top renewable resources. Sweden has many fast-flowing rivers and forests cover 63% of its land area.
- About 80% of electricity production comes from nuclear energy and hydropower. However, nuclear power is a controversial subject in Sweden.
- About 11% of electricity production is from wind power. This is set to increase sharply in the future.
- Combined heat and power (CHP) plants account for 9% of electrical output. These plants are mainly powered by biofuels.
- Solar power remains limited in capacity largely due to Sweden's northerly latitude, but it is growing with the aid of government funding.
- The number of heat pumps has increased sharply since the 1990s. These pumps use renewable energy by transferring heat, mainly from the ground. This reduces demand on electricity from the grid.
- Carbon taxation has proved effective in energy change and efficiency.

The long-term aims of Sweden's energy policy are:

- a transition to 100% renewable electricity production by 2040
- a zero-carbon economy by 2045.

Sweden plans to achieve 50% more efficient energy use by 2030. Since the 1980s, Sweden's population has increased by 25% and GDP has doubled, but Sweden is now using less energy and electricity than then. Sweden also plans to be at the forefront of energy storage.

Topic 6: Urban environments

What students need to learn

Key ideas	Detailed content
6.1 A growing percentage of the world's population lives in urban areas	a) Contrasting trends in urbanisation over the last 50 years in different parts of the world, including the processes of suburbanisation and counter-urbanisation. (1) b) Factors affecting the rate of urbanisation and the emergence of megacities. c) Problems associated with rapid urbanisation: congestion, transport, employment, crime and environmental issues. (2)
6.2 Cities face a range of social and environmental challenges resulting from rapid growth and resource demands	a) Factors affecting urban land use patterns: locational needs, accessibility, land values. (3) b) Urban challenges in a named developed country 🌍: food, energy, transport and waste disposal demands, concentrated resource consumption, segregation. (4) c) Urban challenges in a named developing country 🌍 or emerging country 🌍: squatter settlements, informal economy, urban pollution, and low quality of life.

Case studies of urban environments in a developed country **and** a developing country **or** an emerging country.

6.3 Different strategies can be used to manage social, economic and environmental challenges in a sustainable manner	a) Development of the rural-urban fringe: housing estates, retail, business and science parks, industrial estates, and the greenfield versus brownfield debate. b) The range of possible strategies aimed at making urban living more sustainable and improving the quality of life (waste disposal, transport, education, health, employment and housing) for the chosen urban environment. (5) c) Role of different groups of people (planners, politicians, property developers and industrialists) in managing the social, economic and environmental challenges in the chosen urban area.

Integrated skills	
(1)	Use world maps to show the trends in urbanisation over the last 50 years.
(2)	Interpret photographs and different maps (paper or online) to investigate the impacts of rapid urbanisation.
(3)	Use satellite images to identify different land uses in the chosen urban environment.
(4)	Use and interpret socio-economic data.
(5)	Use quantitative and qualitative information to judge the scale in variations in environmental quality.

What students need to learn

Key ideas	Detailed content
6.1 A growing percentage of the world's population lives in urban areas	a) Contrasting trends in urbanisation over the last 50 years in different parts of the world, including the processes of suburbanisation and counter-urbanisation. (1) b) Factors affecting the rate of urbanisation and the emergence of megacities. c) Problems associated with rapid urbanisation: congestion, transport, employment, crime and environmental issues. (2)

6 Urban environments

6.1 A growing percentage of the world's population lives in urban areas

Contrasting trends in urbanisation

Urbanisation is the process by which an increasing percentage of a country's population comes to live in towns and cities. It may involve rural–urban migration, natural increase and the reclassification of rural settlements as they are engulfed into an expanding city.

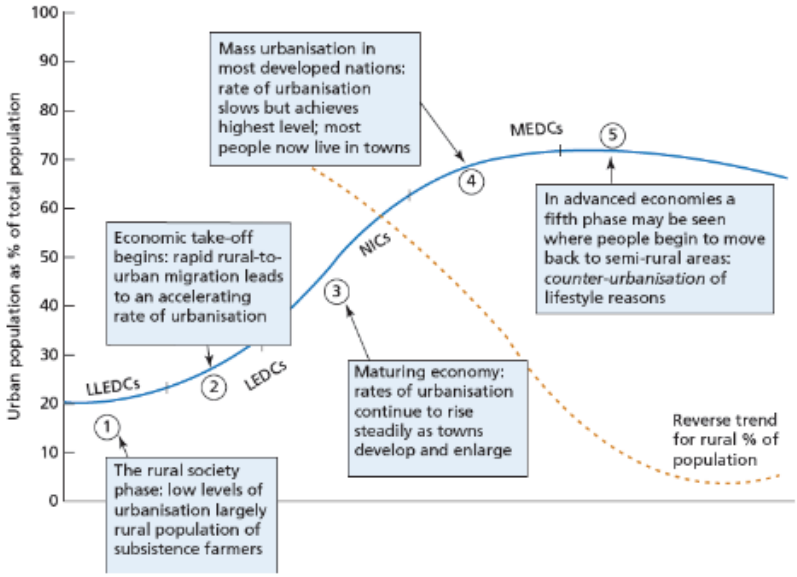

Figure 6.1.1 The process of urbanisation (LLEDCs – Least less economically developed countries; LEDCs – Less economically developed countries; NICs – Newly industrialised countries; MEDC – More economically developed countries)

Suburbanisation is the outward growth of towns and cities to engulf surrounding villages and rural areas. This may result from the out-migration of population from the inner urban areas to the suburbs or from inward rural–urban movement.

Counter-urbanisation is a process involving the movement of population away from inner urban areas to new towns, commuter towns or villages on the edge or just beyond the city limits/rural–urban fringe.

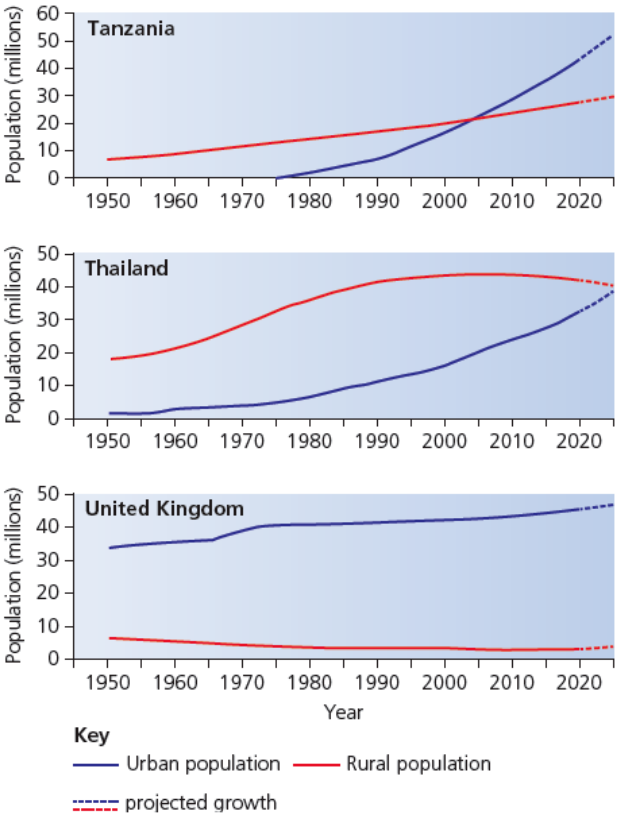

Figure 6.1.2 Contrasts in levels of urbanisation

Exam tip

Remember that any model is a simplification – we would not expect all countries to follow this exact pattern.

Rapid urbanisation and the growth of megacities

There are several reasons for rapid urbanisation in **LICs** and **NICs**. These include:

- The prospects of finding employment, better paid jobs and more secure jobs in urban areas (economi pull factor).
- Better provision of education and health facilities i urban area (social pull factor).
- Fewer economic opportunities in rural areas – farming can be low paid, insecure and subject to climate and natural hazards (economic and physical push factors).
- Poor access to clean water and sanitation, health care and education in rural areas (social push factors).

Consequently, rural–urban migration may be large scale, leading to rural depopulation and the growth of population in urban areas. The majority of those who migrate are young adults.

A **megacity** is a city with over 10 million people. By 2018, there were 33 cities with a population over 10 million and of these, 27 were in developing/emerging countries.

Megacity growth may be slowing down. Several factors help explain this:

- In many cities in the developing world, slow economic growth (or economic decline) has attracted less investment and fewer people.
- Lower rates of natural increase have occurred, as fertility rates have come down.

Table 6.1.1 Population growth (millions) in selected megacities, 2014–2030

Megacity	Population, 2014 (m)	Population (projected), 2030	Percentage increase/decrease
Tokyo	37.8	37.2	-2%
New Delhi	25	36	+45%
Shanghai	23	30.8	+34%
Mumbai	20.7	27.8	+34%
Beijing	19.5	27.7	+42%
Dhaka	17	27.4	+61%
Karachi	16.1	24.8	+54%
Mexico City	20.8	23.9	+14.5%
São Paulo	20.8	23.4	+13%
New York	18.6	19.9	+7%
Calcutta	14.8	19.1	+29%
Buenos Aires	15	17	+13%
Manila	12.8	16.8	+31%
Rio de Janeiro	12.8	14.2	+11%
Los Angeles	12.3	13.3	+8%

Problems associated with rapid urbanisation

The rapid growth of urban areas around the world has been one of the most important geographical phenomena of the late twentieth and early twenty-first centuries. For individuals and families, urban areas offer the prospects of a job, a home and an opportunity to improve their standard of living and quality of life. For some, migration to urban areas improves their standard of living, but for others migration may result in unemployment, poor quality housing and deprivation. Rapid urbanisation is associated with problems of congestion, transport, employment, crime and the environment.

Transport

Congestion is a problem due to vast numbers of cars on the road, and the poor quality/size of roads in many cities. Urban traffic congestion varies with days of the week, time of day, weather and the seasons. Travel is more congested on weekdays, especially during the peak flow times in the morning and evening, i.e. getting to and from work/school.

Congestion may be related to festivals, large sporting events and national holidays. By contrast, during the summer, congestion may decrease as more people walk/cycle to work and schools are closed.

Congestion

Rapid urbanisation can lead to large-scale congestion of people (and economic activity). For example, in Mumbai, up to 1 million people live in the Dharavi slum, an area that covers about 2 km^2. Some 99% of houses do not have a private toilet. Such conditions of congestion fuel the spread of diseases, such as COVID-19 in 2020.

Employment, crime and environmental issues

Most migrants are drawn to large cities by the prospect of employment and a better standard of living. For some this happens, but many are faced with unemployment, underemployment (working only occasionally or just a few hours a day/week), low pay and a lack of job security. Many are forced to enter the informal sector, the unregulated economy with mainly casual jobs, e.g. selling food on the street and domestic service.

In many large urban areas, crime is a problem. This

may be partly related to large-scale unemployment and the lack of job opportunities. Often crime is concentrated in areas of high population density. For example, in Islamabad, an informal settlement in Zanjan in Iran, crime is highly concentrated. The main criminal activities include violence, drug trafficking and drug abuse. In Kaduna, northern Nigeria, burglary and stealing are highest in areas of high population density, whereas in wealthier areas car theft and damage are more common.

Environmental issues are widespread. Waste products and waste disposal is a major problem. Some 25% of urban dwellers in LICs have no adequate sanitation and no means of sewage disposal. Air pollution is common in cities in rapidly industrialising countries. Delhi has some of the worst air quality in the world, and poor air has been linked to higher rates of death. Water pollution is widespread as water is used as a dumping ground for agricultural, industrial and domestic waste and for untreated sewage. Water shortages have become more frequent in some cities – overuse of groundwater has led to subsidence in Bangkok. For some people, not being connected to a water tap means that they have to buy water from sellers, and that is very expensive.

Exam tip

Make sure you provide named support when answering questions about problems associated with rapid urbanisation.

6.2	Cities face a range of social and environmental challenges resulting from rapid growth and resource demands	a) Factors affecting urban land use patterns: locati accessibility, land values. (3) b) Urban challenges in a named developed country energy, transport and waste disposal demands, resource consumption, segregation. (4) c) Urban challenges in a named developing country emerging country 🌍: squatter settlements, infor urban pollution, and low quality of life.

6.2 Cities face a range of social and environmental challenges resulting from rapid growth and resource demands

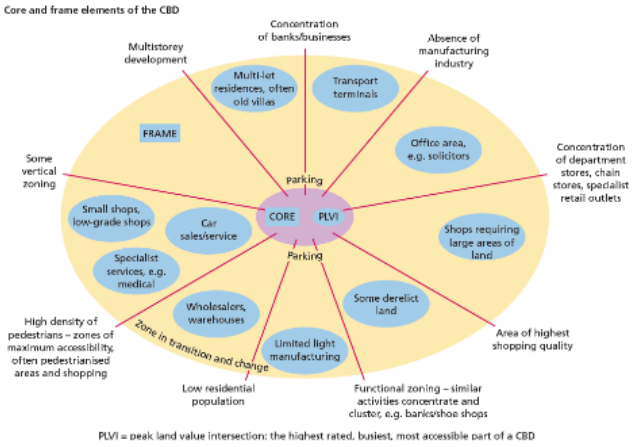

Figure 6.2.2 Core and frame characteristics of the CBD

Urban land use patterns

Urban **land use** refers to activities such as industry, housing and commerce that may be found in towns and cities. Land values decrease with distance from the city centre. Land values also increase with **accessibility** to good transport routes.

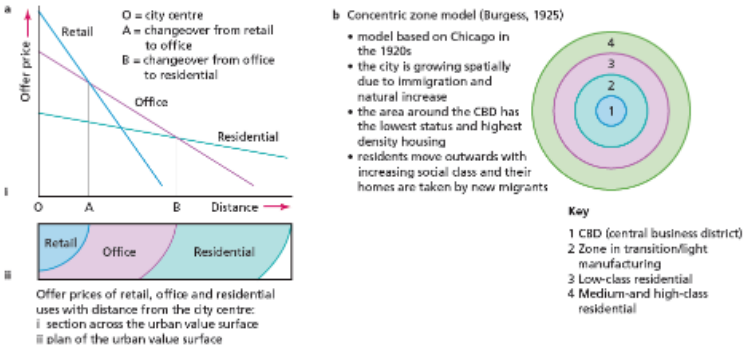

Figure 6.2.1 Bid rent theory and the concentric zone model

The **central business district (CBD)** is where most of the commercial activity is found. It is the most accessible (to public transport) and has the highest land values. It tends to have high rise buildings owing to the strong demand for land, but a shortage of space.

Figure 6.2.2 Core and frame characteristics of the CBD

Most **residential** areas are found in the suburbs. The **suburbs** refer to the outer part of an urban area. Suburbs generally consist of residential housing and shops of a low order (newsagents, small supermarkets).

In contrast, the **rural–urban fringe** is the boundary of a town or city, where new buildings are changing land use from rural to urban.

Industrial areas occur in several locations such as the inner city (the area surrounding the CBD), along major transport routes, and in edge-of-town locations. In many cities, the inner city is the older industrial area of the city and may suffer from decay and neglect, leading to social problems. Inner cities are characterised by poor quality terraced housing with old manufacturing industry nearby.

However, urban areas are changing rapidly. Much retailing and commerce is now taking place on the edge of towns and inner city areas are being used for residential purposes.

Exam tip

No city shows exactly the same pattern as the concentric zone model, but there are many similarities, especially on large urban areas in developed countries.

Urban challenges: developed countries

All urban areas face many challenges, even prominent cities, such as London, UK.

- One of these is to provide food for their residents. There are complex global supply chains, which can be badly disrupted. For example, London's food sector accounts for £20 billion and about 10% of jobs in the city. Nevertheless, there are many **food banks** in London, helping to feed an estimated 1.5 million people who go hungry.
- Most of London's energy comes from gas. Although there is a plan to produce 15% of London's energy from renewable sources by 2030, at present less than 1% comes from renewables.
- Transport faces issues regarding congestion and sustainability. Central London has a 20 mph speed limit and a congestion charge to limit the number of car trips made. However, the number of car journeys is increasing. This reduces the reliability of bus journeys due to increased congestion. London has a well-developed underground network, although some parts of it have very poor air quality.
- London produces a huge amount of waste. Some of this is disposed of in **landfill** sites, some is burnt to generate electricity and some is recycled. On average most households produce around 1000 kg of waste yearly.
- London has concentrated resource consumption due its size and wealth. Its **ecological footprint** is 6.6 global hectares (gha) per person, compared with a world average of 2.8 gha and the UK's overall figure of 6.3 gha.

London is a **multi-cultural** city. However, based on 2011 census data, **segregation** is evident. There is a higher concentration of white British towards the edge of the city. In contrast, some minority ethnic groups are concentrated nearer the centre, such as Bangladeshis (in the east end). Indians and Pakistanis are more likely to be located in the west, the east end and some parts of south London.

Urban challenges in a developing country

The total number of slum dwellers in the world stood at about 980 million people in 2015. This represents about 32% of the world's urban population, but 78.2% of the urban population is in LICs.

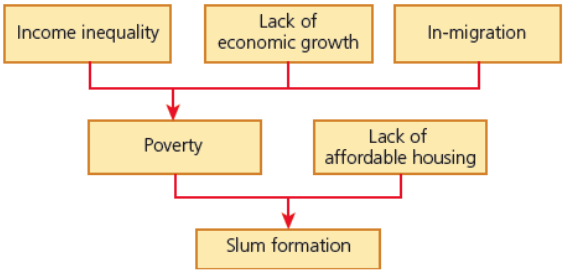

Figure 6.2.3 Inequality, poverty and slum formation

Exam tip

Urban challenges vary from city to city, and in different parts of a country.

Mumbai experiences many of the problems resulting from rapid city growth – poverty, unemployment and underemployment, limited access to health care and education, poor sanitation and access to electricity.

- Most of the residents live in slums/squatter settlements, and these have limited security of tenure.
- Dharavi, the main slum in South Mumbai, is an area of about 2 km^2, and home for up to 1 million people.
- Due to its close proximity to Mumbai's financial and commercial district, there is great pressure to clear parts of Dharavi for modern developments.

Table 6.2.1 The positives and negatives of living in a slum

Positive aspects	Negative aspects
• They are points of assimilation for immigrants. • Informal entrepreneurs can work here and have clients extending to the rest of the city. • Informal employment, based at home, avoids commuting. • There is a strong sense of kinship and family support. • Crime rates are relatively low.	• Security of tenure is often lacking. • Basic services are absent, especially water and sanitation. • Overcrowding is common. • Sites are often hazardous. • Levels of hygiene and sanitation are poor, and disease is common.

Informal economy

- The formal economy refers to the regulated economy, e.g. offices, factories, shops and services such as health care, education and government.
- Much of the formal economy produces goods and services for wealthy people.
- By contrast, the **informal economy** is small scale, locally owned and labour intensive.
- Dharavi has many informal activities that provide a livelihood for many of its residents.
- Up to 85% of Dharavi adults work locally, and there are major recycling industries and pottery industries.
- Working conditions for the recycling industry can be very dangerous.

Water and sanitation

- The Dharavi slum has a poor sewage and drainage system.
- The area is subject to floods in the wet season.
- There are up to 4000 cases per day of diphtheria and typhoid, partly the result of a lack of a proper sewer system.
- Water access is from standpipes. Access to water is limited and many pumps are only available for two hours per day.
- Many people used the Mahim creek for washing but it is also used for urination and defecation.
- Open sewers drain into the creek, bringing a range of pollutants. Dharavi has a very limited number of toilets – about one for every five hundred people.

Air quality

- Air quality in Dharavi (and Mumbai in general) is poor due to industrial and vehicle emissions, open burning and dust.
- Air quality is generally worse in winter (November to February) as there is less rainfall to clear the air.

Quality of life

- Many aspects of Dharavi lead to a low quality of life, e.g. lack of security of housing (up to 90% may be illegal), low life expectancy (about 50 years), low wages (on average between £1 and £5/day), poor air quality and the risk of disease.
- Nevertheless, there are many jobs available and Dharavi's informal economy is worth between US $500 million and $1 billion a year (£250 million–£500 million).

Case studies of urban environments in a developed country **and** a developing country **or** an emerging country.

6.3	Different strategies can be used to manage social, economic and environmental challenges in a sustainable manner	a) Development of the rural-urban fringe: housing estates, retail, business and science parks, industrial estates, and the greenfield versus brownfield debate. b) The range of possible strategies aimed at making urban living more sustainable and improving the quality of life (waste disposal, transport, education, health, employment and housing) for the chosen urban environment. (5) c) Role of different groups of people (planners, politicians, property developers and industrialists) in managing the social, economic and environmental challenges in the chosen urban area.

6.3 Different strategies can be used to manage social, economic and environmental challenges in a sustainable manner

Development of the rural–urban fringe

The **rural–urban fringe** is the area at the edge of a city where it meets the countryside. There are many pressures on the rural–urban fringe. These include:

- more housing, e.g. Blackbird Leys, Oxford
- industrial growth, e.g. Oxford Science Park
- transport infrastructure, e.g. M25, London
- recreational pressures for golf courses and sports stadia, e.g. Kassam Stadium, Oxford.

Table 6.3.1 The advantages and disadvantages of out-of-town (rural–urban fringe) shopping centres

Advantages	Disadvantages
Plenty of free parking	They destroy large amounts of undeveloped, valuable habitats
Lots of space so shops are not cramped	They lead to pollution and environmental problems at the edge of town
Easily accessible by car	They only help those with cars
Developments on the edge of town reduce the environmental pressures and problems in city centres	Successful out-of-town developments may take trade away from city centres and lead to a decline in sales in the CBD

Exam tip

Brownfield sites can occur anywhere in a city – they occur wherever there is derelict land.

Greenfield and brownfield sites

A **greenfield** site is a site that has not previously been developed. Most greenfield sites are on the edge of town, although not necessarily so. A **brownfield** site is a site that has previously been used and has become

Table 6.3.2 The advantages and disadvantages of greenfield and brownfield sites

Greenfield sites		Brownfield sites	
Advantages	**Disadvantages**	**Advantages**	**Disadvantages**
+ Land may be accessible	+ Habitat destruction	+ Redevelopment of disused land	+ Land may be contaminated
+ Cheaper land	+ Reduction in biodiversity	+ Does not harm the environment	+ Widespread air and water pollution
+ People prefer more space and pleasant environments	+ Increased impermeability leads to flooding	+ Creates jobs locally	+ Congestion

Sustainable urban systems

Large cities are often considered unsustainable because they consume huge amounts of resources and they produce vast amounts of waste. Sustainable urban development meets the needs of the present generation without compromising the needs of future generations. The Rogers' model (*Cities for a Small Planet*) compares a sustainable city with that of an unsustainable one. In the sustainable city, inputs are smaller and there is more recycling.

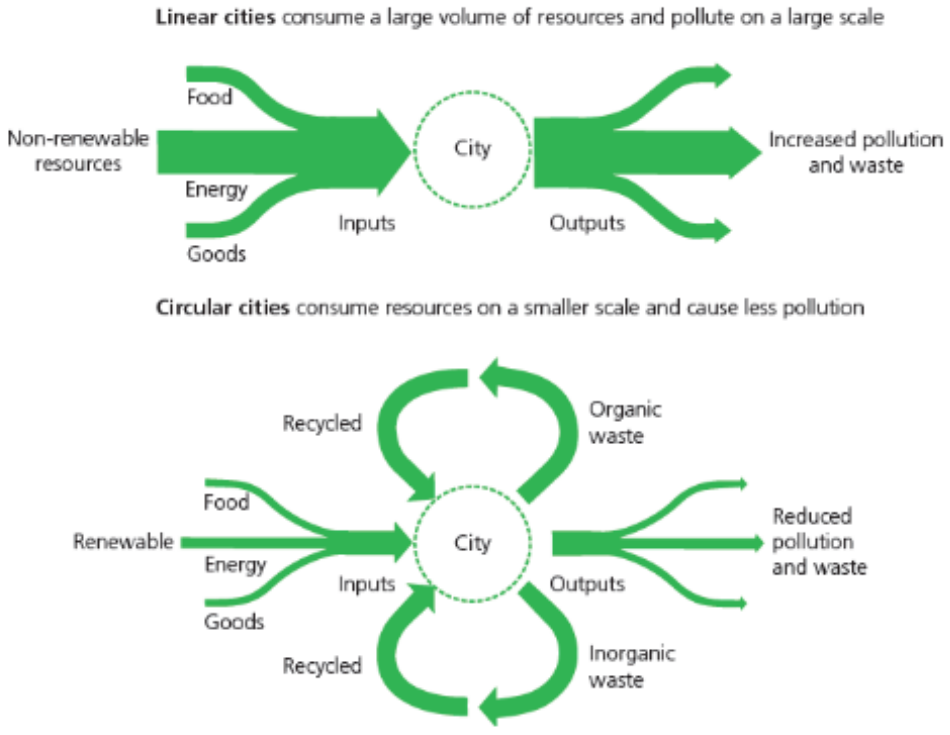

Figure 6.3.1 Linear (non-sustainable) and circular (sustainable) cities

To achieve sustainability, a number of options are available:

- reduce the use of fossil fuel, e.g. by promoting public transport
- keep waste production to within levels that can be treated locally
- provide sufficient green spaces
- re-use and reclaim land, e.g. brownfield sites
- encourage active involvement of the local community
- conserve non-renewable resources
- use renewable resources.

Compact cities minimise the amount of distance travelled, use less space, require less infrastructure (pipes, cables, roads etc.), are easier to provide a public transport network for, and reduce urban sprawl.

But if the compact city covers too large an area, it becomes congested, over-crowded, over-priced and polluted. It then becomes unsustainable.

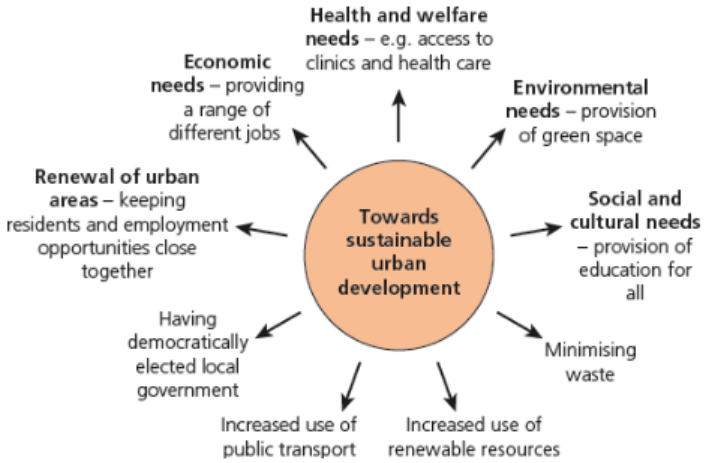

Figure 6.3.2 Developing sustainable urban areas

A sustainable future requires:

- use of appropriate technology, materials and design
- acceptable minimum standards of living
- social acceptability of projects
- widespread public participation.

The main dimensions of sustainable development are:

- provision of adequate shelter for all
- improvement of human settlement management
- sustainable land use planning and management
- integrated provision of environmental infrastructure: water, sanitation, drainage and solid waste management
- sustainable energy and transport systems
- settlement planning in disaster-prone areas
- sustainable construction industry activities
- meet the urban health challenge.

Exam tip

Use examples of sustainable urban development from your home region and comment on how successful they have been.

Stakeholders in managing urban areas

A stakeholder refers to any group or individual who is affected, or can affect, or has an interest in a development, e.g. new housing or a new out-of-town development. Some stakeholders may be supportive of the development, some may be against it, and others may see both advantages and disadvantages of the development. Stakeholders include the individuals involved in a scheme, national and local governments, charities, local churches, local planners, building companies, property owners, retailers, developers and estate agents.

For example, the Houldsworth Village Partnership in Manchester involves at least 60 different stakeholder groups including the Stockport Metropolitan Council, the Guinness Northern Counties Housing Trust, the University of Manchester, St Elisabeth's School, existing residents and traders, Stockport Sports Trust and the Reddish Crime Panel.

Some stakeholders may have conflicting interests, e.g. established residents in areas desiring no new developments compared with younger people desiring new, affordable housing developments. Corporate objectives may differ from individual ones.

The impact of a new development may have negative impacts on others, e.g. an out-of-town development may create jobs locally but also lead to an increase in congestion, air pollution and a decline in habitat.

Stakeholders may have to compromise their individual beliefs and values for the greater good. However, it is possible for stakeholders with an interest in the success of a partnership/development to attempt to minimise the impact on stakeholders with negative views, e.g. a new housing development retaining open space and vegetation rather than having high density housing only.

2.4 Assessment of fieldwork skills – Section B

Fieldwork is assessed in Section B of Paper 2. Students are required to complete **one** geographical enquiry involving fieldwork relating to **one** topic in Paper 2.

Paper 2: Human geography

- Economic activity and energy.
- Rural environments.
- Urban environments.

Centres must ensure that:

- Primary data collection includes quantitative and qualitative techniques.
- Secondary data collection includes the use of at least **two** different secondary data sources for your chosen environment.

Practical skills

As part of – and in addition to – undertaking the geographical enquiry, students should acquire and be able to apply the following skills:

- **graphical skills** – compiling graphs and flow lines, using proportional symbols, annotating maps, diagrams and photographs
- **map skills** (including use of digital maps) – using grid references, understanding scales, recognising symbols, identifying landforms and human features of the landscape
- **photo-interpretation skills** – reading vertical and oblique aerial photographs and satellite images, including GIS
- **sketching skills** – communicating ideas through simple sketch maps and field sketches
- **spatial awareness** – identifying the relative locations and relationships between features.

Cognitive enquiry skills

Students should acquire and be able to apply the following skills:

- **analysis of findings** – reviewing and interpreting quantitative and qualitative information using appropriate media
- **use of statistical skills** – simple descriptive statistics, such as lines of best fit, means, medians, modes, etc.
- **conflict resolution skills** – identifying the views of interested people (stakeholders), recognising that stakeholders may have strongly different attitudes and feelings towards a particular issue
- **evaluation of findings** – appraisal and review of data and information to see if these are accurate and suitable for the purpose, or misleading and unreliable.

Section B topic	Geographical enquiry	Suggested methods of primary data collection	What students need to know for Paper 2
Urban environments	Investigating the changing use of central/inner urban environments through primary and secondary evidence	**Primary** Quantitative e.g. (1) environmental quality survey, and a structured questionnaire, (2) urban land use survey Qualitative e.g. (1) annotated photographs showing evidence of changing rural environments, (2) interviews with different stakeholders **Secondary** (1) A local report (paper or digital) into an aspect of change in an urban area and community, (2) local secondary data on urban change from development, e.g. historic maps and images.	**Primary** Quantitative • Small scale environmental quality survey (EQS) • Structured questionnaire including closed questions Quantitative • Annotated photographs **Secondary:** • Report on change in a local urban community

Contexts for fieldwork Paper 1: Physical geography			
Section B topic	**Geographical enquiry**	**Suggested methods of primary and secondary data collection for familiar fieldwork contexts**	**What students need to learn for unfamiliar primary and secondary fieldwork contexts in Paper 1**
River environments	Investigation of river processes and form through primary and secondary fieldwork evidence	**Primary** Quantitative e.g. (1) channel measurements - velocity, width, depth and gradient (2) measurements of sediment - size and shape Qualitative e.g. (1) annotated field sketches of the river channel and its features, (2) photographs to show how the channel changes downstream **Secondary** (1) A GIS topographic map, e.g. from ArcGIS Online or Google Earth, (2) local secondary data on river flows or regimes	**Primary** Quantitative • River channel characteristics: width, depth and velocity • River gradient Qualitative • Annotated field sketches **Secondary** • GIS topographic map

Topic 7: Fragile environments and climate change

What students need to learn

Key ideas	Detailed content
7.1 Fragile environments are under threat from desertification, deforestation and global climate change	a) Distributions and characteristics of the world's fragile environments. (1) b) Causes of desertification (drought, population pressure, fuel supply, overgrazing, migration) and deforestation (commercial timber extraction, agriculture, mining, transport; settlement and HEP (hydroelectric power). (2) and (3) c) Causes of natural climate change (Milankovitch cycles, solar variation and volcanism) and how human activities (industry, transport, energy, and farming) can cause the enhanced greenhouse effect. (4)
7.2 There are various impacts of desertification, deforestation and climate change on fragile environments	a) Social, economic and environmental impacts of desertification (reduced agricultural output, malnutrition, famine, migration). b) Social, economic and environmental impacts of deforestation (loss of biodiversity, contribution to climate change, economic development and increased soil erosion). c) Negative effects that climate change is having on fragile environments and people (rising sea levels, more hazards, ecosystem changes, reduced employment opportunities, changing settlement patterns, health and wellbeing challenges, including food supply). (5)
7.3 The responses to desertification, deforestation and climate change vary depending on a country's level of development	a) How technology can resolve water-resource shortages in fragile environments under threat from desertification. b) Different approaches to the sustainable use and management of a rainforest in a named region to limit the extent of deforestation. c) Different responses to global warming and climate change from individuals, organisations and governments in a named developed and a named emerging or developing country.

Integrated skills	
(1)	Use world maps to show the location of fragile environments.
(2)	Use and interpret line graphs showing past and predicted global population growth, and population in relation to likely resources.
(3)	Use maps (paper and online) to identify the pattern of deforestation.
(4)	Use and interpret graphs and maps to show human causes of climate change.
(5)	Use and interpret line graphs/bar charts showing climate change and sea level change.

7 Fragile environments and climate change

7.1 Fragile environments are under threat from desertification, deforestation and global climate change

Topic 7: Fragile environments and climate change

What students need to learn

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Distribution and characteristics of fragile environments

A **fragile environment** is one that is vulnerable to change and may find it difficult to recover from natural or human-induced changes. Some ecosystems can cope with wide variations in climatic conditions and human pressures, whereas others are much more sensitive to change. Fragile environments include arid and semi-arid environments, rainforests and cold environments (Figures 7.1.1a, b and c).

Some natural events, such as volcanic eruptions, tsunamis, tropical cyclones and extreme weather may cause change, but increasingly it is anthropogenic events (human-induced events) such as **deforestation**, intensive agriculture and urbanisations that are increasing the pressure on natural ecosystems.

Table 7.1.1 Characteristics of fragile environments

Fragile ecosystem	Reasons for fragility
Tropical rainforest	Infertile soils; rapid deforestation; vulnerability to climate change
Coral reefs	Vulnerable to warming oceans, pollution, tourism
Arid and semi-arid environments	Lack of moisture so regeneration is slowed down
Tundra and alpine environments	Low temperatures so regeneration is limited; vulnerability to climate change as habitats are changed

Exam tip

Make sure you can name an example of each type of fragile environment.

Desertification and deforestation

Desertification

Desertification is the spread of desert-like conditions into areas that were previously green. These areas are becoming biologically less productive than they once were and can no longer support as many people at the same standard of living.

There are many inter-related causes of desertification including drought, population pressure, fuel supply (deforestation for fuelwood), overgrazing and migration. Desertification is especially prevalent in sub-Saharan Africa and Central Asia. Up to two billion people – over one-third of the world's population – are at risk of its effects.

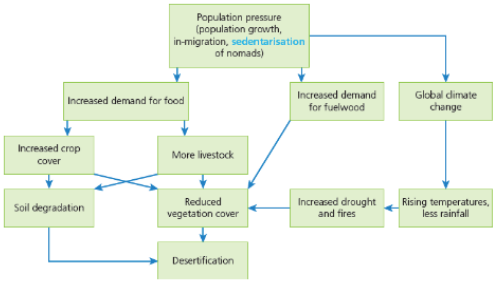

Figure 7.1.2 A model of the causes of desertification

Deforestation

Since agriculture began, almost one-third of the world's forests have been cut down, especially in temperate areas and, increasingly, in areas of tropical rainforest.

Much of the world's forest has been cut down to make way for farming, but some forests have been destroyed due to acid rain. Other forests are cut down for timber, settlement, transport developments and mining, and others are flooded to make way for hydroelectric schemes.

Exam tip

Remember that there are many types of deforestation. Clear-felling is the removal of whole trees but pollarding and coppicing remove only part of the tree. There is also selective deforestation where a particular species of tree or a small percentage of the trees are removed.

Natural climate change and the enhanced greenhouse effect

Natural climate change

There are many reasons for long-term changes in the Earth's climate (and they all pre-date the present **global climate change**), including tectonic movement, mountain building, volcanic activity, solar output, atmospheric dust and changes in the Earth's position relative to the Sun.

The **Milankovitch cycles** show that the amount of solar energy reaching the Earth varies with changes in the Earth's orbit, its tilt and its 'wobble' – the direction of its rotation. The Earth's orbit varies over a timescale of about 100,000 years. When it is further from the Sun, it receives less energy. In addition, when the tilt is greater, seasons are longer. The 'wobble' determines which hemisphere is facing the Sun – northern or southern.

Other natural causes include volcanic eruptions. Those more likely to cause changes to climate are large eruptions, especially in tropical areas. For example, the eruption of Mt Pinatubo in the Philippines in 1991 led to a drop in mean global temperature of 0.3°C. Even by 2005, the drop in global temperatures due to Mt Pinatubo was 0.1°C. Sunspot activity (solar flaring) occurs on an 11- and 22-year cycle. Atmospheric dust is also believed to block or reflect incoming solar energy, thereby leading to lower temperatures on Earth.

Human causes of climate change

The **greenhouse effect** is the process by which certain gases (greenhouse gases) allow short-wave radiation to pass through the atmosphere but trap a proportion of outgoing long-wave radiation from the Earth. This leads to a warming of the atmosphere. It is a natural process and vital for life on Earth.

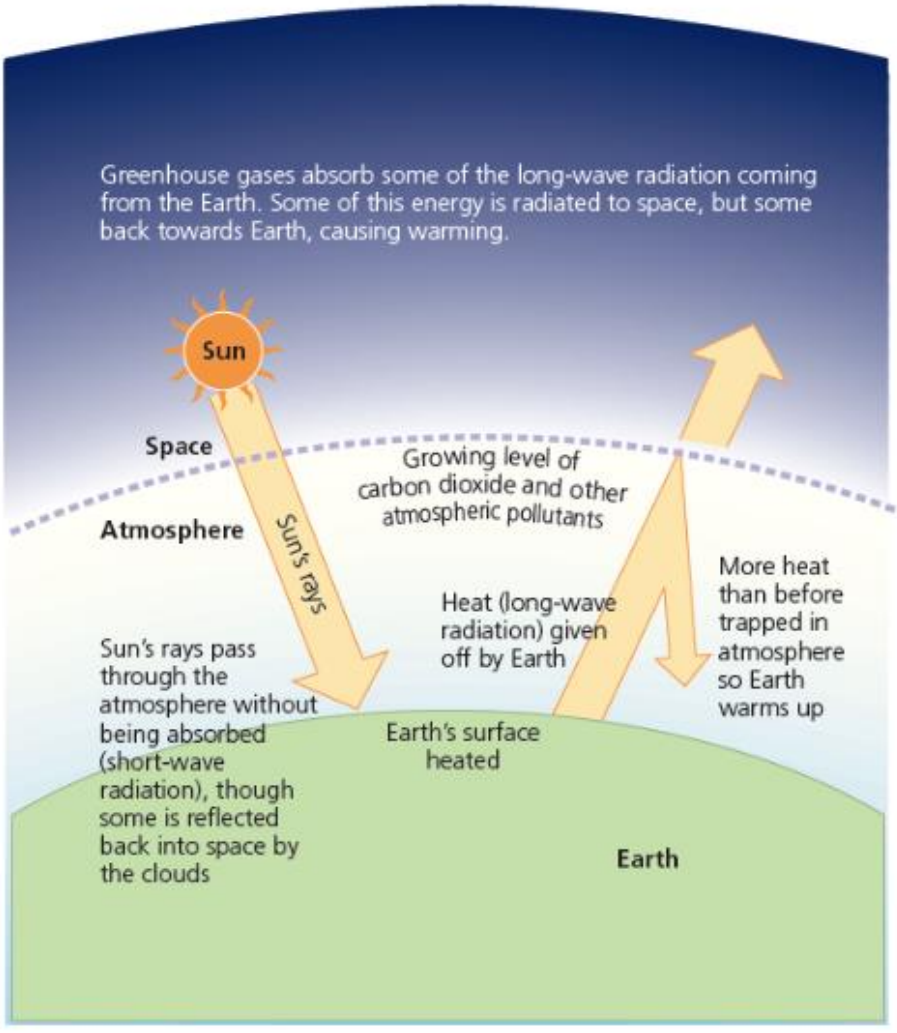

Figure 7.1.4 The greenhouse effect

The most common greenhouse gas is water vapour, which accounts for about 50% of the **natural greenhouse effect**. However, the gases which account for **human causes** of climate change are carbon dioxide (CO_2), methane (CH_4) and chlorofluorocarbons (CFCs).

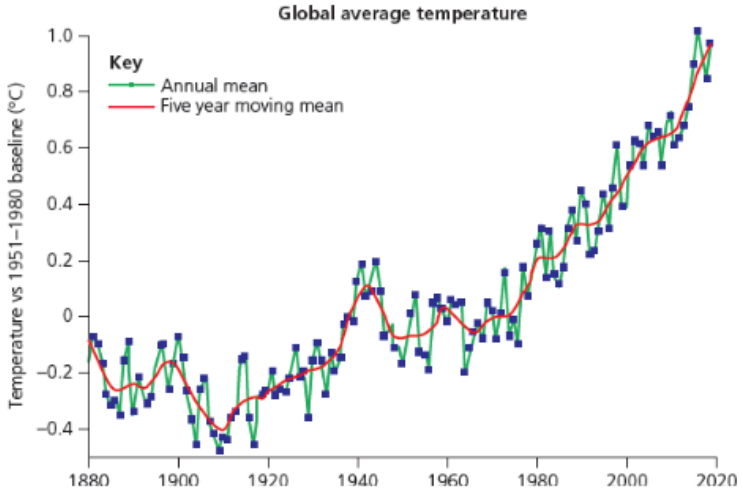

Figure 7.1.5 Changes in the global average temperature relative to the 1951–1980 average

The enhanced greenhouse effect (EGHE)

Atmospheric levels of CO_2 have risen from around 315 parts per million (ppm) in 1950 to over 420 ppm by 2020 and are predicted to rise to 600 ppm by 2050. The rise is due to human activities such as burning fossil fuels (coal, oil and natural gas) and land-use changes such as deforestation. This is known by many terms, e.g. the enhanced greenhouse effect/global climate change/climate crisis/global warming.

7.2 Impacts of desertification, deforestation and climate change on fragile environments

The impacts of desertification

Up to 12 million hectares of land and 20 million tonnes of grain are lost to desertification every year. One-third of the Earth's land is threatened with desertification. Soil exhaustion decreases world food production, and 20 million tonnes of cereal are lost every year due to desertification.

Table 7.2.1 Some impacts of desertification

Environmental	Economic	Social
• Loss of soil nutrients through wind and water erosion. • Loss of **biodiversity** as vegetation is removed. • Reduction in land available for crops and grazing land. • Increased sedimentation of rivers and reservoirs due to soil erosion.	• Reduced income from **pastoralism** and the cultivation of crops. • Decreased availability of **fuelwood.** • Increased rural poverty. • Increased dependence on food aid.	• Loss of traditional knowledge and skills. • Forced migration due to food scarcity. • Increased rural poverty. • Social tensions between migrants and local people.

Exam tip

Desertification does not occur in deserts – they are already non-productive.

The impacts of deforestation

Deforestation has many impacts, including the loss of biodiversity, its contribution to global and local climate change, its impact on economic development and increased rates of soil erosion.

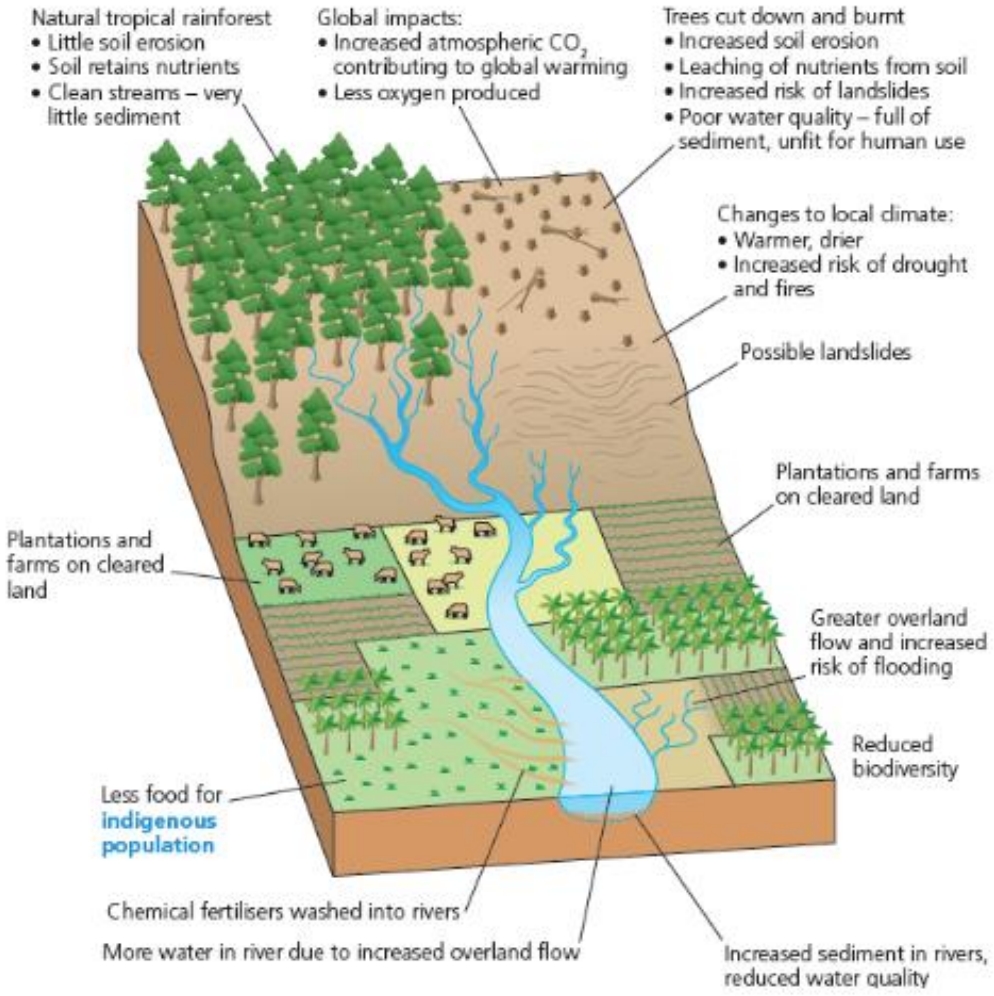

Figure 7.2.1 Some impacts of deforestation

Figure 7.2.1 Some impacts of deforestation

It is thought that the area of tropical rainforests worldwide has halved since 1800 to 1.4 billion hectares. As a result of deforestation, up to 100,000 species may become extinct every year.

Tropical forests are a vital source of material for medicines. Of the 3000 plants that may help cure cancer, 70% are found in tropical forests.

Exam tip

Some impacts are intentional, e.g. clearing of forested land to make way for farmland. Others are unintentional, e.g. clearing of forests leading to drought and fire.

Impacts of climate change on fragile environments and people

Rising sea levels

Sea levels are rising as the oceans warm (the '**steric effect**') and as ice on land melts. Even if there was no ice melt, the oceans would increase in size as warmer water expands.

Tens of millions of people are at risk from rising sea levels. Many low-lying islands and many of the world's megacities are less than 10 m above sea level and coastal flooding is a major risk. In addition, food production in coastal areas is likely to be affected by saltwater intrusion.

Increase in hazards

Climate change is likely to lead to an increase in hazards. Increased atmospheric energy is predicted to lead to an increase in tropical storms (hurricanes), as well as drought and fire.

In the Amazon rainforest there has been an increase in drought events, such as those of 2005, 2010 and 2015. These have led, in part, to increased tree mortality and a reduction of rainfall over the rainforest. Similarly, in the Middle East and North Africa, water stress is likely to increase due to falling rainfall levels and increased demand for water.

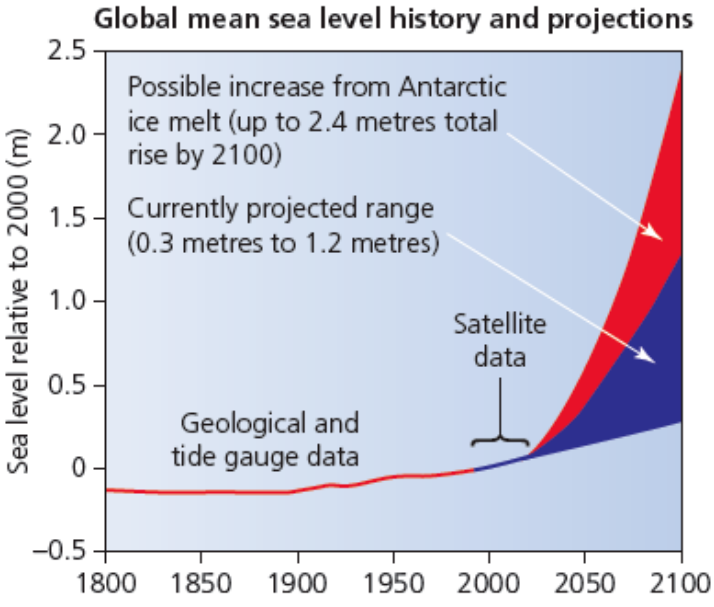

Figure 7.2.2 Sea level rise 1800–2100 (projected)

Ecosystem changes

The effect of climate change is likely to cause latitudinal shifts relative to the Equator and altitudinal shifts as biomes move up-slope. At high altitude and high latitude, biomes may have nowhere to retreat and may become extinct.

There are also changes taking place in the world's oceans. For example, increased ocean temperatures and **ocean acidification** have led to coral bleaching and a decline in species that build their own skeletons. Fish species are migrating pole-wards into cooler water.

Decreased employment opportunities

Climate change may lead to major job losses in different environments. For example, agriculture may become less productive in areas which become drier and hotter, and tourism in many mountainous areas will decline as glaciers retreat. Fishermen may have to change the species that they catch.

Changing settlement patterns

Settlements in low-lying areas may be abandoned or relocated. Many settlements – or parts of settlements such as those along the USA's east coast – will require considerable protection from rising sea levels and coastal flooding or will have to be abandoned.

Health and well-being

A rise in temperature of 2°C could expose up to 60 million more Africans to malaria. Mosquitos would be able to breed in areas previously too cool for them. Rising temperatures could lead to increased risk of dehydration, malnutrition and heat stress.

Agricultural crop yields, limit to cultivation and soil erosion

The decline in water resources may make it difficult for some farmers to continue the type of farming they currently practise. They may have to change crop/type of farming and could be forced out of farming altogether.

A rise of 2°C could lead to 200 million more people experiencing hunger, while a rise of 3°C could lead to up to 500 million more people experiencing hunger.

Exam tip

Remember that there are different scenarios for future climate change – it depends on how much greenhouse gases are released in future and whether there are schemes to tackle global climate change.

7.3 Responses to desertification, deforestation and climate change vary depending on a country's level of development

The use of technology to solve water shortages in fragile environments

Desalination

Desalination refers to the removal of salts from seawater to produce fresh water for human consumption and irrigation use. In many dry areas, seawater is a vital potential source of fresh water and can be used to combat desertification.

Due to high energy input, the financial costs of desalinating seawater are generally still high. But alternative water sources are not always available. There are around 20,000 desalination plants operating worldwide, producing almost 90 million m^3 of water per day for 300 million people.

Other sources of water in dry areas include **groundwater**, which could be brought to the surface by using pumps. However, in dry areas groundwater is a finite, non-renewable resource.

Table 7.3.1 Other measures to tackle desertification

Cause of desertification	Strategies for prevention
Overgrazing	Improve stock quality; breeds that are adapted to dry conditions; reduction of herd size; use of wider area to reduce grazing pressure.
Over-cultivation	Use of fertilisers can increase yields and reduce the amount of land needed; high-yielding varieties (HYVs) of crops and drought-resistant crops could be introduced; crop rotation, irrigation and zero tillage (not ploughing) can improve soil quality and reduce pressure on soils.
Deforestation	Agroforestry (combining agriculture with forestry), e.g. using trees for fodder, fuel and building. Trees protect, shade and

Exam tip

Be aware that small-scale projects are often more successful than large-scale ones as the people running them have immediate benefits from them.

Case study

Approaches to the sustainable use and management of a named rainforest: the Amazon rainforest, Brazil

Central Amazon Conservation Complex

The Central Amazon Conservation Complex is one of the world's largest conservation areas, covering 53,230 km^2. It protects several areas with rare, endemic and/or endangered species.

It is the largest protected area in the Amazon and was formed by the merging of the Jau National Park with the Anavilhanas National Park, Amana Sustainable Development Reserve and the Mamairaua Sustainable Development Reserve.

Brazil's Forest Code

The Forest Code is a law that requires landowners in the Amazon to maintain a proportion of their land (80%) as forest. It was passed in 1965 and revised in 2012.

Other initiatives

At a local scale, some indigenous groups use many ways to use the rainforest sustainably. In the Yanesha Forestry Cooperative Project, farmers cut a strip of rainforest some 20–40 metres wide, farm it and then let it recover. The narrow belt allows rapid recovery and secondary forests grow back within twenty years. Other communities enrich their soils by adding animal bones and charcoal. This increases soil fertility and allows them to farm the land more productively. Others plant fig trees on degraded land. These attract birds and bats which bring in seeds from neighbouring forests. The birds and bats deposit the seeds in their droppings thereby helping forest to regenerate.

Responses to global warming and climate change

Responses to climate change can take two main forms – **mitigation** and **adaptation**. Mitigation refers to programmes to try to prevent climate change from happening or to try to reduce the scale of climate change that occurs. Adaptation refers to measures that are taken to manage the impacts of climate change, e.g. preventing coastal erosion, protecting cities against sea level rise.

Mitigation

The UK's progress on climate change mitigation is predicted to stall in the 2020s, partly as a result of a lack of new climate policies in recent years, failure to meet afforestation targets and a lack of progress in developing **carbon capture and storage (CSS)** technology.

Nevertheless, the UK now burns far less coal than it used to. There is potential for more renewable energy, especially wind and solar power.

Table 7.3.2 UK: Climate change pledges and targets

Paris Agreement	Ratified	Yes
	2030 (unconditional targets)	Greenhouse gas emissions 57% below 1990 levels
	Long-term goal	Net zero greenhouse gas emissions by 2050

Individual choices

There are many actions that individuals can do to reduce their own contribution to climate change. These include walking or cycling rather than using a car; eating less meat and dairy products; switching to renewable sources of energy.

The UK's response

Adaptation

There are many ways in which the UK is adapting to climate change. These include improving and increasing flood defences (Figure 7.3.2), improving public transport, and more bus and cycle lanes.

Figure 7.3.2 The Thames Barrier in London

Responses to global warming and climate change – China

Mitigation

Table 7.3.3 China: Climate change pledges and targets

Paris Agreement	Ratified 2030 (unconditional targets)	Yes Peak CO_2 emissions by 2030 Non-fossil fuel share 20% in 2030

China has responded in many ways to the threat of global climate change. It has reduced its consumption of coal. This is partly due to changes in China's economy – there is more growth in the service sector and less growth in heavy industries, which can be energy-intensive and use vast amounts of cement and concrete. In 2015, China announced its coal consumption would peak by 2020 and that it would not be building any new coal-fired power stations. China has also invested heavily in wind and solar energy. The Three Gorges Dam makes a significant contribution to the production of renewable energy although the vast amount of concrete used in building the dam would have contributed to global climate change.

China is also providing incentives for buying **hybrid vehicles** and electric vehicles, as well as enforcing stricter fuel-efficiency standards. China's high-speed trains transport nearly 3 million passengers daily, thereby reducing large numbers of people from using motor vehicles.

Adaptation

China has a very varied climate and ecosystems which makes adaptation to climate change complicated. Urban populations, such as Shanghai, are extremely vulnerable to sea level rise, while water scarcity in the north has led to changes in crop productivity, increased flood risk, and more frequent and intense droughts.