1 The Changing Landscapes of the UK

LEARNING OBJECTIVE

To study the geological variations within the UK.

Learning outcomes

- To know the characteristics and distribution of the UK's main rock types: sedimentary, igneous and metamorphic.
- To understand the role of geology and past tectonic processes in the development of upland and lowland landscapes.

KEY TERMS

Geology – the science that deals with the physical structure of the Earth, its history and how it changes.

Texture – the feel and appearance of a material.

Composition – what a material is made up of.

Fossils – the remnants of prehistoric organisms, such as a fish skeleton or a leaf imprint, which have become embedded in a rock.

There are geological variations within the UK

How did the UK's main rock types form and what are their characteristics?

The UK, although a small country, has a wide variety of landscapes. The **geology** of the UK has played a role in this variety. The main rock types found in the UK that will be discussed in this chapter are sedimentary (chalk and sandstone), igneous (basalt and granite) and metamorphic (schists and slates). These rocks display a number of distinctive characteristics.

Formation of sedimentary rocks

Sedimentary rocks are formed in layers. Many are formed from weathered or eroded rock debris that has been transported and deposited; the deposited rock grains build up in layers called sediments. The weight of the sediments cause the layers at the bottom to become compacted, forming sedimentary rocks such as sandstone. Other sedimentary rocks are formed in the same way; for example, dead sea creatures get compacted on the sea bed into chalk. This process can take millions of years.

Characteristics of sedimentary rocks

Sedimentary rocks:

- are classified by **texture** and **composition**
- usually have layers
- often contain **fossils**
- are composed of rounded grains pushed together
- have a great variety in colour
- are made of particles that may be the same size or vary.

Figure 1.1 Sandstone at Baggy Point, Devon.

Figure 1.2 Chalk cliffs in Kent.

Formation of igneous rocks

Igneous rocks are formed from molten rock called **magma** that is found inside the Earth. When magma cools it forms igneous rocks. If magma cools underground, it cools slowly, forming rocks that contain large **crystals** such as granite. If magma erupts from a volcano, it cools quickly, forming rocks that contain small crystals, as basalt.

Characteristics of igneous rocks

Igneous rocks:

- are formed from molten rock (magma)
- are made from randomly arranged crystals
- are very **resistant** rocks
- do not contain fossils
- may be intrusive, forming inside the Earth, such as granite
- may be extrusive, forming on the Earth's surface, such as basalt.

KEY TERMS

Crystals – a solid material that is arranged in a regular form with definite lines of symmetry.

Resistant – strong rocks that can withstand weathering and erosion.

Figure 1.3 Granite scenery at Haytor on Dartmoor.

Figure 1.4 Drumadoon basalt columns on the Isle of Arran, Scotland.

Formation of metamorphic rocks

These rocks form when igneous or sedimentary rocks are put under great pressure or are close to a source of heat. The rocks are not melted but are heated. Under these two conditions the minerals within the rock change chemically to form a new type of **metamorphic** rock.

Characteristics of metamorphic rocks

Metamorphic rocks:

- are formed from other rocks, either sedimentary or igneous
- are formed under great heat or pressure
- have crystals that can be arranged in layers, for example slate, which is formed from shale
- can contain fossils, although the fossils are usually squeezed out of shape, for example marble

Figure 1.5 Mica schists in south Devon.

Figure 1.6 Slate extraction in Snowdonia.

Practise your skills

Study Figure 1.7 on page 5. On a blank map of the UK:

1. Locate areas of each of the main rock types.
2. Name an area for each of the main rock types.

The role of geology and past tectonic processes in the development of upland and lowland landscapes

The different types of rocks have varying resistance to physical processes. Igneous and metamorphic rocks tend to be more resistant and therefore form upland, or highland, areas. The igneous and metamorphic rocks in the UK were formed when it had **tectonic** activity. Volcanic cones can still be seen in the UK landscape, for example Abbey Craig near Stirling is built on a volcanic plug (see page 50). The island of Ailsa Craig is also a volcanic plug.

The lowland landscapes are formed from sedimentary rocks. These landscapes are not necessarily flat – they can contain rolling hills, such as the North Downs – but they are much lower landscapes as the rock types are less resistant to physical processes.

Highland areas
Rivers

Location on map	Name of river
A	River Tees
B	River Trent
C	River Thames
D	River Severn
E	River Exe

Location on map	Name of upland
1	Northwest Highlands
2	Grampian Mountains
3	Pennines
4	Cambrian Mountains
5	Cotswolds
6	Chilterns
7	North Downs
8	South Downs
9	Exmoor
10	Dartmoor
11	Mourne Mountains

Figure 1.7a UK upland areas.

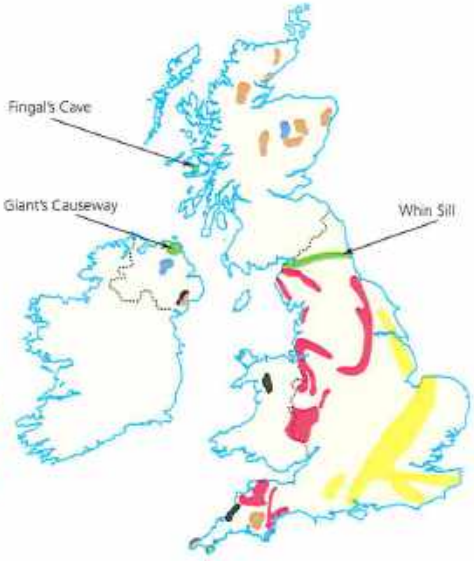


Figure 1.7b Simplified distribution of rock types in the UK.

ACTIVITIES

1. Identify the location of one area of granite landscape in the UK.
2. Is basalt found in the southeast of England?
3. Name two areas of chalk hills in the UK.
4. Name a volcanic cone that can still be seen in the UK.

Extension

Visit the Geological Society's website (www.geolsoc.org.uk) to learn about the distribution of the UK's main rock types.

Review

By the end of this section you should be able to:

- ✓describe the characteristics of the UK's main rock types
- ✓locate the main rock types on a map of the UK
- ✓understand the role of geology and past tectonic processes in the development of upland and lowland landscapes.

A number of physical and human processes work together to create distinct UK landscapes

LEARNING OBJECTIVE

To study the physical and human processes that have created the distinctive landscapes of the UK.

Learning outcomes

- To understand how distinctive upland and lowland landscapes result from the interaction of physical processes (glacial erosion and deposition, weathering and climatological processes, post-glacial river and slope processes).
- To recognise how distinctive landscapes result from human activity (agriculture, forestry, settlement) over time.

The upland landscapes of the UK could not be described as mountainous but they are very different from the lowland areas. The upland areas were formed by resistant rocks millions of years ago and their landscape has been defined by the physical processes at work during the last ice age. The UK has been covered by ice during ice ages on a number of occasions. The extent of the coverage during the last ice age, about 20,000 years ago, is shown on Figure 1.8 on page 7.

Since the last ice age, weathering, climate and other physical agents have had an impact on the landscape. The landscape has been shaped by the work of rivers (see page 26) and slope processes, such as mass movement (see page 27). The climate of the UK has also had an impact on the landscape. For example, heavy rainfall will cause rivers to have greater erosive power. Mechanical, biological and chemical weathering (see page 8) also have a continual impact on the landscape.

The lowland areas of the UK were shaped by glacial outwash. As the glaciers melted the water formed distinctive lowland landscapes. These landscapes have continually been shaped by rivers, weathering and slope processes, outlined in Chapters 2, 3 and 4.

These landscapes have also changed over time due to human activity. The building of settlements is perhaps the most distinctive change: houses, industries and roads connecting settlements have changed the landscape forever, with natural landscapes becoming human ones.

The agricultural landscape also continues to change. Originally the land was farmed with hedges and walls as field boundaries; as farming practices have changed over time, however, the hedges in some parts of the country have been removed and extensive areas of land have been created to allow for the large machinery that is now used. The landscape of the countryside, particularly in lowland areas, is continually evolving.

The landscape of the UK has also been influenced by forestry. Originally much of the UK was covered by **deciduous** woodland. Over hundreds of years the woodland has been felled, which has changed the landscape in a number of ways. Land that was once covered in trees is now open moorland, settlement and farmland. There has also been a change in the *type* of woodland in the UK, because much of the woodland which has been grown to replace the felled woodland is **coniferous**, not deciduous. In Scotland, the amount of woodland had decreased to four per cent of the landscape by 1900. The total is now back up to almost twenty per cent.

Figure 1.8 The extent of the ice sheet during the most recent glaciation – Devensian.

ACTIVITIES

1. Identify three agents of erosion that change the landscape.
2. Describe how rivers can change the landscape.
3. State three human activities that change the landscape.
4. Describe how farming has changed the landscape of the UK over the past 200 years.

Extension

Use the internet to research information about the last ice age. Try to answer the following questions.

1. What is meant by an ice age?
2. When was the last ice age?
3. Which areas of the UK were covered with ice?
4. What was the impact of the ice on the UK landscape of today?

Review

By the end of this section you should be able to:

- ✓understand how upland and lowland landscapes result from the interaction of physical processes
- ✓recognise that distinctive landscapes can result over time from human activity.

Examination-style questions

1	Study Figure 1.7b on page 5. Identify the location of one area of schist landscape.	(1 mark)
2	State one example of igneous rock.	(1 mark)
3	State one characteristic of igneous rocks.	(1 mark)
4	Forestry is a human activity that affects the landscape. Name one other human activity that affects the landscape.	(1 mark)
5	Explain how that activity affects the landscape.	(2 marks)
		Total: 6 marks

3 River Landscapes and Processes

LEARNING OBJECTIVE

To study the physical processes that interact to shape river landscapes.

Learning outcomes

- To understand the impact of weathering, mass movement and erosion on river landscapes.
- To understand the ways that rivers transport and deposit material.
- To recognise that rivers are different between their upper, mid and lower courses.
- To be able to explain why river characteristics change along the course of a river, such as the River Creedy.
- To know how the UK's weather and climate affect river processes and impact on landforms and landscapes.

A variety of physical processes interact to shape river landscapes

What are the main types of weathering?

There are three main forms of weathering: mechanical, chemical and biological.

Mechanical weathering

Freeze-thaw weathering, or frost action, is when water gets into cracks in rocks. When the temperature falls below freezing, the water will expand as it turns into ice. This expansion puts pressure on the rock around it and fragments of rock may break off. This type of weathering is common in highland areas where the temperature is above freezing during the day and below freezing during the night. This can cause the break-up of rocks on riverbanks.

Chemical weathering

Rainwater contains weak acids that can react with certain rock types. The carbonates in limestone, for example, are dissolved by these weak acids and this causes the rock to break up or disintegrate. This can be seen on limestone pavements or on limestone cliffs in a gorge. Figure 3.1 shows chemical weathering on the Devil's Pulpit rock in the Lower Wye Valley.

Biological weathering

This is the action of plants and animals on the land. Seeds that fall into cracks in rocks will start to grow when moisture is present. The roots the young plant puts out force their way into cracks and, in time, can break up rocks. The rocks can then be washed away by rainwater, leaving the roots exposed (see Figure 3.2 on p page 27). Burrowing animals, such as rabbits, can also be responsible for the further break-up of rocks.

Figure 3.1 Chemical weathering on the Devil's Pulpit, Lower Wye Valley.

Figure 3.2 Biological weathering.

What is mass movement?

Mass movement is when material moves down a slope due to the pull of gravity. There are many types of mass movement but, for the purposes of this chapter, only slumping and sliding will be discussed. Slumping, also known as rotational slipping, is common on riverbanks and involves an area of riverbank slipping into the river. Due to the nature of the slip, it leaves behind a curved surface. This is very common on clay riverbanks. During dry weather the clay contracts and cracks; when it rains, the water runs into the cracks and is absorbed until the rock becomes saturated. This weakens the rock and, due to the pull of gravity, it slips down the slope on its slip plane.

How do rivers erode?

The water in a river is continually attacking its bed and banks in a process known as erosion. Many of the same processes are used by both the sea and rivers to erode land. The theory box should be referred to throughout this chapter to understand the processes of river erosion.

Processes of river erosion

Abrasion

Material that the river is carrying is thrown against the river bed and banks. These particles break off more rocks which, in turn, are thrown against the river bed and banks as the water continues to make its way downstream.

Hydraulic action

This is the pressure of the water being pushed against the riverbanks. It also includes the compression of air in cracks: as the water splashes against the riverbanks, it compresses air in cracks; this puts even more pressure on the cracks and pieces of rock may break off.

Solution

This is a chemical reaction between certain rock types and the minerals in the river water. This is particularly evident in limestone areas where rivers can eat away at the rock, disappearing underground for part of their course.

Attrition

This is a slightly different process that involves the wearing away of rocks that are in the river. Rocks in the river roll around; as they do so, they grind away at each other until smooth pebbles or sand are formed.

How do rivers transport materials?

Rivers can transport materials in a number of ways: traction, saltation, suspension and solution.

- **Traction** – large **sediment** such as pebbles roll along the river bed.
- **Saltation** – small pieces of shingle or large grains of sand are bounced along the river bed.
- **Suspension** – small particles such as sand and clays are carried in the water. This can make the water look cloudy, especially after heavy rainfall or when the river has lots of energy.
- **Solution** – some minerals are dissolved in river water. This can change the colour of the water due to the minerals that are present.

KEY TERMS

Gradient – the slope over which the river loses height.

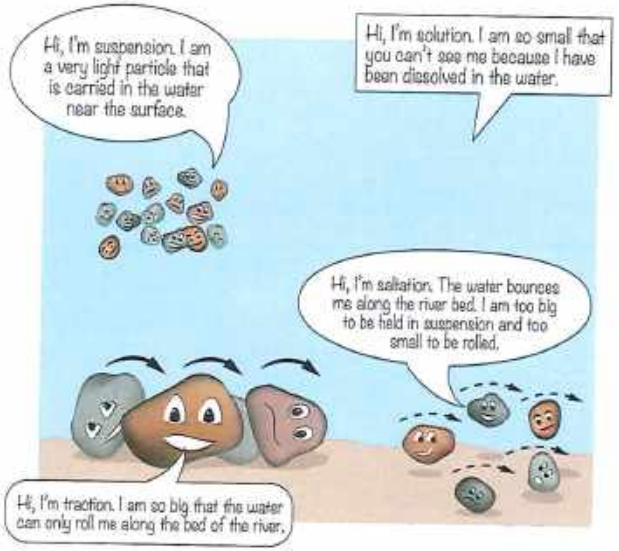


Figure 3.3 How a river transports materials.

What is deposition?

Deposition is the laying down of materials, such as sand and pebbles, that are being transported by the river. Rivers deposit materials when they slow down and lose energy, such as on the shallow bank of a river.

How river landscapes contrast between the upper course, the mid course and the lower course

As a river flows downstream, the contrasts in the river landscapes that occur mostly relate to differences in the river's energy. When it is in an upland area, a river has the power to erode downwards, as it is way above sea level, and it forms a V shaped valley. As the gradient (slope) of a valley decreases, the river uses its energy to transport the material it has eroded. Due to the lack of gradient, it begins to erode laterally (sideways). As the river moves closer to sea level, the gradient decreases further. Although the river is still eroding sideways at this point, deposition is the most important process, and the valley becomes wider and flatter in the lower course. This change from erosion to deposition helps to explain the change in landforms and the shape of the river valley as the river moves towards the sea (see Figure 3.4 on page 29).

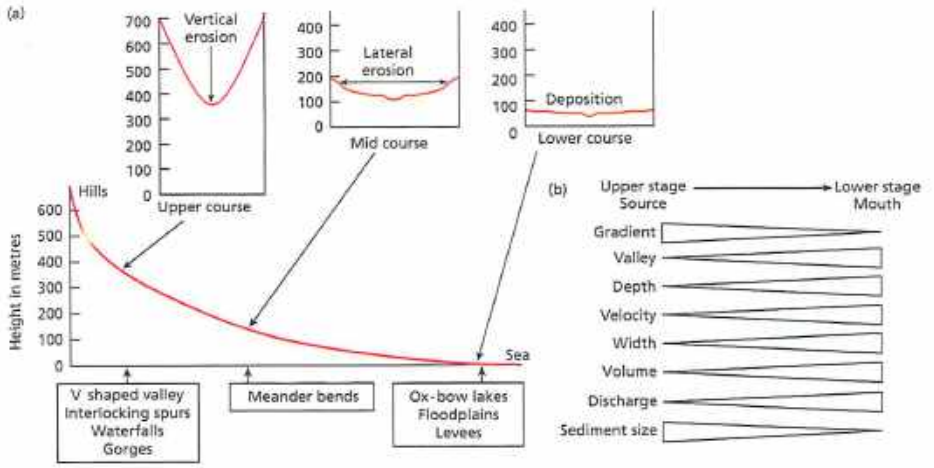


Figure 3.4 The features of a river's course.

The long profile of a river shows the steep gradient at the source gradually becoming more gentle until the river reaches sea level. These changes usually show a river to be split into three sections, known as the upper, mid and lower courses.

As a river moves downstream, its discharge also changes. Discharge is the amount of water passing a specific point at a given time and is measured in cubic metres per second. The discharge depends on the river's velocity and volume. The volume is the amount of water in the river and the velocity is the speed of the river. A river's discharge is equal to its velocity multiplied by its volume.

As a river moves towards the sea, its discharge will increase because of the increased volume as more tributaries join the river. The velocity of the river is determined by the amount of water that is touching the river's bed and banks. If the river is deeper, there will be less contact between the river and its banks and bed, therefore less friction will occur and the river velocity will be greater.

KEY TERMS

Mouth – where the river ends, either when it joins another river or meets the sea.

Long profile – a slice through the river from source to mouth that shows the changes in height of the river's course.

Source – the start of a river.

Channel shape – the width and depth of the river.

Discharge – the amount of water passing a specific point at a given time, measured in cubic metres per second.

Volume – the amount of water in the river.

Velocity – the speed of the river.

Valley profile – a slice across a river showing the changes in height across the valley.

Confluence – the place where two rivers meet.

Why do river characteristics change along the course of the River Creedy?

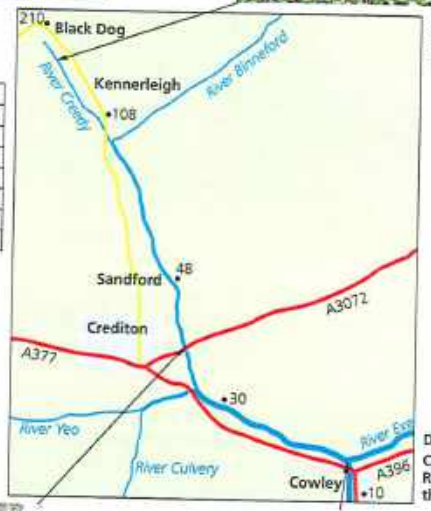
The River Creedy flows through 16 km of mid Devon. Its source is in the hills to the north of Crediton. It ends at its confluence with the River Exe, which is just south of Cowley Bridge. In the upper course the river is shallow and narrow with a steep gradient. As it moves downstream it meets other rivers such as the Binneford. The river becomes wider and deeper as it gains more water from other rivers. To the southeast of Crediton it is met by the River Yeo, adding more water to the river. This gives the river more power to erode. The river is also moving away from the hills into flatter areas, so the gradient of the river is becoming less and the river is less likely to erode vertically and more likely to erode laterally, forming meander bends.

A
Upper course of the River Creedy

Characteristics of the upper course

Characteristic	Detail
Channel shape	Width 1 m, depth 10 cm
Valley profile	V shaped
Gradient	10%
Discharge	0.66 m³
Surface velocity	0.38 m per sec
Sediment size	10 cm
Sediment shape	More angular

B
River Creedy 1 km from its source



Key
- Minor road
- A road
- Built up area
- Rivers
- •10 m Spot height

C
Mid course of the River Creedy

Characteristics of the mid course

Characteristic	Detail
Channel shape	Width 10 m, depth 50 cm
Valley profile	Wide, flat-bottomed V shape
Gradient	0.5%
Discharge	2.8 m³
Surface velocity	0.56 m per sec
Sediment size	15 cm
Sediment shape	Between angular and rounded

D
Confluence of the River Creedy and the River Exe

Characteristics of the lower course

Characteristic	Detail
Channel shape	Width 15 m, depth 1.2 m
Valley profile	V shaped with a very wide, flat bottom
Gradient	0.1%
Discharge	15.5 m³
Surface velocity	0.86 m per sec
Sediment size	3 cm
Sediment shape	More rounded

Figure 3.5 The course of the River Creedy.

How the UK's weather and climate affect river processes and impact on landforms and landscapes

The **seasonality** of the UK's weather and climate affect the rate at which a river can erode. In times of storms or heavy rainfall, rivers will contain a lot of water. This gives them greater erosive power and landforms such as river cliffs will be attacked by the water. During times of heavy rainfall trees on riverbanks can have their roots undermined by erosion and mass movement, eventually causing the bank to collapse. **Levees** are depositional landforms that form when the river is in flood or during times of heavy rainfall. When droughts occur rivers have less water and therefore less power to erode. In the winter the differences between day and night-time temperatures can cause freeze–thaw weathering on riverbanks, possibly causing the banks to collapse.

The human river landscape, such as river defences, are in need of repair more regularly due to the increasing regularity of storms in the UK. Many urban areas have had to install river defences, causing a change to the river landscape on the **floodplain**.

Review

By the end of this section you should be able to:

- ✓explain the impact of weathering, mass movement and erosion on river landscapes
- ✓describe the ways that rivers transport and deposit material
- ✓describe the ways that rivers differ between their upper, mid and lower courses
- ✓explain why river characteristics change along the course of a river, for example the River Creedy
- ✓know how the UK's weather and climate affect river processes and impact on landforms and landscapes.

ACTIVITIES

1. Which of the following is not a way that a river erodes materials?
   abrasion attrition solution traction
2. Describe two of the ways that a river transports materials.
3. What is the difference between a long profile and a valley profile of a river?
4. How do rivers differ between their source and their mouth? Refer to width, depth, gradient and discharge in your answer.
5. Explain how the UK's weather and climate affect river landscapes.

Extension

With reference to a river you have studied, explain the changes between its source and its mouth.

Practise your skills

A class of students recorded the size of sediment at two sites on a river – the source and close to the mouth. Their results are in the table.

Site 1 Sediment size (cm) at the source	Site 2 Sediment size (cm) at the mouth
11, 8, 10, 11, 6, 10, 8, 9, 9, 7, 8, 10, 8, 12.	4, 3, 5, 4, 7, 5, 3, 4, 5, 3, 2, 7, 2, 5.

1. Calculate the mean, mode and range for the pebble sizes in the table.
2. Draw out and complete a dispersion diagram similar to Figure 2.23 on page 23 by plotting the information on sediment sizes for sites 1 and 2. Mark on the dispersion diagram the median, the upper quartile, the lower quartile and the interquartile range for both of the sites.
3. Compare the results for site 1 and site 2.
4. Suggest reasons for your results. Use your knowledge and understanding of river processes to help you.

Fieldwork ideas

How do the characteristics of a river change as it flows downstream?

Primary fieldwork:

- measure width, depth, velocity, gradient, pebble size and shape at six locations, with two measurements to be taken in the upper course, two in the mid course and two in the lower course
- the measurements could be shared between groups but all students should use each of the techniques
- use the measurements for width, depth and velocity to calculate the discharge of the river.

River erosion and deposition interact with geology to create distinctive landforms within river landscapes

LEARNING OBJECTIVE

To study the distinctive landforms created when river erosion and deposition interact with the geology of an area.

Learning outcomes

- To be able to describe and explain the formation of landforms that are created by river erosion interacting with the geology of an area: interlocking spurs, waterfalls and gorges.
- To be able to describe and explain the formation of landforms that are created by river erosion and deposition: meanders and oxbow lakes.
- To be able to describe and explain the formation of landforms that are created by deposition: floodplains and levees.

What landforms are created by river erosion interacting with the geology of an area?

Most river valleys can be split into three courses: the upper course, the mid course and the lower course. A number of different landforms can be found in river valleys which are the result of the interaction of erosion and deposition with the geology of the area.

Interlocking spurs

The river in the upper course is shallow and a lot of the water is in contact with its bed and banks. There is a lot of friction. The main process occurring in this area is erosion. The gradient is usually steep; the river erodes downwards forming a V shaped valley. In Figure 3.6 the River Tees is in its upper course. It is winding its way between interlocking spurs of carboniferous limestone. The river has to go around the rocky outcrops because it does not have the power to go through them.

Waterfalls and gorges

A waterfall forms due to river erosion and the influence of the geology of the area. If a band of more resistant rock crosses a rivers course, a waterfall will form at this point (see Figure 3.8).

The less-resistant, softer rock is eroded more quickly, leaving an overhang of more-resistant, harder rock. In time the harder rock becomes too heavy and falls into the river below. Hydraulic action occurs as the water falls over the lip and splashes on to the back wall. Over time the waterfall moves back (retreats) up the valley forming a gorge. At the bottom of the waterfall a deep pool of water known as the plunge pool forms due to the power of the water falling into it and the process of abrasion - the rocks carried by the river erode the bottom and sides of the plunge pool. Figure 3.9 shows High Force waterfall on the River Tees in County Durham. There are a number of features which caused this waterfall and gorge to form. The area has a rainfall of approximately 800 mm spread evenly throughout the year. The position of the waterfall is where the River Tees crosses the Whin Sill. This hard igneous rock known as whinstone is resistant to the erosional processes of the river water. The lower section of the waterfall is made up of carboniferous limestone. This is a less resistant rock than whinstone and therefore has eroded away at a faster rate. Between these two rocks is a layer of sandstone which is also less resistant then whinstone. This has caused the waterfall to slowly move upstream leaving a deep narrow gorge. The gorge is approximately 700 metres long and the drop of the fall is approximately 21 metres.

Figure 3.6 Interlocking spurs.

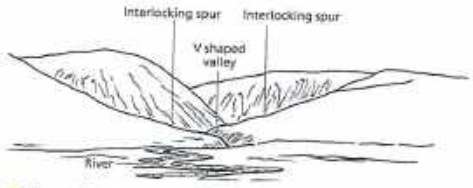


Figure 3.7 A field sketch showing interlocking spurs.

What landforms are created by river erosion and deposition?

Meander bends

These can be found on the river's course where the river is eroding and depositing material forming a bend in the river. The outside of a meander has the deepest water because this is where the greatest erosion takes place. The water is moving fastest at this point due to the lack of friction, eroding the bank using abrasion and forming a river cliff. Less water is in contact with the bed and banks because the river is deeper on this side.

A slip-off slope (point bar) forms on the inside of the meander bend because of deposition. Deposition occurs on the inside because the water is moving more slowly and is shallower. As a result, there is more friction here and the river is less powerful. The river is therefore unable to carry its load and deposition takes place. An underwater current takes some of the eroded material from the river cliff across the river and deposits it on the slip-off slope (see Figure 3.11).

Figure 3.10 Meander bend, Ardèche river, France.

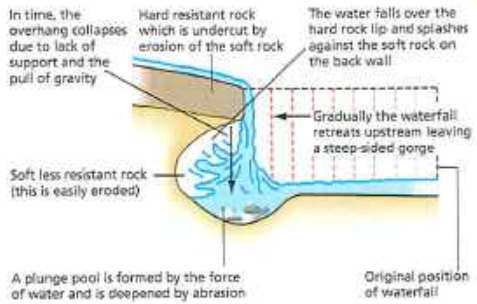


Figure 3.8 The formation of a waterfall.

Figure 3.9 High Force waterfall, County Durham.

ACTIVITIES

1. Which of the following landforms are created by the process of deposition?
   waterfall floodplain river cliff point bar meander
2. State three landforms that are created by river erosion interacting with the geology of an area.
3. Describe and explain the formation of a gorge.
4. Examine how physical processes work together to form the oxbow lake in Figure 3.12.

Extension

Explain how meander bends form floodplains.

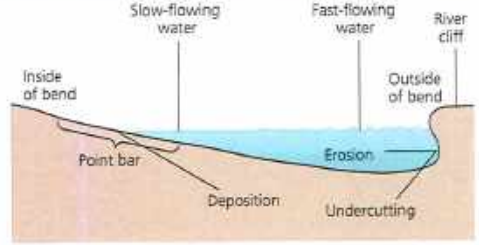


Figure 3.11 A cross-section of a meander bend.

Oxbow lakes

Meander bends can become very large. With continual erosion on the outside of the banks and deposition on the inside, the ends of the meander bend become closer (see Figure 3.12). When flooding occurs, the river is able to cut through the gap and, in time, forms a new straight channel. Continued deposition of alluvium at times of low flow results in the old bend of the river becoming cut off. This is called an oxbow lake.

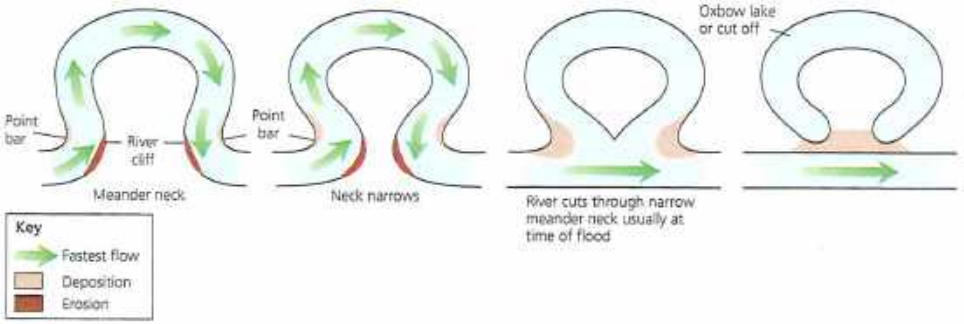


Figure 3.12 The formation of an oxbow lake.

What landforms are created by deposition?

Floodplains and levees

A floodplain is the low flat area of land on either side of a river. It can be found in the middle course of a river, but is more usually found in the lower course. It is formed by the migration of meanders downstream. Meanders are formed by lateral erosion which causes the bend to move across and down the valley in the direction of the river's flow. The outside of the bend, where erosion is greatest, moves the bend in that direction and the inside bend fills in the floodplain with the deposition that occurs there.

When the river contains too much water to stay within its channel, it floods the surrounding land. As it moves away from its channel, it becomes shallower and friction increases. The river has less energy and, therefore, must drop some of the load it is carrying. It drops the largest amount of material close to the river channel. After a number of floods, this builds up to form levees (see Figure 3.13). The river water drops the heaviest material first.

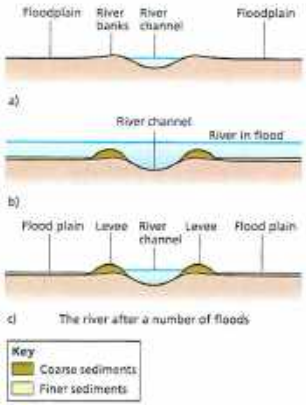


Figure 3.13 The formation of levees.

Review

By the end of this section you should be able to:

- ✓ describe and explain the formation of interlocking spurs, waterfalls and gorges
- ✓ describe and explain the formation of meanders and oxbow lakes
- ✓ describe and explain the formation of floodplains and levees.

Human activities can lead to changes in river landscapes that affect both people and the environment

LEARNING OBJECTIVE

To study how human activities can lead to changes in river landscapes that affect both people and the environment.

Learning outcomes

- To know how urbanisation has affected river landscapes.
- To recognise how agriculture has affected river landscapes.
- To identify how industry has affected river landscapes.
- To recognise the physical and human causes of river flooding.
- To recognise the effects of river flooding on people and the environment.
- To know the advantages and disadvantages of different flood defences used on rivers in the UK.
- To understand how river defences can lead to change in river landscapes.

KEY TERMS

Interception – when trees stop precipitation hitting the ground surface.

Throughflow – when water travels through soil towards a river.

Physical causes – any occurrence that is natural.

Human causes – any occurrence that is created by humans.

Urbanisation – the increase in the number of people living in towns and cities compared to the number of people living in the countryside.

How have human activities such as urbanisation, agriculture and industry affected river landscapes?

The building of settlements in river valleys and on river estuaries has had a major impact on the landscape. The settlements have a visual impact, an impact on wildlife, but also a major impact on the natural processes that are occurring in the area. Settlements developed on riverbanks originally for water supply and transport but, as the urban area spread, its impact has increased. The building of roads and drains means that water can reach the river more quickly after rainfall. This means that the river is much more likely to flood because of the disruption in the balance of water flow to the river. This, in turn, means that river defences are built to protect people's homes, which further disrupts the natural processes at work. For example, the river is **channelised**, which means that the original bank is reinforced. This stops the natural formation of meanders and speeds up the flow of the water. The building of large ports for industry on many river estuaries has also disrupted the natural processes at work in the river. For example, Poole Harbour in Dorset is regularly dredged of river sediments to stop it silting up so that large container boats can continue to access the harbour.

Agriculture has also had a number of impacts on river valleys. Many trees have been felled to make way for farming land, which interferes with the process of interception and has an impact on throughflow. Fewer trees means that rainwater will reach the river faster, impacting on erosion rates in the river because it will be more powerful. Farmers are also using more chemical fertilisers, which have an impact on the ecology of the river, causing algae bloom and water channels to become clogged with vegetation. This, in time, will impact on the river landscapes, as is particularly evident in Norfolk (see Figure 3.14). Farmers also drain land close to rivers with artificial drainage ditches that allow water to flow to the rivers of the area more quickly. This can cause flooding as the natural river landscape has been changed.

Figure 3.14 Algae bloom in a stream in Norfolk.

What are the physical and human causes of river flooding?

Rivers overflow their banks or flood when there is more water available than their channel can hold. There are both physical and human causes of flooding.

Physical causes	Human causes
Heavy rainfall: if there are large amounts of rain day after day, the water will saturate the ground and flow more quickly into the river.	Removal of vegetation on valley slopes: if there is less interception that water will move to the river more quickly.
Cloudburst in a thunderstorm: the rain droplets are so large and fall so quickly that there is no time for the water to sink into the ground; water runs very quickly into the river and causes flooding.	Settlements built on the floodplain: storm drains allow water to move into rivers at a greater speed and so make flooding more likely.
Sudden rise in temperature: a rapid thaw can happen; rivers are unable to cope with the amount of water and flood.	Global warming: melting of polar ice caps and a rise in sea levels, flooding low-lying coastal areas.
Silted up river channels: this makes the channel smaller and more likely to flood.	Dams may burst: which causes excess water in river channels and flooding of large areas.

Figure 3.15 The physical and human causes of river flooding.

What are the effects of river flooding on people and the environment?

Around 2.1 million properties in England are at risk from flooding, with just over 50 per cent of them at risk from flooding from rivers. Some of the effects of river flooding on people are:

- damage to people's homes and belongings from water
- loss of life from drowning of people and livestock
- contamination of fresh water supplies by sewage water
- communication links can be destroyed if bridges and roads are washed away
- disruption to gas and electricity supplies
- fields of food crops can be flooded, so there could be a lack of food in the area.

The destruction of crops is a short-term effect of river flooding on the environment, but it can take the land a number of years to recover from being covered by water. It can also cause different plant species to develop on the flooded land, making it expensive for farmers to get the land ready to be cultivated again. The ecosystem of the area is also affected with animals such as rabbits being drowned and natural vegetation that these animals feed on being lost. It can take many years for the natural environment to recover from the effects of a river flood.

River flooding on the Somerset Levels and Moors

During the winter of 2013–14 the Somerset Levels suffered severe flooding. The Levels are an area of low-lying land with the highest points being only 3–4 m above sea level; much of the land is below sea level. They are dissected by many rivers, the largest being the Parrett and the Tone. The heavy rainfall started in December and didn't stop until February, leading to the flooding of over 600 houses and 11,500 hectares of farming land, including North Curry and Hay Moors and the Greylake area. It could take up to two years for the land to recover. Villages such as Thorney were abandoned, and Mulchelney and Moorland were cut off. The A361 between East Lyng and Burrowbridge was closed for almost three months, leaving residents with the only options of evacuating their homes or using boats to get their shopping.

Figure 3.16 The flooded village of Moorland, Somerset.

KEY TERMS

Hard engineering – this method of river management involves major construction work, for example dams.

Soft engineering – this method of river management works or attempts to work with the natural processes occurring. They tend to be visually unobtrusive and do not tend to involve major construction work, for example washlands.

Hydrograph – a graph showing rainfall and river discharge over a specific period of time.

What are the main types of hard and soft engineering used on UK rivers?

A number of different types of defences are used to manage rivers, but what are their advantages and disadvantages and how do they change river landscapes? River defences can be classified as either **hard** or **soft engineering** techniques.

For the purpose of this chapter the following defences will be discussed:

- hard engineering: **dams**, **reservoirs**, **channelisation**
- soft engineering: floodplain zoning, washlands.

Practise your skills

1. Use the internet to find out the daily rainfall totals for January 2014 for Somerset and the river discharge for the River Parrett, Somerset. Use the figures to draw a **hydrograph** for this period.
2. Use the Environment Agency website to analyse the flood hazard in the area in which you live.

Dams – a large, usually concrete, structure built across a river valley to hold back water.

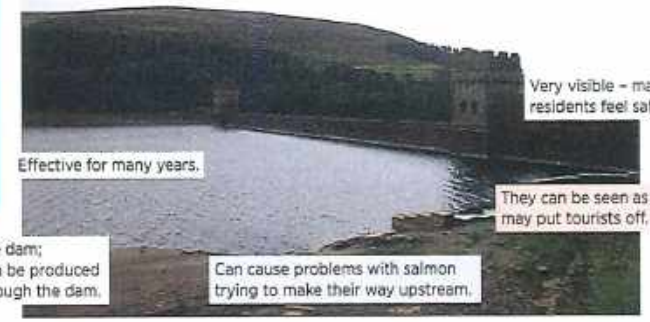


Figure 3.17 The Derwent Dam and Reservoir in Yorkshire.

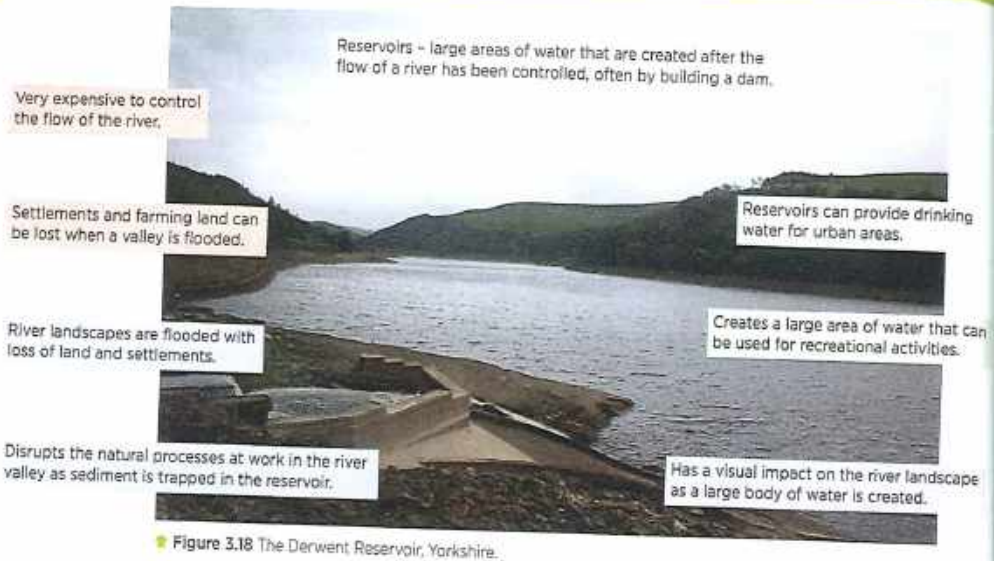


Figure 3.18 The Derwent Reservoir, Yorkshire.

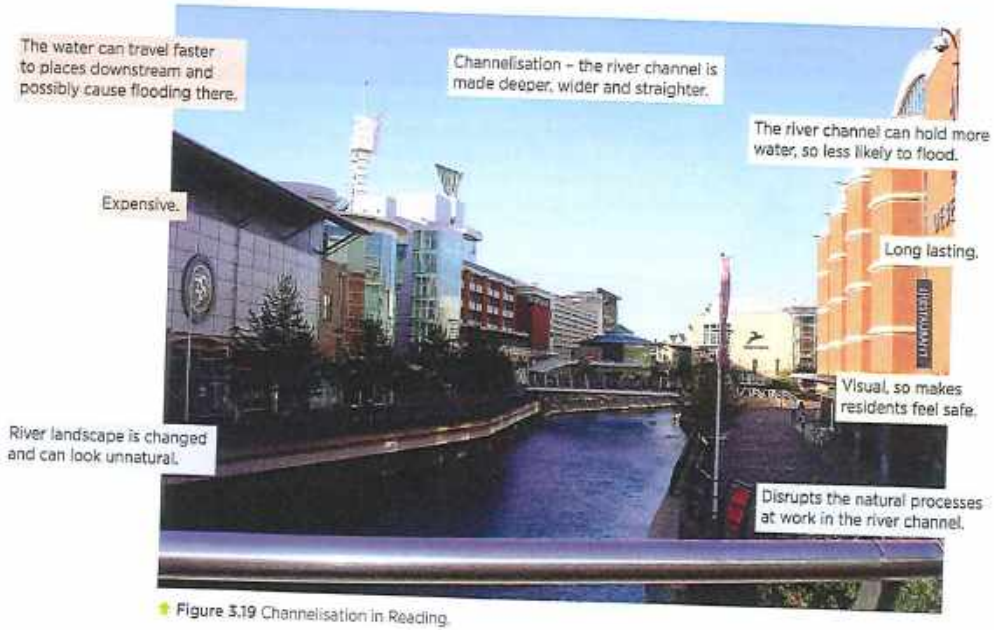


Figure 3.19 Channelisation in Reading.

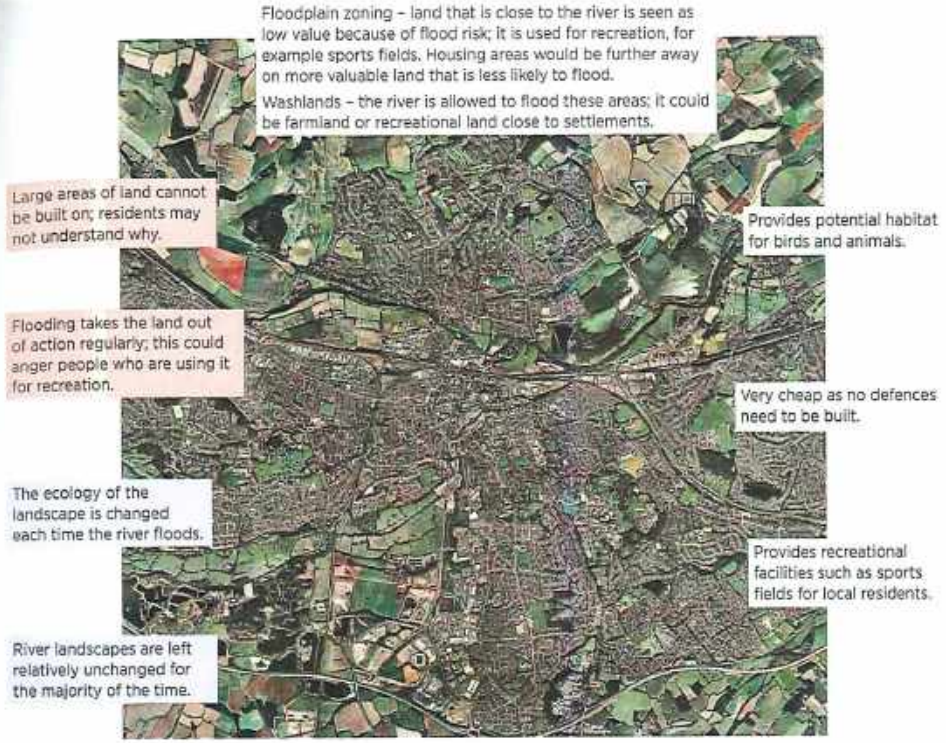


Figure 3.20 Reading town centre: the River Thames has undeveloped land along most of its course through the town; this allows the river to flood without causing damage to people's homes and businesses.

Review

By the end of this section you should be able to:

- ✓understand how urbanisation, agriculture and industry have affected river landscapes
- ✓recognise the physical and human causes of river flooding
- ✓recognise the effects that river flooding have on people and the environment
- ✓know the advantages and disadvantages of river management schemes
- ✓understand how river management schemes can lead to changed river landscapes.

ACTIVITIES

1. Describe one effect of urbanisation on river landscapes.
2. Looking at Figure 3.16 on page 36, describe the effects of river flooding on people and the environment.
3. Name one soft and one hard engineering technique.
4. What is the difference between hard and soft engineering?
5. How does the building of reservoirs lead to changes in river landscapes?

Extension

Evaluate the costs and benefits of hard and soft engineering techniques on river landscapes.

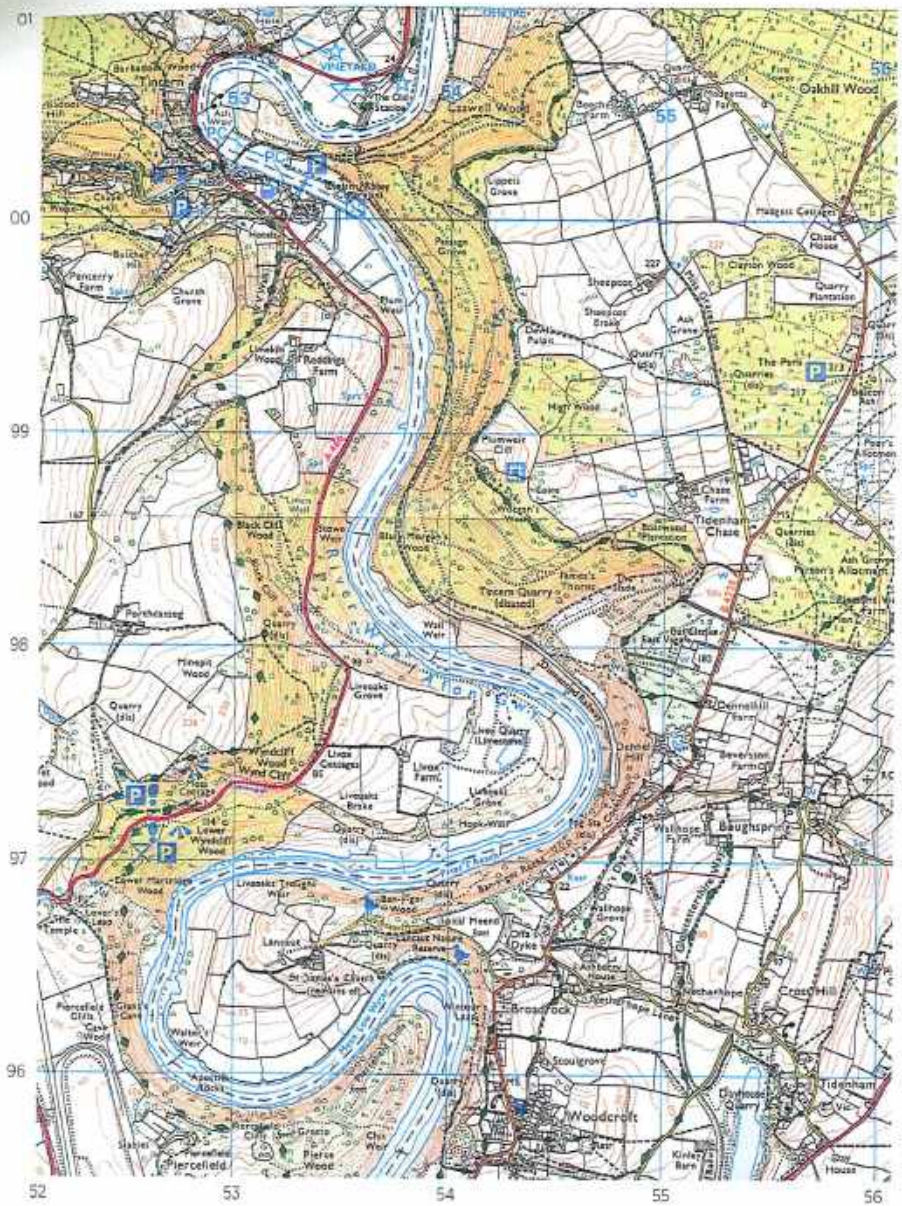


Figure 3.21 OS map of the Lower Wye Valley, 1:25 000.

Located example Distinctive river landscapes are the outcome of the interaction between physical and human processes

LEARNING OBJECTIVE

To study how the interaction between physical and human processes produces distinctive river landscapes.

Learning outcomes

- To know the significance of the location of the Lower Wye Valley between Chepstow and Tintern.
- To know how physical processes formed the distinctive river landscape in this section of the Wye Valley.
- To recognise how physical and human processes have changed the river landscape of the area.

The significance of the location of the Lower Wye Valley between Tintern and Chepstow is that it forms part of the border between England and Wales. It is also significant because of its spectacular scenery, which could have only formed in this particular location due to the geology of the area. The location is also significant because it was where tourism was supposed to have started due to the beauty of the area. Many of the viewpoints that exist today were built for tourists in the mid-eighteenth century.

The formation of the Lower Wye Valley has caused disagreement between geologists because the course of the river today does not relate to the present relief. The landscape either formed on rocks that were more recent than the ones shown today, but these rocks have since been removed by erosion; or the drainage pattern we see today has been superimposed on the present relief. Alternatively, the landscape was formed by glacial melt water which was very powerful and able to cut its way through the limestone, forming the gorge that is there today. The River Wye flows over Old Red Sandstone as far as Tintern where the physical processes of the river have cut deep meanders. After this point the river flows through a gorge cut through carboniferous limestone.

Figure 3.22 Physical processes at work in the Lower Wye Valley.

Physical or human process	Impact on (change to) the river landscape
Industry	Quarrying – the sides of the gorge have been extensively quarried for limestone for building materials and limekilns. This has increased the slopes of the gorge. Iron ore smelting – the valley had a plentiful supply of water, iron ore and wood for charcoal; it was the perfect setting for early iron smelting in Britain.
River erosion	The river erodes and deposits material forming meanders and floodplains. See pages 33–35 for detail on these processes.
Weathering	The processes of mechanical, chemical and biological weathering are all present in the area, providing material for the river to use in erosion and deposition processes.
Forestry	Many trees were felled in the eighteenth and nineteenth centuries for shipbuilding and other industrial uses, such as making charcoal. Up to the Second World War the woodlands were mainly deciduous. After this time extensive planting led to the area having 40 per cent of its woods either dominated by conifers or a substantial amount of conifers and a few broadleaf trees. Since the 1980s this planting has stopped and broad-leaved trees are now the main type being planted. Some woodlands were destroyed completely; others have appeared, such as on Coppet Hill where a wood has replaced previous open common pasture.
Human development	A road was built along the valley in the early nineteenth century and the railway followed in 1876. Before this the river was the economic backbone of the area allowing access for industry and tourists. Settlement in the valley goes back 12,000 years. Offa's Dyke, on the east bank of the river, was built in the eighth century.
Tourism	The Wye Valley was one of the earliest tourist honeypots with visitors flocking to the area in the 1700s. The cliff ascent and walks at Piercefield Park were landscaped at this time. Tourists still flock to the area. There are many lookout points, walks, a number of castles and Tintern Abbey, which dates back to the eleventh century.

Figure 3.23 Physical and human processes that have shaped the landscape of the Lower Wye Valley.

Figure 3.24 The River Wye floodplain at Tintern.

Practise your skills

1. Use the geology maps of the British Geological Survey (www.bgs.ac.uk/data/mapViewers/home.html) to complete your own geological map of the Lower Wye Valley.
2. On the Digimap website (http://digimap.edina.ac.uk) find past and present maps of the Lower Wye Valley to investigate the changes to the human landscape, for example the removal of woodlands and the presence of quarries in the area.
3. Study Figure 3.21, the OS map of the Lower Wye Valley on page 40. Draw a sketch map of the area.

ACTIVITIES

1. What is the significance of the location of the River Wye landscape?
2. Describe how physical processes formed the Lower Wye Valley.
3. Use the information in Figure 3.23 to list the physical and human processes that have changed the River Wye landscape.
4. Explain how physical processes have changed the river landscape of the Lower Wye Valley.

Extension

Copy and complete the table below for the river landforms that can be seen on the OS map of the Lower Wye Valley in Figure 3.21 on page 40.

River landform	How it was formed

Review

By the end of this section you should be able to:

- ✓ recognise the significance of the location of the Lower Wye Valley between Chepstow and Tintern.
- ✓ know how physical processes formed the distinctive river landscape in this section of the Wye Valley.
- ✓ describe and explain how physical and human processes have changed the river landscape of the area.

Practise your skills

You will need to be able to identify certain settlement characteristics on OS maps. The site of a settlement is the land on which the settlement is built. The situation of a settlement is where the settlement is located in relation to other human and physical features in the area. The shape is the form that the settlement takes. Dispersed settlements are where individual buildings are spread out over an area, where there is no obvious centre to the village. Linear settlements have buildings either side of a main road. Nucleated settlements have buildings grouped closely together. They often form at crossroads or around village greens.

Use the OS map of the Lower Wye Valley on page 40 to help with the following questions.

1. Figure 3.24 was taken at grid reference 543995. In which direction was the camera pointing?
2. Give grid references for two tourist features found on the OS map.
3. Describe the shape of the settlement of Boughspring in grid square 5597.
4. Describe the site of the settlement of Tintern Parva in grid squares 5200 and 5300.
5. Describe the physical features of the land in grid square 5300.

Examination-style questions

1. Study Figure 3.22 on page 41. Identify **one** river landform shown in the photograph. (1 mark)
2. Study Figure 3.6 on page 32. State **one** type of weathering which might have had an impact on this river landscape. (1 mark)
3. Dams are an example of hard engineering.
   Explain **one** way that dams help to protect river landscapes. (2 marks)
4. Examine how physical processes work together to form the meander bend shown in Figure 3.10 on page 33. (8 marks)

Total: 12 marks

2 Coastal Landscapes and Processes

LEARNING OBJECTIVE

To study the physical processes that interact to shape the coast.

Learning outcomes

- To understand the impact of weathering, mass movement and erosion on the coast.
- To understand the ways that the sea transports and deposits material along the coast.
- To be able to explain the process of longshore drift.
- To recognise the influence of geological structure, joints and faults, and rock type on landforms.
- To be able to identify concordant and discordant coastlines and recognise their influence on landforms.
- To know the characteristics of destructive and constructive waves and their influence on landforms.
- To know how the UK's weather and climate affect rates of coastal erosion and impact on coastal landscapes.

A variety of physical processes interact to shape coastal landscapes

What are the main types of weathering?

There are three main forms of **weathering**: mechanical, chemical and biological. Not all of them occur on every coastline but combinations of them are usually evident.

Mechanical weathering

Freeze-thaw weathering, or frost action, occurs when water gets into cracks in rocks. When the temperature falls below freezing, the water will expand as it turns into ice. This expansion puts pressure on the rock around it and fragments of rock may break off. This type of weathering is common in highland areas where the temperature is above freezing during the day and below freezing during the night.

Chemical weathering

Rainwater contains weak acids that can react with certain rock types. Carbonates in limestone are dissolved by these weak acids and this causes the rock to break up or disintegrate. This can be seen on limestone statues and limestone pavements.

Biological weathering

This is the action of plants and animals on the land. Seeds that fall into cracks in rocks will start to grow when moisture is present. The roots the young plant puts out force their way in and, in time, can break up rocks (see Figure 2.1). Burrowing animals, such as rabbits, can also be responsible for the further break-up of rocks. This is due to the way that they tunnel through the upper layers of the soil.

Figure 2.1 Biological weathering.

What is mass movement?

Mass movement is when material moves down a slope due to the pull of gravity. There are many types of mass movement but, for the purposes of this chapter, only slumping and sliding will be discussed. Slumping, also known as rotational slipping, involves a large area of land moving down a slope. It is very common on clay cliffs; during dry weather the clay contracts and cracks; when it rains, the water runs into the cracks and is absorbed until the rock becomes saturated (see Figure 2.2). This weakens the rock and, due to the pull of gravity, it slips down the slope on its slip plane. Due to the nature of the slip, it leaves behind a curved surface.

Figure 2.2 Slumping east of Bowleaze Cove, Dorset.

How are coasts eroded?

The coast is a narrow strip between land and sea. It is under continual attack from waves at the base of the cliff and other processes on the cliff face, such as weathering and mass movement. (You should always refer to these processes when answering a question on landform formation.) The theory box should be referred to throughout this chapter to understand the processes of **erosion**.

How does the sea transport materials?

Waves can transport materials in a number of ways, including: traction, saltation, suspension, solution and longshore drift.

- **Traction** – large sediment such as pebbles roll along the sea bed.
- **Saltation** – small pieces of shingle or large grains of sand are bounced along the sea bed.
- **Suspension** – small particles such as sand and clays are carried in the water; this can make the water look cloudy, especially during storms or when the sea has lots of energy.
- **Solution** – some minerals dissolve in sea water and are carried in solution. This is particularly evident near to limestone or chalk cliffs where the sea can appear to be a milky colour due to the amount of sediment being carried in solution.

Processes of coastal erosion

Abrasion

Sand and pebbles carried within waves are thrown against the cliff face with considerable force; these particles break off more rocks which, in turn, are thrown against the cliff by the breaking waves.

Hydraulic action

This is the pressure of the water being thrown against the cliffs by the wave. It also includes the compression of air in cracks: as the water gets into cracks in the rock face, it compresses the air in the cracks; this puts even more pressure on the cracks and pieces of rock may break off.

Solution

This is a chemical reaction between certain rock types and the salt and other acids in sea water. This is particularly evident on limestone and chalk cliffs where the water is a milky blue at the bottom of the cliffs due to the dissolved lime.

Attrition

This process involves the wearing away of the rocks that are in the sea. As the boulders in the sea continually roll around, they chip away at each other until smooth pebbles or sand are formed.

KEY TERMS

Swash – the forward movement of a wave.

Backwash – the movement of a wave back down the beach.

The process of longshore drift

Longshore drift is the movement of sand and pebbles down a coastline. The direction of the waves hitting the coastline is determined by the prevailing wind; if the wind is blowing at an angle to the beach, the waves (swash) will approach the beach at this angle, transporting the sand and pebbles with them. As the returning wave (backwash) is being pulled by gravity, it will take the shortest route back down the beach; it always goes back down the beach in a straight line at 90° to the coast. In this way, material is moved along the beach until it meets an obstruction, see Figure 2.3.

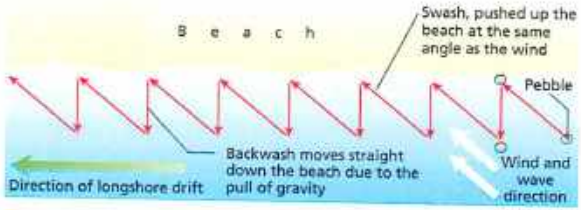


Figure 2.3 The process of longshore drift.

What is deposition?

Deposition is the laying down of materials, such as sand and pebbles, which are being transported by the sea. The sea will deposit materials when it slows down and loses energy, such as waves on a beach.

How does geological structure have an impact on landforms?

A rock's structure can affect the rate of erosion and the landforms that are produced. Rocks that are well jointed or have many faults, such as limestone, will erode more quickly as the waves exploit these lines of weakness. Rocks that have few joints will be harder for the sea to erode. Rocks such as chalk have lines of weakness known as bedding planes that allow the sea to erode them more easily (see Figure 2.4).

Figure 2.4 Chalk cliffs with bedding planes, Old Harry Rocks at Handfast Point, near Swanage, Dorset.

Fieldwork ideas

Suggested hypothesis:
the beach morphology on Swanage beach shows evidence of longshore drift occurring from south to north.

Primary fieldwork:

- measure the height of the sand on each side of the groynes
- do beach profiles on different parts of the beach to ascertain different slopes

The type of rock on a coastline also affects the rate of erosion. Cliffs made from resistant rock, such as granite, will erode more slowly than cliffs made from less resistant rock, such as clay.

What are concordant and discordant coastlines?

Concordant coastlines have rocks that lie parallel to the coastline. **Discordant** coastlines have bands of rocks that lie at right angles to the coast. These geological structures influence the formation of different coastal landforms.

Concordant coastlines have alternate layers of hard (more resistant) and soft (less resistant) rock. The hard rock will act as a barrier to the erosive power of the sea. If the sea erodes through the hard rock it will then quickly erode the softer rock behind, as in the case of Lulworth Cove in Dorset.

Discordant coastlines have rocks that are at right angles to the sea. If there are alternate layers of hard and soft rock, the soft rock will erode more quickly forming bays with the hard rock forming headlands (see Figure 2.9 on page 13).

Figure 2.5 Lulworth Cove, Dorset.

What types of waves are there?

Destructive waves

Destructive waves are the most important agent in coastal erosion and in taking sediment away from coastlines. Landforms produced by destructive waves include headlands, bays, caves, arches, cliffs, **stacks** and **wave-cut platforms**.

Destructive waves have a number of characteristics:

- The backwash is much stronger than the swash and is therefore able to carry sand and pebbles away from the shore.
- They break frequently; there are between ten and fifteen every minute.
- They are high in proportion to their length.
- They are generally found on steep beaches.

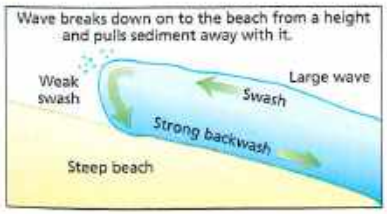


Figure 2.6 A destructive wave.

Constructive waves

Constructive waves are responsible for deposition in coastal areas and landforms such as beaches, bars and spits. They have a number of characteristics:

- The swash is more powerful than the backwash and therefore deposits sediment on beaches.
- They break infrequently, at a rate of ten or fewer per minute.
- They are long in relation to their height.
- They are usually found on gently sloping beaches.

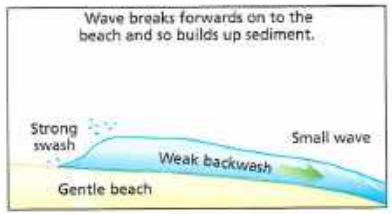


Figure 2.7 A constructive wave.

How do the UK's weather and climate affect rates of coastal erosion?

KEY TERMS

Seasonality – a pattern of change in the UK's weather between spring, summer autumn and winter.

Fetch – the distance over which the wind blows over open water.

The seasonality of the UK's weather and climate affects the rate of coastal erosion. In the winter the differences between day and night-time temperatures can cause freeze-thaw weathering on cliff faces. Storms also have an impact on the landforms of the coastline as storm waves are powerful agents of erosion. The human coastal landscape, such as sea defences, is in need of constant repair due to the increasing regularity of storms.

The prevailing wind in the UK is from the southwest. The coastlines of Cornwall and Devon experience winds that may have blown for several thousand kilometres across the Atlantic Ocean (see Figure 2.8). These winds have a long fetch: the longer the fetch, the stronger the wind and the more powerful the wave, and the faster the rate of erosion.

Figure 2.8 The fetch of waves around the British coastline.

Review

By the end of this section you should be able to:

- ✓describe the impact of weathering, mass movement and erosion on the coast
- ✓describe the ways that the sea transports and deposits material along the coast
- ✓explain the process of longshore drift
- ✓know the influence of geological structure, joints and faults and rock type on landforms
- ✓identify concordant and discordant coastlines and recognise their influence on landforms
- ✓know the characteristics of destructive and constructive waves and their influence on landforms
- ✓know how the UK's weather and climate affect rates of coastal erosion and impact on coastal landscapes.

Coastal erosion and deposition create distinctive landforms within the coastal landscape

LEARNING OBJECTIVE

To study the distinctive landforms created by coastal erosion and deposition.

Learning outcomes

- To be able to describe and explain the formation of headlands and bays, cliffs and wave-cut platforms, caves, arches, stacks and stumps.
- To be able to describe and explain the formation of beaches, spits and bars.

What landforms are created by coastal erosion?

Distinctive and dynamic landforms are formed by destructive waves. These include headlands and bays; cliffs and wave-cut platforms; caves, arches, stacks and stumps.

Headlands and bays

On coastlines where rocks of varying resistance lie at right angles to the sea, bays – indentations in the land – show where the softer rock is. Headlands are the more resistant rock and protrude into the sea. As the bays are made from a less-resistant rock type, the erosion rates from processes such as abrasion are greatest at first. In time, as the sea cuts the bays back, the waves reaching the coast are less powerful because they have to travel over a longer expanse of beach. At this point the headlands, which are further out to sea, start to experience the more powerful waves and are eroded at a faster rate than before, see Figure 2.9.

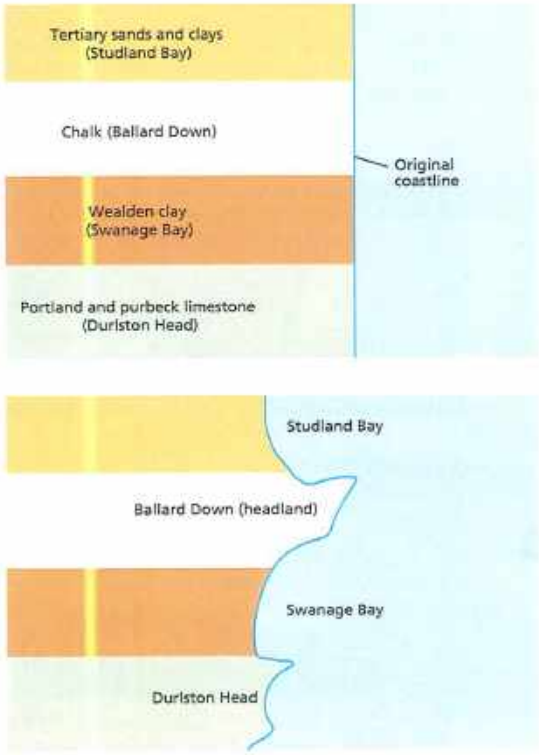


Figure 2.9 The formation of headlands and bays.

KEY TERMS

Dynamic landform – a landform that is changing.

Therefore, the features of the area, such as:

- the differing resistance of the rocks forming a discordant coastline
- the physical processes in the area such as erosion by the sea on the softer clay forming bays
- and eventually the use of hydraulic action on the headlands such as Ballard Down

have formed the characteristics of the landscape seen today. Other processes such as physical weathering attack the cliffs causing them to recede further. At the same time deposition is occurring in the bays to form beaches.

Cliffs and wave-cut platforms

Headlands are usually formed from cliffs. When the sea moves against the base of the cliff, using abrasion and hydraulic action (and solution if the rock type is limestone or chalk – see page 9), it undercuts the cliff and forms a wave-cut notch. An overhang will form above this notch which, in time, will fall into the sea as a result of the pressure of its own weight and the pull of gravity.

The sea will then continue to attack the cliff and form another notch. In this way, the cliff will retreat, becoming higher and steeper. The remains of the cliff rock, now below the sea at high tide, form a rocky, wave-cut platform. As a result of erosion and weathering, some boulders will have fallen from the cliff on to the platform. As the width of the platform increases, so the power of the waves decreases, as they have further to travel to reach the cliff, see Figure 2.10.

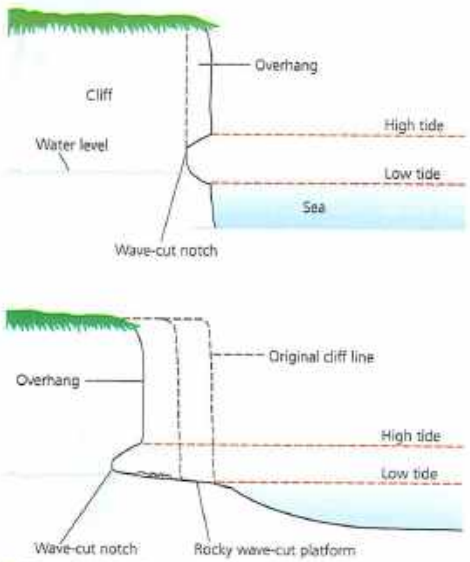


Figure 2.10 The formation of cliffs and wave-cut platforms.

Caves, arches, stacks and stumps

These are formed in rocks that have a fault or line of weakness. The action of the sea will exploit the fault through erosional processes, such as hydraulic action. In time the fault will widen to form a cave. If the fault is in a headland, caves are likely to form on both sides. When the backs of the caves meet, an arch is formed. The sea will continue to erode the bottom of the arch using abrasion. As the sea undercuts the bottom of the arch, a wave-cut notch will form, which will collapse in time as it is pulled down by the pressure of its own weight and gravity. This leaves behind a column of rock not attached to the cliff, known as a stack. Continued erosion will lead to the formation of a stump that is visible only at low tide, see Figure 2.11.

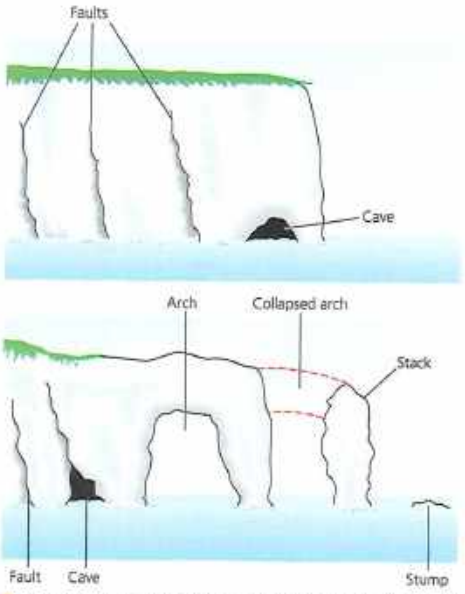


Figure 2.11 The formation of caves, arches, stacks and stumps.

What landforms are created by coastal deposition?

Constructive waves build rather than destroy the coastal environment. They deposit sand and pebbles that form beaches, spits and bars.

Beaches

Beaches are perhaps the most easily recognised and named coastal feature around the British coast. A beach is an area of land between the low tide and storm tide marks and is made up of sand, pebbles and, in some places, mud and silt. They are formed by constructive waves, often in bays where the waves have less energy due to the gently sloping sea bed, and as a result deposit material. They can also be found along straight stretches of coastline where longshore drift occurs. Seaside resorts often build **groynes** to keep beaches in place and to reduce the effects of longshore drift.

Spits

A spit is a long, narrow stretch of pebbles and sand that is attached to the land at one end, with the other end tapering into the sea. It forms when longshore drift (see explanation on page 10) occurs on a coastline. When the coastline ends, the sea deposits the material it is transporting because the change in depth affects its ability to transport the material further.

If there is a river estuary, the meeting of the waves and the river causes a change in speed, which results in both the waves and the river dropping their sediment. In time, the material builds up to form a ridge of shingle and sand known as a spit. On the land side, silt and alluvium are deposited and salt marshes form. The wind and sea currents may curve the end of the spit around. Spits are very dynamic, which means that their shape and form continually change. If spits are present on a coastline, it should be possible to determine the direction of longshore drift (see Figure 2.12).

KEY TERMS

Alluvium – a river deposit of clay, silt and sand.

The spit in Figure 2.12 has formed because the characteristics of the area were ideal for this landform to develop. Longshore drift is occurring along the beach from west to east with the predominant wind direction being from the south-west. Longshore drift is the movement of the swash going up the beach at an angle pushed by the wind and the backwash bringing the sediment straight back down the beach due to the pull of gravity. The coast changes to a north easterly direction. The sea continues to move in a south-westerly direction driven by the wind. It will continue to move the sand, depositing it to build a spit off the end of the coastline. Material will be deposited because the water will become deeper as the waves are further from the coastline. There will be a change in speed of the water (it will move more slowly) causing it to drop what it is carrying. The spit has a number of recurved ends which have formed when the wind or tide have changed direction.

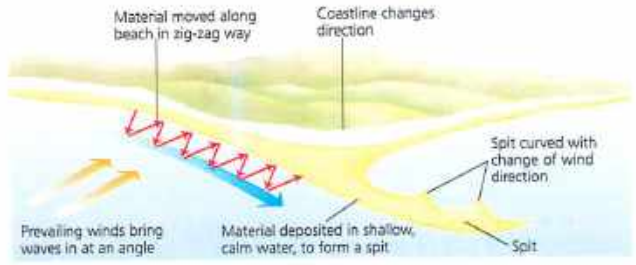


Figure 2.12 The formation of a spit.

Bars

If a spit develops in a bay, it may build across it, linking two headlands to form a bar. This is only possible if there is a gently sloping beach and no powerful river entering the sea. In this way, bars can straighten coastlines. An example is at Slapton in Devon, see Figure 2.13, which has the characteristic lagoon formed behind the bar where any water from streams is trapped and slowly seeps through the pebbles and stones of the bar into the sea. The bar was formed by the process of longshore drift which occurs on this coastline.

Figure 2.13 A bar in Devon.

Review

By the end of this section you should be able to:

- ✓describe and explain the formation of headlands and bays: cliffs and wave-cut platforms; caves, arches, stacks and stumps
- ✓describe and explain the formation of beaches, spits and bars.

Practise your skills

Draw annotated diagrams of coastal erosion and deposition features.

Choose a coastal area close to where you live (or use the Isle of Purbeck, which is the distinctive coastal landscape featured in this book). Look at weather statistics for different years compared to erosion rates on the coastline.

ACTIVITIES

1. Match the term with its correct definition.

Term	Definition
Abrasion	The wearing away of rocks that are in the sea.
Solution	The wearing away of cliffs by the rocks in the sea.
Attrition	A chemical reaction between certain rock types and sea water.

2. List three differences between constructive and destructive waves.
3. What is meant by the term 'fetch'?
4. Explain the process of longshore drift.
5. Examine how physical processes work together to form the cliff and wave-cut platform in Figure 2.10.

Extension

Research the formation of the bar at Slapton in Devon.

Human activities can lead to changes in coastal landscapes that affect people and the environment

LEARNING OBJECTIVE

To study how human activities can lead to changes in coastal landscapes that affect people and the environment.

Learning outcomes

- To know how urbanisation has affected coastal landscapes.
- To recognise how agriculture has affected coastal landscapes.
- To identify how industry has affected coastal landscapes.
- To recognise the effects that coastal recession has on people and the environment.
- To recognise the effects that coastal flooding has on people and the environment.
- To know the advantages and disadvantages of different coastal defences used on the coastline of the UK.
- To understand how coastal defences can lead to change in coastal landscapes.

How have human activities such as urbanisation, agriculture and industry affected coastal landscapes?

The building of towns and cities on the coastline of the UK affects the landscape in many ways, from the visual impact of the settlements to the impact on wildlife and on the natural processes at work.

Urban areas developed on the coast for a number of reasons, such as fishing or trading purposes, which led to the construction of harbours and larger ports. As settlements grew, the coastal landscape changed. Original wetland areas were drained to ensure that the settlements were not flooded, meaning that wading birds and other animals lost their habitat. Harbours were built to give shelter to fishing boats, which involved the building of jetties into the cliffs. Large ports developed to import materials; these were usually on large estuaries, which had a major visual impact on the area as well as causing environmental changes. During the early twentieth century, tourist developments along the coast led to further change in the coastal landscape. All of these developments require defending against the sea. This in turn impacts on the natural processes that occur in coastal areas; for example, the building of groynes interferes with the process of longshore drift.

Parts of the coastal landscape are still mainly farming areas. Such areas are less developed, meaning that the coastal landscape is largely unchanged and natural processes are not interfered with, because the land is not seen as valuable enough to defend. However, many lowland coastal landscapes that were originally wetland areas have been drained and used for farming. This has had an environmental impact on the coastal landscape. For example, Cuckmere Haven in Sussex was drained for farming, which changed the area from a wetland to sheep farming. However, the coastal defences are no longer being repaired and the area will return to salt marsh as the sea gradually reclaims it. Another example is Porlock Bay in Somerset, where a shingle ridge was built to defend low-lying farmland from the sea. As the shingle is no longer being replenished, the bank has been breached by the sea, forming a salt marsh (see Figure 2.14).

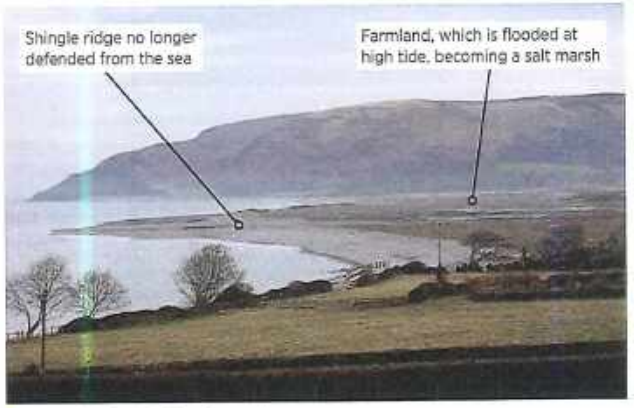


Figure 2.14 Porlock Bay, Somerset.

What are the effects of coastal recession on people and the environment?

England has 2,800 miles of coast, of which 1100 are classed as being at risk from erosion. **Coastal recession** affects both people and the environment. If the recession is occurring where there is a settlement then its effects on people will be greatest. If people lose their homes it will have a major impact both on their daily lives and their finances because they will have lost the money they had invested in their home. An example of this is Seaton in Devon, which will not be defended after 2025 because it is a small town. This means that, over time, the houses, pub and campsite will be lost to the sea due to coastal recession. Other impacts on people could be the effects on farmers who lose their land to the sea. This could impact on the viability of their farm as it loses fields where crops were once grown. Coastal recession also affects transport networks, making it difficult for people to get to work and go about their daily lives.

The environmental effects of coastal recession also relate to the loss of land. An example of this is the National Trust area known as Golden Cap, close to the village of Seaton in Devon. The cliff there has receded 40 m in the past twenty years. This means that animals and birds are losing their breeding grounds, for example the soft cliff faces where sand martins breed.

Coastal recession at Happisburgh on the North Norfolk coast

The village of Happisburgh on the North Norfolk coast, which has a population of approximately 850, is one of the fastest eroding areas in the UK. The area was defended in 1998 with revetments – sloping structures designed to absorb the energy of the waves – which reduced the amount of erosion to about 50 cm a year. However, in 1995 the council stopped repairing the coastal defences, which caused the rate of erosion to accelerate. Since this time, 25 properties and the village's lifeboat launching station have been washed away. This has had a major impact on the people who live in the area (see Figure 2.15). The main area of concern is Beach Road, which terminates in the sea. Houses that were worth £80,000 when the coast was defended are now valued at a £1, even though their sea view improves each year! (See Figure 2.16).

Figure 2.15 The lifeboat station and ramp, Happisburgh.

Figure 2.16 Beach Road terminating in the sea.

Coastal recession at Dawlish, Devon

The main railway line into the South West to Penzance runs along the coast at Dawlish. When the sea is rough the trains have to be cancelled or delayed. On one occasion 160 passengers were stranded for four hours when their train's electrics were affected by sea water that washed over the track. The train was eventually pulled into the station at Dawlish. The railway line is protected by a sea wall that was built in the 1800s; this wall has no wave-refracting curve and is in need of constant repair. The annual rebuilding and repair bill is £400,000. The situation was made worse in February 2014, when 80 m of sea wall beneath the railway collapsed in a storm and the railway line was left with no land beneath it. The storm also damaged the station and a long section of track (see Figure 2.17). The line was closed until early April. For two months commuters from the South West had to use a replacement bus service, which greatly lengthened their journeys. The houses behind the breach in the sea wall were also damaged. Although the residents were rescued, they did lose some of their possessions.

Figure 2.17 The Dawlish railway line after the storm.

What are the effects of coastal flooding on people and the environment?

Around 2.1 million properties are at risk from flooding in England, with nearly 50 per cent of these being at risk from flooding from the sea. Some of the effects of **coastal flooding** on people are:

- damage to people's homes and belongings from water
- loss of life from drowning
- the contamination of fresh water supplies by sewage water
- bridges and roads can be washed away
- disruption to gas and electricity supplies.

The environmental effects of coastal flooding mainly concern the loss of land to the sea. In some areas of the country, land is being allowed to flood as part of the coastal defence technique known as **managed retreat**, where the land is flooded in a controlled way. This forms new habitats for wading birds but it does mean a loss of land for farmers. Another more dramatic type of coastal flooding is when the sea floods land due to storms, causing trees and vegetation to be washed away and crops lost due to inundation by sea water.

KEY TERMS

Coastal recession – the gradual movement backwards of the coastline, which is the dividing line between the land and the sea.

Coastal flooding – the inundation of land close to the sea by sea water.

Coastal flooding on the Norfolk coast, December 2013

In December 2013 a high spring tide combined with an area of low pressure and strong northerly winds caused a storm surge that flooded much of the 45-mile coastline of North Norfolk. Following warnings given by the Environment Agency, flood wardens in the area were able to evacuate over 200 houses before the flood occurred. Although people were taken to safety, 152 houses and businesses were damaged as a result of the storm surge. There was also extensive damage to the sea defences in the area and many beach huts and chalets on the coast were damaged beyond repair. The public were warned that their drinking water might be contaminated and of other health risks such as rats in properties that had been flooded.

Coastal flooding at Chiswell, Portland, February 2014

The Cove House Inn on the Isle of Portland is continually fighting back the waves when there is a storm surge. It lies behind the 9 m sea defences built at Chiswell, Portland. During one storm in 2014, 18 m waves were crashing over the top of the three-storey building, smashing windows with pebbles, and sea water was pouring into the bar and living accommodation. The building itself is made from Portland stone which is very strong, although it does bear the battle scars of the many pebbles which have been thrown against it. The road to Portland from the mainland was closed twice during the winter of 2014 but, in the future, it may not be defended and it will become a true island, cutting off the 25,000 people who live there from the mainland.

KEY TERMS

Hard engineering – this method of coastal management involves major construction work, for example sea walls.

Soft engineering – this method of coastal management works or attempts to work with the natural processes occurring on the coastline, for example beach nourishment. They tend to be visually unobtrusive and do not involve major construction work.

What are the main types of hard and soft engineering used on the coastline of the UK?

A number of different types of coastal defences are used to defend the UK coastline, but what are their advantages and disadvantages and how do they change coastal landscapes? Coastal defences can be classified as either hard or soft engineering techniques. For the purpose of this chapter the following defences will be discussed:

- hard engineering: sea walls, groynes, **rip rap**.
- soft engineering: **beach nourishment**, **offshore reefs**.

Figure 2.18 Sea walls are usually made of concrete; the newer ones have a recurved top, like this one at Blackpool.

Figure 2.19 Groynes are usually made of rock or wood like these at St. Bees in Cumbria; they stretch from the coastline into the sea.

Figure 2.20 Rip rap are large rocks placed in front of a cliff; these are below a landscaped cliff at Whitby in Yorkshire.

Figure 2.21 Swanage beach before (2005) and after (2007) the placing of sand and pebbles on a beach, known as beach nourishment.

Figure 2.22 Offshore reefs in Norfolk: enormous concrete blocks, natural boulders or even tyres are sunk offshore to alter wave direction and dissipate wave energy.

ACTIVITIES

1. Describe one effect of coastal recession on people.
2. Using Figure 2.16 (see page 18), describe the effects of coastal flooding on people and the environment.
3. Name one soft and one hard engineering technique.
4. What is the difference between hard and soft engineering?
5. How does the building of offshore reefs lead to changes in the coastal landscape?

Extension

Explain the formation of the discordant coastline to the east of the Isle of Purbeck.

Review

By the end of this section you should be able to:

- ✓understand how urbanisation, agriculture and industry have affected coastal landscapes
- ✓recognise the effects that coastal recession and flooding have on people and the environment
- ✓know the advantages and disadvantages of different coastal defences used on the coastline of the UK
- ✓understand how coastal defences can lead to change in coastal landscapes.

Practise your skills

Draw a field sketch of Figure 2.24 (see page 24). Include the following on the sketch:

1. Four landforms created by erosion.
2. Two landforms created by deposition.
3. Name processes that occur on this coast.
4. Name the rock types (see Figure 2.9, page 13).
5. A class of students recorded the size of pebbles at two sites at each end of a beach. Their results are in the table.

Site 1 Pebble size (cm) at western end of beach	Site 2 Pebble size (cm) at eastern end of beach
12, 16, 10, 11, 6, 10, 8, 9, 6, 7, 14, 10, 15, 12	4, 9, 5, 3, 7, 5, 3, 4, 5, 3, 2, 7, 2, 5

a) Calculate the mean, mode and range for the pebble sizes in the table.
b) Draw out and complete the dispersion diagram, Figure 2.23, by plotting the information on pebble sizes for the eastern end of the beach. Mark on the dispersion diagram the median, the upper quartile, the lower quartile, and the interquartile range for both of the sites.
c) Compare the results for site 1 and site 2.
d) Suggest reasons for your results. Use your knowledge and understanding of beach processes to help you.

Fieldwork ideas

Suggested hypothesis: the landforms that make up the coastline of Swanage Bay are landforms resulting from deposition.

Primary fieldwork:

- draw field sketches of the landforms in Swanage Bay
- take photographs of the landforms in Swanage Bay and then anotate them.

Suggested hypothesis: the coastal processes at work in Swanage Bay have implications for people who live in the area.

Primary fieldwork:

- take measurements either side of selected groynes to measure the extent of longshore drift
- take photographs of cliff faces to show evidence of slumping and erosion.

Secondary fieldwork:

- use the internet to research recent cliff falls in the area.

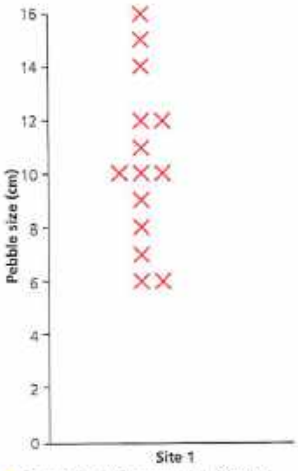


Figure 2.23 A dispersion diagram of pebble size.

Located example Distinctive coastal landscapes are the outcome of the interaction between physical and human processes

LEARNING OBJECTIVE

To study how the interaction between physical and human processes produces distinctive coastal landscapes.

Learning outcomes

- To know the significance of the location of the Isle of Purbeck.
- To know how physical processes formed the discordant coastline in the Swanage area.
- To recognise how physical and human processes have changed the coastal landscape of the area.

Figure 2.24 An aerial photograph of part of the Isle of Purbeck.

The Isle of Purbeck in Dorset has a distinctive coastal landscape that formed due to the interaction of physical and human processes. The location is significant because it is part of the Jurassic Coast of Dorset, famous for fossils and coastal features such as headlands, bays and stacks. The Isle of Purbeck is made up of a concordant coastline to the south of the promontory and a discordant coastline to the east where the main settlement, Swanage, is located.

The coastal landscape formed due to the type and formation of rock present in the area: this is shown in Figure 2.26, a simplified geological map of the area. The coastline to the east of the Isle of Purbeck is made up of rocks with varying resistance to erosion that lie at right angles to the sea. This has allowed the sea to erode the rock types at different speeds, forming headlands and bays (see page 8 for information on the different types of erosion and Figure 2.9 on page 13).

Physical or human process	Impact on the coastal landscape
Coastal erosion	The headland of Ballard Down is constantly changing due to erosion and weathering. Originally there were two stacks off the coast – Old Harry and his wife – but, in 1896, Old Harry's wife collapsed forming a stump.
Landslips	The coastline to the south of Ballard Down has frequent landslips, causing the coastal path to have to be redirected on a number of occasions.
Coastal defences	In 2005–6 new coastal defences were built in Swanage Bay consisting of eighteen groynes and beach nourishment. This changed the area by creating a new higher beach, although it will have to be replenished every twenty years due to the erosion rates in the area.
Human development	The building of Swanage town, especially the houses and hotels on the cliff, have made the problem of land slipping in the area worse.
Tourism	Studland Bay to the north of the area is a tourist hot spot. The beach is owned and managed by the National Trust. The area is protected from excessive tourist damage by limiting the parking available and, therefore, the number of people who can access the beach. The sand dunes are also protected by being fenced off. In this way change to the area from human processes is being managed.

Figure 2.25 Physical and human processes that have an impact on the coastal landscape around the Isle of Purbeck.

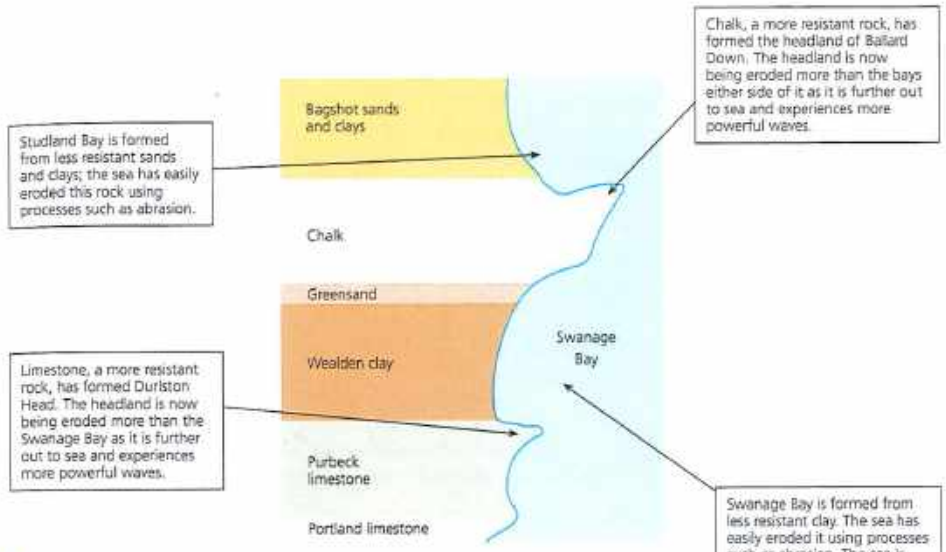


Figure 2.26 Simplified geological map of the Isle of Purbeck.

Review

By the end of this section you should be able to:

- ✓ recognise the significance of the location of the Isle of Purbeck
- ✓ understand how physical processes formed the discordant coastline in the Swanage area
- ✓ describe and explain how physical and human processes have changed the coastal landscape of the area.

Practise your skills

1 Use the geology maps of the British Geological Survey (www.bgs.ac.uk/data/mapviewers/home.html) to link the shape of the coastline at Swanage to the geological formation.

Examination-style questions

1 Study Figure 2.13 on page 16. Identify **one** depositional landform shown on Figure 2.13. (1 mark)

2 Study Figure 2.4 on page 10. State **one** type of weathering which might have an impact on this landscape. (1 mark)

3 Groynes are an example of hard engineering.
Explain **one** way that groynes help to protect coastal landscapes. (2 marks)

4 Examine how physical processes work together to form the stack shown in Figure 2.4. (8 marks)

Total: 12 marks

5 Weather Hazards and Climate Change

The atmosphere operates as a global system transferring heat and energy

LEARNING OBJECTIVE

To study how the atmosphere operates as a global system that transfers heat and energy.

Learning outcomes

- To know the features of the global atmospheric circulation.
- To understand how circulation cells and ocean currents transfer and redistribute heat energy across the Earth.

What are the features of global atmospheric circulation?

The features of **global atmospheric circulation** are:

- The transfer of heat from the Equator to the poles.
- There are three **circulation cells** – Hadley, Ferrel and Polar.
- Jet streams impact on the movement of heat energy.
- The spin of the Earth creates the Coriolis effect.

KEY TERMS

Global atmospheric circulation – the worldwide movement of air which transports heat from tropical to polar latitudes.

Latitude – the distance north or south of the Equator. It is measured in degrees with the maximum being 90 °N or 90 °S.

Hemisphere – a half of the Earth. The northern hemisphere is above the Equator, the southern hemisphere is below the Equator.

Troposphere – the lowest layer of the atmosphere. It is thicker at the Equator (approximately 20 km) than at the poles (approximately 10 km).

Depression – a low-pressure system that produces clouds, wind and rain.

Ocean current – a continuous, directed movement of ocean water. The currents are made from forces acting on the water such as the wind, different temperatures and the Earth's rotation.

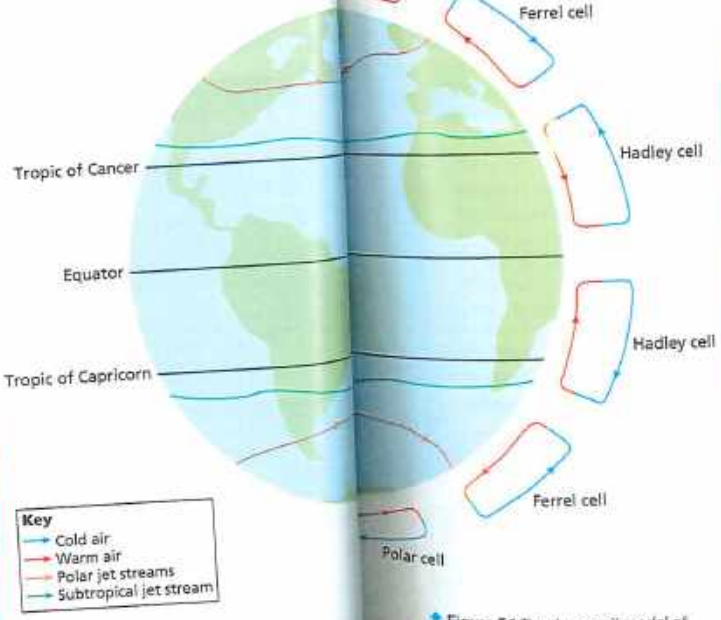
ITCZ – Inter Tropical Convergence Zone.

Trade winds – a wind that blows steadily from the tropics towards the Equator. In the northern hemisphere it is from the northeast and in the southern hemisphere from the southeast.

Hadley cells

Hadley cells stretch from the Equator to **latitudes** 30 °N and 30 °S. The features of Hadley cells are:

- Warm **trade winds** blow towards the Equator.
- At the Equator the trade winds from each hemisphere meet. The warm air rises rapidly causing thunderstorms. An area of low pressure is formed in the **ITCZ** where the air from the two cells meets over the Equator.
- The air at the top of the troposphere moves towards 30 °N and 30 °S where it becomes cooler and starts to sink back to the Earth's surface. As it descends, it warms and any moisture is evaporated. This creates high pressure areas, with cloudless skies. The world's hot deserts are found in these areas, such as the Sahara, in North Africa.
- On returning to the ground some of the air returns to the equatorial areas as trade winds; this completes the circle.



How do circulation cells and ocean currents transfer and redistribute heat energy across the Earth?

The main source of heat energy for the world is the Sun. The Sun heats the Earth's surface unevenly; it heats the Earth more at the Equator than at the poles. This creates a heat surplus at the Equator and a heat deficit at the poles. As the poles are not getting colder and the Equator is not getting noticeably warmer, there must be a redistribution of heat energy across the Earth. But how does this work? The heat energy is transferred in two ways: circulation cells and **ocean currents**.

Circulation cells

The three-cell model of global atmospheric circulation is shown in Figure 5.1. The air in each cell moves in a sort of circle. The cells transfer surplus heat energy from the Equator to the poles. In each **hemisphere** there are three pressure cells in which the air circulates through the **troposphere**: Hadley cells, which are closest to the Equator; Ferrel cells, and Polar cells, which are closest to the poles.

Figure 5.1 The three-cell model of global atmospheric circulation.

Ferrel cells

Ferrel cells stretch from latitudes 30 °N and 30 °S to latitudes 60 °N and 60 °S. The features of Ferrel cells are:

- Air on the surface is pulled towards the poles. This forms the warm southwesterly winds in the northern hemisphere and northwesterly winds in the southern hemisphere.
- These winds collect moisture as they blow over oceans on the Earth's surface.
- At about 60 °N and 60 °S they meet cold air from the poles.
- The warm air rises over the cold air as it is less dense. This produces low pressure at the Earth's surface and pressure systems known as **depressions**.
- Some of the air returns to the tropics and some is diverted to the poles as part of the Polar cells.
- The cell has a motion to the right in the northern hemisphere and to the left in the southern hemisphere due to the spin of the Earth. This is called the Coriolis effect.

Polar cells

Polar cells stretch from latitudes 60 °N and 60 °S to the north and south poles. The features of Polar cells are:

- The air sinks over the poles producing high pressure.
- The air then flows towards the low pressure in the mid-latitudes, about 60 °N and 60 °S. Here it meets the warm air of the Ferrel cells.

KEY TERMS

Atmosphere – the gases that surround the Earth.

Jet streams

In the upper **atmosphere**, winds blow around the Earth in a westerly direction. Within these winds there are bands of extremely fast-moving air known as jet streams. These jet streams can be hundreds of kilometres in width, but only 1,000–2,000 m high. They are found at altitudes of about 10,000 m. The jet streams can be found in two areas of the world.

- Polar front jet stream – this is formed when cold Polar air meets warm tropical air high above the Atlantic Ocean, usually between latitudes 40° and 60°N and 40° and 60°S. Its exact location can vary. It marks the division between the Polar and Ferrel cells.
- The Subtropical jet stream – this is also generally in a westerly direction. It can be found at approximately 25°N and 35°S.

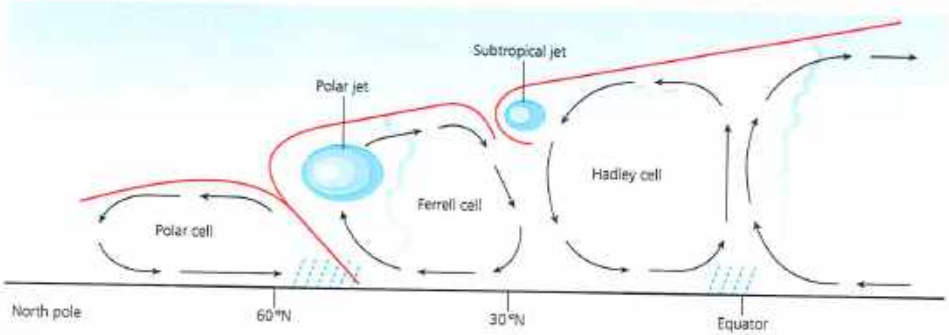


Figure 5.2 A cross-section showing the location by latitude of the jet streams and the global circulation cells.

Ocean currents

The oceans transfer approximately twenty per cent of the total heat that is transferred from the tropics to the poles. Each ocean has a circular pattern of surface currents, known as a gyre. They are produced as masses of water move from one climatic zone to another. The currents of all the oceans are similar because they are created by the surface winds generated by global atmospheric circulation. In the northern hemisphere currents move in a clockwise direction and in the southern hemisphere they move in an anticlockwise direction.

The strongest currents are on the western side of oceans. For example, warm ocean currents such as the North Atlantic Drift transfers heat from low to high latitudes. This is particularly noticeable between latitudes 40° and 65° in winter, when warm winds blow onshore on the western sides of continents raising the temperature. Cold currents have less effect as they are usually offshore winds. One exception is the Labrador current off the east coast of North America.

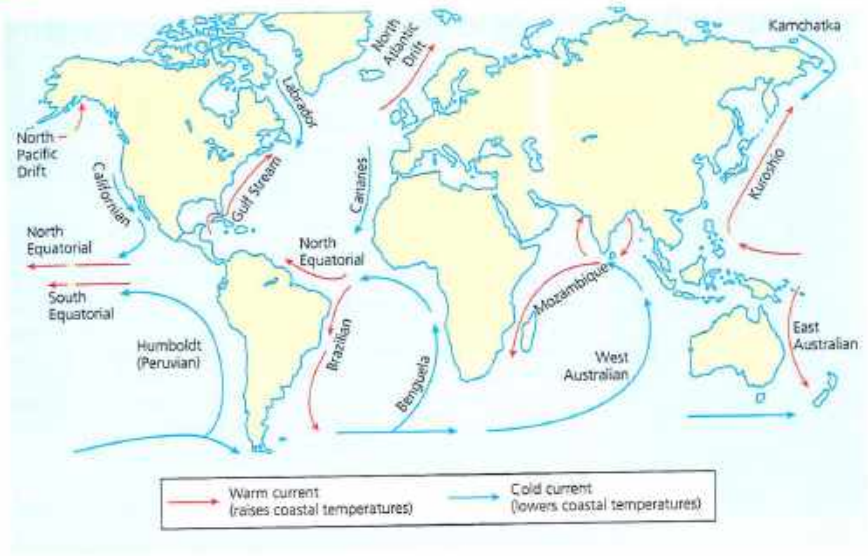


Figure 5.3 Major ocean currents.

ACTIVITIES

1. What is the main source of heat energy for the world?
2. Complete the following sentence.
   Ocean currents move in a ..... direction in the southern hemisphere.
3. State three features of global atmospheric circulation.
4. Where are Ferrel cells found on the Earth's surface?
5. Describe how air moves in a Hadley cell.
6. Why are deserts found at approximately 25°N and 25°S of the Equator?

Extension

1. Explain how circulation cells and ocean currents redistribute heat energy across the Earth.
2. Research why low pressure is found at the Equator and high pressure is found at the poles.

Practise your skills

Study atlas maps to identify areas where the climate is affected by warm and cold ocean currents. Use the information to create a table.

Review

By the end of this section you should be able to:

- ✓describe the main features of global atmospheric circulation
- ✓explain how circulation cells and ocean currents transfer and redistribute heat energy across the Earth.

The global climate was different in the past and continues to change due to natural causes

LEARNING OBJECTIVE

To study how the global climate was different in the past and continues to change due to natural causes.

Learning outcomes

- To be able to describe how global climate was different in the past.
- To recognise how it continues to change due to natural causes.
- To describe the evidence there is for natural climate change.

KEY TERMS

Climate – the average temperature and precipitation figures for an area.

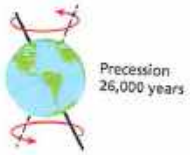
How the climate has changed in the past over different time scales: glacial and interglacial periods during the Quaternary Period

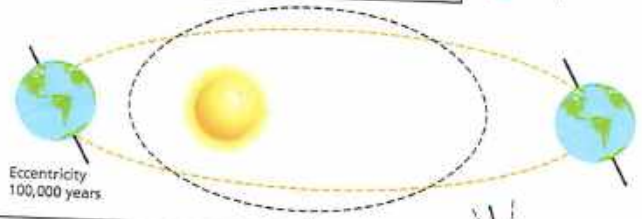
The Quaternary Period covers the past 1.8 million years of the world's history. During this period there have been times when the temperature of the Earth has dropped. Continental ice sheets covered the northern hemisphere. These are known as glacial periods (or ice ages). The temperature then became warmer, melting the large ice sheets. These are known as interglacial periods. The most recent glacial period occurred between about 120,000 and 11,500 years ago. Since then, the Earth has been in an interglacial period called the Holocene epoch. The remnants of the last ice age still cover ten per cent of the Earth's surface in Greenland, Antarctica and mountainous regions.

What are the causes of natural climate change?

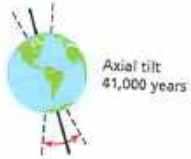
A number of causes have been put forward for natural **climate** change. These include **Milankovitch cycles**, **solar variation** and **volcanism**.

Precession
The Earth's axis wobbles like a spinning top. A wobble cycle usually takes about 26,000 years. The motion is caused by the gravitational action of the Sun and the Moon. This cycle has an impact on the seasons and can cause warmer summers.





Eccentricity
The path of the Earth's orbit around the Sun is not a perfect circle, it is an ellipse. This shape can change from being nearly a perfect circle to more elliptical and then back again. This is due to the effect of the gravitational pull of other planets on the Earth such as Jupiter and Saturn. The measure of the shape's change is called its eccentricity. One complete cycle lasts for about 100,000 years. It appears that colder periods occur when the Earth's orbit is more circular and warmer periods when it is more elliptical.



Axial tilt
The Earth is spinning on its own axis. The axis is not upright; it tilts at an angle between 22.1°C and 24.5°C. A complete cycle for this tilt takes about 41,000 years. A greater degree of tilt is associated with the world having a higher average temperature.

Figure 5.4 Milankovitch cycles.

Milankovitch cycles

These were developed by Milutin Milankovitch, a mathematician from Serbia. He put forward the theory that the amount of heat the Earth receives from the Sun is affected by its orbit. He identified three different cycles: eccentricity, axial tilt and precession, which are described in Figure 5.4.

Solar variation

This is a change in the amount of heat energy that comes from the Sun although these variations are very small and hard to detect. Sunspots on the Sun's surface do seem to have an impact on the heat energy of the Sun and therefore the climate of the Earth. There was a reduction in sunspot activity between 1645 and 1715 which corresponds with the Little Ice Age (see page 71). There has been a lot of sunspot activity since the 1940s, which could be a reason for the Earth's climate becoming warmer.

Volcanism

Large volcanic eruptions release ash and sulphur dioxide into the atmosphere. The ash quickly returns to Earth but the sulphur dioxide can have a cooling effect on the Earth's climate. The sulphur dioxide mixes with water in the atmosphere to form sulphuric acid droplets known as aerosols. These microscopic droplets absorb radiation from the Sun, heating themselves and the surrounding air. This stops heat reaching the Earth's surface. During the 1900s, there were three large eruptions that may have caused the planet to cool down by as much as 1°C. Eventually the effect will decrease as the aerosols fall as rain.

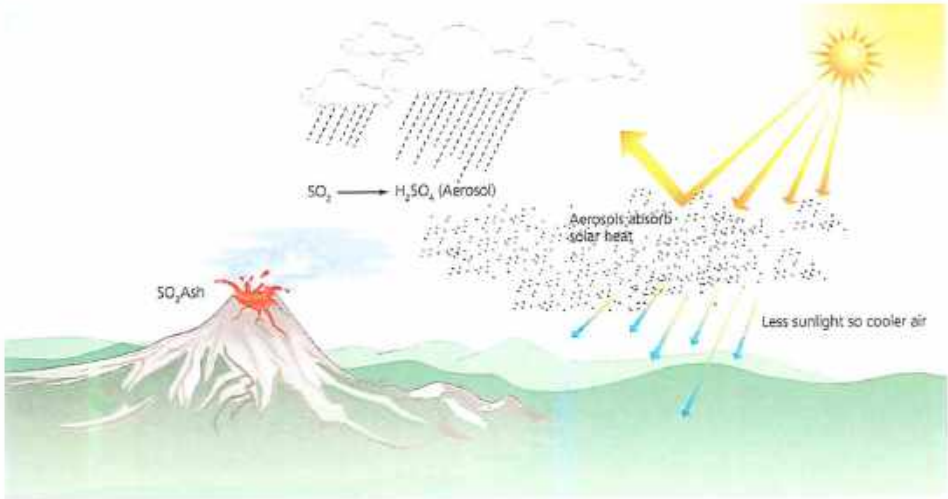


Figure 5.5 How volcanic eruptions can have an impact on global climates.

What evidence is there for natural climate change?

Ice cores

The ice in areas such as Antarctica and Greenland has been there for millions of years. Cores can be drilled into it to measure the amount of carbon dioxide trapped in the ice. This is a climatic indicator because levels of carbon dioxide tend to be lower during cooler periods and higher when it is warmer.

Pollen records

Pollen analysis shows which plants were dominant at a particular time due to the climate. Each plant species has specific climatic requirements that influence their geographic distribution. Plants have a distinctive shape to their pollen grains. Pollen falls into areas such as peat bogs it resists decay. Changes in the pollen found in different levels of a bog indicate changes in climate over time.

Tree rings

Each year the growth of a tree is shown by a single ring. If the ring is narrow it indicates a cooler, drier year. If it is thicker it means the temperature was warmer and wetter. These patterns of growth are used to produce tree ring timescales, which give accurate climate information.

Historical sources

These include cave paintings, diaries and documentary evidence, for example, the fairs held on the River Thames when it froze. Since 1873 daily **weather** reports have been kept. Parish records are a good source of climate data for a particular area.

KEY TERMS

Weather – the day-to-day changes in temperature and precipitation.

Review

By the end of this section you should be able to:

- ✓describe how climate has changed in the past over different time scales
- ✓recognise the causes of natural climate change
- ✓identify the evidence there is for natural climate change.

Figure 5.6 Tree rings.

ACTIVITIES

1. What is meant by the term glacial period?
2. Describe three different forms of evidence for natural climate change.
3. How do volcanic eruptions cause the climate to change?
4. Describe two of Milankovitch's cycles.

Extension

Research how the climate has changed in the past. Produce a graph to show these climate changes.

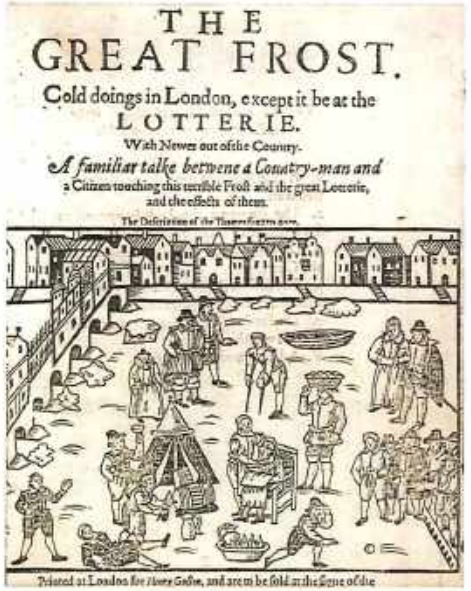


Figure 5.7 Illustration on the cover of a tract entitled *The Great Frost. Cold doings in London*, published in 1608.

Global climate is now changing as a result of human activity

LEARNING OBJECTIVE

To study how global climate is now changing as a result of human activity.

Learning outcomes

- To know how human activities produce greenhouse gases.
- To recognise the negative effects that climate change is having on the environment and people.

How human activities produce greenhouse gases that cause the enhanced greenhouse effect

Human activities such as industry, energy, transport and farming produce carbon dioxide and **methane**. These gases are contributing to the **enhanced greenhouse effect**.

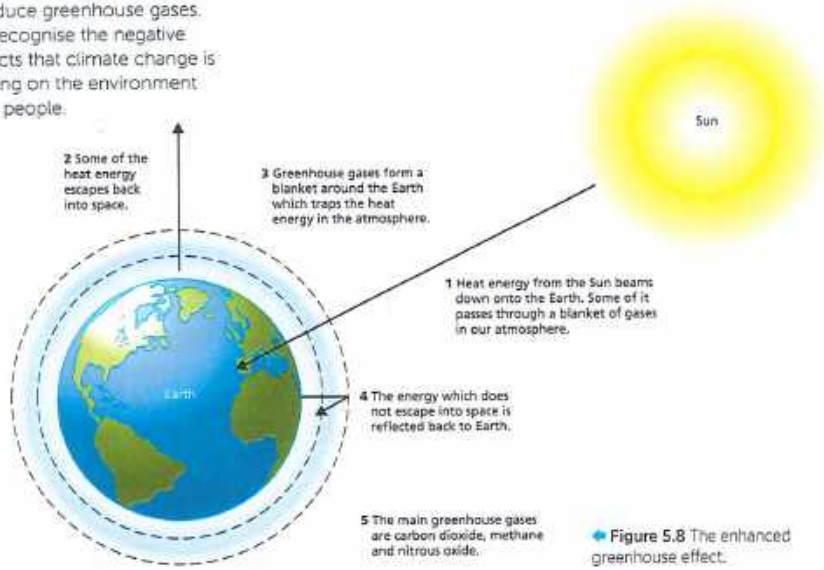


Figure 5.8 The enhanced greenhouse effect.

Sector	Carbon dioxide (m tonnes equivalent)	Methane (m tonnes equivalent)
Energy	180.8	7.6
Transport	115.7	0.1
Industry	12.2	0.1
Agriculture (farming)	4.9	27.0

Figure 5.9 The contribution of energy, transport, industry and farming contribution to the enhanced greenhouse effect in the UK.

KEY TERMS

Enhanced greenhouse effect – also called climate change or global warming. It is the impact on the global climate of the increased amounts of carbon dioxide and other greenhouse gases that humans have released into the Earth's atmosphere since the Industrial Revolution.

Methane – fossil methane, which provides approximately 30 per cent of methane released into the atmosphere, was formed underground many years ago. It comes to the surface when fossil fuels are mined. Methane is a greenhouse gas; this means that it can trap heat within the Earth's atmosphere. It makes up twenty per cent of the greenhouse gases in the atmosphere and is twenty times more potent than carbon dioxide.

Industry

Some industrial processes contribute to the enhanced greenhouse effect, emitting large amounts of greenhouse gases such as carbon dioxide and methane. This occurs during the production process, for example during the production of iron and steel, chemicals and cement. In the UK the most prominent gas is carbon dioxide, and the most polluting process is the making of cement. Since 1990, however, there has been a 79 per cent reduction in greenhouse gas emissions from the industrial process sector in the UK. However, between 2012 and 2013 there was a rise in emissions as more cement, iron and steel were being produced.

Transport

Most forms of transport use **fossil fuels** to power them. When fossil fuels are burnt gases such as carbon dioxide are released, which build up in the atmosphere adding to the enhanced greenhouse effect. Since 1990 the emissions from transport in the UK have stabilised with a three per cent decrease overall. Passenger cars make up the largest part of this sector.

Energy

The generation of power accounts for 25 per cent of global carbon dioxide emissions. The main source is the use of coal and natural gas to produce electricity. For example, in China 75 per cent of energy is produced from coal. In the UK, since 1990 there has been a reduction in emissions of 32 per cent but the figure is still too high. The reduction has mainly been caused by a movement of power generation from coal as a fuel to gas.

Sector	USA greenhouse gas emissions (%)	UK greenhouse gas emissions (%)
Energy	31	33
Transport	27	21
Industry	21	12
Agriculture (farming)	9	9
Other (including residential)	12	25

Figure 5.10 UK and USA percentage of greenhouse gas emissions per sector.

KEY TERMS

Fossil fuels – a naturally occurring fuel such as coal, oil and natural gas (methane) formed from the remains of dead organisms over millions of years.

Figure 5.11 Coal-fired power station.

Farming

Farming creates greenhouse gases in a number of ways, the main gas being methane. Livestock, especially cattle, produce methane as part of their digestion. This represents almost one-third of the emissions from the agriculture sector. Numbers of livestock in the UK are declining which has reduced emissions in this sector by nineteen per cent. However, in other parts of the world the numbers are increasing as there has been an increase in demand for Western-style diets which contain meat. An increase in rice production due to growing populations in Asia has also resulted in an increase in the production of methane. Manure is another producer of methane. New manure storage methods that allow less exposure to oxygen have reduced the amount of methane produced.

Sources of methane:

- wetlands including marshes and swamps
- the growing of rice
- landfills that contain rotting vegetable matter
- burning vegetation
- the bowels of animals
- mining of fossil fuels.

Figure 5.12 Livestock can add to the greenhouse effect.

What are the negative effects that climate change is having on the environment and people?

Rising sea levels

Research published by the Intergovernmental Panel on Climate Change (IPCC) states that the global mean sea level has risen by between 10 and 20 cm over the last 100 years. According to The Met Office Hadley Centre for Climate Science and Services it has been rising by about 3 mm a year since the early 1990s. Predicting the amount of sea level rise in the future is more difficult. Recent studies predict a rise of between 0.8 and 2 metres by 2100. This would mean that a number of the world's largest cities would be under water such as New York. Other studies predict a meltdown of the Greenland ice sheet which would mean a sea level rise of 7 metres which would be enough to submerge London. In the worst case scenarios for sea level rise, between 665,000 and 1.7 million people who live on the Pacific islands of the nations of Tuvalu and Kiribati would have to find new homes.

Figure 5.13 Rising sea levels.

Changing patterns of crop yield

Countries closest to the Equator are likely to suffer the most as their crop yields will decrease. In Africa, countries such as Tanzania and Mozambique will have longer periods of **drought** and shorter growing seasons. They could lose almost a third of their maize crop. It is forecast that in India there will be a 50 per cent decrease in the amount of land available to grow wheat due to hotter and drier weather.

Retreating glaciers

The vast majority of the world's glaciers are retreating (that is, melting), some more quickly than others. This is thought by some to be due to the increase in temperatures caused by climate change. Research has shown that 90 per cent of the glaciers in Antarctica are retreating. For example, between 1991 and 2013 the Sheldon Glacier, Adelaide Island, Antartica, retreated by 2 kms on its northern edge. The melting of the glaciers at the poles could also affect ocean water movement. It is believed that melting ice in the Arctic could cause the Gulf Stream to be diverted further south. This will lead to colder temperatures in western Europe, matching the temperatures found across the Atlantic in Labrador at the present time. Temperatures are frequently below 0 °C in the winter with averages of 8–10 °C in July, which is 10 °C cooler than the average UK summer temperature. The Columbia Glacier shown on satellite images in Figure 5.14 is in southern Alaska. It is one of the fastest retreating glaciers in the world. Between 1982 and 2014 it has retreated by 16 km and lost half of its thickness and volume.

Figure 5.14 The retreat of the Colombia Glacier, Alaska.

Practise your skills

1. Draw a bar graph to show the data in Figure 5.10.
2. Describe the UK and USA's contribution to greenhouse gas emissions. Use data in your answer.
3. Check out the satellite images at http://earthobservatory.nasa.gov/Features/WorldOfChange/columbia_glacier.php to see how the Columbia Glacier is retreating. Think of the following: What impact will this have on sea level rises? What do you think is causing this retreat?

ACTIVITIES

1. Name two greenhouse gases.
2. Which sector in the UK produces the most carbon dioxide?
3. How do animals contribute to climate change?
4. Explain two negative effects of climate change.
5. How will changes to crop yields have an impact on food globally?

Extension

Examine how human activities can cause climate to change.

Review

By the end of this section you should be able to:

- ✓describe how human activities produce greenhouse gases
- ✓recognise the negative effects that climate change is having on the environment and people.

The UK has a distinct climate which has changed over time

LEARNING OBJECTIVE

To study how the UK has a distinct climate which has changed over time.

Learning outcomes

- To describe the climate of the UK today and to know how it has changed over the past 1,000 years.
- To understand the spatial variations in temperature, prevailing wind and rainfall within the UK.
- To recognise the significance of the UK's geographic location in relation to its climate.

How has the UK climate changed over the past 1,000 years?

The climate that the UK has experienced over the past 1,000 years has changed quite considerably. Between AD 800 and 1300, known as the medieval period, the UK experienced a warm period with temperatures around 1°C warmer than the average, see Figure 5.15. This is known because there are records of vineyards in Yorkshire, and agricultural productivity for the whole of the UK was high. Between 1300 and 1900 AD there was a period known as the 'Little Ice Age'. Temperatures were about 1°C cooler than present for most of the UK. The River Thames froze twenty times between 1564 and 1814 and **ice fairs** were held. In Scotland temperatures were 2°C cooler with prolonged winters and much snow. Between 1690 and 1700 the harvest in Scotland failed seven times, causing widespread famine. This is known because of parish records.

KEY TERMS

Precipitation – any form of moisture that reaches the earth; rain, snow, etc.

Maritime – influenced by the sea.

Annual temperature range – the difference between the highest and lowest temperatures of a place in a year.

Total annual rainfall – the sum of all the rainfall that falls in a year in an area.

Ice fairs – amusements held on the River Thames during the Little Ice Age.

Figure 5.15 How the UK climate has changed over the past 1,000 years.

What is the UK climate like today?

The UK climate today shows the characteristics of a **maritime** climate. The temperature does not have extremes and the **annual temperature range** is small, with maximum average temperatures of 15 °C and minimum temperatures of 4 °C. The temperature changes gradually between the months. The summers are warm and the winters are cool rather than cold.

Precipitation (mainly rain) falls every month; the total amount varies with location within the UK, from approximately 550 mm in London to 1,800 mm in Fort William. There is, however, little difference between the wettest and driest months. Figure 5.16 shows climate figures for different settlements in the UK.

KEY TERMS

Prevailing wind – the direction from which the wind usually blows. In the UK it is the southwest.

Figure 5.16 Climate data for UK settlements.

How does temperature, prevailing wind and rainfall vary within the UK?

As shown on Figure 5.16, there are variations in the temperature and rainfall of the UK depending on where you are located in the country. Settlements to the east of the country tend to receive less rainfall than settlements to the west. The main reasons for this are the type of rainfall the UK experiences and the relief of the country (see Figure 5.17). Temperature variations are the result of the influence of latitude and the distance the settlement is from the sea, as shown in Figures 5.19 and 5.20 on page 74. The **prevailing wind** of the UK is from the southwest, with little variation across the country. As this wind is blowing over the Atlantic Ocean it will bring rainfall to the UK. The predominance of this wind can be seen on the wind roses for different locations around the country shown on Figure 5.18 on page 5.73.

Number on map	Settlement	Max. temp (°C)	Min. temp (°C)	Rainfall (mm)
1	Belfast	13	6	950
2	Birmingham	13	6	800
3	Cardiff	15	7	1150
4	Durham	13	5	650
5	Edinburgh	13	6	700
6	Fort William	11	4	1800
7	Inverness	12	6	750
8	Keswick	13	6	1500
9	London	15	8	550
10	Norwich	14	6	650
11	Plymouth	14	8	1000
12	Rhyl	13	7	800
13	Blackpool	13	6	900
14	York	13	5	600

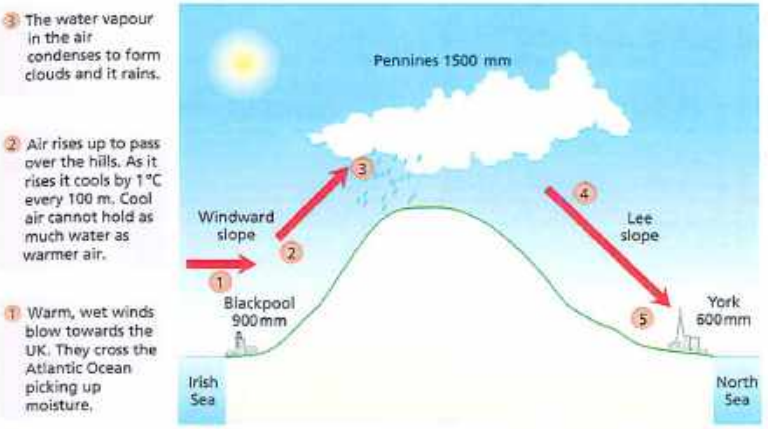


Figure 5.17 An explanation of relief rainfall.

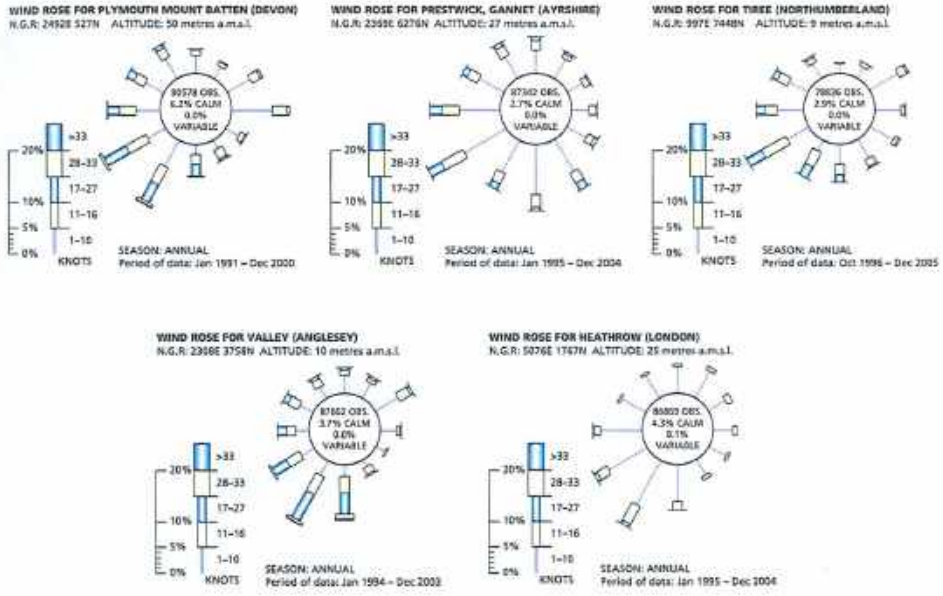


Figure 5.18 Wind roses for various areas within the UK.

What is the significance of the UK's geographic location in relation to its climate?

The UK's geographical location has a major impact on its climate due to a number of factors. These include latitude, air masses, distance from the sea and ocean currents.

Latitude

The latitude of the UK will impact on the amount of heat energy it receives from the Sun; places closer to the Equator are warmer than those at the poles. This is explained in Figure 5.19. Latitude also affects the temperature by influencing the length of the days. In the winter, the day length is short. This means that there are fewer hours of sunlight, resulting in lower temperatures.

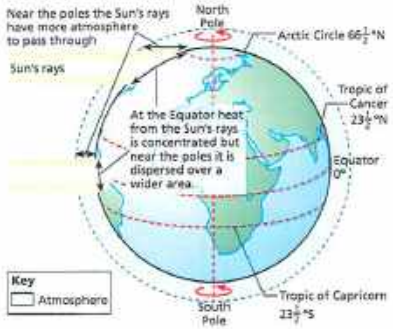


Figure 5.19 How latitude affects temperature.

Air masses

The geographical location of the UK means that its climate is influenced by five air masses. This is unusual and helps to account for the changeable weather that is experienced by the UK. Each air mass has different weather characteristics, as shown in Figure 5.20.

KEY TERMS

Source region – a large area of the Earth's surface where the air has a uniform temperature and humidity.

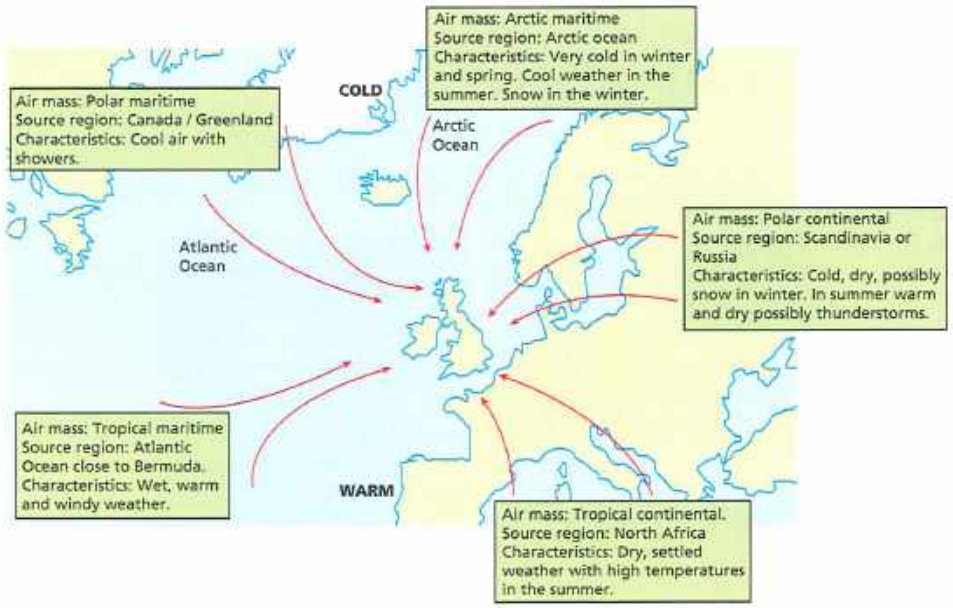


Figure 5.20 Air masses that affect the UK's weather.

Distance from the sea

The distance a settlement is from the sea has an effect on its climate. Settlements that are close to the sea will have less extreme temperatures than places further inland. In the winter, settlements close to the sea will be warmer than settlements inland, and in summer they will be cooler. The reason for this is that the land and sea respond differently to the heat energy from the Sun.

- The sea is constantly moving. Water that is heated or cooled on the surface circulates to a great depth. Therefore it takes a long time for the sea to heat up and cool down.
- The land is still. It is only heated to a depth of approximately 30 cm. Therefore, the land heats up and cools down quickly.

Ocean currents

Ocean currents also have an impact on temperatures. The UK is influenced by a warm current called the North Atlantic Drift. This current originates close to the Equator, moves through the Caribbean and across the Atlantic, and almost circles the UK. It is a warm body of water. It raises the temperature of the UK considerably as can be seen in Figure 5.21. The UK is further north than Boston and Montreal but its temperatures are much warmer in the winter due to the effect of the North Atlantic Drift.

City	Latitude	Av min temp (°C)
London	51	6
Boston	42	-2
Montreal	45	-9

Figure 5.21 A comparison of lowest average temperatures.

Month	Temp (°C)	Rainfall (mm)
Jan	5	55
Feb	5	40
Mar	8	41
Apr	10	43
May	13	49
Jun	16	45
Jul	18	44
Aug	18	49
Sep	15	49
Oct	12	68
Nov	8	59
Dec	5	55

Figure 5.22 Climate data for London.

KEY TERMS

Climate graphs – graphs which show temperature as a line at the top and rainfall in bars beneath on the same graph.

ACTIVITIES

1. How could ice fairs be held on the Thames during the 1700s?
2. Calculate the mode and mean for London's rainfall.
3. Draw a dispersion diagram for London's rainfall using Figure 5.22. Mark on the diagram the median, the upper quartile, the lower quartile and the interquartile range.
4. State two reasons why Birmingham's temperatures are lower than Plymouth's temperatures.
5. Explain the importance of the UK's geographical position in relation to its climate.
6. Compare the information on the wind rose for Heathrow with the wind rose for Plymouth.

Extension

London is warmer in winter than Boston in the USA. Discuss this statement.

Practise your skills

- Use the data in Figure 5.22 to produce a **climate graph** for London.
- Describe the pattern of rainfall for London shown on your graph.
- Use an atlas to find climate graphs for different cities in the UK. Choose three and compare the temperature and rainfall information. Give a reason for each of your comparisons.

Review

By the end of this section you should be able to:

- ✓describe the climate of the UK today and to know how it has changed over the past 1,000 years
- ✓understand the spatial variations in temperature, prevailing wind and rainfall within the UK
- ✓recognise the significance of the UK's geographic location in relation to its climate.

Tropical cyclones are extreme weather events that develop under specific conditions and in certain locations

LEARNING OBJECTIVE

To study how tropical cyclones are extreme weather events that develop under specific conditions and in certain locations.

Learning outcomes

- To understand how global circulation in the atmosphere leads to tropical cyclones in source areas and the sequence of their formation.
- To know the characteristics, frequency and geographical distribution of tropical cyclones and how they change over time.

KEY TERMS

Non-frontal system – weather systems that do not contain a warm or a cold front; that are usually associated with mid-latitude low-pressure weather systems which bring rain.

What are the characteristics, frequency and geographical distribution of tropical cyclones and how do they change over time?

A tropical **cyclone** is a **non-frontal** intense low pressure weather system that is known by different names around the world , for example hurricane and typhoon, but have the same characteristics. Characteristics of tropical cyclones are:

- They develop over tropical and subtropical oceans between the Tropic of Cancer and the Tropic of Capricorn.
- They need a water temperature of over 27°C to be able to form.
- They usually form towards the end of the summer and in the autumn.
- The highest number of storms occur in the North Pacific Ocean.
- The pressure gradient is very steep with close isobars.
- They feature strong winds and heavy rain, and often thunderstorms.
- The average wind speed is 120 kph but winds of 400 kph have been known.
- They normally move from east to west with the trade winds.
- They have an 'eye', which is the calm centre of the storm.
- Once they reach a wind speed of 60 kph they are given a name, each letter of the alphabet being used in turn. The lists rotate every six years. If a storm is particularly destructive the name is not used again and a new one is chosen. Floyd was replaced with Franklin in 2005.

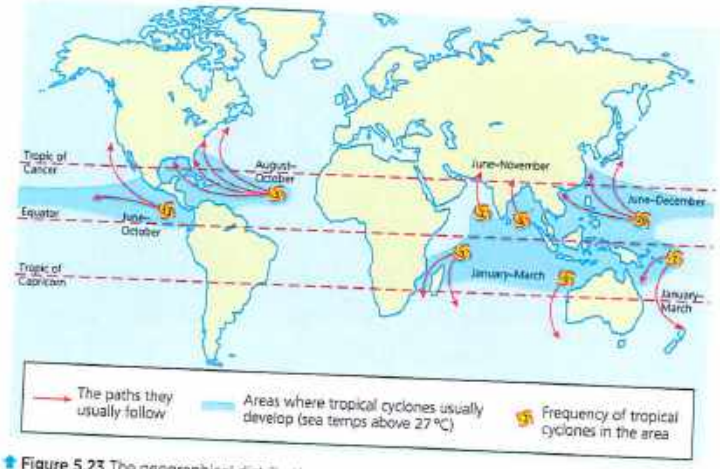


Figure 5.23 The geographical distribution and frequency of tropical cyclones.

How does global circulation in the atmosphere cause tropical cyclones and what is the sequence of their formation?

Tropical cyclones all start over oceans with a minimum temperature of over 27°C. Hot air rises taking a lot of water vapour with it. As it rises it cools to form big cumulus clouds. This creates low pressure at sea level. Air with higher pressure then moves in to replace it. This air does not move straight into the low pressure area because of the Earth's circulation, it whirls into it (just like water going down the plughole in a bath). This air then moves upwards with more water vapour. This has two effects: storm clouds are pulled into a spin by the incoming wind, and the spinning storm is pulled outward leaving a low pressure funnel, the eye, in the centre. The cold air, which is under high pressure, sinks down into the centre where it is heated and pulled into the spinning circle of air. The spinning circle begins to drift sideways because of the trade winds. This huge bundle of energy depresses the sea level under it, so there is a ridge of sea water giving rise to storm surges both before and after the cyclone has passed.

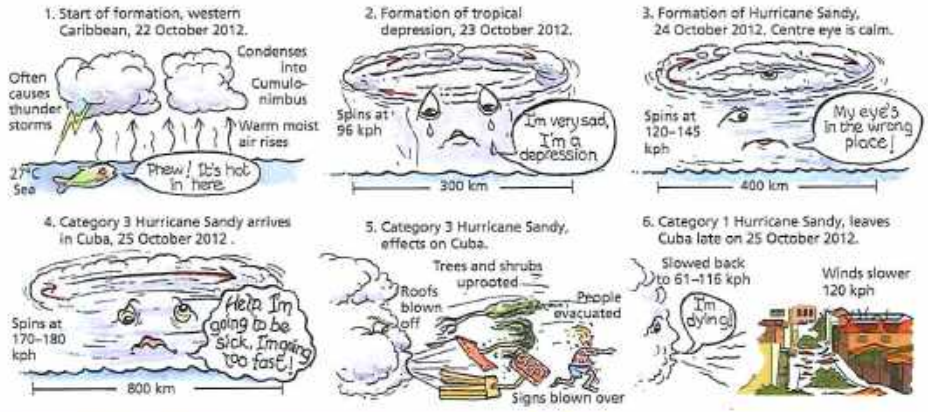


Figure 5.24 Stages in the formation of a hurricane.

KEY TERMS

Source region – where tropical cyclones start their development.

Practise your skills

Describe the pattern of tropical cyclones shown on Figure 5.24.

ACTIVITIES

1. Copy out and complete the following sentences.
   a) Tropical cyclones need sea temperatures above ..... to form.
   b) Tropical cyclones normally move from ..... to west.
   c) Tropical cyclones normally form in the .....
2. State two other characteristics of tropical cyclones.
3. Draw your own annotated cartoon to show the stages in the formation of a hurricane.
4. Study Figure 5.23. In which months of the year does Australia experience tropical cyclones?

Extension

Research in depth what is meant by El Nino and El Nina.

Review

By the end of this section you should be able to:

- ✓describe the characteristics, frequency and geographical distribution of tropical cyclones and how they change over time
- ✓understand how global circulation in the atmosphere leads to tropical cyclones in source areas and the sequence of their formation.

There are various impacts of and responses to tropical cyclones depending on a country's level of development

LEARNING OBJECTIVE

To study the various impacts of and responses to tropical cyclones, and realise that they are related to a country's level of development.

Learning outcomes

- To know the reasons why tropical cyclones are hazards: high winds, intense rainfall, storm surges, coastal flooding and landslides.
- To understand the different social, economic and environmental impacts that Hurricane Sandy had on the USA and Cuba.
- To recognise the different responses to Hurricane Sandy by individuals, organisations and governments in the USA and Cuba.

Why are tropical cyclones hazards?

Tropical cyclones are hazards because of the high winds and intense rainfall that is experienced. The high winds can rip off house roofs and, in some cases, cause houses to simply fall over. During Hurricane Sandy in October 2012, up to 250 mm of rain fell in many places within just a few hours. This amount of rainfall will destroy crops and cause rivers to burst their banks. It can also cause landslides in many countries, which have been known to destroy whole villages.

Storm surges are caused when the high winds whip up the ocean's waves. Some waves experienced in Cuba during Hurricane Sandy were up to 10 m high and caused substantial coastal flooding.

Located example What were the social, economic and environmental impacts of Hurricane Sandy on Cuba and the USA?

On 23 October 2012, the government of Cuba warned the eastern states of the country about the imminent approach of Hurricane Sandy. The hurricane continued north affecting 24 states of the USA, causing particularly severe damage in New Jersey and New York (see Figure 5.27). The hurricane had different social, economic and environmental impacts on Cuba and the USA, however, because of the stage of development of the two countries.

Practise your skills

- Use GIS and satellite images to track the path of Hurricane Sandy.
- Use storm surge data to calculate the Saffir-Simpson magnitude of Hurricane Sandy.

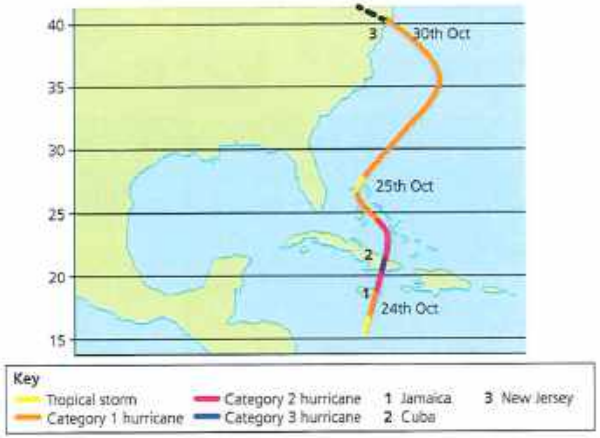
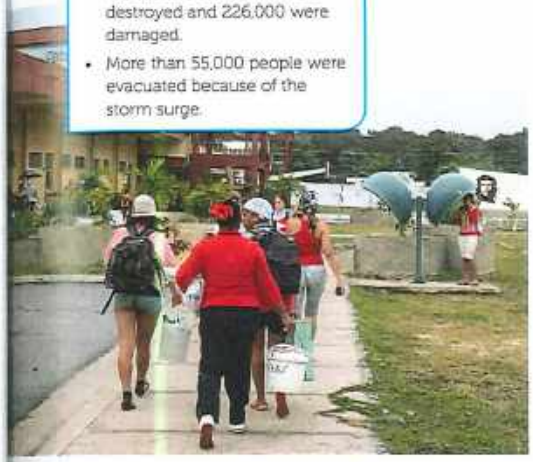


Figure 5.25 The path of Hurricane Sandy, October 2012.

The social, economic and environmental impacts of Hurricane Sandy on Cuba

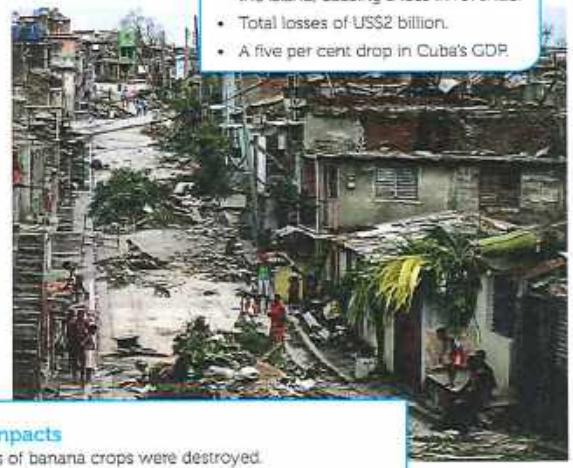
Social impacts

- There was no electricity or fresh water.
- Eleven people were killed.
- Around 17,000 homes were destroyed and 226,000 were damaged.
- More than 55,000 people were evacuated because of the storm surge.



Economic impacts

- Total losses in the Santiago de Cuba area came to £50 million.
- Roads to the airport were blocked, so no tourists could arrive or leave the island, causing a loss in revenue.
- Total losses of US$2 billion.
- A five per cent drop in Cuba's GDP.



Environmental impacts

- Around 2,600 hectares of banana crops were destroyed.
- In Santiago de Cuba trees were uprooted and stripped of their leaves.
- Coffee plantations in mountainous areas were swept away.
- Areas close to the coast were flooded, with beaches being swept away, destroying wildlife habitats.

Figure 5.26 The impact of Hurricane Sandy on the island of Cuba.

The social, economic and environmental impacts of Hurricane Sandy on the USA

1 Social impacts

- 117 people were killed.
- Roughly nine million homes had power cuts.
- 650,000 homes were damaged or destroyed in the USA; 250,500 cars were destroyed by flood water.
- The streets of New York were flooded, as was the subway.

2 Economic impacts

- Insurance claims in New Jersey totalled US$3.3 billion.
- US$1.1 billion was spent repairing the damage to sewage and water pipes in New Jersey and New York.
- The damage cost in New York totalled US$19 billion.

3 Environmental impacts

- The storm surge meant that sea water got into fresh water habitats, which had severe impacts on wildlife from Delaware Bay to Long Island Sound.
- Approximately 1.5 billion litres of sewage was released into the Raritan River in New Jersey.
- Around 90 per cent of beaches in New York and New Jersey were damaged; on average the beaches were 9–12 m narrower after the hurricane.
- 1.5 million litres of oil was spilt into Arthur Kill (the stretch of water between New Jersey and Staten Island, New York), damaging wildlife habitats and killing fish and birds.

Figure 5.27 The impact of Hurricane Sandy in the USA.

KEY TERMS

CERF – the United Nations' Central Emergency Response Fund.

Humanitarian aid – help given after a natural disaster to save lives and reduce suffering.

FEMA – the USA's Federal Emergency Management Agency.

Located example How different were the responses of individuals, organisations and the governments of Cuba and the USA to Hurricane Sandy?

Responses by	Cuba	USA
Individuals	Many people moved in with relatives or friends; others took shelter in state workers' holiday homes where basic food was provided. They used materials provided by the government and other organisations to rebuild their own homes. The people of Cuba have no home insurance.	After the hurricane, people moved in with relatives and used shelters. People rebuilt their homes but used builders rather than doing it themselves. Americans have home insurance but those affected also received aid from the government and other organisations.
Organisations	The UN provided US$5.5 million to Cuba from the CERF and US$1.5 million in emergency funds. Venezuela sent 650 tonnes of aid, including non-perishable food, potable water and heavy machinery. Venezuela, Russia and Japan sent humanitarian aid. In the seven months following the hurricane, the Cuban Red Cross delivered support with the help of the Norwegian, Spanish and German Red Cross and Red Crescent Societies. The relief aid went to approximately 25,000 families and included roofing materials, mattresses, clean drinking water, and hygiene and kitchen kits. The World Food Programme responded immediately with US$1 million to assist the 788,000 people in the worst affected areas of Cuba with a one-month food ration from December 2012 to February 2013.	Hurricane Sandy caused extensive erosion to the Delaware Bay beaches, which had an impact on the breeding grounds of horseshoe crabs. The Canadian Rivers Institute worked with a number of other NGOs and public agencies to restore these beaches by clearing rubble and replenishing sand to provide a nesting area for horseshoe crabs. The Red Cross had 17,000 trained workers, 90 per cent of them volunteers, providing over 300 response vehicles, 74,000 overnight stays, and 17 million meals and snacks, among other aid. AmeriCares, an American charity, responded quickly by sending teams of relief workers to hard-hit areas, sending aid shipments, providing funding and deploying a mobile medical clinic. In the two years following Hurricane Sandy, AmeriCares has provided US$7.1 million in aid benefiting 450,000 people.
Governments	The government sent teams of electricians from all over the island to Santiago province within hours of the hurricane hitting. The government announced a 50 per cent price cut for construction materials and interest-free loans to repair the damage. The aid will be means tested and more subsidies will be available for the poorest or hardest hit. The government made building materials available to residents, including corrugated iron sheets, metal rods and cement. Local government officials compiled data from families about the damage they had suffered so that the government could send the appropriate help. Military teams were mobilised quickly to clear the streets of rubble and an estimated 6.5 million m^3 of felled trees.	The US government approved US$60.3 billion in aid to the victims of Hurricane Sandy. The government promised that there would be improved weather forecasting, especially of storm surges. FEMA teams and resources were put in place to help people even before the hurricane had caused any problems. They were on hand to offer any help that was needed. FEMA and the Army Corps of Engineers worked with state and local governments to quickly reopen most of the beaches in New Jersey. The Department of Agriculture promised US$6.2 million for emergency food assistance, infrastructure and economic programmes to help repair farmland and flood plains.

Figure 5.28 The responses of individuals, organisations and the governments of Cuba and the USA to Hurricane Sandy.

Review

By the end of this section you should be able to:

- ✓ explain why tropical cyclones are hazards
- ✓ understand the different social, economic and environmental impacts that Hurricane Sandy had on the USA and Cuba
- ✓ recognise the different responses that individuals, organisations and the governments of the USA and Cuba had to Hurricane Sandy.

ACTIVITIES

1. State four characteristics of tropical cyclones.
2. Explain why tropical cyclones can be hazards.
3. Use Figure 5.25 to describe the path of Hurricane Sandy.
4. Construct a table showing two economic, environmental and social impacts of Hurricane Sandy on Cuba and the USA.
5. How did the help given by the government of Cuba differ to that given by the government of the USA?
6. Choose two of the responses by organisations to the disaster in Cuba. Explain why this help was given.

Extension

The impacts of Hurricane Sandy were different in Cuba than in the USA. Examine three reasons for these differences.

Practise your skills

Research the impact of Hurricane Sandy on Cuba and the USA. Ensure that you use each of the following types of information:

- socioeconomic data to assess the impacts on different countries
- aerial, oblique and ground photographs to interpret the damage caused by the hurricane
- social media, such as blogs, and news sources for comments on the impact of Hurricane Sandy
- satellite images to assess the impact of Hurricane Sandy.

The causes of drought are complex, with some locations more vulnerable than others

LEARNING OBJECTIVE

To study the causes of drought and to understand why some locations are more vulnerable than others.

Learning outcomes

- To describe the characteristics of arid environments compared to the characteristics of areas suffering from drought.
- To understand the different causes of drought: meteorological, hydrological and human.
- To explain why global circulation makes some locations more vulnerable to drought than others and how this changes over time.

What are the characteristics of arid environments compared with those suffering from drought?

The characteristics of arid environments are:

- an average rainfall of between 100 and 300 mm
- variations in rainfall totals of between 50 and 100 per cent each year
- **pastoral farming**, usually by **nomadic herdsmen**
- natural vegetation is sparse – grasses, small shrubs and trees
- a short growing season of about 75 days.

Areas suffering from **drought** can be in arid environments but can also be in other climate regions. Therefore, the main characteristic of an area suffering from drought is a gradual reduction in the amount of available water supply. By contrast, a characteristic of arid environments is the fact that there is *always* only a small amount of rainfall and, therefore, water available for human use. It is the gradual nature of droughts which makes them so dangerous. It is also the fact that its occurrence is unpredictable and, to some extent, unexpected. This is shown in more detail in the examples of the droughts in California and Namibia at the end of this chapter.

KEY TERMS

Pastoral farming – the rearing of sheep, cattle, pigs or any other animals on a farm.

Nomadic herdsmen – people raising animals for their own food; they move around and have no fixed land.

Drought – a period of below-average precipitation resulting in prolonged shortages in water supply.

Figure 5.29a An arid environment.

Figure 5.29b An area suffering from drought.

What are the different causes of drought?

Causes of drought	Definition
Meteorological	This concerns the amount of precipitation an area receives compared to its average. It is all about the weather and occurs if there is a prolonged period of below-average precipitation, which creates a natural shortage of available water; this is then called a drought.
Hydrological	This is how a decrease in precipitation can have an impact on overland flow, reservoirs, lakes and ground water. This is often defined on a river basin scale: water reserves in aquifers, lakes and reservoirs fall below an established statistical average This can be related to precipitation or human demand and increased usage.
Human – agricultural	This is when there is not enough water available to support crop production on farms. This can occur when the crops are planted or during their growing season; it often occurs when there is a fall in precipitation but can also occur if farming techniques change. For example, farmers could use irrigation to start growing crops that require more water than is available; if the irrigation source dries up then the plants will die.
Human – dam building	If a dam is constructed on a large river it can produce electricity and plenty of water for the area close to the dam. However, places further downstream may suffer from drought because they will be receiving a reduced flow of water. For example, the building of the Atatürk Dam on the River Euphrates provided electricity and water for irrigation in Turkey but has restricted the flow of water to Syria and Iraq, meaning they have less water for irrigation.
Human – deforestation	The cutting down of trees for fuel reduces the soil's ability to hold water. This can cause the land to dry out, which can result in drought in an area.

Figure 5.30 Natural and human causes of drought.

Why does global circulation make some locations more vulnerable to drought than others?

The movement of air from the Equator to the middle latitudes is discussed on page 60. The air rises at the Equator causing thunderstorms and a loss of moisture. The drier air moves north towards the mid latitudes. When it reaches approximately 30 °N and 30 °S; the dry air descends and warms. Many of the world's arid areas are found at these latitudes because of this air circulation pattern. The climate regions aren't fixed, however, and studies have found that global winds are shifting: it is thought that the jet streams have moved towards the poles, and the tropical belt has widened by several degrees latitude since 1979. This means that the arid areas of the world are changing. For example, the Upper Colorado River Basin, which is suffering from drought, is at latitude 37 °N.

Review

By the end of this section you should be able to:

- ✓describe the characteristics of drought and arid environments
- ✓explain the different causes of drought: meteorological, hydrological and agricultural
- ✓explain why global circulation makes some locations more vulnerable to drought than others.

The impacts of and responses to drought vary depending on a country's level of development

LEARNING OBJECTIVE

To study the impacts of and responses to drought, and to investigate how they vary depending on a country's level of development.

Learning outcomes

- To know how droughts are hazardous.
- To understand how the impacts of drought on people and ecosystems vary in the USA and Namibia.
- To recognise the different responses to drought from individuals, organisations and governments in the USA and Namibia.

KEY TERM

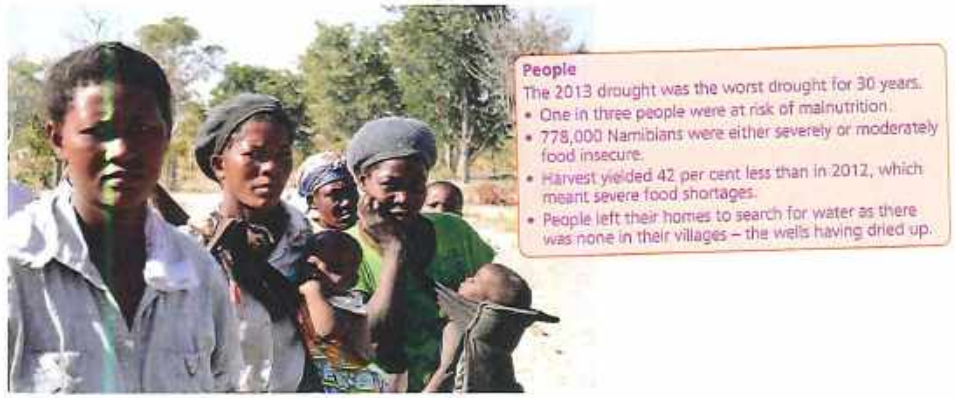
Savannah ecosystem – an area of grassland which has a few shrubs and trees; it can be found in tropical areas.

Why are droughts hazardous?

There are a number of reasons why droughts are hazardous. People and environments cannot survive without water; if there are drought conditions, it is likely to become a natural disaster. Droughts are different to other natural hazards in that they develop slowly over many years. They can have devastating effects.

- There will be a shortage of water supplies and residents will be asked to conserve water. In the UK water supplies have been switched off for periods of the day and residents have had to use stand pipes in the street to obtain fresh drinking water. If these conditions persisted, it could lead to diseases associated with poor living conditions. In developing countries the lack of clean drinking water due to droughts can lead to deaths from diseases such as cholera.
- Crops fail during droughts and animals die due to the lack of grazing land. This lack of food causes malnutrition and ill health among the population of the area experiencing the drought.
- The environment can also be destroyed by drought. When soil becomes dry due to lack of rain, vegetation dies leaving the soil unprotected. The dry soil can then be blown away by the process of wind erosion. When rain returns to the area there is no top soil left, so natural vegetation cannot regrow and crops cannot be planted.
- Wildfires are more common during periods of drought. This is because the trees are very dry and burn easily. There will also be a lot of fallen branches and dead wood lying in the forest. If a fire does start, water supplies to help control it will also be scarce.

Located example Impacts and responses to a drought in a developing country: Namibia, drought of 2013



People

The 2013 drought was the worst drought for 30 years.

- One in three people were at risk of malnutrition.
- 778,000 Namibians were either severely or moderately food insecure.
- Harvest yielded 42 per cent less than in 2012, which meant severe food shortages.
- People left their homes to search for water as there was none in their villages – the wells having dried up.

Responses by organisations

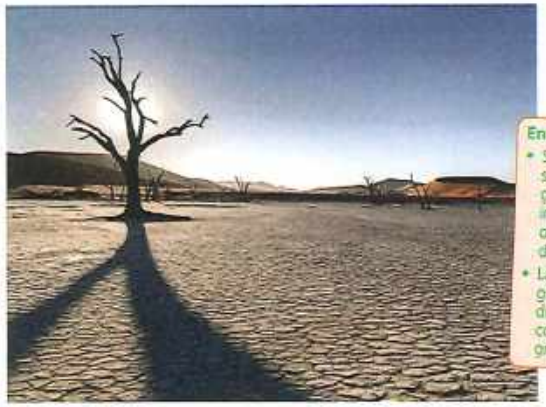
- UNICEF appealed for US$7 million to support their efforts to respond to the needs of women and children.
- The International Red Cross and Red Crescent asked for US$1.5 million.
- Algeria donated US$1 million in food aid.
- The Lutheran Church helped in a number of ways. For example, by providing basic food assistance to vulnerable communities with no access to governmental distribution points, trying to ensure a safe environment and access to clean water.

Responses by individuals

- Farmers been forced to sell their livestock.
- People migrated to towns in search of work.
- In one village almost all the people, about 350, left in search of water and grazing land for their cattle.

Responses by the government

- In May, President Pohamba declared a state of emergency and requested US$1 million in international support to avert a crisis.
- Pledged £13 million in relief for the worst-hit households.
- The Ministry of Agriculture, Water and Forestry (MAWF) gave two options to farmers who do not have enough grazing for their animals: either to sell their livestock while they are still in good condition or a subsidy for the cost of transporting their animals to emergency grazing areas.



Environment

- Severe drought can have a great impact on a savannah ecosystem. It can change an area of grassland that could sustain livestock to an area of inedible grasses and plants that livestock cannot live on. This is because the grasses that can cope with drought are not good for livestock.
- Large areas of Namibia are changing from savannah grasslands to desert due to the lack of rainfall. Only drought-resistant plants can survive in these conditions but the Namibian farmers' cattle cannot graze on them.

Figure 5.31 The impacts and responses to drought in Namibia.

Looked example Impacts and responses to a drought in developed country: California, drought of 2014

People

The effects on people can be seen in this photo, which indicates how people were restricted in their usage of water.

- Farmers use 80 per cent of the human usage of water. If there are water shortages their crops will die or they will plant fewer crops, resulting in less food for people.
- Loss of 17,100 jobs in farming.
- 5 per cent of the irrigated land in California won't be planted.
- The Department of Agriculture predicts that prices of fruit and vegetables will rise by 6 per cent.

Environment

A lack of water will have an impact on the environment of California in many ways.

- Wildfires are becoming a regular occurrence because of the dry and dead wood. There were more than a dozen fires in May 2014 near San Diego. Fires of this nature usually occur in the autumn.
- Some rivers and streams are closed to fishing. If water levels continue to drop the water will become warmer and the young salmon will be unable to survive as they require cool running water.
- The earth is shrinking because of depleted groundwater reserves.
- Between 2008 and 2011, parts of the Central Valley subsided more than 60 cm.
- The dry weather meant a better grape harvest and better tasting wines.

Responses by the government

- The state is preparing to undertake fish rescues – capturing them in shallow waters and transporting them to deeper waters closer to the ocean. For example, Chinook salmon have been taken in trucks to San Pablo Bay because there was little water for them to swim through to get to the ocean.
- Governor Brown issued a state of emergency.
- In February President Obama gave US$183 million from federal government funds.
- In March Governor Brown signed drought-relief legislation worth US$687 million. It included US$25.3 million for food and US$21 million for housing for people such as farmworkers who are out of work.
- Residents in the Santa Clara Valley have been told to limit watering of lawns to twice a week or face a US$500 fine.
- The Reclamation and Natural Resources Conservation Service announced that they hope to provide up to US$14 million of federal funds to help farmers to conserve water and improve water management.

Responses by organisations

- New mandatory laws forbid restaurants to put water on tables without it being requested.
- Hotels must also ask guest if they will reuse their linen and towels to save water.
- Advanced forecasting models are being developed by NASA to help with the water shortage.
- They are also developing new ways to better manage and monitor the state's water resources.

Responses by individuals

- Farmers will have to pump more water, which will cost an extra US$453.
- People have been asked to use water more sparingly.
- Farmers are planting smaller crops because there is not enough water for them to grow.

Figure 5.32 The impacts and responses to drought in California.

ACTIVITIES

1. State one human and one physical cause of drought.
2. Draw a table that compares the impact of drought on people and the environment in the USA and Namibia.
3. State one impact of drought for people living in the USA.
4. Compare the response to drought by organisations in the USA and Namibia.

Extension

Evaluate the responses of individuals and governments to drought in developing and developed countries.

Review

By the end of this section you should be able to:

- ✓explain the reasons why droughts are hazardous
- ✓describe the impacts of drought on people and ecosystems in Namibia and the USA, and how they differ between the two countries
- ✓compare and contrast the different responses to drought from individuals, organisations and governments in Namibia and the USA.

KEY TERMS

Irrigation – the artificial watering of land for farming.

Examination-style questions

1 a) State which of the following is a greenhouse gas.
A oxygen B nitrogen C carbon monoxide D methane (1 mark)
b) State **two** human causes of climate change. (2 marks)
c) Explain **one** negative effect that climate change is having on people. (3 marks)

2 Study Figure 5.3 on page 63.
a) State if the California current is a warm or a cold current. (1 mark)
b) State which ocean current has an effect on the climate of the UK.
A Canaries B Gulf Stream C Labrador D North Atlantic Drift (1 mark)
c) Ocean currents influence the climate of the UK.
Explain **one** way that ocean currents affect the climate of the UK. (3 marks)

3 The UK's climate is very variable. This is shown on Figure 5.16 on page 72.
a) Calculate London's annual temperature range (see Figure 5.22). (1 mark)
b) Calculate the median maximum temperature shown on Figure 5.16. (1 mark)
c) Blackpool has a higher total annual rainfall than York (see Figure 5.17 on page 73).
Suggest reasons why? (3 marks)

4 Study Figure 5.1 on pages 60 and 61.
a) State **two** features of global atmospheric circulation. (2 marks)
b) Explain how air moves in the Polar circulation cell. (4 marks)

5 Evaluate the different responses to the impact of a tropical cyclone on people in a named developing country.
Named developing country ..... (8 marks)

Total: 30 marks

6 Ecosystems, Biodiversity and Management

LEARNING OBJECTIVE

To study large-scale ecosystems.

Learning outcomes

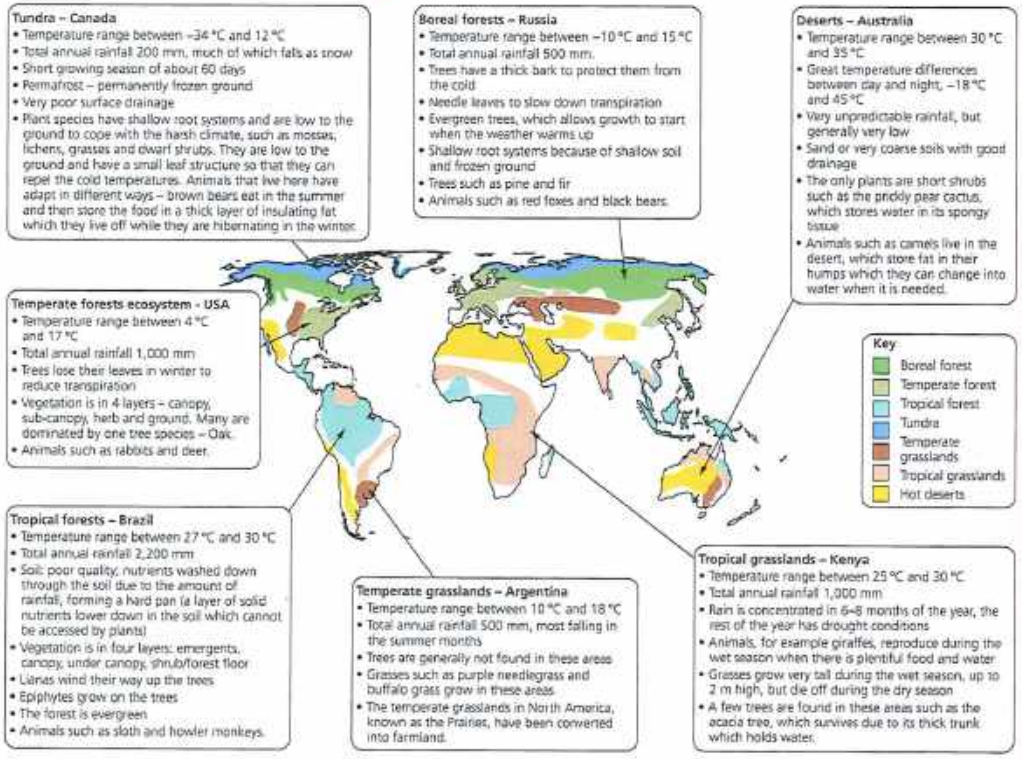
- To know the distribution of the world's large-scale ecosystems.
- To be able to describe the characteristics of the world's large-scale ecosystems.
- To understand the role of climate and local factors in influencing the distribution of large-scale ecosystems.

Large-scale ecosystems are found in different parts of the world and are important

What is the distribution and characteristics of the world's large-scale ecosystems?

The world's large-scale **ecosystems** are tropical forests, **temperate forests**, **boreal forests**, tropical grasslands, temperate grasslands, **deserts** and **tundra**. The **distribution** of these ecosystems is shown in Figure 6.1, along with the characteristics (or main features) of each ecosystem and a country where it can be found.

Figure 6.1 The distribution and characteristics of the world's large-scale ecosystems.



How does climate and other more local factors, such as soils and altitude, influence the distribution of large-scale ecosystems?

The distribution of large-scale ecosystems is determined to a great extent by climate. As shown in Figure 6.1, the different ecosystems have different climatic requirements. For example, tropical rainforests require warmth and moisture for plants to survive. Boreal forests are found in areas that have a short growing season and are made up of tree species that do not lose their leaves when the weather becomes colder. **Deciduous** forests would not survive in these areas because the trees would not have time to regrow their leaves.

Altitude is another factor that influences the type of vegetation because, as the land becomes higher, a number of changes take place in the **abiotic** factors.

- The temperature drops by 1°C per 100 m.
- **Soils** become thinner and contain less **organic** matter.
- The soil temperature also drops.

This has a number of impacts on the vegetation. Plant size decreases and there are more grasses and fewer trees. There is less diversity of both plants and animals species, and plants have a lower growth rate. The degree to which these trends happen depends on where the mountain is located. Figure 6.2 shows the possible changes for a mountain close to the Equator.

Soils are also important because different plants require different types of soil. The underlying bedrock and soil are therefore important for the type of ecosystem found in an area. For example, boreal forests have a very acidic soil because of the leaf **litter** from the trees. Deciduous forests have a more nutrient-rich litter because of the leaf fall every autumn.

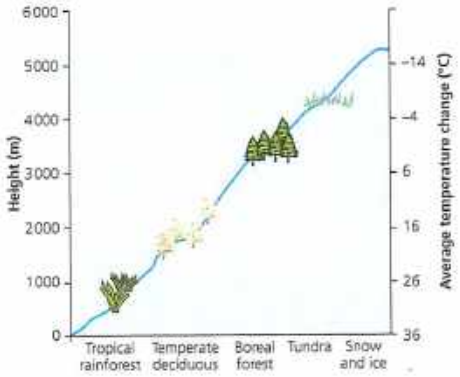


Figure 6.2 Changes in vegetation type and temperature as altitude rises.

Review

By the end of this section you should be able to:

- ✓ recognise the distribution of the world's large-scale ecosystems
- ✓ describe the characteristics of the world's large-scale ecosystems
- ✓ explain the role of climate and local factors (soils and altitude) in influencing the distribution of large-scale ecosystems.

KEY TERMS

Litter – decomposing leaf and other organic debris found on forest floors.

Ecosystems – a community of plants and animals and their non-living environment.

Distribution – where something is located.

Altitude – height above sea level.

ACTIVITIES

1 Complete the following table for all of the ecosystems shown in Figure 6.1.

Ecosystem	Location	Main characteristics
Tropical forests		
Temperate forests		
Boreal forests		
Tropical grasslands		
Temperate grasslands		
Deserts		
Tundra		

2 Explain how altitude affects the distribution of ecosystems.

Extension

Altitude has an impact on ecosystems. Explain how the location of a mountain also has an impact on the ecosystems which are found there.

The biosphere is a vital system

LEARNING OBJECTIVE

To study why the biosphere is a vital system.

Learning outcomes

- To know how the biosphere provides resources for people.
- To understand how it is increasingly being exploited commercially for energy, water and mineral resources.

KEY TERMS

Resource – a stock or supply of something that is useful to people.

Biosphere – the part of the Earth and its atmosphere in which living organisms exist or that is capable of supporting life.

Exploitation – the act of using natural resources.

Finite resource – a resource that will eventually run out.

Water cycle – the closed system in which water moves between the atmosphere, the oceans and land.

How does the biosphere provide resources for people?

The Earth has always provided **resources** which have been used by people to survive, from the food that we eat to the materials we use to build homes and heat them. Many of the medicines that we use come from plants. Figure 6.3 gives some examples of each of these resources.

Resource	Human use
Oil	Used as a fuel to produce electricity and to power engines.
Wood	Used to as a building material and as a fuel to provide heat.
Wheat	Used to make bread and breakfast cereals.
Periwinkle	Used in medicines to treat leukaemia.

Figure 6.3 Natural resources and how we use them.

How is the biosphere being exploited for energy, water and mineral resources?

Energy

The **biosphere** is being **exploited** in a number of ways to provide energy.

- Oil is extracted from the ground and used to power engines in many forms of transportation. The main use of oil for transportation is to power cars for private use. Other uses of oil are as a fuel to provide electricity.
- Coal has been mined for hundreds of years. It was first used as a fuel to heat people's homes and later used to produce electricity. The extraction and use of coal has changed between different countries but coal is still a major energy provider in many countries of the world.

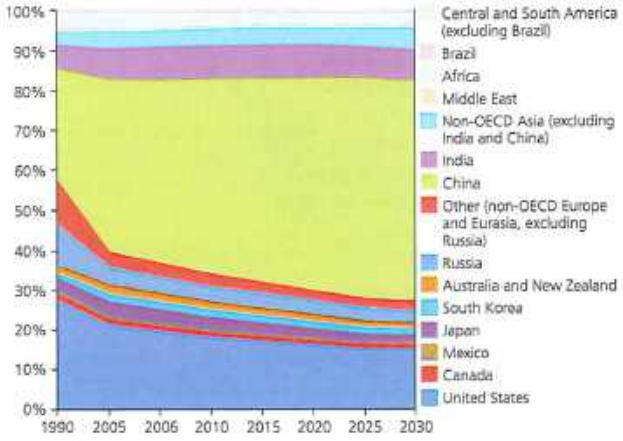


Figure 6.4 World coal consumption by region 1990–2030.

Use	Percentage
Electricity generation	68
Steel manufacture	7
Cement plants	4
Other industry	8
Heating	3
Other uses	10

Figure 6.5 World uses of coal, 2012.

Practise your skills

Construct a pie chart to show the information in Figure 6.5.

More recently the biosphere has been exploited to provide green energy. Wind turbines have been built on land and at sea to provide energy using the power of the wind. Solar panels have been put in fields to provide electricity using solar radiation. More recently, the sea has been exploited to provide energy through the use of wave and tidal barrages.

Water

People use water in many ways. In a domestic situation water is used for drinking, washing, toilets and cleaning. It is also used in the production of electricity in thermal power stations. Farmers use water to irrigate their crops; this is more important in some countries than others, for example in the USA 37 per cent of all water used is for irrigation. Water is also used by many different industries, from the food industry to the paper industry. In Canada, the paper industry uses 45 per cent of all water used by industry. Water is also used as a means of transporting materials and people from one place to another.

All of these uses of water have an impact on the water which is being used. The amount of water in the world is **finite** and human's use of it is interfering with the **water cycle**.

Figure 6.6 Renewable power from the sea: wave barrages, Cardiff.

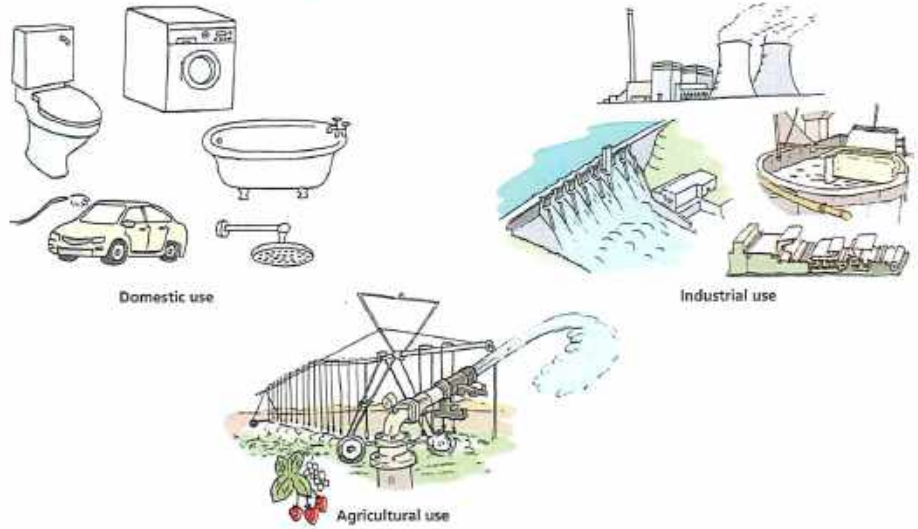


Figure 6.7 How water is being exploited.

Mineral resources

Minerals have been extracted and used by humans for thousands of years. We use them in our everyday lives without even realising it, for example when you cleaned your teeth this morning! Gold and silver are easily recognised as minerals used in the making of jewellery, but silver is also used in the making of mirrors. Figure 6.8 shows a number of minerals that are used in the construction of a house and the making of a car. It is easy to see that the use of minerals is being exploited, and that certain minerals will soon start to be in short supply.

KEY TERMS

Mineral – a solid, naturally occurring non-living substance, such as coal or diamonds.

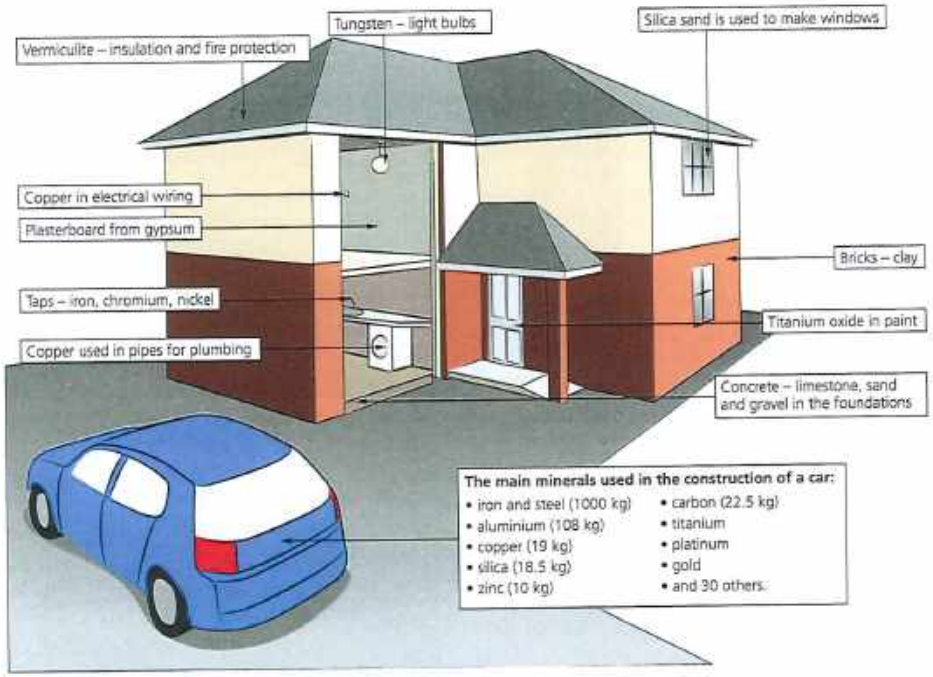


Figure 6.8 Minerals in everyday use.

ACTIVITIES

1. Name one resource that is both a fuel and a building material.
2. Describe how water as a resource is being exploited.
3. Explain how the energy resource is being exploited.

Extension

Research different plants that are used to treat diseases.

Review

By the end of this section you should be able to:

- ✓explain how the biosphere provides resources for people
- ✓understand how the biosphere is increasingly being exploited commercially for energy, water and mineral resources.

The UK has distinctive ecosystems

What is the distribution and characteristics of the UK's main ecosystems?

LEARNING OBJECTIVE

To study the variety of ecosystems in the UK and their importance.

Learning outcomes

- To know the distribution of the UK's main ecosystems.
- To be able to describe the characteristics of the UK's main ecosystems.
- To understand the importance to the UK of marine ecosystems as a resource.
- To know how human activities are causing problems for marine ecosystems.

Type of ecosystem	England (%)	Northern Ireland (%)	Wales (%)	Scotland (%)
Farming	58	41	42	19
Moorlands and mountains	4	19	10	42
Grasslands	16	18	25	18
Woodlands	7	14	15	17
Wetlands	2	3	3	2
Urban	13	5	5	2

Figure 6.9 Ecosystems across the UK.

Practise your skills

Construct a divided bar chart to show the information in Figure 6.9.

Marine ecosystem in Scotland most degraded in the UK!

The Firth of Clyde on the west coast of Scotland has been named as the most degraded marine ecosystem in the UK. Over 100 years of overfishing of cod, mackerel and herring, to name but a few species, has led to this sorry state of affairs. Few fish are caught by the fishing boats today as none are left in the waters.

In September 2008, in response to this sad state of affairs, a fully protected marine reserve was established in Lamlash Bay on the Isle of Arran – the first in Scottish waters. It is hoped that fish will breed in this area and then find their way back to the waters of the Firth of Clyde. If we want to continue to enjoy Great British fish and chips, we can only hope it works!

KEY TERMS

Moorland – land which is not intensively farmed. It is found in upland areas of the UK and tends to have acidic, peaty soils. The plants are small shrubs such as heather; there are few trees.

Heathland – tends to be open countryside in lowland areas. The plants are small shrubs, such as heather and gorse, with a few silver birch trees.

Deciduous – broad-leaved trees, such as oak and ash, which lose their leaves in the autumn and regrow them each spring.

Coniferous – trees which stay in leaf all year round (evergreens).

Wetlands – areas of low-lying land that is predominantly wet and boggy. Some wetland areas have been drained, such as the Somerset Levels and the Fens. The term 'wetland' also refers to small ponds and river estuaries.

Type of ecosystem	Distribution	Characteristics
Moorland  Figure 6.10 Moorland in North Yorkshire.	Found in highland areas with heavy rainfall. Examples in the UK include the Cairngorms in Scotland, North Yorkshire, the Pennines, Dartmoor, Exmoor and mid Wales.	Moorlands have been created by people. The hills used to be covered in trees and shrubs but the moorland ecosystem has developed through grazing the land with sheep and managing it for grouse shooting. In many areas the moors are burnt to control the growth of plants. Typical plants: soils are acidic and peaty so only certain plants can survive, such as bell heather and bracken. Typical animals: red deer and foxes. Typical birds: buzzards and grouse.
Heathland  Figure 6.11 Heathland in Devon.	Much of lowland UK has heaths. Heaths are found in Cornwall, Devon and Dorset, at Cannock Chase in Staffordshire and the Gower Peninsula in Wales.	Heathlands have dry sandy soils which can have depressions that are peaty and boggy. The sandy soil is free draining, acidic and has few plant nutrients. In the past heathlands were used for sheep grazing and for building materials. Typical plants: they contain small shrubs such as heather and gorse, but trees such as silver birch will colonise the area if they are not controlled. Typical animals: rabbits and hares; they are particularly important for reptiles. Typical birds: nightjar and skylark.
Woodland  Figure 6.12 Mixed woodland in Devon.	The UK has many different types of woodland. In England, Wales and Northern Ireland, native trees are broad-leaved, deciduous trees such as oak and ash. In Scotland the native tree is the Scots pine, although broad-leaved trees are also found in lowland areas. There are plantations of non-native conifers in many upland areas, such as the valleys of southern Wales and the Lake District.	Trees are the dominant plant. Broad-leaved trees tend to be deciduous, which means they lose their leaves in autumn and regrow them each spring. This leaf fall provides rich humus for the wood. Coniferous woods are made up of conifers which have needle-like leaves. They shed and replace their leaves throughout the year. Their seeds are protected by cones. Typical plants: in addition to trees, mosses and lichens grow under the canopy, as well as plants such as bluebells and ferns. Typical animals: roe deer and badger. Typical birds: sparrow hawk and tawny owl.
Wetland  Figure 6.13 The Somerset Levels.	Wetlands in the UK range from ponds and streams to rivers like the Severn and areas such as the Somerset Levels, the East Anglian Fens and the Norfolk Broads. They are also found in central and northeast Scotland, Wales and Northern Ireland.	Lowland fens have peaty, fertile soils that are periodically waterlogged. They support lush vegetation. Much of the land has been drained to use as farmland. Typical plants: reeds and bulrush grow along the sides of the streams. Typical animals: otters. Typical birds: mallard and teal.

How important a resource are marine ecosystems?

The UK's marine resources have great economic, environmental and social value. The marine area of the UK is three and a half times its land area. It is rich in resources, which were estimated to be worth £46 billion in 2005. The most recent development is the use of the marine environment for large-scale renewable energy developments.

The marine environment provides vital goods and services:

- oil, natural gas and renewable energy
- sand and gravel for the construction of roads and buildings
- seafood
- ports, through which 90 per cent of our imports and exports travel
- sport and recreation.

The UK's seas also absorb vast amounts of greenhouse gases while releasing oxygen. They moderate our climate, making it warmer in the winter than the UK would be given its latitude, and cooler in the summer, as well as giving millions of people the opportunity for leisure and recreation at the many coastal resorts around the country.

KEY TERMS

Aquaculture – breeding of fish in pens under controlled conditions.

Colonise – to become established in an area.

Resource/activity	Gross value to the UK economy (£ billion)	Number of people employed in that activity
Oil and gas	37.00	290,000
Ports	5.05	54,000
Telecom	2.70	26,750
Recreation	1.29	114,670
Fisheries	0.20	31,633
Aquaculture	0.19	
Renewable energy	0.05	4,000

Figure 6.14 Resources from the marine environment.

Practise your skills

Construct a bar chart to show the information from the first two columns in Figure 6.14.

How are human activities causing problems for marine ecosystems?

The pressure on the UK's seas to provide resources has never been greater and this is causing problems for marine ecosystems. The problem of overfishing has been recognised for many years and laws have been introduced to address it at both a national and EU level, the latest being the creation of Marine Protected Areas (MPA). No fishing is allowed to take place in these areas of the sea.

The fastest-growing human activity is marine energy. The extraction of oil and natural gas over the last 50 years has had an impact on marine ecosystems in the North Sea. The expansion now is into renewable energy in the form of wind farms, wave farms, barrages and tidal turbines. These constructions will have a far greater effect on marine ecosystems as there are more of them and their construction requires interference with the sea bed.

Figure 6.15 Wind farm in Kent.

The construction industry is also increasingly looking to the sea, rather than quarries on land, to provide sand and gravel. The growth in shipping also requires the development of port facilities.

Perhaps the largest growth area, however, is in marine leisure and the growth of marina facilities to provide recreation facilities for a growing population in the UK.

Due to these increasing and sometimes conflicting demands on marine ecosystems, the Marine and Coastal Access Act was passed in 2009. Its aim is to help with some of these concerns by managing the activities that take place in marine environments and balancing them with conservation.

Review

By the end of this section you should be able to:

- ✓ explain how the biosphere provides resources for people
- ✓ understand how the biosphere is increasingly being exploited commercially for energy, water and mineral resources
- ✓ describe the distribution of the UK's main ecosystems
- ✓ describe the characteristics of the UK's main ecosystems (moorlands, heaths, woodlands, wetlands)
- ✓ understand the importance to the UK of marine ecosystems as a resource
- ✓ explain how human activities are causing problems for marine ecosystems.

ACTIVITIES

1. Copy out and complete the following sentences:
   Cannock Chase is an example of .....
   Dartmoor is an example of .....
   The Norfolk Broads are an example of .....
2. Describe the different types of woodland found in the UK.
3. State three resources that we get from marine ecosystems.
4. Explain how human activities are causing problems for marine ecosystems.

Extension

Research the location and numbers of Marine Protected Areas around the UK. The following website will help: www.ukmpas.org/mapper.php

Tropical rainforests have a range of distinguishing features

LEARNING OBJECTIVE

To study the distinguishing features of tropical rainforests.

Learning outcomes

- To know the biotic and abiotic characteristics of the tropical rainforest ecosystem.
- To be able to explain the interdependence of biotic and abiotic characteristics and the nutrient cycle.
- To understand why rainforests have very high biodiversity.
- To be able to describe how plants and animals have adapted to the rainforest environment.

What are the biotic and abiotic characteristics of the tropical rainforest ecosystem and how have plants and animals adapted to these conditions?

The **abiotic** (or non-living) characteristics of the tropical rainforest are the amount of rainfall, temperature, **soil** and light that the forest receives. Its **biotic** factors are the plants, animals and humans that can be found there. These characteristics can be seen on Figure 6.18 (page 100). The figure also contains information on how some plants and animals adapt to life in the rainforest environment.

KEY TERMS

Abiotic factors – the physical, non-living environment, such as water, wind, oxygen.

Biotic factors – the living organisms found in an area.

Detritovore – an animal that feeds on dead plant or animal matter.

Organic material – something that was once living.

Inorganic material – something that was never living matter.

Soil – the top layer of the earth in which plants grow; it contains organic and inorganic material.

Biomass – the amount or weight of living or recently living organisms in an area.

Nutrient cycle – the movement and exchange of organic and inorganic material into living matter.

Food chain – a series of steps by which energy is obtained and used by living organisms.

Food web – a network of food chains by which energy and nutrients are passed from one species to another; it is essentially 'who eats who'.

Biodiversity – the number of species present in an area.

Limiting factors – factors that limit biodiversity/population size, such as temperature, moisture, light and nutrients; these factors are in abundance in tropical rainforests, which accounts for their high biodiversity.

Figure 6.16 Plants in the shrub layer of the rainforest.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperature (°C)	28	28	28	27	28	28	28	29	29	29	28	28
Rainfall (mm)	278	278	300	287	193	99	61	41	62	112	165	220

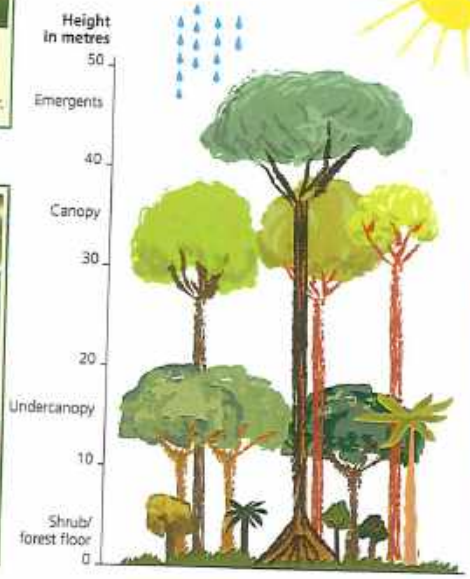
Figure 6.17 Climate data for Manaus, Brazil.

The hummingbird lives in the canopy. It has strong flight muscles; figure-of-eight wing beats allow it to hover in the air.

Rains every day – total annual rainfall of 2,200 mm

Toucans live in the canopy. They have long bills to reach fruit on branches that are too small to support their weight.

The harpy eagle lives in the canopy. It has a 2 m wing span and is so powerful that it can snatch a sloth from a tree in flight.



Temperature range between 27 °C and 30 °C
Very little light variation throughout the year – 12 hours daylight, 12 hours night

The trees in the canopy have small leaves to prevent water loss through transpiration

The large trees have buttress roots which give them stability because of their great height. The roots are also a nutrient store.

Plants on the forest floor have adapted: they have large leaves due to lack of light, and drip tips to help them to shed rainwater quickly.

Soil poor quality; nutrients are washed down through the soil by the heavy rains. This forms a hard pan, which is a layer of solid nutrient lower down in the soil that cannot be accessed by plants.

Sloths live in the canopy. They use camouflage and amazing slowness to escape predators. Green algae grows in the sloth's fur, which helps to camouflage it in the forest canopy. Sloths are among the slowest moving animals of all. They hang from branches in the canopy and are so still that predators such as jaguars don't see them. Their fur grows the other way so that the heavy rainfall runs off them easily in their upside-down position.

Figure 6.18 The biotic and abiotic characteristics of tropical rainforests and how plants and animals have adapted to these characteristics.

Practise your skills

1. Draw a **climate graph** for the climate data for Manaus in Brazil (see Figure 6.17 on page 99).
2. Describe the climate in Manaus using the data chart and your climate graph in your answer.

What are the characteristics of the tropical rainforest food web?

Every organism needs energy to live and grow. A **food chain** is the sequence of who eats who in an ecosystem to obtain the energy to survive. A network of food chains is known as a **food web**. The food web starts with plants, which are known as producers; they gain their energy from the Sun. Plants are eaten by herbivores, or primary consumers. Primary consumers are eaten by secondary consumers, which in turn may be eaten by tertiary consumers. When an organism dies it is eaten by tiny microbes, which are known as **detritivores**. The nutrients are then recycled within the system. Figure 6.19 shows a food web in the tropical rainforest.

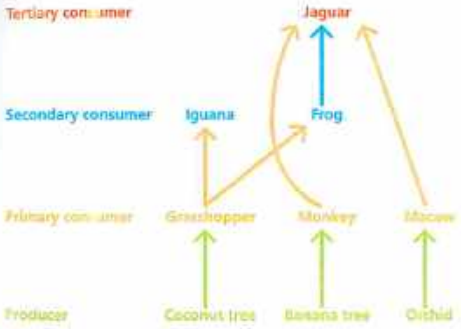


Figure 6.19 A tropical rainforest food web.

Review

By the end of this section you should be able to:

- ✓describe the biotic and abiotic characteristics of the tropical rainforest ecosystem
- ✓understand the interdependence of biotic and abiotic characteristics and the nutrient cycle
- ✓explain why rainforests have a very high biodiversity
- ✓describe how plants and animals have adapted to the rainforest environment.

What is the nutrient cycle?

Nutrients are chemical elements and compounds that are needed for organisms to grow and live. The **nutrient cycle** is the movement of these compounds from the non-living environment to the living environment and back again. For example, a tree loses its leaves, the leaves fall to the forest floor and quickly decompose because of the hot and damp conditions. The resultant litter provides nutrients for the tree to grow. In the rainforest the majority of the nutrients are stored in the **biomass** with small amounts stored in the litter and soil. This is due to the heavy rainfall, which leaches nutrients down through the soil to an area where the plants cannot reach them. The tropical rainforest has a very high **biodiversity** because of the hot and wet conditions provided by the climate. Due to this, and consistent hours of sunlight all year round, there are very few **limiting factors**; this allows a great variety of plants to grow in the rainforest.

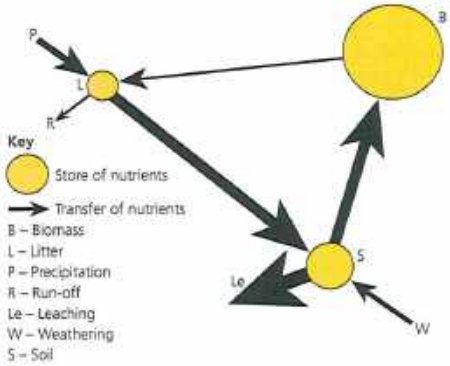


Figure 6.20 The nutrient cycle in the tropical rainforest (Gersmehl model).

ACTIVITIES

1. How are sloths adapted to living in the rainforest?
2. State two ways that plants adapt to living in the rainforest.
3. Copy out and add to the tropical rainforest food web (see Figure 6.19). Add at least one other animal or plant to each level of the food web.

Extension

This topic has many new terms to learn. Make an ecosystem glossary and learn all the new terminology.

Tropical rainforests provide a range of goods and services, some of which are under threat

LEARNING OBJECTIVE

To study the range of goods and services provided by the tropical rainforest ecosystem.

Learning outcomes

- To know the goods and services provided by the tropical rainforest ecosystem.
- To be able to explain how climate change presents a threat to the structure, functioning and biodiversity of tropical rainforests.
- To understand economic and social causes of deforestation.
- To be able to describe the political and economic factors that have contributed to the sustainable management of a rainforest in Costa Rica.

KEY TERMS

Structure – the structure of a tropical rainforest is the layers of plants and animals in the forest.

Function –the function of a tropical rainforest is its ecosystem and how it works.

Transpiration – evaporation of moisture from the leaves of a plant.

Eutrophication – the growth of algae on water courses due to the increase in chemical fertilisers being used on the land.

Monoculture – the growing of one crop on large areas of land.

Which goods and services are provided by the tropical rainforest ecosystem?

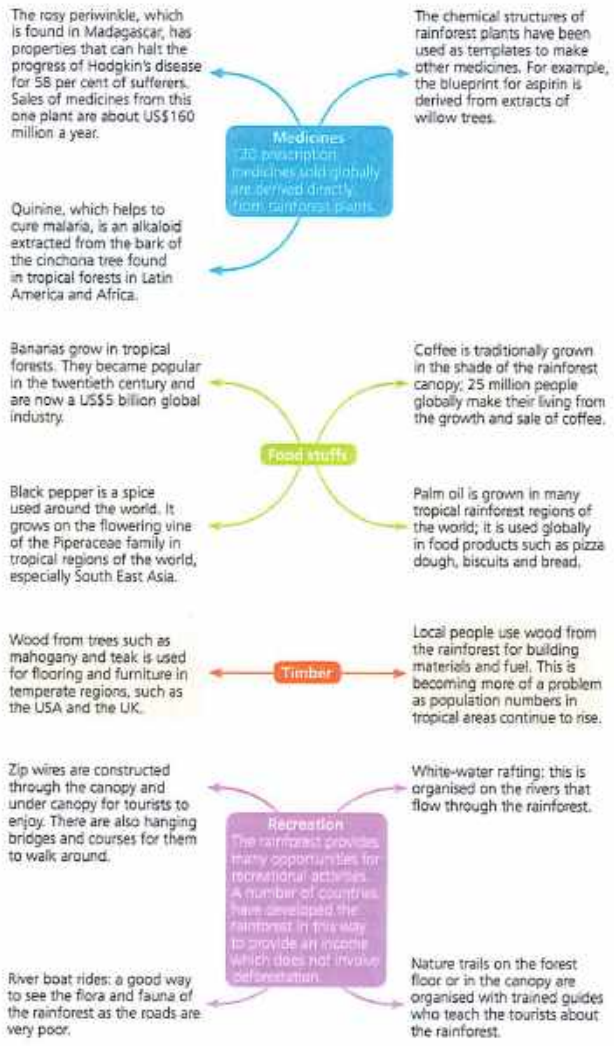


Figure 6.21 Goods and services provided by tropical rainforest ecosystems.

How does climate change present a threat to the structure, functioning and biodiversity of tropical rainforests?

Climate change presents a threat because the **structure** and **function** of rainforests rely on the climate. Therefore, if there are changes in temperature and rainfall distribution, the rainforest will be unable to survive in its present form. The rainforest is vulnerable to climate change because its resilience has been weakened by human activities such as deforestation. If part of the forest is felled or suffers from a fire, it has an impact. The humidity in the rainforest and the vast amount of **transpiration** means that much of the rainfall is recycled from the forest itself. If the forest is felled there are fewer trees to provide water through transpiration and therefore less rainfall occurs. Climate change means that eastern areas of the Amazon rainforest may receive twenty per cent less rainfall by 2030. This will cause the temperature to rise and will have a major impact on the forest in that area. The Amazon rainforest contains 40 per cent of the species on earth. This biodiversity will be threatened by less rainfall and higher temperatures because links in the food chain could be broken if species fail to adapt to the new climate conditions. The predictions are that deforestation and climate change could damage or destroy 60 per cent of the Amazon rainforest by 2030.

What are the economic and social causes of deforestation?

The economic causes of deforestation are related to a country using its natural resources to generate income. The social causes of deforestation relate to pressure from the growing population in many countries where there are tropical rainforests. This has resulted in more timber being felled for use as fuel and building materials, and to make way for new roads and houses.

Agriculture

Figure 6.22 Farming in the Brazilian Amazon.

Tropical rainforest is cleared for agriculture as many believe that the soils must be rich to support the lush vegetation. The forest is felled and burned; this adds nutrients to the soil which last for a few years. The cleared area is quickly planted and good crops are harvested. After a few years large amounts of fertiliser are needed to produce high yields. This makes the farming less profitable and causes fertilisers to be washed into rivers, causing **eutrophication**. The land is then abandoned or left to cattle ranchers.

Some land on floodplains is suitable for growing cash crops on a **monoculture** system such as rice and tea. This can be risky because of disease spreading through the crop or price fluctuations on global markets.

Resource extraction

Figure 6.23 Gold mining in the Amazon rainforest.

Resources have been extracted from rainforest areas for many years. Governments such as Brazil's have sold the rights to minerals in the rainforest as a way of raising money to help develop their country. The indigenous inhabitants are rarely consulted which has caused many disagreements because they believe that they own the land and that the government has no right to grant mineral rights to large companies. The forest has been cleared for large-scale mining operations including access roads and settlements where the workers live.

Most mining in the Brazilian Amazon today is for gold. This releases mercury into the environment, which is very dangerous to the health of both humans and other top carnivores.

Population pressure

Figure 6.24 Population pressure in the Amazon Rainforest.

The main reason for deforestation is population pressure due to **overpopulation**. This relates to the growth in population in the country where the **tropical forest** is situated, which places growing demands on the forest area. It is predicted that the world's population will reach 8 billion by 2026. Over 99 per cent of this growth will be in developing countries, many of which have areas of rainforest.

In Brazil, the biggest increases in population are in the Amazon. Ten cities in the Brazilian Amazon doubled their population between 2000 and 2010, with the region's population increasing by 23 per cent to 25 million. This growth is shown in the city of Parauapebas which, over the past ten years, has changed from a frontier settlement with gold mines and gunfights to a sprawling urban area with an air-conditioned shopping mall. The reason for this growth is the promise of work in new energy, **resource extraction** and agricultural developments in the area. This attracts migrants from all over Brazil, which still has many people living in poverty. The growth of Parauapebas is because of employment in a large iron ore mine and the plans for more mines as demand increases from China. The population has grown from 154,000 to 220,000 since the 2010 census.

On the outskirts of the city, **favelas** of wooden shacks stretch to the horizon on land that used to be rich in tropical rainforest biodiversity.

Located example Sustainable management of the tropical rainforest in Costa Rica

KEY TERMS

Overpopulation – too many people living in an area for the area to support.

Favela – homes for the poor in Brazil. They are made from waste materials and have no water supply, electricity or toilets. They are also usually known as shanty towns.

NGO – non-governmental organisation; a not-for-profit organisation that is not under government control. They are usually set up by private individuals and can be funded by donations or governments.

Carbon credits – a permit which allows the holder to emit one ton of carbon dioxide or another greenhouse gas; they can be traded between businesses or countries.

For example, a steel producer in the USA has been allowed to emit ten tons of CO_2 but knows it will emit eleven tons. The company could buy one credit from Costa Rica to ensure it keeps to international law. Costa Rica has many carbon credits because of its rainforest. In this way wealthy countries are encouraging poorer countries to protect their rainforests.

Ecotourism – travel to natural areas that does no damage, conserving the environment and improving the well-being of local people.

The rainforest in Costa Rica is being managed sustainably by the government in a number of ways.

- National parks and reserves take up twenty per cent of the land area. People are not kept out of these areas completely but their use is monitored and carefully managed.
- Reserves that are owned and protected by private owners make up another five per cent. For example, the Monteverde Cloud Forest Reserve.
- Non-governmental organisations (**NGOs**) and charities have been encouraged to take an interest; for example, the World Land Trust.
- Direct government action, for example, new laws.
- Selling **carbon credits** to wealthy nations in order to protect the rainforest.
- **Ecotourism** has become the main export of the country, bringing in US$1.92 billion annually.

Year	Forested area (%)
1990	50.2
1995	48.4
2000	46.5
2005	48.8
2010	51.0
2015	52.1

Figure 6.25 Forested area in Costa Rica.

Practise your skills

1. Draw a line graph of the information in Figure 6.25.
2. Explain why a line graph is an appropriate way to display this information.

Direct government action

In 1979, Costa Rica passed legislation giving tax deductions and grants to owners of rainforest if they conserved their forest area and used it to benefit society by protecting water resources, biodiversity and scenic beauty. The government issues forest protection certificates and pays landowners US$50 annually for every hectare of forest they protect.

In 1995, the government set up national parks to protect eighteen per cent of the country's territory; privately owned reserves protect another thirteen per cent. The areas targeted for protection are those with high biodiversity.

The government has decentralised its decision making with regards to protecting the rainforest. It has grouped all protected areas in the country into eleven eco-regions. Each area is allowed to make decisions on how its rainforest will be protected.

In 1997 the Costa Rican government introduced the Certificate for Sustainable Tourism (CST) for businesses that can prove their commitment to sustainable tourism. The certificate has five levels, which include how the business looks after the environment and local people.

1. Guanacaste
2. Santa Rosa
3. Marino Las Baulas
4. Rincon de la Vieja
5. Miravalles Volcano
6. Tenorio Volcano
7. Palo Verde
8. Barra Honda
9. Cabo Blanco
10. Arenal Volcano
11. Santa Elena Cloud Forest
12. Children Eternal Rain Forest
13. Monteverde Cloud Forest Reserve
14. Poas Volcano
15. Penas Blancas
16. Braulio Carrillo
17. Barra del Colorado
18. Tortuguero
19. Turrialba Volcano
20. Tapanti
21. Los Quetzales
22. Carara
23. Manual Antonio
24. Marino Ballena
25. Isla del Cano
26. Corcovado
27. Piedras Blancas
28. La Amistad
29. Chirripo
30. Hitoy Cerere
31. Gandoca Manzanillo
32. Ostional
33. Cahuita
34. Caño Negro
35. Irazu Volcano
36. Juan Castro Blanco

Figure 6.26 National Parks and reserves in Costa Rica.

NGO projects

One of these projects is run by FUNDECOR (the Central Volcanic Mountains Development Foundation). Using a US$10 million grant from USAID (aid from the USA), it works with local landowners to help them manage the rainforest sustainably so that they can qualify for government grants. In 2014, FUNDECOR was working with 400 landowners who owned approximately 46,000 hectares of land in the Central Volcanic Mountain Region.

Ecotourism

In 1983, an ecotourism project called Rara Avis S.A. started in the Braulio Carrillo National Park. The idea was to show that the rainforest is a valuable economic resource that should be protected. The reserve looks after 485 hectares of rainforest and has indirectly conserved another 1,000 hectares. The previous owners planned to cut down the trees and sell the timber but now it is being managed sustainably. It fulfils the government criteria for environmental management and social management as all of the employees are from the local village of Las Horquetas.

Figure 6.27 Ecotourism in Costa Rica.

Private reserves: Monteverde Cloud Forest Reserve

This 10,500 hectare reserve was founded in the 1950s by a group of Americans and is now known as one of the most outstanding wildlife sanctuaries in the world. Its varied climate and altitude has a very high biodiversity. The reserve allows **ecotourism** but restricts the numbers of tourists it lets in by only having one place to stay in the reserve. It has guided walks and trails.

Charities: World Land Trust

A World Land Trust project concentrated on the Ora Peninsula, which is one of the top twenty places of highest biodiversity in the world. The project was to conserve the rainforest but also to work with local farmers. It purchased just over 2,000 hectares of land, which is now part of the Corcovado National Park. The trust worked with local farmers promoting growing vanilla to sell commercially. Small-scale ecotourism was also developed in the area.

Carbon credits

Another way that Costa Rica is using its rainforest as a **commodity** is by selling carbon credits. Wealthy countries buy them to offset the carbon emissions that they produce. This is a way for Costa Rica to earn money from its rainforest without cutting down the trees. In 1999, this idea generated US$20 million for the country.

Review

By the end of this section you should be able to:

- ✓describe the goods and services provided by tropical rainforests
- ✓explain how climate change presents a threat to the structure, function and biodiversity of tropical rainforests
- ✓understand the economic and social causes of deforestation
- ✓describe political and economic factors that have contributed to the sustainable management of a rainforest in a named region.

Figure 6.28 Monteverde Cloud Forest Reserve.

Deforested areas

Deforested areas of the rainforest are also being used to support the country economically. For example, in the Talamanca region deforested land is being used for farming. Commercial crops such as bananas and cocoa are grown and sold for export.

ACTIVITIES

1. State two goods and two services provided by tropical rainforests.
2. Describe how climate change will have an impact on tropical rainforests.
3. Explain the economic causes of deforestation in tropical rainforests.
4. State two ways that the government is trying to protect the rainforest in Costa Rica.
5. What is meant by the term 'ecotourism'?
6. Explain three ways in which the rainforest provides income for Costa Rica.
7. How are deforested areas in Costa Rica being used to generate income?

Extension

Use the internet to research the Monteverde Cloud Forest Reserve (www.monteverdeinfo.com), an example of a private reserve in Costa Rica.

Practise your skills

Use GIS mapping to research the amount of rainforest destruction in Brazil over the past twenty years.

Deciduous woodlands have a range of distinguishing features

LEARNING OBJECTIVE

To study the distinguishing features of deciduous woodlands.

Learning outcome

- To know the biotic and abiotic characteristics of the deciduous woodland ecosystem.
- To be able to explain the interdependence of biotic and abiotic characteristics and the nutrient cycle.
- To understand why deciduous woodlands have a moderate biodiversity.
- To be able to describe how plants and animals have adapted to the deciduous woodland environment.

KEY TERMS

Hibernate – to spend the winter in close quarters in a dormant (sleeping) condition.

Practise your skills

1. Draw a climate graph for the climate data given for London in Figure 6.30.
2. Compare the climate data for Manaus (on page 99) and London.

What are the biotic and abiotic characteristics of the deciduous woodland ecosystem and how have plants and animals adapted to these conditions?

The abiotic (non-living) characteristics of deciduous woodlands are the amount of rainfall, temperature, the soil and light that the forest receives. The biotic factors are the plants, animals and humans that can be found there. These characteristics can be seen in Figure 6.29. The figure also contains information on how plants and animals have adapted to life in the rainforest environment.

Figure 6.29 Bluebells in a deciduous woodland field layer.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperature (°C)	4	5	7	9	12	16	18	17	15	11	8	5
Rainfall (mm)	54	40	37	37	46	45	57	59	49	57	64	48

Figure 6.30 Climate data for London.

The nightingale migrates to Africa in September, returning to the UK in April, to avoid the cold months when the woodlands offer little food.

In spring, deciduous trees grow thin, broad, lightweight leaves. These leaves capture the sunlight easily and allow the tree to grow quickly as the temperature warms and the days grow longer. However, these leaves have too much exposed surface area for the cold winter months and, therefore, the tree loses its leaves as the weather becomes colder and daylight hours shorter.

Temperature range between 4 °C and 17 °C. Long periods of light in the summer, approximately 18 hours, contrasting with short days in the winter of about 8 hours of light.

Total annual rainfall 1,000 mm.

Height in metres

30

20

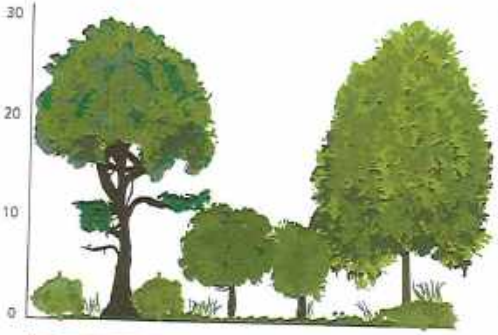
10

0

Canopy layer – trees such as oak and ash.

Sub-canopy layer – trees such as rowans and dogwoods, and shrubs such as rhododendrons.

Field or herb layer – plants in this layer flower early in the year before the trees in the canopy have grown their leaves, which block out the light.



Ground layer – this area is dark and damp; mosses and lichens grow here.

The soil is fertile. The autumn leaf fall means that there are plenty of nutrients. Earthworms in the soil help to mix the nutrients. The tree roots are deep and therefore help to break up the rock below, which gives the soil more nutrients.

Hedgehogs hibernate during the cold winter months from about November to April.

Squirrels store food in the ground under fallen leaves so that they have food in the colder months.

Figure 6.31 The biotic and abiotic characteristics of deciduous woodlands and how plants and animals have adapted.

What are the characteristics of the deciduous woodland food web?

Every organism needs energy to live and grow. A food chain is the sequence of who eats who in an ecosystem to obtain the energy to survive. A network of food chains is known as a food web. The food web starts with plants, known as producers, which gain their energy from the Sun. Plants are eaten by herbivores, or primary consumers. Primary consumers are eaten by secondary consumers which, in turn, may be eaten by tertiary consumers. When an organism dies, it is eaten by tiny microbes which are known as detritivores. The nutrients are then recycled within the system. Figure 6.31 shows a food web in deciduous woodland.

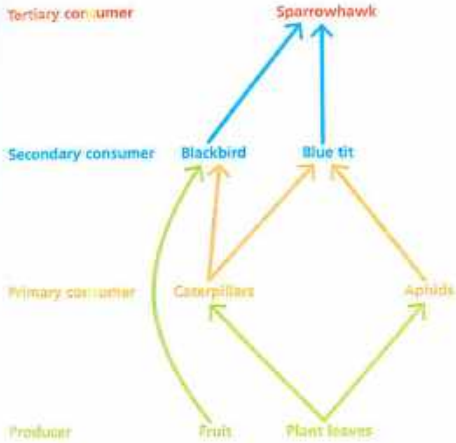


Figure 6.32 The characteristics of the deciduous woodland food web.

Review

By the end of this section you should be able to:

- ✓ know the biotic and abiotic characteristics of deciduous woodland ecosystems
- ✓ explain the interdependence of biotic and abiotic characteristics and the nutrient cycle
- ✓ understand why deciduous woodlands have moderate biodiversity
- ✓ describe how plants and animals have adapted to the deciduous woodland environment.

What is the nutrient cycle?

Nutrients are chemical elements and compounds that are needed for organisms to grow and live. The nutrient cycle is the movement of these compounds from the non-living environment to the living environment and back again. In the deciduous woodland nutrients are stored in the biomass and soil in almost equal amounts, with a slightly smaller store in the litter. Flows of nutrients move freely between these stores.

Deciduous woodland has a moderate biodiversity because of warm summers with a consistent amount of rainfall and long hours of daylight. The autumn leaf fall supplies plenty of nutrients for the woodland plants to live and grow.

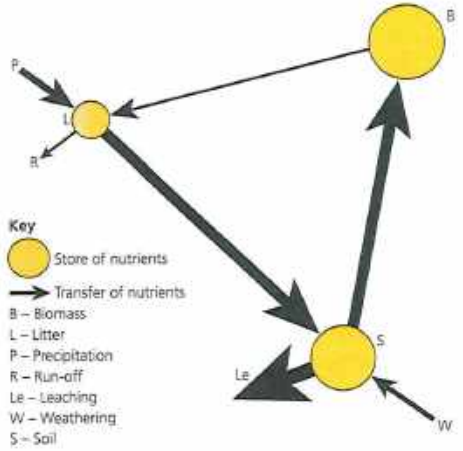


Figure 6.33 The nutrient cycle in a deciduous woodland (Gersmehl model).

ACTIVITIES

1. State two ways that plants have adapted to life in deciduous woodlands.
2. Copy out the deciduous woodland food web (Figure 6.32) and add at least one other animal or plant to each level.
3. Describe the characteristics of the deciduous woodland nutrient cycle.

Extension

Explain what is meant by the nutrient cycle.

Deciduous woodlands provide a range of goods and services, some of which are under threat

LEARNING OBJECTIVE

To study the range of goods and services provided by deciduous woodland ecosystems.

Learning outcomes

- To know the goods and services provided by deciduous woodland ecosystems.
- To be able to explain how climate change presents a threat to the structure, function and biodiversity of deciduous woodland ecosystems.
- To understand the economic and social causes of deforestation.
- To be able to describe different approaches to the sustainable management of deciduous woodlands in the Wyre Forest, West Midlands.

KEY TERMS

Broad-leaved trees – deciduous trees which lose their leaves in winter, such as oak and elm.

Short rotation coppice – trees, usually willow, grown specifically to be used fuel for biomass boilers for domestic heating or power stations. They are planted densely and harvested on two- and five-year cycles.

Ancient woodlands – contain trees that were planted before 1600.

Afforestation – the planting of trees in an area that has not been forested before.

Which goods and services are provided by deciduous woodland ecosystems?

Woodlands in the UK are managed as a resource for the goods and services that they can provide. They are also managed for the benefit of the wildlife that lives within them.

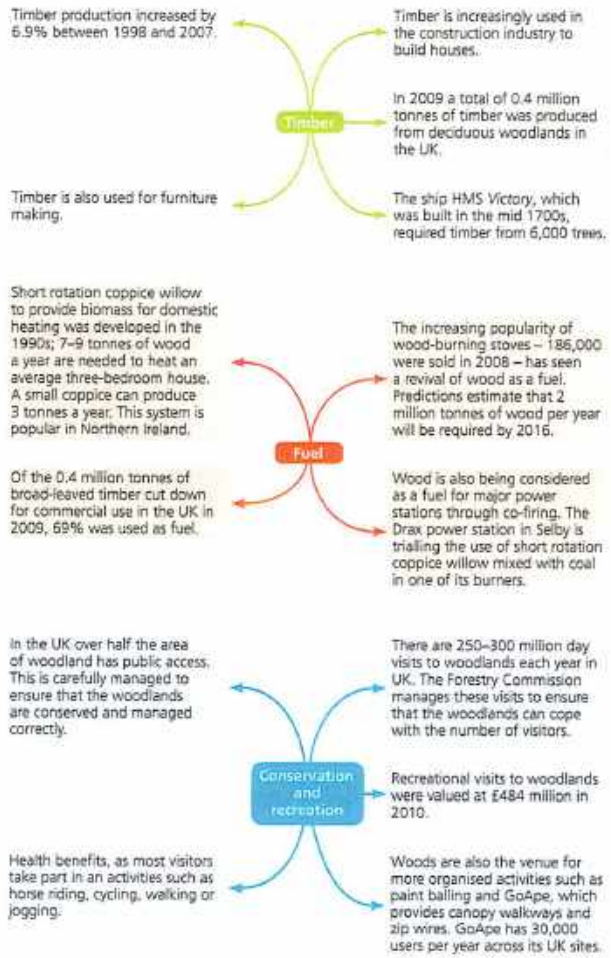


Figure 6.34 Goods and services in deciduous woodland ecosystems.

How does climate change present a threat to the structure, function and biodiversity of the deciduous forest ecosystem?

Recent climate change has not had a major impact on woodland structure and function, although small changes can be identified. Increasing temperatures have led to faster tree growth in some areas but, overall, there has been little impact. The lack of information about the impact of climate change on deciduous woodlands is partly due to the fact that the trees are long lived and can adapt to climate variability. They are, therefore, fairly resilient to the small changes in climate that have happened in recent years.

There have been more storms however, which can have an impact on the stability of the trees. In some areas increased droughts in the summer have had a detrimental effect on tree growth. It is also feared that the stress that droughts put on trees may make them more susceptible to disease. Droughts also lead to more forest fires, which have a major impact on woodland areas. In 2011, the Swinley Forest fire destroyed 200 hectares of forest.

Changes have been noted in the fauna of woodland ecosystems, such as the birds, which will eventually cause changes to the structure of the ecosystems as some species disappear and others arrive. For example, in Wytham Woods near Oxford, blue tits and great tits are breeding two weeks earlier than they did in 1980, which means they have time for more broods.

Milder winters might also cause problems as many trees need cold weather to help them to reset their clocks for spring. Without this, fruiting and flowering may be disrupted. Milder winters also mean that pests and diseases are not killed in winter frosts. It is predicted that temperatures in the UK will rise by 2.5 °C during the twenty-first century. This will mean that species will have to move north by 300 km or 300 m uphill to find the growing conditions they require or adapt to the new conditions. This would be fine for mobile species but some woodland trees might not be able to adapt fast enough. Plants such as bluebells and wood anemones are particularly under threat. This will result in the complex food web of **ancient woodlands** being disrupted by a succession of damaging impacts related to climate change.

Figure 6.35 Walkways and zip wires in Grizedale Forest, Lake District.

What are the economic and social causes of deforestation?

Deforestation in the UK has taken place over many centuries. The first cause was an economic one: the demand for more land for agricultural purposes. Later, a social cause was population growth and the resulting demand for food; the growth of urban areas for people to live in saw the removal of yet more of the native forest. Timber extraction to generate income has been occurring for many centuries but the situation came to a head after the First World War when timber was in such short supply that only five per cent of the UK's forest remained in 1919. This led to the government setting up the Forestry Commission to promote forestry, develop **afforestation**, the production of timber and make grants available to private landowners.

Agricultural change

The farming landscape of the UK has changed many times since the Middle Ages, causing deforestation. The dissolution of the monasteries and then the agricultural revolution saw great changes to the countryside in which landowners cut down large areas of forest to plant crops. This was linked to the growing population of the time and the fact that people moved to towns and cities and so were not producing their own food.

As farming has changed through the centuries, the amount of forested area in the UK has continued to decline. Some parts of the UK have kept more of their forested area but, overall, the country's forested area declined to a low of five per cent in 1919. The impact of agricultural change on woodlands was still occurring in the 1980s as can be seen in the newspaper article below.

Deforestation in the UK!

Deforestation is happening in Kent, not just the Amazon. The new owners of a 231-hectare area of land near Maidstone in Kent have shown complete disregard for preservation orders on woodland and trees. Copses and hedgerows have been destroyed in the owner's greed for more land for intensive agriculture. Approximately 73 hectares of woodland has been lost, over half of which was ancient woodland.

Urbanisation and population growth

As the population grew in the Middle Ages there was a greater demand for housing. This meant that trees had to be felled to provide beams to support roofs. Forests were also cleared to make way for towns, especially in the north of England where the Industrial Revolution took place. This sped up of the deforestation that had been taking place in the UK for centuries. Population growth between 1945 and 1975 meant that many of the remaining deciduous woods were cut down to make way for suburbs in existing towns and cities, or for the 'new towns' that were built during that period. For example, the new town Bracknell was built by clearing large areas of Windsor Forest. Some cities such as Birmingham and Manchester, have lost almost all of their ancient woodland. Other cities, such as London (2,500 hectares) and Sheffield (650 hectares) have retained some in parks and other woodlands, which are now used for recreational purposes.

Timber extraction

Timber has been extracted from UK forests for centuries. It was first used for house building and for fuel. The great cathedrals built across the country used thousands of trees in their construction. For example, Salisbury Cathedral required 1,000 oak trees. English oaks were also used in shipbuilding and the rise of the British Empire saw a great demand for timber in the late sixteenth century. In the 1600s the British monarchy ordered an overhaul of navy ships and about 3,000 tons of timber was felled from the New Forest each year. A survey of the New Forest in 1608 found almost 124,000 trees fit for navy timber. By 1707 that figure had fallen to less than 12,500.

Further timber extraction occurred during the First World War as it was needed to build trenches. This led to the forested area of the UK being at an all time low at the end of the war. Since 1919 the Forestry Commission has planted millions of hectares of land with fast-growing conifers. Thanks to this measure, it was able to cope with the demands of the Second World War and the demands from the developing coal industry for pit props. However, conifers are not native trees and the ecosystem of the woodlands suffered due to the dense canopy cover and the soil becoming more acidic.

Since the 1970s the Forestry Commission has changed it planting policy. As trees are extracted for timber, they are replaced with broad-leaved trees such as oak and elm in an attempt to re-establish deciduous woodlands in the UK.

More recently, the demand for timber as a fuel source has increased with the rising popularity of wood-burning stoves. Biomass boilers, which use wood chips as a fuel, have also been introduced.

Practise your skills

Use websites such as Digimap (http://digimap.edina.ac.uk) to research the amount of woodland in the UK in 1850, 1900, 1950 and 2000.

Try to discover how much of the woodland was deciduous and how much was conifer plantations in 2000.

Located example Sustainable use and management of deciduous woodlands: Wyre Forest, West Midlands

The Wyre Forest is the largest area of ancient woodlands in England. It covers 2,400 hectares. There are also stands of conifer plantations within the forest boundary and areas of orchard, meadows and mixed farming, making a total land area of nearly 5,000 hectares. The Forest is situated in the West Midlands to the west of the Birmingham conurbation and lies on the borders of Worcestershire, Shropshire and Staffordshire. The Forest is bisected by the River Severn with Bewdley on the eastern side and Cleobury Mortimer on the west.

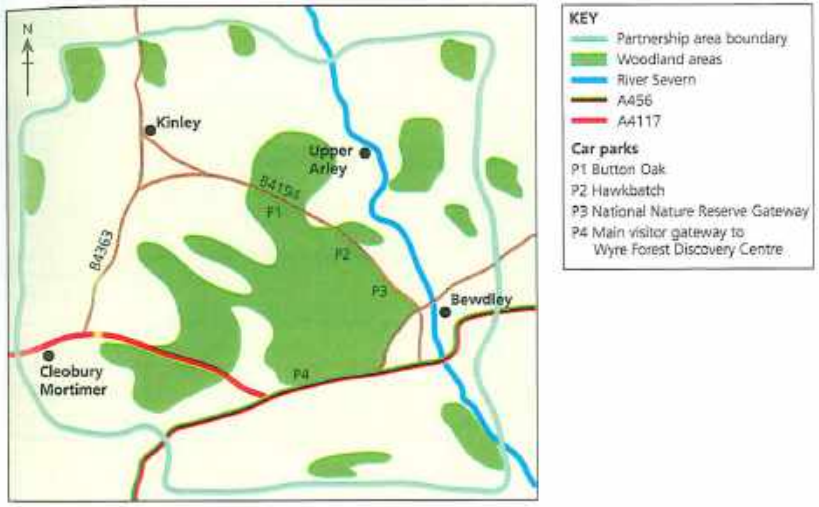


Figure 6.36 Sketch map of the Wyre Forest area.

Composition of the Wyre Forest	Hectares
Site of Special Scientific Interest (SSSI)	1,756
National Nature Reserve (NNR) of predominantly oak high forest of 100–120 years old	600
Ancient Semi Natural Woodland, roughly comparable to the NNR and covering the oak high forest and also the railway embankments on the current cycle path	1,564
Ancient Replanted Woodland, predominantly Forestry Commission and private ownership currently with conifer crops	1,131

Figure 6.37 Landscapes of the Wyre Forest.

The forest is managed by the Wyre Forest Landscape Partnership (WFLP). Through meetings and consultation documents the partnership has decided on an action plan for the use and **sustainable management** of the forest. Core members of the partnership are the Forestry Commission, Natural England, Wyre Community Land Trust, Bewdley Development Trust, Cleobury Country, Wyre Forest District Council, Worcestershire County Council and English Heritage.

Woodland management

- On steep slopes deciduous woodland will be left unmanaged to develop undisturbed.
- Areas previously planted with conifers will be gradually restored to woodland with oak as the predominant tree canopy.
- Other trees such as silver birch, aspen and rowan will be encouraged with an understorey of hawthorn, hazel and holly.
- Coppice management and tree felling will be restored so that the forest develops glades of young and mature trees.
- The deer population and non-native invasive plant population will be carefully controlled.

Figure 6.38 Woodland management.

Figure 6.39 A woodland ride.

Wildlife management

- A varied landscape of woodland, meadows, orchards, heathland and scrub will provide a variety of habitats for wildlife in the area.
- Wildlife-rich meadows and orchards will be extended.
- Invasive species such as Himalayan balsam will be removed.
- Any cattle grazing will be carefully monitored to ensure that the wildlife habitat is enhanced, not destroyed.
- A network of woodland rides will provide corridors for wildlife as well as people.

Community management

- Local residents will be encouraged to take part in conservation work.
- There will be community woods in which local people can cut their own firewood.

Figure 6.40 Wyre Forest centre and play area.

Leisure and recreation management

The forest will provide a place where people of all abilities can go for leisure and recreation.

- The visitor centre at Callow Hill will include displays to help people understand the forest and what it has to offer them.
- Easy bicycle access will be available from local communities.
- The Forestry Commission already provides a number of recreational activities including walking trails, cycle paths and a play area. The forest now has a GoApe experience with zip wires, Tarzan swings and walkways.

Figure 6.41 Display boards at the visitor centre.

Education

The Wyre Forest Centre has become a hub for sharing knowledge about usage and sustainable management of ancient deciduous woodlands.

- Monitoring takes place on the impact of using woodlands for recreation.
- Research is also being carried out on how the woodland is responding to external influences such as pollution and climate change.
- Children and adults from the surrounding communities, particularly from Birmingham, have been introduced to woodlands and wildlife through interactive displays and workshops.
- The Wyre Forest Landscape Partnership provides many opportunities for skills development and training, including forest industries apprenticeships and internships.

Figure 6.42 Education centre at Wyre Forest.

Review

By the end of this section you should be able to:

- ✓describe the goods and services provided by deciduous woodlands
- ✓explain how climate change presents a threat to the structure, function and biodiversity of deciduous woodlands
- ✓understand the economic and social causes of deforestation
- ✓describe different approaches to the sustainable management of deciduous woodlands in the Wyre Forest, West Midlands.

ACTIVITIES

1. State two goods and two services provided by deciduous woodlands.
2. Describe how climate change will have an impact on deciduous woodlands.
3. Explain the economic causes of deforestation in deciduous woodlands.
4. Describe two ways in which the Wyre Forest is being managed sustainably.

Extension

1. What is meant by the term 'ancient woodland'?
2. Where in the UK are other ancient woodlands located, besides the Wyre Forest?

Examination-style questions

1. Define the term food web. (1 mark)
2. Study Figure 6.2.
   a) Describe how changes in altitude affect the type of vegetation. (3 marks)
   b) Explain **one** reason for the changes describe in part (a) (2 marks)
3. Study Figure 6.20 on page 101 and Figure 6.33 on page 109.
   Compare the two nutrient cycles. (4 marks)
4. Study the OS map of Snowdonia on page 52.
   a) Identify the feature at 598545. (1 mark)
   b) Calculate the distance to the nearest km along the A4086 between the spot height 359 m in grid square 6455 and spot height 119 m in grid square 6157. (1 mark)
5. a) State **two** goods and services provided by deciduous woods. (2 marks)
   b) Explain **two** ways that plants have adapted to living in deciduous woodlands. (4 marks)
   c) Explain the economic reasons for deforestation of deciduous woodland in the UK. (4 marks)
6. Assess the following statement: 'The sustainable management of tropical rainforests is a greater concern than the sustainable management of deciduous woodlands.' (12 marks)

Total: 34 marks

Part 2 The Human Environment

In the following chapters, you will study the content you need for Component 2: The Human Environment. This component is divided into three topics:

Topic 4 Changing Cities

In this topic you will study:

Chapter 7: Changing Cities

Chapter 8: The Study of a Major UK City, Bristol

Chapter 9: The Study of a Major City, Sao Paulo, Brazil

Topic 5 Global Development

In this topic you will study **Chapter 10**, an overview of global development and a case study of development in a developing country.

Topic 6 Resource Management

In this topic you will study **Chapter 11**, an overview of resource management and one of the following two chapters:

Chapter 12: Energy Resource Management

Chapter 13: Water Resource Management