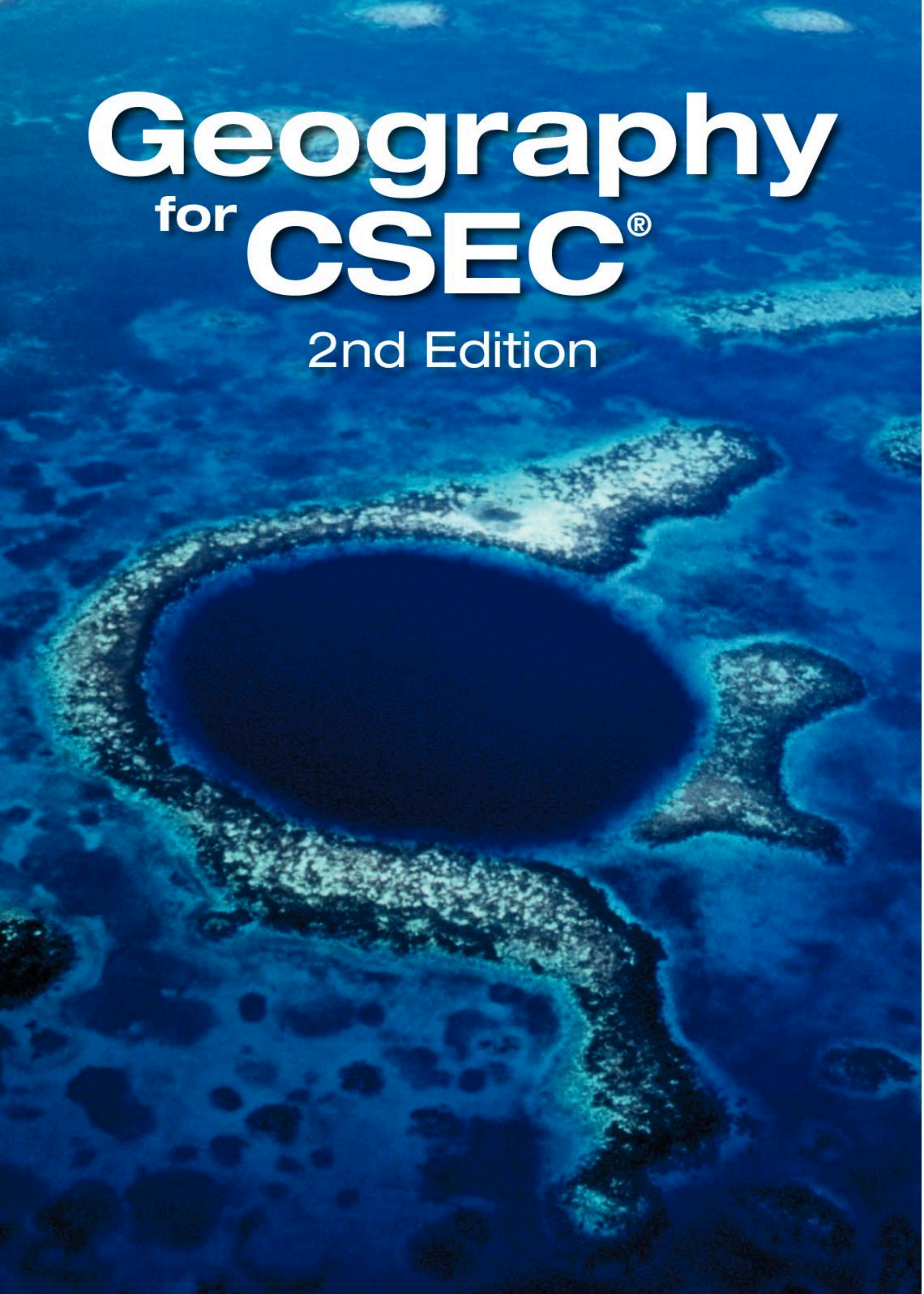
Geography for CSEC®

2nd Edition



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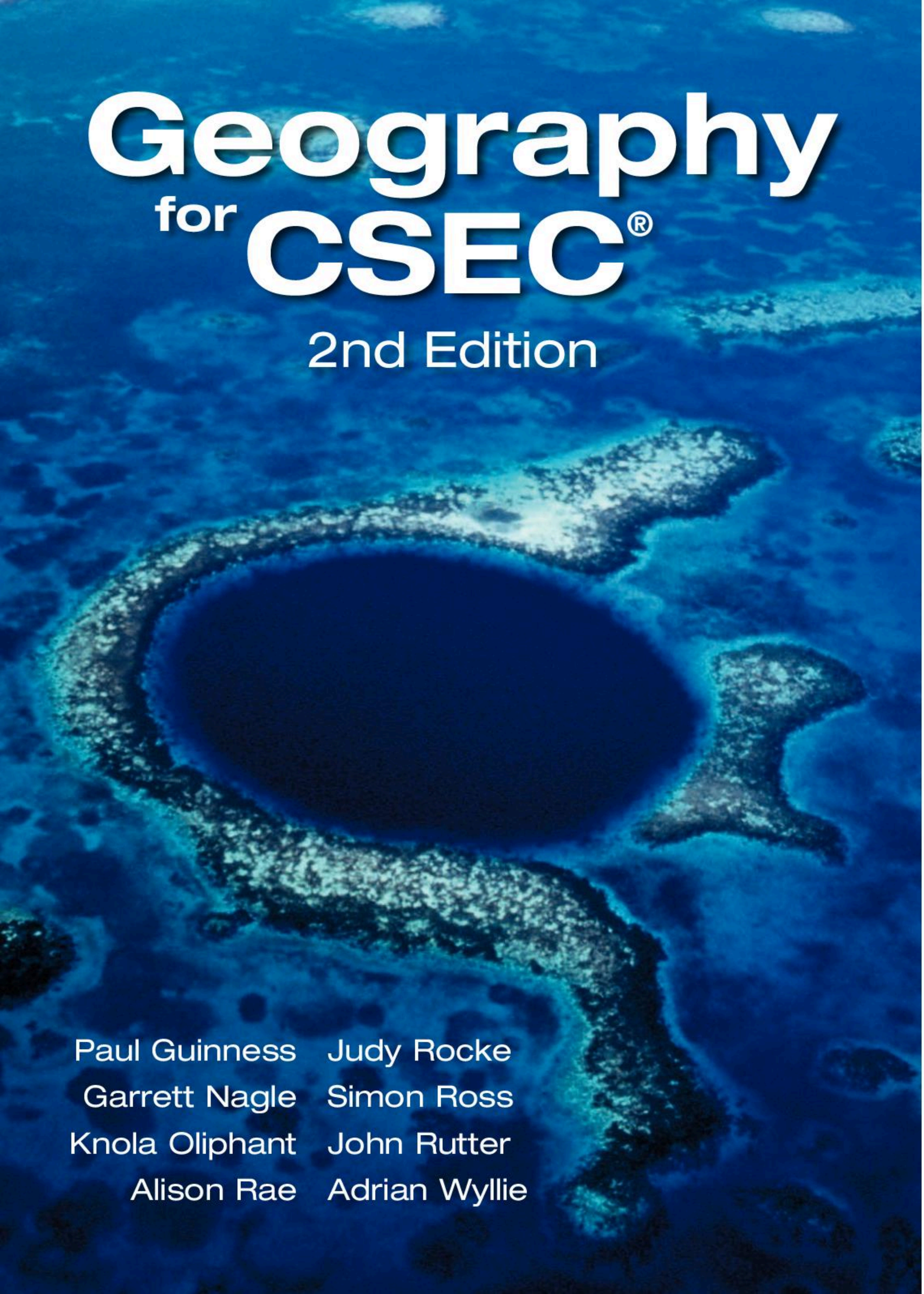

Geography for CSEC®

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CSEC Geography Links to Syllabus

The main purpose of this book is to prepare students for the CXC examinations in CSEC Geography. The book has been written by a team of experienced authors and examiners and builds on the success of the popular first edition. It presents the CSEC Geography syllabus content in a clear, concise and student friendly manner and contains many opportunities for the development of geographical skills and exam practice. The book is revised and updated to reflect the changes in the new syllabus and to meet the changing needs of Caribbean Geography students as well as those who might take an interest in this diverse subject area. It covers the major geographical issues facing the Caribbean region and the wider world such as climate change, environmental degradation and disaster management.

CSEC Syllabus sections	Chapter	Pages
Section 1		
Practical skills and field study	Practical skills are integrated throughout the book	
Section 2		
Natural systems		
Structure of the lithosphere, plate tectonics and rock formations	Chapter 1: Structure of the lithosphere, plate tectonics and rock formations Chapter 6: Limestone	7–33 107–125
Weathering and mass movement	Chapter 2: Weathering and mass movement	34–54
Weather, climate, vegetation and soils	Chapter 7: Weather and climate Chapter 8: Ecosystems	126–158 159–181
Fluvial and coastal processes	Chapter 3: Fluvial processes Chapter 4: Coastal processes Chapter 5: Coral reefs and mangrove wetlands	55–77 78–93 94–106
Natural hazards and natural disasters	Chapter 13: Natural hazards	309–336
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Human systems		
Population	Chapter 9: Population Chapter 10: Urbanisation	182–211 212–243
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Agricultural systems	Chapter 12: Agriculture	282–308
Environmental degradation and sustainable development	Chapter 14: Environmental degradation	337–352
School-Based Assessment		353–358

Contents

1 Structure of the Lithosphere, Plate Tectonics and Rock Formation

In this chapter you will study:

- the theory of plate tectonics
- types of plate boundary
- the Caribbean plate and adjacent plate boundaries
- the formation and distribution of earthquakes, volcanoes and fold mountains
- intrusive and extrusive volcanic features
- changes to volcanic features
- the rock cycle.

Your will also learn:

- how to locate a place using latitude and longitude
- about time zones
- how to use a line scale.

Theory of plate tectonics

The layers of the Earth

The Earth is made up of three main layers: the **core**, the **mantle** and the **crust** (*Figure 1.1*). These layers become more dense toward the centre of the Earth. Density is the degree of compactness, which increases with depth as a result of higher temperature and greater pressure.

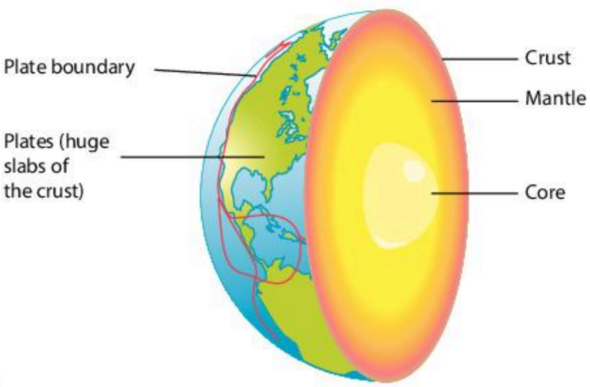


Figure 1.1 Cross-section of the Earth showing core, mantle and crust

- The core is the innermost layer of the Earth. It is very dense and extremely hot. At the centre of the Earth the temperature rises to about 5500 degrees Celsius (°C). The centre of the Earth is 6400 km below the surface.
- The mantle is between the crust and the core. It makes up 82 percent of the volume of the Earth. It extends to a depth of 2900 km.
- There are two types of crust: **continental crust** and **oceanic crust** (*Figure 1.2*)**.** On the continents silica (si) and aluminium (al) are very common. When combined with oxygen they make up the most common rock, granite. Below the oceans the crust is made up mainly of basalt where silica (si) and magnesium (ma) are dominant. Thus continental crust is called **sial**, and oceanic crust is called **sima**. Oceanic crust is continuous around the Earth's surface.

Continents occur where continental crust rests on top of oceanic crust. Oceanic crust is between 6 and 10 km thick. Continental crust can be up to 70 km thick.

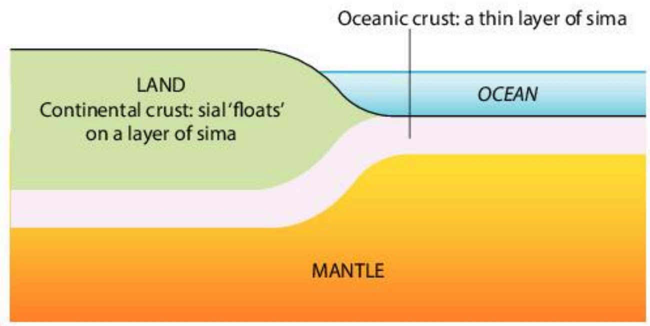


Figure 1.2 Simple cross-section showing sial and sima

The crust is very thin compared with the diameter of the Earth as a whole. If a guava represented the Earth, the skin of the guava would be about the thickness of the crust. However, the crust is not a continuous layer like the skin of a guava. Instead it is broken up into a number of large and small segments known as **plates**. The word *tectonics* comes from Greek; it means 'building'. So *plate tectonics* means 'plate building'.

History of theories

For most of human history people had no idea that the positions of the continents had slowly changed over time. However, in 1912, Alfred Wegener published his theory of **continental drift**. He said that the continents had slowly drifted apart from one super-continent called Pangaea which existed 200 million years ago (*Figure 1.3*). The evidence for this included:

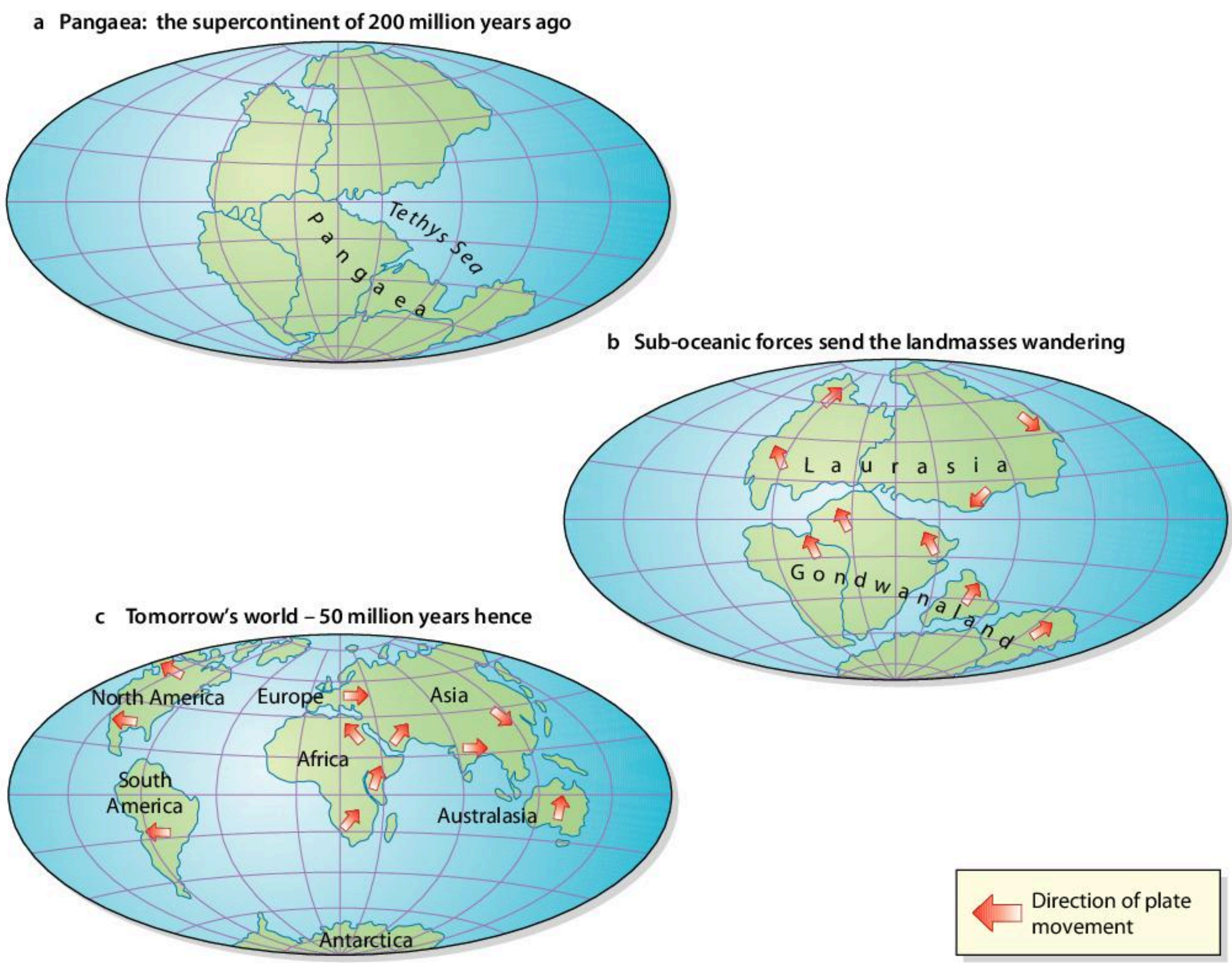


Figure 1.3 Continental drift


Figure 1.4 Soufrière, Dominica

- the fit of continents – the 'jigsaw' effect
- similar plant (India and Antarctica) and animal (South Africa and Brazil) fossils found in then neighbouring continents now separated by water
- rocks of similar type and age found at the edges of continents that could have once fitted together.

The American Harry Hess then suggested that deep convection currents would force molten rock to well up just under the crust. Eventually the increasing pressure would crack the crust and force it apart (*Figure 1.4*).

Research on rocks on the bed of the Atlantic Ocean in the 1960s supported Hess's ideas. It became clear that the newest rocks were in the centre of the ocean at the underwater mountain range known as the Mid-Atlantic Ridge, which is made up of volcanic rocks. The age of the rocks steadily increases with distance from the Mid-Atlantic Ridge.

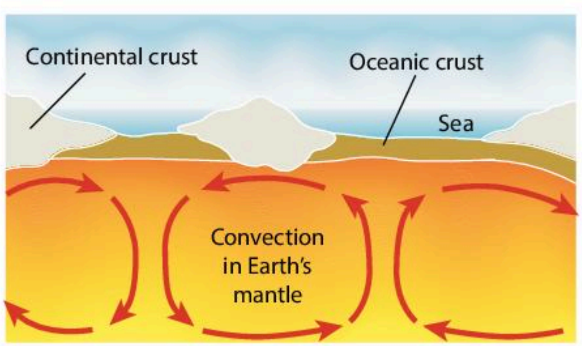


Figure 1.5 Convection currents in the Earth's mantle

In 1965 the Canadian geologist John Wilson linked the ideas of continental drift and sea-floor spreading. He introduced the idea of moving belts and rigid plates which formed the basis of the theory of plate tectonics.

Why plates move

Plates move because of what happens in the mantle below. The intense heat coming from the Earth's core causes the magma in the mantle to move very slowly in giant convection currents (*Figure 1.5*). These movements of magma are in places:

- upward toward the crust
- sideways or horizontal to the crust
- downward toward the core.

These very powerful convection currents cause the plates of the Earth's crust to move. Where the movement is upward, plates are forced apart and new crust is formed. Where the movement is downward, plates are brought together and plate material may be destroyed. Plate movement is usually no more than a few centimetres per year. The movement is usually continuous and causes no problems on the surface of the Earth. However, sometimes movement can be very sudden, causing earthquakes. Most earthquakes are small and have little effect on people. However, some are of great magnitude and have terrible consequences.

Global distribution of plate boundaries

Figure 1.6 shows the plates and the boundaries between them. There are seven very large plates:

- Pacific
- North American
- South American
- Eurasian
- African
- Indo-Australian
- Antarctic.

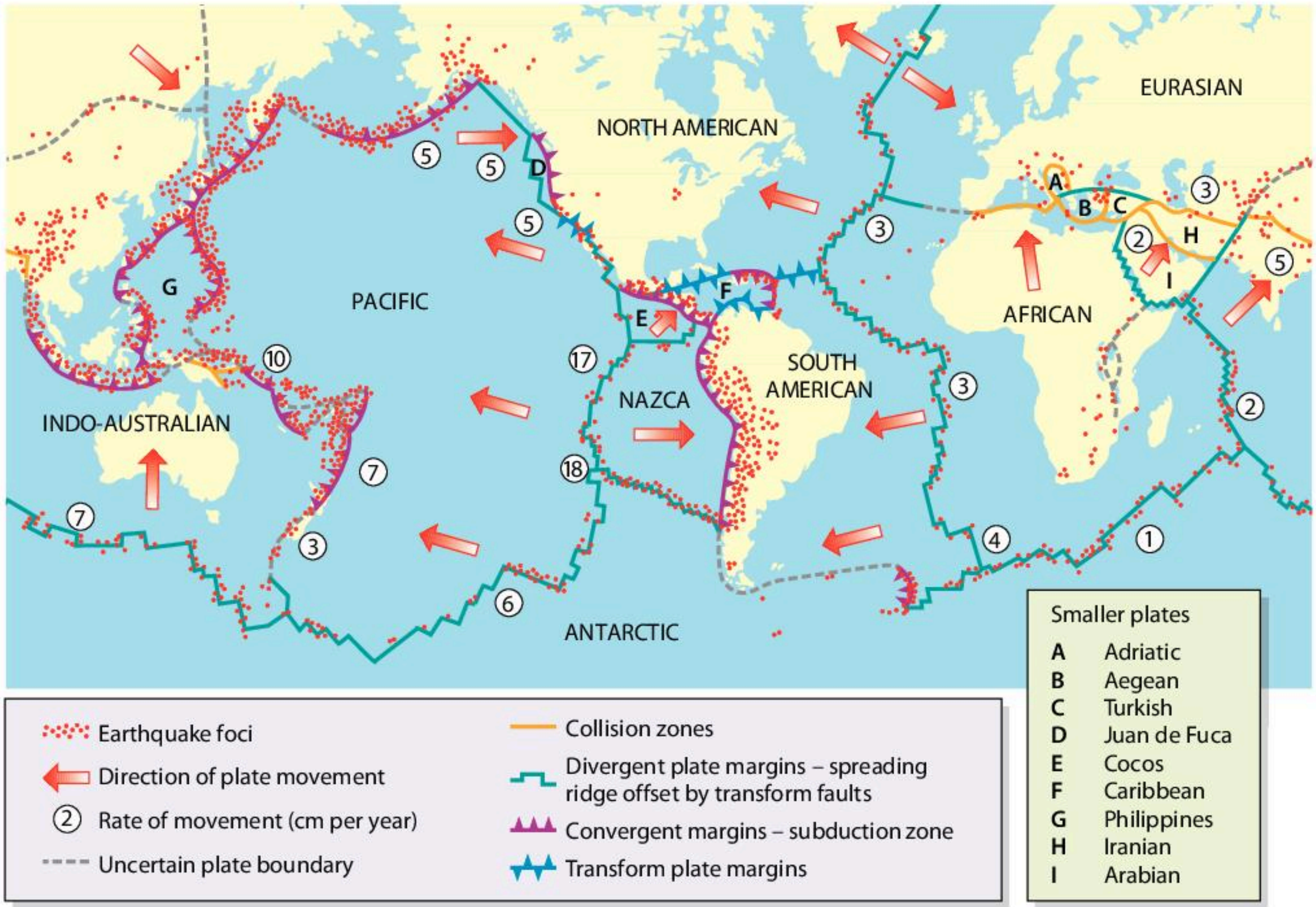


Figure 1.6 Plate boundaries and active zones of the Earth's crust

The smaller plates include the Nazca, Cocos and Caribbean plates (*Figure 1.6*).

Where plates are brought together by convection currents, either one plate is forced down into the mantle and destroyed or they are both pushed upward to form mountains. The sima which forms oceanic crust is more dense than the sial of continental crust. Where the two come together the heavier oceanic crust sinks into the mantle beneath the lighter continental crust. The continental crust is permanent.

In contrast, oceanic crust is always being formed in some places and destroyed in others. Oceanic crust is therefore younger than continental crust. In Greenland the continental crust is more than 3500 million years old but oceanic crust is nowhere older than 250 million years. The formation of new oceanic crust and the destruction of old oceanic crust is in balance as the Earth is neither shrinking nor expanding in size.

Activities

1 a What does the term *plate tectonics* mean?

b Draw a simple diagram to show the layers of the Earth and label the core, mantle and crust.

c Explain the difference between oceanic crust and continental crust.

2 a Describe the movement of the continents shown in *Figure 1.3*.

b Draw a labelled diagram to show why plates move.

c Which type of plate boundary can be found between the following plates:

- **i** Nazca and South American
- **ii** North American and Eurasian
- **iii** North American and Pacific?

Figure 1.6 also shows that most earthquakes and volcanoes are on or close to plate boundaries. However, there are a few places where volcanoes occur well away from plate boundaries. These volcanoes are caused by **hot spots**. A good example is the volcanoes that make up the Hawaiian islands.

Types of plate boundary

Divergent plate boundaries

Divergent plate boundaries (also known as 'constructive' plate boundaries) occur when two plates move away from each other. New crust is formed at the boundary as magma moves up from the mantle below (*Figure 1.7*). When this happens underwater, it is described as **sea-floor spreading**. This happens at a number of places around the world, for example along the Mid-Atlantic Ridge. This huge underwater volcanic mountain range has been formed from magma coming up from the mantle below. The lava has an unusual rounded shape and is called **pillow lava**. As it oozes out along the plate boundary it cools quickly on the ocean bed. In places volcanic cones have built up along the ridge.

Over time these underwater volcanoes may become large enough to reach the surface.

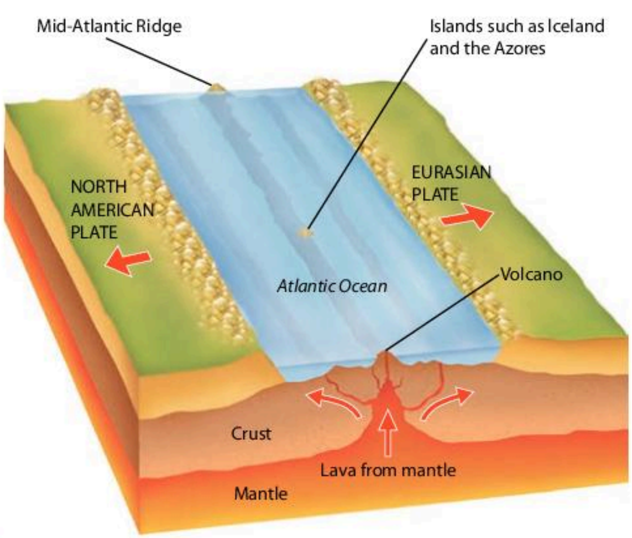


Figure 1.7 A divergent plate boundary

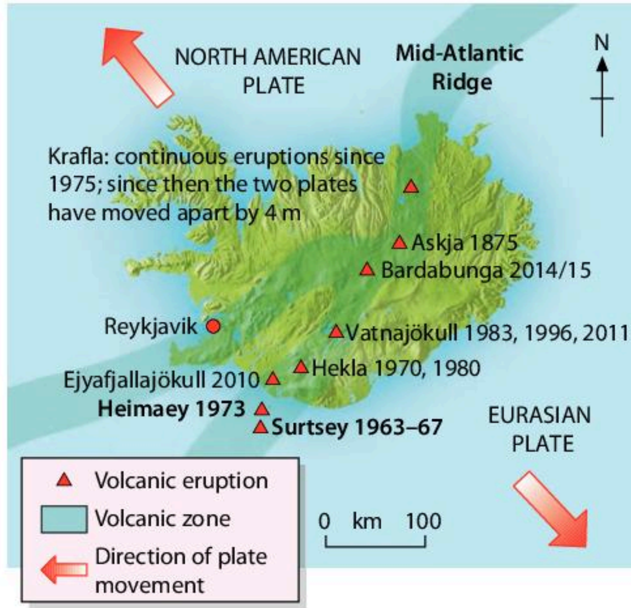


Figure 1.8 Iceland in the North Atlantic Ocean

This has happened in Iceland in the North Atlantic Ocean (*Figure 1.8*). The main island of Iceland was formed a long time ago, but in recent times two new small islands have appeared from below the sea. Surtsey was formed between 1963 and 1967, and Heimaey in 1973. *Figure 1.8* also shows the years when there were other big volcanic eruptions in Iceland.

Other islands along the Mid-Atlantic Ridge include the Azores, Ascension Island and Tristan da Cunha. Because of sea-floor spreading the Atlantic Ocean is being widened by 2–5 cm per year. Almost three-quarters of the lava that pours out onto the Earth's surface each year is found in mid-ocean ridges.

The other major mid-ocean ridges are:

- East Pacific
- Pacific-Antarctic
- South-west Indian Ridge
- Carlsberg
- Central Indian Ridge.

Where plates move apart on land, **rift valleys** are formed. In East Africa the African plate is splitting to form the Great African Rift Valley (*Figures 1.9* and *1.10*).

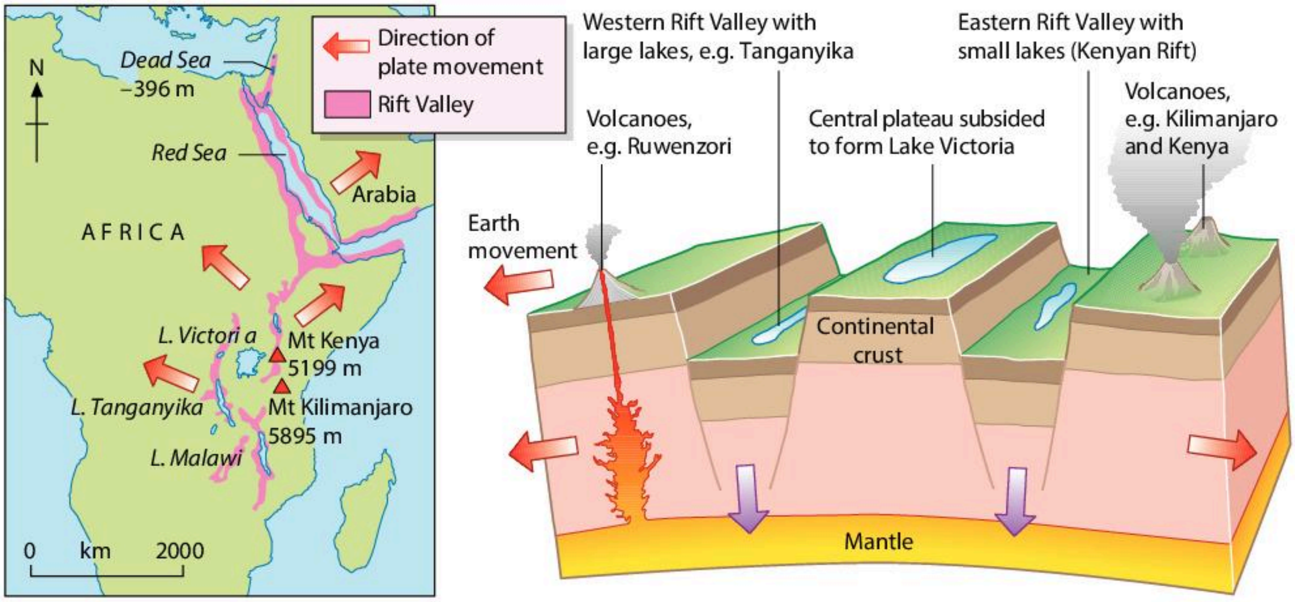


Figure 1.9 The African Rift Valley

It extends for 4000 km from the Red Sea to Mozambique. Its width varies between 10 and 50 km and its sides are up to 600 metres above the floor. This rift valley is possibly the start of the formation of a new ocean as east Africa splits away from the rest of the continent.

Convergent plate boundaries

Oceanic and continental plates come together at convergent plate boundaries (also known as 'destructive' plate boundaries). In *Figure 1.11* the Nazca plate (oceanic crust) is moving toward the South American plate (continental crust).

- A deep-sea trench (the Peru-Chile trench) or **subduction zone** occurs where the Nazca plate is forced downward into the mantle.
- The increase in pressure along the plate boundary causes the descending plate to crack. This can cause large earthquakes.
- The oceanic crust breaks up and melts to form new magma as it descends to great depths. This is due to friction and the very high temperatures as it enters the mantle.

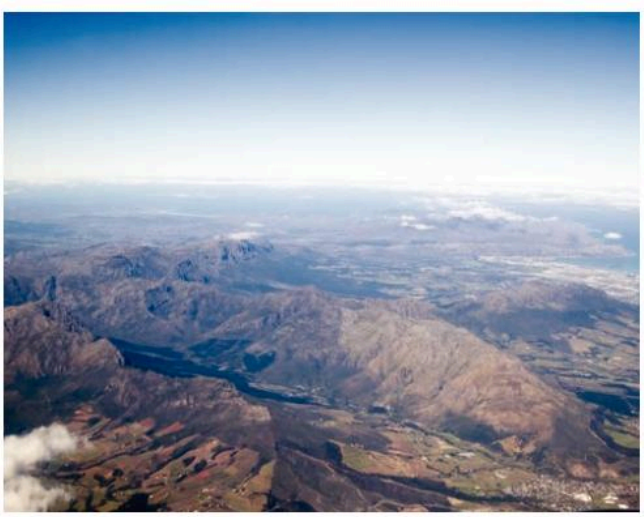


Figure 1.10 Aerial view of the African Rift Valley

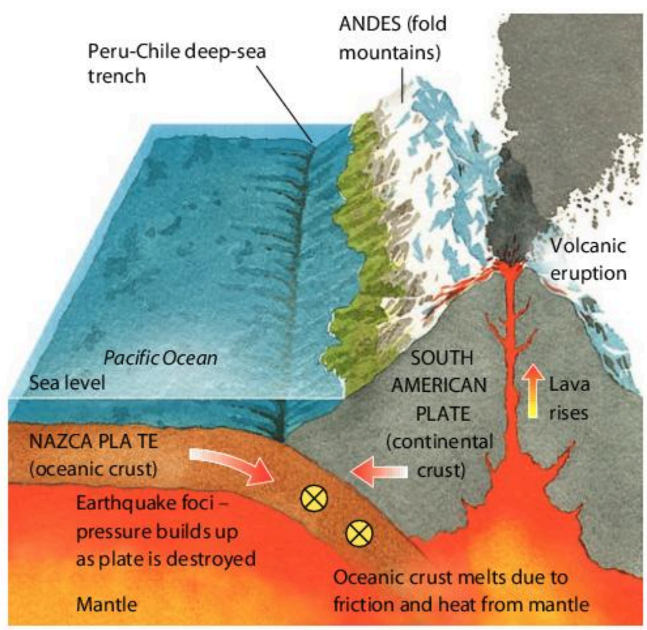


Figure 1.11 A convergent plate boundary showing a subduction zone

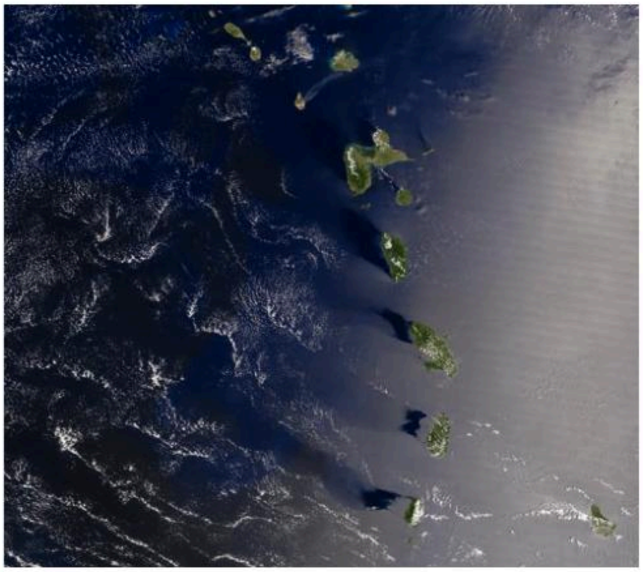


Figure 1.12 Island arc in the Caribbean – Windward and Leeward Islands

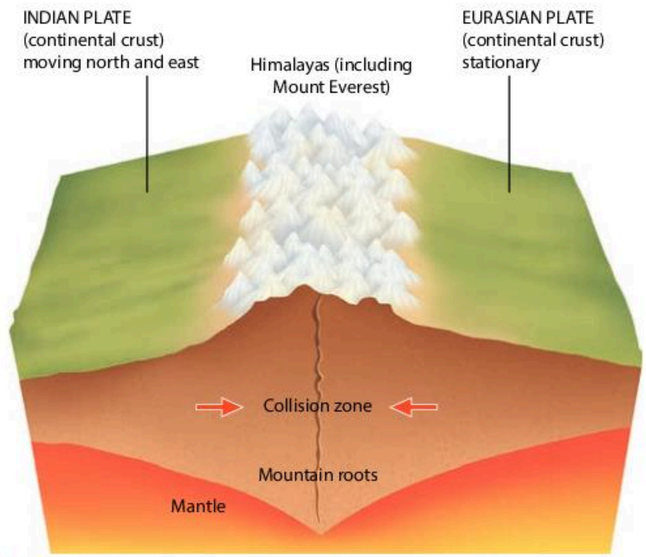


Figure 1.13 A collision plate boundary

- The newly formed magma is lighter than the mantle. Some of it may rise to the surface along lines of weakness in the crust.
- If a lot of magma rises upward volcanoes may be formed. Sometimes the magma rises through the sea floor to form **island arcs**. The Windward and Leeward Islands are a good example of an island arc (*Figure 1.12*).

The Peru-Chile trench is 8050 metres deep. The deepest trench in the world is the Mariana trench in the west Pacific Ocean which is 11 022 metres deep.

Collision zones

Sometimes two plates of continental crust come together. This is called a **collision zone**. Because continental crust cannot sink, the crust is forced upward to form fold mountains. An example is the formation of the Himalayan mountains (*Figure 1.13*). Here the Indian plate is still moving into the Eurasian plate at a rate of 5 cm a year. At times this movement causes major earthquakes. A long time in the past the Tethys Sea lay between the two land masses (*Figure 1.3*). But as the land masses slowly moved together the sea was drained away. The rock strata on the seabed were folded up to form mountains. Marine fossils found high in the Himalayas prove that these rocks were formed on the sea floor. The world's highest mountains are in the Himalayas.

Transform plate margins

Two plates slide past each other at a transform plate margin (also known as a 'conservative plate boundary'). Crust is neither formed nor destroyed, nor is there any volcanic activity. However, major earthquakes can occur. Usually the plates slide past each other very slowly without any impact on the surface. But now and then the plates 'stick'. When this happens huge pressure can build up. If the pressure is released suddenly, an earthquake occurs.

This has happened many times along the San Andreas Fault in California (*Figures 1.14* and *1.15*). In the 1906 San Francisco earthquake the surface moved by 6 metres. It measured 8.3 on the Richter scale (see Chapter 13 page 312). Over 450 people were killed and almost 30 000 buildings were destroyed.

Plate boundaries and tectonic activity: a summary

Table 1.1 summarises the relationship between earthquakes and volcanoes and the different types of plate boundary. Both can occur at convergent and divergent boundaries. However, earthquakes and volcanoes are at

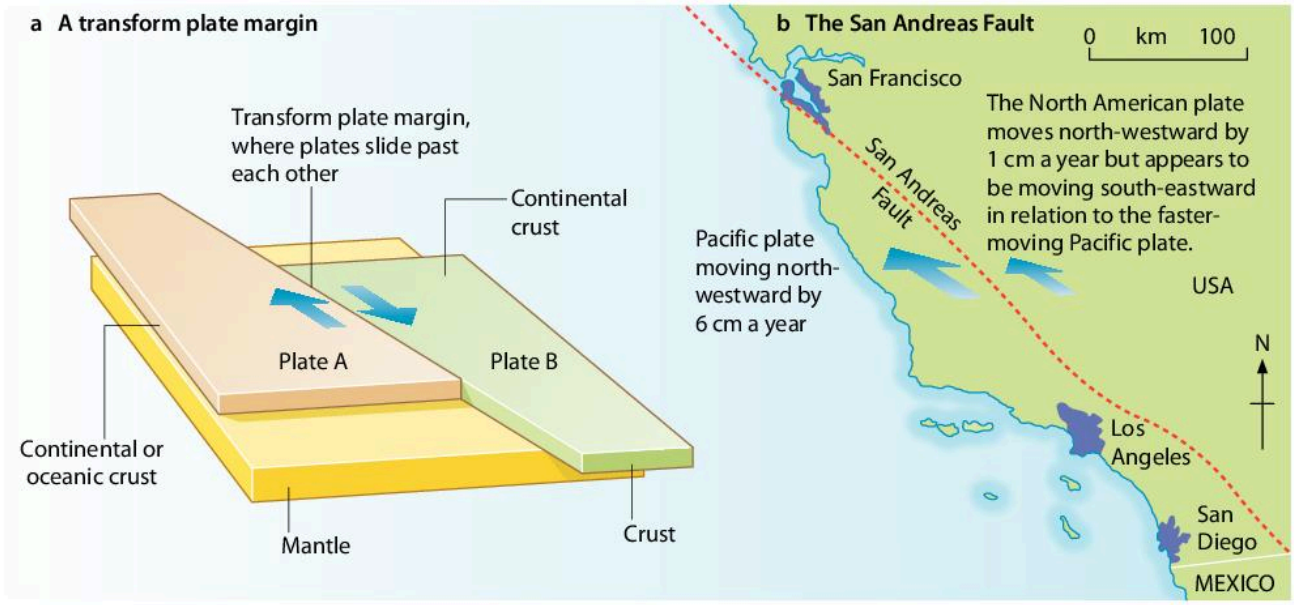


Figure 1.14 A transform plate margin

Figure 1.15 The San Andreas Fault, California

Table 1.1 Plate boundaries and the associated activity

Type of plate boundary	Earthquake/volcanic activity
Divergent plate boundaries	Gentle volcanic and earthquake activity
Convergent plate boundaries	Violent volcanic and earthquake activity
Collision zones	Earthquake activity (no volcanic activity)
Transform plate margins	Can be violent earthquake activity (no volcanic activity)

their most violent at convergent boundaries. Earthquakes occur only at collision zones and transform plate margins.

The Caribbean plate and adjacent plate boundaries

The islands of the Caribbean were formed by tectonic activity. Most people in the region live under the threat of tectonic hazards. (The exceptions are the Bahamas to the north, and Suriname and Guyana to the south. These countries are located in geologically stable continental areas.) Tectonic disasters occurring in the region in the past include:

- the 1692 earthquake when the old city of Port Royal, south of Kingston harbour, was destroyed and 2000 people were killed
- the eruption of La Soufrière volcano on Guadeloupe in 1836
- the 1902 eruption of Mount Pelée on Martinique which caused 30 000 deaths
- the St Vincent eruption of 1902–03 which killed 2000 people and devastated nearly a third of the island
- the strong earthquake in Kingston in 1907 which killed more than 800 people and

Activities

1 a What is sea-floor spreading?
   b Look at an atlas map which shows the structure of the oceans. On an outline map of the world draw in and label the mid-ocean ridges named on page 11.

2 a Describe the precise location of the African Rift Valley.
   b Draw a diagram to show how it was formed.
   c Name the two major mountains along the African Rift Valley (*Figure 1.9*).

3 a What happens at a subduction zone?
   b Where is the Peru-Chile trench?
   c Find the depth of the Mariana Trench below sea level and the height of Mount Everest above it. What is the difference in height between the two?

4 a What happens at:
   - collision zones
   - transform plate margins?

   b Explain why volcanoes do not occur in these regions.

which was followed by a devastating fire that destroyed much of the settlement

- the eruption of the Soufrière volcano on St Vincent in 1979.

Evidence of current volcanic activity can be seen, for example, in the ongoing eruption of the Soufrière volcano on the island of Montserrat and the bubbling Soufrière hot springs on the island of St Lucia. Experts believe that the main danger areas are the zone running from the Cayman Islands in the west to Haiti in the east, and the north–south volcanic island arc in the eastern Caribbean. A large earthquake has not affected these tectonic zones for some time.

Figure 1.16 shows that there are a number of plates in the region and three types of plate boundary: divergent, convergent and transform plate boundary.

- The Caribbean plate holds a central position. Most Caribbean countries lie close to its boundaries. This plate is moving eastward relative to South America.
- The North American plate is to the north and east. It is moving westward.
- The South American plate is to the south. It is also moving westward.
- The Nazca plate is to the south and west. It is moving to the east-north-east.
- The Cocos plate lies to the south-west. It is moving to the north-east.

Five tectonic zones can be recognised in the Caribbean:

- **Zone 1**: The Bahamas and Cuba lie on the North American plate. This is a geologically stable area.
- **Zone 2**: The oldest rocks in Jamaica, Hispaniola and Puerto Rico were formed as part of an island arc system 100 million years ago. There was once a subduction zone here. However, it is now a transform plate margin. Earthquakes can occur here. To the west of Jamaica there is a short divergent boundary called the Cayman Island Ridge. Gentle earthquake and volcanic activity is possible here. The Puerto Rico trench (8400 metres deep) is in this zone.
- **Zone 3**: The eastern Caribbean is an island arc. This is a chain of volcanic islands. It follows the line of the subduction zone along the edge of the Caribbean plate (*Figure 1.17*). Here the South American plate is being pushed under the Caribbean plate. The islands stretch from Saba in the north to Grenada in the south. Barbados is located to the east of the island arc. It is not a volcanic island. It was pushed to the surface by earth movements near to the plate boundary.

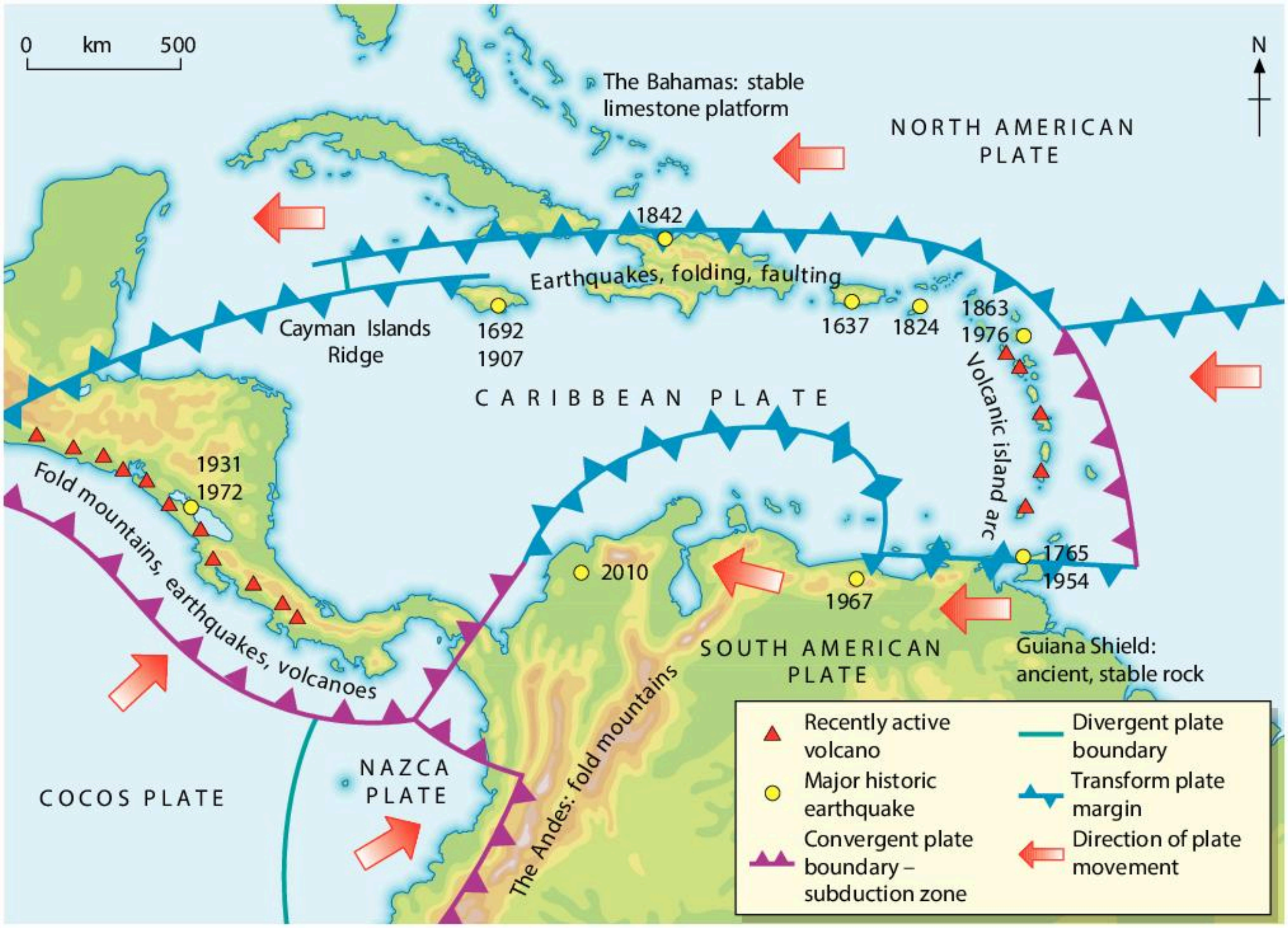


Figure 1.16 Plate boundaries in the Caribbean

- **Zone 4**: Central America and Mexico is a very complex area. There is a convergent boundary along the Pacific coast. Earthquakes are common here and there are many active volcanoes. This is an area of fold mountains.
- **Zone 5**: There are more fold mountains along the southern edge of the Caribbean, in northern Venezuela and Trinidad.

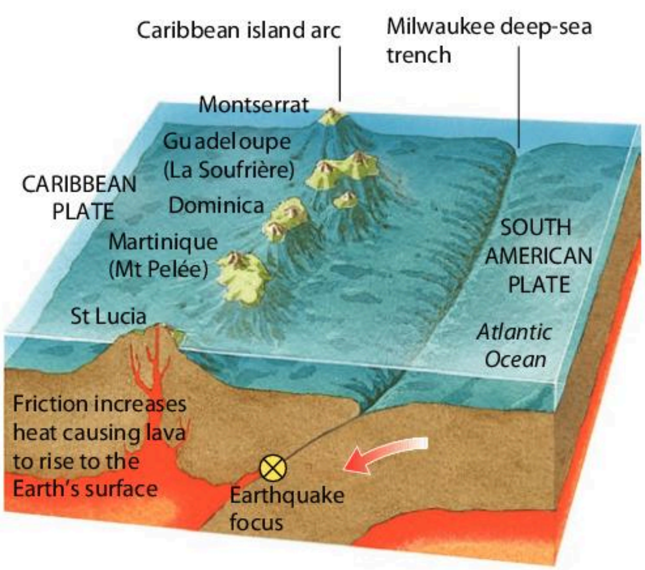


Figure 1.17 Formation of the eastern Caribbean island arc

Activities

1 In which direction are these plates moving:
  a Caribbean plate
  b North American plate
  c South American plate?

2 Which Caribbean countries are in geologically stable areas?

3 a What is an island arc?
  b Draw a diagram to show how the eastern Caribbean island arc was formed.

Formation and distribution of earthquakes, volcanoes and fold mountains

Earthquakes

Figure 1.18 shows the places where earthquakes occur most often. Some of the largest earthquakes in the 20th century are also shown on the map.

- Earthquakes result from a slow build-up of pressure along plate boundaries. This occurs when the plates 'stick'.
- If this pressure is suddenly released, a violent, jerking movement may occur on the surface. This is an earthquake.
- The point below the surface where the pressure is released is known as the **focus** (*Figure 1.19*).
- The point directly above the focus on the surface is the **epicentre**.
- The epicentre usually experiences the greatest shock or **seismic waves**.
- The vibrations due to seismic waves cause both vertical and lateral movements.
- These movements can create faults and cause partial or total destruction of buildings.
- The impact of an earthquake generally reduces with distance from the epicentre.
- The energy released by an earthquake, described as the **magnitude**, is measured on the 10-point Richter scale (see Chapter 13 page 312).
- A large earthquake can be preceded by smaller tremors known as **foreshocks** and followed by numerous **aftershocks**.

The main earthquake may last less than a minute but aftershocks can continue for several weeks afterward. Following the earthquake in Christchurch, New Zealand, in 2011 (*Figure 1.20*), many aftershocks were recorded in the following months.

Faulting deep below the surface can cause earthquakes which in turn can cause rocks above to fracture along a line known as a **fault**. However, faults can also be caused by surface movements not associated with earthquakes. A major surface movement can cause a minor

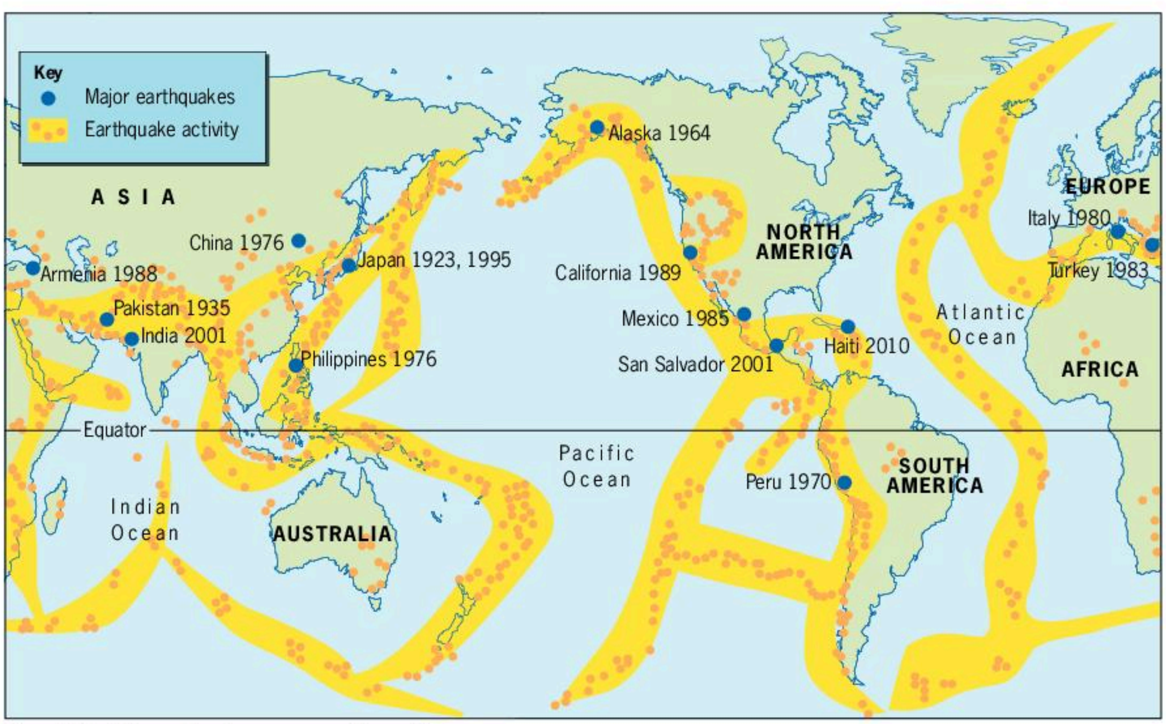


Figure 1.18 Major earthquake zones around the world

earthquake. There are different kinds of fault (*Figure 1.21*):

- **Normal fault**: rocks are pulled apart by **tension**. Movement takes place along a fault plane. A long, steep slope called an **escarpment** can be formed along a fault line. The vertical displacement (the new difference in height caused by faulting) is called the **throw**. Lateral displacement is called the **heave**.
- **Reverse fault**: rocks are pushed together by **compression**. The rocks on one side are pushed over those on the other side.
- **Transform (tear) fault**: rocks are pushed past each other in a horizontal direction.

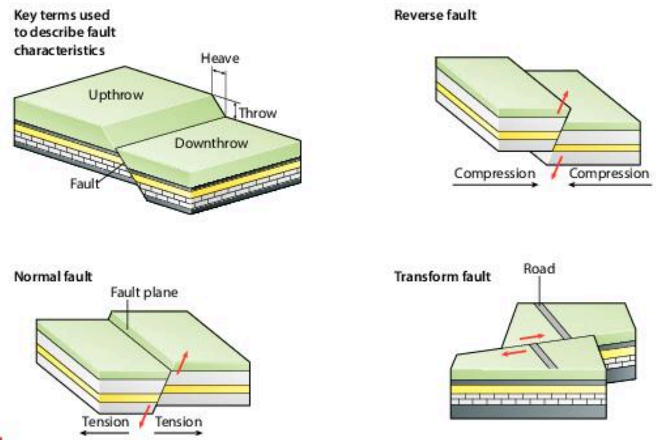


Figure 1.21 Features of faults

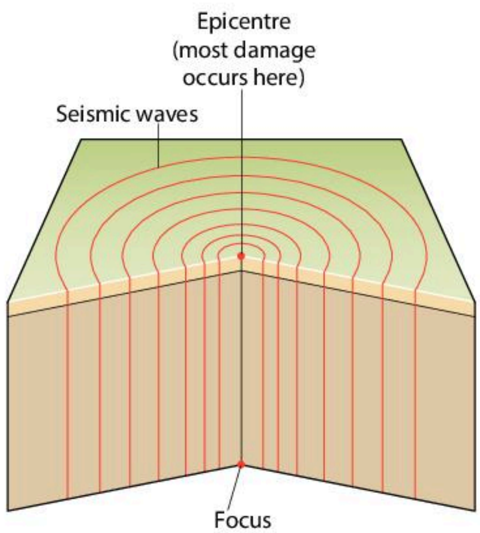


Figure 1.19 Focus, epicentre and seismic waves

Look back at *Figure 1.9* which shows the African Rift Valley. Here the faulting is very complex because there have been many earthquakes over a long period of time. As a result, there have been many movements in the area.

Large blocks of land can be pushed upward to create a block mountain or **horst** (*Figure 1.22*). A Caribbean example is Long Mountain in Jamaica. Blocks of land can also be pushed downward. This creates a rift valley or **graben**; a Caribbean example is the Takutu graben in Guyana.

Volcanoes

The name of the Roman god of fire, Vulcan, gave rise to the English word 'volcano'. A volcano is a vent, or opening in the crust, from

Figure 1.20 Reconstruction in the aftermath of the Christchurch earthquake, 2011

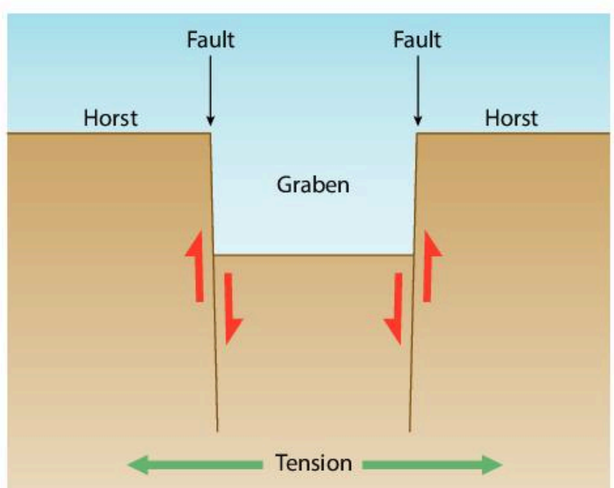


Figure 1.22 A horst and graben landscape

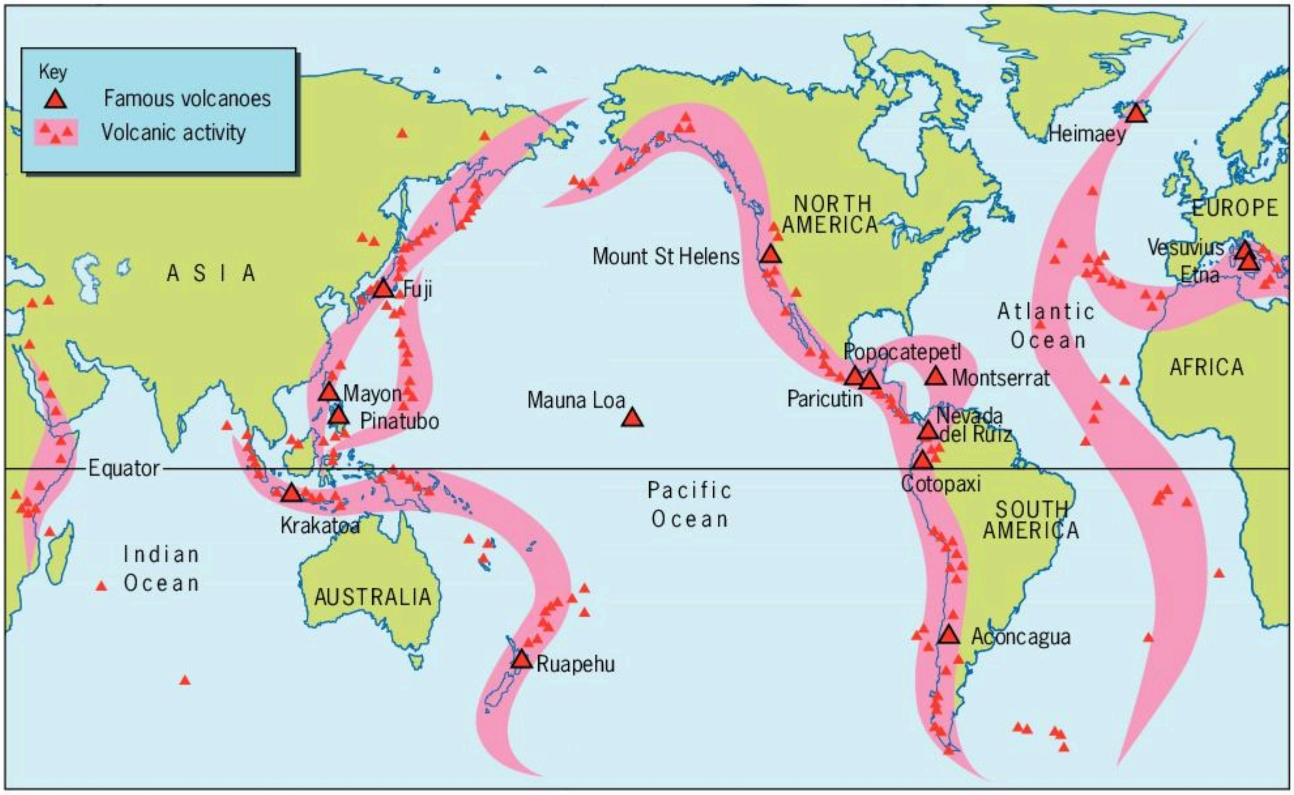


Figure 1.23 Global distribution of volcanoes

which pour molten rock, rock debris, gases and steam. When magma penetrates the surface it is known as **lava**. *Figure 1.23* shows the global distribution of famous volcanoes. Most volcanoes are found along convergent and divergent plate boundaries. Here there is molten rock or magma to supply the volcanoes. There are about 1300 potentially active volcanoes in the world today.

A small number of volcanoes are a long way from plate boundaries. These are found at **hot spots**. Here the temperature at the boundary of the mantle and crust is unusually high, and there are lines of weakness in the crust which the magma can follow to reach the surface. The Hawaiian islands, in the middle of the Pacific Ocean, have been formed in this way. Hot spots can also be found beneath continents; an example is the Yellowstone Basin in the USA (*Figure 1.24*).

Volcanic eruptions affect people and the environment in the following ways:

- **Lava flows**: these can extend over tens of kilometres, covering everything in their path.
- **Tephra**: solid material varying in size from volcanic bombs to ash particles. Air thick with ash caused the asphyxiation of many people in the town of Pompeii when Mount Vesuvius erupted in AD 79.
- **Pyroclastic flows**: a mixture of burning gases and hot rocks thrown out from a volcano

Figure 1.24 Steam vents in the Yellowstone Basin, USA

by a violent eruption. They can reach temperatures of 800 °C and travel at over 200 km/hour.

- **Volcanic gases**: these include carbon monoxide, carbon dioxide, hydrogen sulphide and sulphur dioxide. These gases can cause suffocation.
- **Lahars**: when ash combines with water (rainfall or ice-melt) a thick, hot slurry or lahar may be formed.
- **Tsunamis**: giant waves caused by the eruption of an underwater volcano, earthquake or landslide.

An average of about 50 volcanoes erupt each year. Probably the largest eruption in the last thousand years was in Tambora, Indonesia in 1815. The massive explosion pushed ash and gases high into the atmosphere causing unpredictable weather around the world for over a year. Super-eruptions large enough to cause global disasters occur on average every 100,000 years. The last super-eruption was 74,000 years ago in Toba, Indonesia.

Volcanoes usually pass through three stages in their life cycle. Volcanoes are:

- **active**: when eruptions occur at frequent intervals
- **dormant**: when eruptions are infrequent and one has not occurred for some time (*Figure 1.25*)
- **extinct**: when it is thought a volcano will never erupt again.

Figure 1.25 Dormant volcano, La Soufrière, St Vincent, last erupted in 1979

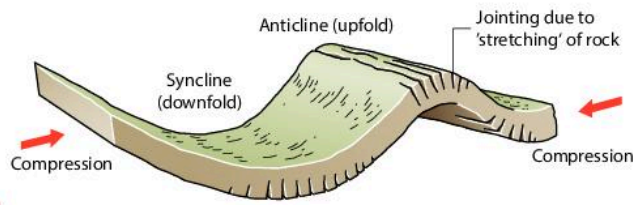


Figure 1.26 Simple folding showing an anticline and a syncline

Folding and fold mountains

Not all rocks fracture or fault when they are compressed. Some rocks buckle into **folds**. Folds can vary in scale from small ripples to many kilometres.

- An **anticline** is formed when rocks are folded upward.
- A **syncline** is formed when rocks are folded downward.

Figure 1.26 shows **simple folding** where the angle of slope from the top of the anticline is roughly the same in both directions. However, folding is often much more complex than this. *Figure 1.27* shows what can happen under major forces of compression:

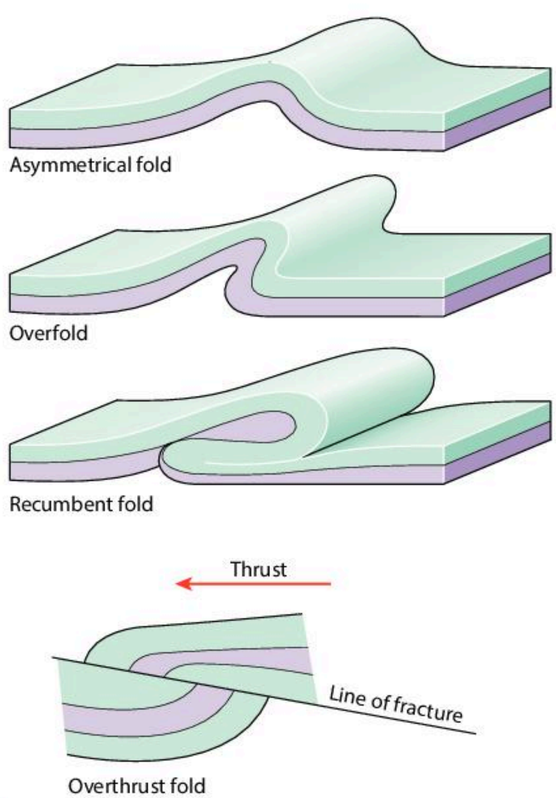


Figure 1.27 Different types of fold

Activities

1 a Describe the distribution of earthquakes shown in *Figure 1.18*.
b Explain the difference between:
i focus and epicentre
ii foreshock and aftershock.

2 a What is the difference between lava and magma?
b Why are there volcanoes in the Hawaiian Islands which are far away from the nearest plate boundary?
c In which ways can a volcanic eruption affect people and the landscape in the surrounding area?

3 a Draw a labelled diagram to show simple folding.
b What are fold mountains?
c Make a list of the two highest mountains and their altitudes in:
i the Himalayas
ii the Rockies
iii the Andes.
d Suggest one piece of evidence you might look for to prove that the sedimentary rocks of the Himalayas were originally formed below the sea.

- **asymmetrical fold**: any fold in which one limb (side of the fold) is steeper than the other limb
- **overfold**: one limb of the fold is pushed steeper than the other limb
- **recumbent fold**: one limb of the fold is pushed until it lies on top of the other limb
- **overthrust fold**: compression is so great that the crest of the fold snaps and one limb overrides the other.

All the world's great mountain ranges are **fold mountains**. They have been formed close to convergent plate boundaries or at collision zones.

The world's major fold mountain ranges show not only complex folding but also large-scale faulting. Here, large blocks of land have been forced upward as plates come together. Near convergent boundaries volcanic action over millions of years has also played an important role in mountain building.

The largest-scale example of folding in the world is the Himalayas. These mountains form a huge arc to the north of the Indian sub-continent. The mountain range is over 200 km wide and 2500 km long. It contains large areas above 8000 metres in altitude.

Intrusive volcanic features

Only a small amount of the magma that moves up from the mantle and through the crust reaches the surface. Most magma cools and solidifies (hardens) before it reaches the surface. As the magma moves upward it forces its way into lines of weakness in the rock. Bedding planes, joints and faults are all lines of weakness followed by the magma. Once magma gets into a crack in the crust the huge force behind it can cause the crack to widen.

Although intrusive volcanic features (*Figure 1.28*) are formed underground, they may be exposed millions of years later if the rocks at the surface are eroded. Because volcanic rocks are hard they are often more resistant to erosion than the rocks around

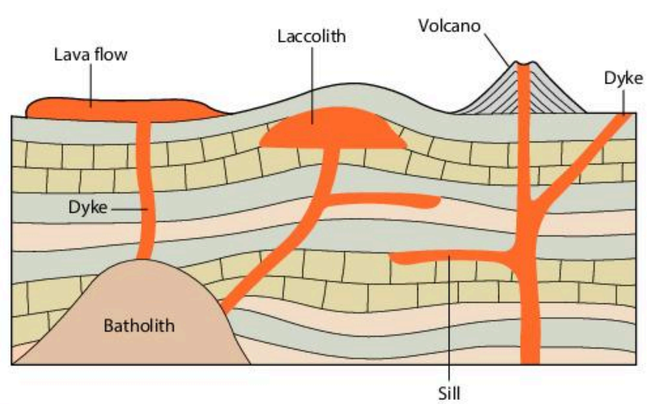


Figure 1.28 Intrusive volcanic features

them and they stand out in the landscape as higher ground.

- A **dyke** is formed when magma moving upward toward the surface cools and solidifies. The magma cuts across the **bedding planes** of sedimentary rock. Sometimes a large number of dykes, called a **dyke swarm**, can occur together in an area. An example is the Moule à Chique headland found at the southern tip of St Lucia.
- A **sill** is formed when the magma lies along the bedding planes of sedimentary rock. This may be horizontal or angled toward the surface.
- A **laccolith** is the result of large amounts of magma moving between bedding planes, causing overlying rock strata to arch upward.
- A **batholith** is much larger than the other intrusive volcanic features. It forms when a giant underground reservoir of magma cools and hardens to form granite. Batholiths can be several hundred kilometres in diameter. A batholith may form the roots of a mountain. Perhaps the best known example in the Caribbean is the Tobago batholith. It crosses the whole island from west to east, and is about half of the size of the island.
- A **plug** is a vertical column of volcanic rock which is formed in the vent of a volcano when the magma present cools and hardens (*Figure 1.29*).

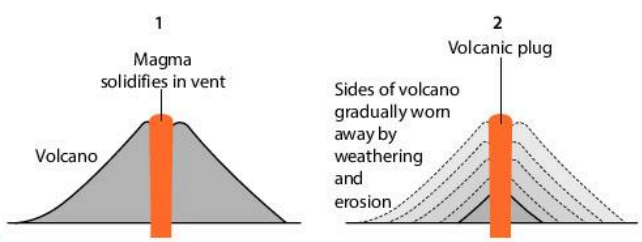


Figure 1.29 A volcanic plug

Activity

Explain clearly the difference between:
a a dyke and a sill
b a laccolith and a batholith.

Extrusive volcanic features

There are two types of lava:

- **Acidic lava** is described as being 'viscous' (thick and sticky). It is rich in silica, which makes it explosive. It solidifies on contact with air, often blocking the plug and causing pressure to build. Volcanic eruptions are violent. Acidic lava produces steep-sided volcanic landforms.
- **Basic lava** is non-viscous. It has a lower silica content, so it flows more easily. Volcanic activity is less violent and the lava may flow a long way before it solidifies. It produces landforms with lower, less steep slopes.

Extrusive volcanic features (*Figure 1.30*) are formed when magma pours out onto the surface as lava. The main extrusive landforms are:

- **Dome volcanoes**: formed by acid lava which solidifies quickly, producing a steep-sided, convex cone or dome. In most cases the lava solidifies near the crater. There are a number of good examples in the Caribbean including the lava dome formed in the crater of the Soufrière volcano, Montserrat, since recent eruptions began in 1995.
- **Ash and cinder cones**: in a violent volcanic eruption lava can be thrown to great heights where it cools and breaks into small fragments of lava known as volcanic ash/cinders. The ash falls to the surface building up a cone. An example is Parícutin in Mexico.
- **Composite cones**: composed of alternate layers of lava and ash. The ash is the result of violent eruption, while the lava is produced by more gentle eruption. Over a long period of time many layers of ash and lava can be built up. One of a number of examples in the Caribbean is the St Vincent Soufrière cone.
- **Shield volcanoes**: composed of basic lava which spreads over a wide area before solidifying. This produces a gently sloping cone which often has many layers of lava from repeated eruptions. An example is Mauna Loa on Hawaii.

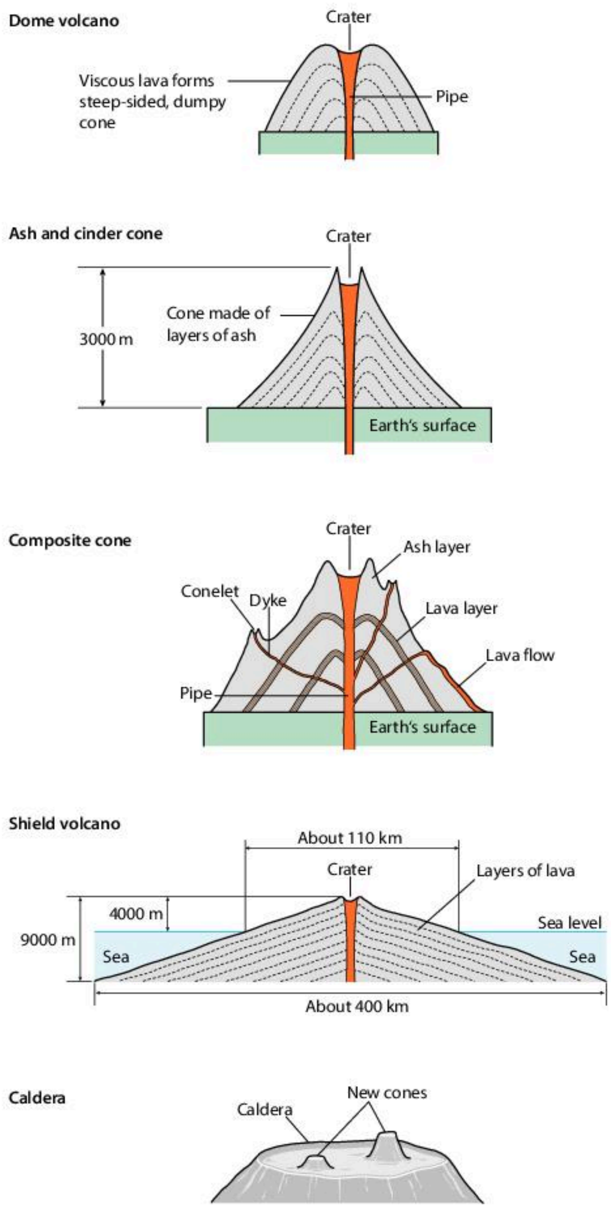


Figure 1.30 Extrusive volcanic features

- **Calderas**: a volcanic eruption may be so explosive that the whole top of the volcano sinks into the magma below. A huge crater is left which may be many kilometres in diameter. Later eruptions may form new cones inside a caldera. Lakes may form in the lowest parts of a caldera. An example is Krakatoa in Indonesia.
- **Lava [basalt] plateaus**: lava does not always reach the surface in a spectacular way. Sometimes large quantities of lava ooze out slowly onto the surface from fissures (surface cracks). These **fissure eruptions** can cause lava to spread out over a very wide area. Over time, a number of fissure eruptions in the same area can build up a high plateau. In India, the Deccan is a lava plateau which covers almost 650 000 km^2.

Activities

1 Why do some volcanoes have steep sides and others have gentle sides?

2 **a** What is a caldera?
  b Yellowstone National Park in the USA is said to be a *super-caldera*. Do some research to find out what this means.

Changes in intrusive and extrusive volcanic features

It is easy to see the impact of a volcanic eruption shortly after it has occurred. A large and violent volcanic eruption can totally alter the landscape for tens of kilometres around it. However, over time the new volcanic landscape will begin to change due to:

- erosion by rivers, glaciers, wind and the sea
- weathering – physical, chemical and biological.

Case Studies

St Lucia

There has been no major volcanic eruption on St Lucia for 40 000 years, yet the landscape has changed considerably during that time. The south and centre of the island is young and mountainous. The Soufrière Volcanic Centre (SVC) is a dramatic reminder of the island's volcanic origin. *Soufrière* is French for 'sulphur'.

The SVC is an 11 km wide crater or **caldera**. Within the caldera is a geothermal field which contains numerous hot springs, mud pools and fumaroles (steam vents). These features occur because hot molten rock remains close to the surface. Water that seeps through the surface rocks is heated by the molten rock below. The hot water moves back to the surface under pressure where it forms **hot springs**. The water contains sulphur which was dissolved from the magma below. Over time, some springs and vents have dried up while newer ones have appeared.

The Pitons in the south-west of St Lucia (*Figure 1.31*) are resistant lava plugs left standing like pinnacles. The rest of the volcanoes that surrounded the plugs have been worn away by weathering and erosion. Grand Piton and Petit Piton both rise from the sea to over 750 metres; they are the most dramatic landforms on St Lucia. The older northern part of St Lucia has been so worn down by erosion that the outlines of the old volcanoes are no longer recognisable.

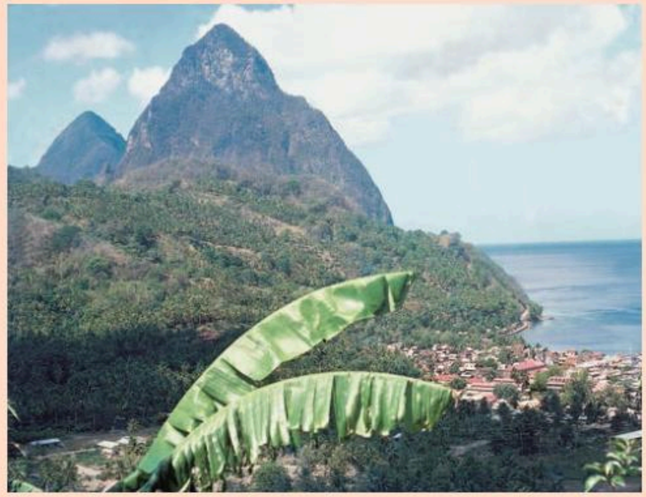


Figure 1.31 The Pitons, St Lucia

St Vincent

On St Vincent, although the Soufrière is young, some deep, narrow gullies have already been cut into it by the streams that flow off its slopes after heavy rain. They radiate like the spokes of a wheel.

Lava plateaus

Figure 1.32 shows how the landscape of a lava plateau can change over time due to the effects of erosion and weathering. River action causes the most dramatic changes (*Figure 1.33*).

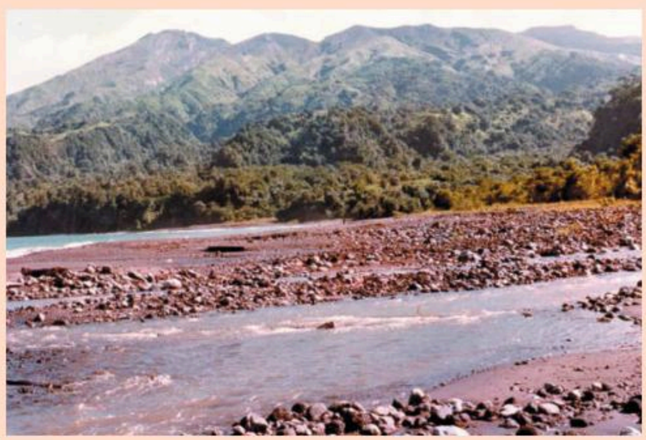


Figure 1.33 La Soufrière, St Vincent

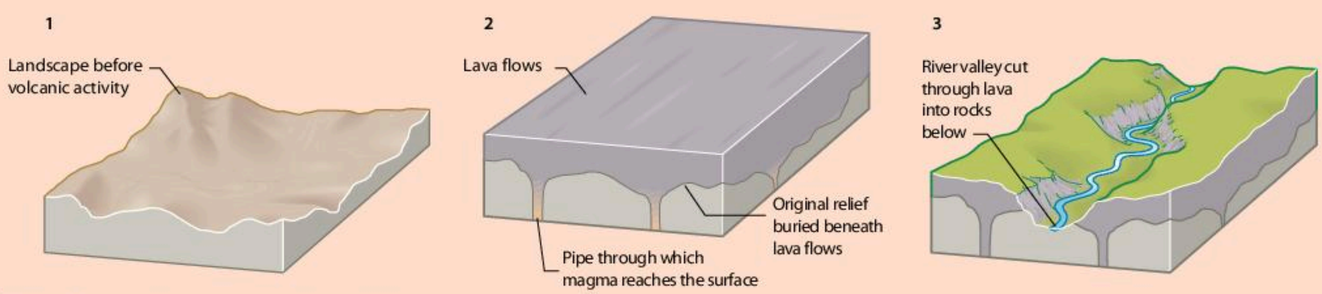


Figure 1.32 Formation and erosion of a lava plateau

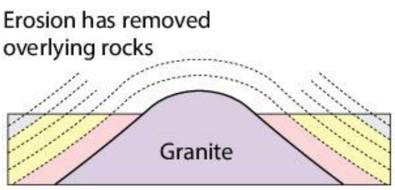


Figure 1.34 Batholith exposed by the erosion of surface rocks

Batholiths

Batholiths are usually formed deep underground, but the erosion of softer surface rocks can expose these huge granite features at the surface. Erosion of a granite batholith can result in the formation of **tors**.

Sills and dykes

Some sills and dykes (see pages 21 and 22) are harder and more resistant than the surrounding rocks and stand out in the landscape as ridges after the surrounding rocks have been worn down by erosion (*Figures 1.35* and *1.36*). Sills can form ridge-like escarpments when the overlying rocks are eroded. Sills and dykes can also result in waterfalls and rapids when they are crossed by rivers.

Figure 1.35 Whin Sill – a striking feature of the landscape in northern England

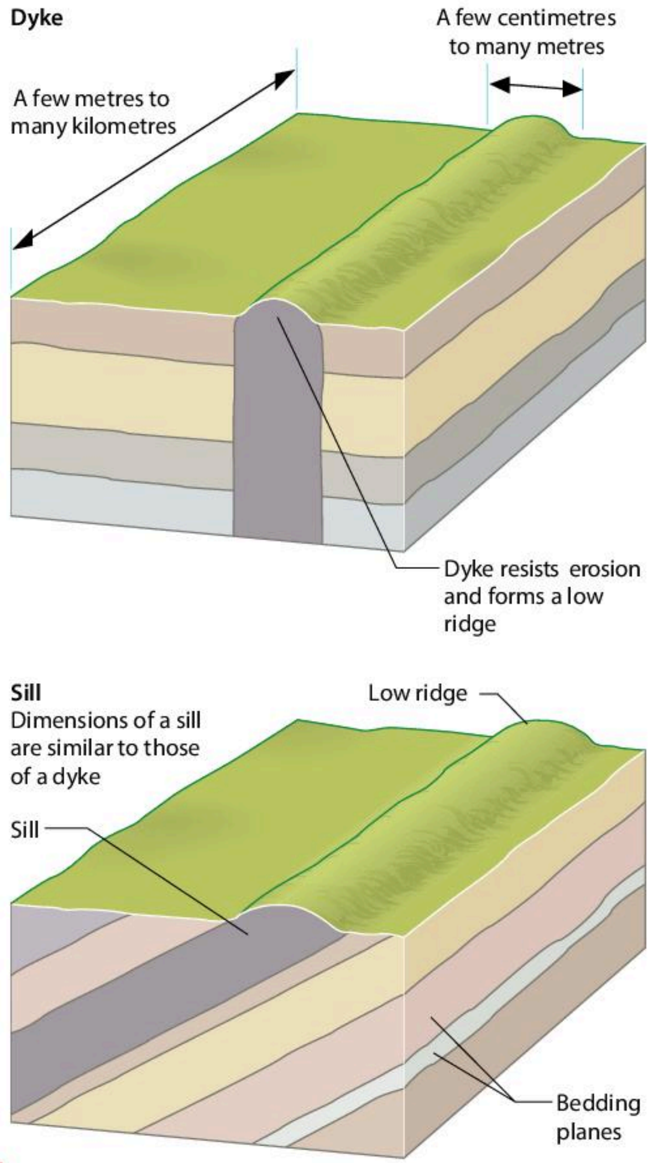


Figure 1.36 Dyke and sill exposed by the erosion of overlying rocks

Activity

Using no more than 100 words, explain how volcanic features can change over time.

Case Study

The Soufrière volcano in Montserrat

The island of Montserrat forms part of the island arc in the eastern Caribbean. This is a chain of volcanic islands formed where the North American plate is forced under the Caribbean plate. There are at least 15 potentially active volcanoes along the island arc. The Soufrière Hills volcano in southern Montserrat is currently the most active. Montserrat is only 16 km long and 10 km wide. It is built almost entirely of volcanic rocks.

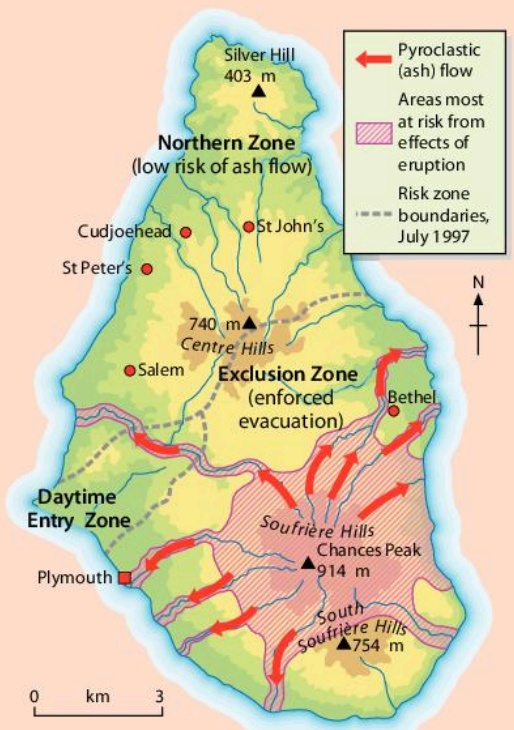


Figure 1.37 Montserrat

During the last 120 years there have been several earthquake crises associated with the volcano: in the 1890s, the 1930s and the 1960s. The earthquakes were accompanied by the increased activity of fumaroles on the sides of the volcano. During these periods it is likely that magma rose up below the volcano but failed to reach the surface.

Figure 1.38 Montserrat volcano and the town of Plymouth

The volcano had been dormant for almost 400 years. In 1988, scientists suggested there was likely to be an increase in volcanic activity on the island. Earthquakes were felt in 1992 and the present period of eruption began in July 1995. The Montserrat Volcano Observatory (MVO) was set up soon after the first eruption in 1995 to monitor volcanic activity and provide advice to civil authorities.

Lava was seen for the first time in November 1995 and local residents were evacuated from the area likely to be affected by an eruption. In the following month, December, a second evacuation of southern Montserrat took place. In June 1997, nineteen people died within the exclusion zone due to a **pyroclastic flow**. A major dome collapse destroyed the W H Bramble Airport terminal building. Plymouth, the capital, was abandoned following the 1997 eruption. *Figure 1.37* shows that the town is less than 5 km from the Soufrière Hills. Over 5000 people moved off the island, while others moved to safety in the north. Over half of Montserrat was covered in a thick layer of ash.

Figure 1.39 A church buried by the Montserrat eruption

By early 2007 there had been five phases to the eruption:

1 A period of extrusion from 1995 to early 1998: the volcano's dome grew and collapsed a number of times.

2 Early 1998 to late 1999: no extrusion of lava. Small to moderate size explosions. Several collapses of the dome.

3 November 1999 to July 2003: lava extrusion and the growth of a large lava dome. Three major collapses of the dome.

4 August 2003 to July 2005: no extrusion of lava. Occasional ash and steam venting, pyroclastic flows and explosive eruptions.

5 August 2005: renewed lava extrusion. Dome growth and collapse.

The southern part of the island remains an exclusion zone. However, there is a small Daytime Entry Zone where vehicles can enter if it is considered safe to do so. In contrast, the north is experiencing rapid development. There has been a large increase in housing in St John's. Roads have been improved in the area, as have port facilities. Government offices have been relocated to St John's. New service industries have developed in Salem and there has been an increase in ecotourism and adventure tourism.

Between 1995 and 2015 the volcano has had five phases of lava extrusion and five pauses. At the time of writing (late 2015) the level of volcanic activity was very low. There has been no surface activity since February 2010.

Table 1.2 Alert levels for the Montserrat volcano

Alert level	Volcanic activity
0	Background earthquake activity but no new surface evidence of volcanic activity.
1	Low-level earthquake activity, ongoing ground deformation. May be mild heating of underground water.
2	Dome building in progress within crater, or small to moderate explosions of water and/or steam. Low to moderate levels of rockfall activity, pyroclastic flows and associated light ash fall. Low to moderate long-period earthquake activity, low-level tremors.
3	Confined dome growing rapidly, or growing to west or north; or unconfined dome growing to east or south. May be high levels of gas or long-period earthquake activity, or moderate tremors. Moderate to high levels of rockfall and pyroclastic flows with associated light to moderate ash fall.
4	Large unconfined dome growing to north or west; or large dome with high levels of pyroclastic flow in other directions; or intense earthquake activity; or tropical storm imminent or already affecting island.
5	Major dome collapse with pyroclastic flows and heavy ash fall. Explosive event possible; or other obvious signs and accelerating activity indicative of imminent explosion/eruption.
The designation of an alert level is a decision based on a combination of observational evidence relating to the behaviour of the volcano, past experience, and scientific judgement.	

The rock cycle

The rocks on the Earth's surface are in a constant state of change due to a variety of physical processes such as weathering, erosion, transport and deposition. The changes that occur in surface rocks are referred to as the **rock cycle**. The three rock types are:

- igneous
- sedimentary
- metamorphic.

Igneous [Latin: *ignis* – fire] rocks such as granite and basalt are formed from the crystallisation and solidification of magma. The main mass of the Earth's crust is composed of rocks which have solidified from a former molten state. However, igneous rocks do not form the ground surface over large areas of the world because they have been:

- buried under layers of sedimentary rocks of later origin such as limestone and sandstone
- changed in structure by intense heat and pressure to form metamorphic rocks.

If cooling of magma takes place rapidly, as is usual on the Earth's surface, then fine-grained rocks such as basalt are formed. If cooling is slow, as usually happens at depths below the Earth's surface, then coarse-grained rocks such as granite are formed. Igneous rocks:

- are often very hard
- rarely show any layering
- do not contain fossils.

Sedimentary rocks are formed by the accumulation of material derived from the erosion and weathering of pre-existing rocks (inorganic sediments) and from organic sources (organic sediments). The pre-existing rocks providing sedimentary material may be:

- igneous
- metamorphic
- older sedimentary rocks.

Figure 1.40 The Giant's Causeway, Northern Ireland

Sediments are deposited in layers and consolidated by the weight of overlying sediments, a process known as **lithification**. Sedimentary layers are separated by **bedding planes**. Sediments accumulate in environments such as:

- deep oceans
- continental shelfs
- lakes
- large river valleys.

Many areas of sedimentary rock, particularly those formed by limestone, were formed by organic processes. For example, the chalk that covers considerable areas of southern England (*Figure 1.41*) was formed when this part of the world was covered by warm tropical water. These warm waters were inhabited by trillions of tiny sea creatures called **coccoliths**. When they died their bones and shells accumulated on the sea floor to be gradually compacted by the weight of new overlying sediments. Hundreds or even thousands of metres thick of sedimentary rock was formed in this way.

During the Alpine moutain-building period about 30 million years ago, the chalk and the inorganic sedimentary rocks above it (such as sandstone and clay) were pushed up to form land. Since then these rocks have been weathered and eroded. In this way they have contributed to the rock cycle.

Figure 1.41 Chalk landscape, southern England

Figure 1.42 Metamorphic rock (marble)

Metamorphic rocks have been altered from their original state by intense heat and pressure, generally as a result of:

- mountain-building (orogeny)
- the intrusion and extrusion of magma.

Metamorphic rocks are either igneous or sedimentary in origin. Examples of metamorphism are the transformation from:

- sandstone to quartzite
- limestone to marble
- mudstone to gneiss.

Skills

Longitude and latitude

Any place on the Earth's surface can be located exactly by its latitude and longitude. The Equator divides the world into the northern hemisphere and the southern hemisphere. Every point on the Equator is exactly between the north pole and the south pole. Lines of latitude are parallel to the Equator. They decrease in diameter from the Equator to the poles. On a world map they run from west to east.

Both latitude and longitude are measured in degrees, minutes and seconds. The Equator is at 0 degrees (0°) latitude. The north pole is 90° north latitude. This is because lines from the north pole and the Equator meeting at the centre of the Earth form an angle of 90°. The south pole is 90° south for the same reason. If a place is 45° north it is because lines from that place and from the Equator meeting at the centre of the Earth form an angle of 45°.

There are five major circles of latitude. These are the Equator, the tropics of Cancer and Capricorn, and the Arctic and Antarctic circles. The tropic of Cancer [23.5° N] is the most northerly position where the sun shines directly down onto the Earth's surface at an angle of 90 degrees. The tropic of Capricorn [23.5° S] is the most southerly position where the sun shines directly down on the Earth's surface at an angle of 90 degrees. During summer in the northern hemisphere the duration of daylight hours increases toward the North Pole. It reaches daylight for a whole 24 hour period on 21 June at 66.5° N. This is the significance of the Arctic Circle. In the southern hemisphere, the Antarctic Circle [66.5° S] plays the same role.

Because the Earth is a sphere, its circumference decreases from the equator to the poles. At the Equator the circumference is 40 075 km. At the Arctic Circle it has been reduced to 17 602 km.

One **degree** of latitude covers a distance of 111 km. Because this is quite a long distance, a degree of latitude is divided into sections known as **minutes**. There are 60 minutes (60') in a degree. Thus the latitude of Kingston, Jamaica is 18° 0' N while London, UK is 51° 30' N. A minute measures 1.85 km. For an absolutely precise location **seconds** are also used. A minute is divided into 60 seconds (60"). A second measures 31 metres.

1 Give the latitude of each of the following:
   a Miami, USA
   b Nassau, Bahamas
   c Port of Spain, Trinidad
   d Georgetown, Guyana.

Lines of longitude (or meridians) link the north and south poles. They are at right-angles to the Equator. Just as the Equator is the main point of reference for latitude, Greenwich in the UK provides a similar function for longitude. The line of longitude that passes through the old Royal Observatory in Greenwich is known as the Prime Meridian (0° longitude). The longitude of any other place is referred to as being east or west of Greenwich. It is measured by an angle at the centre of the Earth from the Prime Meridian. Because each line of longitude encircles the whole of the globe, the maximum longitude is 180°, which is on the opposite side of the world from Greenwich.

2 Which capital cities are found at the following locations?
   a 6° 50' N, 58° 12' W
   b 38° 54' N, 77° 2' W
   c 13° 6' N, 59° 37' W
   d 10° 40' N, 61° 31' W

Longitude and time zones

Daylight occurs when a place on the Earth's surface is facing the sun. When a place is facing away from the sun it is night. The Earth rotates on its axis (makes a full turn) once every 24 hours. One rotation makes a circle of 360°. This means that it moves 15° every hour ($24 \times 15 = 360$).

The world is therefore divided into 24 standard time zones (*Figure 1.44*). Each is centred on lines of longitude at 15° intervals. The Prime Meridian, or Greenwich Meridian, is at the centre of the

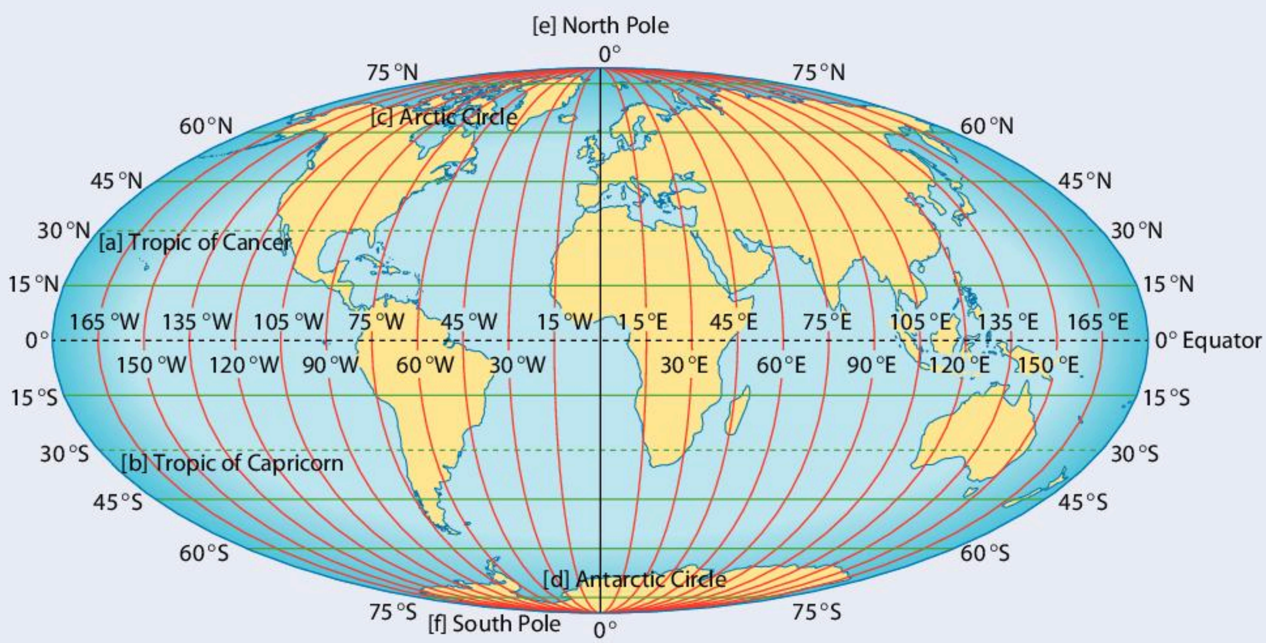


Figure 1.43 Lines of latitude and longitude

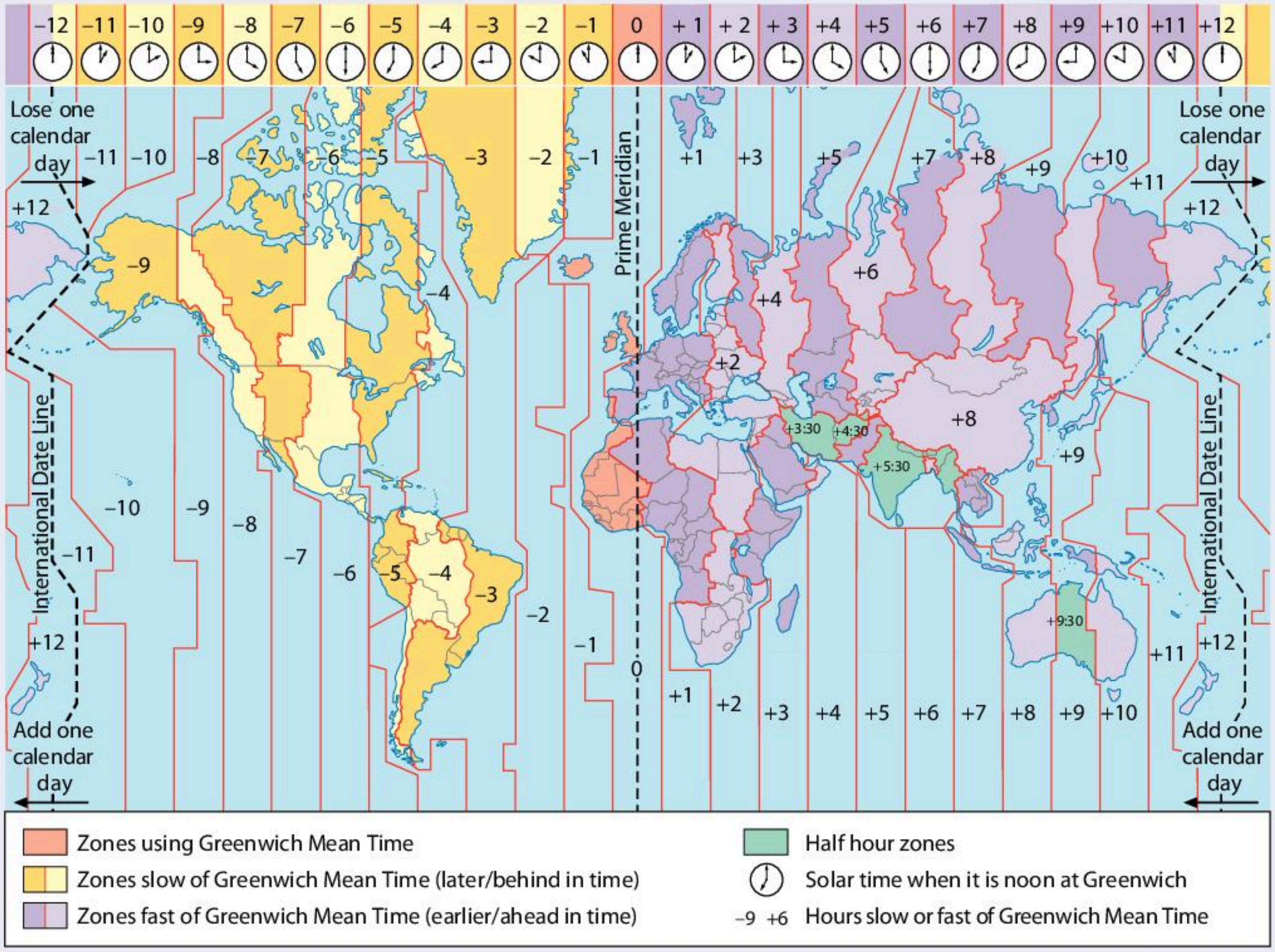


Figure 1.44 Time zones

first zone. All places to the west of Greenwich (which is in London, England) are one hour behind for every 15° of longitude. Places to the east are ahead by one hour for every 15°.

The sun rises in the morning in the east. Its angle is very low at first but gradually it appears to move higher into the sky. When the sun reaches its highest position in the sky over a place it is said to be 12 noon Local Time along this line of longitude. When the sun is highest in the sky at Greenwich it is 12 noon Greenwich Mean Time or GMT. After noon the angle of the sun declines until sunset. The sun sets in the west.

Most countries have just one time zone. This means it is the same time everywhere in that country. This applies to every individual country in the Caribbean, although the Caribbean region has three time zones.

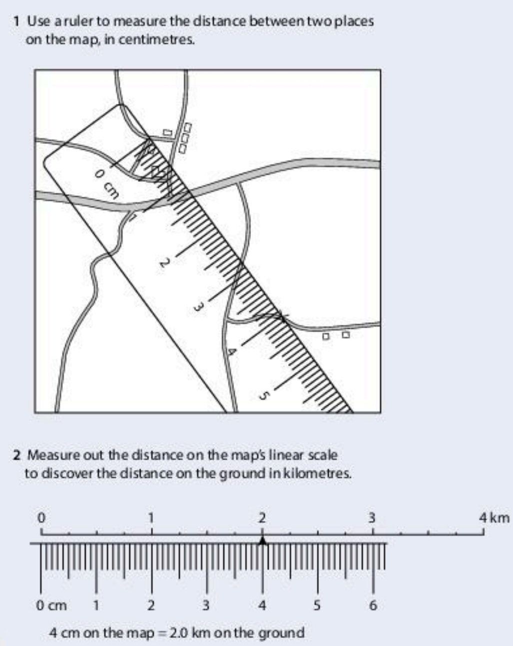


Figure 1.45 A line scale used in measuring distance

However, some countries are so wide, covering many degrees of longitude, that they need more than one time zone. Russia has eleven and Canada has six.

3 Using *Figure 1.44*, how many time zones are there in:
- the USA
- Australia
- Brazil?

Using a line scale

All maps should have a line scale. This gives important information about distance on the ground compared with distance on the map. *Figure 1.45* is a line scale for a 1:50000 map. Place a ruler alongside the line scale and notice that 1 kilometre on the ground is represented by 2 cm on the line scale (the map). So if you were to measure the distance between two places on a 1:50000 map as 6 cm, this would represent 3 km on the ground.

- What would a distance of 18 cm represent on the ground?
- What would be the length of a map line representing a ground distance of 5 km?

Glossary of terms

Collison zone: an area where two plates of continental crust come together.

Continental drift: the breakup of the super continent Pangea as land masses drifted apart to eventually form the present structure of continents.

Convergent plate boundary: where oceanic and continental plates collide.

Core: the innermost part of the Earth.

Crust: the thin outer shell of the Earth.

Divergent plate boundary: where plates move away from each other and new material emerges from the mantle.

Epicentre: the point on the Earth's surface directly above the focus of an earthquake.

Fault: A fracture of the Earth's crust where rocks have been displaced either vertically, horizontally or at some intermediate angle.

Focus: the point of origin of an earthquake within the Earth from which seismic waves are generated.

Fold: Buckling [folding] of the Earth's crust, varying in scale from small ripples to many kilometres.

Fold mountains: Mountains formed by folding on a massive scale close to convergent plate boundaries or at collison zones.

Hotspot: An area of volcanic activity distant from plate boundaries. Here the temperature at the boundary of the mantle and crust is unusually high.

Igneous extrusions: where molten rock is forced to the Earth's surface, forming a variety of landforms such as lava flows and volcanoes.

Igneous intrusions: molten rock which cools and solidifies below the Earth's surface. These igneous rocks may be exposed by later erosion of the overlying rocks.

Island arc: a chain of volcanic islands located on the continental side of an ocean trench.

Latitude: an imaginary line [a circle] around the earth running parallel to the Equator. It is the angular distance north or south from the Equator.

Longitude: imaginary lines drawn through the North and South Poles, used to measure distance east and west. Greenwich, England, is designated as 0 degrees, with other distances being measured east and west of Greenwich.

Lava: molten material which flows on the surface.

Magma: molten material from the mantle under the Earth's surface.

Mantle: the layer between the core and the crust.

Ocean trench: landform on the ocean floor marking a subduction zone.

Plate: a large section of the Earth's crust.

Sea-floor spreading: the gradual widening of ocean areas as new crust is formed at divergent plate boundaries.

Seismic waves: shock waves emanating from an earthquake.

Subduction: the process at convergent plate boundaries where dense oceanic crust is forced below lighter continental crust.

Transform plate margin: where plates slide past each other.

Ideas for SBA

- *What are the characteristics of volcanic origin in a specific area in your country?*

Exam-style Practice

1 a Make a copy of Figure 1. Insert the following labels in the correct places: *oceanic plate, continental plate, deep-sea trench, fold mountains, earthquake zone, magma rising.* [6]

b Give TWO examples of convergent plate boundaries. [2]

c Name TWO fold mountain ranges. [2]

d Explain how movements in the mantle cause plates to come together. [6]

e Why do earthquakes occur at convergent plate boundaries? [6]

f Name TWO other types of plate boundary where earthquakes occur. [2]

Total 24 marks

2 a Make a copy of Figure 2. Insert the following labels in the correct places: *batholith, laccolith, sill, dyke, lava flow, volcano.* [6]

b What is the difference between intrusive and extrusive volcanic features? [2]

c Name TWO extrusive volcanic features. [2]

d Name TWO volcanoes in the Caribbean region. [2]

e Explain how any two volcanic intrusions are formed. [6]

f i What is a caldera? [2]

ii How is a caldera formed? [4]

Total 24 marks

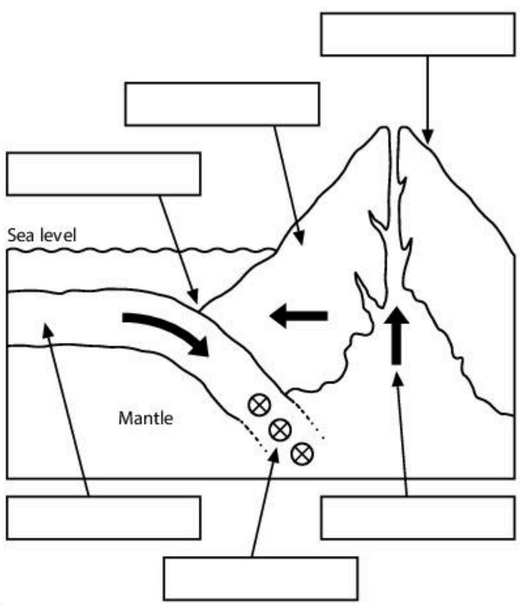


Figure 1 A convergent plate boundary

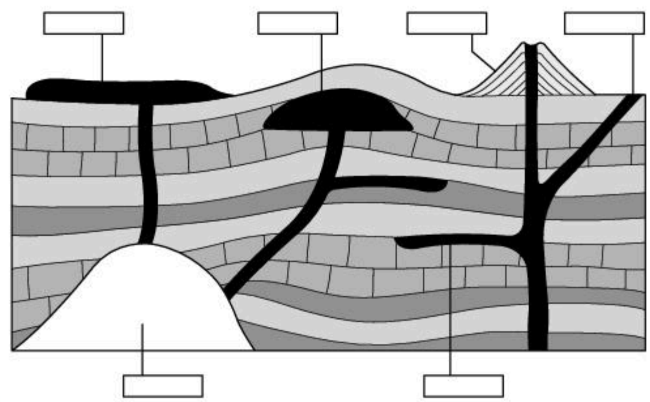


Figure 2 Volcanic intrusions

2 Weathering and Mass Movement

In this chapter you will study:

- some key definitions
- different types of weathering – physical, chemical, biotic
- mass wasting – slow and rapid movements.

You will also learn how to:

- draw three-dimensional diagrams
- draw a cross-section
- describe landscapes through the reading of contours.

Everywhere in the world rocks are worn away by many different processes. Depending on the exact location, the processes that operate vary because they are affected by climate, rock type, relief and slope angle. For example, rock types are different in hardness (**resistance**); the more resistant ones wear away more slowly than the softer ones. The hotter and wetter the climate the faster **weathering** and **erosion** happen (see definitions below).

Figure 2.1 Road collapse in the Blue Mountains, Jamaica

Some key definitions

Denudation

Denudation simply means the wearing away of the land by weathering and erosion. It includes all natural agencies, for example sun, rain, frost, wind, rivers, sea, ice, temperature change and even the actions of plants and animals. This set of major processes is responsible for the creation of the Earth's varied landscapes.

Weathering

Weathering is the wearing away (disintegration and decomposition) of rocks by the effects of the weather and the atmosphere. No movement is involved in this, so the breakdown of the rock is said to be *in situ* – in other words, 'in that place'. Sometimes, after the break-up of the rock, fragments are moved but only by gravity, for instance slipping down a slope.

Erosion

Water, ice and wind also wear away the Earth's surface. Water can mean either rivers or the sea. Ice is in the form of glaciers. Wind **erodes** especially when it is carrying something to help it wear away rock, usually sand. (Imagine how a blast of wind carrying sand would feel against your skin!)

The difference between weathering and erosion

The key difference here is **movement**. In the case of weathering, no movement is involved (remember the term *in situ*). The agent that weathers the rock does not move the debris. Any movement of loose fragments happens due to gravity. However, in erosion, the agent breaking up the rock also removes the debris.

For example, the sea attacks cliffs and moves the fragments out to sea or along the beach. As a glacier erodes the rock it moves over and carries fragments within it, depositing them many kilometres away when it melts.

Mass wasting

Mass wasting or **mass movement** follows weathering. It is the downhill movement of rock debris and soil due to the force of gravity. Water acts as a lubricant, making the debris more slippery and easy to move. In wet weather (or after a period of snowmelt) the speed and amount of mass wasting therefore increase. Landslides are often the result of this process. As the Caribbean receives high rainfall it suffers particularly badly from landslides.

There are various types of mass movement. Slow movements are called **soil creep** or **rock creep**. **Earth flow**, **earth slide**, **rock flow** and **rock slide** are all terms for faster movements of debris down a slope. The first two are very slow and cannot be seen with the naked eye, but the faster movements can be very dramatic as they happen very quickly indeed. A common word for the rapid movements is **landslide** (*Figure 2.1*).

Erosion, weathering and mass wasting are all part of the **rock cycle**. The landscape is weathered and eroded and the particles are moved by wind and rivers, eventually ending up in the sea. Sediments collect on the seabed where they build up to form new beds of rock which may later be uplifted to form new land (*Figure 2.2*).

Activities

1 State three processes of weathering and three of erosion.
2 Explain the key differences between:
  a erosion and weathering
  b rock creep and rock flow.

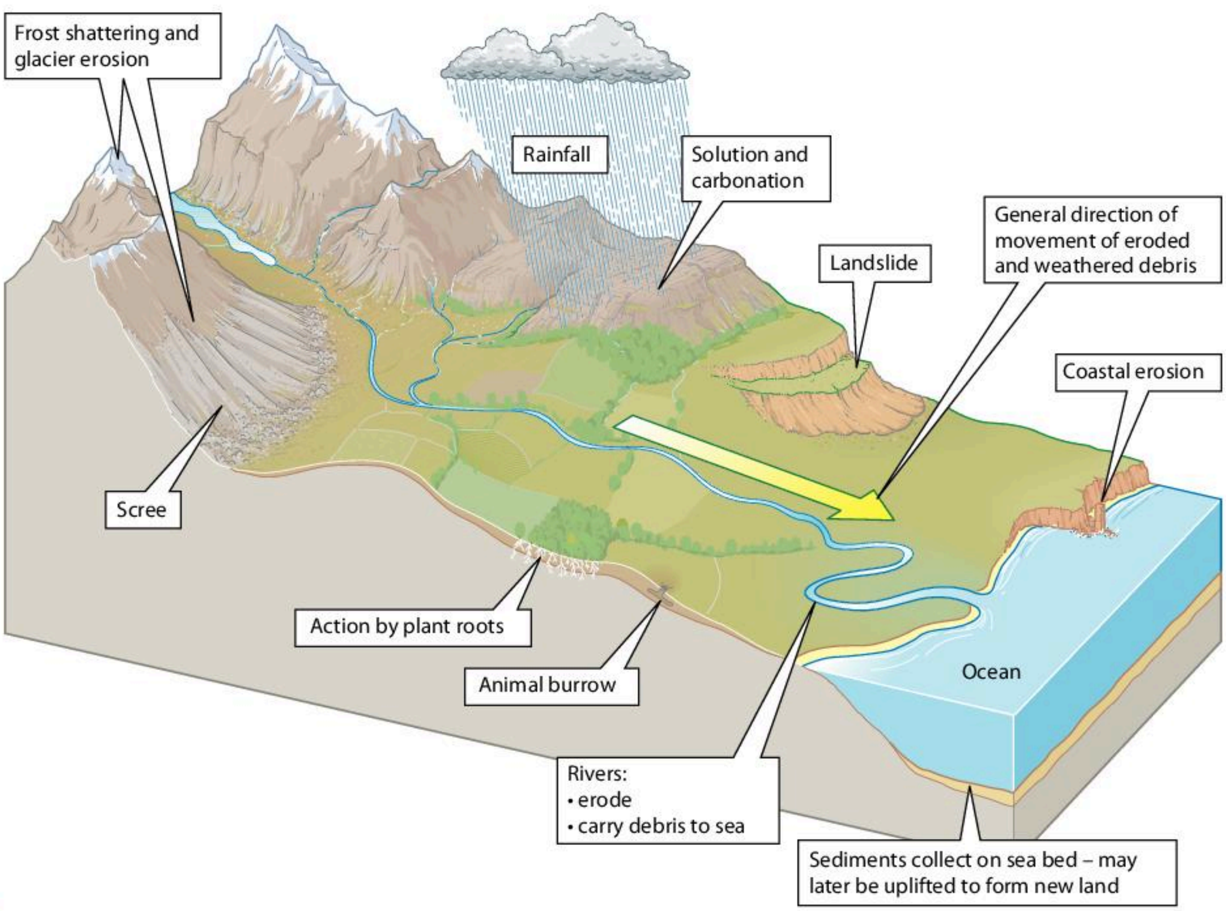


Figure 2.2 Cycling of weathering and erosion (rock cycle)

Types of weathering

There are three different types of weathering:

- **physical** (or mechanical) weathering
- **chemical** weathering
- **biotic** (or biological) weathering.

Figure 2.3 shows how these categories can be subdivided further.

Physical weathering processes

Frost shattering

Globally, **frost shattering**, or the **freeze–thaw process**, is the most important and widespread type of weathering, although it is less common in the Caribbean due to this region's tropical latitude. Only the highest areas could be affected.

For this type of weathering to occur, the temperature must **fluctuate** (change or vary) either side of 0 °C. There must also be bare rock exposed at the surface, with little vegetation cover to protect the rock from the weather conditions.

If it rains during the day, or there is moisture from dew or melting ice or frost, water can trickle into cracks, crevices or pores in the rock. Daytime temperatures are more than 0 °C. If at night the temperature drops below zero, the water in the cracks or pores freezes. Ice takes up 9 percent more space than the equivalent amount of water and so exerts pressure on the rock. Repeated freeze–thaw conditions continue throughout the winter in the cool temperate zones of the world, slowly widening the cracks until pieces of rock break off (*Figure 2.4*). Frost shattering is most likely to happen on steeper bare rock slopes, so the broken pieces will slip downhill easily under the force of gravity. They collect at the bottom of the slope in a fan-shaped pile. This is called **scree** or **talus**. Where the land is more level, boulders and smaller stones litter the surface. These too have been broken off by frost shattering. They are known as **blockfields** or **felsenmeer**.

In colder regions frost shattering is less common, as temperatures are too low; the fluctuation around 0 °C does not happen very often. It rarely

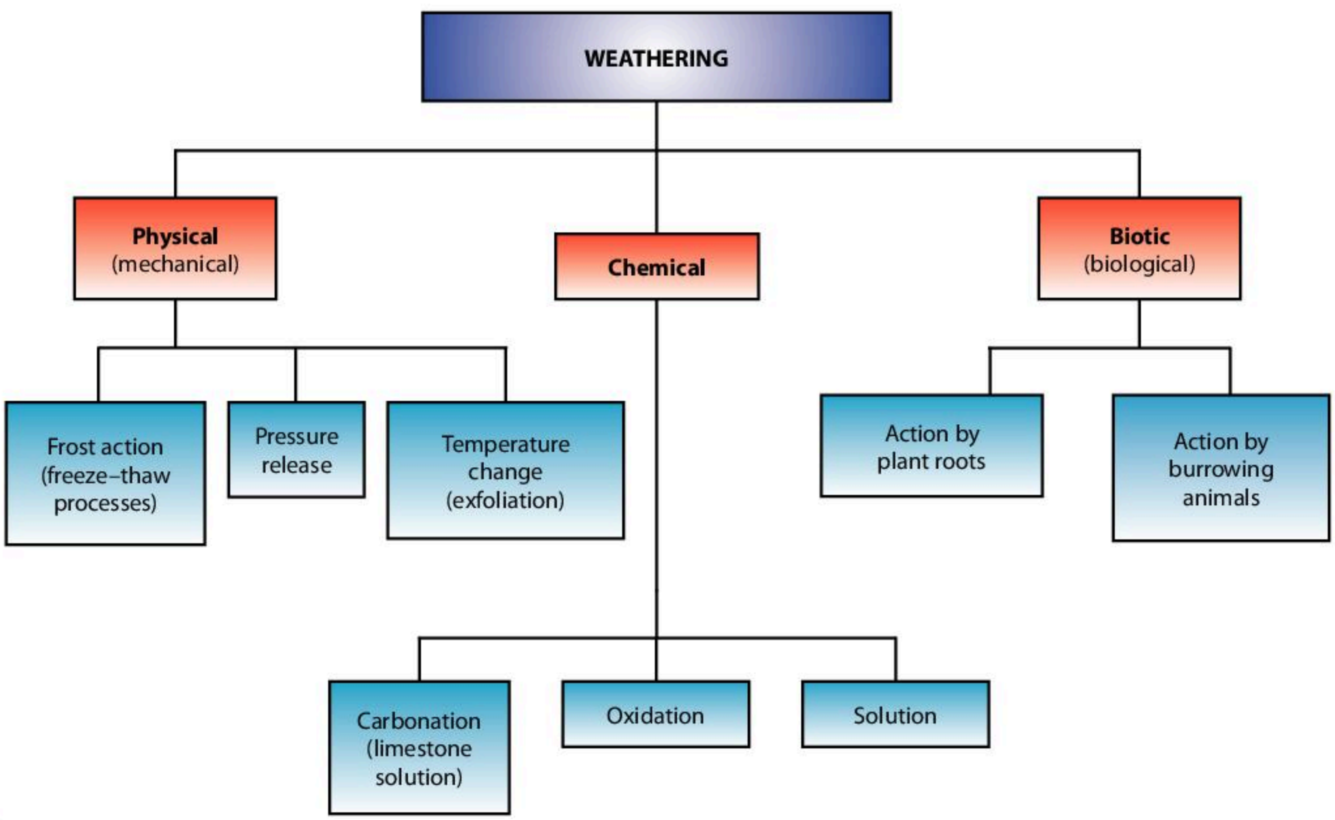


Figure 2.3 Types of weathering

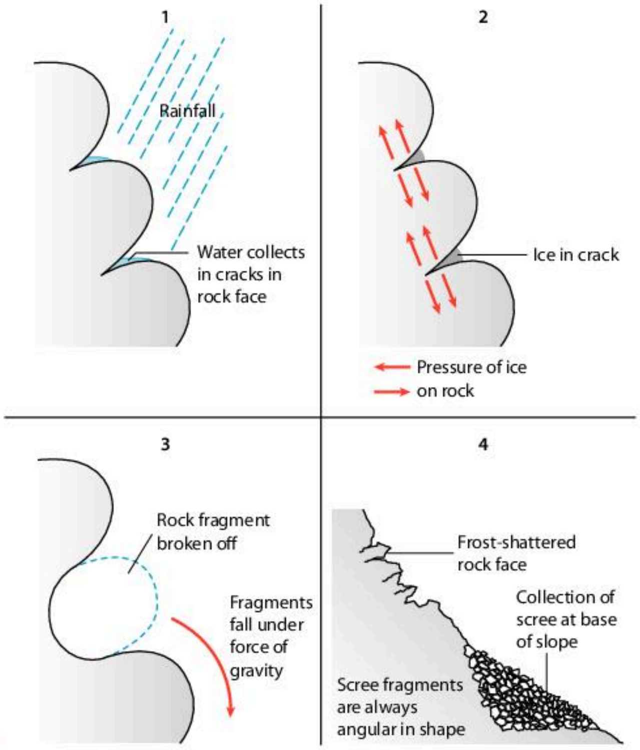


Figure 2.4 The frost-shattering process

becomes warm enough, even during the day, for melting to occur. In polar regions it is very unusual for temperatures ever to rise above zero.

Activities

1 Where are freeze–thaw processes most likely to occur in the world? Why?

2 Describe the process of frost shattering in your own words.

3 Why does frost shattering rarely occur in the Caribbean?

Exfoliation

Rocks expand when heated and contract when cooled. Regular heating and cooling occurs in some climates. In hot deserts the **diurnal range of temperature** (that is, temperature differences within a 24-hour period) can be as much as 50 °C. A midday temperature in excess of 40 °C is not uncommon in desert areas, but at night temperatures may drop below freezing (0 °C).

The outside layer of rock therefore expands and contracts regularly. This weakens it until eventually it falls off. This process is known as **exfoliation** or **onion peeling** (*Figure 2.5*). After one layer has broken off, the next one is attacked by temperature change.

Rocks like granite are made up of different minerals, such as mica, quartz and feldspar. These minerals can expand and contract at different rates which causes the rock to disintegrate – a process known as **granular disintegration**.

Hydrolysis

Hydrolysis is a key chemical weathering process, especially in tropical and subtropical regions like the Caribbean. Rocks are weathered (broken down) by chemical reactions between hydrogen in the soil water or rain, and in certain minerals such as feldspar in rocks like granite.

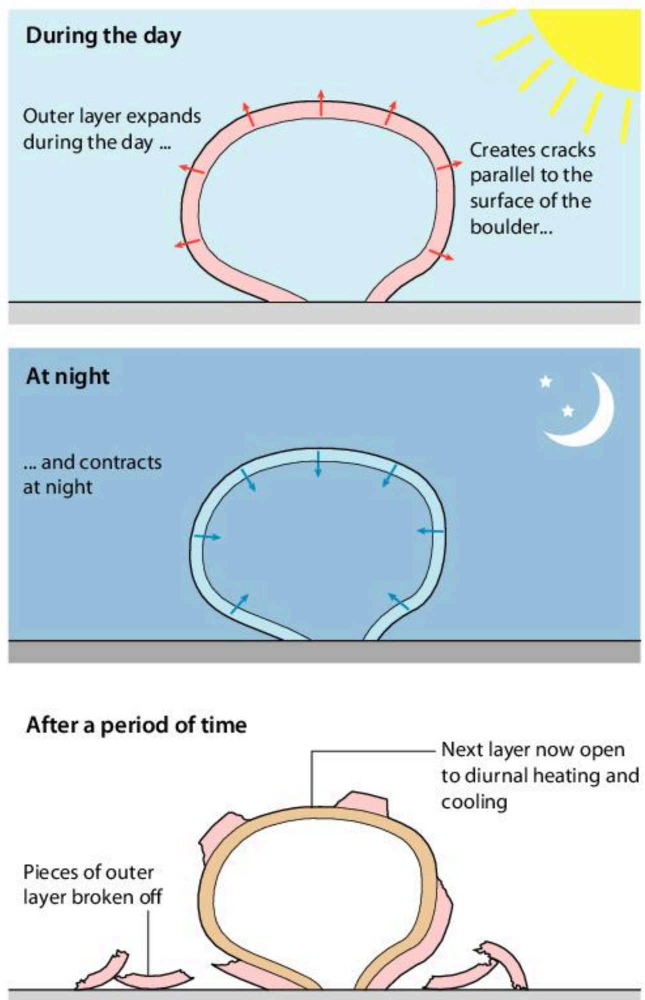


Figure 2.5 The process of exfoliation

Figure 2.6 Kaolin deposits in South Africa's Cape Province

This process is known as **cation exchange**. Hydrogen ions from the water swap with ions from the mineral in a chemical reaction.

The resulting product is clay, known as kaolin (*Figure 2.6*) or China clay because it is used for making porcelain or china dishes. The clay can form a surface deposit over the weathering granite. The Black River area of St Elizabeth Parish in south-west Jamaica has granite rocks and it also outcrops along the beaches of some coastal areas (*Figure 2.7*).

Activities

1 What is meant by the term *diurnal range*?

2 Explain why exfoliation is also known as *onion peeling* or *onion weathering*.

3 Why is *granular disintegration* so called?

Figure 2.7 Granite outcrops in Jamaica

Chemical weathering processes

Carbonation

Carbonation is the most important form of chemical weathering in limestone areas, whether they are in tropical or temperate zones of the world. Rainwater containing carbon dioxide absorbed from the atmosphere is able to dissolve calcareous (calcium-based) rocks. Carboniferous limestone and chalk are the types of limestone affected most because they are made of almost pure calcium carbonate.

Here are the stages of the process:

1 Rainwater dissolves carbon dioxide from the air as it passes through it.

H_2O	+	CO_2	=	H_2CO_3
rainwater		carbon dioxide		mild carbonic acid

2 The mildly acidic rainwater reacts chemically with the calcium carbonate in the rock.

H_2CO_3	+	$CaCO_3$	=	$Ca(HCO_3)_2$
mildly acidic rainwater		limestone (calcium carbonate)		calcium bicarbonate

3 Calcium bicarbonate is soluble in water, so it is easily washed away. Most rain falling in these areas percolates (soaks) into the ground. Calcium carbonate may be deposited later from this water to form features like stalactites and stalagmites (see Chapter 6). The clints and grikes of limestone pavement are the direct result of the solution of surface joints (*Figure 2.8*). Solution not only takes place on the surface but continues underground, creating tunnels, caves and massive caverns.

Few minerals are soluble in pure water. It is important to understand that it is the weak acid that allows this natural process of carbonation to take place. However, the carbon dioxide in rainwater is not the only source of acid that can attack limestone. Any acid will attack calcium carbonate, including those that come from industrial pollution. Nitrates and sulphates make nitric and sulphuric acids and both of these can dissolve in rainwater too.

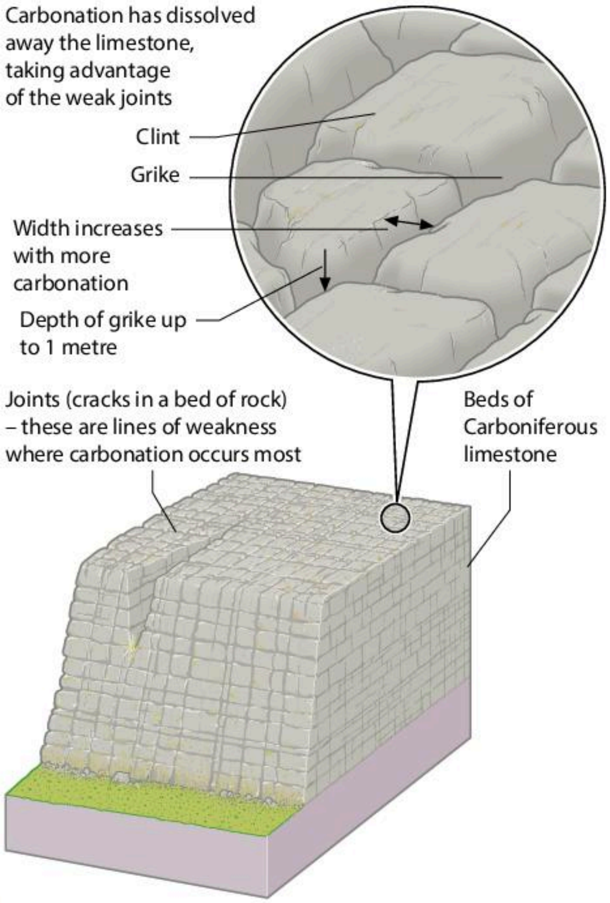


Figure 2.8 Carbonation forming limestone pavement (clints and grikes)

The Carboniferous limestone of the Pennine Hills in northern England may have been dissolved faster due to the pollution from nearby industrial areas in that part of the country.

The higher temperatures in tropical areas increase the speed of carbonation. Chemical reactions are faster as temperature increases. Higher rainfall also plays a part because the rain is the weathering agent. An example is the Ankarana Specialist Reserve, a high region in northern Madagascar, now protected as a National Park. Here, temperatures between 25°C and 30°C and annual rainfall of around 2200 mm combine to cause extremely rapid limestone weathering. This is concentrated in the rainy season, when hundreds of millimetres of rain may fall in just a few weeks.

Solution

Rocks other than limestone can be affected by solution weathering. Many minerals are soluble in water, especially if that water is slightly acidic, as explained above. The greater the acidity (the lower the pH), the more soluble minerals become. Rock salt is an example of a rock that is easily dissolved *in situ*. Rocks made up of a mixture of different minerals can be weathered by one or more of them being dissolved, leaving the rock structure weaker. Other agents of weathering and of erosion can then attack more easily.

Oxidation

Oxidation occurs when rocks are exposed to oxygen in air or water. It is the chemical addition of oxygen to compounds in the rock and it can weaken the structure of the rock. Iron compounds are particularly affected. Iron can combine with oxygen to make two different compounds: ferrous iron oxide (FeO) and ferric iron oxide (Fe_2O_3). Ferric oxide clearly contains more oxygen per atom of iron than ferrous oxide.

$4FeO$	+	O_2	=	$2Fe_2O_3$
ferrous iron oxide		oxygen		ferric iron oxide

This weathering process is also known as **rusting**, and the rock discolours to the reddish-brown colour seen on rusty metal (*Figure 2.9*). Oxidation is an important form of weathering because it causes rocks to crumble more easily.

Activities

1 Why does rainwater cause carbonation but pure water does not?

2 Describe the chemical process that is involved in carbonation.

3 Why have the areas named below suffered particularly severely from carbonation?
   a The Carboniferous limestone area of the Pennines in northern England
   b The Ankarana Special Reserve in northern Madagascar

4 Explain the colour difference between rock that has been oxidised and rock that has not.

Figure 2.9 Oxidation on a bank of Wag Water river, Jamaica

Biological weathering processes

Biotic weathering involves both physical and chemical processes. Plant roots are amazingly strong. Not only can they grow into cracks in rock (*Figure 2.10*) but they may actually widen them too! Trees sometimes cling on to remarkably steep slopes simply because their roots can anchor them right into the rock (*Figure 2.11*). This is physical biotic weathering. At the other end of the scale, tiny plants like lichen extract iron from rocks, a form of chemical weathering.

Burrowing animals such as rabbits, insects, and other animals including earthworms can loosen pieces of rock only to a limited extent. Rock is usually protected by a layer of soil,

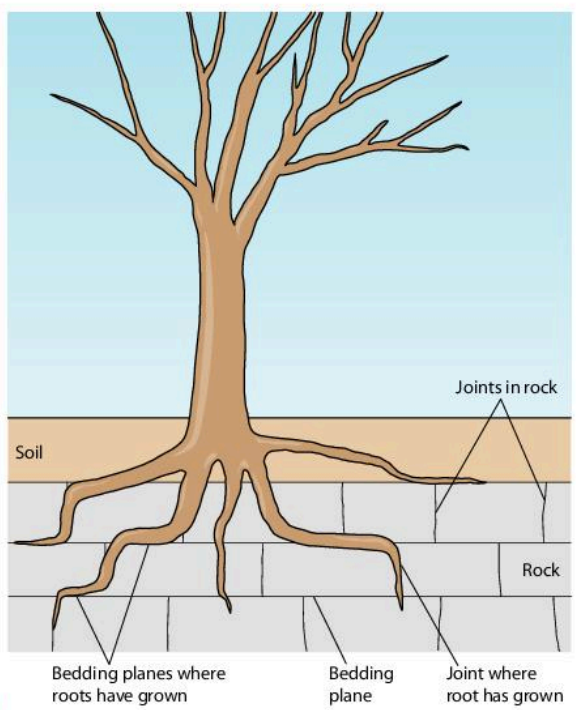


Figure 2.10 Tree root action

Activities

1 Draw a three-column table with the headings 'Physical weathering', 'Biotic weathering' and 'Chemical weathering'. In your table list the different types of weathering processes.

2 Which types of biotic weathering have the greatest impact? Why?

Figure 2.11 Tree roots breaking up limestone

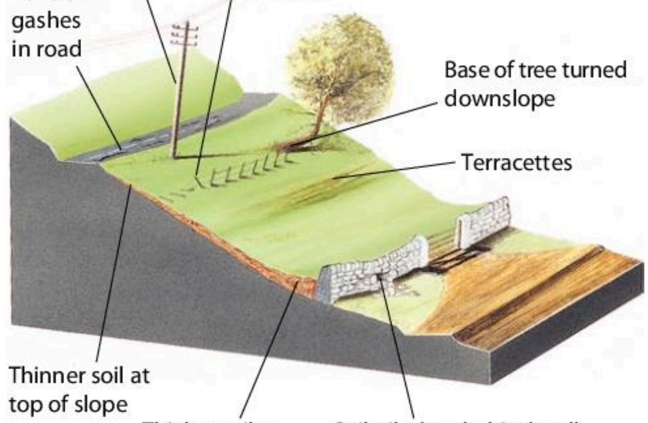


Figure 2.12 The effects of soil creep

keeping rain and frost out. The main impact of animals and insects is to allow other weathering agents deeper into the soil so that they can attack the rock directly and break it down further.

Humic acid is the product of decaying dead plants and animals. It is found in soil water. It can be strong, especially in tropical areas, and weathers rock rapidly. This too is chemical biotic weathering.

Mass movement

Slow movements – soil creep

What is soil creep?

Soil creep is the slowest type of mass movement. More material ends up at the bottom of a slope by this process than in any other way. Soil creep is the slow downhill movement of soil particles. It is a major type of mass movement which can take place on gradients as slight as 2 degrees but more usually on those of over 5 degrees. It is a gradual but constant process, generally so slow that it cannot be seen, but over several years the results become apparent.

There are several indicators on a slope that soil creep is happening (*Figure 2.12*). The clearest one is the formation of **terracettes**, step-like features around the hillside, 20–50 cm in height, roughly parallel to the contour lines. They develop because vegetation is stretched and torn as the soil slips downhill.

Trees also clearly show the effects of soil creep. As they slip gradually down a slope they try to grow vertically as before, resulting in the bending of the trunk. Human-made landscape features also show tell-tale signs. Fences or walls running around the slope break. Soil and rock fragments may pile up behind a wall toward the bottom of the slope, forcing it to bulge and eventually break. Electricity poles may tilt and roads become cracked or even partially collapsed. The speed of soil creep can be measured in centimetres per year by studying the downslope movement of such objects.

Factors affecting soil creep

In temperate environments soil can creep downhill at between 1 and 2 mm per year, but in tropical regions it is quicker, perhaps 3–6 mm. In cold, semi-arid areas it is even faster.

Soil creep is caused by:

- the alternate wetting and drying of the soil and,
- the alternate freezing and thawing of the soil.

The expansion and contraction of water in soil is the main cause of soil creep. Movement is aided by lubrication – in other words, the wetting of the soil. The wetter soil is, the faster it is able to flow. Therefore soil creep is much more active in wet areas of the world. In regions of seasonal wetting and drying the soil contracts when dry and expands when wet. Wet soil moves much more easily, so most soil creep occurs during wet periods. Rainwash and rainsplash (the impact of raindrops) can also move soil downslope. Particles can be washed out from below stones, so they fall downhill too. Gravity plays a part as well; it drags the wet material downhill.

Freezing and thawing in colder parts of the world also encourage soil creep. This is why the fastest rates of soil creep are in semi-arid areas with cold winters.

Activities

1 Explain the process of soil creep.
2 Why is soil creep likely to be more active in tropical regions such as the Caribbean than in temperate parts of the world?

Rapid movements – landslides

What is a landslide?

A landslide is a sudden and rapid downslope movement of a large volume of soil and/or rock. It can carry vegetation and buildings with it, potentially causing huge destruction. The word 'landslide' covers a range of events. Whole sections of hillside can slide downward, such as at Judgement Cliff on the side of the lower Yallahs valley in St Thomas Parish, Jamaica (see page 48). In very wet conditions soil turns to mud and flows like a thick liquid (see case studies on pages 46 to 48).

All slopes are affected by gravity, so loose material will eventually slip or fall. On gentler slopes, around 5 degrees, soil creep operates (see above) which is so slow that it has relatively little effect on human life, property or activity. However, as slope angles increase so does the risk of a slide, as well as its possible size. Landslides are natural events and would occur without people, but human activities do increase the risks, scale and frequency of these hazards.

Physical causes of landslides

Unconsolidated material on the slope: In 1998 the rains from Hurricane Mitch caused devastating **mudflows** from the unconsolidated ash slopes of the Casita volcano which killed 1900 people and destroyed the town of Posoltega in Nicaragua.

Slippery rocks like shale and clay: Shale and clay are both slippery, especially when wet. Wet clay acts as a **lubricant**, so rock beds above it slip down more easily (*Figure 2.17*). Shale is made of several very thin layers, so it slides easily, again taking any rocks above with it.

Bedding planes being roughly parallel to the slope surface: This makes it easy for material to slip downward along the bedding planes. Gravity can exert its force easily on the rock beds. The effects are even greater if the rock layer below is impermeable. This keeps all the moisture in the top layer of rock, so it becomes saturated quickly.

The base of a slope being undercut by river or coastal erosion: Rivers meander and undercut their valley sides. If the slope above is made of unconsolidated or very wet material and becomes unsupported it is much more likely to collapse (*Figure 2.13*). Coastal erosion can produce a similar effect.

Earthquakes: In 1977 an earthquake of 7.7 on the Richter scale (see page 312) shook parts of Peru. Ice and snow near the summit of Huascaran (the highest mountain in Peru) formed an avalanche which picked up rocks and boulders on its way. When it hit the town of Yungay in the Rio Santo Valley it was

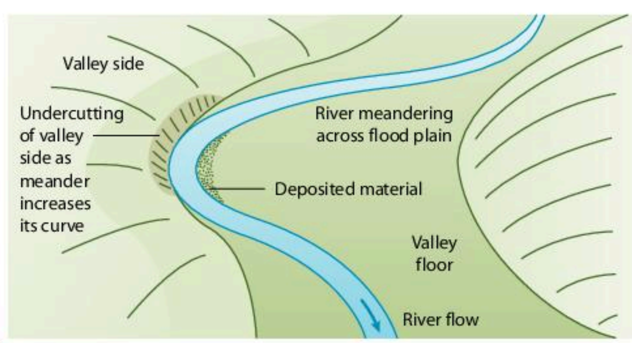


Figure 2.13 Undercutting a slope

Figure 2.14 The disaster of Armero

Figure 2.15 Aftermath of Hurricane Mitch, Tegucigalpa, Honduras (October 1998)

moving at 480 km per hour. Few of the 20 000 population survived. All that could be seen of the settlement was the tops of 30 metre-high trees in the town square.

Volcanic eruptions: Perhaps the best-known **lahar** (volcanic ash and mudflow) is the one that occurred in Colombia in 1985, when 21 000 of the 22 000 population of Armero died following the eruption of the volcano Nevado del Ruiz (*Figure 2.14*).

Heavy rainfall: All the above causes of landslides are made worse by the surface material becoming saturated, which makes it heavier and reduces friction. This happens most effectively during a short period of intense rainfall, for example from tropical storms or hurricanes. Water does two things:

- it adds weight to the material, making the slope less stable
- it decreases friction which helps movement downslope.

The torrential rain from Hurricane Mitch in October 1998 caused flooding and landslides which affected 3 million people on the Caribbean side of Nicaragua and Honduras (*Figure 2.15*).

Human causes of landslides

Building on unstable slopes: In December 1999 there were hundreds of landslides in and around Caracas, the capital of Venezuela (*Figure 2.16*). These had three major causes: heavy rain, a physical reason, was one. The other two causes involved human factors: steep-sided valleys with unstable slopes had been used for high-rise buildings, and vegetation had been removed to make way for these. This disaster left 30 000 dead and 200 000 homeless.

Undercutting the base of a slope by road building: A road may be built along the base of a valley side to keep it above the likely flood zone, but undercutting the slope has the same impact as does physical erosion. The slope is left unsupported so that any additional stress will cause it to slip.

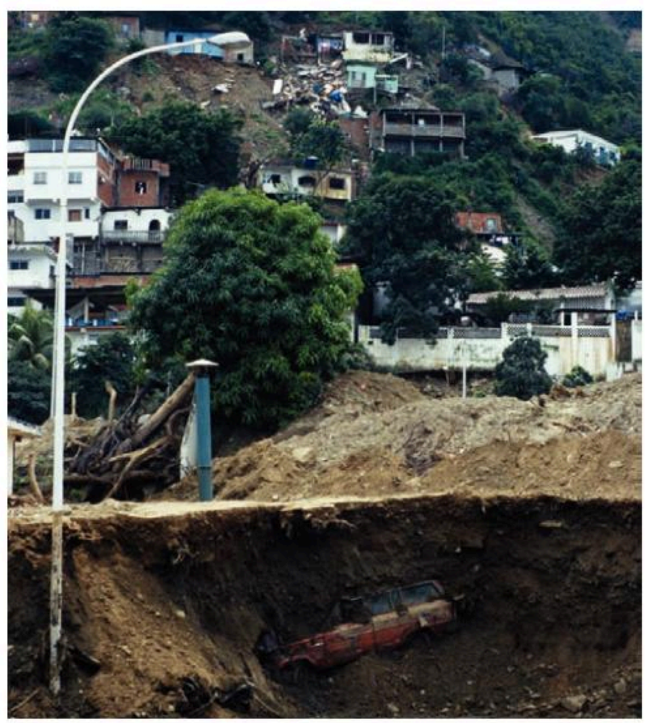


Figure 2.16 The Caracas landslides

Dumping waste material: Waste from activities such as coal mining can be difficult to dispose of. In the village of Aberfan in South Wales, UK, the material was piled up on slopes of 25 degrees above the village. A wet autumn in 1966 saturated the waste heap. The tip collapsed on the morning of 21 October, engulfing the local junior school, killing 116 children and five teachers. This was one of the worst disasters in the UK in the 20th century.

Building dams: One of the worst disasters of the 20th century in Europe was in north-east Italy in 1963. The Vajont dam had been built across the narrow, steep-sided Piave valley. The rock beds of alternate limestone and clay sloped toward the reservoir (*Figure 2.17*). The pressure of the weight of water in the reservoir caused a small earthquake. A block of limestone slipped on the clay beneath, falling into the water and forcing a 100 metre wave over the dam. Within seven minutes it hit three small towns including Longarone. The speed of the disaster and the fact it happened at night caused the high death toll of 3000. This could have been avoided through better planning and quicker reaction to earlier ground tremors.

Activities

1 **a** List the physical causes of landslides.
  b Place them in an order of most to least destructive. (Hint: This is not easy and there is no single correct answer.) Give reasons for your order.

2 Research landslides within the Caribbean region. For one or more that you find:
  a list their causes
  b state whether mainly physical or human factors were involved.

3 The Vajont disaster had several causes but one main effect.
  a List the causes.
  b What was the one main effect?

4 Draw a labelled three-dimensional diagram to show these causes and the effect.

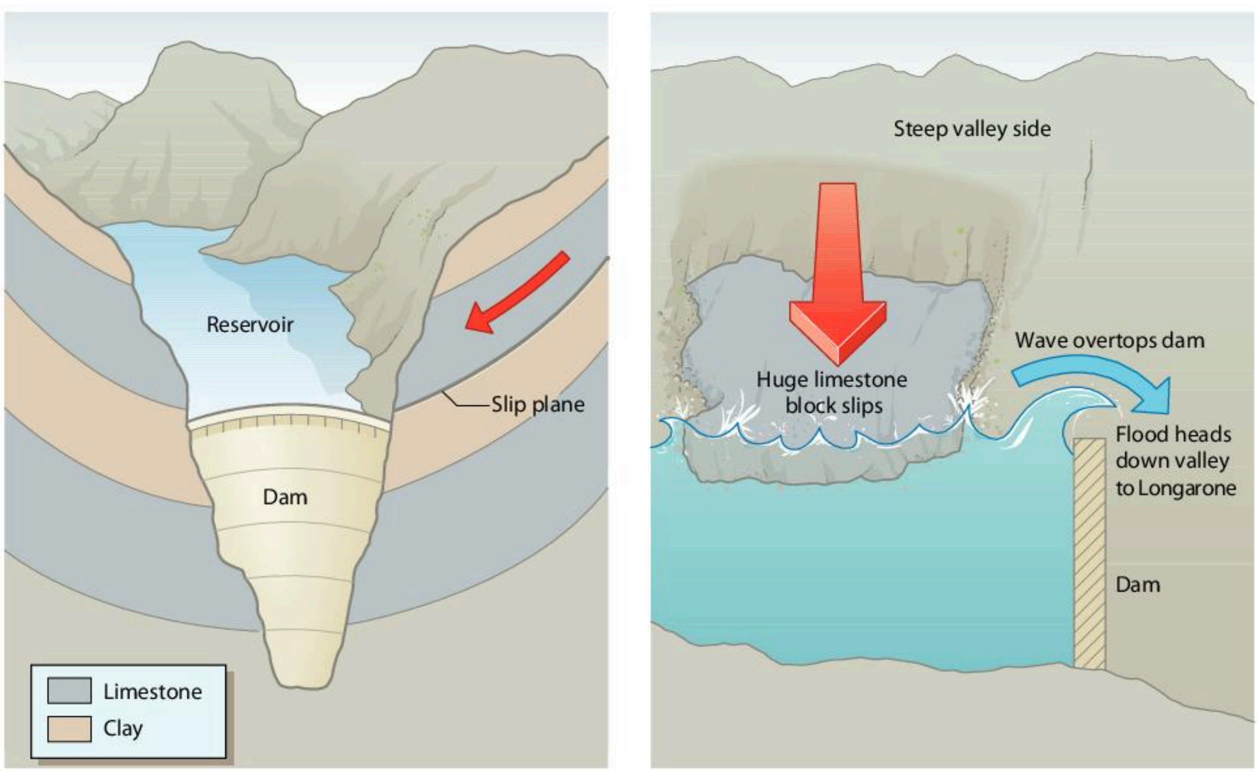


Figure 2.17 The Vaiont disaster – reasons against dam building

Skills

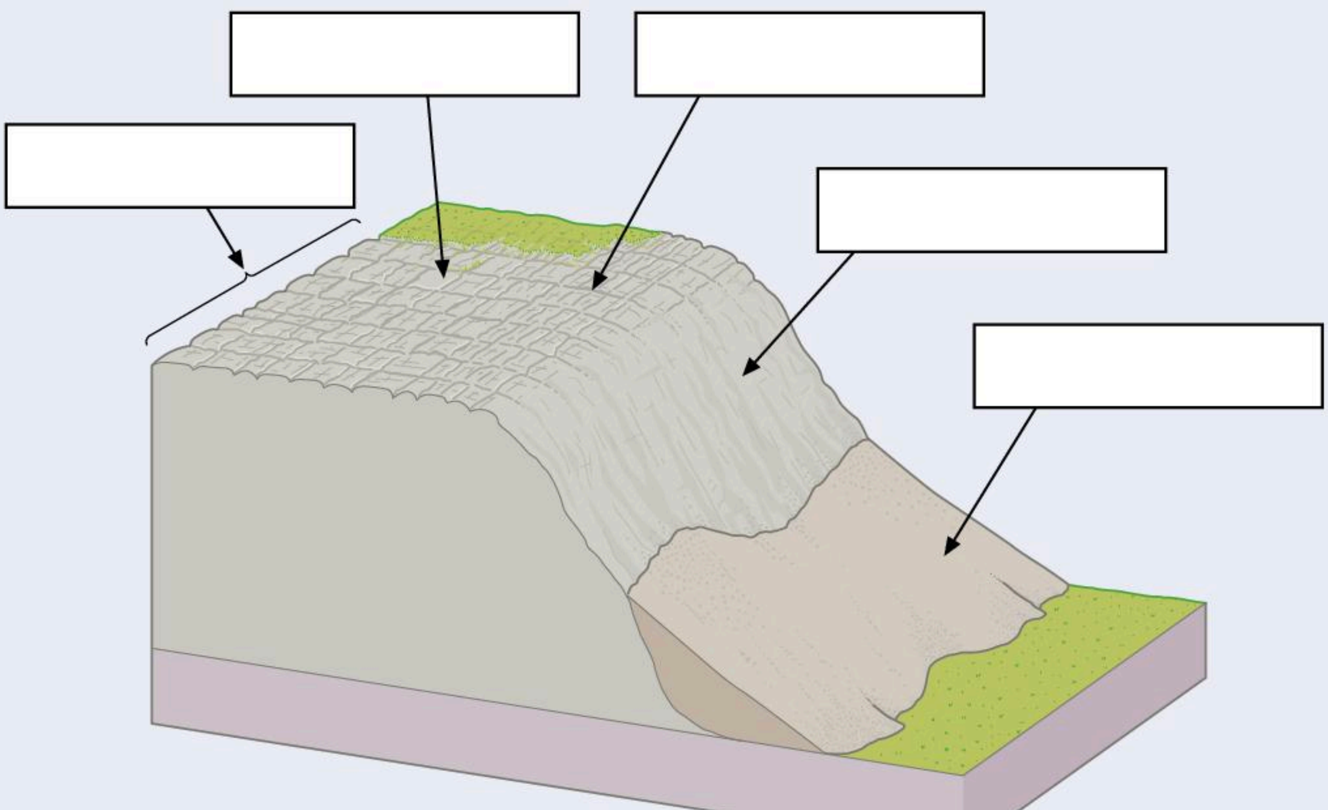
Three-dimensional diagrams

The purpose of three-dimensional (or block) diagrams is to create a clearer impression of a whole landscape and the processes going on there. Although cross-sections (two-dimensional diagrams) are a very useful geographical tool, a three-dimensional diagram is sometimes more appropriate and more detail can be shown.

Figure 2.12 is an example of a three-dimensional diagram. It clearly shows the impact of soil creep on the whole hillside. The effects on the tree, the fence, the wall, the road and the electricity pole are separately drawn. Three-dimensional diagrams are not very easy to draw, but it is always the labels that are the most important feature on any diagram, so they must give accurate information.

Figure 2.18 is an outline of a three-dimensional diagram to show the landscape features of a limestone area. The landforms include limestone pavement and scree. The processes involved are carbonation and frost shattering.

1 Label a copy of *Figure 2.18* to show these processes and landforms. The arrows have been drawn in to help you.
2 Draw your own three-dimensional diagram to show any aspect of weathering, erosion or mass wasting.



- Scree collected at base of slope
- Limestone pavement, formed by carbonation
- Clints: blocks of limestone not yet weathered
- Grikes: weathered limestone joints
- Steep slope, experiencing frost shattering

Figure 2.18 The processes and landforms in a limestone area

Case Studies

Tobago landslide, November 2004

On 12 November 2004, six hours of heavy rain caused widespread flooding and landslides in western Tobago, affecting the villages of Delaford, Lambeau, Carnbee, Mt Irvine, Turtle Beach and the area between Mt St George and Charlotteville. Two people were reported dead and five seriously injured. All the injured and one of the dead were from the same family.

The Ferguson family's home in Delaford was crushed by one landslide as it rushed downhill. Earth, trees and other debris buried the house, killing 16-year-old Kathy Ferguson and placing her mother and four other family members in a critical condition in hospital. Firemen fought for almost four hours to save the injured, hampered by a shortage of equipment.

The other fatality was Tyrone McMillan, aged 30 and with a young family, who died trying to save his van. At 5.45 am on the afternoon of 12 November a small landslide occurred and Mr McMillan went to move his van. As he was doing so, the major landslide occurred, completely covering both him and the van.

Clinton Ross, the Public Information Officer of Tobago's National Emergency Management Agency, assured the press that clean-up efforts were underway and that everything was under control. However, the severity of this disaster should not be underestimated. The Chief Secretary of the Tobago House of Assembly, Orville London, compared this damage with that done by Hurricane Ivan two months earlier: the November landslides were more severe (*Figure 2.19*). The Prime Minister, Patrick Manning, after touring the devastated areas, said that the extent of the damage was far worse than he had expected and promised that the necessary funds for reconstruction would be found.

Tobago landslide kills two, five family members critical

'It was very chaotic. The situation was beyond my imagination and we suffered from an acute shortage of equipment for such a situation,' Fire Officer David Thomas said.

'Yes, it is much worse. I estimate the damage to be in the vicinity of TT$50 to TT$60 million (around US$9 million). But we Tobagonians are a resilient people. We will bounce back,' said London [Orville London – see main text above], who is now visiting several villages.

Figure 2.19 Press statements on the Tobago landslide

Source: *Caribbean Net News*, 16 November 2004

1 Re-read the text in this case study very carefully, including that in *Figure 2.19*.

Imagine you are a journalist visiting one of the villages a few hours after the disaster. Your task is to prepare an accurate report for that evening's news.

a Give a detailed description of the scene of devastation.
b Explain how the emergency services are working to rescue the victims of the disaster.
c Take quotes from people at the scene: the victims, the rescuers, government officials. Quotes from the victims should convey their feelings of terror, and what it was like to feel the land sliding away beneath them.
d Include suggestions on how people in the area might prepare for similar situations in the future.
e Also comment on how the government might provide support and help to prevent similar disasters.

Your report should be presented as a newspaper article. Think about a suitable heading, appropriate language, and presentation.

You could prepare a class display of your reports, accompanied by appropriate illustrations.

2 Explain why Tobago and the rest of the Caribbean are prone to hazardous events like landslides. (Hint: Consider climate and vegetation.)

3 Why is the damage from landslides so severe in the Caribbean? (Hint: Consider building structure and quality, funds available and the emergency services.)

Hong Kong – a series of urban landslides, 1948–98

Hong Kong was a newly industrialising country in the latter half of the 20th century. Large-scale industrial development and urbanisation began in the 1950s and today it is generally described as a 'developed' country.

Hong Kong is situated on several hilly islands and a small part of the Chinese mainland. The best sites for building were rapidly used up, so steeper ones were developed. High-rise blocks are the main housing type because land is so expensive, but high-rise buildings place greater stresses on the slope, simply because they are heavier per unit area of their base.

Figure 2.20 Consequences of a landslip in Hong Kong

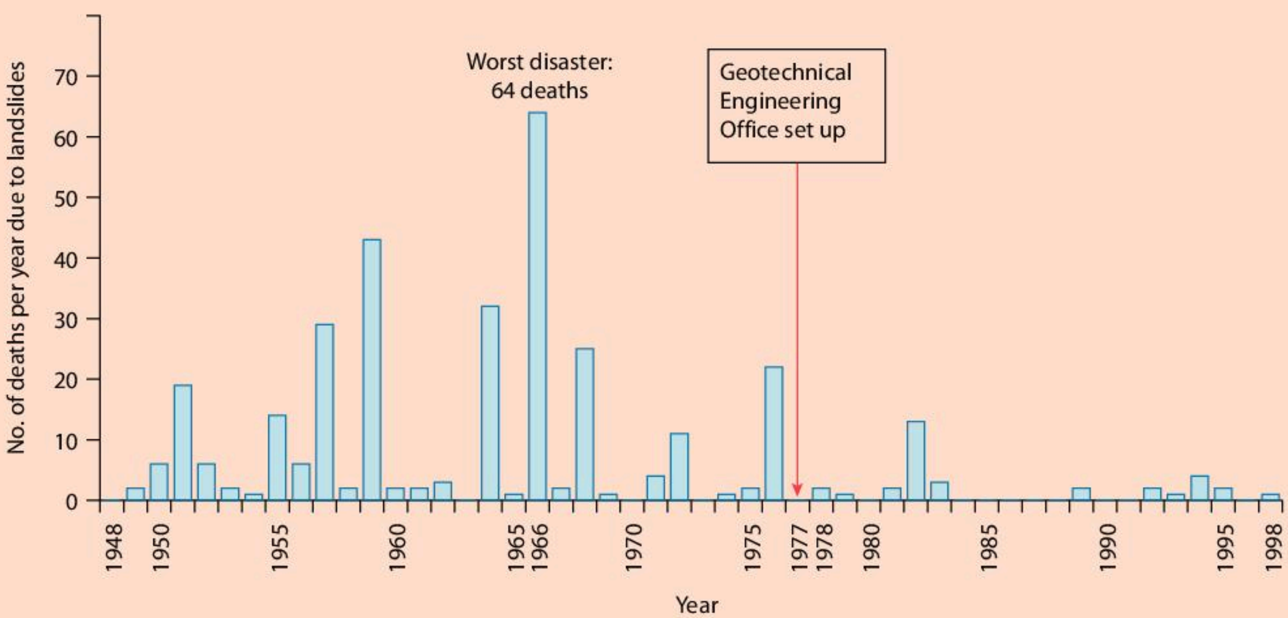


Figure 2.21 Deaths in Hong Kong landslides, 1948–98

Source: D Waùgh *Geography An Integrated Approach* (2000) p55

Landslips in Hong Kong (*Figure 2.20*) have been caused by a combination of physical and human factors:

- poor building quality (human)
- lack of maintenance of slopes once they have been built on (human)
- torrential rainstorms (physical).

Severe rainstorms in 1966 triggered massive landslides that killed 64 people, made 2500 homeless and forced the evacuation of 8000. Ten years later landslides were still killing people. Technological skill was then applied to the problem.

In 1977 the Geotechnical Engineering Office (GEO) was set up. Its tasks were to:

- assess risks on built-up slopes
- take preventative action
- improve maintenance by landowners and the city authorities
- assess risks on slopes about to be developed
- devise a warning system
- train the emergency services.

The GEO has been very successful. *Figure 2.21* shows the reduction in the death rate since the system was set up. A huge rainstorm in 1997 (800 mm in one day, 110 mm of this in just one hour) caused some landslips, but resulted only in a single death and eight injuries.

1 How did the level of development of Hong Kong contribute to landslide damage between 1948 and 1998?

2 When did the level of development become more of a solution to the hazard rather than a cause of it? Explain your answer.

Judgement Cliff

Judgement Cliff in Jamaica's Yallahs valley is a well-known and complex landslide. The slide happened in 1692, but is still a major feature in the landscape of the area today. In fact it is 'one of the largest and most spectacular landslide landforms in Jamaica' (R. Ahmad, 1998, 'Physical environment and geohazards in Kingston, St Andrew and St Thomas, Jamaica'). The whole length of the eastern side of the valley has been affected as there have been several landslides. The Judgement Cliff section stands out because the upper slope is so bare and because debris from the slip has created a conical hill (*Figure 2.22*).

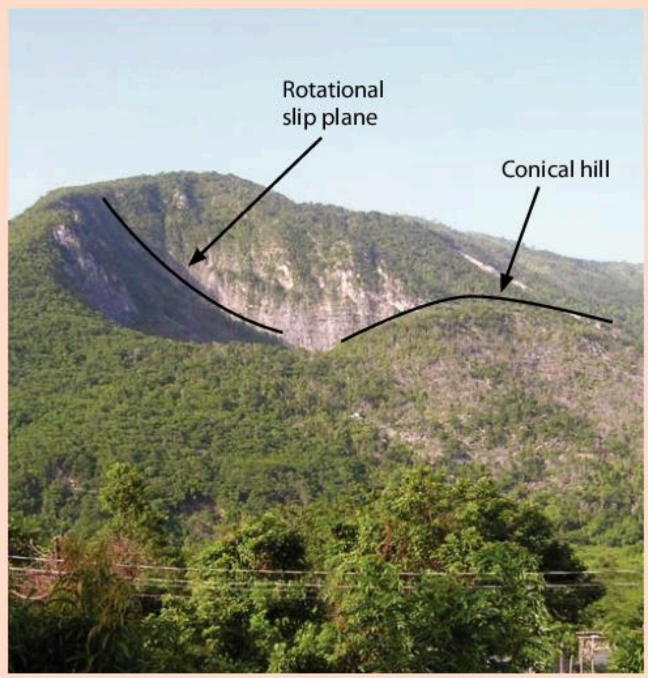


Figure 2.22 The Judgement Cliff landslide

Figure 2.23 is a cross-section of this landslide. It shows a thick bed of limestone on top of clay, gypsum and shale. Clay is the softest rock that exists and is not quite rigid. It absorbs rainwater very easily. Gypsum is a soft calcium rock and shale, though harder, is made up of many thin layers, which makes it weaker. The weak, slippery lower rocks were unable to support the heavy mass of limestone above, especially when it became saturated. The angle of the beds also encouraged the slope failure. The steeper the slope, the less stable it is likely to be. This landslide was triggered either by the Port Royal earthquake of 6 June 1692 or by the hurricane rainfall that followed. The cross-section (*Figure 2.23*) also shows that the slide is complex; it has three sections. Each one is slightly curved and this type of movement is called **rotational slip**. This is shown by the red arrow in the diagram. Several settlements were covered by this landslide but the exact death toll was not recorded. We do know that land in a plantation owned by a man named Hopkins moved almost a kilometre from its original position!

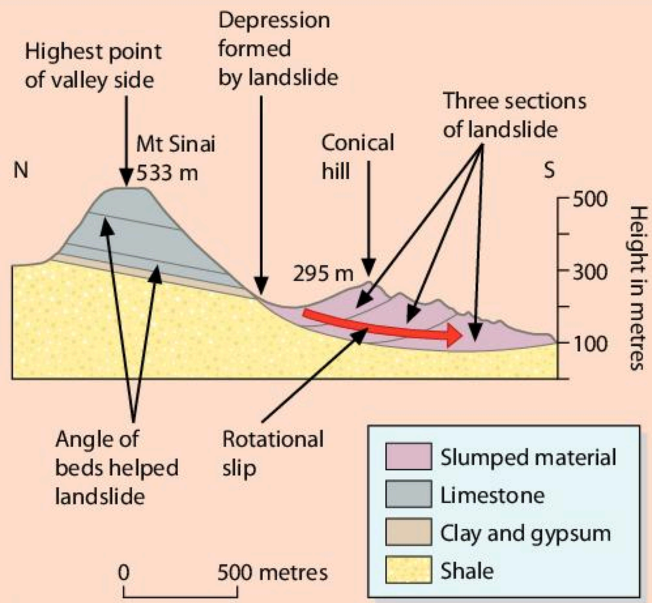


Figure 2.23 Cross-section of the Judgement Cliff landslide

Skills

How to draw a cross-section

A cross-section is a 'slice' through the landscape. It helps us to see more accurately what the landscape looks like. To draw a cross-section, you need to follow the steps below and refer to *Figure 2.24*.

1 Draw a line of section (from A to B) across the contours (*Figure 2.24a*).
2 Study the pattern of the contours and try to imagine what is happening to the land. Is the land rising or falling? Is there a valley?
3 Place the straight edge of a piece of paper along the line of section (*Figure 2.24b*). Mark the start (A) and the finish (B). Now mark the points where each contour crosses the edge of the paper. Write the value of each contour on the paper. Check to see whether any contours are 'doubling-back'. Mark on any other important details such as rivers.
4 Now, on a piece of graph paper, place the paper along a horizontal line the same length as the line of section A–B (*Figure 2.24c*). Draw two vertical axes, one at each end.
5 Choose a vertical scale that shows the variations in height but does not make the landscape look unrealistic.
6 Carefully draw crosses at the correct height for each contour value. To do this you need to read heights across from the vertical scale, and up from the marks on your original piece of paper (*Figure 2.24c*).
7 Use a freehand curve to join up the crosses (*Figure 2.24d*). Continue the curve to both vertical axes. Notice how this has been done at the start of the section, where the value at A lies somewhere between 60 and 70 metres.
8 Complete your section by writing labels and giving your diagram a title (*Figure 2.24d*).

Drawing a cross-section is one of the most challenging geographical skills that you will attempt. However, with a bit of practice, it isn't too difficult and the result can be really impressive. Here are a few tips:

- Always use a sharp pencil and be prepared to erase mistakes.
- Double-check that you have written down the correct contour values on your piece of paper.

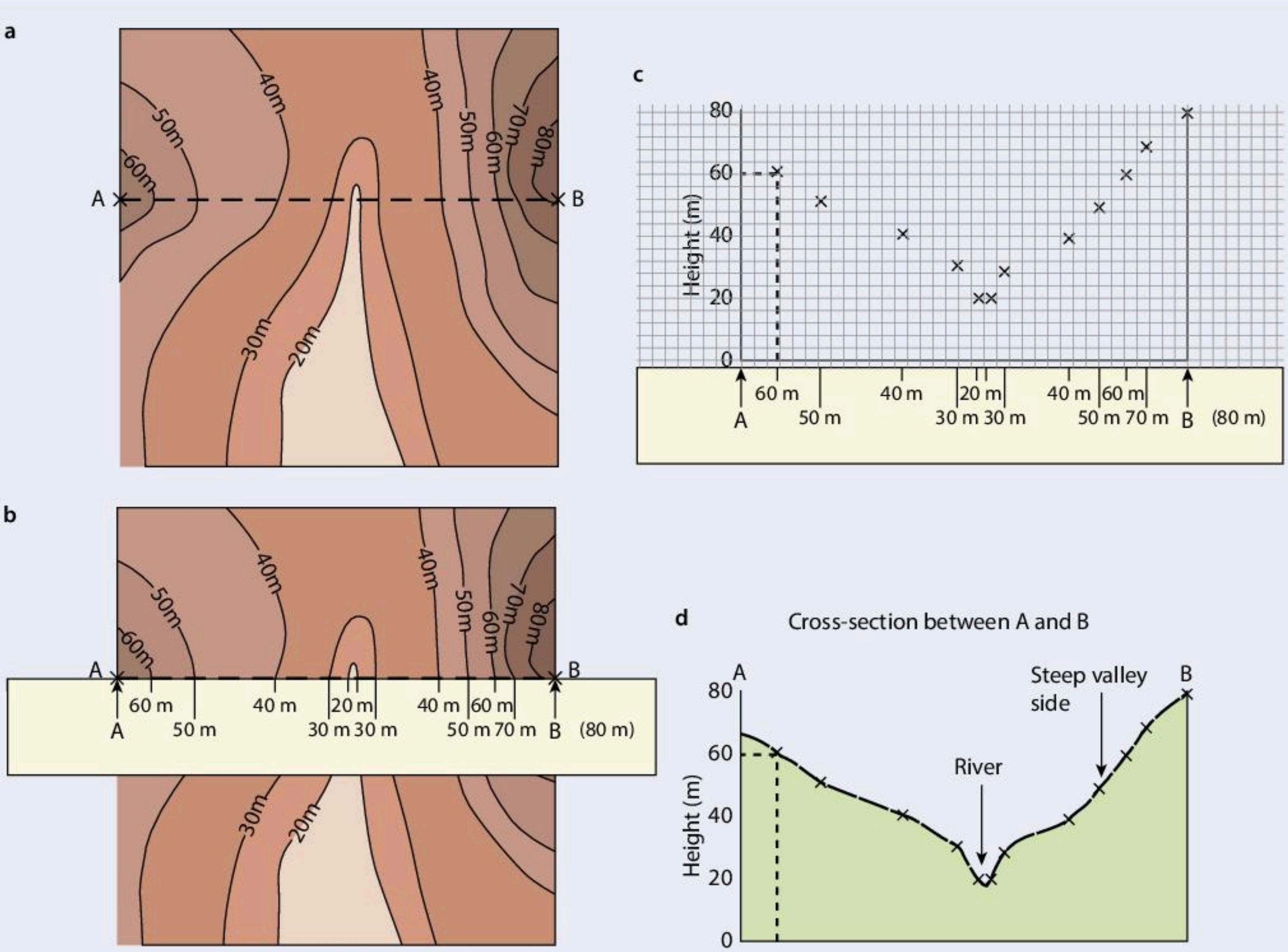


Figure 2.24 How to draw a cross-section

- If the contours are very close together, then mark every other one.
- Take time to consider an appropriate vertical scale. The following scales tend to work well, although it will depend a bit on 'trial and error':

  1:50000 map   1 cm represents 100 metres
  1:25000 map   1 cm represents 50 metres.

Describing landscapes using contours

Contours are lines that join points of equal height. The pattern of contours can tell us a great deal about the physical landscape, or the relief, of an area. Look at *Figure 2.25*. It shows the common relief features of a landscape together with the contour patterns. Notice the following patterns:

- When the contours are close together they indicate a steep slope.
- When the contours are far apart the slope is gentle.
- If there are no contours the land is flat.
- Where contours form a circular pattern, increasing in height in the centre, they represent a hill. If the values decrease in the centre then the land is in the form of a depression or hollow.
- River valleys have contours increasing in height on either side of flatter ground which is usually occupied by a river. The contours show a V shape.

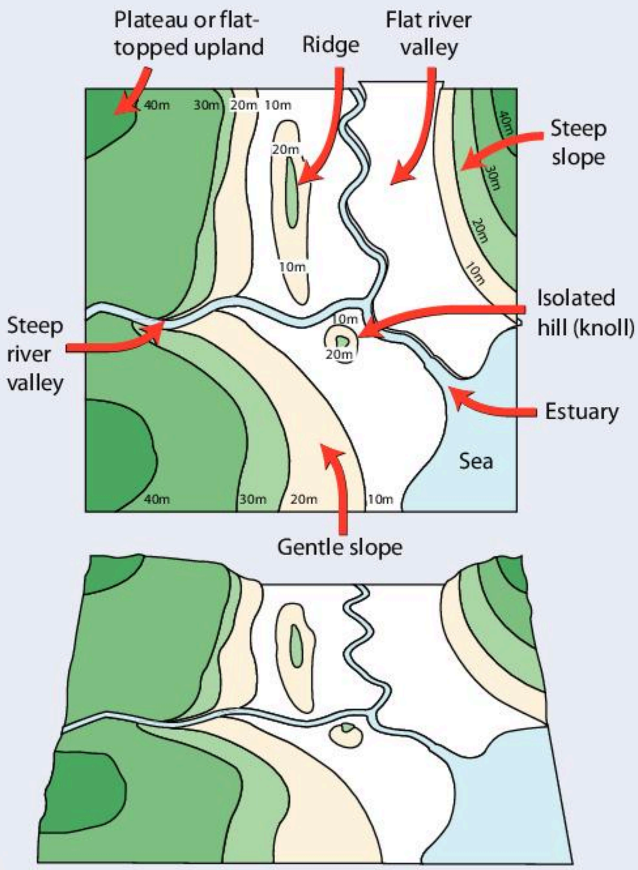


Figure 2.25 Landscape and contour patterns

- If the land is so steep that it rises almost vertically in places, 'cliff' symbols are used instead of contours.

In an exam question it is very important to be precise when describing relief. A good plan would be to start by assessing the whole area of the map to be described. Does it divide naturally into areas with different relief patterns, for example valley floor/valley sides? If so, identify these at the start of your answer. Then, taking each area at a time, describe its features. This approach makes your task more manageable and you are therefore likely to score higher marks because you do not miss anything out.

Refer to actual heights using values from contour lines or spot heights. This really improves the quality of your answer and is essential for hilltops and valley floors.

Key words for describing relief are:

Flat: no real variation in relief, few contour lines. Height more likely to be given with spot heights.

Undulating: land varying in height but without steep slopes. Contours are rather winding and well spaced.

Hilly: contours are closer together and more parallel; slopes are becoming steeper and longer.

Mountainous: here slopes are very steep so contours are close together. Spot heights for summits may be hundreds or thousands of metres high.

Look out for relief features such as valleys, valley floors, steep or gentle slopes, hilltops and depressions. Use place names and grid references to help you locate the places to which you refer. This makes it easier for the reader to follow.

Drawing cross sections and assessing intervisibilty

1 Using *Figure 2.26*, draw a cross section along the line AE.

Intervisibility means whether or not you can see between two points in a real-world landscape. Nothing must get in the way and block the view.

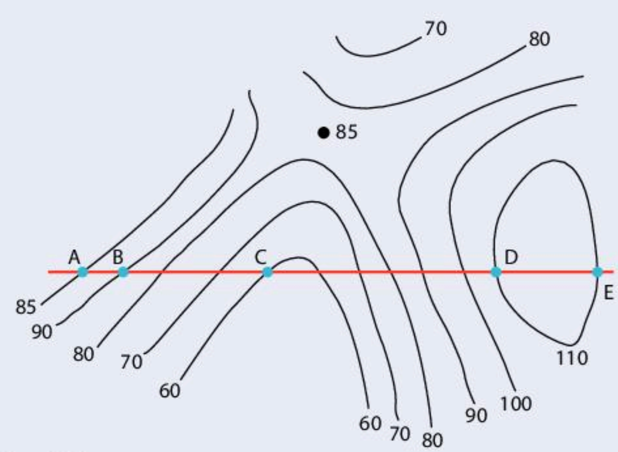


Figure 2.26 Cross-section practice

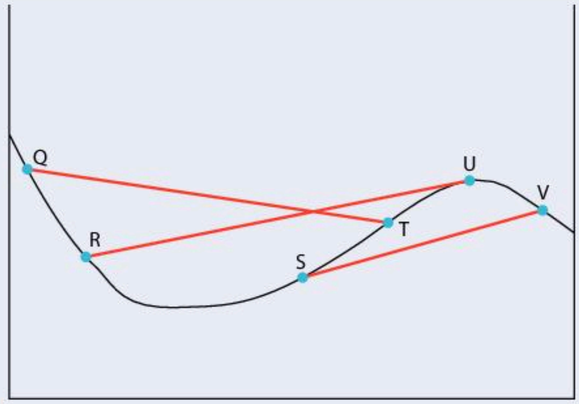


Figure 2.27 Intervisibility

In *Figure 2.27*, straight lines have been drawn on a cross-section between points to help you determine whether, when standing at one point, you can see someone at the other point.

2 a Use the drawn lines to help you decide:

i If you were standing at Q, could you see someone at point T?

ii If you were standing at point R, could you see someone at point U?

iii If you were at point V, could you see someone at point S?

b Write a reason for each of your answers.

3 Go back to *Figure 2.26*. Draw the lines yourself this time.

If you were standing at point D could you see another person at:

a Point C

b Point A?

Give a reason for your answer in each case.

c Test intervisibility between other points on your cross-section.

Weblinks

1 Find USGS (United States Geological Survey Information Centre) and look for 'Caribbean natural hazards', then links to 'Landslides in the Bahamas/Barbados/Jamaica' etc.

2 Look up YouTube for film clips of landslides in the Caribbean and elsewhere.

3 Look up the Geological Society on biological weathering of tree roots.

4 Look up sites about weathering processes such as at www.geography.learnontheinternet.co.uk.

5 Tropical storm Erika caused extensive flooding and landslides in Dominica in August 2015, killing at least four people and cutting water and power supplies. At one point 80 percent of the island was without power, the main airport was closed due to flooding and roads were littered with fallen trees; buildings collapsed due to landslides removing their foundations. Research the storm further online.

Glossary of terms

Bedding plane: the boundary or join between two beds/layers of sedimentary rock. A weak point where weathering and erosion are more likely to happen.

Blockfields / felsenmeer: boulders and smaller stones, the products of weathering, which litter the ground surface in some areas.

Carbonation: the solution of limestone (especially of Carboniferous limestone) by acidic rainwater.

Cation exchange: a chemical process causing granite to break down into kaolin, and also it can help plants to take up nutrients from the soil.

Cliff: a very steep slope at the back of a beach.

Col: similar to a pass, but between three or four peaks in a mountainous area.

Concave: a slope which curves inward.

Convex: a slope which bulges outward.

Denudation: the wearing away of the Earth's surface by weathering and erosion.

Depression: a lower area within a landscape.

Diurnal: change that happens over a period of 24 hours.

Erosion: the wearing away of the Earth's surface by moving agents such as water (rivers, the sea), wind and ice. The agent of erosion also removes the eroded material (debris).

Escarpment: a line of hills with each main slope being of a different angle – the steeper side is the scarp slope; the gentler side is the dip slope.

Exfoliation / onion-peeling: weathering that causes the break-up of the outer layers of rock, due to extreme diurnal temperature change.

Exfoliation dome: a hill or mountain of granite or a similar rock type, weathered and eroded into a steep-sided, curved shape, e.g. Sugar Loaf Mountain, Rio de Janeiro.

Frost shattering / freeze–thaw processes: a type of physical (mechanical) weathering caused by regular temperature change around 0 °C.

Gentle: a slope of gentle gradient.

GEO: a department set up by the Hong Kong government to reduce the hazard of landslides.

Granite: an intrusive igneous rock with clearly visible, differently coloured crystals. It experiences pressure release and exfoliation weathering.

Granular disintegration: the breakup of rocks composed of different materials.

Humic acid: liquid formed by the decomposition of dead plants and animals and forming the water in soil. It can weather rock.

In situ: a process that occurs in a particular place. No movement is involved. This applies to weathering, but not to erosion.

Joint: a crack within a bed of sedimentary rock due to drying out, or within a mass of igneous rock caused by cooling and shrinking.

Lahar: a mudflow resulting from a volcanic eruption, e.g. the heat from the eruption melts ice and snow which flows rapidly as water, picking up mud and other debris as it proceeds.

Landform: a physical feature on the Earth's surface: a river valley, a bay, a sinkhole.

Landslide (including **earth flow**, **earth slide**, **rock flow**, **rock slide**)**:** rapid downslope movement of a large volume of soil and/or rock.

Lubricant: something that makes movement easier and faster, e.g. water in soil creep or a landslide.

Mass wasting / mass movement: the downhill movement of rock and soil debris after weathering of the rock has created the loose material.

Mudflow: a mass of thick wet mud, usually carrying other material within it, flowing downhill.

Oxidation: the chemical addition of oxygen to compounds in rock which helps to break them down, e.g. the rusting of iron.

Pass: a lower area between two peaks in a mountain range which may allow a route through from one side to the other.

Plain: a flat landscape, usually not much above sea level – may be coastal.

Plateau: a flat area of high ground (pl. Plateaux).

Relief: the shape of the Earth's surface, including altitude and angle of slope.

Resistance: how soft or hard a rock is; how well it stands up to attack by the agents of weathering and erosion.

Ridge: a long, narrow, steep-sided piece of ground, higher than its surroundings.

Rock cycle: the whole cycle of rock formation and destruction from erosion and weathering of the land surface, through the deposition of debris on the sea bed, its consolidation into new rock, then the uplifting of this to form new land.

Rotational slip: the movement in a landslide which is curved (as in Fig 2.28)

Saddle: similar to a col or pass.

Scree / talus: the debris that collects at the base of a slope after the physical weathering (freeze–thaw) of the bare rock slopes above.

Slope: a hillside, at an angle to the horizontal.

Soil creep / rock creep: the slow movement of soil / loose rock downslope due to any combination of gravity, wetting and drying, freezing and thawing.

Solution: some minerals in rock are soluble in water, especially acidic water. This leads to both weathering and erosion.

Spur: part of a hillside which protrudes from the rest.

Straight slope: a slope of equal gradient from top to bottom.

Terrace/stepped: a slope made of steps: steep and flat sections alternately.

Terracettes / sheep tracks: small ridges which form on hillsides, parallel to the contours, as a result of soil creep. They look like pathways around the hill.

Unconsolidated material: loose material, not held together.

Undercutting: erosion of the base of a hillside, which usually leaves it unstable.

Undulating: a landscape of flat areas and gentler slopes, randomly mixed.

Uneven: a slope with varying gradients.

Valley: a lower section within an upland area cut by a river or glacier.

Weathering: the wearing away of the Earth's surface by the weather (rain, frost, temperature change) or by plants and animals.

Ideas for SBA

- *How do landslides affect people in my community?*
- *What are the conditions promoting soil creep on a farm in my community?*
- *What contributes to erosion of hillsides in my community?*

Exam-style Practice

1 a Draw a diagram of clints and grikes and explain why they develop in limestone regions. [5]

b Name the type of weathering that causes the features in Fig 1a. [1]

c Define the following processes: denudation, frost action, hydrolysis. [6]

d Explain the difference between weathering and erosion. [3]

e Explain why exfoliation occurs in hot deserts. [5]

f Explain why frost action does not occur in cold deserts and the tropics. [5]

Total 25 marks

2 a Copy the diagram and identify labels A – E. [5]

b Define the following terms: *slide plane, terracettes.* [4]

c State FOUR natural ways in which a landslide can be triggered. [4]

d Explain how humans can trigger a landslide. [4]

e Explain the responses of individuals, national and regional agencies to reduce the effects of landslides in the Caribbean. [8]

Total 25 marks

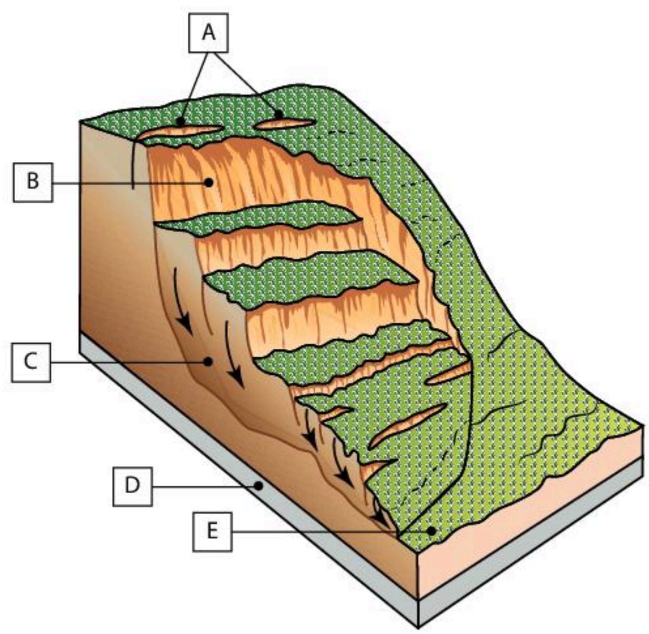


Figure 1

3 Fluvial processes

In this chapter you will study:

- the hydrological cycle
- drainage systems, basins and patterns
- rivers – energy and processes
- landforms of the upper, middle and lower courses of rivers.

You will also learn how to:

- use grid references
- calculate gradient using ratios.

Fluvial is a term used to refer to the processes and landforms associated with rivers.

The hydrological cycle

Over 97 percent of the world's water is stored in oceans and seas. These water bodies make up about 70 percent of the surface of the Earth. The remaining stores of water are:

- 2.1 percent as ice and snow (most of this is in Antarctica and Greenland)
- 0.6 percent as groundwater (held in rocks)
- 0.1 percent in rivers and lakes
- 0.001 percent held in the atmosphere as water vapour and clouds (water droplets). This amounts to about 10 days' supply of average rainfall around the world. If evaporation and transpiration from the Earth's surface suddenly stopped, the world would run short of fresh water very quickly!

The three main processes in the **hydrological cycle** (*Figure 3.1*) are evaporation, condensation and precipitation.

- **Evaporation** is the process in which liquid water is changed into water vapour which is a gas. Evaporation takes place mainly from surface water. Energy is needed for it to occur. The energy comes from the sun's heat and from wind. Look how quickly water evaporates from a concrete or tarmac surface on a very hot day compared with a cooler day!

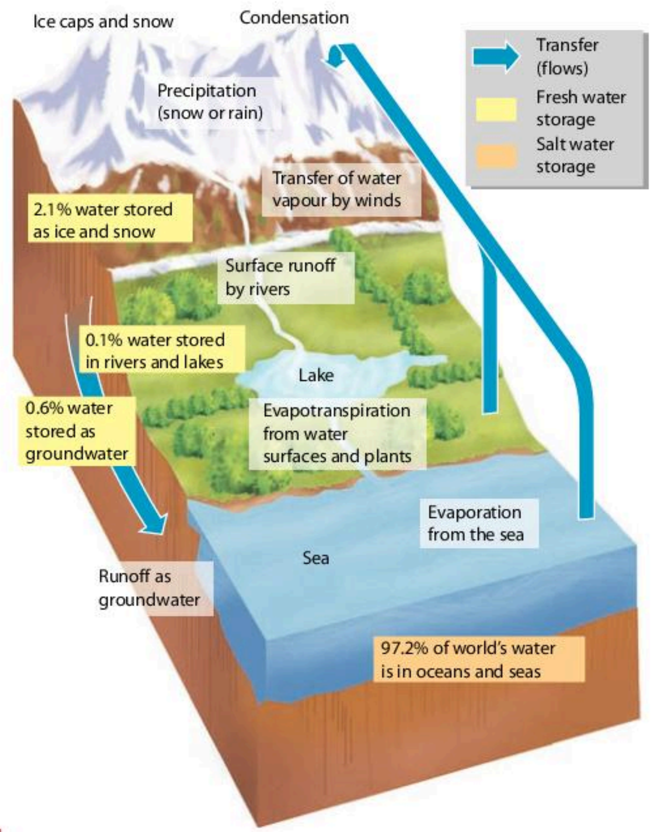


Figure 3.1 The hydrological cycle

Evaporation is also faster on a windy day compared with a calm day.

Evaporation from water surfaces on land would not be enough to keep rivers and lakes full and provide the human population with drinking water. Fortunately, large amounts of water evaporated from the seas and oceans are carried by air masses onto land where condensation and precipitation take place.

Figure 3.2 A meltwater stream emanating from a glacier

- **Condensation** is the process by which water vapour changes into water droplets. It happens when water vapour is cooled to a level known as the **dew point**. Condensation forms clouds and can also occur at the surface as fog.
- **Precipitation** occurs when water in any form falls from the atmosphere to the surface. This is mainly as rain, snow (*Figure 3.2*), sleet and hail. Thus, water is constantly recycled between the sea, air and land.

The drainage basin system

When precipitation reaches the surface it can follow a number of different pathways. A small amount falls directly into rivers as **direct channel precipitation**. The rest falls onto vegetation or the ground. If heavy rain has fallen previously and all the air pockets in the soil (pore spaces) are full of water, the soil is said to be **saturated**. Because the soil is unable to take in any more water, the rain flows on the surface under the influence of gravity. This is called **surface runoff** or **overland flow**.

If the soil is not saturated, rainwater will soak into it. If the rock below the soil is **permeable** (allows water into it), the rainwater continues to soak down deeper into the rock. It eventually comes to **impermeable** rock (which does not allow water into it). The underground water level builds up toward the surface from here. It does not remain stationary but flows downslope under gravity. The upper level of underground water is the **water table**. Water contained in rocks is known as **groundwater** and water on the move in rocks is called **groundwater flow**. Rock that holds groundwater is known as an **aquifer**.

A spring occurs when underground water emerges at the surface. This happens where:

- a permeable rock such as limestone covers an impermeable rock such as clay. Rainwater that can percolate into the permeable rock is unable to penetrate the impermeable rock below. This water will emerge at the surface as a spring provided the water table is above surface level.
- when the water table in a normally dry area reaches the surface during a period of unusually heavy rain. Such springs generally flow for only a short period of time.

Throughflow is the term for water flowing through the soil. **Infiltration** is the passage of water into the soil. **Percolation** is the downward vertical movement of water within soil or rock.

Rainwater can be **intercepted** by vegetation. Interception is greatest in the wet season when trees and plants have most leaves. Some rainwater is stored on leaves and then evaporated directly into the atmosphere. The remaining intercepted water either drips to the ground from leaves and branches or trickles down tree trunks or plant stems (**stemflow**) to reach the ground.

Vegetation takes in moisture through its root system. It loses some of this into the air by **transpiration**. Surface water is also lost by evaporation. The combination of the two is known as **evapotranspiration**.

Inputs are where water enters the system. **Stores** are places where water is held (*Figure 3.5*).

Figure 3.3 Spring emerging from hillside

Figure 3.4 Almost dry stream bed, Gobi region, Southern Mongolia

Transfers are where water is flowing through the drainage basin system. **Outputs** are where water is lost to the system.

In some countries precipitation is fairly even during the year. However, in other countries there may be distinct wet and dry seasons. In the Caribbean, rivers may dry up completely for several months. In deserts, small river channels may be dry for most of the time (*Figure 3.4*).

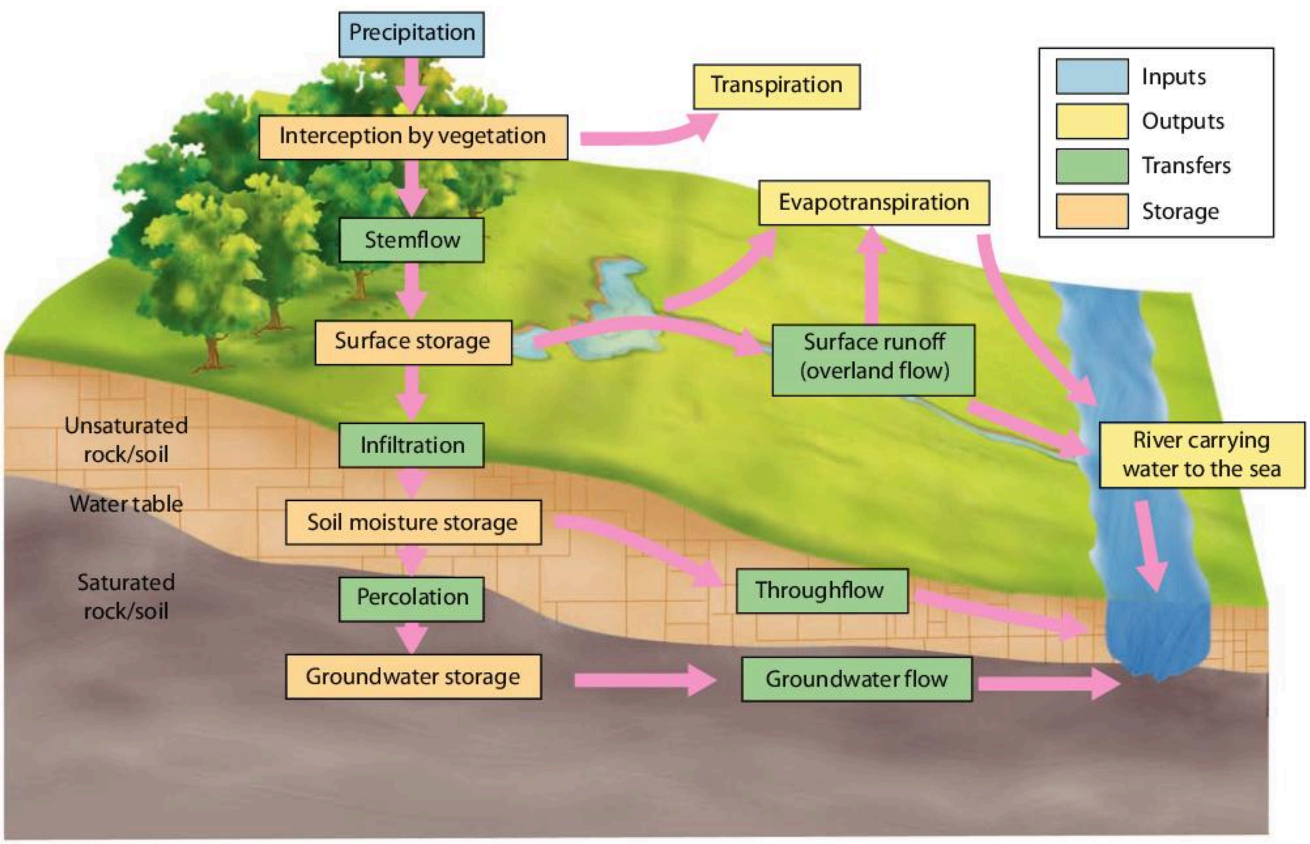


Figure 3.5 The drainage basin system

Activities

1 Draw a simple diagram to show the water cycle.

2 Define the following terms:
  a *permeable rock*
  b *water table*
  c *groundwater flow*
  d *interception*
  e *evapotranspiration.*

3 Look at *Figure 3.5*.
  a Draw a table to show the inputs and outputs of drainage basins.
  b What are **i** stores and **ii** transfers?
  c List the stores and transfers shown on *Figure 3.5*.

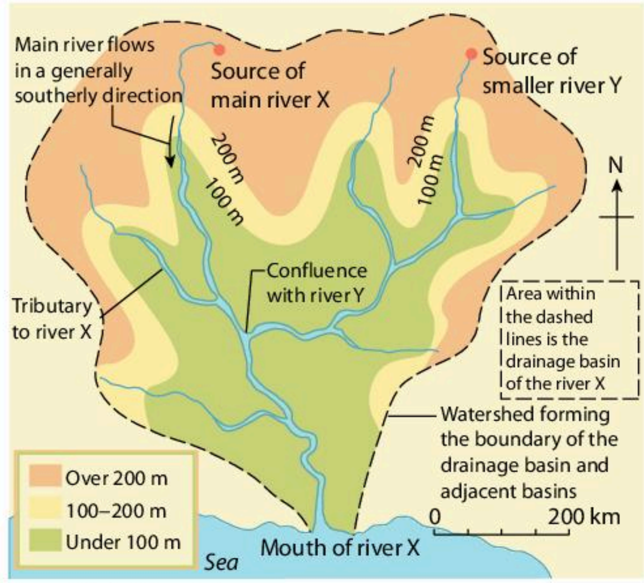


Figure 3.6 A drainage basin

Drainage basins

A **drainage basin** (or catchment area) is the area drained by a river and its tributaries (*Figure 3.6*). The boundary of a drainage basin is called the **watershed**. This is a ridge of high land that separates one drainage basin from another (*Figure 3.7*). The point where a river begins is its **source**. A river reaches the sea at its **mouth**.

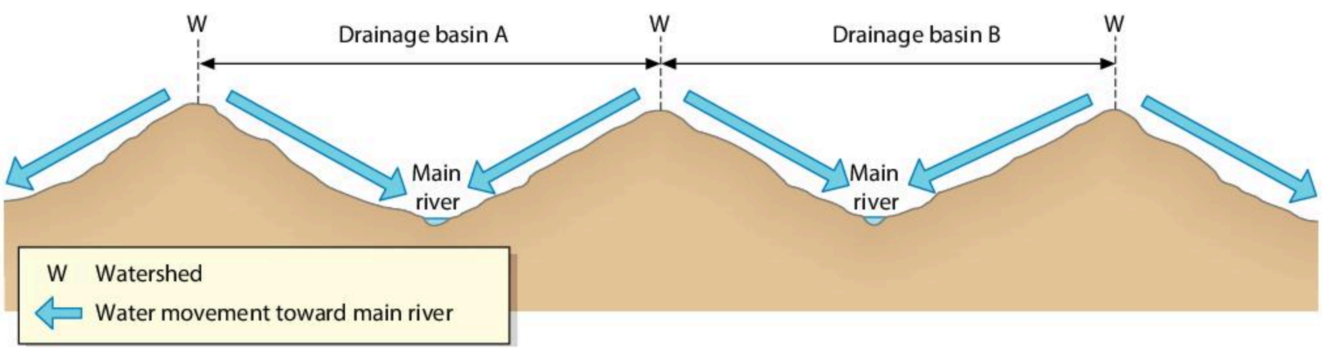


Figure 3.7 Cross-section showing drainage basins and watersheds

Table 3.1 Fact file: some of the world's major rivers

River	Continent	Length (km)	Area of drainage basin (km^2)	Average discharge (m^3/sec)
Mississippi/Missouri	North America	6270	3 202 230	16 200
Nile	Africa	6690	3 254 555	5100
Amazon	South America	6387	6 144 727	219 000
Yangtze	Asia	6211	1 800 000	31 900

Note: Not surprisingly, it is difficult to make accurate measurements of the world's greatest rivers. The figures shown here may differ from those seen in other sources.

A tributary joins the main river at a **confluence**. A main river and all its tributaries form a **river system**. Some drainage basins are very large (*Table 3.1*). For example, the Mississippi and its tributaries drain over one-third of the land area of the USA.

Watersheds in the Caribbean islands are typically 'pear-shaped': they are broad along the upstream divide and relatively narrow near the sea. In the volcanic Windward Islands, watersheds are steep and deeply dissected (*Figure 3.8*).

When small streams begin to flow they act under gravity, following the fastest route downslope. Along the way, water is added to them from **tributaries**, **groundwater flow**, **throughflow** and **overland flow**.

Figure 3.8 A deeply dissected river valley, Jamaica

The source of a river

The starting point of a river may be:

- an upland lake
- a melting glacier
- a spring in a boggy upland area where the soil is so saturated that recognisable surface flow begins
- a spring at the boundary between permeable and impermeable rocks.

Drainage density

Some big rivers have a large number of tributaries so that no place in the drainage basin is very far from a river or stream. Such an area is said to have a high drainage density. Where a main river has few tributaries the drainage density is low (*Figure 3.9*).

High drainage densities occur where:

- the bedrock is impermeable
- the soils are easily saturated
- precipitation is high
- slopes are steep
- interception by vegetation is limited.

Where drainage density is high, water reaches streams quickly. It moves rapidly through the basin. Therefore the flood risk is high compared with basins with low drainage densities.

In the Windward Islands, for example, drainage density is relatively high due to the steep slopes and the volcanic nature of the islands. However, in the coralline/limestone Leeward Islands, slopes within watersheds tend to be gentle with relatively low drainage densities. In these watersheds on limestone there is significant percolation into rocks which builds up groundwater reserves.

Drainage patterns

River systems often form a distinct pattern which is due to the structure of rocks in the drainage basin. The point at which one river or stream flows into another is known as the **confluence**.

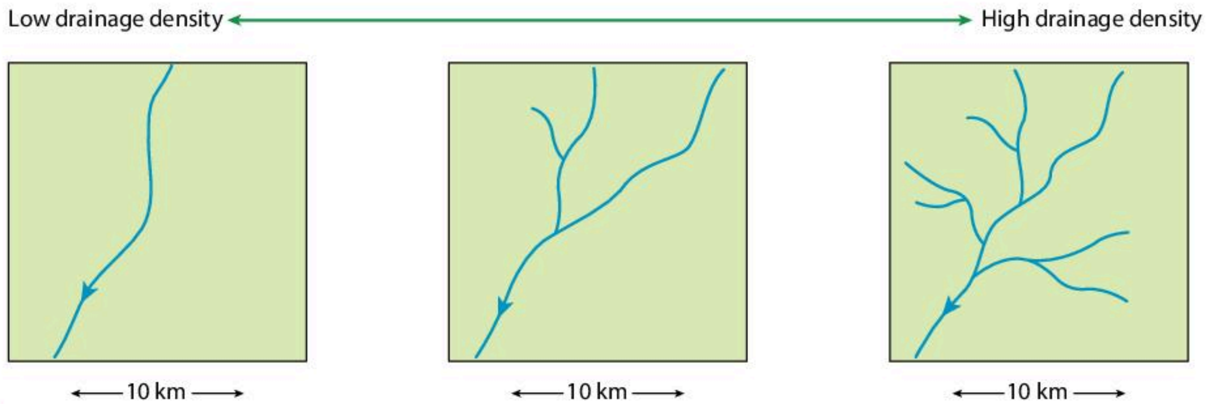


Figure 3.9 Areas with different drainage densities

- A **dendritic** drainage pattern resembles the branches of a tree (*Figure 3.10*). This pattern develops in gently sloping basins with a fairly uniform rock type. Streams flow into each other almost at random. The Caroni River in central Trinidad and the Oropuche in the south are good examples. Both rivers cross unresistant sands and clays on their way to the sea. Within the Caribbean, this is the most common drainage pattern.
- A **trellised** drainage pattern resembles a rectangular grid (*Figure 3.11*). It occurs when there are alternate bands of hard and soft rock at right angles to the main direction of slope. The main river has the power to cut through the hard rock as well as the soft rock. The tributaries mainly form in the soft rock, joining the main river more or less at right angles. This pattern of drainage can be seen in some areas of western Barbados where surface drainage occurs. It is also present in the Northern Range, Trinidad in some north-flowing rivers; here the influence of the secondary folding created smaller tributary valleys that are positioned at right angles to the main valley.

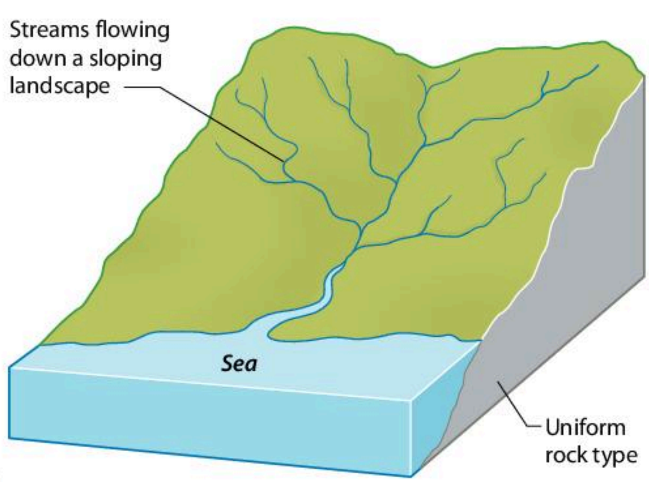


Figure 3.10 A dendritic drainage pattern

Activities

1 Look at a topographical map or atlas to find a river of reasonable size near your school.
  a Draw a map to show the river system and its drainage basin.
  b Label the main river and its tributaries.
  c Mark the source and the mouth of the main river on your map.
  d Use the scale on the original map to work out the size of the drainage basin.

2 Look at *Figures 3.10, 3.11* and *3.12* and at an atlas map of the country in which you live. Which type/s of drainage basin can you recognise in your country?

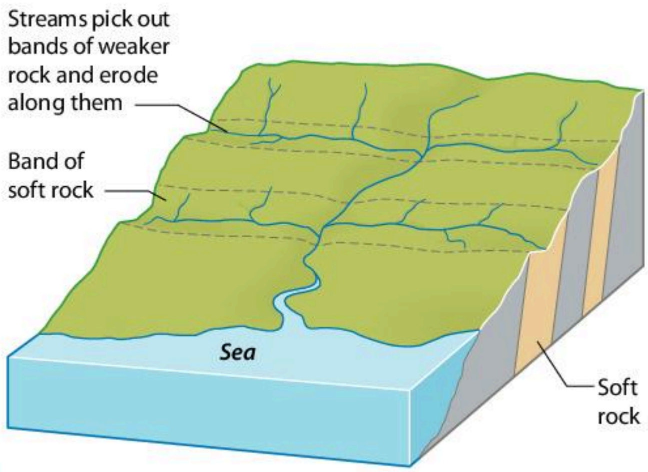


Figure 3.11 A trellised drainage pattern

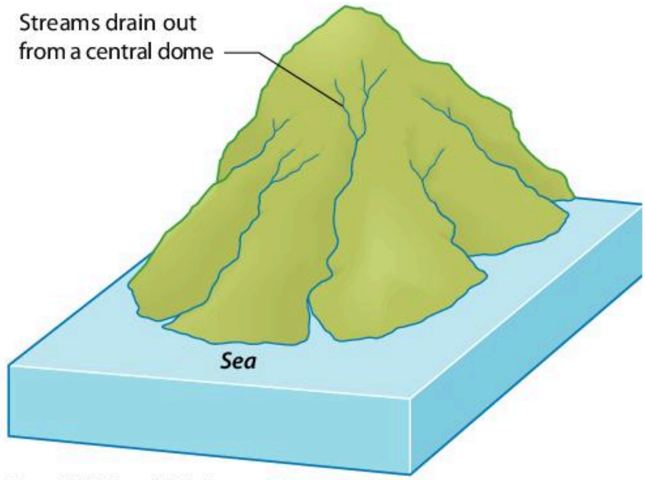


Figure 3.12 A radial drainage pattern

- A **radial** drainage pattern resembles the spokes of a wheel (*Figure 3.12*). Here, rivers radiate outward in all directions from a high central point or dome. The volcanic islands in the eastern Caribbean have radial patterns. St Lucia (particularly the southern half of the island) and Nevis are good examples.

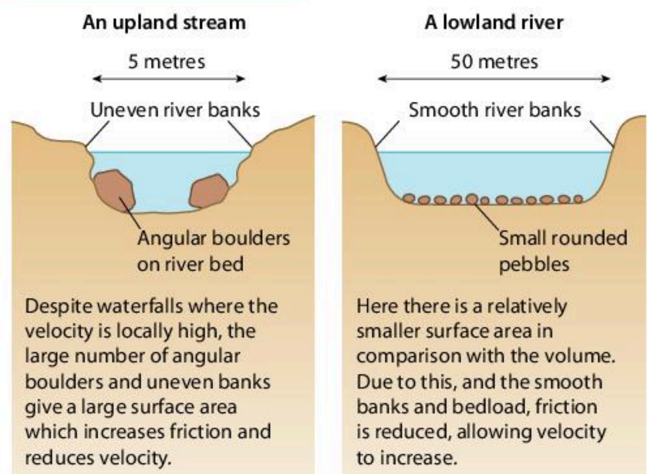


Figure 3.13 Velocity and discharge in the upper and lower course of a river

Rivers: energy and processes

Energy is needed for transfers to occur (*Figure 3.5*). Around 95 percent of a river's energy is used to overcome **friction**. The remaining 5 percent or so is used to erode the river channel and transport material downstream. The amount of energy in a river is determined by:

- the amount of water in the river
- the speed at which it is flowing.

Near the source, river channels are shallow and narrow. Also, the bed is often strewn with boulders and very uneven (*Figure 3.13*). High levels of friction upstream can cause considerable turbulence. The water flows more slowly here than further downstream where the channel is wider, deeper and less uneven.

Although every river is unique, most show similar changes from source to mouth. Three sections can be recognised along rivers: the upper course, the middle course and the lower course. *Figure 3.14* shows these sections which combine to form the **long profile** of the river. In each section the main process taking place and the shape of the valley are different. From source to mouth, the river's:

- gradient decreases
- depth increases
- width increases
- volume increases
- velocity increases
- discharge increases.

The **volume** is the amount of water in the river. The **velocity** is the speed of the water. The **discharge** is the volume times the velocity. Discharge is defined as the amount of water passing a specific point at a given time. It is measured in cubic metres per second (m^3/sec).

Apart from those on the South American mainland, Caribbean rivers are small and few have a discharge exceeding 30 m^3/sec. The discharge rate can also show big variations between dry and wet seasons. The Amazon has the world's highest discharge at around 219 000 m^3/sec.

Figure 3.14 shows how the contours change as a river moves from its upper course to its lower course. In the upper course the steep V-shaped valley is indicated by contours that are very close together. They form an 'arrowhead' with the point facing the high land. By the middle course the contours are further apart and the 'arrowhead' is less pronounced. In the lower course the contours are far apart, indicating the gentle gradient of the flood plain.

Erosion

In most countries rivers are the main causes of erosion and deposition. There are four processes of erosion:

- **Hydraulic action**: the sheer force of river water removes loose material from the bed and banks of the river. It is most effective on the banks and can lead to undercutting and collapse.
- **Corrasion** (or abrasion): this is the wearing away of the bed and banks by the river's load. The load can vary from small particles of clay and sand to large boulders. This is the main type of erosion in most rivers.
- **Attrition**: when pieces of rock are broken away from the bed and banks the edges are usually sharp. However, in swirling water rocks and stones collide with each other and with the bed and banks. Over time the sharp edges become smooth and the pieces of rock become smaller in size (*Figure 3.15*).
- **Solution**: some rocks, such as limestone, dissolve slowly in river water which contains dissolved carbon dioxide from the air.

Most erosion occurs when discharge is high and rivers are said to be in flood. Erosion acts on the landscape in three ways:

- Near its source a river cuts down into its bed, deepening the valley. This is **vertical erosion**.
- In the middle and lower courses, sideward or **lateral erosion** is most important. This widens the valley.

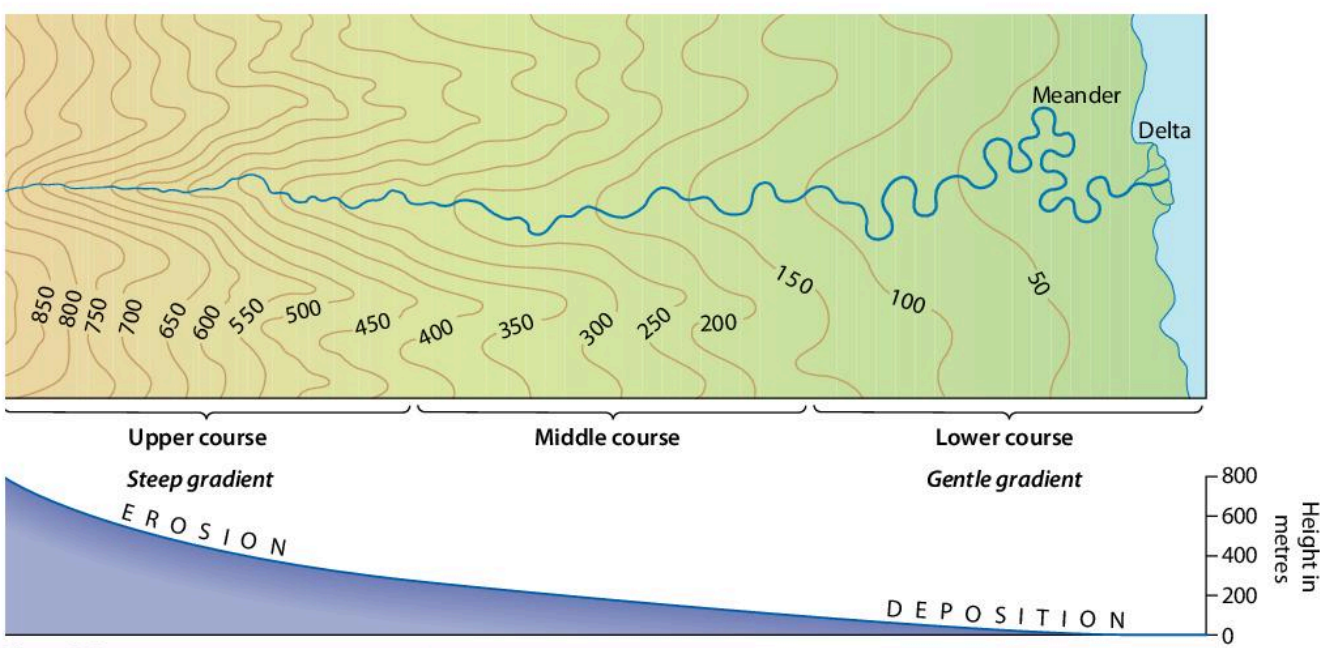


Figure 3.14 Long profile of a river: upper, middle and lower courses

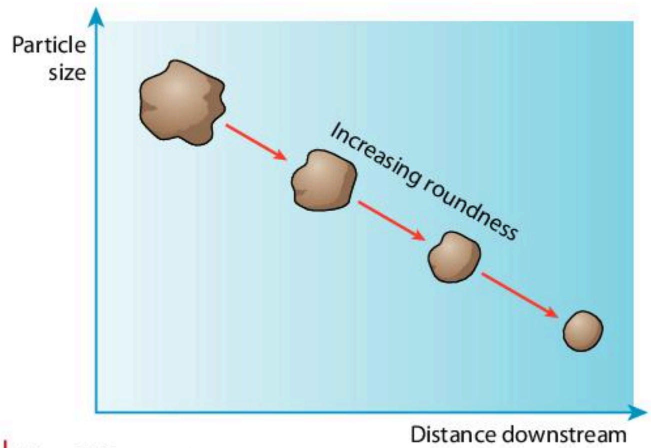


Figure 3.15 Erosion by attrition

- **Headward erosion** (*Figure 3.16*) takes place at the source. It causes the valley to grow very slowly upstream.

Transportation

The **load** is the total amount of material being carried by the river. There are four processes by which a river can transport its load: traction, saltation, suspension and solution (*Figure 3.17*). Parts of the load that are moved by traction when the discharge of the river is low may be transported by saltation when the discharge is high.

Deposition

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

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

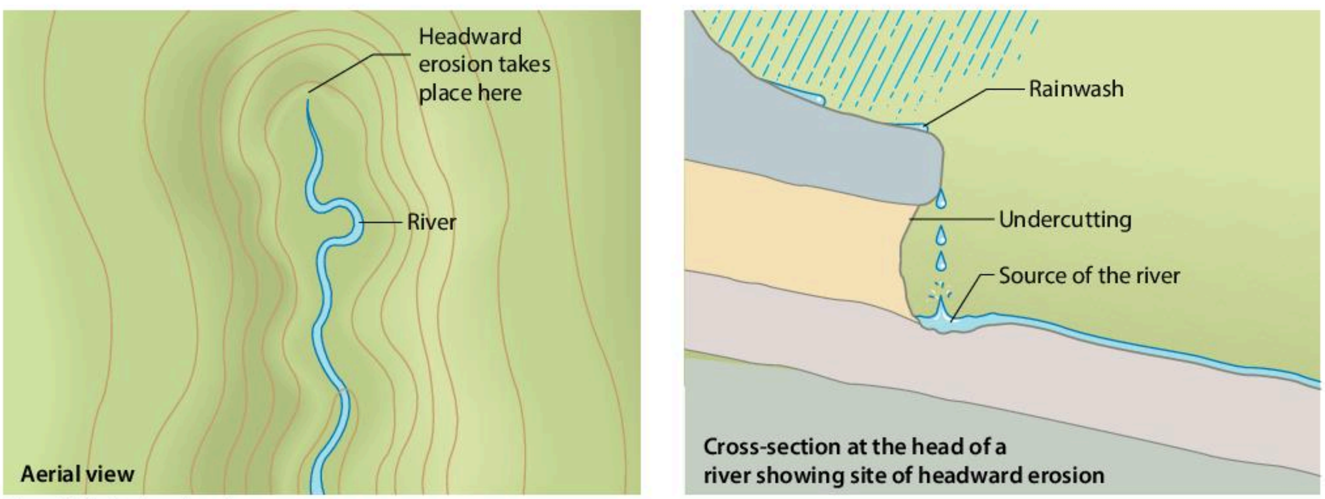


Figure 3.16 Headward erosion

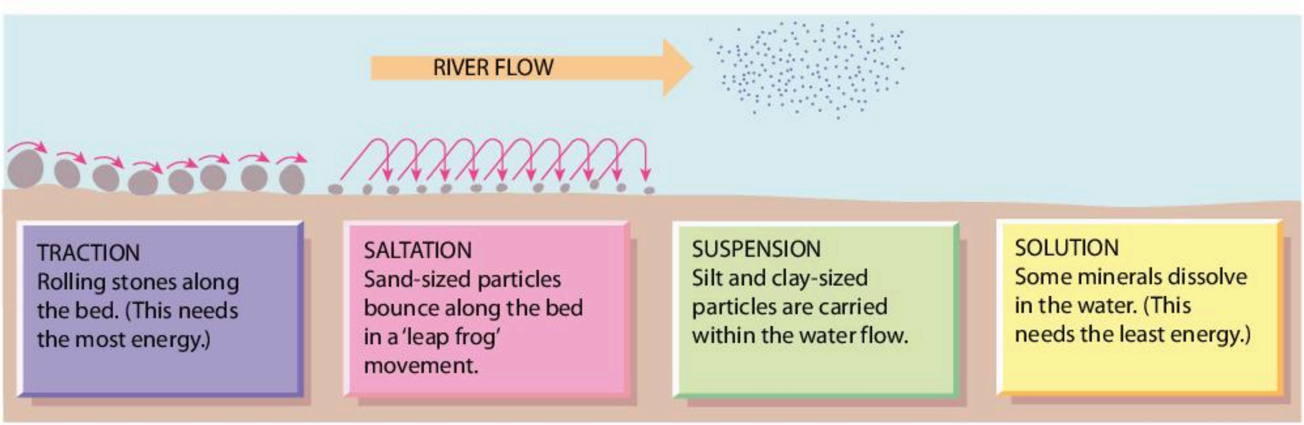


Figure 3.17 Transportation

Figure 3.18 A river, in flood, carrying a large bedload

When a river loses energy, the first part of the load to be deposited is the large, heavy material known as the **bedload** (*Figure 3.18*). Lighter material is carried further. The gravel, sand and silt deposited is called **alluvium**. This is spread over the flood plain. The solution load – the lightest suspended particles which include clay – is carried out to sea. Some rivers get their name from the colour of the silt that they carry, for example the Yellow River in China.

The upper course

The main features of the upper course of a river are:

- a steep V-shaped valley
- a steep gradient
- interlocking spurs
- potholes
- waterfalls, rapids and gorges.

Activities

1 Why is friction greater nearer the source of a river?

2 What is the difference between:
  a hydraulic action and corrosion
  b traction and saltation?

3 Referring to *Figure 3.14*, explain how the contour pattern changes from the upper course of a river, through the middle course to the lower course.

V-shaped valleys

In the upper course, much of the river's energy is needed to overcome friction. The rest is used to transport the load. The river in this section contains large boulders which can erode the bed rapidly when the river is in flood. This results in the river cutting downward into its bed, a process known as **vertical erosion**. It forms steep V-shaped valleys. Soil and loose rock on the valley sides are washed down the steep slopes into the river. This adds to the load.

Interlocking spurs

The river **meanders** (winds its way) around obstacles of hard rock. Erosion is concentrated on the outside banks of these small meanders. This eventually creates spurs which alternate on each side of the river, so they 'interlock'. A spur is a ridge of high land (*Figure 3.20*) which projects toward a river at right-angles, decreasing in height toward the river.

Potholes

Where the bed is very uneven, pebbles carried by fast, swirling water can become temporarily trapped by obstacles in the bed. The swirling currents cause the pebbles to rotate in a circular movement, eroding circular depressions in the bed (abrasion). These are **potholes** (*Figure 3.19*). They generally increase in size only very slowly.

Waterfalls, gorges and rapids

Waterfalls are the most spectacular feature of the upper course, but they can also be found in the middle course. They occur when there is a sudden change in the course of the river. This may be due to differences in rock hardness along the valley (*Figure 3.22*) or for several other reasons:

- a fault line has created an escarpment over which the river flows
- glaciation has left a tributary valley hanging high above the main valley
- a steep drop at the edge of a plateau has been formed by uplift of the land
- a lava flow crosses the path of the river which pours over its edge as a waterfall.

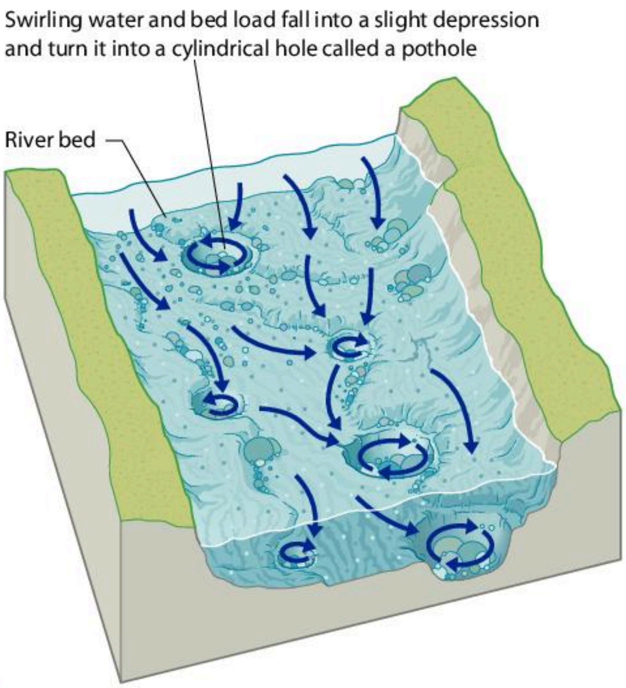


Figure 3.19 Formation of potholes

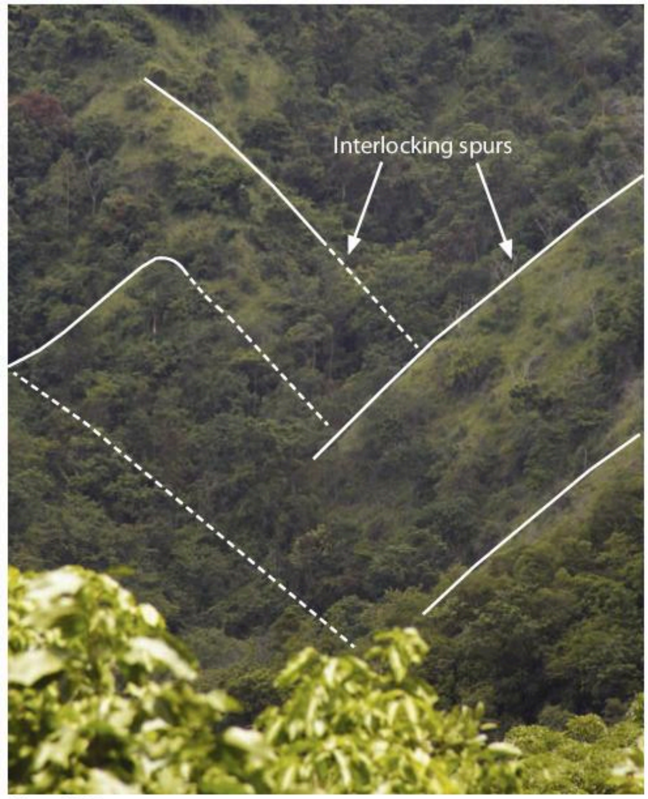


Figure 3.20 Interlocking spurs: overhead view of a river valley close to Kingston, Jamaica

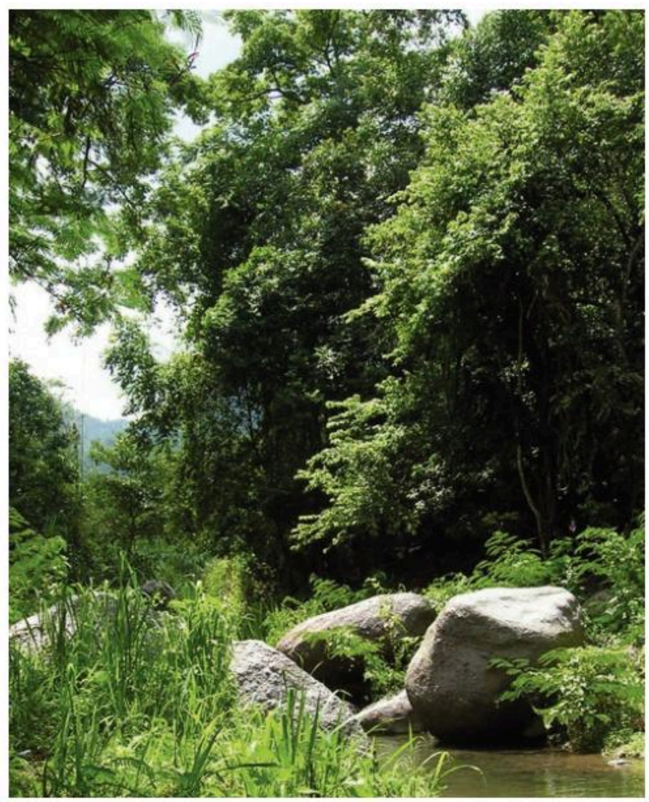


Figure 3.21 Huge boulders in a small stream in Jamaica, which only move when there is torrential rain (during a hurricane, for example)

Figure 3.22 shows what happens when a river flows from a band of hard, resistant rock onto a band of softer rock. Waterfalls (*Figure 3.23*) can form when the hard rock is horizontal, vertical or dipping upstream. The lower softer rock is eroded more quickly causing the hard rock to overhang. The undercutting is caused by corrosion and hydraulic action, with water swirling around in the plunge pool (*Figure 3.24*) and spray hitting the soft rock as the water plunges over the waterfall. The overhang steadily becomes larger until finally it collapses. The rocks that crash down into the plunge pool are swirled around by the currents. This increases erosion and makes the plunge pool deeper. The rocks in the plunge pool are eroded mainly by attrition.

This process, beginning with the collapse of a layer of hard rock, is repeated time and again. As a result, the waterfall retreats upstream, leaving a steep-sided gorge behind (*Figure 3.25*).

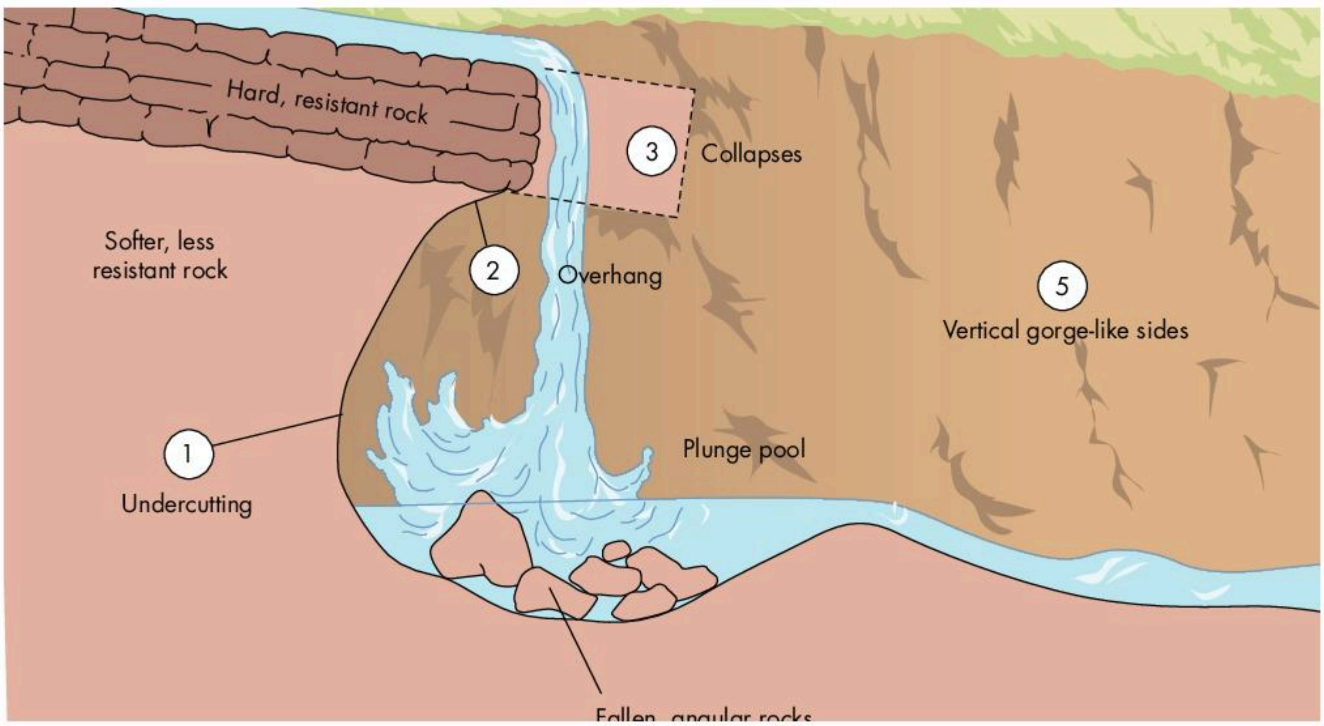


Figure 3.22 Formation of a waterfall

Figure 3.23 Kaieteur Falls, Guyana

Figure 3.24 Plunge pool below a waterfall

Figure 3.25 The start of a gorge below a small waterfall, Black Bay river, Grenada

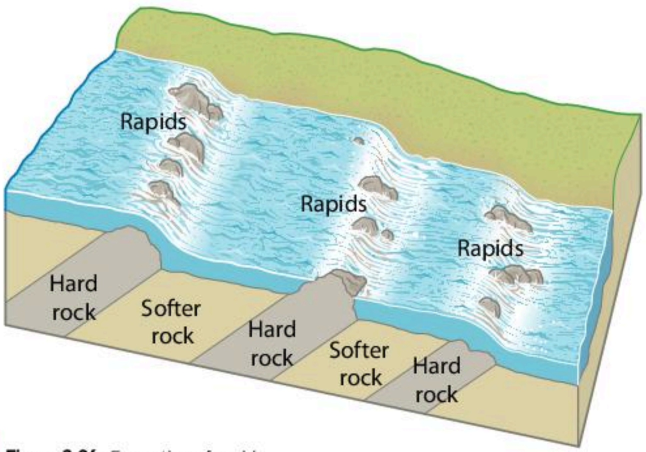


Figure 3.26 Formation of rapids

Sometimes very thin alternating bands of hard and soft rock cross the course of a river. This creates an uneven river bed and a zone of turbulent water known as **rapids** (*Figures 3.26* and *3.27*). Rapids can also form when a layer of hard rock dips gently downstream. An impressive example of rapids in Guyana is at Kurupukari on the Essequibo River.

Activities

1 Using simple diagrams, explain the following processes:
  a vertical erosion
  b lateral erosion
  c headward erosion.
2 Name three features of the upper course of a valley.
3 Write a bullet-point summary to explain the formation of a waterfall.
4 Draw a labelled diagram to show how rapids are formed.

The middle and lower courses

River cliffs and slip-off slopes

In the middle course of the river profile the gradient is much less than in the upper course. The volume of water increases, with more tributaries joining the main river. More water is also added by throughflow and, if the rock is permeable, by groundwater flow. **Lateral erosion** takes over from vertical erosion as the most important process (*Figure 3.28*). As a result, meanders become larger. The current is fastest and most powerful on the outside of the meander, particularly on the downstream section. Erosion is relatively rapid and the outside bank is **undercut**. Again the emphasis is on the downstream section. Eventually the bank collapses and retreats, causing the meander to spread further across the valley. If the meander has already reached the side of the valley, erosion on the outside bend may create a very steep slope or **river cliff** (*Figure 3.29*).

The current on the inside of the meander is much slower. As the river slows it drops some of its load and deposition occurs (*Figure 3.29*). This builds up to form a gently sloping **slip-off slope**, or point bar (*Figures 3.28* and *3.31*). Thus the water is shallow on the inside of the meander and deep on the outside.

Figure 3.27 Section of rapids in a river in Yorkshire, UK

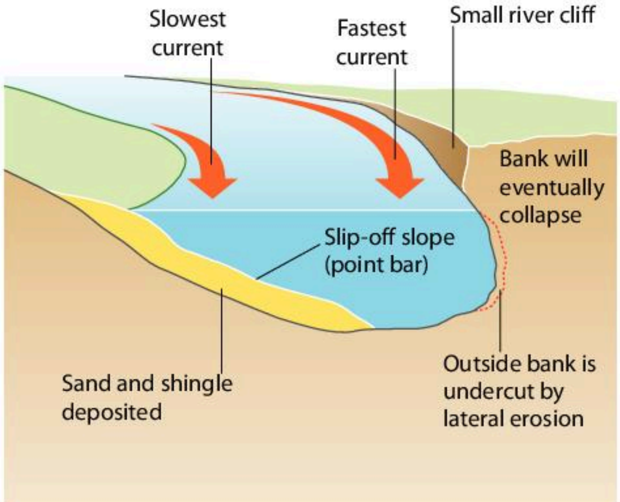


Figure 3.28 Cross-section of a meander

Figure 3.29 A river cliff

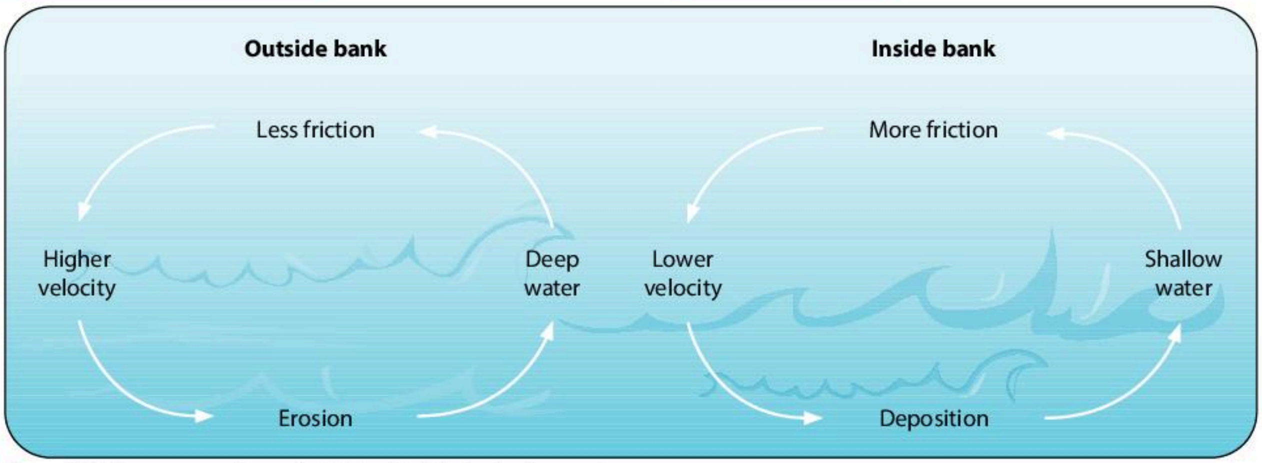


Figure 3.30 Processes operating on the inside and outside banks of a meander

Meander migration

Because of the power of lateral erosion in the middle course, meanders slowly change their shape and position. As they push sideways they widen the valley. But they also move or migrate downstream. This erodes the interlocking spurs, giving a much more open valley compared with that in the upper course (*Figure 3.32*).

Figure 3.31 Meanders and slip-off slopes

Meander necks and ox-bow lakes

As a river flows from its middle course to its lower course, meanders become even more pronounced and the valley becomes wider and flatter. Erosion continues to cut into the outside bends of a meander and a **meander neck** may form, which becomes narrower and narrower (*Figure 3.33*). Eventually, when the river is in flood and discharge is high, it may cut right across the meander neck and shorten its course. For a while, water will flow along both the old meander route and along the new straight course. However, because the current slows down at the entry and exit points of the meander, deposition will occur. After a time, the meander will be cut off from the new straight course, leaving behind an **ox-bow lake**. When cut-off occurs the only sources of water for the ox-bow lake will be precipitation and flooding from the river. If evaporation is greater than these additions of water the ox-bow lake will eventually dry up.

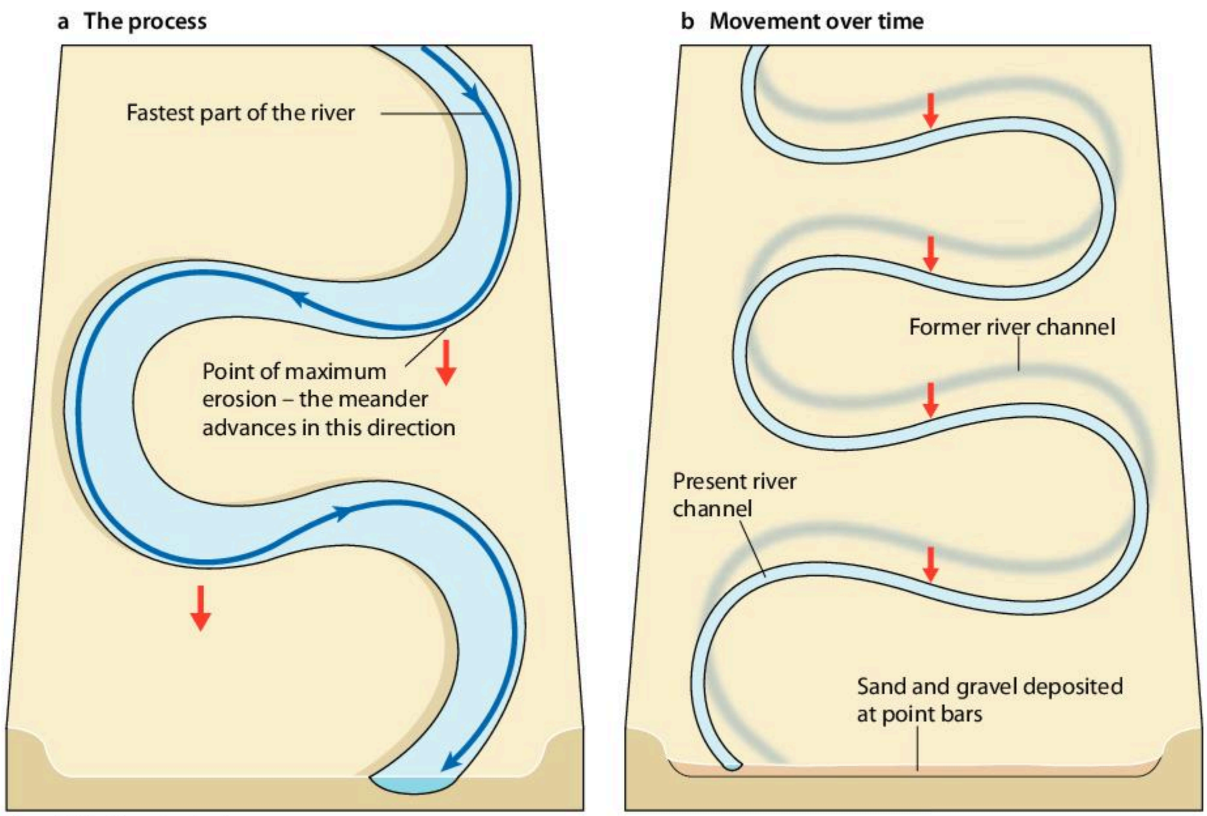


Figure 3.32 Meander migration

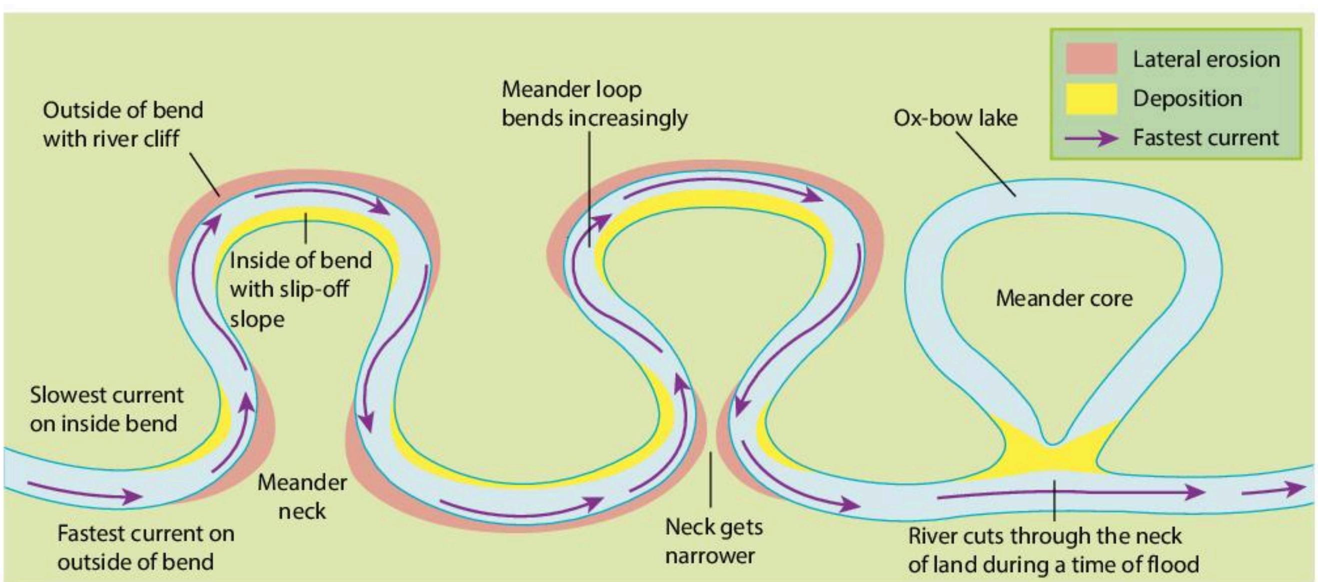


Figure 3.33 Formation of an ox-bow lake

Figure 3.34 Aerial view of an ox-bow lake beginning to form

Flood plains and levees

A **flood plain** is the area of almost flat land on both sides of a river. It is formed by the movement of meanders explained above. When discharge is high, the river is able to transport a large amount of material in suspension. At times of exceptionally high discharge the river will overflow its banks and flood the low-lying land around it. The sudden increase in friction as the river water surges across the flood plain reduces velocity and causes the material carried in suspension to be deposited on the flood plain. The heaviest or coarsest material will be dropped nearest to the river. This can form natural embankments alongside the river called **levees** (*Figure 3.35*). Levees are sometimes strengthened by engineers to control flooding.

The lightest material is carried toward the valley sides. Each time there is a flood a new layer of **alluvium** is formed. This gradually builds up the height of the flood plain. Trinidad's River Ortoire has a flood plain which extends for 25 km in length. At its maximum this flood plain is 1 km wide.

If the sea level falls and the river starts to cut down into its bed to adjust to the new coastline, the old flood plain will be left perched above the new river channel. This is then known as a **river terrace**.

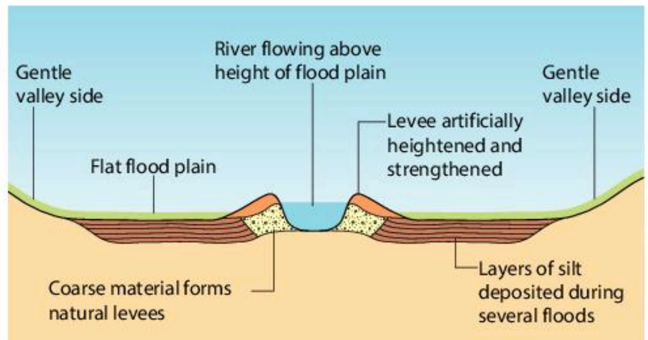


Figure 3.35 Cross-section of a river flood plain

Braiding

Braiding is when a river divides for various distances into two or more channels (*Figure 3.36*). The channels are separated by islands of sediment. Braiding occurs when:

- a river carries a very large load, particularly of sand and gravels, in relation to its velocity
- the discharge changes rapidly from season to season.

The river then deposits so much sediment that the river channel becomes choked. The river is forced to split up and find its way through its own deposits. The banks formed from sands and gravels are unstable. As a result the channel becomes very wide in relation to its depth. The channels and the islands of sediment within them are constantly changing.

Figure 3.36 Braiding along the River Nile, Egypt

Deltas

Deltas are formed by the deposition of sediment at the mouth of a river as it enters a sea or a lake. Deltas only form under certain conditions and most rivers do not end in a delta.

Large rivers in their lower course have the energy to transport a great deal of material in suspension. As a river enters the sea its speed of flow is reduced, sometimes very suddenly, causing deposition. Sand is deposited first, with the lighter silts and clays being carried further out. Thus layers of different sediments are built up on the sea floor until they reach the surface. This happens first at the landward end of a delta, extending gradually out to sea. This huge platform of river sediment is called a **delta** (*Figure 3.37*). When a river flows into a delta it has to flow over its own deposits. This causes the river to braid. Each channel in a delta is called a **distributary**. The two main conditions required for deltas to form are:

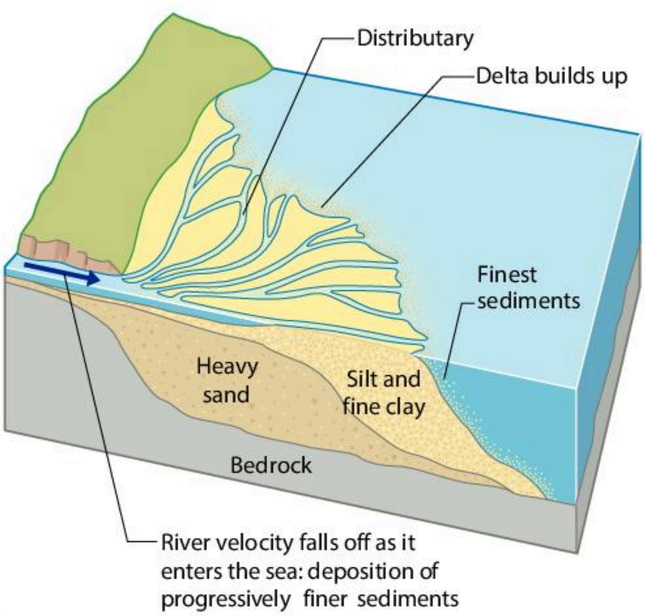


Figure 3.37 Deposits in a delta

- the river must have a large amount of sediment
- coastal currents and waves must not be so strong as to remove sediment faster than the river can deposit it – if this happens the sediments are spread over a much wider area of sea floor beyond the mouth of the river.

There are three main types of delta:

- **Fan-shaped** or **arcuate**: this is triangular in shape with a slightly rounded outer margin. The Nile (*Figure 3.38*), and Yallahs River in Jamaica are examples.
- **Bird's foot** or **digitate**: distributaries flanked by sediment extend out to sea like the claws of a bird's foot. The Mississippi delta is a good example (*Figure 3.39*).
- **Estuarine** or **cuspate**: the delta forms as islands in the the river's mouth. The Amazon, and Essequibo River in Guyana, are examples.

Major deltas are not common in the Caribbean. This is because it usually takes a really large river to build out into the sea. However, Cuba has several small but well-developed examples:

- Sagua la Grande and Sagua la Chica in Villa Clara Province
- Cauto in Holguin
- Rio Manati in Sancti Spiritus.

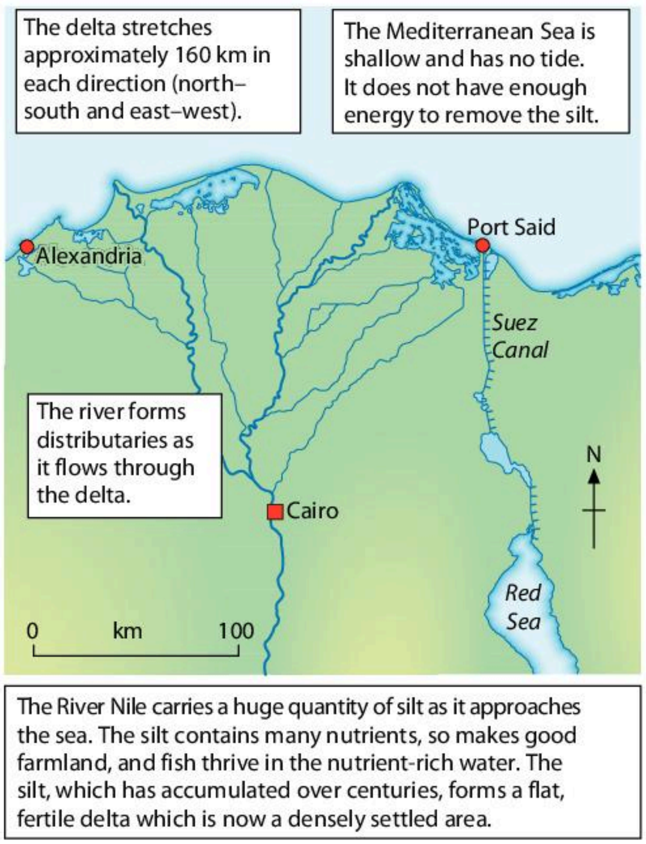


Figure 3.38 The Nile delta

Figure 3.39 Aerial view of the Mississippi delta

Activities

1. Look at *Figures 3.28* and *3.30*. Explain carefully what is happening on **a** the outside bank and **b** the inside bank.
2. Draw a labelled diagram to show how meanders erode interlocking spurs and create flood plains.
3. Write a bullet-point summary to explain the formation of an ox-bow lake.
4. Look at an atlas and find some examples of arcuate and bird's foot deltas (different from those listed above).

Case Study

Rivers in Guyana

Guyana is often described as a water-rich country as it has a **high drainage density**. It has the longest rivers in the English-speaking Caribbean. The country stretches 725 km inland from the coast. The main **direction of flow** of the numerous rivers is in a generally northerly direction toward the Atlantic Ocean. However, in western Guyana a number of rivers flow eastward into the Essequibo River, draining the Kaieteur Plateau. A few minor Amazon tributaries flow south-west out of the country – they are part of the Amazon drainage basin. The drainage pattern is generally dendritic.

Figure 3.40 Guyana's rivers

High rainfall and dense tropical vegetation contributes to a **high rate of infiltration**. This ensures a **continuous discharge** for most rivers. However, there are big seasonal variations. The July discharge of the Essequibo River is more than 7.5 times higher than the November discharge.

The Essequibo River forms the country's largest **river system** (*Figure 3.40*). The Essequibo flows for 1000 km from the border with Brazil in the south to the coast west of Georgetown. Its **drainage basin** covers much of Guyana. This river has all the classic features associated with the upper, middle and lower courses. There are numerous **waterfalls** and rapids along the course of the Essequibo. Its main tributaries include the Rupununi, Potaro, Mazaruni, Siparuni, Kiyuwini and Cuyuni rivers.

Approaching the Atlantic Ocean, Guyana's rivers cut across the coastal plain making east–west transportation difficult. There are numerous islands along the river and for its final 30 km the river channel is **braided** by large flat, fertile islands. The largest are Leguan (47 km^2), Wakenaam (44 km^2) and Hogg Island (57 km^2). It has been estimated that 5–10 million tonnes of silt is carried by rivers into the coastal waters each year.

Guyana has more than 300 waterfalls. Waterfalls tend to limit the use of rivers for transport. Some waterfalls are spectacular and are important tourist attractions. The Kaieteur Falls on the Potaro River has a drop of 226 metres, more than four times the height of the Niagara Falls between the USA and Canada. The average width of the falls at Kaieteur is 113 metres. The discharge has been recorded at 663 m^3/sec. The falls plunge over an escarpment of the Guyana highland called the Pakaraima Plateau. There are eight other waterfalls on the Potaro. The source of the Potaro River is in the Mount Ayanganna area of the Pakaraima Mountains. The river flows for 225 km before its confluence with the Essequibo River.

The Pakaraima Mountains vary in height from 500 metres to 2777 metres at Mt Roraima. These mountains are the source of many rivers renowned for their waterfalls when they reach the edge of the plateau. The mountains form a part of the extensive Guyana Highlands. There are many deep and spectacular gorges in this region.

The **average gradient** of the main rivers is only 1 metre for every 5 km. This results in slow flow and poor quality of drainage throughout most of the country. Swamps and areas that are flooded from time to time are common outside the mountainous regions. Guyana has more than 8000 km of canals that were built to drain land for agriculture, industry and settlement. Georgetown, the capital, lies below sea level and needs dykes to protect it from the Demerara River and the Atlantic Ocean.

Skills

Map reading: using grid references

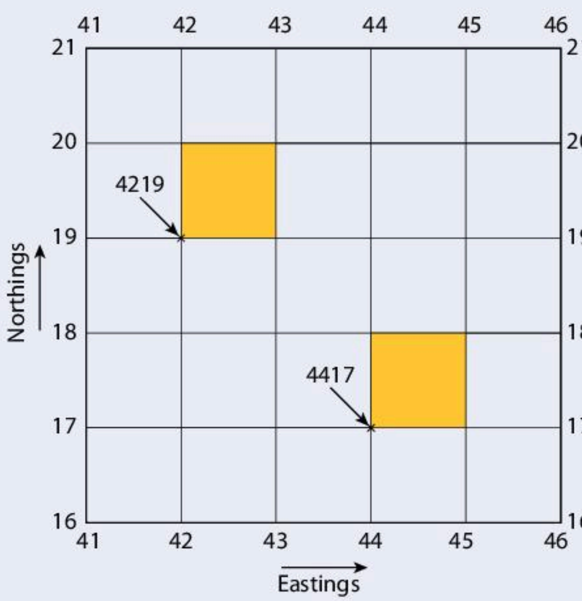


Figure 3.41 Finding four-figure grid references

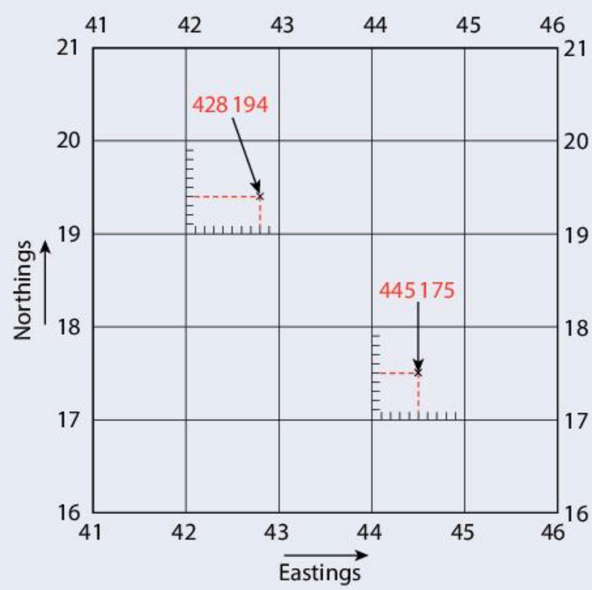


Figure 3.42 Finding six-figure grid references

Topographical or survey maps have grid lines drawn on them so that a place can be located precisely from the grid reference. There are two sets of grid lines:

- **Eastings** are the vertical lines on topographical maps. They increase in value from west to east (left to right). This is why they are called eastings. In *Figures 3.41* and *3.42* the vertical grid lines 41–46 are eastings.
- **Northings** are the horizontal lines. They increase in value from south to north (bottom to top). This is why they are called northings. In *Figures 3.41* and *3.42* the horizontal grid lines 16–21 are northings.

A **four-figure grid** reference is used to locate a grid square. The first two digits refer to the easting value and the second two digits to the northing value. Unless the location that this set of four digits describes is at the edge of the map, it will be at the intersection of four grid squares. The square in question will be the one to the north-east (upper right). *Figure 3.41* gives two examples: 4219 and 4417.

A **six-figure grid reference** is needed to locate an exact point within a grid square. Once you have found the correct grid square, use the third figure (the final easting number) and the sixth figure (the final northing number) to find the precise location (*Figure 3.42*). The third figures represent tenths of the square in each direction. This measurement is usually estimated visually but a ruler can be used to be more precise.

What is:

a an easting

b a northing?

Calculating gradients using ratios

Gradient describes the steepness of a slope. It tells us how much the land is rising or falling over a particular distance. Gradient is expressed as a fraction or a percentage (*Figure 3.43*). *Figure 3.44* explains how to calculate gradient.

The most important thing to remember when calculating gradient is to make sure that the units for *height* and *distance* are the same.

1 Express the gradient '1 in 5' as a percentage.

2 Express 12.5 percent as a fraction.

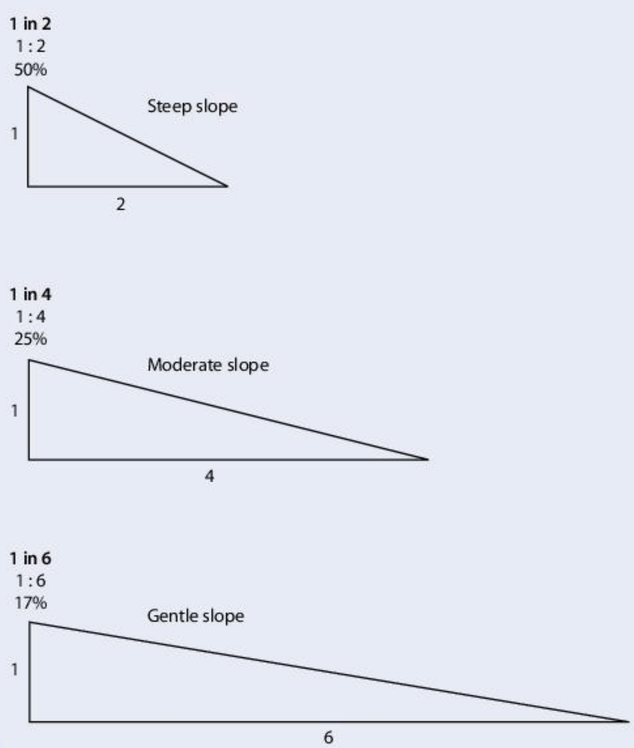
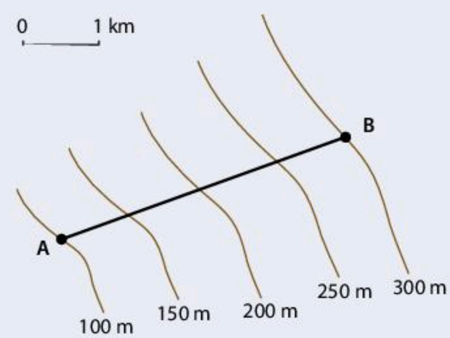


Figure 3.43 Different gradients



$$\text{Gradient} = \frac{\text{change in height (m)}}{\text{distance (m)}} \rightarrow \frac{200\text{ m}}{4000\text{ m}} \rightarrow \frac{1}{20}\ (1{:}20) \rightarrow 5\%$$

Figure 3.44 How to calculate gradient

Glossary of terms

Aquifer: A water-bearing rock.

Braiding: where a river divides for various distances into two or more channels.

Condensation: the change in state from water vapour to water droplets.

Corrasion: the wearing away of the bed and banks by a river's load.

Delta: deposition created by a river as it flows into a lake or the sea, often forming a triangular shape (arcuate delta).

Discharge: the amount of water passing a specific point in a river at a given time. It is measured in cubic metres per second (m^3/sec).

Drainage basin: the area drained by a river and its tributaries.

Drainage density: the total length of all the rivers in a drainage basin in relation to its area.

Evaporation: the change in state from liquid to vapour.

Flood plain: the area of almost flat land on both sides of a river, characteristic of the middle and lower courses.

Groundwater flow: water flowing downhill through rock under the influence of gravity.

Hydraulic action: the force of water alone eroding the bed and banks of a river.

Infiltration: water soaking into soil in a downward direction.

Levees: natural embankments alongside a river formed by fluvial deposition.

Long profile: a river's course from its source in an upland area, along its channel to its mouth.

Meander: a sinuous bend in a river or stream.

Overland flow: water flowing over the surface under the influence of gravity. It occurs when the soil is saturated.

Ox-bow lake: a horseshoe shaped lake separated from an adjacent river of which it was once a part.

Percolation: the movement of water through soil and rock.

Spring: the emergence of underground water at the Earth's surface.

Throughflow: water flowing downslope through the soil.

Transpiration: the loss of moisture from vegetation into the atmosphere.

Hydrological cycle: the constant recycling of water between sea, air and land. The main processes involved are evaporation, condensation and precipitation.

Watershed: a ridge of high land that forms the boundary of a drainage basin.

Water table: the upper level of underground water in a permeable rock.

Ideas for SBA

- *How does the bedload vary in size and shape at two locations in a particular river?*
- *How are the features in a stretch of a specific river likely to change because of erosion or deposition?*

Exam-style Practice

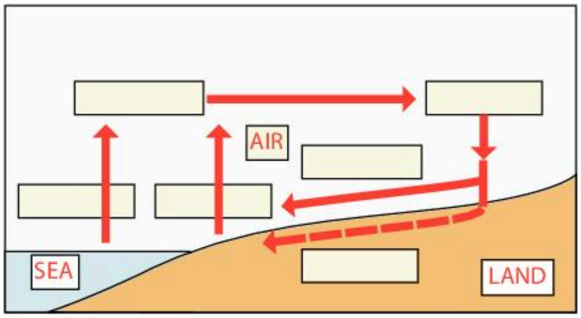


Figure 1 The water cycle

1 a Make a large copy of Figure 1. Insert the following terms in the correct boxes:
- *condensation*
- *throughflow*
- *surface runoff*
- *evaporation*. [4]

b What is the difference between throughflow and groundwater flow? [4]

c Suggest TWO ways in which water may be stored. [2]

d Draw a diagram to explain drainage density. [4]

e List FOUR factors that result in high and low drainage densities. [4]

f Explain TWO of these factors. [6]

Total 24 marks

2 a Draw and label diagrams showing the stages in the formation of an ox-bow lake. [5]

b State FOUR main features of the river in its upper course. [4]

c Describe TWO river landforms caused by erosion. [4]

d Describe how levees are formed. [3]

e What causes braiding in a river channel? [5]

f Why are there differences in the shapes of deltas? [4]

Total 25 marks

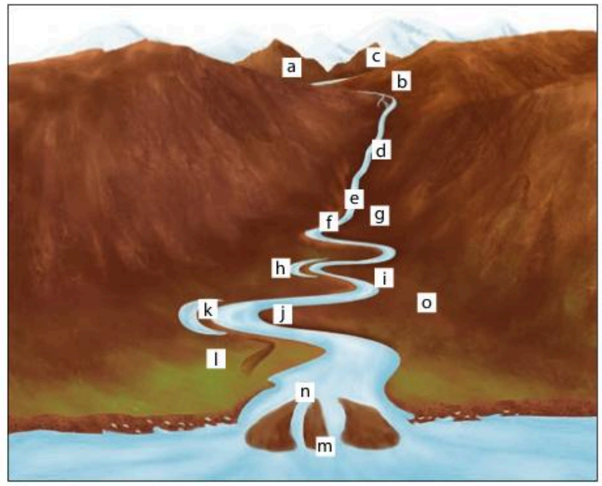


Figure 2 River landforms

3 a Name the letter on Figure 2 that identifies each of the following landforms:
- **i** interlocking spur
- **ii** waterfall
- **iii** ox-bow lake
- **iv** flood plain
- **v** delta
- **vi** levee. [6]

b With the aid of a diagram, explain how a waterfall is formed. [6]

c i In which section of a river's course is vertical erosion most active?

ii Explain why vertical erosion is most active in this part of the river. [3]

d List THREE methods of transportation. [3]

e Describe the main features of a flood plain. [6]

Total 24 marks

4 Coastal processes

In this chapter you will study:

- waves – their formation and characteristics
- wave processes – erosion, transportation and deposition
- landforms of coastal erosion
- landforms of coastal deposition.

You will also learn how to:

- interpret a coastal map.

The Caribbean coast

The coastline of the Caribbean is extremely varied. There are dramatic rocky headlands and golden sandy beaches, colourful coral reefs, dense mangrove forests and majestic sand spits. The coast is wild, desolate and peaceful in some places yet busy, bustling and vibrant in others. Many people in the Caribbean live on the coast, as towns have grown up based on fishing, trade and tourism. The Caribbean coast is a fragile ecological environment. It needs careful management if it is to provide future generations with the resources and beauty that most of us take for granted today.

Activities

1 In what ways is the Caribbean coastline 'varied'?
2 What features of the coast make it attractive to tourists?
3 Why is it important to manage the activities that take place at the coast?

Waves

How are waves formed?

Waves are usually formed by the wind blowing over the sea. Friction with the surface of the water causes ripples to form and these develop

Figure 4.1 A Caribbean coastal landscape

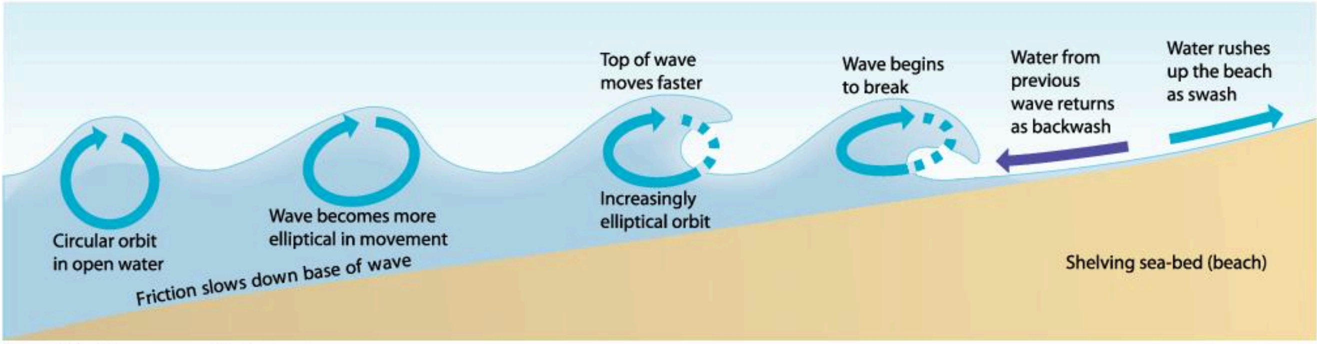


Figure 4.2 Waves approaching the coast

into waves. Waves can also be formed more dramatically when earthquakes or volcanic eruptions shake the seabed. These waves are called **tsunamis**.

In December 2004 giant tsunami waves devastated the countries bordering the Indian Ocean and 240 000 people were killed. When the volcano Krakatoa erupted in 1883, a tsunami said to be 35 metres high killed 36 000 people on the Indonesian island of Sumatra. In the Caribbean, there have been ten significant tsunamis since 1492. The most deadly of these occurred in 1946 when 1800 people were killed in Dominican Republic. Scientists in the USA are predicting further tsunamis in the Caribbean, with the Greater and Lesser Antilles thought to be at greatest risk.

What happens when waves reach the coast?

In the open sea, despite the wavy motion of the water surface, there is little horizontal transfer of water. It is only when the waves approach the shore that there is forward movement of water, as waves break and wash up the beach. *Figure 4.2* describes what happens as waves approach the shore. Notice how the sea bed affects the circular orbital movement of the water. As the water becomes shallower, the circular motion becomes more elliptical. This causes the wave to rise up and then eventually to topple onto the beach. The water that rushes up the beach is called the **swash**. The water that flows back toward the sea is called the **backwash**.

Constructive and destructive waves

It is possible to identify two types of wave at the coast. **Constructive** waves are waves that surge up the beach with a powerful swash. They carry large amounts of sediment and 'construct' the beach, making it more extensive. These are the waves that are loved by surfers! They are formed by storms often hundreds of kilometres away. The waves are spaced well apart and are very powerful when they reach the coast. *Figure 4.3* shows the typical characteristics of a constructive wave.

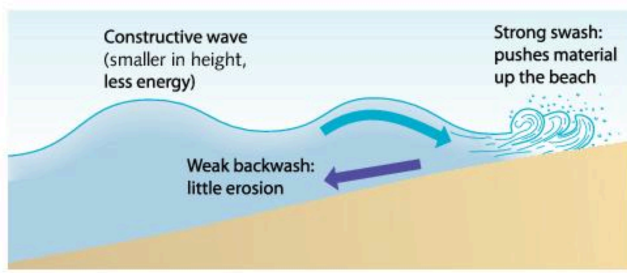


Figure 4.3 A constructive wave

Destructive waves are so-named because they 'destroy' the beach. They are formed by local storms close to the coast. Destructive waves are closely spaced and often interfere with each other, producing a chaotic swirling mass of water. They rear up to form towering waves before crashing down onto the beach (*Figure 4.4*). There is little forward motion (swash) when a destructive wave breaks but there is a powerful backwash. This explains the removal of sediment and the destruction of the beach.

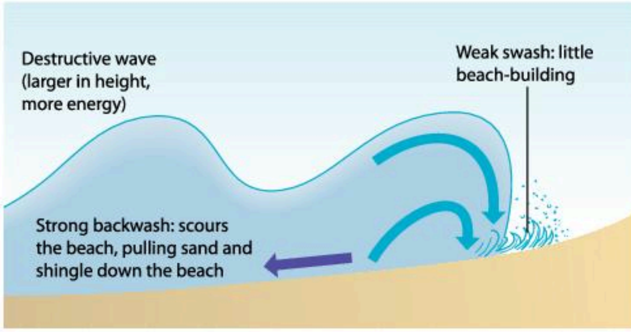


Figure 4.4 A destructive wave

Winds and waves in the Caribbean

In the Caribbean the prevailing winds are from the north-east (*Figure 4.5*). These winds are known as the **trade winds**. The east-facing coasts on islands in the eastern Caribbean are therefore exposed to high-energy constructive waves. When these powerful waves crash against headlands they are capable of carrying out a great deal of erosion. They also drive a lot of sediment onshore to form extensive beaches. The west-facing coasts tend to have much lower-energy waves, as they are sheltered from the strong winds.

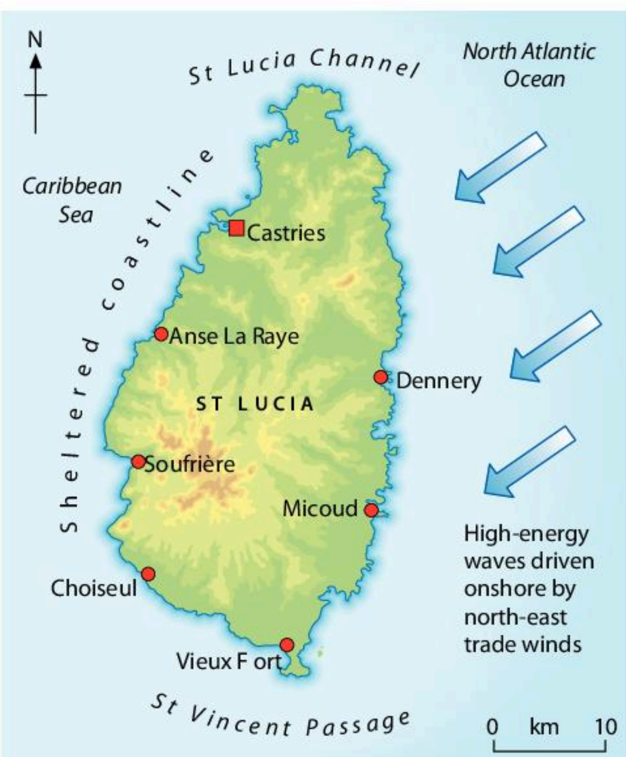


Figure 4.5 Influence of high-energy waves on the coast of St Lucia

On these more sheltered coastlines, features of deposition are more likely to be found than features of erosion.

Activities

1 a Make a copy of *Figure 4.2*. Write the labels *swash* and *backwash* in the correct places on your diagram.

b When waves break on a sandy or pebbly beach, the amount of backwash is often less than the amount of swash. Why do you think this is?

2 a Is the wave in *Figure 4.6* a constructive wave or a destructive wave? Explain your answer.

b Make a copy of *Figure 4.6*, adding as many labels as you can.

c Use *Figure 4.5* to explain why these powerful waves are often found on the east coast of islands in the eastern Caribbean.

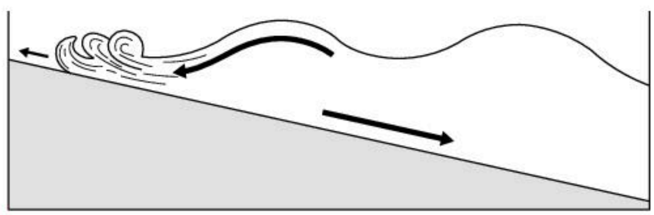


Figure 4.6 Diagram of a wave

Wave processes: erosion, transportation and deposition

Waves are powerful natural forces that help to shape the coast by erosion, transportation and deposition.

Erosion

When a wave crashes down on a beach or smashes against a cliff it will carry out the process of erosion. There are several different processes of coastal erosion. (Some of these are similar to processes of erosion by rivers – see Chapter 3.)

- **Hydraulic action**: this involves the sheer power of the water as it smashes into a cliff. Trapped air is blasted into holes and cracks in the rock, eventually causing fragments of rock to break off. The explosive force of trapped air operating in a crack is called **cavitation**.
- **Corrasion/abrasion**: this involves fragments of rock being picked up and hurled by the sea at a cliff. The rocks act like erosive tools scraping and gouging the rock. Rock fragments moving across a rocky platform will scrape it smooth, rather like the effect of sandpaper on wood. This sandpapering effect is called **abrasion**.
- **Corrosion/solution**: some rocks at the coast are especially vulnerable to being dissolved by sea water. This is particularly true of limestone, which forms cliffs in many parts of the Caribbean. Acids in the water slowly dissolve away the rock, often forming strange jagged rocky platforms.
- **Attrition**: rock fragments carried by the sea frequently knock into each other or are scraped against one another. This causes them to become rounded and smaller.

Activities

Figure 4.7 shows a typical coastline being affected by the processes of erosion.

1 Make a careful copy of *Figure 4.7*.

2 Write labels in the correct places to show where you would expect the processes of hydraulic action, corrasion, corrosion/solution and attrition to take place.

3 Mark a symbol ✱ to show where you might expect the process of cavitation to occur. Explain this symbol in a key.

4 Under what conditions do you think the greatest rates of erosion will take place at a coast? (Think about the waves, the presence of sediment, the strength of the cliffs.)

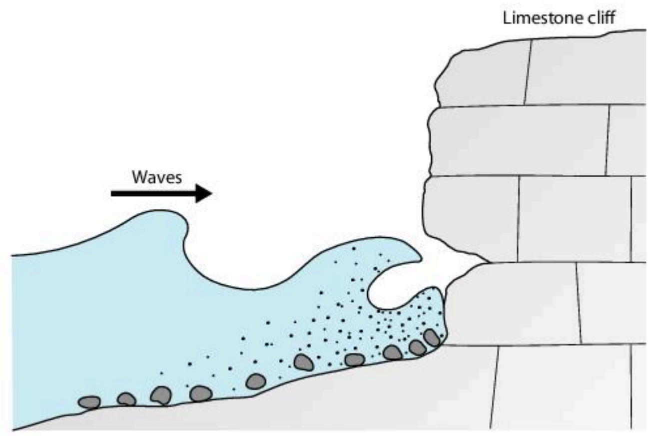


Figure 4.7 Processes of coastal erosion

Transportation

Once rock fragments have been broken off a cliff or brought to the coast by rivers, they enter the coastal (littoral) transport system. Waves are very effective transporters of sediment. After a storm, beaches can look very different. New ridges called **berms** may have been created on the beach or rocky platforms exposed when sand and shingle has been washed away.

Sediment is moved by the waves in a number of ways (*Figure 4.8*).

- **Traction**: this is where heavier particles are slowly rolled along the sea bed.
- **Saltation**: some particles move in a bouncing manner as they are disturbed by other particles knocking into them. They are too heavy to be carried by the water but light enough to 'hop' along the sea bed.
- **Suspension**: lighter particles can be picked up and carried within the water. Sand is most commonly transported in this way.

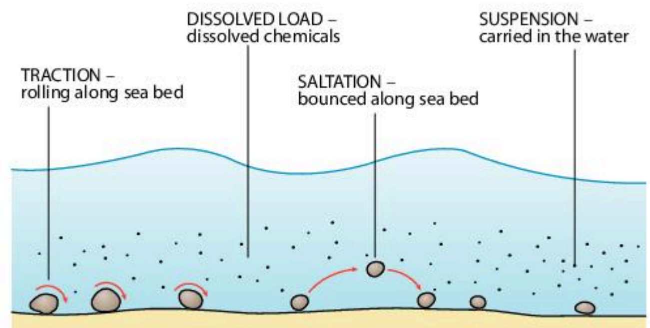


Figure 4.8 Sediment movement

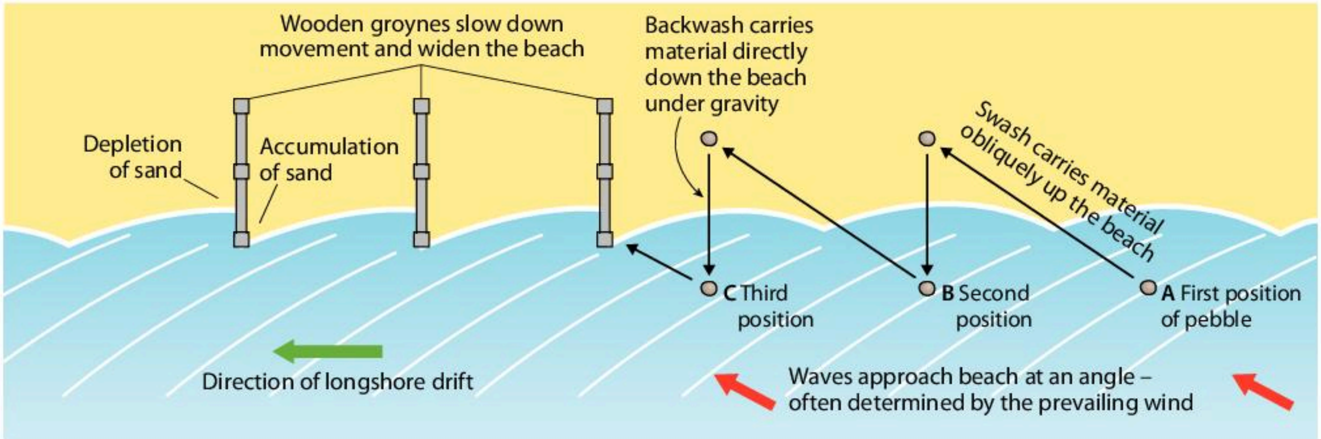


Figure 4.9 Longshore drift

- **Dissolved load**: dissolved chemicals will be transported in solution. Limestone (calcium carbonate) is often transported in this way before precipitating out of solution to form new limestone deposits on the sea bed. This is a very common process in the warm Caribbean seas.

One important factor affecting the movement of sediment and its deposition at the coast is the angle at which the waves approach a shoreline (*Figure 4.9*). If the waves approach parallel to the coast, sediment will simply be moved up and down the beach. There will be very little sediment movement along the coast. Under these conditions beaches will form in bays.

If the waves approach a shoreline at an angle, sediment is transported along the coast in a 'zig-zag' fashion (*Figure 4.9*). This process is called **longshore drift** and it results in a pile-up of sediment at one end of a bay.

Deposition

Coastal deposition takes place in areas where the flow of water slows down. Sediment can no longer be carried or rolled along and it has to be deposited. Coastal deposition most commonly occurs in bays where the energy of the waves is reduced upon entering the bay. This explains the presence of beaches in bays and accounts for the lack of beaches at headlands where wave energy is much greater.

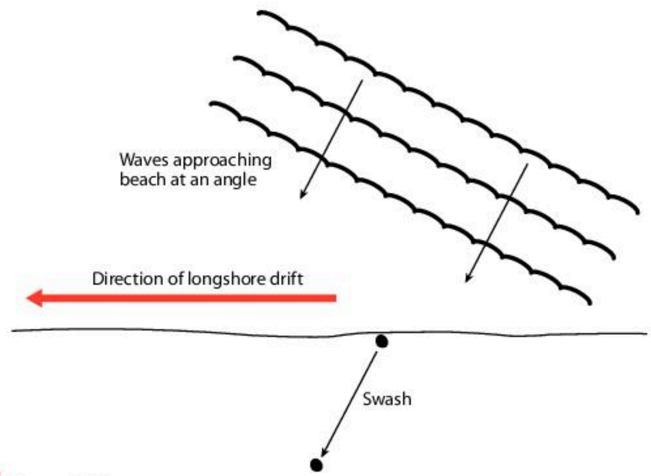


Figure 4.10 Longshore drift at work on a coastline

Activities

Study *Figure 4.10*. It shows a stretch of coastline where the process of longshore drift is operating – but the diagram is incomplete.

1. Make a copy of *Figure 4.10*.
2. Use *Figure 4.9* to help you show the process of longshore drift.
3. Most of the sediment moved by longshore drift is rolled along the sea bed. What name is given to this process of transportation?
4. Occasionally, lighter sediment is bounced along the sea bed. Draw a simple sketch to show how this process operates. Write the name of the process beside your sketch.
5. Name and describe the other two processes of sediment movement along the coast.

Landforms of coastal erosion

Look at *Figure 4.11*. It shows a stretch of coastline in Antigua, which exhibits many features typical of coastal erosion. There are steep cliffs, caves and a rocky wave-cut platform at the bottom of the photograph. You can see a sandy bay toward the top of the photograph and a striking headland jutting out into the sea. The rocks in this part of Antigua are tough and resistant, which is why they form excellent examples of coastal erosion landforms.

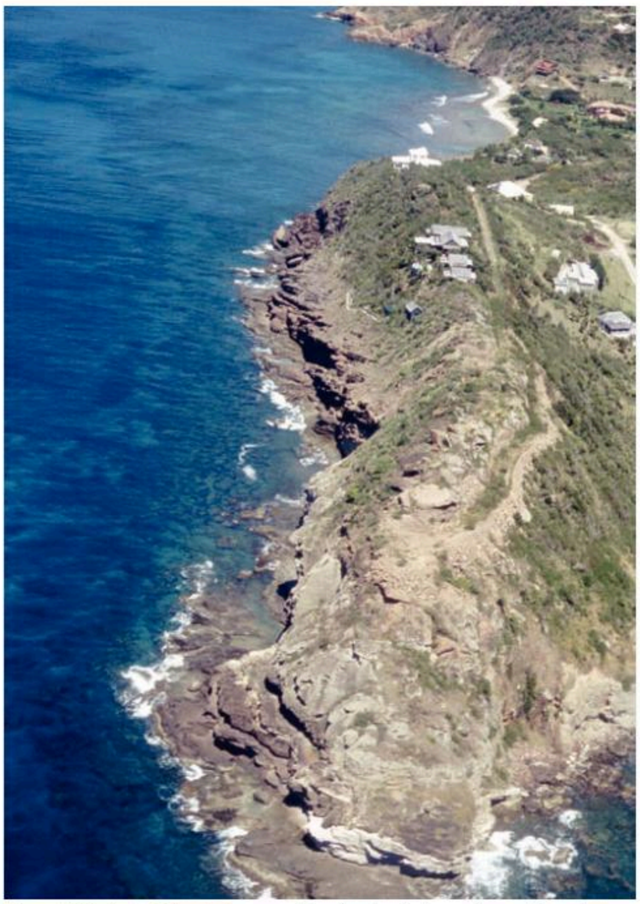


Figure 4.11 Part of the Antigua coastline showing features of coastal erosion

Cliffs and wave-cut platforms

When waves break against a **cliff**, they erode close to the high tide line, taking a 'bite' out of the cliff to form a feature called a **wave-cut notch**. Over a long period of time – usually hundreds of years – the notch gets deeper until the overlying cliff can no longer support its own weight and it collapses.

Figure 4.12 A wave-cut platform and cliff

Through a continual sequence of wave-cut notch formation and cliff collapse, the cliff line gradually retreats. In its place is a gently sloping rocky platform called a **wave-cut platform** (*Figure 4.12*). A wave-cut platform is typically quite smooth due to the process of abrasion, but in some places it may be pockmarked with rock pools. In parts of the Caribbean where limestone and coral are the coastal rocks, **low-tide platforms** can form (*Figure 4.13*). These are relatively flat, rocky surfaces formed by a combination of chemical dissolving and wave action. There is often a small overhang at the coast called a **visor**.

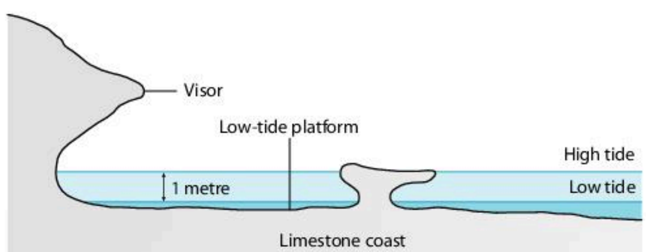


Figure 4.13 A low-tide platform

Headlands and bays

Cliffs rarely erode back at an even pace. Sections of cliff that are particularly resistant to erosion stick out to form **headlands**. Weaker sections of coastline that are more easily eroded form **bays**. *Figure 4.14* describes the changes that take place on a coastline where rocks of different resistances meet the coast. Headlands are most vulnerable to the power of the waves, which explains the presence of erosion features such as cliffs and wave-cut platforms. In contrast, bays are often much more sheltered from the full fury of the sea. The waves are less powerful and deposition tends to dominate. This explains why a sandy beach is the most common feature found in a bay.

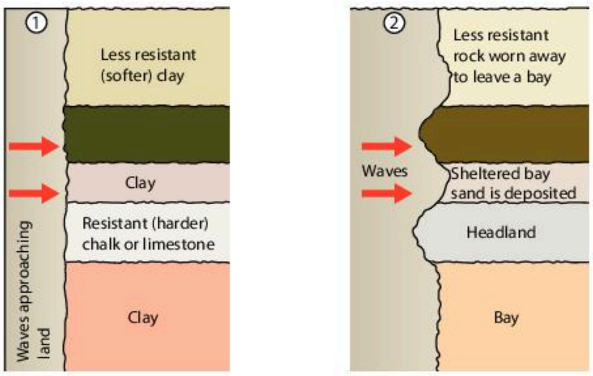


Figure 4.14 Development of headlands and bays

Headlands and bays are common in the Caribbean. One of the best examples can be seen in Trinidad (*Figure 4.15*). Tough metamorphic rocks in the north of the island form the Northern Range. Where these rocks outcrop on the west and east coasts, they form substantial headlands. The weaker Quaternary rocks have been more easily eroded by the sea.

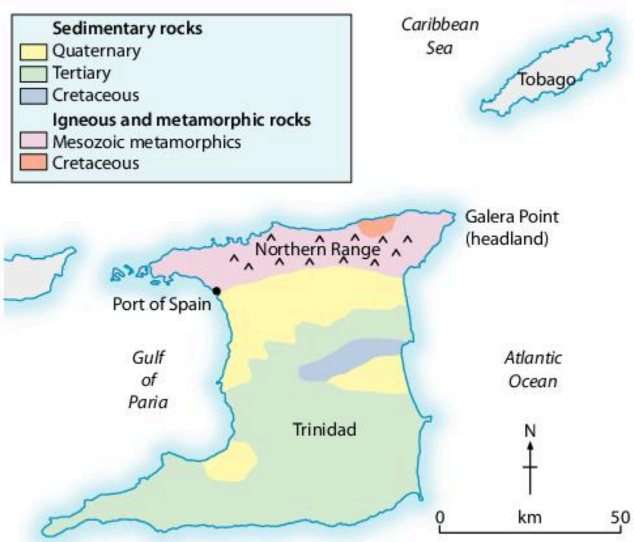


Figure 4.15 Geology of Trinidad

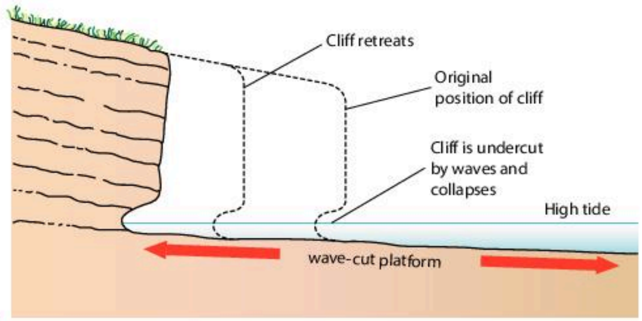


Figure 4.16 Formation of a wave-cut platform

Activities

Study *Figure 4.16*. It shows a cliff being eroded by the sea.

1. Make a copy of *Figure 4.16* (omit the dotted lines). Add the labels *cliff* and *wave-cut notch*.
2. Add labels to indicate where the processes of erosion are operating. Name the processes in your labels.
3. Draw a second diagram to show how the cliff collapses to form a wave-cut platform. Add labels to show what is happening and label the *wave-cut platform*.

Caves, arches and stacks

Processes of erosion are particularly active along lines of weakness in a headland, such as joints or faults. The energy of the waves is concentrated on these weaker points, gouging out the rock to form a **sea cave**. Over time, erosion may lead to two back-to-back caves

Figure 4.17 Erosion features on the coast of Dominica

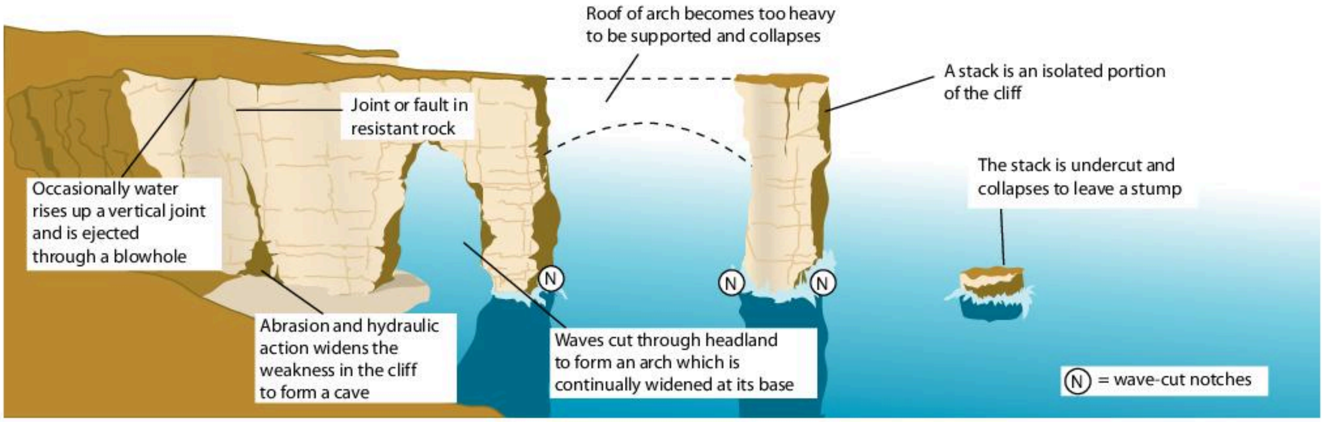


Figure 4.18 Formation of caves, arches and stacks

breaking through a headland to form an **arch**. Gradually the arch is enlarged by erosion at the base and by weathering processes acting on the roof. Eventually the roof collapses to form an isolated pillar of rock known as a **stack**. The formation of a stack is described in *Figure 4.18*.

Activities

Figure 4.19 is a sketch of coastal erosion features.

1 Make a careful copy of *Figure 4.19*.

2 Add the following labels in their correct places: *headland, sea cave, arch, stack.*

3 How and why do you think this headland will change in the future? Use a simple sketch to show the changes you have suggested.

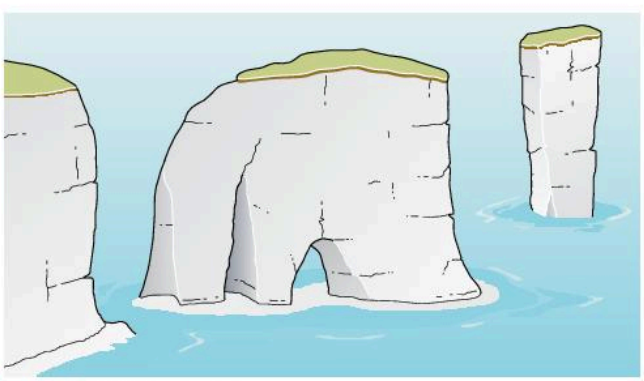


Figure 4.19 Sketch of a stack

Landforms of coastal deposition

Beaches

Most beaches in the Caribbean are made of sand. Sandy beaches are very important to the economy of the Caribbean, attracting tourists from around the world (*Figure 4.20*).

Figure 4.20 Tourists enjoying the gentle waves on a bayhead beach

Sandy beaches are most often found in sheltered bays where they are called **bayhead beaches**. When waves enter these bays they are forced to bend to mirror the shape of the coast. This is called **wave refraction** (*Figure 4.21*). It is caused by the shallowing of the water as the waves enter the bay. Refraction spreads out and reduces the wave energy in a bay, which is why deposition occurs here.

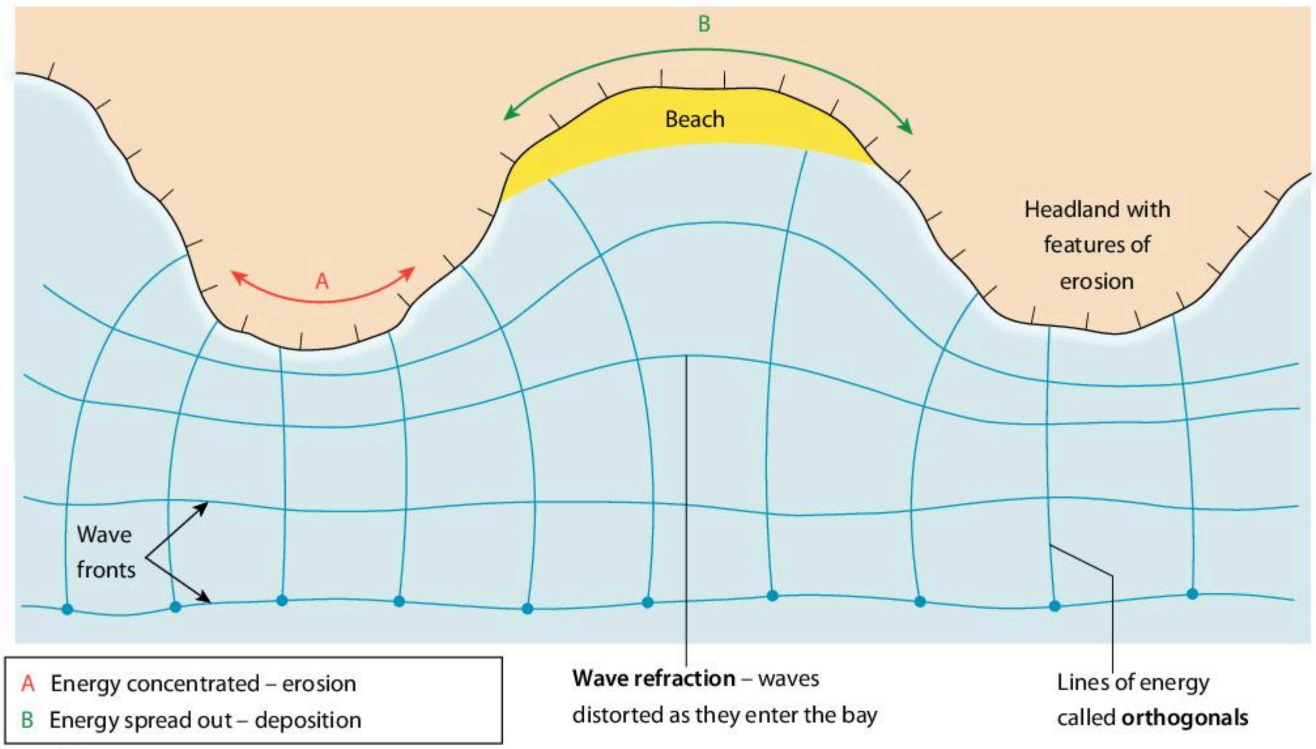


Figure 4.21 Wave refraction

Sandy beaches can also be found on stretches of coastline protected by fringing coral reefs, such as Anse de Sable beach on the southern coast of St Lucia (*Figure 4.22*).

Figure 4.22 Anse de Sable beach, St Lucia

Elsewhere along the coast pebble beaches may form. These are most commonly found in areas where cliffs are being eroded and where there are higher-energy waves.

Activities

Study the photo in *Figure 4.22*.

1 Describe the shape and size of the beach.

2 Is the beach made of sand or pebbles? What does this suggest about the waves – are they high-energy waves or low-energy waves?

3 What evidence is there that the beach is popular with tourists?

4 How do you think the fringing coral reef helps in the formation of Anse de Sable beach?

5 Draw a simple sketch of the beach in *Figure 4.22*. Add arrows to show the most likely direction of longshore drift.

Spits, tombolos and bars

A **spit** is a long, narrow finger of sand or shingle jutting out into the sea from the land. Spits are very common features across the world and there are some good examples on the east coast of Trinidad (Cocal spit, for example).

Figure 4.23 A Coastal spit

Spits are formed by the process of longshore drift, and they tend to occur where there is a change in the direction of the coastline – for example, at a river mouth. In order for a spit to form, waves must approach the coast at an angle (*Figure 4.24*) so that material is moved along the coast rather than simply up and down the beach.

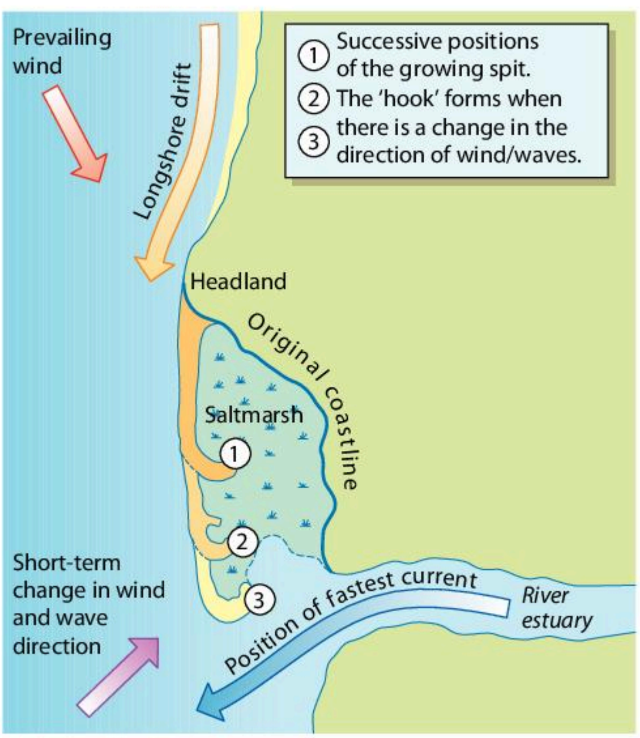


Figure 4.24 Formation of a spit

Activities

Figure 4.25 shows a stretch of coastline.

1. Make a copy of *Figure 4.25*.
2. Draw a spit on your diagram in the correct place.
3. Use *Figure 4.24* to help you add labels to your diagram.
4. Write a few sentences in your own words explaining why a spit has formed here.

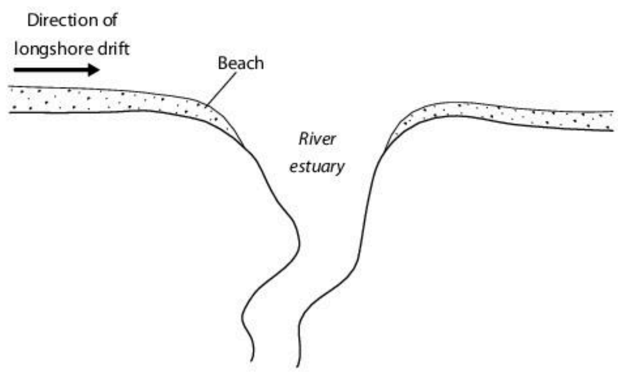


Figure 4.25 Stretch of coastline affected by longshore drift

Over time, a spit becomes colonised by grass and bushes, and eventually trees will grow. On the sheltered landward side of a spit, where the water is very calm, mudflats and salt marshes will form. These are important habitats for plants and birds. Being close to sea level, spits are very vulnerable to erosion, especially

Figure 4.26 Scotts Head tombolo, Dominica

during storms and when there are storm surges associated with tropical cyclones.

Sometimes a spit may grow out to join an island which is then connected to the mainland. This feature is known as a **tombolo**.

The island of Scotts Head on the south coast of Dominica has become attached to the mainland by a tombolo as a result of deposition of sediment by longshore drift from east to west (*Figure 4.26*).

Case Study

Palisadoes spit, Kingston, Jamaica

One of the most extensive features of coastal deposition in the Caribbean is the Palisadoes just south of Kingston in Jamaica (*Figure 4.27*). The 13 km-long feature is a highly complex spit that has formed and re-formed over hundreds of years. Scientists believe that it may be 4000 years old. There is some debate as to whether it is a spit or a tombolo, as in places and at times in the past it has become joined to small islands called cays. You can see some examples of these cays on *Figure 4.31*.

Several processes are at work in the formation of the Palisadoes.

- Longshore drift operates along the south coast of Jamaica from east to west, driven by the easterly trade winds. Gradually sediment is transported along the beach in a characteristic zig-zag fashion. The sediment is the result of rocks eroded from the cliffs together with sediment that has been washed onshore by waves and currents. River sediment also adds to the material being transported along the coast. Just to the south of Kingston, the coastline takes a sharp bend and this accounts for the precise location of the spit. Continued westerly deposition has caused the spit to gradually extend out to sea further and further away from the mainland. As it has extended, it has linked up with the cays.

Figure 4.27 Port Royal at the end of the Palisadoes spit, Jamaica

- Hurricanes and tropical storms frequently batter the area, often causing significant erosion. Storm surges associated with hurricanes can roll right over the top of the spit removing huge amounts of sediment and re-depositing it elsewhere. Most recently, in 2004, Hurricane Ivan eroded as much as a metre off the 2 metre high sand dunes on the spit.
- Summer sea breezes blow onshore. These result from the relative temperature differences between the land and the sea. Warm air rising over the land draws in cooler air from the sea. The greater the difference in temperature, the stronger the winds. Once generated, the sea breezes often create powerful destructive waves which are capable of eroding the seaward face of the spit, causing it to become steeper.

In December 2013 a revised 'zoning plan' was published for the Palisadoes-Port Royal Protected Area. The five-year (2014–19) plan aims to protect key habitats, while promoting the sustainable use of the natural and heritage resources.

The zoning plan defines the 'limits of acceptable use' and the types of development and activities that can and cannot occur in each zone.

Occasionally a sand or shingle spit extends right across a bay to form a **bay-bar**. River water trapped behind the bar can form a freshwater lake or **lagoon** (*Figure 4.28*).

Figure 4.28 A bay-bar and lagoon in Antigua

Along some stretches of coastline, tidal currents and waves combine to cause a build-up of sediment on the sea bed just offshore. This feature is called a sandbank or **offshore bar** and it very often extends for several kilometres parallel to the coast (*Figure 4.29*). The calm, shallow saltwater trapped between the offshore bar and the coast is called a seawater **lagoon**.

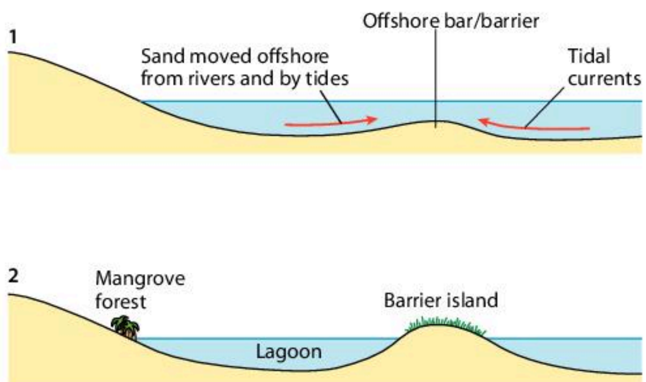


Figure 4.29 Formation of a barrier bar and lagoon

In some parts of the world where sea levels have risen since the last Ice Age, offshore bars have been driven onshore by the waves to form extensive **barrier beaches**. Chesil Beach in southern England is an example of a beach formed in this way.

Offshore bars may lie just below the surface of the water, combed flat by breaking waves, or they may emerge over time to form **barrier islands**. The barrier islands off the coast of Miami in Florida form the densely urbanised part of the city called Miami Beach (*Figure 4.30*). Barrier beaches are very important in protecting the mainland from the full force of hurricanes. (This fact is not much comfort for the people who live in Miami Beach!)

Figure 4.30 Development at Miami Beach on barrier islands

Activities

1 Design a poster to show the formation of barrier islands. Include a series of colourful diagrams showing how barrier bars and then barrier islands are formed. Don't forget to include some writing or labels to describe what is happening.

2 Study *Figure 4.30*. Do you think the people who live in Miami Beach should be worried about where they live? Explain your answer.

Skills

Coastal mapwork

1 Locate the Palisadoes on the south coast of the map extract in *Figure 4.31*.

- a What is the straight-line distance between Harbour View and Fort Charles?
- b What is the distance by road between Harbour View and Fort Charles?
- c Why do you think the International Airport is sited on the Palisadoes?
- d In what direction do you think longshore drift is operating? Explain your answer.
- e Draw a simple sketch map to show the Palisadoes spit and the adjacent coastline. Use arrows to indicate the direction of longshore drift. Locate and label Harbour View, Kingston and Portmore. Mark on the International Airport and the main roads. Include a scale and a North arrow.

2 Study the south coast on the map.

- a Identify and name one example of a feature of coastal erosion.
- b Locate Hunts Bay. A student has suggested that this feature is a freshwater lagoon. Do you agree? Why?
- c Several bays are named on the south coast. Which one do you think is the best example of a bay, and why?
- d Imagine that you lived in Harbour View. Where is your nearest public beach?

3 Study the north coast on the map. Notice that it is a stretch of coastline with clearly defined headlands and bays.

- a Which headland (identified by the term 'Point') do you think is the clearest example? Why?
- b Locate Buff Bay. Measure the straight-line distance across the mouth of the bay from Palmetto Point to Savanna Point.
- c What is the compass direction from Palmetto Point to Savanna Point?
- d Why do you think there are alternating headlands and bays along this stretch of coastline?
- e On which side of Savanna Point is the public beach?
- f What does this suggest about the direction of the main waves at this location? (Hint: Think what conditions would be necessary for the build-up of a sandy beach.)

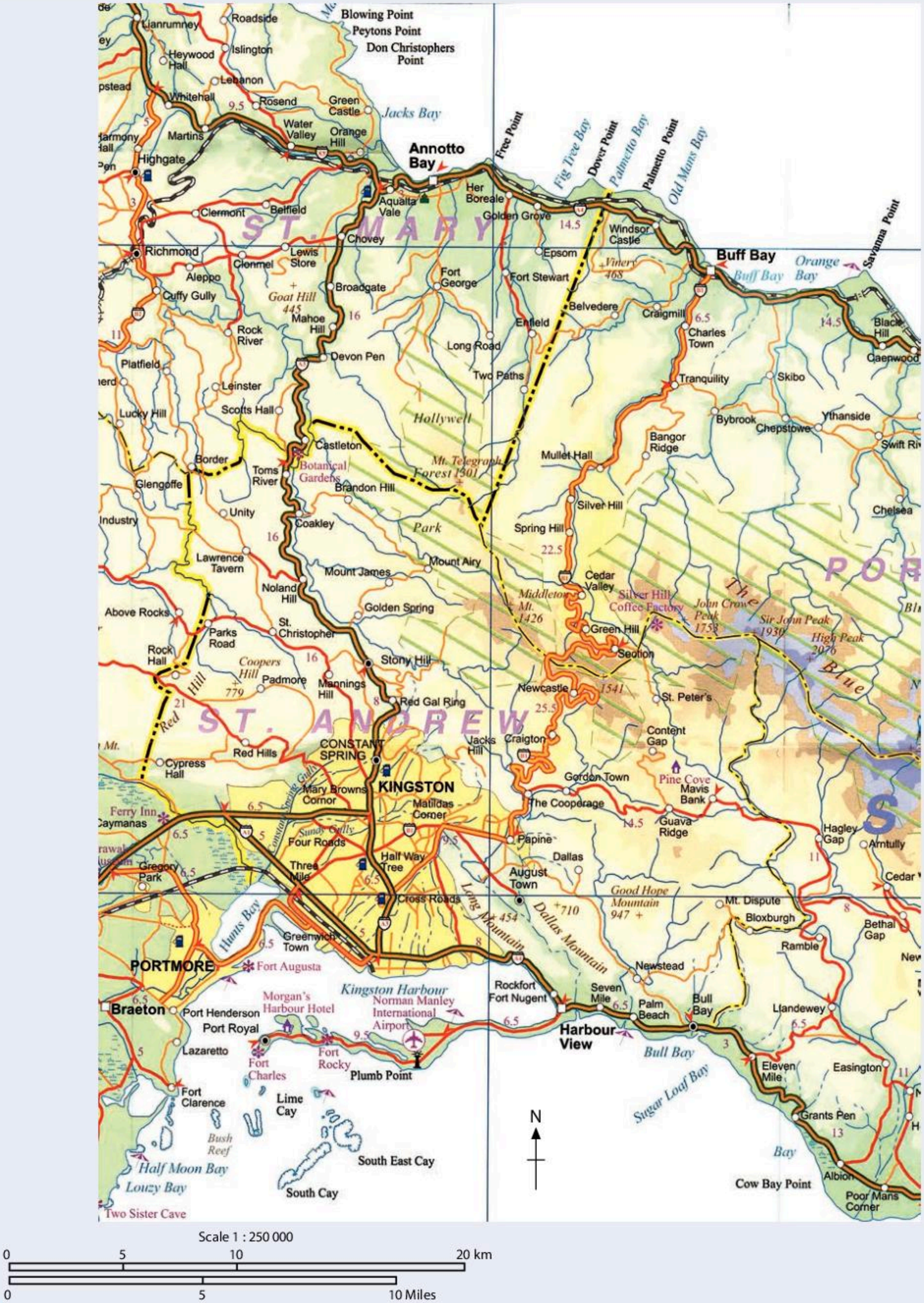


Figure 4.31 Map extract of Jamaica

Glossary of terms

Barrier islands: low-lying islands, often lying parallel to the coast, formed by coastal deposition.

Constructive wave: surging wave generated by distant storms with a powerful swash and less powerful backwash.

Corrasion/abrasion: major erosion process involving material carried by the water scraping away at a cliff or wave-cut platform.

Destructive wave: towering wave generated by local storms with a powerful backwash and less powerful swash.

Hydraulic action: major erosion process involving the sheer power of the waves crashing against a cliff.

Longshore drift: common process of coastal transportation whereby sediment is moved along a coast in a zig-zag fashion.

Saltation: a type of coastal transportation involving the bouncing motion of sediment that is light enough to be picked up off the sea bed temporarily but too heavy to be suspended in the water.

Spit: long, narrow finger of sand/shingle jutting out from the land into the sea.

Stack: isolated pillar of rock resulting from coastal erosion and formed by the collapse of an arch.

Tombolo: spit that has joined an offshore island to the mainland.

Traction: a type of coastal transportation involving the rolling of sediment on the sea bed.

Tsunami: a giant wave usually generated by tectonic activity. Most are caused by submarine earthquakes, volcanic eruptions or landslides.

Wave: undulation of the sea surface resulting from friction as wind blows over the water.

Wave-cut platform: flat or gently sloping rocky platform at the foot of a cliff.

Wave refraction: the bending of waves as they approach a headland and bay coastline.

Ideas for SBA

- *What are the features in a stretch of the coast at low tide?*
- *How may physical features along a stretch of the coast change after a hurricane passes?*

Key for Figure 4.31

Exam-style Practice

1 Figure 1 shows some of the main features of a coastal headland.

a Name features A, B and C on Figure 1. [3]

b How wide is feature A? [1]

c What depositional feature might be formed between the high water mark and the low water mark? [1]

d Why has a cave formed on the coast here? [2]

e With the aid of an annotated sketch map of a stretch of coastline that you have studied, describe the formation of headlands and bays. [5]

f Draw labelled diagrams to show the main differences between constructive and destructive waves. [6]

g With the aid of diagrams, describe in detail how an arch turns into feature B on Figure 1. [6]

Total 24 marks

2 Study Figure 2.

a What is a spit? [2]

b What is the length of the spit from where it leaves the mainland at A to its tip at B? [2]

c Spits commonly form as a result of longshore drift.

i Draw a labelled diagram to describe the process of longshore drift.

ii What is the direction of longshore drift in Figure 2? [6]

d With reference to an example you have studied, describe how tropical storms and sea breezes can affect spits in the Caribbean. [4]

e Why has a salt marsh formed behind the spit in Figure 2? [4]

f With the aid of labelled diagrams, describe the formation of:

i a tombolo

ii a barrier island. [6]

Total 24 marks

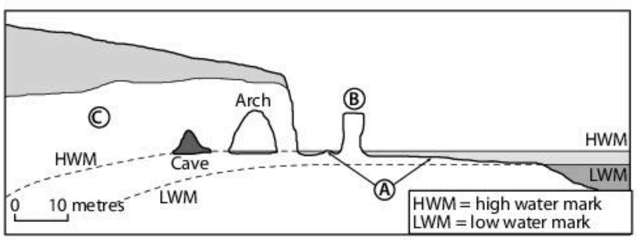


Figure 1 Features of a coastal headland

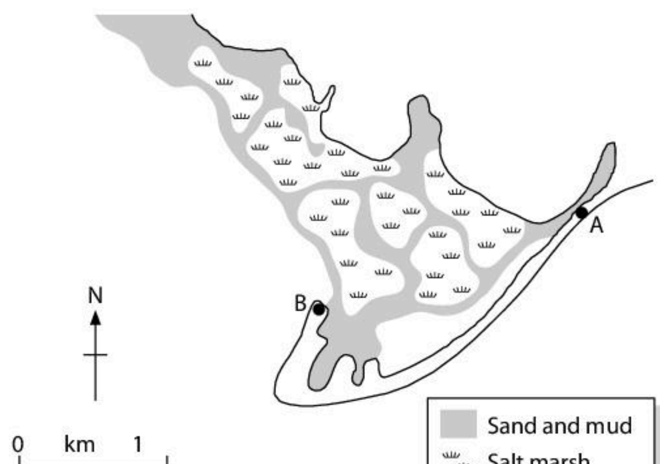


Figure 2 A spit

5 Coral Reefs and Mangrove Wetlands

In this chapter you will study:

- the importance of the coral reef ecosystem
- the location of coral reefs
- types of coral reef
- mangrove wetlands.

You will also learn how to:

- find information on a map
- work with maps and photographs.

What is a coral reef?

A coral reef is a hard, rocky ridge built up from the sea bed by many tiny coral animals. It is one of the richest ecosystems on Earth and is sometimes called the 'rainforest of the sea'. Some living reefs are several million years old.

Why are coral reefs valuable ecosystems?

Coral reefs are extremely important ecosystems providing a range of benefits. An estimated 500 million people depend on coral reefs for food, coastal protection, building materials and income from tourism. About 30 million people are totally dependent on coral reefs for their livelihoods or because they live on atolls. The main benefits of coral reefs include the following:

- **Coastal protection:** coral reefs act as buffer zones providing vital shoreline protection from storms and tsunamis. The shallow water above a reef forces waves to break early before reaching the mainland shore. This reduces

Figure 5.1 A colourful coral reef in the Caribbean

coastal erosion and the risk of flooding. Corals also provide sheltered conditions for the growth of mangrove forests, which themselves are important breeding grounds for fish (*Figure 5.1*).

- **Beach development**: the erosion of coral reefs creates the white sand that typically forms the beaches of tropical coastlines. Some of this sand is extracted for the construction industry to make cement (*Figure 5.2*).
- **Ecological benefits**: coral reefs are extremely diverse ecosystems. They provide a home to over 25 percent of all known marine fish. One hectare of reef off Southeast Asia was found to support over 2000 species of fish! Coral reefs are important breeding grounds for fish offering shelter and food.

Figure 5.3 Coral reefs are a popular tourist attraction

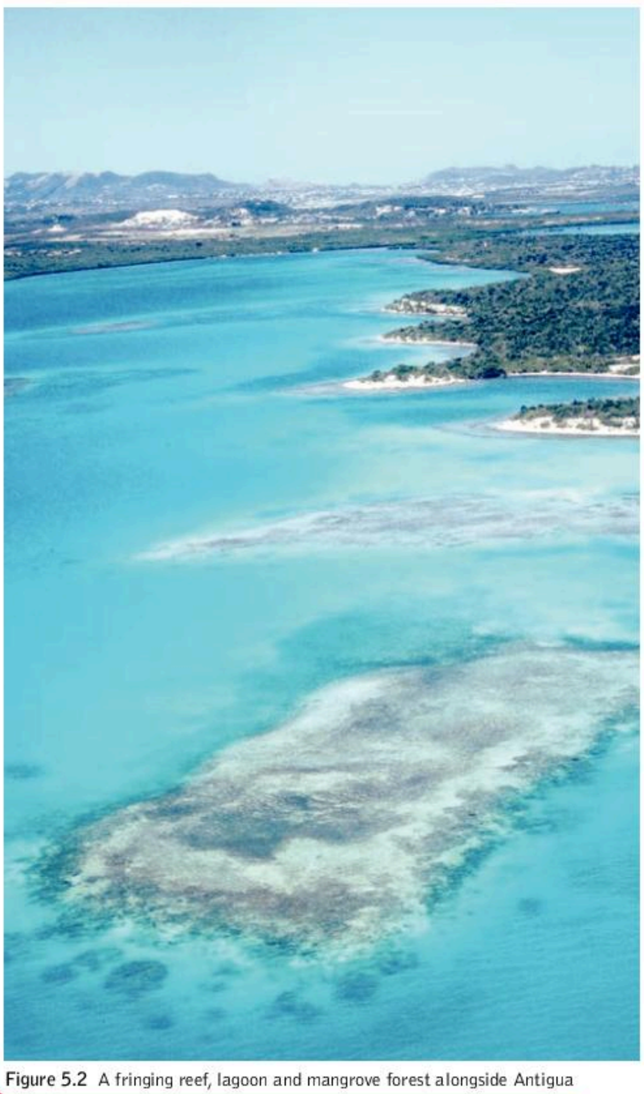


Figure 5.2 A fringing reef, lagoon and mangrove forest alongside Antigua

- **Economic benefits**: the global value of the world's coral reefs has been estimated at almost US$30 billion each year! In Hawaii alone, the benefits associated with tourism, fishing and biodiversity amount to US$360 million a year. Coral reefs are extremely important commercial fishing grounds providing some 25 percent of the total fish catch of low-income countries. It is estimated that coral reef fisheries in East Asia feed over 1 billion people. Coral reefs are extremely popular tourist destinations, providing a huge source of income and employment for thousands of people. Millions of people visit the Caribbean each year to enjoy its tropical beaches and coral reefs. Coral reefs are increasingly valued for medicinal purposes. Scientists believe that some of the chemicals released by coral species for self-protection could have applications for the treatment of some viruses and cancers.

Activities

1 Study *Figure 5.1*.
  a Why do you think a coral reef is sometimes described as being the 'rainforest of the sea'?
  b What makes a coral reef such a special ecosystem? If possible, write about your own experiences of visiting a coral reef.

2 Study *Figure 5.2*.
  a Describe the features in the photograph that show the value of the coral reef to the local coastal communities.
  b Suggest some problems that might arise if the coral reef were to be damaged or overwhelmed by a rising sea level.

3 Look at *Figure 5.4*.
  a Describe what is happening in the photo.
  b Why is coral mined from the reefs?
  c What will be the long term effects of mining on the coral reef ecosystem?

4 Produce a poster describing the benefits and values of coral reefs. Try to include some pictures (simple sketches will do) using the text and photographs above. Don't forget to write a large, eye-catching title at the top of your poster.

Figure 5.4 Coral rock being extracted

Formation of coral reefs

Corals reefs are formed by millions of coral polyps, tiny animals resembling overturned jellyfish! They use excess carbon dioxide in the water, converting it into limestone to form solid reefs. Corals need very particular conditions in order to develop, survive and thrive. They grow best in sunny, shallow, warm and clear water conditions. This explains why they are only found in certain parts of the world (*Figure 5.5*).

The main factors controlling the development of corals are water temperature, depth, salinity and turbidity together with the presence of beneficial algae and fish.

- **Temperature**: tropical corals only live in seawater that has an average temperature of 18 °C and over. The ideal temperature is between 23 °C and 25 °C. Therefore, coral reefs are mostly found in tropical latitudes. The exception is where warm ocean currents transfer these conditions into subtropical regions such as Bermuda.
- **Depth**: corals feed on tiny algae, and the algae need light in order to photosynthesize and grow. If there is not enough light, there can be no algae. This means that coral develops only in relatively shallow water conditions where sunlight can penetrate the water. In clear tropical waters coral can live as deep as 48 metres. Very few species are found below this depth.
- **Salinity**: corals thrive in salty water where the salinity is between 30 and 40 parts per thousand. They do not develop so successfully in areas where freshwater runoff enters the sea at river mouths.
- **Turbidity** (water movement): some turbidity is necessary to distribute coral larvae, to

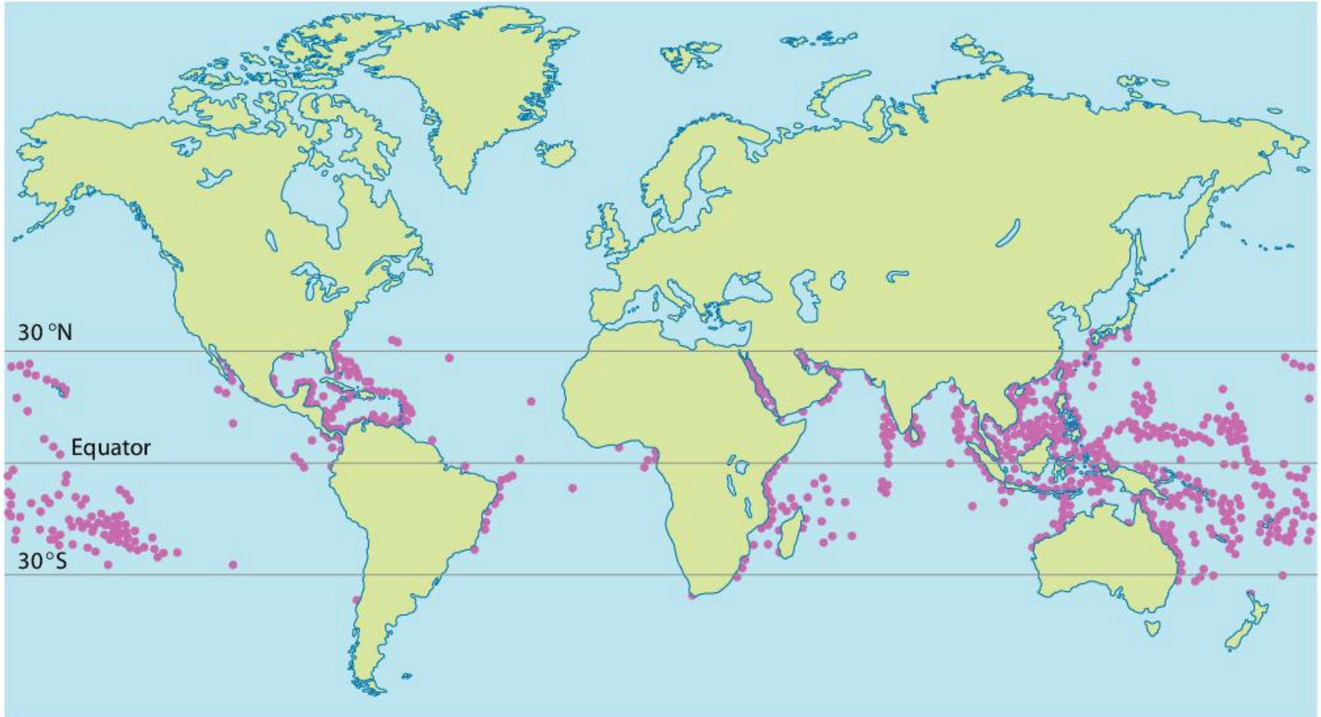


Figure 5.5 Global distribution of coral reefs

provide food and oxygenated water to the sedentary polyps, prevent smothering of the polyps by sediment and to remove waste products. However, strong waves and currents can inhibit or prevent coral formation. Under such conditions, sediment becomes agitated reducing light and smothering coral and preventing feeding and respiration.

- **Presence of beneficial algae and fish**: coral enjoys a symbiotic relationship with both algae (zooxanthellae) and fish. This means that they benefit from their association with one another. The algae live within the coral structures and up to 90 percent of the organic material produced through the process of photosynthesis is passed directly to the host coral tissue. Fish are abundant in coral reefs, using them as sheltered breeding grounds. Corals consume small fish using their tentacles to stun and kill the fish.

Activities

1 Study *Figure 5.5*.

a 'Coral reefs are found mostly in the tropics between 30°N and 30°S.' Is this true or false?

b Locate the Caribbean region on *Figure 5.5*. You will notice that there are lots of coral reefs here. Use an atlas to help you identify five other concentrations of coral reefs around the world.

c What is the main reason for the global distribution of coral reefs?

d A cold ocean current called the Peruvian Current runs up the west coast of South America. What effect does this have on the distribution of coral reefs in this part of the world?

2 *Figure 5.7* shows the distribution of coral reefs in the Caribbean. On a blank outline map of the Caribbean, carefully draw on the coral reefs. Use an atlas to name the main reefs and some of the countries of the Caribbean that are fringed by coral reefs. Also label the Atlantic Ocean, the Caribbean Sea and the Gulf of Mexico.

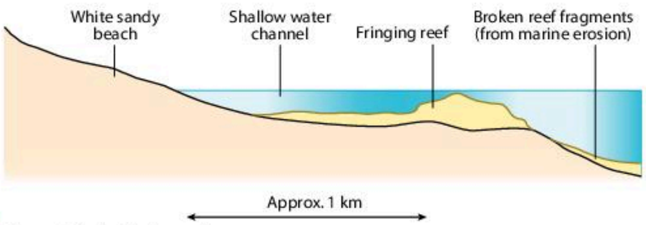


Figure 5.6 A fringing reef

Types of coral reef

It is possible to identify three types of coral reef:

- A **fringing reef** is a shallow-water feature found close to and running parallel to the shore (*Figure 5.6*). These reefs are associated with many of the islands in the Caribbean (*Figure 5.7*). A fringing reef forms from the gradual accumulation of coral in ideal environmental conditions close to the coast. Over time, natural processes such as storms and marine erosion move the coral to form the shallow irregular coral platforms that exist throughout the Caribbean today. Between the reef and the shore is a shallow **lagoon** that is rich in marine life.
- A **barrier reef** is a much larger feature than a fringing reef. It lies in deeper water, much further out to sea (*Figure 5.8*). The Great Barrier Reef in Australia is the world's best example of a barrier reef. It runs for some 2600 km off the east coast of Queensland and is made up of 3000 separate reefs and 900 islands. It has been designated a World Heritage Site. In the Caribbean there is a barrier reef some 25 km off the coast of Belize. Barrier reefs are thought to develop where a fringing reef is formed next to a low-lying coastal plain. A relative rise in sea level over thousands of years floods the coastal lowland, creating a much wider body of water between an

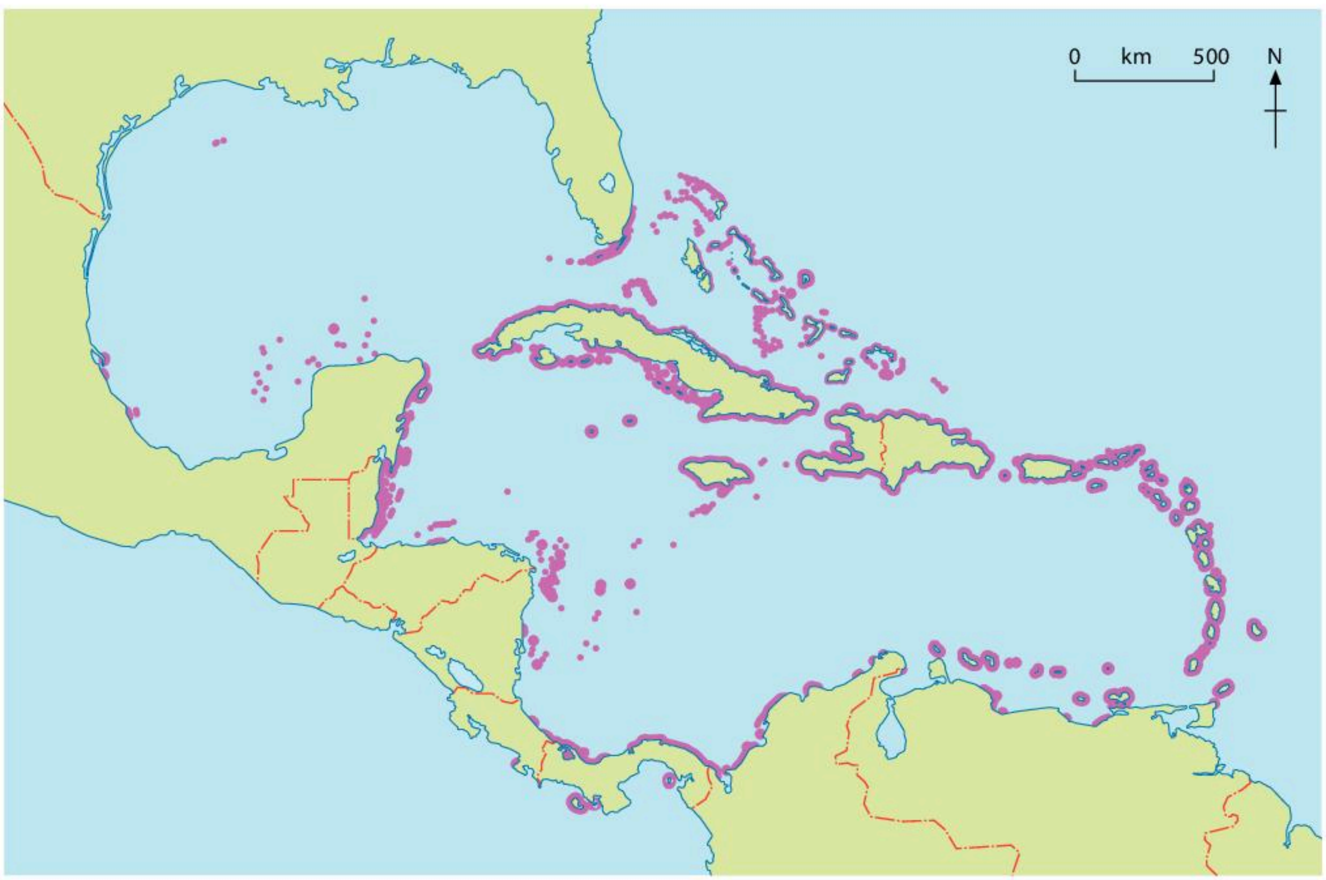


Figure 5.7 Distribution of coral reefs in the Caribbean

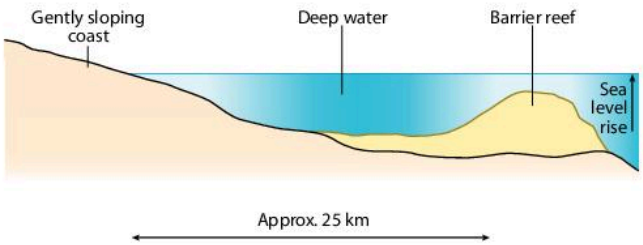


Figure 5.8 A barrier reef

initial fringing reef and the coast. Coral continues to grow to form a large barrier reef feature that is now separated from the coast by many kilometres of sea.

- A **coral atoll** is an isolated ring-shaped reef rising out of deep water (*Figure 5.9*). In the centre of an atoll is a lagoon.

Figure 5.9 A coral atoll

Coral atolls are largely concentrated in the Indian Ocean, for example the Maldives.

Case Study

The Belize barrier reef

The Belize barrier reef is the second largest barrier reef in the world after Australia's Great Barrier Reef. It extends for some 300 km along the coast of Belize as a series of separate coral reefs (*Figure 5.10*). In the north, the reef is close to the coast, whereas in the south it is up to 40 km from the shore.

Figure 5.10 Belize barrier reef

The barrier reef supports a rich and diverse ecosystem, with many species of coral and over 500 species of fish. In 1842 Charles Darwin described it as 'the most remarkable reef in the West Indies'. It is much studied on account of its wide biological diversity and yet, incredibly, 90 percent of the reef is yet to be thoroughly researched. A large part of the reef has been granted special protection by being designated a 'Reserve System'. In 1996 the Belize Barrier Reef Reserve System became a UN World Heritage Site. The reef is Belize's top tourist attraction with over 100 000 people visiting it each year. It is also vital for the country's fishing industry.

Despite its status, the reef is suffering from a number of threats. Pollution, uncontrolled tourism and over-fishing have already damaged parts of the reef. Temperature rises associated with global warming could be a significant issue in the future, leading to coral bleaching (see page 151). An estimated 40 percent of the reef has been damaged since 1998.

Skills

Finding information on a map

Study *Figure 5.11*, which shows a part of Smith's Province in Bermuda.

1 Name the place where the fringing coral reef is closest to the shore.

2 What is the distance from the reef to the shore at this point?

3 What is the greatest distance from the shore to the reef? Where is that?

4 Describe the distribution and pattern of the fringing coral reef.

5 What is the height of the land at the coast?

6 What is the main type of land use along this stretch of the coast?

7 Why might tourists be interested in visiting the area of Bermuda shown in the map extract?

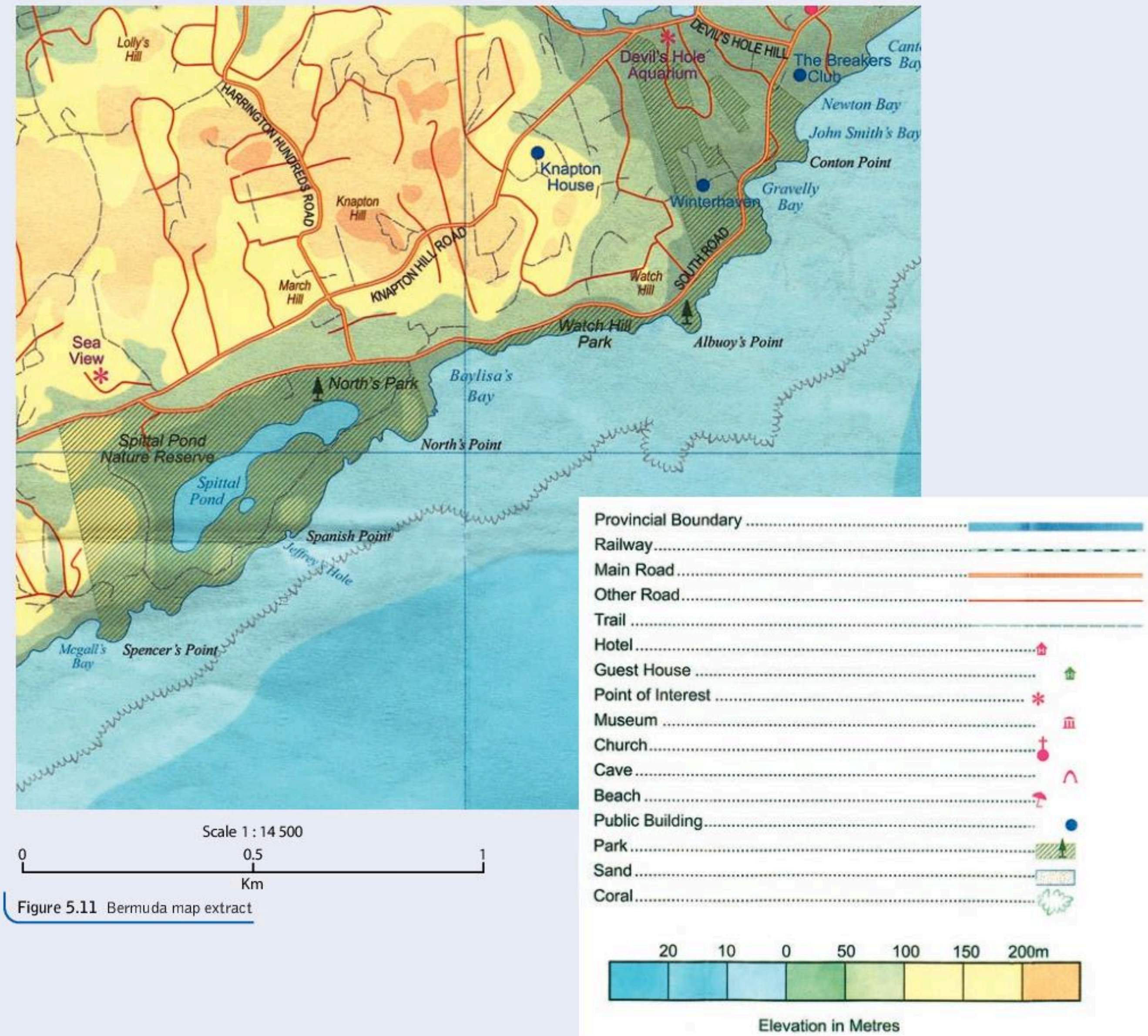


Figure 5.11 Bermuda map extract

Explaining relationships on topographical maps

Exam questions often ask candidates to look at 'patterns' on maps. Such questions often apply to vegetation, drainage, relief features such as valleys, and settlements.

When looking for patterns you should consider the whole picture rather than looking in detail at one part of the map only. Patterns are about trends. Here are some examples:

- Do the river valleys run parallel to each other or do they radiate out from a central hilltop? (See *Figures 3.11* and *3.12* on page 61 for drainage patterns.)
- Do the settlements occur in one part of the map only or in river valleys only? Are they mostly on the coast?
- Do forests occur on a particular slope aspect or on land over a certain height? Are they found in one part of the map only?

There are often links between the physical features of a landscape (for example, hills and valleys) and the human land uses of that landscape, such as settlements and forestry. Maps are very useful in suggesting these links and helping to explain patterns.

For example:

- In mountainous landscapes, settlements and farming are often found on the sunnier sides of steep valleys whereas trees tend to occupy the shaded, cooler sides.
- Settlements are often situated in valley bottoms where the flat land makes it easier to build houses. Communications also tend to follow valley bottoms, partly because they are linking the settlements but also because it is easier and cheaper to build roads and railways on flat land.
- Farming land uses often reflect the steepness of the slopes and the altitude of the land. Arable farming is usually on flat or gentle slopes because machines cannot operate on steep slopes. Dairy cattle are usually found close to farms because they need regular milking.

Many more links can be made between geographical features of the landscape. Using maps it is possible to make sense of the patterns we see around us.

Working with maps and photographs

Study *Figures 5.12* and *5.13*.

1 What is the name of the city marked A on *Figure 5.13*?

2 What is the name of the group of islands at B?

3 The yellow line at C marks the international border between Belize and which neighbouring country?

4 Locate the barrier reef on *Figure 5.12*. How does this feature stand out on the photograph in *Figure 5.13*?

5 What common name is given to the many islands that form along Belize's barrier reef?

6 'The barrier reef extends in a north–south direction.' True or false?

7 What name is given to the southernmost extent of the barrier reef?

8 What is the straight-line distance between the southernmost point of the barrier reef and the airport at San Pedro, just south of the border with Mexico?

9 Give the location of the airport at San Pedro in terms of its approximate latitude and longitude.

10 Locate Ranguana Cay toward the southern end of the barrier reef. Measure the straight-line distance from here to the mainland at Monkey River Town.

Figure 5.12 Map of the Belize barrier reef

11 What is the name of the coral reef at D?
12 What type of coral reef is the reef at D?
13 What name is given to the area of much deeper water to the east of the barrier reef?

Figure 5.13 Satellite photograph of the Belize barrier reef

The importance of mangrove wetlands

What are mangrove wetlands?

Mangrove wetlands or swamps are coastal ecosystems found in tropical and subtropical regions. Look at *Figure 5.14*. Notice that mangroves are found extensively in the Caribbean as well as in many other regions around the world. One of the largest mangrove swamps in the world is on Florida's southwest coast.

Mangrove swamps are characterised by halophytic (salt loving) trees, shrubs and other plants growing in brackish to saline tidal waters. These wetlands are often found in estuaries, where fresh water meets salt water. They are famous for their dense maze of woody vegetation (*Figure 5.15*).

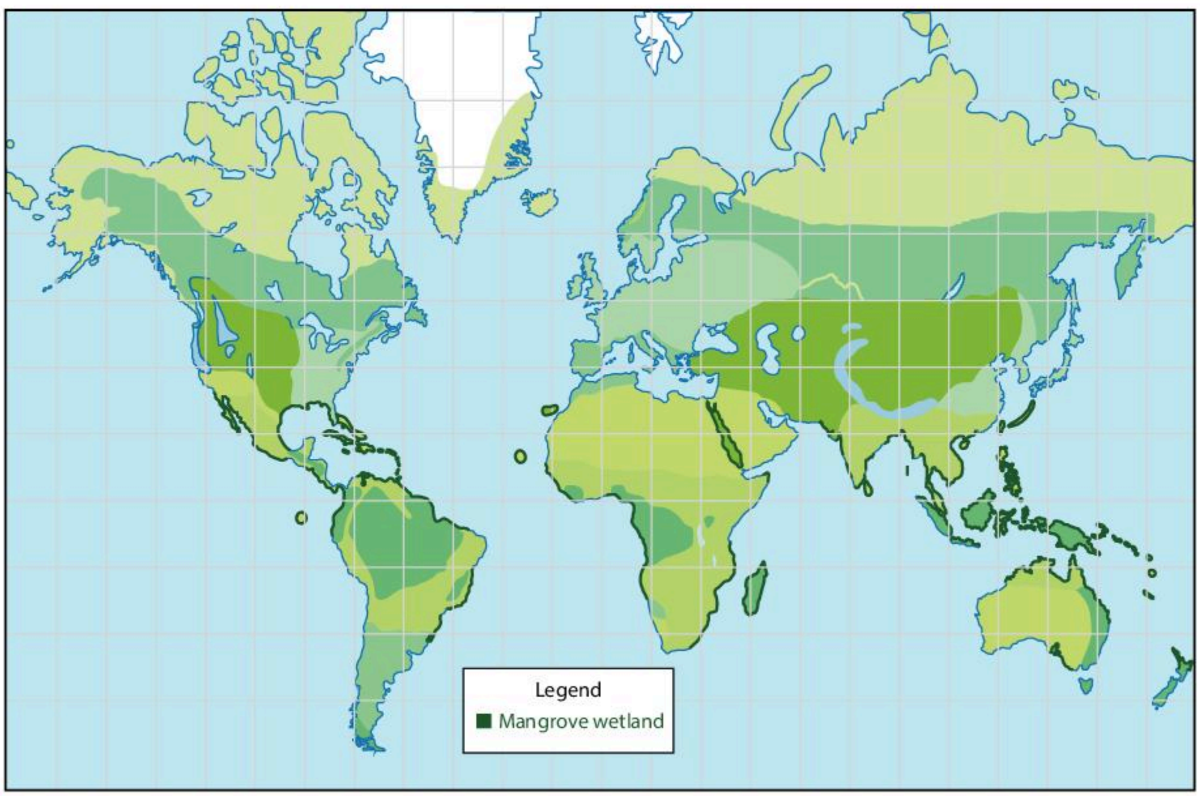


Figure 5.14 Global distribution of mangrove wetlands

Figure 5.15 Dense red mangroves in the Caribbean

Caribbean mangrove wetland ecosystems

In the Caribbean there are three types of mangrove (*Figure 5.16*):

- **Red mangroves**: these are found closest to the sea and have their roots submerged at high tide. They cope with high levels of salt by obtaining water from the ocean through a process known as 'reverse osmosis'. In this process, magnesium ions exclude salt from the roots enabling the plant to survive. The long arching aerial woody roots help anchor the plant in the soft muddy sediment. It is through the roots that oxygen is obtained. The roots also trap sediment helping to stabilise this coastal environment.
- **Black mangroves**: these are found further inland where conditions are saltier. They cope by excreting the excess salt onto their leaves. Spongy structures called pneumatophores protrude from the roots to stick out through the sediment rather like periscopes (*Figure 5.16*). They can transfer oxygen direct to the roots.
- **White mangroves**: these are found further inland. Like the black mangroves, they do not have the extensive aerial roots systems of the red mangroves. They also excrete salt onto their leaves.

Mangrove swamps support a wide diversity of animals. They are constantly replenished with nutrients that are transported by fresh water runoff from the land and flushed by the ebb and flow of the tides. These ecosystems sustain billions of worms, protozoa, barnacles and oysters which in turn feed fish and shrimp. These then support wading birds, pelicans, and the endangered crocodile!

Why are mangrove wetlands important?

Mangrove wetlands are one of the most important ecosystems in the world (*Figure 5.17*).

- **Coastal protection**: the dense tangle of mangrove roots help to trap sediment. This creates an effective coastal defence against hurricanes, storm surges and tsunami. As sea levels rise due to global warming, mangroves will continue to grow and thrive, providing lasting protection to coastal areas. If the mangroves are removed, the muddy sediment quickly washes away leaving the coastline unprotected. In the tsunami of 2004, many areas of Indonesia that were still protected by their mangroves experienced relatively little damage to human structures.

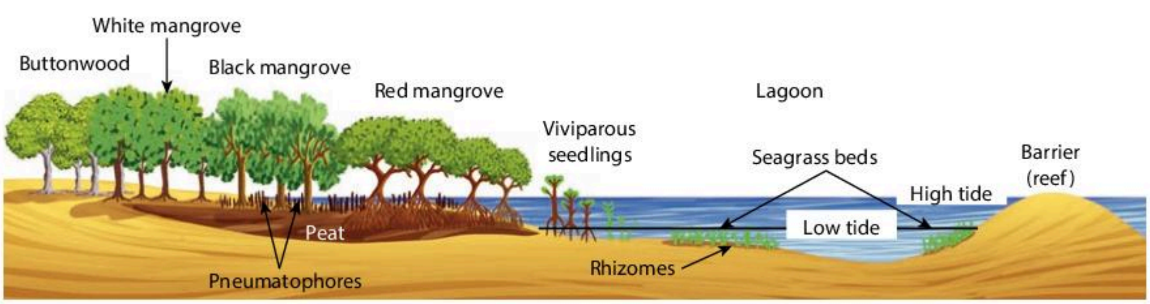


Figure 5.16 The typical mangrove succession in the Caribbean

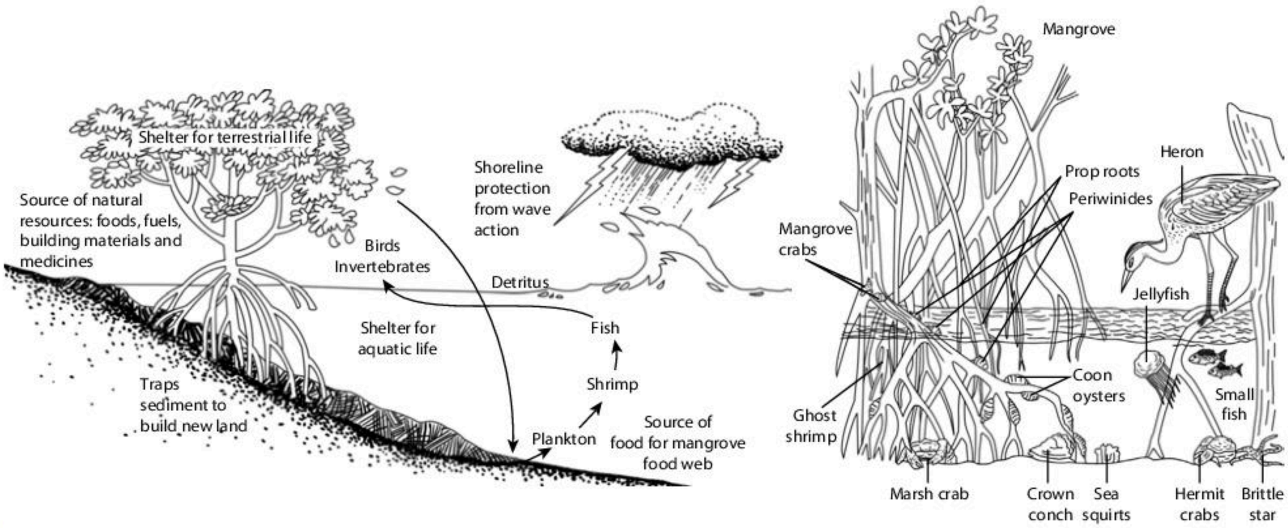


Figure 5.17 The importance of mangrove wetlands

- **Ecological (biodiversity) importance**: mangrove swamps provide valuable habitats for many species of animal and fish which benefit from the calm, sheltered waters. Mangroves are also very important to nearby coral reefs. They filter out silt and nutrients that would otherwise go out to the reef, smothering the coral polyps and encouraging algal growth. Mangrove swamps also serve as a breeding ground and nursery for young fish.
- **Socio-economic benefits**: mangrove swamps are popular tourist attractions despite the biting insects! They are home to a wide variety of wading birds and crocodiles and alligators. Mangroves provide many products and raw materials and they have significant value for local communities (*Figure 5.18*).

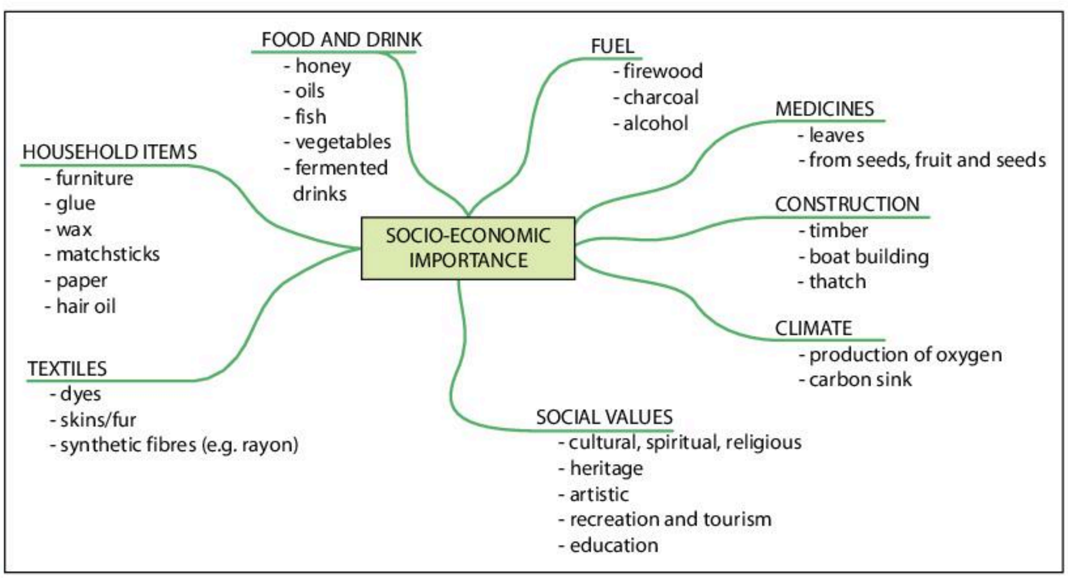


Figure 5.18 Socio-economic importance of mangrove wetlands

Activities

1 Study *Figure 5.14*.
  a Make a copy of the global distribution of mangrove wetlands. Use an atlas to label a selection of locations where mangroves are found.
  b Carefully draw and label the Equator and the Tropics of Cancer and Capricorn.
  c Briefly describe the distribution of mangrove wetlands.

2 Study *Figure 5.16*. Describe the characteristics of the three different types of mangrove found in the Caribbean. How do they cope with the saltiness of the water? How do they obtain oxygen?

3 Use the text and the diagrams to help you to draw a mangrove forest food chain.

4 Design an information poster to describe the importance of mangrove wetlands. Use the internet to provide you with photos to illustrate your poster.

Exam-style Practice

1 a What are coral reefs? [2]
  b Describe any FOUR important features of coral reefs. [8]
  c i Name the THREE types of coral reefs. [3]
    ii Describe the formation of any ONE type of coral reef. [8]
  d Briefly describe FOUR conditions necessary for the successful formation/development of coral reefs. [4]

Total 25 marks

2 a What are mangrove wetlands? [2]
  b Where can one of the largest mangrove swamps in the world be found? [1]
  c i Name the THREE types of mangroves found in the Caribbean. [3]
    ii Describe any TWO of the Caribbean mangroves mentioned above. [6]
  d Explain THREE ways in which mangrove wetlands are important. [9]
  e Describe ONE measure taken in a named Caribbean country to protect mangrove wetlands. [4]

Total 25 marks

6 Limestone

In this chapter you will study:

- the characteristics of limestone
- processes leading to limestone features
- examples of limestone in the Caribbean.

You will also learn how to:

- interpret photographs
- use direction – compass points and bearings
- interpret signs and symbols on topographical maps.

The characteristics of limestone

Limestone is a hard rock and a permeable one. Being permeable, it allows water to percolate (seep) into it, along lines of weakness known as joints and bedding planes. This helps create many distinctive landforms. The main chemical weathering process to affect limestone (especially in tropical areas) is carbonation, or carbonation-solution. This occurs in rocks with a large calcium carbonate content, such as chalk and limestone. Rainfall combines with dissolved carbon dioxide or organic acid to form a weak carbonic acid. The process of carbonation is described on page 38.

The effectiveness of carbonation is related to the pH of the water. The more acidic the water the greater the rate of carbonation.

There are many different types of limestone and they vary in terms of hardness, chemical composition, jointing and bedding planes. In the Caribbean there are two main types of limestone:

1 **Jurassic coralline limestone** formed between 120 and 150 million years ago, such as that on Cuba, Jamaica and Puerto Rico.

2 **Oolitic limestone** formed between 70 million years ago and the present day, such as that on the Bahamas Platform and the Turks and Caicos Islands.

Limestone consists mainly of calcium carbonate ($CaCO_3$) and is known as a calcareous rock. It is formed of the remains of organic matter, notably coral, plants and shells. Owing to its permeability, limestone areas are often dry on the surface and are known as **karst** areas (from the Kras limestone region of Slovenia). Karst features are best developed on older limestone on account of its greater strength, and its lower porosity and permeability compared with younger limestones.

There are important differences between limestone in tropical and subtropical areas, and limestone in cooler, temperate areas. Limestones in tropical and subtropical areas often show rounded landforms, known as cockpit karst (*Figure 6.1*) and tower karst (*Figure 6.2*) while those in temperate areas may be more angular and rugged.

Figure 6.1 Cockpit karst, Jamaica

Figure 6.2 Tower karst, China

Limestone has a distinctive bedding plane and joint pattern, which is described as being **massively jointed**. This means that the joints are often spaced quite far apart, and often at regular intervals. The joints act as weaknesses allowing water to percolate into the rock and dissolve it – the process of carbonation. The process is reversible, so under certain conditions calcium carbonate can be deposited in the form of cave deposits such as stalactites and stalagmites. Limestone is also affected by freeze–thaw, river erosion, glacial erosion and mass movements.

The ability of water to dissolve calcium carbonate depends on the acidity and temperature of the water. If it contains carbon dioxide it can dissolve limestone and is termed 'aggressive'. When the water is carrying as much calcium as it can, it may have to deposit some of that calcium.

The amount and rate of limestone solution is affected by a number of factors:

- The amount of carbon dioxide in the atmosphere, soil and groundwater – the more carbon dioxide, the greater the rate of solution.
- The amount of water in contact with the limestone – the greater the area of contact the more solution that can take place.
- Water temperature – carbon dioxide is more soluble at low temperatures.
- The turbulence of the water – the greater the turbulence the greater the rate of solution.
- The presence of organic acids from vegetation – this increases the acidity of the water and increases the rate of solution.

Human activity has many effects on the nature and rate of limestone denudation:

- The burning of fossil fuels and deforestation has increased atmospheric levels of carbon dioxide, so the weathering of limestone is likely to increase.
- There are increasing levels of acidity in rainwater due to sulphur dioxide and nitrogen oxides in the atmosphere – some of this may be the consequence of physical events such as the continuing eruption of Soufrière on Montserrat, which releases large quantities of sulphur into the atmosphere.

Activities

1 What are the main processes that affect limestone?

2 What does the word *karst* mean?

3 What factors affect the rate of carbonation of limestone?

Surface features

The term 'karst' refers to well-developed features on dry limestone – that is, areas without surface drainage (*Figure 6.3*). As the joints and cracks are attacked and enlarged over thousands of years, the permeability of limestone increases. **Clints** (outcrops of bare rock) and **grikes** (the gaps between the rocks where the joints are located) develop on the surface of the exposed limestone. Large areas of bare exposed limestone are known as **limestone pavements** (*Figure 6.3*).

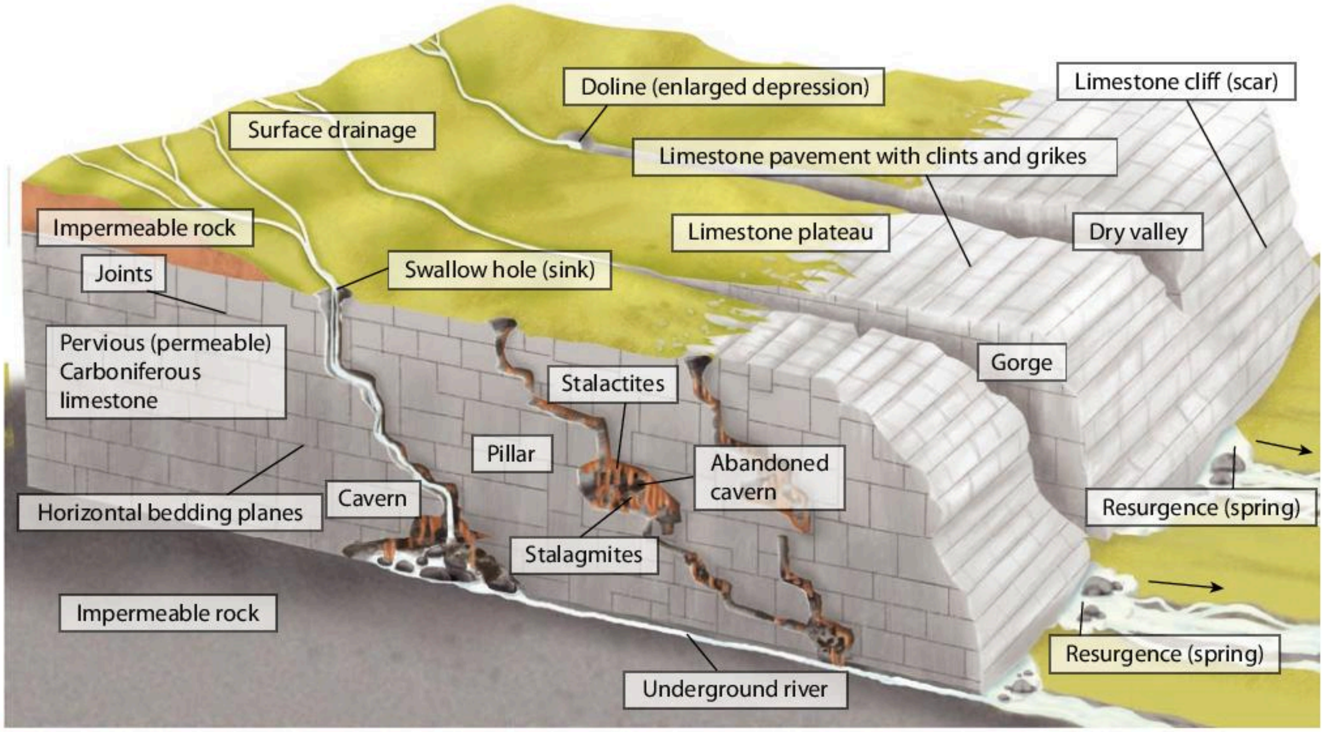


Figure 6.3 Limestone features

The processes involved include carbonation, freeze–thaw and ice action. In the past ice action stripped away horizontal bedding planes and the overlying soil.

Dolines are large surface depressions formed by the solution or collapse of limestone. Frequently they are covered by other deposits. Depressions can range from small-scale hollows to large depressions up to 30 metres in diameter. **Swallow holes** (or **sinks**) are smaller surface depressions in the landscape which may be caused by the solution of limestone; or by the enlargement of a grike system, by carbonation or river erosion; or by the collapse of a cavern. Often a river disappears down the hole, hence the term ‘sink’. Rivers flow underground, following joints and bedding planes. **Resurgent streams** arise when the limestone is underlain by an impermeable rock, such as clay. This forces the water out into the open, forming a spring or resurgent stream.


Figure 6.4 A limestone pavement showing clints and grikes

Cockpit karst is another type of surface depression in tropical areas. See pages 107–108 for more details.

Other important surface features include dry valleys. A dry valley is a river valley without a river and is a common feature on chalk and limestone. A number of ideas have been put forward to explain their origin:

- Carboniferous limestone is initially impermeable, but becomes increasingly permeable owing to carbonation over a period of thousands and even millions of years. Therefore river systems that originally developed on impermeable limestone tend to disappear as the rock becomes more permeable.
- Dry valleys could be formed by the collapse of a cave system.
- Climate change and decreased levels of precipitation since the creation of the valley have left it dry.
- Human activities – such as the use of groundwater for farming and industrial or residential uses – may lower the water table and cause rivers to become dry.

Figure 6.5 Stalactites in Harrison's Cave, Barbados

Figure 6.6 Stalagmites in Harrison's Cave, Barbados

Activities

1 What is the difference between a clint and a grike?

2 What is another name for a sink?

Underground features

Underground features include caves and tunnels formed by carbonation and by erosion by rivers. Carbonation is a reversible process. When calcium-rich water drips from the ceiling it leaves behind calcium in the form of **stalactites** and **stalagmites** (*Figures 6.5* and *6.6*). These are cave deposits formed by the precipitation of dissolved calcium carbonate. **Stalactites** develop from the top of the cave whereas **stalagmites** are formed on the base of the cave. Rates of deposition are slow – about 1 mm per 100 years (the thickness of a coat of paint). The speed at which water drips from the cave ceiling appears to have some influence on whether stalactites (slow drip) or stalagmites (fast drip) are formed. **Pillars** occur when stalagmites and stalactites join from a continuous deposit from ceiling to ground.

Activity

What is the difference between a stalactite and a stalagmite?

Case Study

Blue holes in the Bahamas

Sea-level changes in the Caribbean have caused some limestone caves to be submerged, forming **blue holes** (*Figure 6.7*). Many of these are a major tourist attraction, in the Bahamas for example. The Bahamas has a variety of blue holes (*Figure 6.8*). The islands' limestone has been carved out by carbonation as the sea level fluctuated over thousands of years – the sea was some 130 metres lower 10 000 years ago, for example. As the sea level rose, it submerged (drowned) many of the limestone sinks, caves and tunnels. These drowned sinks became the blue holes. The classic form of a blue hole is circular, extending in a bell shape beneath the surface. However, some open into the edge of an oceanic wall or are simply openings in a shallow reef. Not all are oceanic, and many blue holes are found inland. The deepest known blue hole in the Bahamas reaches down to over 200 metres, while many systems drop to around 100 metres and then extend into a network of caverns and caves at the bottom.

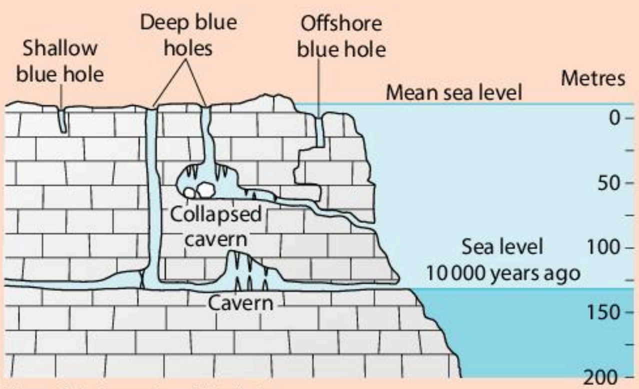


Figure 6.7 Formation of blue holes

Figure 6.8 Oceanic blue hole

Features of tropical karst

There are two major landform features associated with tropical karst. **Cockpit karst** is a landscape pitted with smooth-sided, soil-covered depressions and cone-like hills. **Tower karst** is a landscape characterised by upstanding rounded blocks set in a region of low relief. Although water is less able to dissolve carbon dioxide in tropical areas (owing to higher temperatures) the presence of large amounts of organic matter produces high amounts of carbon dioxide in the soil water.

Some geographers believe that there is an evolution of limestone landscapes which eventually lead to cockpit karst and tower karst (*Figure 6.9*). However, according to Marjorie Sweeting, a well-known researcher of tropical karst, the distinction between cockpit karst and tower karst relates to the specific hydrological and tectonic conditions associated with each type (*Karst Landforms*, 1972).

Cockpit karst

This type of karst landscape is characterised by groups of hills which are fairly uniform in height (*Figure 6.10*). These can be up to 160 metres high in Jamaica, with a base at up to 300 metres above sea level. They develop mainly as a result of solution. They are as common in some tropical areas as dry valleys and dolines are in temperate areas. Cockpit karst tends to occur in areas:

- that have been subjected to high rates of tectonic uplift and
- where vertical erosion by rivers is intense.

The spacing of the cones may be related to the original stream network. Concentrated solution along preferred routes, such as wider joints, leads to accelerated weathering of certain sections of the limestone, especially during times of high flow, such as during a storm. Water will continue to weather the limestone as far down as the water table. This creates closed depressions and dolines. Once the water table is reached water will flow laterally (sideways) rather than vertically, thus developing a flat plain.

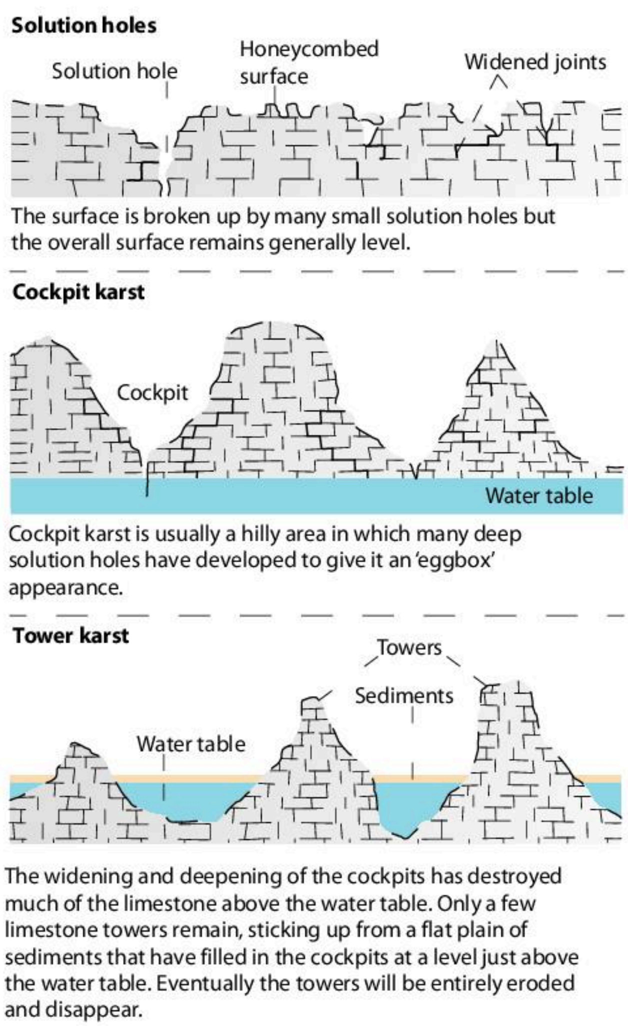


Figure 6.9 Features of tropical karst

Figure 6.10 Cockpit karst country

An alternative theory suggests that the formation and subsequent collapse of cave systems is the main mechanism for cockpit karst formation. Caves in limestone migrate upward through the hillside. Collapse of the ceiling is due to the solution by water percolating downward. Every time the ceiling collapses, the ceiling gets higher and the floor is raised by the debris, so the whole chamber gets higher. Eventually the cave roof collapses.

Tower karst

By contrast, tower karst is much more variable in size than the conical hills of cockpit karst, and ranges from just a few metres to over 150 metres in height in Sarawak, Malaysia. Areas of tower karst include southern China, Malaysia, Indonesia and the Caribbean. These towers are characterised by steep sides, with cliffs and overhangs, and with caves and solution notches at their base. The steepest towers are found on massive, gently tilted limestone. According to Sweeting, tower karst develops in areas where:

- tectonic uplift is absent or limited
- limestone lies close to other rock types
- the water table is close to the surface.

In wet monsoonal areas, rivers will be able to maintain their flow over limestone, erode the surface and leave residual blocks set in a river plain. It is likely that there are other important processes. These include:

- differential erosion of rock with varying resistance
- differential solution along lines of weakness
- the retreat of cockpit karst slopes to produce isolated tower karst
- lateral erosion.

Activities

1 What is the difference between cockpit karst and tower karst?

2 Why is there so much carbonation in tropical areas?

3 How are blue holes formed?

Caribbean karst

The principal karst landscapes of the Caribbean are in the Greater Antillean islands of Cuba, Hispaniola, Jamaica and Puerto Rico. Smaller karst areas occur throughout the Caribbean, notably in the Bahamas, the Lesser Antilles, Barbados, the Netherlands Antilles and the Cayman Islands (*Figure 6.11* and *Table 6.1*).

There is great diversity within the karst landscapes of the Caribbean but they can be classified into three main types:

1 **Doline karst** with enclosed depressions and subdued hills.

2 **Cockpit karst** with enclosed depressions and residual hills in approximately the same proportions.

3 **Tower karst** characterised by isolated residual hills separated by almost flat surfaces.

Climatically, there is considerable variation between the individual karst areas although all experience the tropical wet climate. Mean annual temperatures range around 25 °C, and mean annual precipitation ranges between 1000 and 3000 mm. Altitude and a windward

Figure 6.11 Caribbean karst in the Cayman Islands

Table 6.1 Caribbean karst areas

Country	Approximate limestone area (km^2)
Antigua and Barbuda	120
Bahamas	10 000
Barbados	370
Cayman Islands	200
Cuba	70 000
Dominican Republic	30 000
Guadeloupe	580
Haiti	20 000
Jamaica	7500
Netherlands Antilles	800

Source: adapted from M. J. Day, 'Human impacts on Caribbean and Central American karst', *Catena Supplement* 25, 1993 or leeward location affect rainfall totals; some areas, particularly on the leeward side of islands, experience a marked dry season between January and May. Typically, much of the rainfall occurs as convectional storms, especially during the warmer period from May to October, and much of the region experiences hurricanes between July and October.

Activities

1 Which islands of the Caribbean have the most limestone?

2 What three types of limestone landscape are found in the Caribbean?

The impacts of urbanisation

Urban development includes highway construction, in some places requiring destruction of karst landforms (*Figure 6.12*), and increased use of limestone for making roads and cement; this has been especially apparent in northern Puerto Rico. Numerous regional urban centres use karst water supplies. For example, Port-au-Prince, the capital of Haiti, draws in part on karst groundwater. Other urban centres using karst groundwater include those in northern Jamaica and northern Puerto Rico, Antigua, Barbuda, and to a lesser extent the Netherlands Antilles.

Urban water demands have also led to water contamination, particularly by salt water in low-lying karst areas or where groundwater is at shallow depths. This has occurred in northern Puerto Rico and in the Bahamas, and where the waste disposal infrastructure is unreliable. Contamination problems have occurred in limestone aquifers in Jamaica. An investigation of groundwater quality throughout the karst area of Puerto Rico detected widespread water quality problems, including high salinity due to seawater intrusion and irrigation practices, high levels of bacteria due to inadequate sewage disposal, and traces of organic chemicals.

Urbanisation has also caused increased flooding problems. Hard concrete surfaces lead to reduced infiltration and a rapid input of storm waters to drainage channels. This is a particular problem in places where rainfall can be locally intense, for example the urban areas of northern Jamaica and Puerto Rico.

Industrial activities, in particular quarrying and mining, have had pronounced impacts on many karstlands. Limestone is quarried for road building and for cement production (*Table 6.2*). The Caribbean region produces some 42 million tonnes of limestone per year, and more than 10 million tonnes of cement. The main producers and exporters of limestone include Cuba, Jamaica and Puerto Rico; major producers of cement include Cuba, Dominican Republic and Puerto Rico.

Open pit bauxite mining and alumina production are important industries in the karstlands of Jamaica and Hispaniola. Commercial bauxite production began in Jamaica only in the 1950s. Some 100 000 hectares of northern Jamaican karst, particularly in the Dry Harbour Mountains, have been exploited for bauxite and alumina, and current annual production is about 13 million tonnes of bauxite and about 4 million tonnes of alumina. Mining and quarrying activities inevitably have an impact on local water quality. This has been a particular problem in Jamaica, where contamination of surface water and groundwater by 'red mud' – the caustic waste from alumina production – has been severe, causing extremely high sodium concentrations in groundwater.

Activities

1 How does urbanisation affect limestone areas?

2 What are the advantages of limestone areas for urbanisation and industrial activities?

Table 6.2 Limestone and cement production in the Caribbean, 2004

Country	Limestone (tonnes)	Cement (tonnes)
Barbados	1 874 250	322 270
Cuba (2002)	n.a.	1 326 900
Dominican Republic	1214	2 636 274
Guadeloupe	5000	230 000
Jamaica	2 500 000	800 000
Trinidad and Tobago	850 000	768 400

n.a. = not available

Source: O. Bermudez-Lugo, 'The mineral industries of the islands of the Caribbean', *US Geological Survey Minerals Yearbook 2004*

Figure 6.12 A limestone quarry in Barbados

Case Studies

Cockpit Country, Jamaica

Cockpit Country is the classic example of cockpit karst (*Figure 6.13*). Although Cockpit Country receives a high annual rainfall (1500–2500 mm), it is still considered 'waterless' because the water drains away vertically and rapidly and each cockpit bottom (sink) is drained by a sink hole.

The formation of Cockpit Country started about 12 million years ago when a faulted limestone plateau emerged from the sea. The plateau rose to about 600 metres above sea level, with a tilt of between 5 and 15 degrees. Erosion of this plateau formed the regular array of round-topped, conical hills and sinks.

Cockpits average in depth between 100 and 120 metres and walls generally slope at 30–40 degrees. Drainage of the cockpit bottoms is by percolation through joints or flowing down sink holes. Drainage by sink holes creates a complex underground network of caves

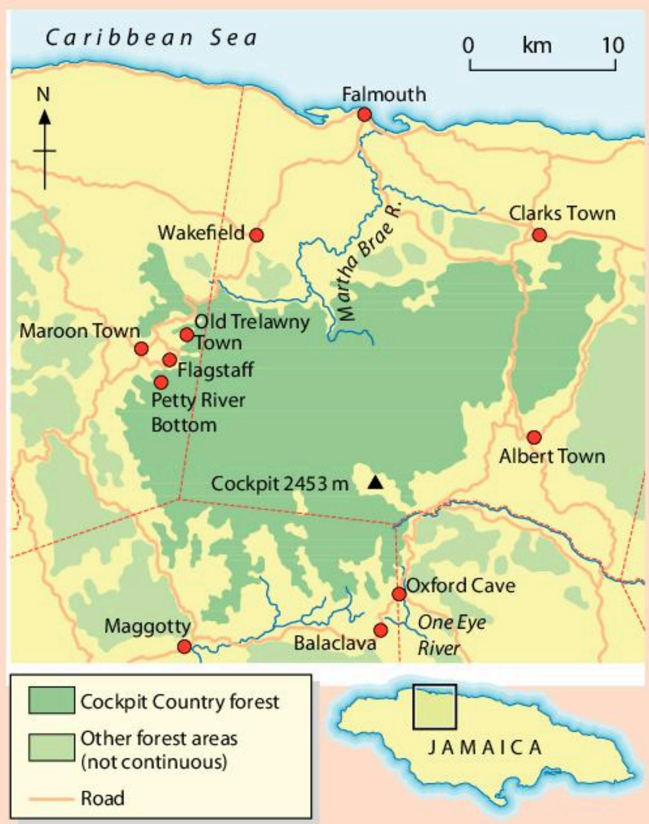


Figure 6.13 Cockpit Country

and tunnels. The edge of Cockpit Country is marked by 'degraded' cockpits, glades and valleys (**poljes**), such as Queen of Spains Valley, the best-known and largest polje in Jamaica (*Figure 6.20*, page 122). Tower karst with steep, nearly vertical sides is found to the north in the Duanvale fault zone, and in the south-east region.

1 Where is Cockpit Country?

2 What is a polje?

3 What is a sink hole?

The importance of Cockpit Country

Cockpit Country is an area of outstanding ecological and cultural significance. It is an island-within-an-island and contains specially adapted plants and animals found nowhere else in the world. Cockpit Country's biodiversity is of global significance. It is the largest remaining intact primary wet limestone forest in Jamaica and is the home to the endangered Giant Swallowtail butterfly. Many of Jamaica's threatened birds are found here, including the endangered Jamaican blackbird, and 95 percent of the endemic Black-billed parrot population. Four of Jamaica's fourteen endemic frogs are found only in the forests and caves of Cockpit Country. Unique in the world is a species of crab that inhabits the water at the base of leaves of the bromeliad that grows here.

Cockpit Country also replenishes the aquifers of four major rivers. The municipal and agricultural water supply for much of western and northern Jamaica is dependent on groundwater from Cockpit Country. The headwaters of a number of the island's major rivers are found within Cockpit Country, including the Martha Brae to the north, the Hector's River and Black River systems to the south, and the Rio Bueno to the east.

Cockpit Country is also of historical significance. It is renowned in Jamaican history as the refuge of the fiercely independent Maroons, descendants of the earliest slaves who were freed by the Spanish settlers around the time of the British conquest in 1655. After almost a century of resistance to British rule in the 'Land of Look Behind', the Maroons forced the British into signing a peace treaty in 1738.

4 Why is the protection of Cockpit Country so important?

Current threats to Cockpit Country

Cockpit Country is threatened by a range of human activities:

- conversion of forest to agriculture in accessible areas
- illegal hunting of birds
- extraction of charcoal and commercial hardwood timber from the forest.

Clearing forest areas not only reduces the overall size of the forest, but the associated fragmentation speeds the spread of harmful non-native plants and animals. Clearing of the forest occurs most along the edges of Cockpit Country that have been made accessible by roads.

Roads also enable illegal logging and open up corridors to sunlight and airflow, which alters the microclimates of the cockpits. The flora and fauna of Cockpit Country are adapted to very high humidity, so it is important that these conditions are maintained – otherwise many plants and animals will not survive even in remaining patches of forest. Frogs and butterflies are particularly dependent on the high humidity of the undisturbed cockpits and cave systems.

Most significantly, however, Cockpit Country is now threatened by bauxite mining (*Figure 6.14*). Although 22 327 hectares of Cockpit Country is a designated Forest Reserve, prospecting for and mining of bauxite can be done within a Forest Reserve. Alcoa

Figure 6.14 Bauxite mining in Jamaica

Minerals of Jamaica and Clarendon Alumina Production applied for the renewal of a Special Exclusive Prospecting Licence, which was first granted in May 2004. This allowed them exclusively to prospect for bauxite within a specified area in Cockpit Country. In November 2006, the Minister of Agriculture renewed Alcoa's licence. However, the public outcry that ensued prompted the Minister to suspend the licences almost immediately.

5 What are the main threats to Cockpit Country?

6 How can road building affect limestone environments in Cockpit Country?

The impacts of mining

During the exploration or prospecting phase, considerable damage can be done because roads are needed to bring in drilling equipment. In the mining phase, a more extensive road network is needed, and all the vegetation on the surface of the land where bauxite deposits occur is removed. This causes increased surface runoff and may impede infiltration of water to the groundwater level.

Because water resources here are based on underground caves and tunnels, underground streams in the region are particularly prone to damage through in-filling, siltation, and accumulation of solid waste. These result in reduced flow and reduced water quality downstream, and flooding upstream. Mining could lead to flooding of previously safe areas and a reduction in the volume of major rivers flowing from Cockpit Country, reducing the water supplies for the western half of Jamaica's north coast.

Deforestation resulting from bauxite mining in the Cockpit Country would also contribute to greenhouse gas emissions. Bauxite mining itself is energy intensive and most of the energy comes from fossil fuels, further adding to greenhouse gases.

It is clear that no matter what approach is taken to the reclamation of mined lands, the present biological diversity would be lost forever. And if bauxite mining were allowed even on the edges of Cockpit Country, the region would soon be opened up to logging and limestone quarrying on a massive scale.

7 How could mining affect Cockpit Country?

The alternatives for managing Cockpit Country

There are a number of long-term benefits and costs of bauxite mining. Apart from the mining company, its relatively small workforce and the Government of Jamaica, it is not clear who would benefit from mining in Cockpit Country, especially among local residents. The rural residents, mainly small farmers, would lose their family lands and traditional livelihoods.

When the impacts of air and water pollution of mining are taken into account, people living in or near to bauxite mining or processing pay a very high price in terms of their health and quality of life. Protecting the Cockpit Country forests is also critical for maintaining the water supply for the wider population of western and northern Jamaica.

There are several alternative uses of Cockpit Country, which can be sustainable if they are properly managed: ecotourism, cultural tourism, health tourism, geo-tourism, educational and scientific exploration, as well as careful harvesting of natural products for nutritional and medicinal purposes. These activities can be undertaken by local people.

Jamaica is facing a choice between:

- conserving and managing Cockpit Country as a world-class tropical forest and wildlife reserve – a UNESCO World Heritage Site enjoyed by thousands of local people and visitors every year for generations to come, or
- allowing it to become a sterile wasteland of so-called restored pits, its biological diversity and cultural heritage being lost forever.

Mining in Cockpit Country would destroy the natural, cultural and archaeological resources of the area. On the other hand, this area could be a source of future sustainable livelihoods; many rural communities of Jamaica could benefit from the development of ecotourism and heritage tourism in Cockpit Country.

8 List the advantages and disadvantages of mining in Cockpit Country.

Limestone in Puerto Rico

The limestone region of Puerto Rico covers about 27.5 percent of the island's surface and contains many karst features. The karst belt in the northern limestone has the most spectacular karst landforms. It covers 65 percent – 142 544 hectares – of the northern limestone. The northern limestone contains Puerto Rico's most extensive freshwater aquifer, its largest continuous expanse of mature forest, and largest coastal wetland, estuary, and underground cave systems. The karst belt is extremely diverse, and its multiple landforms, concentrated in such a small area, make it unique in the world. Karst forests contain the largest reported number of tree species per unit area in Puerto Rico and both flora and fauna are rich in variety. Many rare, threatened, endangered and migratory species find refuge in the karst belt.

Limestone in Puerto Rico contains a variety of caves, limestone cliffs and other karst features. The karst belt extends from Aguadilla in the west, to a small 'haystack hills' formation in Loíza, just east of San Juan (*Figure 6.15*). Puerto Rico also has some of the most important caves in the western hemisphere (*Figure 6.16*). The Rio Camuy runs underground for part of its course, forming the third largest subterranean river

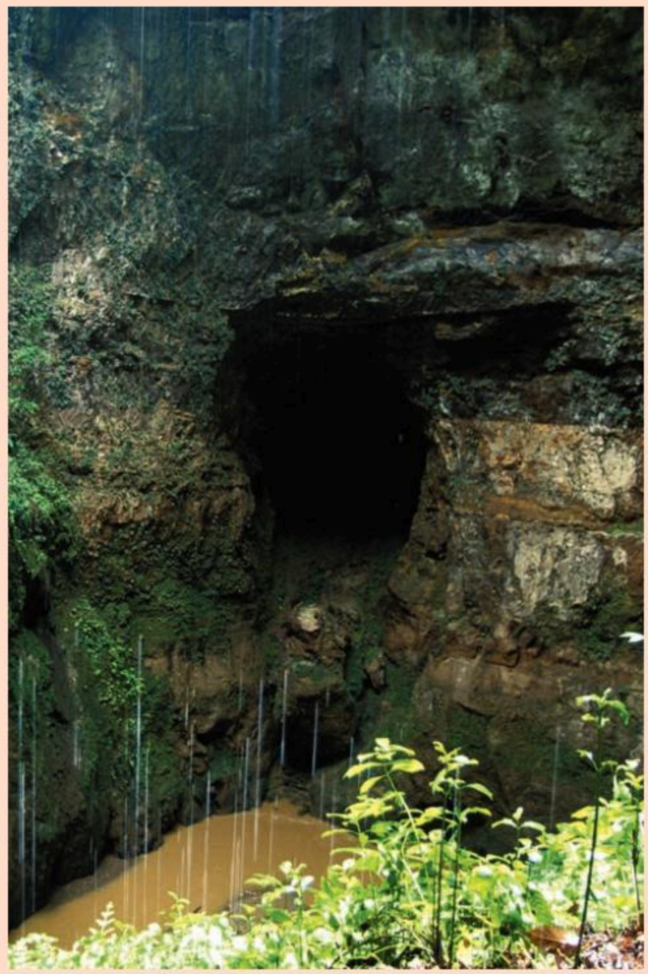


Figure 6.16 An entrance to the Rio Camuy cave system

Figure 6.15 Limestone outcrops in Puerto Rico

in the world. Rio Camuy Cave Park covers an area of 108 hectares. Sixteen entrances to the cave system have been found and 11 km of passages explored so far. There are fine examples of stalactites and stalagmites here – and plenty of bats. The caves are also home to a unique species of fish that is totally blind.

However, there are problems associated with human use of karst areas. The upper aquifer contained within the Manatí-Vega Baja area has undergone a degradation in water quality, largely because it has been subjected to extensive agricultural, industrial and urban development.

At some locations, nitrate concentrations have exceeded the maximum permissible contaminant level of nitrate in drinking water. The sources of nitrates are mainly from fertilizer used in the cultivation of pineapples and from septic tank effluent at rural communities. Nitrate concentrations in these areas are between 6.8 and 10.0 milligrams per litre (the US Environmental Protection Agency permissible level for nitrates in water is 10 milligrams per litre).

1 What are the attractions of Puerto Rico's limestone areas?

2 In what ways have human activities affected the limestone of Puerto Rico?

Skills

Interpreting photographs

Figure 6.17 shows a limestone landscape in China. When studying photographs it is important to consider general themes such as:

- Physical geography – What is the type of environment here? Can we identify any important factors or processes?
- Human geography – What are the main issues here?
- Scale – How large is it?
- Human activity – Is there evidence of human activity? How might human activity have affected this landscape?

1 Make a sketch of the photograph and add the following labels:

mounds of tower karst, exposed bare limestone, luxuriant forest, steep slopes, flat ground, small-intensive farming, farmhouse.

2 Beside your sketch, list three questions that you could ask about the photograph. Suggest how you might set about finding the answers to your questions.

Figure 6.17 Tower karst scenery in China

Using directions

Compass points

Figure 6.18 shows 16 points of the compass. Usually on a map the direction North is 'straight up' and South is 'straight down', East is to the right and West is to the left. Directions can be given using these points. For example, you might say 'Kingston airport is to the south of Kingston town centre' – always look at the compass directions on the map to make sure. Whenever you draw a map always include a North point. Once you know in which direction North is, you can work out all the other directions.

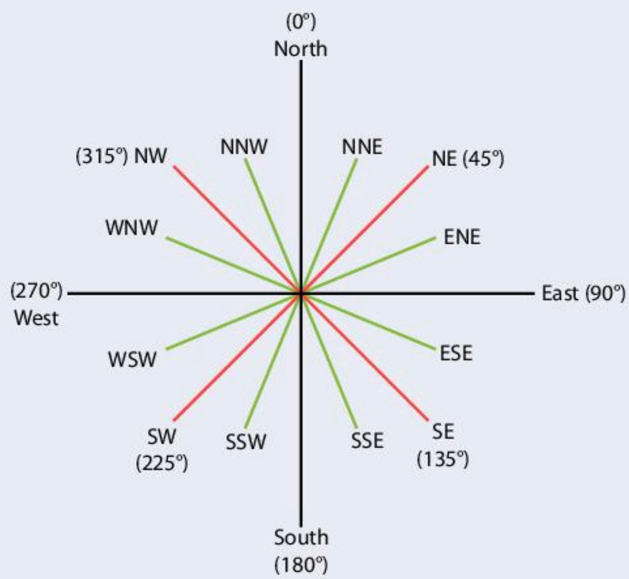


Figure 6.18 The 16 points of the compass

Give the opposite directions to the following:

a North-east
b North-north-west
c West-south-west
d South-east.

Compass bearings

To find where you are, you can also use compass bearings. This involves using degrees rather than directions. For example, an East direction is the same as 90° and a West direction is the same as 270°. (Which direction has a bearing of 180°?)

The simplest way to take a bearing from a map is to use a protractor (*Figure 6.19*). You do need to be very careful when converting degrees on a protractor to compass bearings but it is simpler and cheaper than using an actual compass.

The most important thing about giving a direction or a compass bearing is to state very clearly which way you are looking or travelling. This is because there are always two opposite directions or compass bearings between two places.

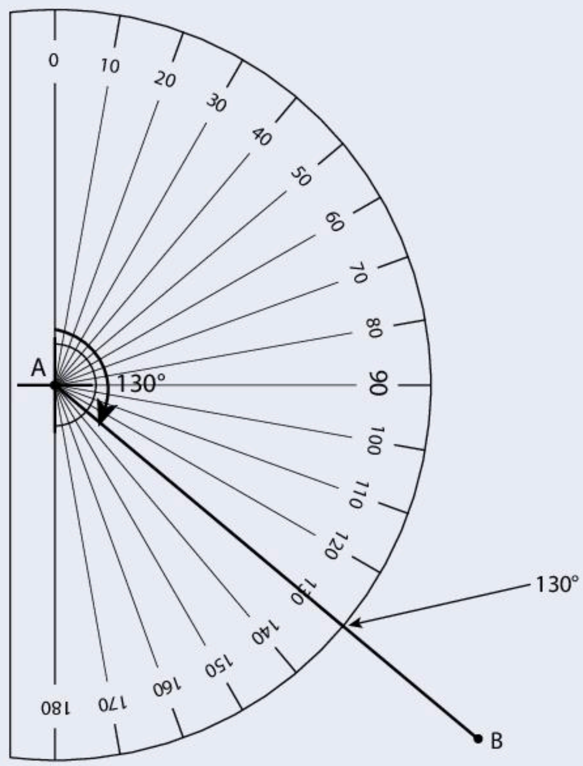


Figure 6.19 How to take a bearing using a protractor

Interpreting topographical maps

Signs and symbols are used on maps in place of words. They are simple to read and are often very logical in their design. Imagine how complicated a map would be if all the signs and symbols were replaced with words!

Signs and symbols are explained in the map key (the key for *Figure 6.20*). It is a good idea to try to learn the most common signs and symbols as this will help you read a map quickly without having to keep looking them up. However, it is always a good idea in an exam to double-check by referring to the key.

Study *Figure 6.20* carefully.

1 What is the main land use in the Queen of Spains valley?
2 Give a four-figure grid reference for an area of trees and scrub.
3 Locate and identify a banana plantation on the map.
4 What type of land use is found in grid square 7296 (Gales valley)?
5 What limestone feature can be found in square 7092?
6 Find, and give a reference for, an example of a depression on the map.
7 What type of settlement is:
   a Adelphi (6699)
   b Somerton (6697–6797)
   c Chatham (6901–6902)?
8 What types of services are found in Deeside and Hastings (7093–7193)? How does this compare with those in Adelphi?

Study *Figure 6.21* on page 123 carefully.

1 What is the height of Silver Hill?
2 Suggest why there are so few settlements in the northern part of the map extract.
3 What is the four-figure grid reference for Little Bay?
4 What is the six-figure grid reference for the peak of Silver Hill?
5 Name one of the sandy beaches shown on the map.
6 Try to suggest why there is no port shown on the map.
7 From the map evidence, suggest what the term *ghaut* might mean.
8 Comment on the distribution of settlements at Davy Hill (8456) and in grid square 8556.

Key for Figure 6.20

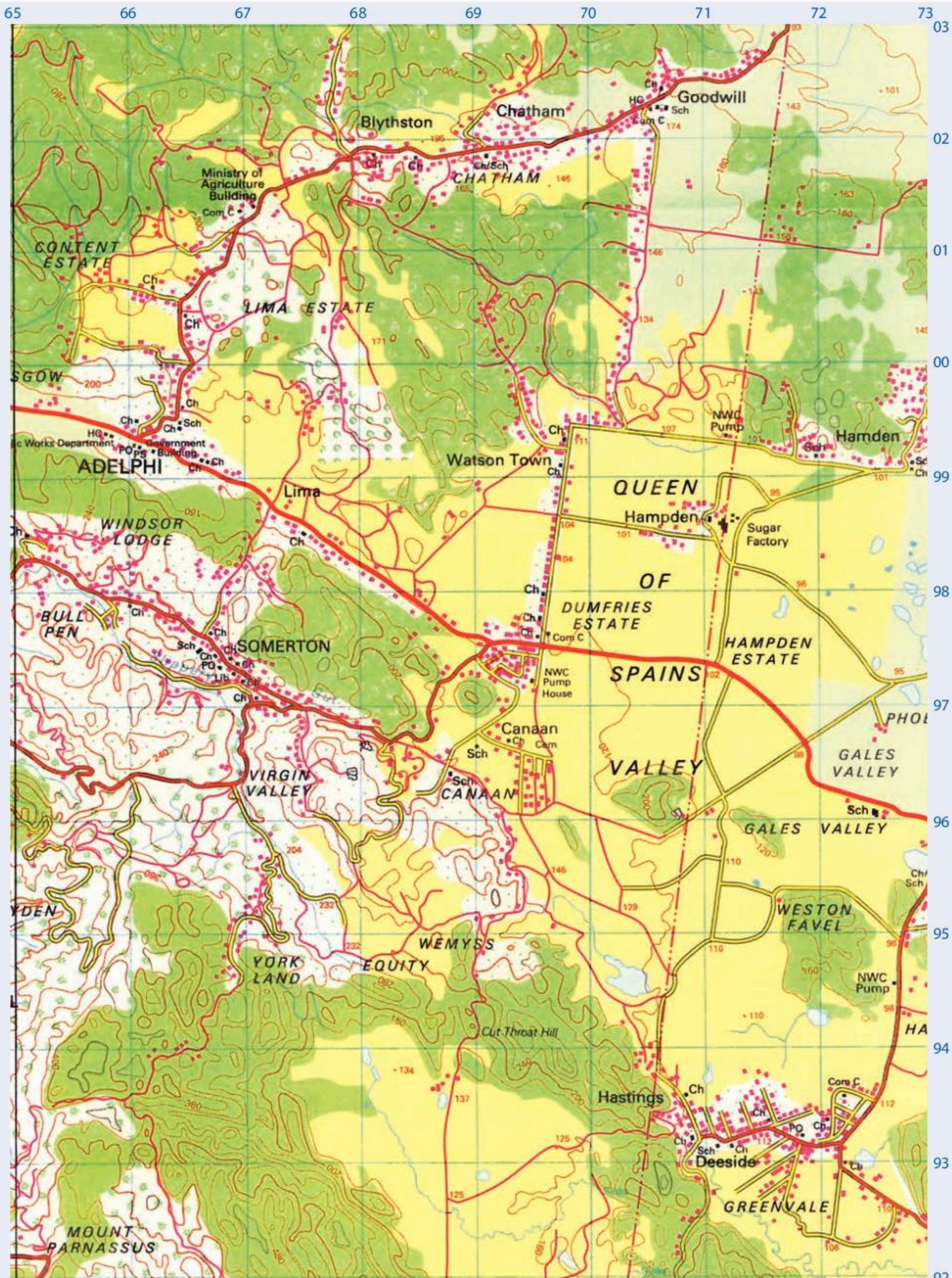


Figure 6.20 Extract from 1:50000 map of Jamaica

Scale 1:50 000

0 1 2

Km

Figure 6.21 Extract from 1:25000 map of Montserrat

Scale 1:25000
0 0.5 1
Km

Glossary of terms

Aggressive: describes any water that, when it comes into contact with limestone, has the ability to dissolve it.

Blue hole: drowned sink hole formed by the rise of sea level, leading into drowned caves and tunnels.

Carbonation: a form of chemical weathering in which rainfall combines with dissolved carbon dioxide or organic acids to form a weak acidic solution. This attacks calcium carbonate and changes it to calcium bicarbonate, which is soluble.

Clint: an area of bare rock on a limestone pavement.

Cockpit karst: a landscape pitted with smooth-sided, soil-covered depressions and cone-like hills.

Doline: a large depression formed by the solution or collapse of limestone.

Grike: the gap separating areas of bare rock on a limestone pavement.

Karst: limestone areas which are often dry on the surface and contain underground features such as caves, stalactites and stalagmites.

Stalactite: deposits of calcium hanging and growing down from the ceiling.

Stalagmite: deposits of calcium growing up from the floor of a cave.

Tower karst: a landscape characterised by upstanding rounded blocks set in a region of low relief.

Water table: the upper level within a rock below which all the pore spaces are filled with water.

Ideas for SBA

- *What are the processes causing landscape changes in a limestone area in my country?*
- *What causes changes in coral reefs off the coast at a location in my country?*

Exam-style Practice

1 Study Figure 1.

a Identify each of the features A, B and C. [3]

b On a copy of Figure 1, indicate where a stalactite may be formed. [1]

c Briefly explain the process of carbonation-solution. [2]

d i Draw a labelled sketch to show the main features of cockpit karst. Make sure you include these labels: *cockpit, flood plain*.

ii Explain how *either* tower karst *or* cockpit karst is formed. [12]

e Using examples, describe:

i how limestone in the Caribbean has affected human activities [3]

ii how human activities have affected limestone landscapes. [4]

Total 25 marks

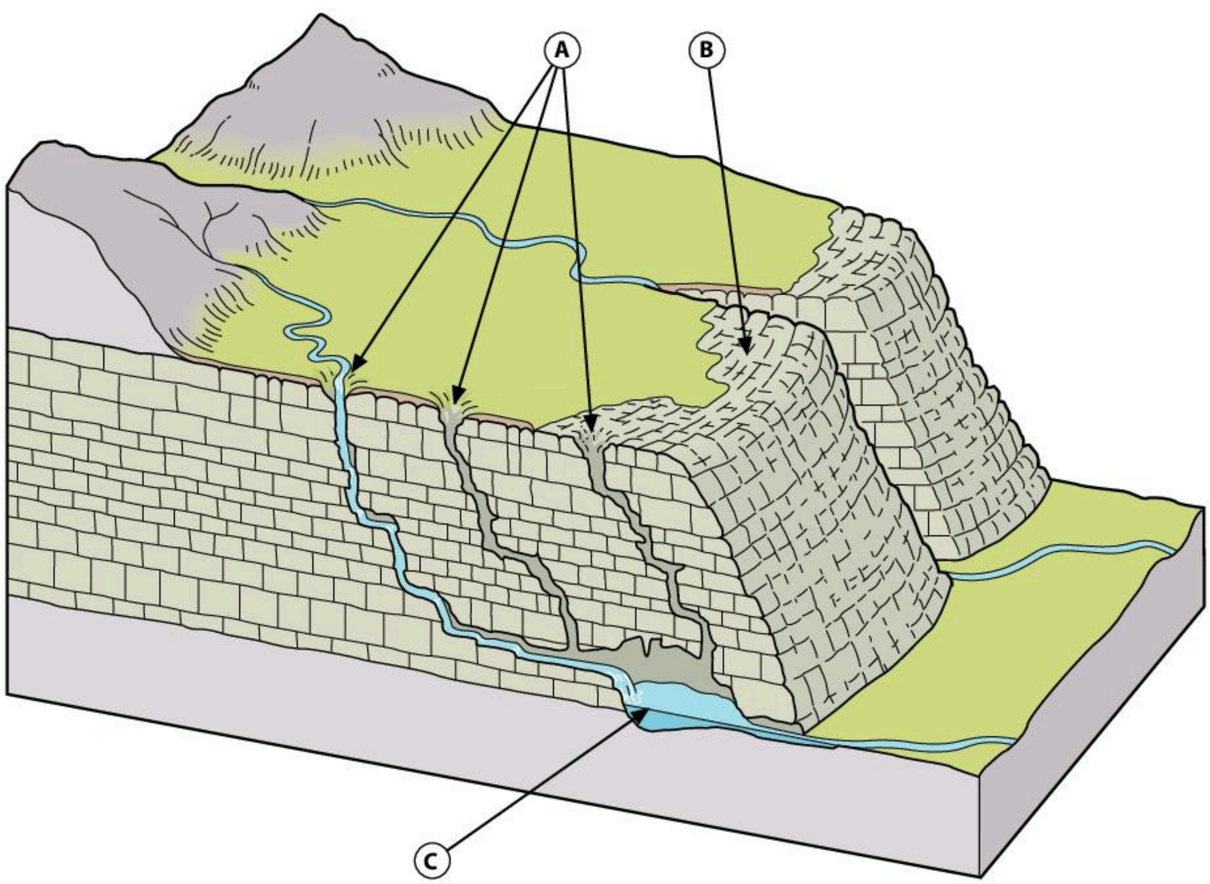


Figure 1 A cross-section through limestone

7 Weather and Climate

In this chapter you will study:

- the differences between weather and climate
- the factors influencing weather and climate
- the characteristics of equatorial and tropical marine climates
- the weather conditions associated with Caribbean weather systems, including tropical waves, hurricanes and cold fronts, ITCZ and anticyclones
- global warming and long-term changes to the world's temperature
- combating climate change
- the greenhouse effect
- the influence of human activities on climate change
- a comparison of the impacts of climate change on the Caribbean and the USA
- a comparison of measures to reduce the impacts of climate change on the Caribbean and the USA.

You will also learn how to:

- analyse tables
- read a climate graph
- interpret a weather map
- plot isopleths.

The term **weather** refers to the atmosphere at a particular instant. In general, we talk about the weather when we refer to conditions over a few days or up to a week (*Figure 7.1*).

According to recent measurements:

- the wettest place on Earth is Lloro in Colombia which receives 13 299 mm rainfall per year
- in Cherrapunji in India over 1870 mm of rain fell in one month in 1861
- the hottest place on Earth is Aziz Iyah in Libya, where shade temperatures have been recorded as high as 58 °C
- the coldest inhabited place is Oymyakon in Siberia where temperatures can drop to −68 °C
- wind speeds in Antarctica can reach 320 km per hour
- in 1921 in Colorado, USA, 1930 mm of snow fell in one day.

Figure 7.1 Some weather facts

By contrast, the term **climate** refers to the average as well as the highest and the lowest rates of temperature, rainfall, wind, cloud cover and air pressure over a period of at least 30 years. The term **microclimate** refers to the distinct climate associated with small areas such as a city, a woodland, a coastal area or even a school.

Temperature in the Caribbean

The Caribbean has a tropical maritime climate. One of its most noticeable features is the uniformity of its high temperatures. Tropical temperatures at sea level are high and do not vary much, either geographically or seasonally. This uniformity extends over the entire region. It also extends over the year. The hottest months have average temperatures of about 27–28 °C, while the coolest months have average temperatures of between 21 °C and 26 °C.

The high temperatures are due, in part, to the region's tropical location and the relatively high position of the overhead sun for much

Figure 7.2 Caribbean high pressure conditions – ideal for attracting tourists

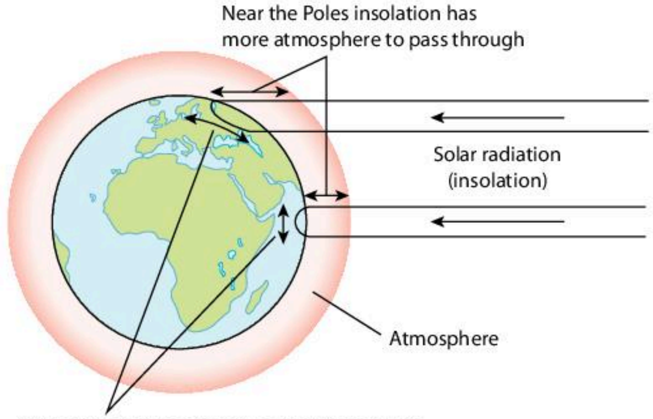


Figure 7.3 The effect of latitude

of the year. The Atlantic Ocean plays a major role in producing steady temperatures throughout the year. Oceans heat up and cool down much more slowly than the land, and temperatures remain more consistent throughout the year. In turn, the oceans influence the winds that blow over them, and this provides the relatively reliable temperatures throughout the Caribbean.

There is, however, a much greater difference between daytime and night-time temperatures. In the Greater Antilles, for example, daytime temperatures may exceed 30 °C while at night they may drop below 20 °C.

Temperatures also vary with altitude. In general, temperatures decline by 1 °C for every 100 metres in height.

Explaining weather and climate

There are many factors which affect the temperature of a place. These include latitude, distance from the sea, the nature of nearby ocean currents, altitude, dominant winds, cloud cover, and aspect. In addition, differences in pressure systems affect whether it rains or whether it is dry (*Figure 7.2*).

Latitude

On a global scale, **latitude** is the most important factor determining temperature (*Figure 7.3*).

Two factors affect the temperature: the angle of the overhead sun and the thickness of the atmosphere. Firstly, at the Equator, the overhead sun is high in the sky, hence high intensity insolation is received. By contrast, at the poles, the overhead sun is low in the sky, hence the quantity of energy received is low. Secondly, the thickness of the atmosphere affects temperature. Radiation has more atmosphere to pass through near the poles, due to its low angle of approach. Hence more energy is lost, scattered or reflected than over equatorial areas, making temperatures lower over the poles.

Tropical rainforest climates have high temperatures throughout the year on account of their equatorial location. They also receive high levels of rainfall due to the daily convection. Hot deserts are hot because of their tropical location, but receive low rainfall for a variety of reasons, including the presence of the subtropical high pressure belt.

Altitude or relief

In general, air temperature decreases with increasing **altitude** (*Figure 7.4*). This is because air under the greater pressure of lower altitudes is denser and therefore warmer. As altitude increases so the pressure on the air is reduced and the air becomes cooler. The normal decrease of temperature with height is on average 10 °C/km.

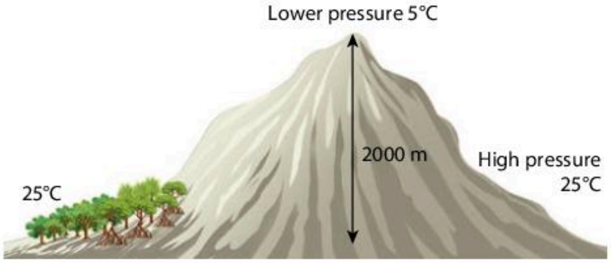


Figure 7.4 The effect of altitude or relief

Proximity to the sea

The **specific heat capacity** is the amount of heat needed to raise the temperature of a body by 1 °C. Land heats and cools more quickly than water. It takes five times as much heat to raise the temperature of water by 1 °C as it does to raise land temperatures.

Water also heats more slowly because:

- it is clear, hence the sun's rays penetrate to great depth (distributing energy over a wider area)
- tides and currents cause the heat to be distributed further.

Thus a greater volume of water is heated for every unit of energy than land, hence water takes longer to heat up.

Therefore, distance from the sea has an important influence on temperature. Water takes up heat and emits it much more slowly than the land. During winter, in mid latitudes, sea air is much warmer than land air, therefore onshore winds bring heat to the coastal lands. By contrast, during summer, coastal areas remain much cooler than inland sites. Areas with a coastal influence are termed maritime or oceanic, whereas inland areas are called continental. Areas that are far from the sea may be arid, such as parts of central Sahara.

Ocean currents

The effect of ocean currents on temperatures depends upon whether the current is cold or warm (*Figure 7.5*). Warm currents from equatorial regions raise the temperatures of polar areas (with the aid of prevailing westerly winds). However, the effect is noticeable only in winter. Areas that lie close to cold upwelling ocean currents, such as Namibia, may contain hot deserts, such as the Namib Desert. This occurs because the cold current cools the air above it, reducing the amount of evaporation from the ocean, and producing dry conditions.

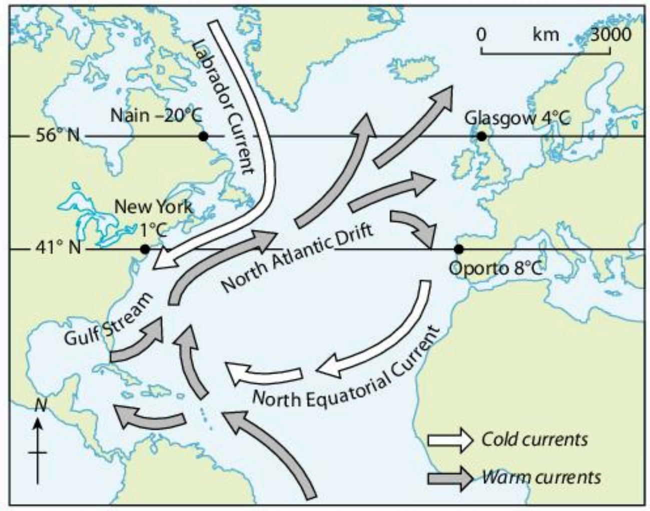


Figure 7.5 The effect of ocean currents

Winds

The effects of winds on temperature depend upon the initial characteristics of the wind. In temperate latitudes **prevailing** (dominant) winds from the land lower the winter temperatures, but raise the summer ones. This is because continental areas are very hot in summer but very cold in winter. Prevailing winds from the sea do the opposite – they lower the summer temperatures, but raise the winter ones. Land-sea breezes develop as a result of differences in pressure between land and sea (*Figure 7.6*). By day, as the land is warmer than the sea, there is lower pressure over the land than over the sea. Wind blows from high pressure to low pressure, so a breeze may develop blowing from the sea inland, and lowering the air temperature. By contrast, during the night the land cools, but the sea remains warm. High pressure is now over the land rather than the sea. As a result the breeze blows from the land toward the sea.

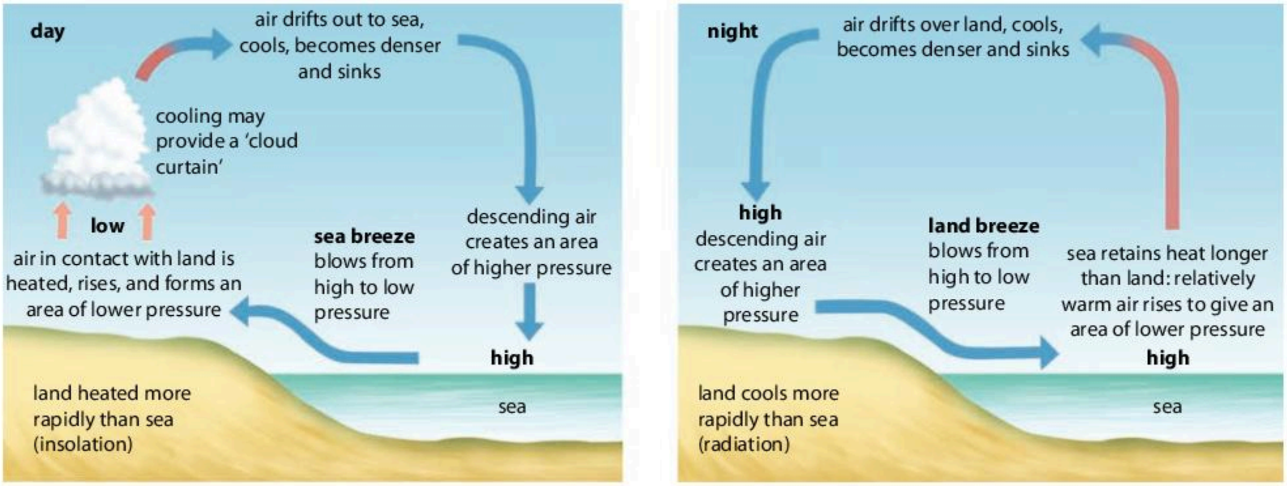


Figure 7.6 Land-sea breezes

Cloud cover

Cloud cover decreases the amount of insolation reaching the surface by reflecting some of it. Clouds also reduce the amount of insolation leaving the surface by absorbing the radiation. If there is limited cloud then incoming short-wave radiation and outgoing long-wave radiation are at a maximum. This is common in many hot deserts.

Pressure

In low pressure systems air is rising. Low pressure produces rain as the air may rise high enough, cool, condense and form clouds and rain. This can happen in very warm areas such as rainforests, at mountain barriers and at weather fronts, when warm air is forced over cold air. In contrast, where there is high pressure, air is sinking, and rain formation is prevented. The world's great hot deserts are located where there is high pressure caused by sinking air.

Activities

1 What is the difference between weather and climate?

2 Suggest reasons why temperatures in the Caribbean are generally very high.

Pressure and winds

As everywhere else in the world, Caribbean weather and climate are linked to the global atmospheric circulation. The Caribbean is dominated by a high pressure belt, the Azores-Bermuda anticyclone. The term **anticyclone** is another name for high pressure. This stretches from the Azores in the west Atlantic to Bermuda. Winds blowing out from this area of high pressure are known as the north-east trade winds (*Figure 7.7*). North-east trade winds are constant and blow for much of the year. As they approach the Equator they are deflected clockwise, so that at the Equator they are almost easterly winds. In the southern hemisphere a similar high pressure belt produces the south-east trade winds.

The trade winds contain moisture but do not generally produce heavy rain. Often the relative humidity is around 70 percent, although local disturbances may lead to rainfall. These disturbances include:

- a decrease in air pressure during the summer months
- the movement of air over high ground
- the movement of weak low pressure systems.

The zone where the north-east trade winds and the south-east trade winds meet is

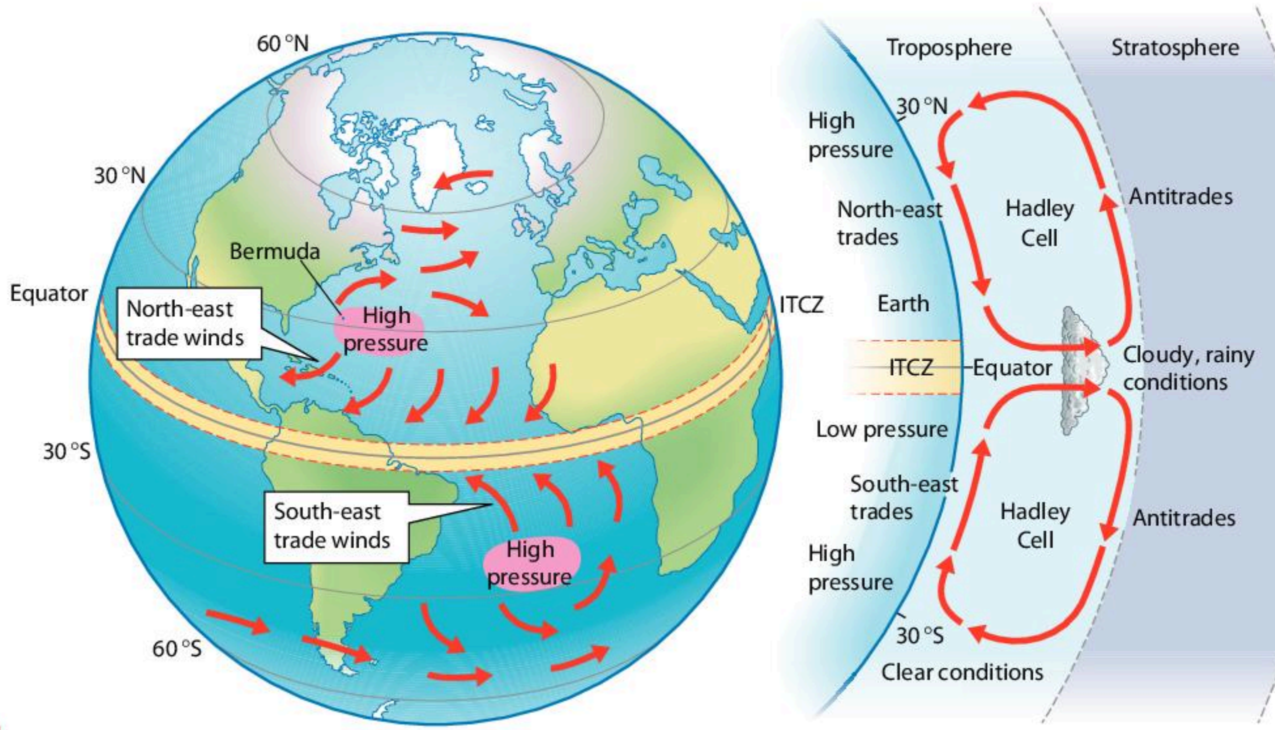


Figure 7.7 General circulation model and the Caribbean

known as the **intertropical convergence zone** (ITCZ). Where these air masses meet there is some uplift resulting in the cooling of air, condensation and rainfall. Rain may be in the form of showers or longer, heavier thunderstorms. If there is little difference in the temperature of the two air masses there is limited uplift. On the other hand, if one of the air masses is much warmer than the other, the uplift of the warmer air may produce heavy rain. However, as both air masses originate in tropical areas the difference in temperature is often slight.

After rising for thousands of metres, the upper air flows back, away from the Equator. These high-level winds are the reverse of the surface winds and are known as **antitrades**. Occasionally these antitrade winds carry volcanic ash and dust north-eastward from the eastern Caribbean to Barbados (*Figure 7.8*). Once the antitrade winds reach the high pressure belts, they begin to sink back to the ground and form the trade winds. Thus there is a circulation of air between the Equator and latitudes 30° North and South, in the regions known as the tropics.

Activities

1 Study *Figure 7.7*.
- **a** What is happening to air at the Equator?
- **b** Suggest reasons why air sinks at around 30º North and South latitude.
- **c** State one way in which the pattern of winds differs in the northern hemisphere from the southern hemisphere.

2 *Figure 7.8* shows the transport of volcanic ash from the east Caribbean volcanic island arc.
- **a** State the direction in which the volcanic ash is transported.
- **b** Explain how this occurs if the surface winds are from east to west.

Rainfall

Most of the Caribbean region has a summer rainfall maximum, with distinct wet and dry seasons. Trinidad's rainy season lasts from June to December, with peaks in June/July and November. There may be a short, dry period in late September/early October known

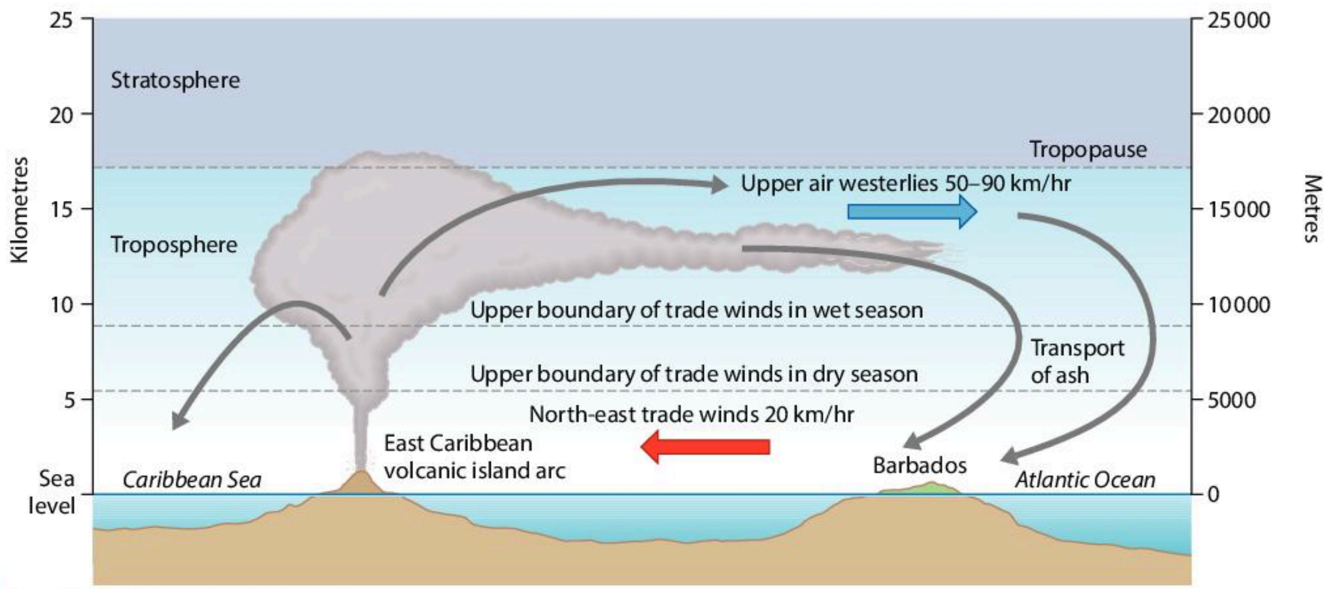


Figure 7.8 Antitrade winds and volcanic ash

as *petit carême*. In contrast, Jamaica has two rainy seasons: one in May and June, and the other in September and October, the last two being the wettest months. The northern Caribbean experiences cold fronts from North America, which can cause torrential rain in Cuba and on the north coast of Jamaica.

Although the trade winds are moist, they do not always produce heavy rain. Rainfall in the Caribbean is very varied – spatially (from place to place) and temporally (from season to season and from year to year). There are, however, certain characteristics associated with rainfall in the Caribbean:

- it frequently occurs as heavy showers
- there is a wet season in summer and a drier season in winter – in fact, drought is a problem in many areas.

The seasonal shift of the ITCZ has a major influence on Caribbean weather. It affects the seasonal variations in wet and dry seasons, hurricane activity and tropical storms. In summer the ITCZ is at about 5–10°N. The Azores-Bermuda high pressure region is further north, and pressure is not as high in the summer.

Individual islands may have a variety of local climates as a result of their particular size, shape and topography. The southern Caribbean is affected by the position and character of the ITCZ. The size and strength of the ITCZ depends on the convergence of the north-east trades and south-east trades. When their convergence is limited in extent, the weather is generally fine (*Figure 7.9a*). In contrast, when the convergence is over a larger area, rainfall can be heavy and prolonged (*Figure 7.9b*).

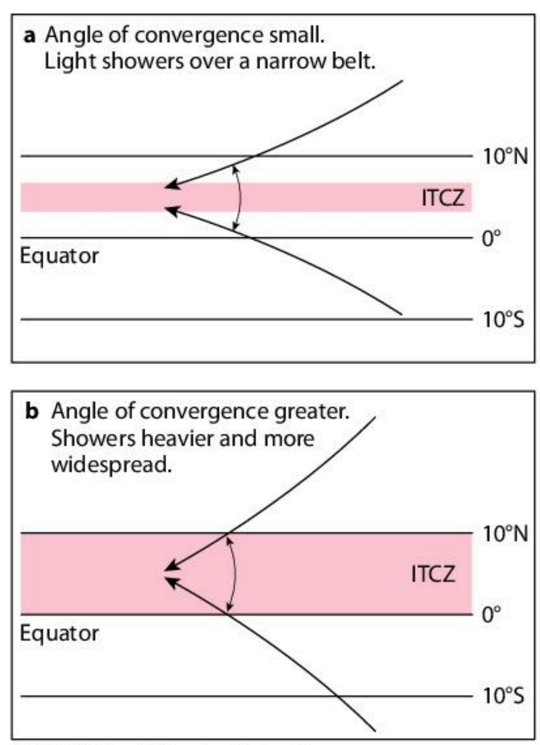


Figure 7.9 The ITCZ and rainfall patterns

In addition, the ITCZ moves seasonally. In December when the sun is directly overhead at the Tropic of Capricorn (23 °S) the ITCZ moves southward, reaching as far south as 1–3 °N. In contrast, by the end of June the ITCZ has moved north to between 5 °N and 10 °N. This is the rainy season in Trinidad. If the ITCZ moves further north, Trinidad may experience dry weather, whereas rain falls over the southern islands of the eastern Caribbean.

In contrast, the size and height of the Greater Antilles influences rainfall patterns there. The trade winds are forced to rise over the mountains and are cooled (*Figure 7.10*).

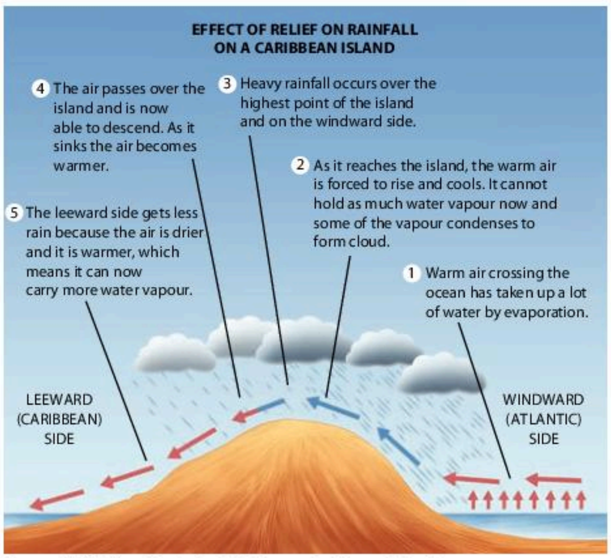


Figure 7.10 The effect of rainfall on a Caribbean island

Figure 7.11 Relief rainfall

Figure 7.12 Cumulus clouds over St Lucia

Condensation follows and rain falls (*Figure 7.11*). In Jamaica, for example, Port Antonio on the north-east coast receives 3200 mm each year. The central mountains receive up to 5000 mm annually while Kingston, on the south side of the island, receives just 760 mm on average. Kingston is therefore said to be in the rainshadow of the central mountains.

The amount of **convectional rain** falling on islands in the Greater Antilles depends on the size of the island. Land heats up quickly and in turn heats the air above it. Over the bigger islands, larger amounts of warm air rise, cool and condense to form cumulus clouds, which produce rain (*Figure 7.12*). Some of these convectional storms can be very intense, producing thunderstorms. Convectional activity is greatest when the air is hot and moist.

Local winds may also develop. During the day, warm air blows in from the sea to replace the rising air inland. This produces a sea breeze. In contrast, during the night, cool air sinks off the land out to sea, producing a land breeze.

The islands of the Lesser Antilles are generally too small to produce much convectional rain. Some are high enough, however, to produce relief rainfall, whereas the lower islands remain quite dry. **Orographic** or **relief rainfall** is heavy and prolonged. It tends to occur on the windward slopes of mountain ranges along northern and eastern coasts, and is reinforced by sea breezes. Low rainfall areas include:

- rainshadow areas on the drier leeward side of mountains
- low-lying islands such as the Bahamas, Turks and Caicos
- more extensive flat areas of islands away from mountains.

Activities

1 What types of rainfall occur in the Caribbean?

2 What is meant by the term *rainshadow effect*?

3 What is the main cause of rainfall
 a in the wet season
 b in the dry season?

4 When is the wet season in the Caribbean?

5 How does convectional rainfall vary with size of island?

Case Study

Rainfall in St Lucia

Rainfall can be as high as 3750 mm in the south-central uplands, close to the highest point, Mount Gimie (950 metres). The north-east windward coast of St Lucia is relatively dry because it is low-lying and wide (*Figure 7.13*). The low-lying south-east and the northern tip of St Lucia are the driest parts of the island. However, the drier coastal areas do not extend all the way around the island as the Pitons, in the south-west, is an

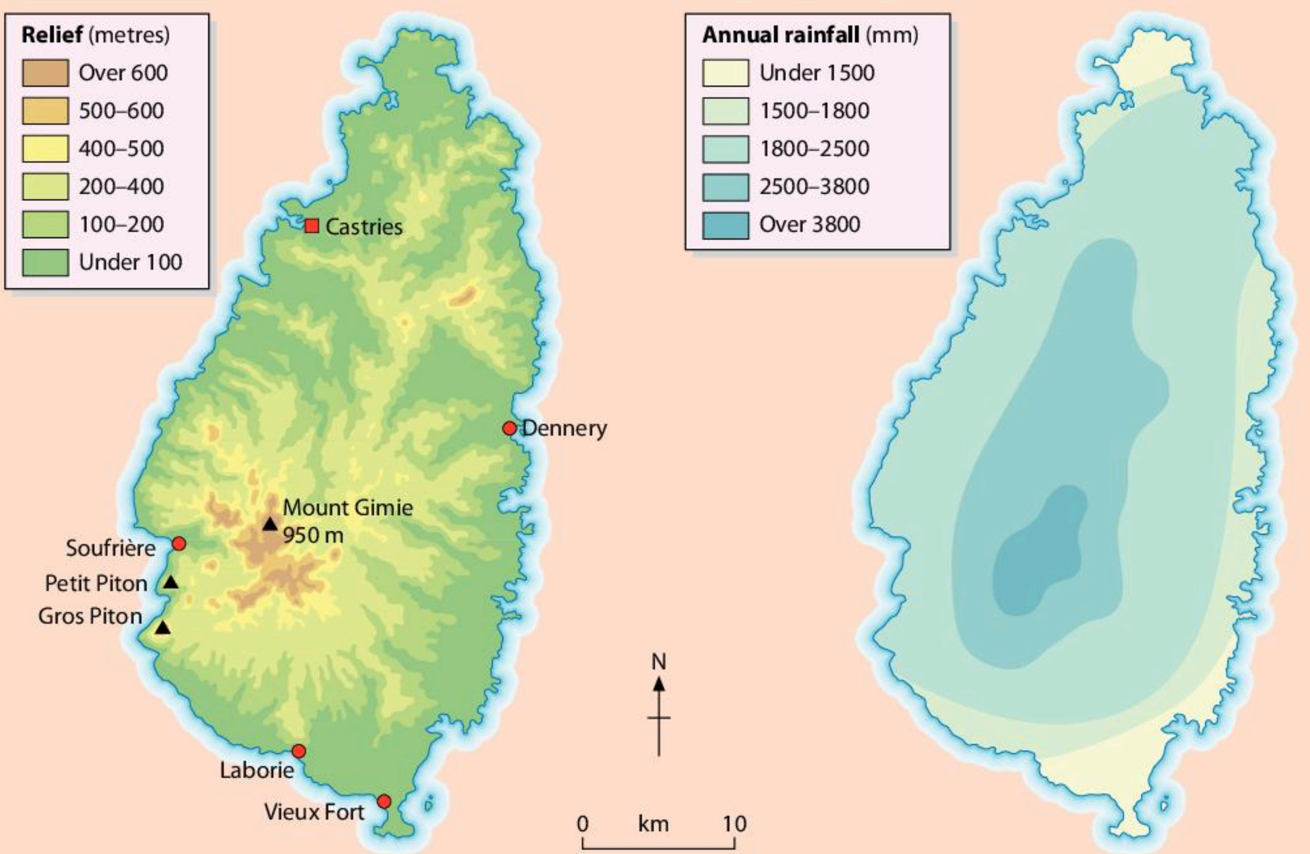


Figure 7.13 Rainfall and relief in St Lucia

area of high ground and is associated with increased amounts of rainfall in the area (*Figure 7.14*).

1 Study *Figure 7.13*.
  a What is the general relationship between altitude and rainfall?
  b Where is the highest rainfall in St. Lucia, and how high is it?
  c In which area is the lowest rainfall in St Lucia? Suggest a reason to explain this.

Figure 7.14 Rainfall over St Lucia

Skills

Analysing tables

Tables present a wide range of data in an accessible form. The things to look out for are:

- the maximum – the highest value in a set of data
- the minimum – the lowest value in a set of data
- the range – the difference between the highest value and the lowest value
- the average (or mean) – the total of all values divided by the number of observations
- the mode – the most common value
- the median – the middle value when all values are placed in rank order
- the trend – any observable pattern such as seasonal or long-term changes
- anomalies – these are exceptions to the pattern or trend.

1 Which of the weather stations in *Table 7.1* receives
  a the most rain
  b the least rain?

2 In which months is the rainy season in
  a Nassau
  b Bridgetown?

3 Approximately how much is the average monthly rainfall in
  a Bridgetown
  b Willemsted?

4 What is meant by the term *range*?

5 What is the range of temperatures for each of the four weather stations in *Table 7.2*?

6 What is the modal (mode) for mean monthly temperature at Port of Spain?

7 What is the median monthly temperature for the Bahamas (Nassau)?

Reading a climate graph

Simple climate graphs (or **climographs**) tell us about seasonal variations in the pattern of temperature and rainfall. More detailed graphs allow us to look at variations within individual months.

Figure 7.15 shows the temperature and rainfall experienced during one year at Kingston, Jamaica. It shows:

- the mean monthly maximum (the maximum temperature on each day of the month divided by the number of days in that month)
- the mean monthly minimum (the minimum temperature on each day of the month

Table 7.1 Average rainfall for selected Caribbean stations

Rainfall (mm)	J	F	M	A	M	J	J	A	S	O	N	D	Total
Nassau, Bahamas	39	49	54	69	**106**	218	161	236	164	162	81	50	1389
Kingston, Jamaica	18	19	20	39	**100**	74	42	98	114	177	65	47	813
Bridgetown, Barbados	66	28	33	36	**58**	112	147	147	170	178	205	96	1276
Piarco, Trinidad	77	61	27	71	**129**	269	243	213	144	151	212	153	1750
Willemsted, Curaçao	68	31	14	12	**18**	26	34	48	31	67	98	85	532

Sources: World Meteorological Organization 2007; World Survey of Climatology (most data for period 1951-60) in Potter R.B. et al., *The Contemporary Caribbean*, Pearson, 2004, Table 1.2

Table 7.2 Monthly temperatures for selected Caribbean islands

Temperature (°C)	J	F	M	A	M	J	J	A	S	O	N	D	Average
Port of Spain, Trinidad	26	26	27	28	28	27	27	27	28	27	27	26	27.0
Barbados	28	28	29	30	31	31	30	31	29	30	29	28	29.5
Montego Bay, Jamaica	24	24	25	26	26	27	27	27	27	27	26	25	25.9
The Bahamas (Nassau)	21	21	22	24	25	27	28	28	28	26	24	22	24.6

Sources: World Meteorological Organization 2007; adapted from N. Sealey, *Caribbean World: A Complete Geography*, Cambridge University Press 1992

divided by the number of days in that month)

- the mean monthly average (the average temperature on each day of the month divided by the number of days in that month)
- the total rainfall that fell every month.

Normally rainfall is shown as a series of bars, while temperature is shown by a line graph. Notice that there are two scales: the one on the left shows the scale for temperature and the one on the right shows the scale for rainfall.

1 Study *Figure 7.15*.
 a In which months is the maximum daytime temperature at its highest in Kingston, Jamaica?
 b In which months is the minimum daytime temperature at its lowest?

2 Describe the pattern of average daily temperature for Kingston.

3 Look at the rainfall bars in *Figure 7.15*.
 a Which is the wettest month in Kingston? How much rain does it receive in that month?
 b Which is the driest month in Kingston? How much rain does it receive in that month?

4 When is the dry season in Kingston?

5 When is the wet season in Kingston?

Interpreting a plotted weather map

The isobars on a weather map join lines of equal atmospheric pressure. They are useful because they identify features such as anticyclones (large areas of high pressure),

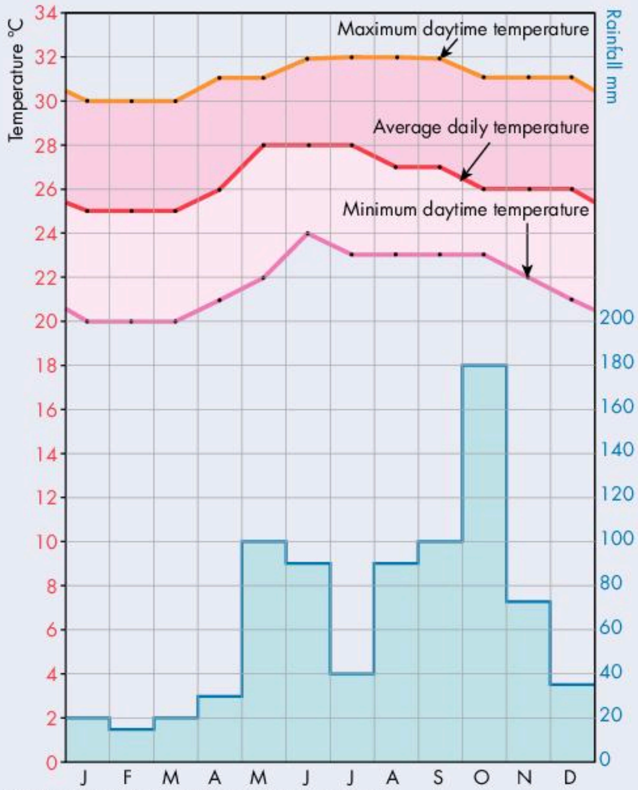


Figure 7.15 Climate graph for Kingston, Jamaica

ridges (small areas of high pressure) and depressions and troughs (areas of low pressure), which are each associated with particular kinds of weather. These features move in an essentially predictable way.

Isobars are drawn at intervals of 4 millibars (mb), unless there is a particularly deep depression where too many isobars would be difficult to read. In this case they are drawn at 8-millibar intervals. Also, wind speeds and directions are related to the spacing and orientation of the isobars.

Relationship between winds and isobars

There are three important relationships between isobars and winds:

- the closer the isobars, the stronger the wind (just like the contour lines on a topographical map: where they are close together the land is steep and where they are far apart the land is flat)
- the wind blows almost parallel to the isobars
- the direction of the wind is such that if you stand with your back to the wind in the northern hemisphere, the pressure is lower on the left than on the right.

These factors make it possible to deduce the wind flow from the isobars.

Wind speed and direction

The direction given for the wind refers to the direction from which it comes. For example, a westerly wind is blowing from the west and toward the east. The arrow on a weather map indicates the direction from which the wind is blowing. A system of 'feathers' and 'pennants' is used to indicate wind speeds (*Figure 7.16*).

Temperature is given in degrees Celsius. Cloud cover is shown by the symbol in the centre of the weather station map (*Figures 7.16* and *7.17*).

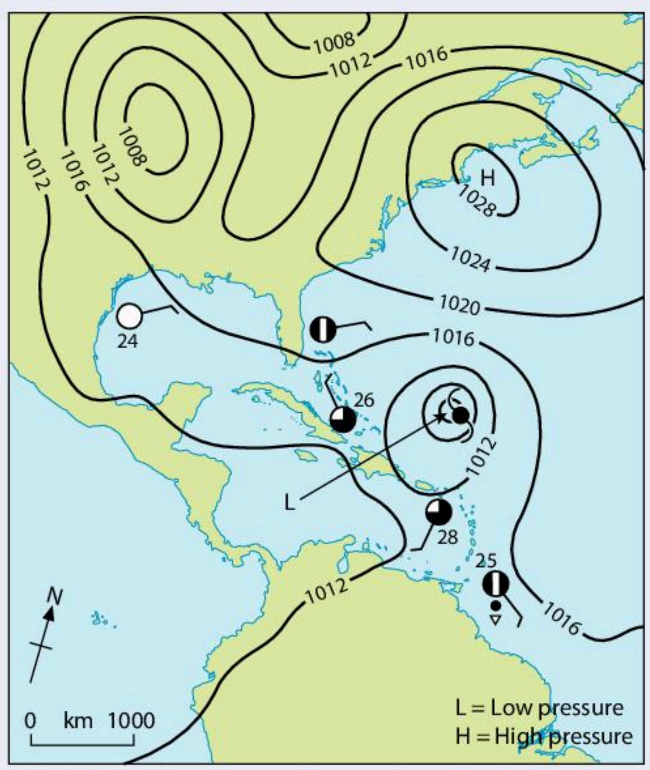


Figure 7.16 Synoptic weather map of the Caribbean, 14 September 2003

Source: based on Meteorological Office information

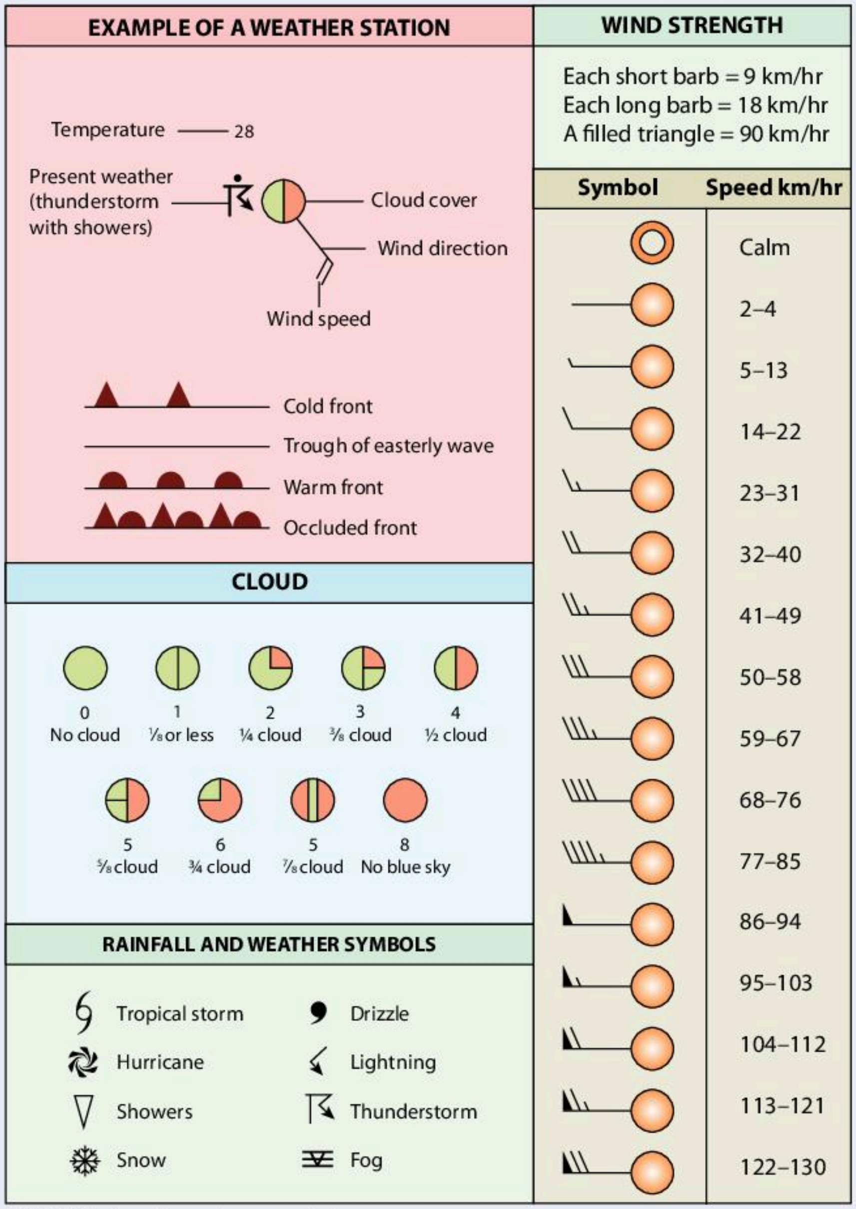


Figure 7.17 Synoptic weather map symbols

1 What is an isobar?

2 Give another name for:
  a a depression
  b an anticyclone.

3 What type of weather does a cold front bring?

4 If the isobars are spaced far apart, what is the wind like?

5 How would the isobars be drawn if the wind was very strong?

6 Study *Figure 7.16*.
  a Describe the weather conditions near to Puerto Rico.
  b How does wind direction differ between Puerto Rico and southern Cuba?
  c What type of weather is there at
    i Grenada
    ii near the Bahamas?
  d What type of weather is Dominican Republic likely to experience?

Plotting isopleths

Isopleths or **isolines** are lines that join places of equal value or amount. Isopleth maps are used when there is data from a number of study points in an area. Drawing isopleths allows the data to be used to describe the whole study area rather than just a series of points. Examples of isopleths commonly used in geography include:

- **contour lines** which join points of equal height
- **isobars** which join points of equal air pressure
- **isotherms** which join points of equal temperature
- **isohyets** which join points of equal rainfall.

Constructing an isopleth map

Drawing an isopleth map involves more than just joining the dots. Choose isopleths that increase at regular intervals (for example every 10, 25 or 50 depending on the data). The more data available the more accurate the map will be. Then estimate the position of the isopleth relative to the points on the map (*Figure 7.18*).

Make a copy of *Figure 7.18*.

1 Complete the plot for the 1012 isopleth. Remember that:
   - any value of 1012 must fall on the 1012 line
   - any value below 1012 must be located between the 1012 line and the 1008 line
   - any value above 1012 should be located between the 1012 line and the 1016 line.
2 Plot the 1004 line in area A.
3 What types of weather system are found at B and C?
4 What is the air pressure at locations C and D?

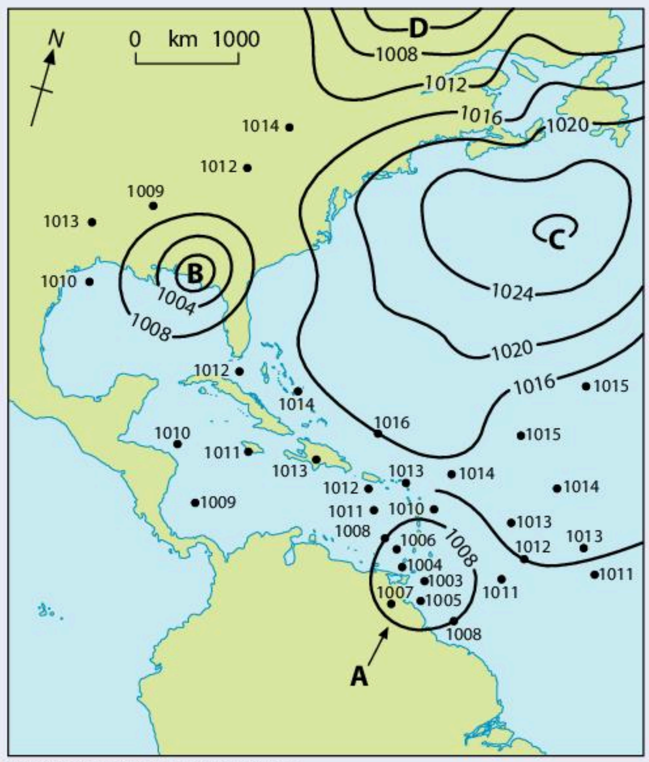


Figure 7.18 Plotting an isopleth map

Equatorial climate

The main characteristics of the **climate** in equatorial areas include:

- hot conditions – generally above 26°C – throughout the year
- high levels of rainfall, often over 2000 mm
- a lack of seasons – the temperatures are high throughout the year
- the differences between daytime and night-time temperatures (known as the diurnal range) is, in fact, higher than the seasonal differences in temperature

- rainfall is mainly **convectional** and may fall on as many as 250 days each year
- cloud cover varies – in the morning it may be limited, but by afternoon, towering cumulonimbus clouds mark the start of the convectional rains
- the presence of clouds tends to reduce the amount of heat that is lost at night – hence the diurnal range is low
- the humidity (moisture in the atmosphere) is high, and relative humidities of 100 percent are often reached in the late afternoon
- wind speeds within the forest are reduced by the large numbers of trees present.

The data for Manaus in Brazil (*Table 7.3*) show that the warmest months are August–October with a mean monthly temperature of 29 °C. The mean annual temperature range is just 2 °C.

Rainfall in Manaus is high; nearly 2100 mm. There is a definite wet season between November and May, whereas the months of June to October are relatively dry.

Tropical marine climate

Many islands and coastal areas located around 10–20° north or south of the Equator experience a tropical marine climate. These include most of the Caribbean islands and the Guyana coastal zone. Much of Central America also experiences a tropical marine climate.

Tropical marine climates (*Table 7.4* and *Figure 7.19*) are characterised by high temperatures (around 25–30 °C) throughout the year, and with a marked seasonal pattern to rainfall. Temperatures are slightly higher during the wetter season. There is rainfall throughout the year, although it is generally wetter during the late summer and autumn (the opposite seasonal pattern to Manaus). Total rainfall is usually between 1200 mm and 2000 mm.

In the Caribbean, the north-east trade winds blow year round, bringing moisture from the Atlantic Ocean. They may produce relief rainfall as they rise over high ground. Places with a tropical marine climate often experience tropical waves (*Figure 7.20*). These are regions of low pressure which create a belt of heavier rain. Some tropical waves may develop into tropical depressions or even hurricanes.

Table 7.3 Climate data for Manaus, Brazil

	J	F	M	A	M	J	J	A	S	O	N	D
Average monthly temperature (°C)	28	28	28	27	28	28	28	29	29	29	29	28
Monthly total rainfall (mm)	278	278	300	287	193	99	61	41	62	112	165	220

Table 7.4 Climate data for Montego Bay, Jamaica

	J	F	M	A	M	J	J	A	S	O	N	D
Average monthly temperature (°C)	25	25	26	26	27	28	29	29	28	27	26	26
Monthly total rainfall (mm)	70	30	30	60	80	80	60	80	110	130	120	100

Figure 7.19 Tropical marine climates have excellent potential for tourism

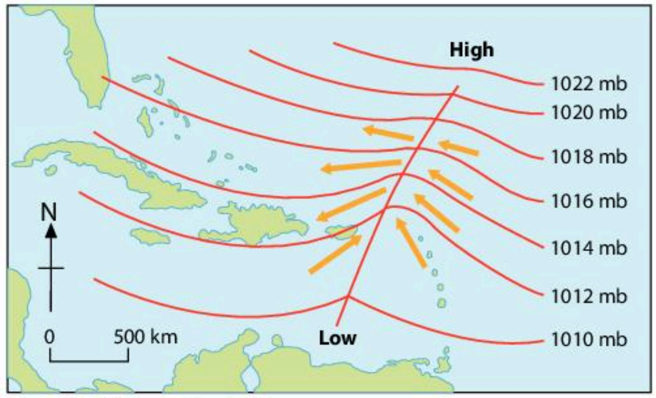


Figure 7.20 A tropical (easterly) wave

Caribbean weather systems

Tropical waves

The Lesser Antilles are affected by tropical (easterly) waves. These are areas of low pressure that originate off the coast of West Africa. They travel across the Atlantic Ocean along the edge of the ITCZ. The trade winds have a lower moist layer and an upper drier layer. If the lower air is lifted up, it cools causing condensation and rain. The driving force of a tropical wave is heat – warm air is lighter and so is lifted up, creating a low pressure zone. Tropical waves are large – they can be up to 2000 km across. So they may take several days to pass a particular point.

Ahead of the tropical wave, air is subsiding (sinking). This air is being warmed, relative humidity is dropping, and there are dry, sunny conditions. As the tropical wave passes, air pressure is reduced, and the air begins to rise vigorously. Tropical waves are associated with cumulonimbus clouds and rainfall can be quite heavy (*Figure 7.21*). Windspeed is fastest

Activities

1 Study *Figure 7.21*.
  a What is happening to the air in front of the tropical wave?
  b What is happening to air at the tropical wave?

2 How does the tropical wave appear on *Figure 7.22*?

3 Suggest what the weather conditions are likely to be:
  a ahead of the tropical wave
  b at the tropical wave
  c behind it.

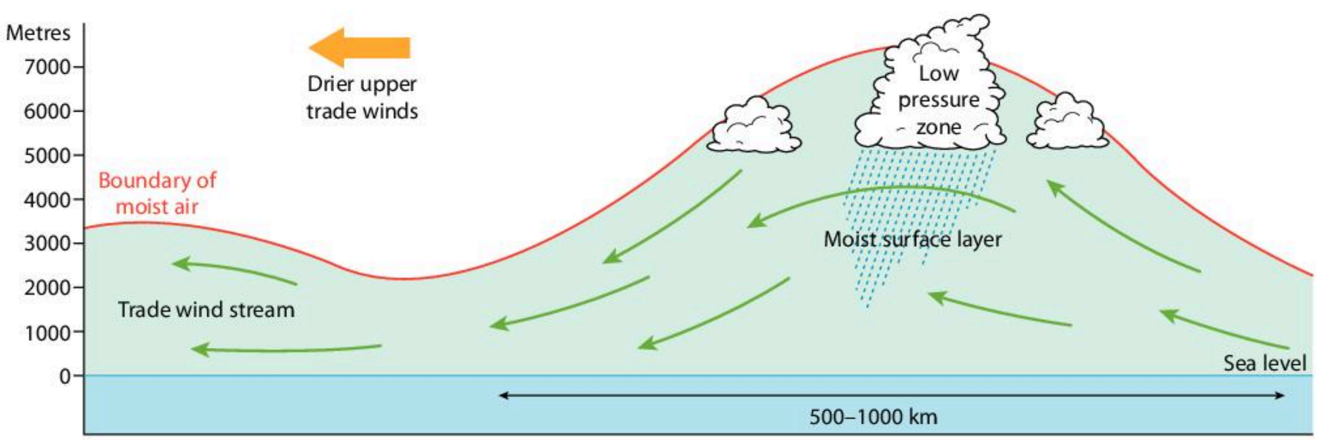


Figure 7.21 A tropical wave

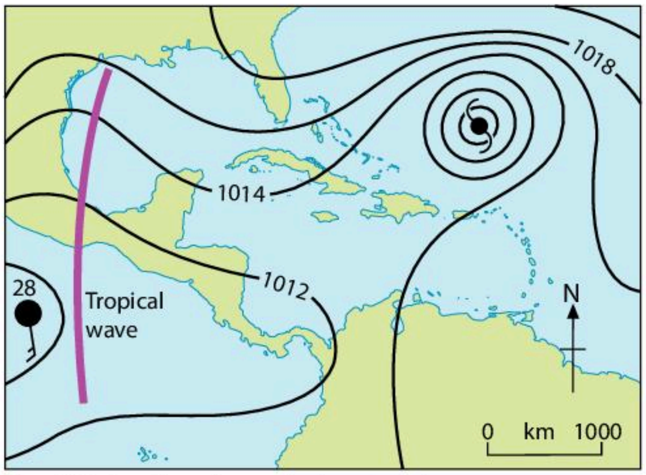


Figure 7.22 Synoptic weather map showing a tropical wave

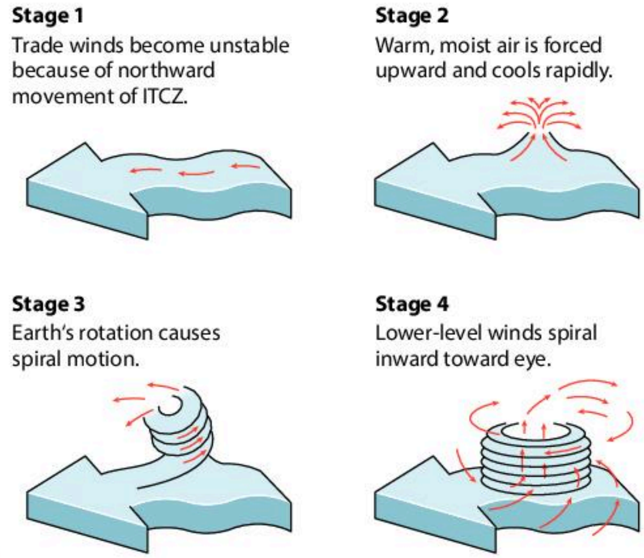


Figure 7.23 Hurricane formation

and most gusty along the front of the tropical wave. Behind the tropical wave there is still uplift, although not as much, so conditions may be very cloudy, but rainfall is not heavy. Tropical waves are most common between May and November (*Figure 7.22*).

Hurricanes

A hurricane is one of the most dangerous natural hazards to people and the environment (see Chapter 13 pages 309–320). Every year, immense damage is done by tropical storms and hurricanes. In Asia, hurricanes are also known as tropical cyclones. These storms are essential features of the Earth's atmosphere, as they transfer heat and energy between the Equator and the cooler regions toward the poles.

Some tropical waves travelling over the Atlantic become unstable and develop into hurricanes. A hurricane is a tropical revolving storm. It is a very large circular area of low pressure, driven by evaporation from warm seas (*Figure 7.23*). In areas away from the Equator, air is drawn into the hurricane to replace the rising air. Owing to the Earth's rotation, winds in a hurricane spiral inward in an anticlockwise direction. Wind speeds can reach 300 km/hour, although there is an area at the centre of the hurricane – the eye – where conditions are calm. The hurricane is driven by the latent heat released as water vapour condenses into droplets.

Hurricanes form between latitudes 5° and 30° and initially move westward (driven by the easterly winds) and slightly toward the poles. Many hurricanes eventually drift far enough north or south to move into areas dominated by westerly winds (found in the middle latitudes). These winds tend to move the hurricane to an eastward path. As the hurricane moves poleward it picks up speed and may reach between 30 and 60 km/hour. An average hurricane can move between 192 km and 768 km per day, and can travel over 4000 km before it dies out. Hurricanes are measured using the Saffir-Simpson scale – see page 316.

Hurricanes in the Atlantic occur between June and November. In the eastern and western Pacific north of the Equator, they occur between July and October. South of the Equator, off Australia and in the Indian Ocean, they occur between November and March.

Several different factors are required to transform storms, which occur frequently, into rarer hurricanes. These trigger mechanisms depend on several conditions being 'right' at the same time. The most influential factors are:

- a source of very warm, moist air derived from tropical oceans with surface temperatures greater than 26 °C
- sufficient spin or twist from the rotating Earth – this is related to latitude.

As the warm sea heats the air above it, very warm moist air rises up quickly, creating a centre of low pressure at the surface. Winds rush in toward this area of low pressure and the inward-spiralling winds whirl upward releasing heat and moisture. The rotation of the Earth causes the rising column to twist. The rising air cools and produces towering cumulus and cumulonimbus clouds. Further aloft at around 10 km the cloud tops are carried outward to create a thick layer of clouds which mark the outward-spiralling winds as they leave the hurricane core. The whole system may move slowly, at speeds of 15–20 km/hour on average. Hurricanes start off as very small areas of low pressure – often less than 10 km in diameter – yet can end up as huge systems over 1000 km wide. The eye itself can be up to 40 km wide.

Large amounts of energy are transferred when warm water is evaporated from tropical seas. This energy is stored within the water vapour contained in moist air. As this air ascends, 90 percent of the stored energy is released by condensation, giving rise to the towering cumulus clouds and rain. The release of heat energy warms the air locally, causing a further decrease in pressure. Consequently, air rises faster to fill this area of low pressure and more warm, moist air is drawn off the sea, feeding further energy into the system. Thus a self-sustaining heat engine is created. Only as little as 3 percent of the heat (potential) energy may be converted into the mechanical (kinetic) energy of the circulating winds. However, even this relatively small amount would be enough to supply the USA with all its electrical energy for six months!

On average, 10–25 percent of the rain experienced in the Caribbean comes from hurricanes. Areas within 80 km of the centre of a hurricane receive 100–250 mm of rain over a period of up to four days. Even places up to 320 km from the eye will receive rainfall. Other phenomena associated with hurricanes include:

- storm surges – large sea waves up to 15 metres high created by the strong winds which can cause extensive flooding
- swells – an increase in ocean level.

These phenomena can cause major destruction, especially when the hurricane's path takes it over land. However, a path over land also causes the destruction of the hurricane itself. As it moves over land its energy source is depleted and friction across the land surface distorts the air flow. This leads to the eye filling with cloud and the hurricane dies.

Hurricane movement is difficult to predict, although it is generally westward and northward in the Caribbean. Hurricanes normally die out when they leave the tropics or start moving over land.

Other than basic knowledge of general hurricane characteristics, there are no atmospheric conditions that can be measured and combined to predict where a hurricane will develop. Therefore a hurricane's path can be forecast only once it has formed. Satellites detect hurricanes in their early stages of development and can help to provide early warning of imminent hurricanes. Reinforced aircraft fitted with instruments fly through and over hurricanes, and weather radar can locate storms within 320 km of the radar station.

Although hurricanes are very difficult to predict, certain patterns can be seen (*Figure 7.24*):

- some hurricanes originate in the Atlantic between 10°N and 20°N; of these some travel generally westward toward the USA ⓐ
- others travel westward and then north or north-east toward the Bahamas and the USA ⓑ
- some avoid the Caribbean and head north-west toward Bermuda and the USA ⓒ
- some hurricanes originate in the Caribbean and strengthen as they travel north toward Cuba and the USA ⓓ

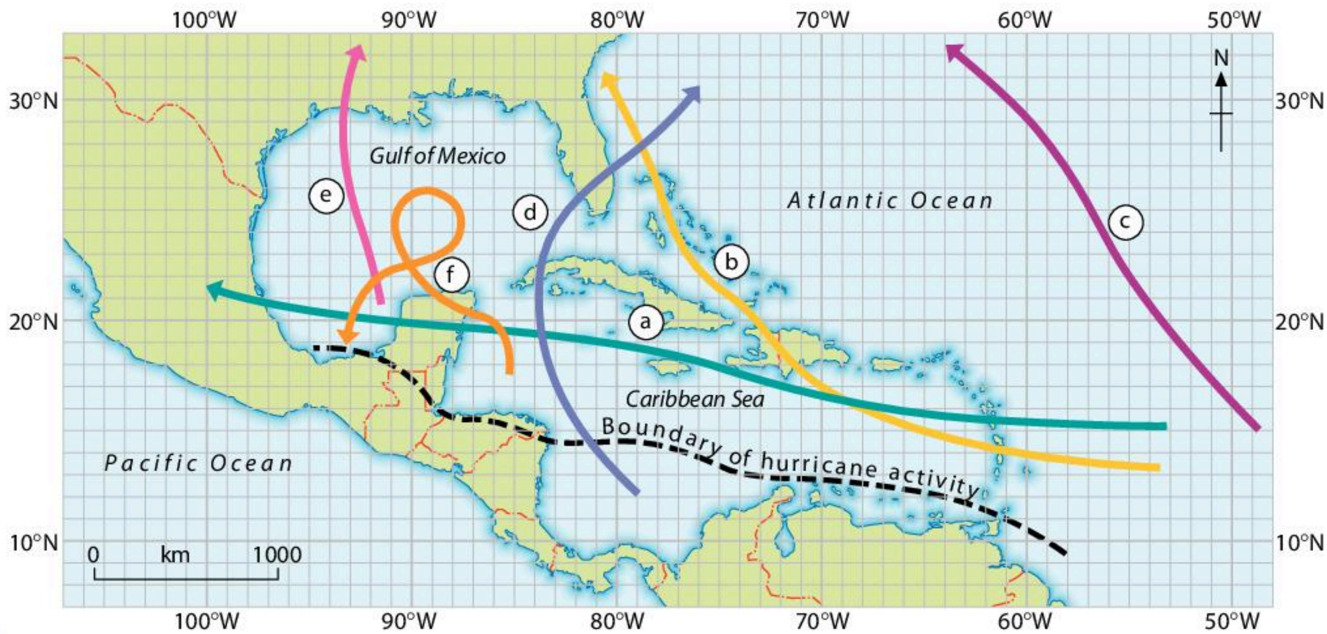


Figure 7.24 Hurricane tracks in the Caribbean

- others originate in the Gulf of Mexico, usually late in the season, and head westward or northward toward the densely populated coasts of the USA and Mexico (e)
- other hurricanes in the region are very unpredictable (f), such as Hurricane Mitch in 1999 and Hurricane Katrina in 2005
- others, like Hurricane Patricia in 2015, originate in the Pacific Ocean.

Case Study

The impact of Hurricane Ivan on Grenada, September 2004

Hurricane Ivan struck Grenada in the afternoon of Tuesday 7 September 2004 (*Figure 7.25*). The eye of Ivan passed about 10 km south of the airport at Point Salines. According to the National Hurricane Center the sustained (duration of at least one minute) wind speed in the eye wall at that time was 193 km/hour. Ivan was one of the most powerful hurricanes to hit the Caribbean region for a decade. It ravaged Grenada with rain and winds of 220 km/hour. Ivan, a category four hurricane on the Saffir-Simpson scale (see page 314), left behind a scene of destruction (*Figure 7.26*).

The relative lack of rain, coupled with the hurricane's arrival during daylight hours, served to reduce the potential loss of life, and limit damage to roads and the drainage infrastructure. Had it passed during the night, the death toll would undoubtedly have been much higher.

Hurricane Ivan affected the entire island of Grenada. The most severe damage was experienced in the southern part of the island, south of a line between St George's in the south-west and Grenville on the east coast. Visible damage included the partial or total loss of building structures, broken and uprooted trees, broken utility poles and damaged vehicles.

Figure 7.25 Satellite image of Ivan

Figure 7.26 Destruction caused by Ivan

As Ivan was a relatively dry hurricane, damage from flooding and mudslides was not extensive. Streams did flood and where debris piled up to block water flow, in areas such as bridges and culverts, flooding was more pronounced. Roadways were blocked by debris and fallen trees, but generally remained intact with little evidence of landslides or washouts. The storm surge associated with Ivan was apparently not a major factor and sea defences resisted the force of the waves without significant damage.

The water supply system suffered little damage owing to the limited rainfall and erosion associated with Ivan. Reservoirs were intact and dams appeared to be undamaged and serviceable.

However, damage to the natural features of Grenada was widespread. In St Andrew Parish, the Grand Etang Forest Reserve suffered extensive and severe damage. An estimated 50 percent of the tallest canopy trees lay on the ground. The remaining 50 percent were virtually stripped of all their leaves and suffered significant bark limb damage. The forest understorey also suffered severe damage.

Thirty-seven people died and most of the population of Grenada was affected. Of the six parishes, St Andrew, St David, St George

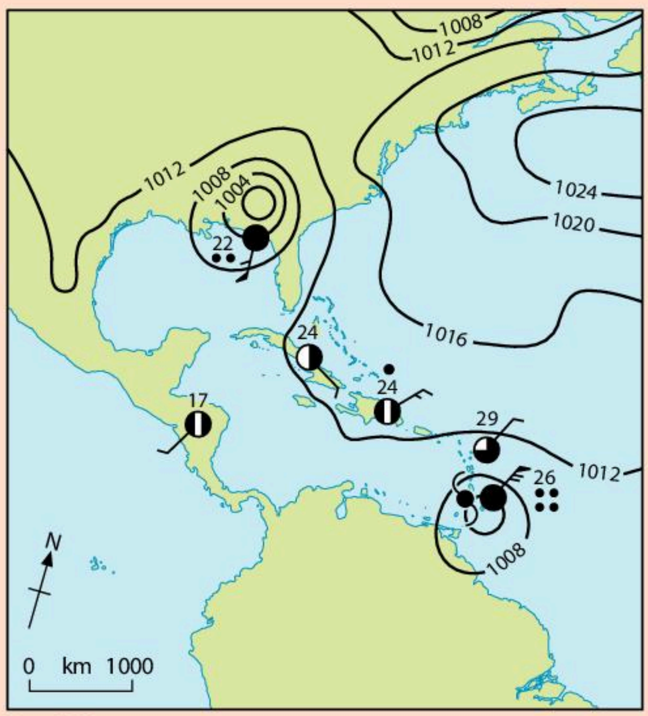


Figure 7.27 Hurricane Ivan: synoptic weather map for 7 September 2004

Figure 7.28 Grenada: parishes affected by Hurricane Ivan

and St John suffered the most (*Figure 7.28*). Approximately 90 percent of the houses were damaged or destroyed (*Table 7.5*) and 50 percent of the population were made homeless. The massive number of houses damaged or destroyed was one of the main problems.

Government buildings, the main prison, hospitals, schools and churches did not escape the fury of the hurricane. Consequently, most of the ministries and public services were paralysed for several days immediately following the hurricane. The official residences of both the Governor General and the Prime Minister were destroyed. The public infrastructure, in particular school buildings, suffered major losses. While St George's Hospital remained functional, Princess Alice Hospital (the island's second largest) was more than 70 percent destroyed. Other government buildings, including the government complex, suffered significant water damage.

Of 19 secondary schools, 18 were severely damaged. There are 56 primary schools on the island and 55 suffered significant damage. Most of the 74 pre-school and 23 daycare centres, as well as the national college, were also severely affected.

Utilities services such as water, power and telecommunications were severely disrupted.

Table 7.5 Housing damage assessment

Parish	Total households	ND	Level 1	Level 2	Level 3	Level 4	Level 5
Carriacou and Petite Martinique	1926	1156	482	193	96	0	0
St Patrick	3210	963	963	642	482	161	0
St Mark	1210	363	363	303	121	61	0
St John	2739	548	685	959	411	137	0
St Andrew	7140	357	1071	1428	2142	1428	714
St David	3530	0	177	353	706	1765	530
St George	11 367	0	568	1137	2273	5684	1705
Total households	31 122	3386	4308	5013	6231	9234	2949

Source: Grenada 2004, Flash Appeal, UN Consolidated Appeals Project (CAP)

ND = no damage
Level 1 = windows, doors, furnishings destroyed
Level 2 = partial roof covering damaged
Level 3 = roof structure damaged
Level 4 = complete roof destroyed
Level 5 = significant damage to structural frame

However, within three weeks, some 90 percent of the water supply system had been restored.

Two and a half weeks after the disaster, food shortages and distribution continued to be a major challenge, with many people lacking food and water as well as medical care.

Agriculture suffered too. Of particular concern was the destruction of cash crops and nutmeg (nutmeg accounts for 80 percent of Grenada's agricultural exports). It takes at least seven years for nutmeg trees, when replanted, to grow and bear fruit. Consequently, Grenada faced a long-term decline in its foreign exchange earning capacity. Crop damage was almost 100 percent for bananas and sugarcane. The infrastructure for the production and export of nutmeg and other spices was seriously affected. Nutmeg plantations in the St Andrew Parish were devastated, but farms located predominately in the northern sector of the island escaped with minimal losses. Vegetable gardens, which traditionally constitute an additional source of food for the population, were badly damaged. The fishing sector was also badly affected, with a considerable number of boats, equipment and icemakers lost or damaged.

Tourism and agriculture are the 'twin pillars' of the Grenadian economy, but over 60 percent of employment in the tourism industry was lost. Damage to structures and grounds was extensive with roofs destroyed and hard landscaping uprooted. While beaches and shore areas remained intact, 70 percent of the supporting infrastructure was damaged. This was also a major environmental disaster, with many forested areas destroyed, which in turn had a serious effect on watershed management.

According to industry experts, infrastructure recovery was expected to take over a year. In fact, approximately 30 percent of the hotel infrastructure was operational by January 2005, and another 30 percent by June 2005, and by January 2006, 90 percent of the hotel infrastructure had been re-established.

Communications were severely affected. Limited cell-phone coverage was available but most of the land-based telephone service was cut. Even where phone lines were operational, off-island calls could not be made. Restoration depended on the re-establishment of the wired grid, which is attached to the same utility poles as those used for electrical services.

Roads on the island survived with remarkably little damage. The lack of intense rainfall associated with the storm limited flood damage and consequent erosion, preserving the existing structures. Bridges were intact and passable, and there were few landslides. The main problem was obstruction of roads due to fallen trees and debris.

Northers and cold fronts

Northers are occasional winds that blow from the cold interior plains of North America in winter. Between December and March they can blow out from a centre of high pressure in continental North America (*Figure 7.29*). Hence, they are called 'northers'. They are fast-moving and are associated with a sudden drop in temperature. The boundary between the cold air from North America and the warm air of the Caribbean is known as a **cold front**. At a cold front, warm air is lifted up by dense cold air. As the cold air travels south it pushes the warm air it meets upward, leading to uplift, cooling, condensation and cloud formation. Further uplift causes heavy rain to fall. Northers cause cold, wet conditions in the northern part of the Caribbean (*Figure 7.29*). They may persist for many days and can damage crops on north-facing slopes.

Some northers have reached as far south as Trinidad but generally those that do push south pick up heat as they travel over the Caribbean Sea. Therefore by the time they reach the southern Caribbean they are not as cold – but they can still be quite wet.

As *Figure 7.30* shows, ahead of the cold front there is warm air. In the example shown, temperatures range between 26 °C and 28 °C. Wind speeds are lower away from the cold front and the wind direction is from the south-east. At the cold front, warm air is forced to rise over the colder, denser air. The rising air may form cumulonimbus clouds, and there is heavy rain and the possibility of thunder. Behind the cold front, the temperature drops dramatically and the intense rain finishes. The cold winds are known as 'northers'. Notice that the air coming from the USA is just 11 °C, although it will be warmed as it passes over the ocean.

Key fact

The Great Norther that affected Oklahoma city on 11 November 1911 saw daytime temperatures of 28 °C (a record high for the time of year) fall within hours to −8 °C (a record low for the time of year). These records still stand.

Activities

1 What is a hurricane?

2 Where do hurricanes occur?

3 What causes hurricanes to form?

4 To what extent can hurricanes be predicted?

5 At what time of the year do hurricanes occur?

6 Study *Figure 7.24*. Suggest why it is difficult to predict where a hurricane will strike.

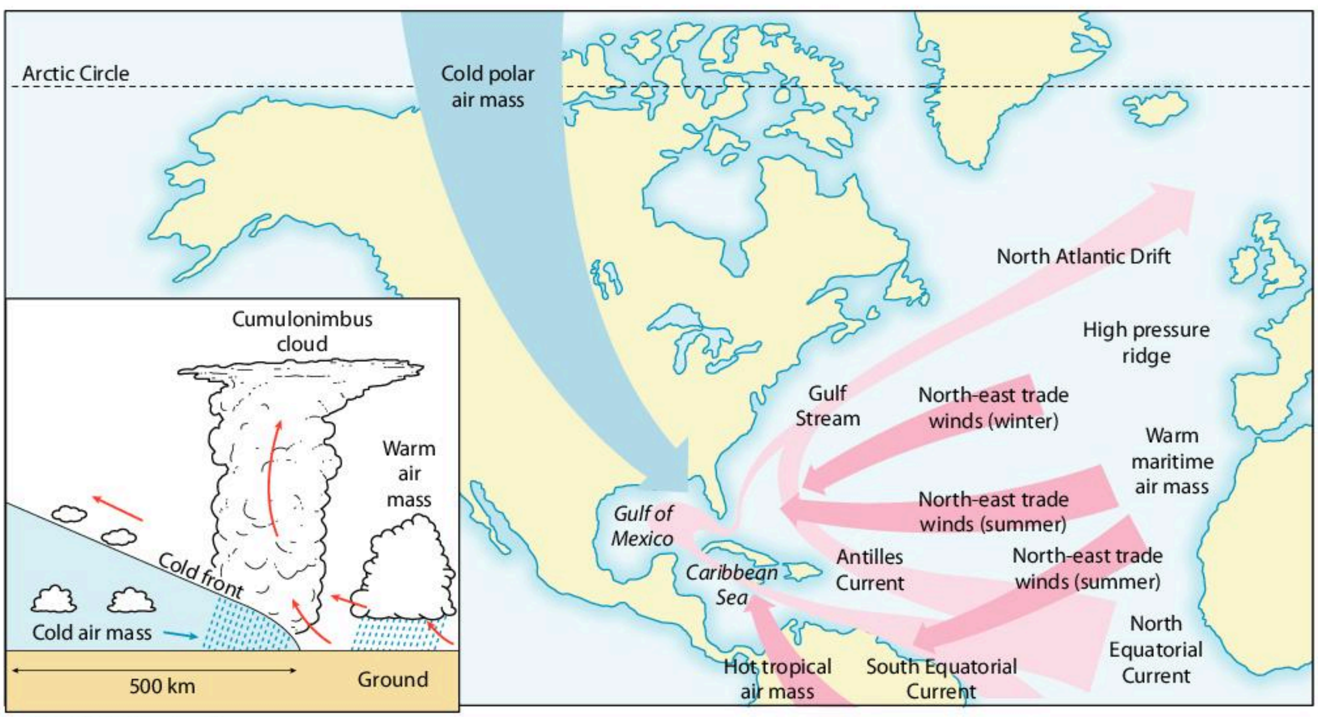


Figure 7.29 Origin of northers

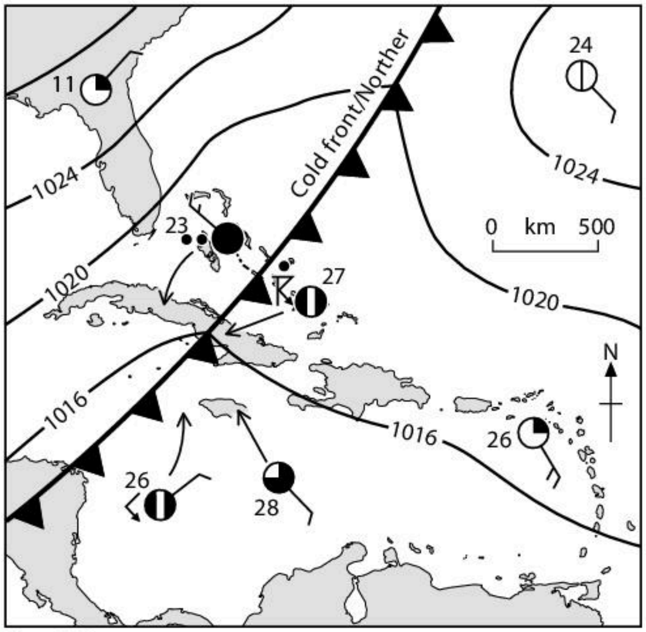


Figure 7.30 Synoptic map showing northers (a cold front)

Intertropical convergence zone (ITCZ)

The intertropical convergence zone is a broad belt of unsettled weather that is caused by the convergence of winds of the two Hadley Cells. At ground level, moist air converges and is forced to rise. This results in cooling of air, condensation, and the formation of towering cumulonimbus clouds associated with thunderstorms. The ITCZ brings heavy rain to countries in the southern Caribbean, and is responsible for the unsettled wet weather that occurs between June and November. In the summer, in the northern hemisphere, as the overhead sun moves north toward the Tropic of Cancer, the ITCZ affects much of the southern Caribbean. In contrast, during winter in the northern hemisphere, the ITCZ moves south to lie much closer to the Equator. The weather over much of the Caribbean is affected by the large subtropical high pressure belt anticyclone and consequently the weather is more settled with drier conditions.

Anticyclones are large areas of relatively high pressure. They bring settled weather conditions with relatively calm winds, clear skies, high temperatures and low rainfall. The main cause of anticyclones in the Caribbean is related to the general circulation model (*Figure 7.7* on page 130). As a result of global circulation, air descends at about 25–30 °N, the northern edge of the Hadley Cell. Sinking air causes high pressure. This gives rise to the dry conditions that are experienced in many parts of the Caribbean, especially in winter and spring.

Global warming

The world is getting warmer. Many countries are beginning to see changes in their weather that are quite unexpected and which could threaten both the economy and the lives of their people. Rising temperatures have been described as the greatest environmental threat the world will face in the 21st century.

However, while nearly everyone accepts that **global warming** is now taking place, there are many different theories for why it is happening, whether the rising temperature is natural or caused by humans and what, if anything, can be done to stop it.

In the 20th century, average global temperatures rose by 0.6 °C. Most of this increase has taken place in the last 40 years (*Figure 7.31*).

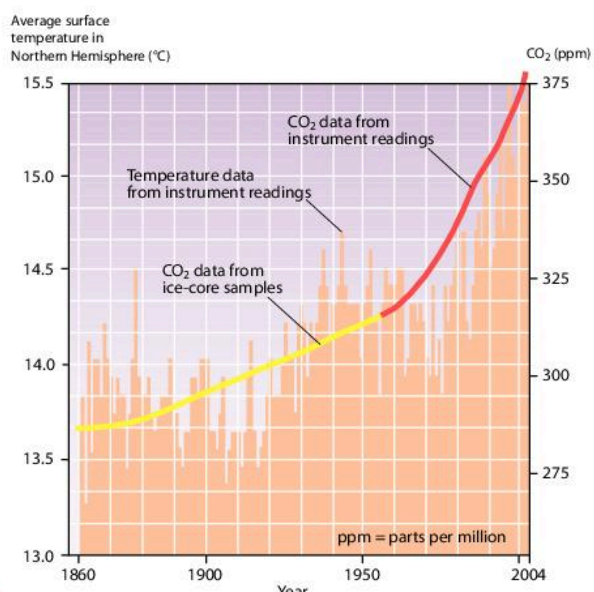


Figure 7.31 Increased carbon dioxide emissions and global warming

Source: P. Jones, Climatic Research Unit, University of East Anglia, UK; C. D. Keeling, Scripps Institution of Oceanography, San Diego, USA

- **Carbon dioxide** is the most damaging greenhouse gas. It is produced by road vehicles and by burning fossil fuels in power stations, factories and homes. Deforestation and the burning of rainforests also releases carbon dioxide into the atmosphere.
- **CFCs (chlorofluorocarbons)** come from aerosols, air conditioning, foam packaging and refrigerators.
- **Nitrous oxide** comes from car exhausts, power stations and fertilizers.
- **Methane** is released from plants and animals when they die and from farms (especially rice paddy fields), peat bogs, swamps, landfill sites and animal dung. Domestic animals, such as cows, also give off a lot of methane as they eat.

Figure 7.32 The main non-natural greenhouse gases

Many scientists predict that the Earth's climate is going to get even warmer and that by 2100 the average global temperature could be between 1.6 °C and 4.2 °C higher than it is today. Extreme predictions put the temperature rise at 6 °C, which would have very severe consequences worldwide.

The greenhouse effect

Global warming is a result of the greenhouse effect. The Earth is surrounded by a layer of gases, including oxygen and carbon dioxide. During the day the Earth is warmed by heat from the sun's rays (**incoming solar radiation** or insolation) but this heat is lost back out into space by **radiation** at night. Insolation is in the form of short-wave radiation whereas re-radiation is in the form of long-wave radiation. Greenhouse gases keep the Earth warm by stopping some of this radiation leaking out of the atmosphere. They allow short-wave radiation to pass through the atmosphere but trap a proportion of the outgoing long-wave radiation. Some of these gases are natural, for example from volcanic eruptions, but many are due to human and animal activity (*Figure 7.32*). They reflect the heat back in the same way as a greenhouse – letting heat in but preventing it from escaping (*Figure 7.33*).

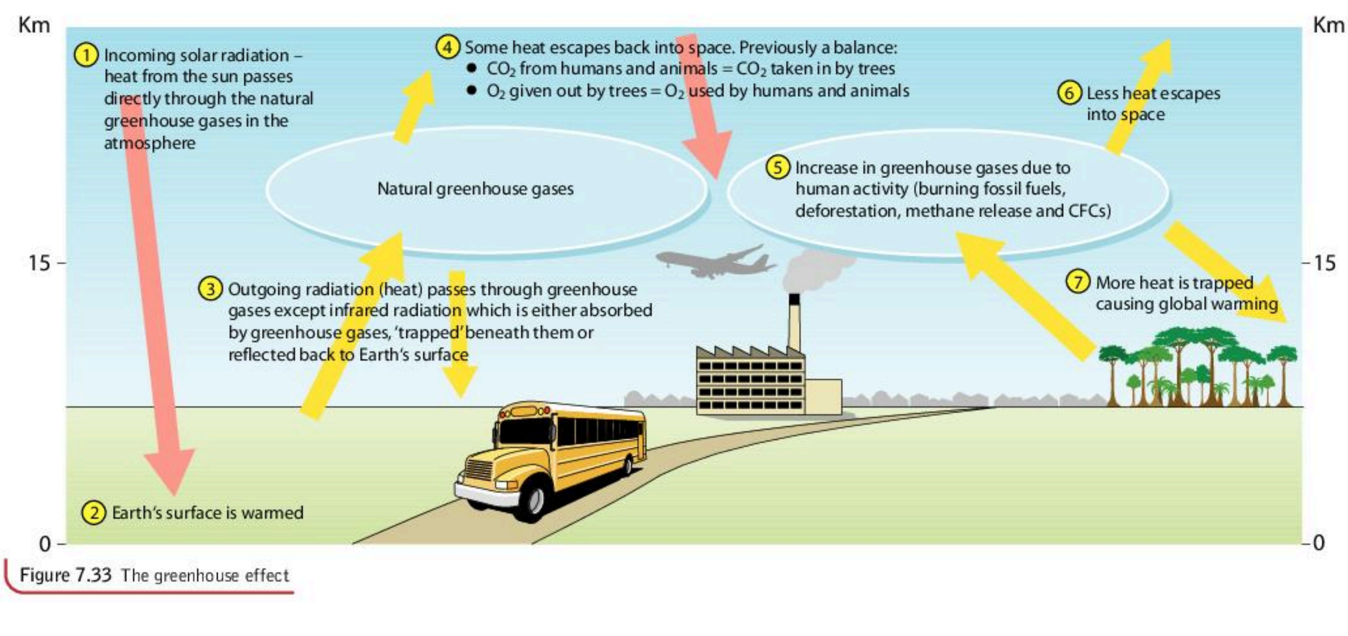


Figure 7.33 The greenhouse effect

Without greenhouse gases, the Earth's average temperature would be around 33 °C lower than it is today and very few areas would be able to support human life. Many scientists, and an increasing number of economists and politicians, believe that human activities have increased the amount of greenhouse gases (*Figure 7.33*) so that more heat is prevented from leaving the atmosphere. This could be the cause of the rise in global temperatures.

Causes of global warming

As can be seen from *Figure 7.31*, the increase in carbon dioxide over the last 150 years or so has come at the same time as the increase in global temperatures. This is why many scientists think global warming is due to human activities and especially the worldwide increase in industry.

Most sources of greenhouse gases are in developed countries (*Figure 7.34*) because these are the countries where most of the world's manufacturing industries are found. However, over the last couple of decades, countries including India, Brazil and China – all with large and increasing populations – have developed their own industries and are now producing a lot more pollutants. In China, for instance, it is estimated that one new coal-burning power station is being built every week to provide energy for the country's rapidly expanding industry. Meanwhile, the Caribbean countries together produce less than 0.1 percent of global greenhouse gases.

Although rich countries, such as the USA, produce more carbon dioxide per person than poor countries, it is in the poorer areas where most of the serious damage from climate change is likely to take place because they do not have the money to fund solutions to the problems that are caused.

The effects of global warming worldwide

While scientists now generally agree there will be changes to world climates and that, as the world gets hotter, the polar icecaps may begin to melt, there is still a lot of disagreement as to the exact changes that will take place.

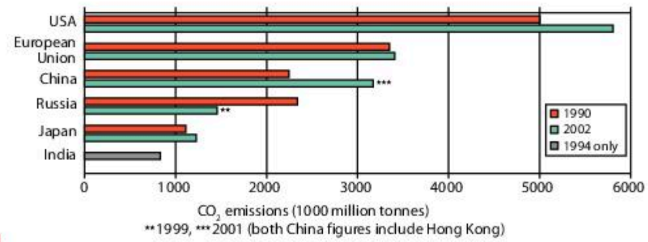


Figure 7.34 The world's biggest producers of greenhouse gases

Sources: UNFCCC/China; IEA

Already, information from satellites shows that icecaps and glaciers are melting at a rate never seen before. In 2012, the extent of Arctic sea ice was 44 percent less than the 1981–2010 average. The mean thickness of Arctic sea ice declined from 3.64 metres in 1980 to 1.89 metres in 2008, a decline of nearly 50 percent.

Predictions about global warming from scientists and computer models include:

- rising sea temperatures, meaning the water in the oceans will expand – scientists think this will cause an average sea level rise of 0·4 metres in this century
- melting icecaps and glaciers, causing a further sea level rise of five metres, which would mean severe problems for the 40 percent of the world's population living within 100 km of the coast
- changing rainfall patterns – those countries that get plenty of rainfall are likely to get more while those with not enough rainfall (including desert countries in Africa) are likely to get less
- wildlife not having a chance to adapt to rapidly changing temperatures, so many species will be wiped out
- falling crop yields in countries that already have problems feeding their people
- more people around the world at risk from diseases such as malaria, dengue fever and cholera.

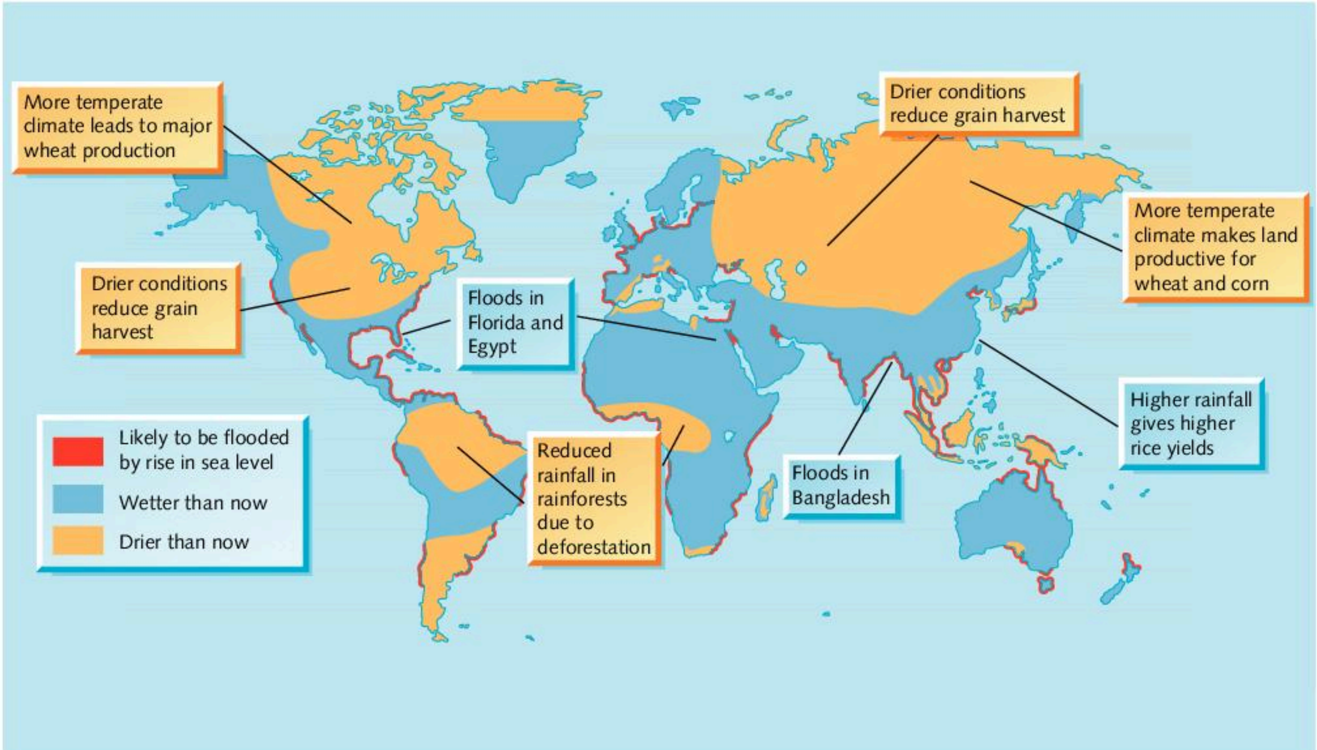


Figure 7.35 Predicted effects of global warming on the world

How some of these computer-predicted changes will affect the world is shown in *Figure 7.35*.

The effects of global warming on the Caribbean

Since August 2005, the Caribbean Community Climate Change Centre has been putting forward the region's views on global warming and trying to put pressure on international organisations such as the United Nations to act to stop it happening. This is because any rise in sea level or increase in sea temperature could have disastrous consequences for Caribbean economies:

- Rising sea levels will flood low-lying islands and countries, ruin beaches and threaten hotels and the tourist industry.
- The warming of the Caribbean Sea is causing 'bleaching' of coral reefs which are important for tourism and fishing. In the last decade, more than 300 km of Belize's barrier reef has been bleached and could die. Corals have a symbiotic relationship with algae (zooanthellae). The algae are the coral's main food source and give it its colour. When sea temperatures rise, the algae leave the coral. The coral looses it main food supply and turns white (bleaching).
- As oceans get warmer, tropical storms could become more violent and hurricanes could produce more powerful winds. Costly damage to buildings and roads could become worse in the more frequent storms.

The consequences of climate change in the USA

According to the Environmental Protection Agency (EPA) climate change in the USA is likely to have the following impacts:

Agriculture and fisheries

- Moderate warming and more carbon dioxide in the atmosphere may help plants to grow faster. However, more severe warming, floods, and drought may reduce yields.

- Livestock may be at risk, both directly from heat stress and indirectly from reduced quality of their food supply.
- Fisheries will be affected by changes in water temperature that shift species ranges, make waters more hospitable to invasive species, and change lifecycle timing.

Ecosystems

- Mountain and arctic ecosystems and species are particularly sensitive to climate change as they do not have areas where they can seek refuge.
- Projected warming could greatly increase the rate of species extinctions, especially in sensitive regions.

Forests

- Climate change is likely to alter the frequency and intensity of forest disturbances, including wildfires, storms, insect outbreaks, and the occurrence of invasive species.
- The productivity of forests could be affected by changes in temperature, precipitation and the amount of carbon dioxide in the air.

Transport

- Climate change is likely to damage transportation infrastructure through higher temperatures, more severe storms, and higher storm surges.
- Coastal roads, railways and airports are vulnerable to sea level rise, which could lead to delays as well as temporary and permanent closures.

Coasts

- Climate change could put additional stress on coastal areas, which are already stressed by human activity, pollution, invasive species, and storms.
- Coastal development reduces the ability of natural systems to respond to climate changes.
- Sea level rise could erode and inundate coastal ecosystems and eliminate wetlands.

Energy

- Climate change is likely to both increase electricity demand for cooling in the summer and decrease electricity, natural gas, heating oil, and wood demand for heating in the winter. New infrastructure investments may be necessary to meet increased energy demand, especially peak demand during heatwaves.
- Climate change could affect the amount of water available to produce electricity or extract fuel. In areas where water is already scarce, competition for water between energy production and other uses could increase.

Human health

- Climate change is likely to increase the frequency and strength of extreme events (such as floods, droughts, and storms) that threaten human safety and health.
- Climate changes may allow some diseases to spread more easily.
- Climate change will affect certain groups more than others, particularly groups located in vulnerable areas and the poor, young, old, or sick.

Activities

1 On a map of your country showing height above sea level (contours), trace the 50 metre contours. Would the land area above 50 metres be enough for the population to survive?

2 If your country became impossible to live in due to climate change, where would people move to? What problems would this cause?

Water resources

- Warming temperatures, changes in precipitation, and sea level rise have affected (and is likely to continue to affect) water supply and quality.
- Changes will vary in different regions of the United States; potential effects include increased flooding and drought, water quality impairment, and salt water intrusion to coastal water supplies.

Table 7.6 The potential impacts of climate change in the Caribbean

Variable	Possible scenario	Possible impacts
Temperature	Increase of between 0.8 °C and 2.5 °C by 2050, and between 0.9 °C and 4 °C by 2080	• Rising sea temperatures leading to coral bleaching • Loss of ecosystems
Rainfall	Variations of between −36% and +34% by 2050 and of between −49% and +29% by 2080	• Reduced reliability of water reserves • Increased risk of drought • Declining crop yields
Sea level	Could rise by 35 cm by 2050	• Loss of agricultural land • Displacement of people • Flooding of urban areas and resorts • Transport networks disrupted
Extreme weather events	Frequency and intensity of hurricanes could increase by 5–10% by 2080	• Damage to infrastructure • Huge economic impacts • Loss of life

Source: Philip's School Atlas, 2015, 7th Edition, Certificate Atlas for the Caribbean

Case Study

Climate change in Barbados

Estimates of how high sea levels may rise are very varied. It is possible there will be a rise of one metre by the end the century. However, some extreme estimates predict that if the world's ice melts, including the Himalayan glaciers and the Antarctic icecap, then sea levels will rise by 50 metres or more. The effect of this extreme scenario on Barbados is shown in *Figure 7.36.*

Sea level rise is just one aspect of climate change that could have catastrophic effects for the 280000 people who live and work on the island.

- As well as sea levels rising, sea temperature is increasing and this could increase the number and power of tropical storms and hurricanes. In May 2005 the Barbados Nation News reported that a storm called Adrian had already passed over the Caribbean and Central America, signalling a very early start to the storm season. Over the past few decades the length, maximum wind speeds and destruction of each tropical storm has increased by an estimated 70 percent.
- Computer projections from the Belize National Meteorology Service show that air

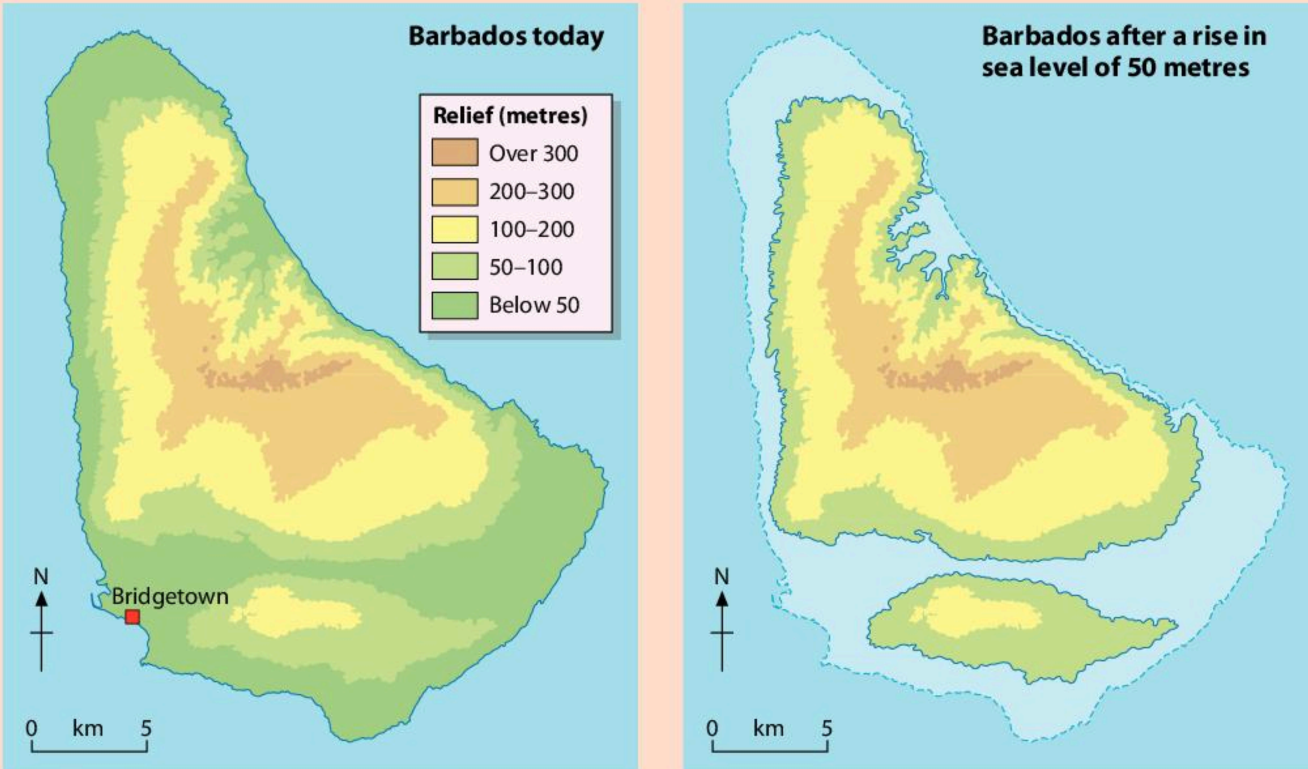


Figure 7.36 Barbados today, and after a rise in sea level of 50 metres

temperatures across the Caribbean will rise by 1 °C every ten years, meaning more hot days, hot nights and rainless heatwaves in Barbados. Water supplies will decrease, less water will be available for agriculture and this will have an effect on both the economy and poor farmers. Increased temperature will also change the types, and amounts, of crops that can be grown.

- Rising sea levels will cause flooding of property and farmland in the low-lying areas and there will be erosion of the coastal sandy beaches – one of Barbados' main tourist attractions. The Tyndall Centre for Climate Research claims that if the beach area of the country declined significantly, money from tourists could drop by 62 percent.
- Higher sea temperatures and more hurricanes would damage the coral reefs around the island and cause bleaching of the coral. While diving and snorkelling are not a major resource for tourism in Barbados, the Tyndall Centre again estimates that destruction of the coral would mean a 9 percent decrease in tourist income.

While Barbados will obviously suffer from the effects of climate change, the country's emissions of greenhouse gases are insignificant on a world scale, so there is very little Barbadians can do by themselves to stop global warming. Organisations such as the United Nations Environment Programme, the Barbados government, CARICOM and the Small Island Developing States are making attempts to pressurise the governments of more polluting countries to try and control their own emissions.

Combating climate change

Environmental, or **green**, issues are becoming increasingly important, especially in developed countries. As people become aware of the damage being done to the environment through industry and motor vehicles, politicians and governments are taking more and more steps to try to stop climate change.

Measures to reduce the impacts of climate change

There are a number of ways in which households could try to reduce their emissions of greenhouse gases.

- When choosing new appliances, use the EPA's Energy Star label. This identifies the most energy-efficient products, including appliances, lighting, heating and cooling equipment, electronics, and office equipment.
- Heating and cooling accounts for almost half of US households' energy bill. Simple steps such as changing air filters regularly, using a programmable thermostat, and having efficient heating and cooling equipment can save energy and increase comfort.
- The three Rs – Reduce, Reuse, Recycle – help conserve energy and reduce pollution and greenhouse gas emissions from resource extraction, manufacturing, and disposal.
- Composting food and garden waste reduces the amount of rubbish that is sent to landfills and reduces greenhouse gas emissions.
- Switching to public transportation, car-sharing (car-pooling), cycling, or telecommuting, can save energy and reduce greenhouse gas emissions. Using a fuel-efficient vehicle such as those powered by E85 and biodiesel is energy efficient. Both are renewable fuels (made from renewable sources such as corn) that can reduce greenhouse gas emissions from vehicles. E85 is a fuel blend containing 85 percent ethanol and 15 percent gasoline that can be used in certain vehicles called Flex Fuel Vehicles (FFVs).

At a government level, US President Obama introduced the Clean Power Plan, which set out plans to reduce, by 2030, carbon dioxide levels by 32 percent from 2005 levels. The government believes that this will save money and save lives. The USA has increased its production of solar energy and wind energy, and 2012 had the lowest emissions of greenhouse gases from the USA for nearly 20 years. Power plants are the main source of greenhouse gas emissions in the USA, and the Clean Power Plan has introduced carbon pollution standards for existing power plants.

Hydrofluorocarbons (HFCs) are among the fastest-growing greenhouse gases, and the USA has set a goal of decreasing HFC emissions, by the equivalent of 700 million tonnes of carbon emissions by 2025.

However, the advances made in reducing greenhouse gas emissions must be set in context. The USA's expansion of natural gas production, as a result of fracking, means that its efforts to tackle climate change are compromised by the increased emissions from natural gas.

Renewable energy in the Caribbean

As countries in the Caribbean region have come to realise how they will be affected by climate change, many have started to produce their electricity from renewable energy. This is expensive but some countries are getting help from the developed world. Several projects are already up and running:

- Jamaica's first wind energy project, the Wigton wind farm: with 23 wind turbines (*Figure 7.37*) and support from the Netherlands government, the project is already meeting Jamaica's renewable energy targets.
- The promotion of solar water heaters in Barbados (*Figure 7.38*) using heat from the sun: 32 000 solar heaters have already been installed in homes, businesses

and hotels, saving around US$6.5 million in fuel that would otherwise have been imported.

- Barbados is looking at using offshore wind farms, based at sea, to generate electricity.
- St Lucia, Dominica and Grenada are all trying to become the world's first non-carbon fuel-based economies – using wind, wave and solar power instead of coal, oil and diesel to provide all their energy needs.

Despite difficulties in funding and problems in building the power plants necessary to provide renewable energy, many Caribbean countries, with the support of CARICOM and several governments of developed countries, are making big efforts to use alternative and less environmentally damaging power sources.

Figure 7.37 Wigton wind farm in Jamaica

Figure 7.38 Solar heater to provide hot water in Barbados

Activities

1 Look at the methods used to combat climate change in developed countries. Would any of them be suitable in your own country? Would people be willing or able to change their lifestyle to use these methods?

2 Do you think the governments of developed countries, where most pollution comes from, should be doing more to combat global warming? Explain your answer.

Ideas for SBA

- *What is the weather associated with the passage of a weather system in the rainy season?*
- *What factors influence the characterstics of the weather in my community?*

Glossary of terms

Carbon sink: an area, such as a forest, that soaks up carbon dioxide released from other areas.

Cold front: the boundary between a warm air mass and a cold air mass, in which the warm air is forced to rise, condenses and produces rain.

Convectional rainfall: rainfall formed during very hot conditions. The heated ground heats the air above it. As this warm air rises, it cools, condenses and produces heavy rain.

Fossil fuel: oil, coal and natural gas formed millions of years ago from decaying plants and animals.

Global warming: the increase in the average temperature of the Earth's atmosphere and oceans.

Greenhouse effect: the trapping of heat within the Earth's atmosphere.

Greenhouse gases: the gases that trap heat within the Earth's atmosphere, such as carbon dioxide, methane and water vapour.

Hurricane: a tropical storm with very strong winds producing storm surges. Hurricanes may be over 1000 km in diameter and bring winds of over 300 km/hour.

Intertropical convergence zone (ITCZ): the area in which the north-east trade winds and the south-east trade winds converge. If there is a difference in temperatures between the winds, the warmer air rises over the denser, colder air and may produce rain.

Northers: cold northerly winds that blow out from North America toward the Caribbean bringing cold, wet conditions, especially between December and March.

Recycling: processing items like cans, paper and glass so that they can be used again.

Relief rainfall: rainfall that occurs when air is forced to rise over high ground and mountains. As it rises, it cools and condenses, and rain may fall.

Renewable energy: energy produced from sources that, unlike fossil fuels, will not run out. Examples include tidal power, solar power and wind power.

Tropical wave: an area of low pressure that brings rain to the Caribbean; also known as an easterly wave.

Exam-style Practice

1 a Define the term *tropical cyclone*. [2]

b Where do tropical cyclones that affect the Caribbean region have their origin? [3]

c Briefly describe the conditions necessary for the formation of a tropical cyclone. [6]

d Describe the conditions associated with the passage of a hurricane. [6]

e Describe the impact of hurricanes in a named Caribbean country. [8]

Total 25 marks

2 a What is meant by the term *greenhouse effect*? [3]

b Describe the major causes of global warming. [4]

c Explain FOUR effects of global warming. [8]

d Describe TWO major effects of global warming in the Caribbean. [4]

e Discuss THREE measures that can be taken to reduce climate change. [6]

Total 25 marks

3 a Describe the difference between weather and climate. [3]

b Refer to Figure 1 and identify the month with:

i The lowest average temperature [1]

ii The highest rainfall [1]

iii What was the average minimum temperature recorded in October? [1]

iv Approximately how much rain fell in June? [1]

c i Name any three factors that affect the temperature of a place. [3]

ii Explain how any one of the above factors affects the temperature of a place. [6]

d Describe how the Intertropical convergence zone (ITCZ) affect rainfall in the Caribbean. [6]

e Explain how relief or orographic rainfall is produced. [3]

Total 25 marks

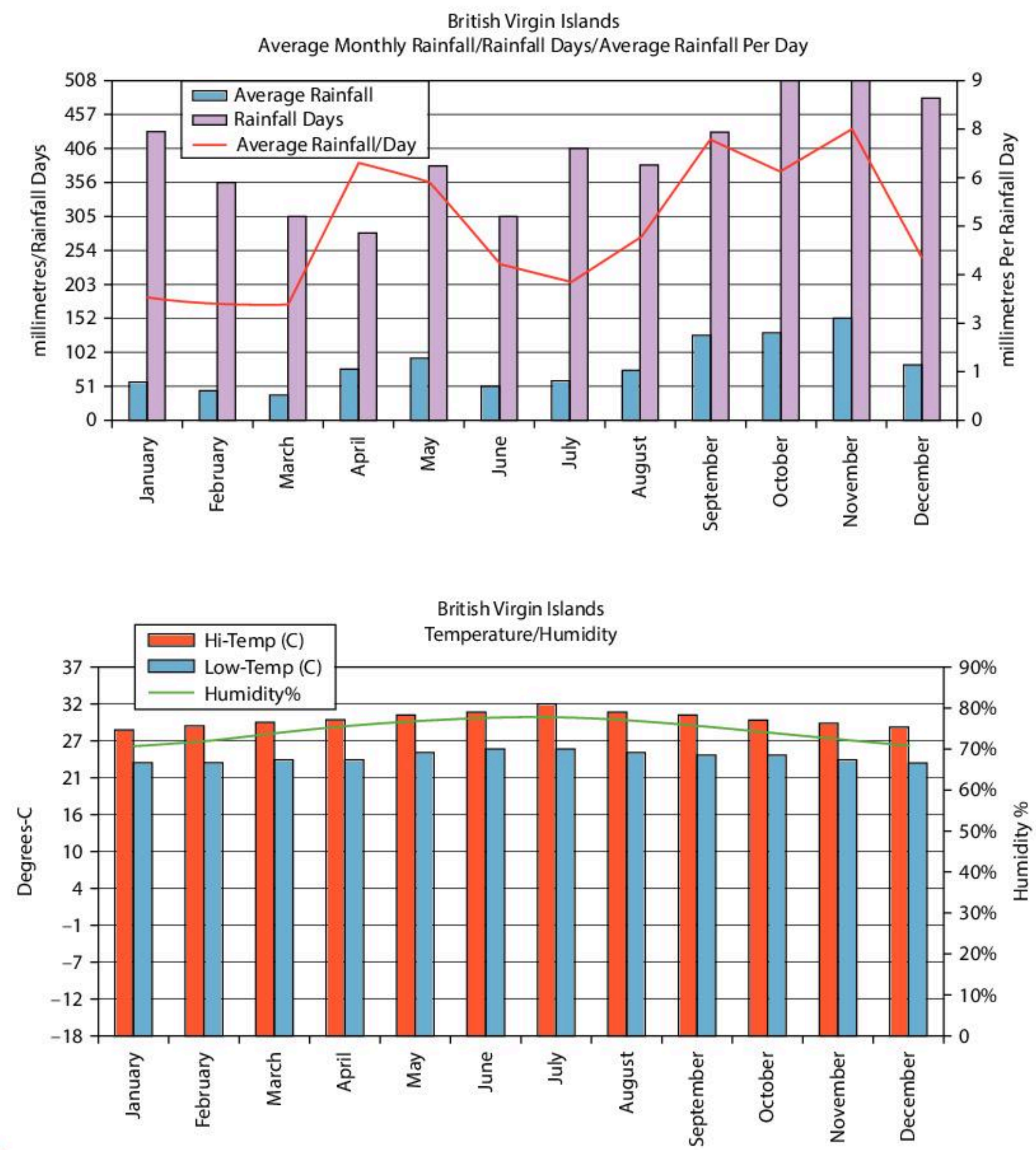


Figure 1 Rainfall and temperature for British Virgin Islands

8 Ecosystems

In this chapter you will study:

- what an ecosystem is
- how an ecosystem functions
- components of ecosystems
- soils and soil profiles
- tropical biomes.

You will also learn how to:

- interpret climographs
- draw a climograph
- interpret soil and vegetation maps.

What is an ecosystem?

An **ecosystem** is a community of plants and wildlife and the environment they occupy (*Figure 8.1*). All parts of an ecosystem are interconnected (*Figure 8.2*) and a change anywhere in the ecosystem affects other parts.

An ecosystem develops a balance, unless something happens to upset that balance. People are part of the ecosystem in which they live and are the most likely factor to upset the system. Sudden physical change like natural disasters can upset the balance, but only for a relatively short time. An example is the eruption of the volcano Krakatau, Indonesia, in 1883. The island's rainforest ecosystem was destroyed, yet had virtually recovered within a hundred years.

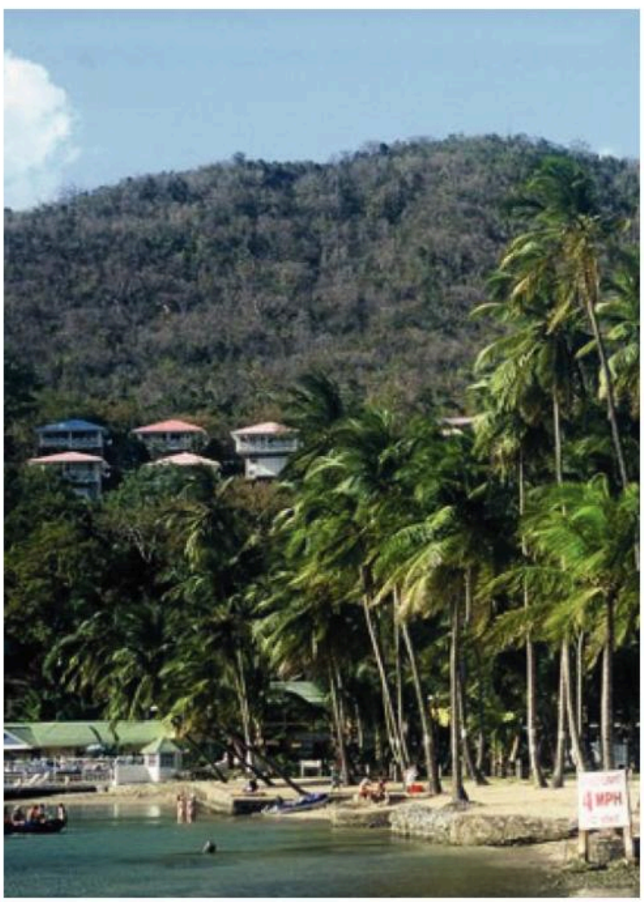


Figure 8.1 Different ecosystems operate closely together

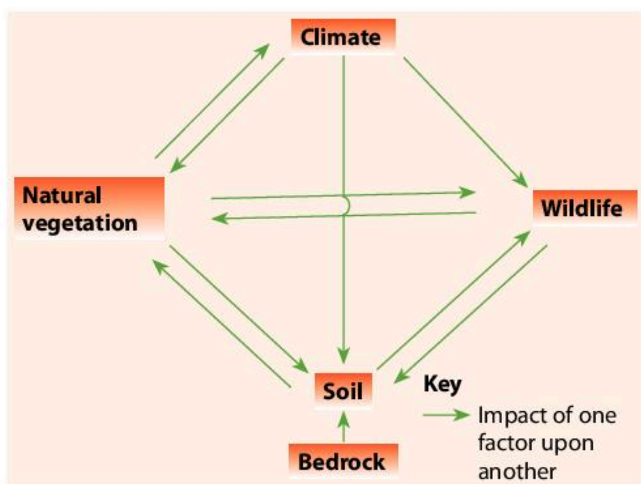


Figure 8.2 A basic ecosystem

The scale of ecosystems varies hugely. An ecosystem can be as small as a pond, an individual tree, a garden, a beach or a field, but the Earth's surface can also be divided into larger-scale ecosystems, or biomes. Each biome covers a huge area of land surface (*Figure 8.3*).

Activities

1 Write a definition of an *ecosystem*.

2 a What is the main difference between an *ecosystem* and a *biome*?

b Give examples of ecosystems and biomes.

How does an ecosystem function?

Figure 8.4 shows a **food chain**. Energy and nutrients flow through the system. Ecosystems receive their energy from the sun. Solar radiation (the sun's energy) is absorbed by chlorophyll in leaves. The process of **photosynthesis** then takes place, shown in the equation:

Light + water + CO_2 = carbonates + O_2

Carbonates are plant food and allow plants to grow and breathe. The energy stored in plants moves through the ecosystem as one species eats another (*Figure 8.4*). Each level of plants or animals/insects becomes the food source for the level above it in the system.

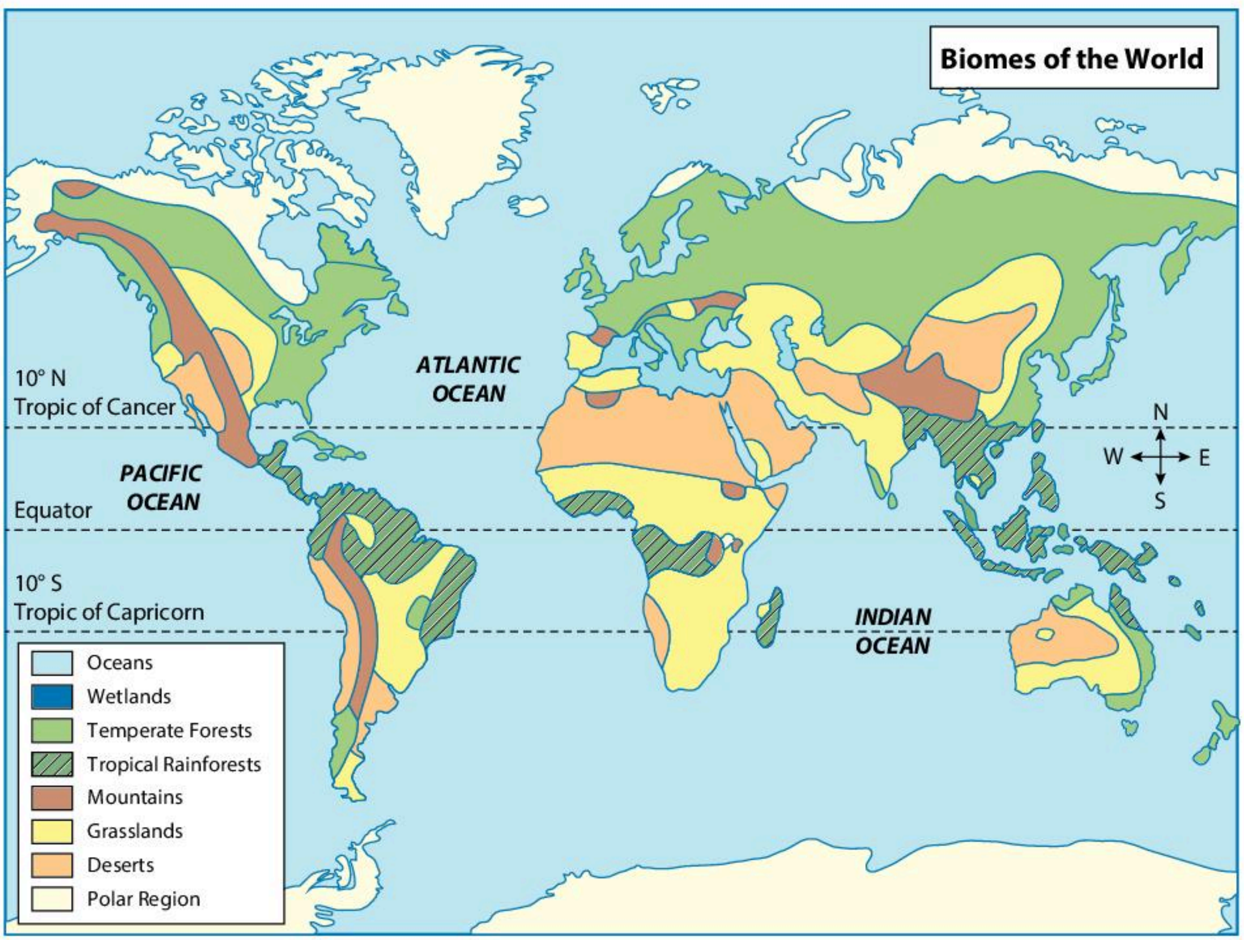


Figure 8.3 Global biomes to highlight location of the tropical rainforest biome

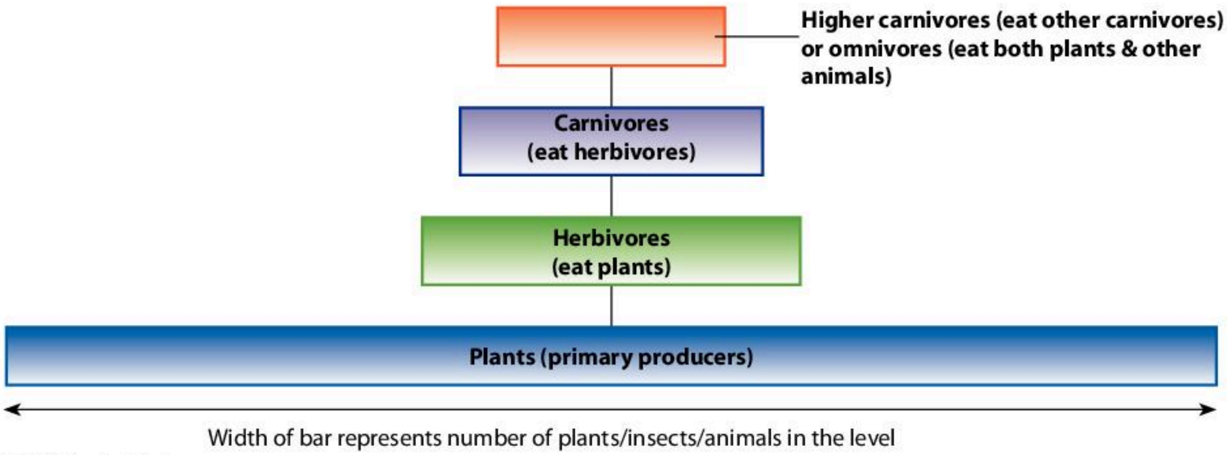


Figure 8.4 The food chain

Starting from the bottom, plants are the **primary producers**, eaten by **herbivores** (plant-eating animals and insects) also known as the **primary consumers** (*Figure 8.5*).

Meat-eaters, or **carnivores (secondary consumers)**, feed on the herbivores. **Higher carnivores** and **omnivores** (creatures which eat anything, plant or animal), are known as **tertiary consumers**.

Decomposers are a crucial part of the food chain, the bacteria and fungi which rot down dead plant and animal material. They allow the nutrients in the ecosystem to be available to the next generation of plants and then to the rest of the levels in the system.

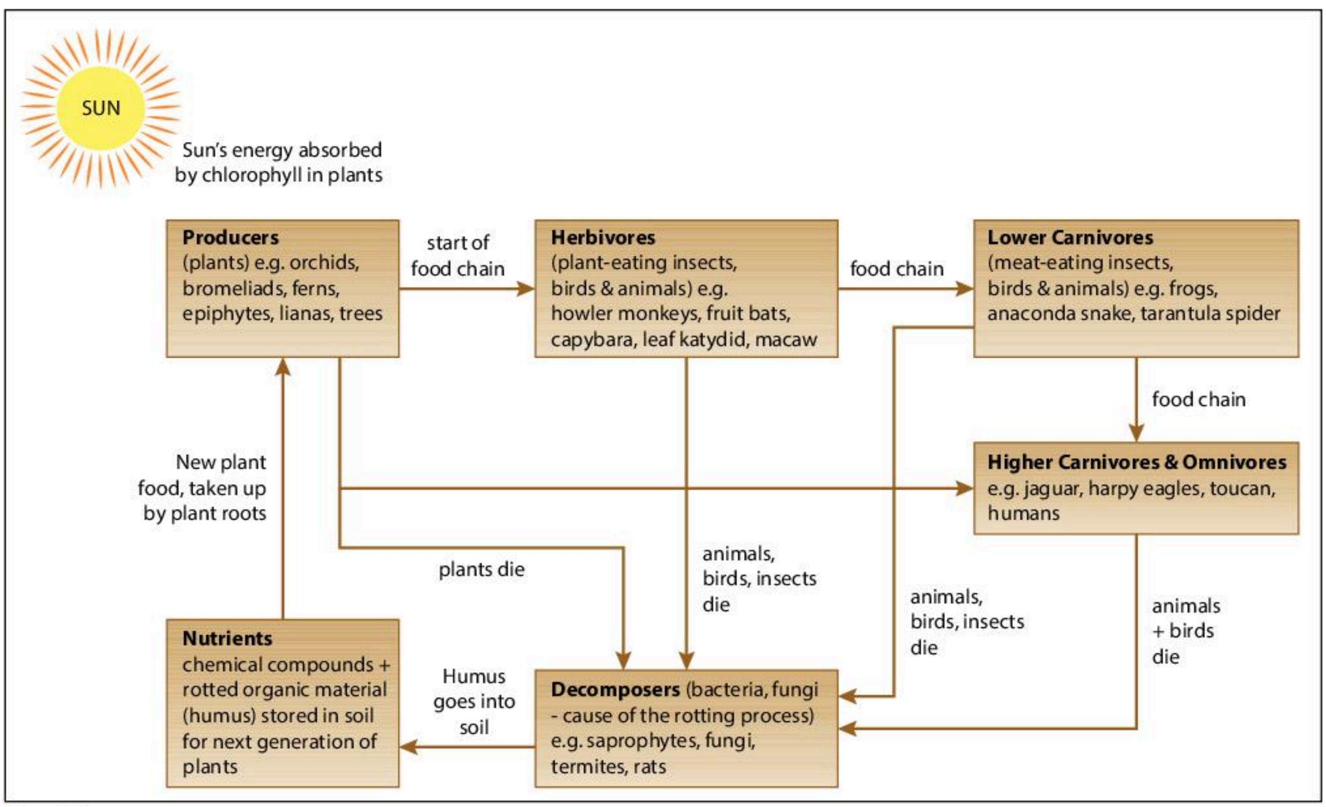


Figure 8.5 The food chain in a tropical rainforest

Activities

Go outdoors and find an ecosystem.

1 Identify at least one of the following:
  a Producers
  b Primary consumers
  c Secondary consumers
  d Tertiary consumers

2 Using the list of organisms identified above, construct a food chain of no less than 4 organisms.

3 **a** Identify one decomposer.
  b Describe the function and importance of decomposers.

4 Why are producers such an important part of an ecosystem?

Tropical rainforest biome

Tropical rainforest is a global biome stretching across equatorial latitudes (*Figure 8.3*). The densest equatorial rainforest is found between 10 degrees North and South of the Equator. Similar ecosystems thrive on either side of this zone and are generally referred to as tropical rainforest. The main regions are:

- Parts of the Caribbean – southern Cuba, much of Hispaniola, northern Puerto Rico and Trinidad (*Figure 8.6*)
- Central America
- The Amazon Basin of South America
- Coastal West Africa (although much has now been cleared for urban development)
- Central Africa – the Congo Basin
- Southeast Asia – Malaysia, Indonesia
- Australia – the northern tip of Queensland

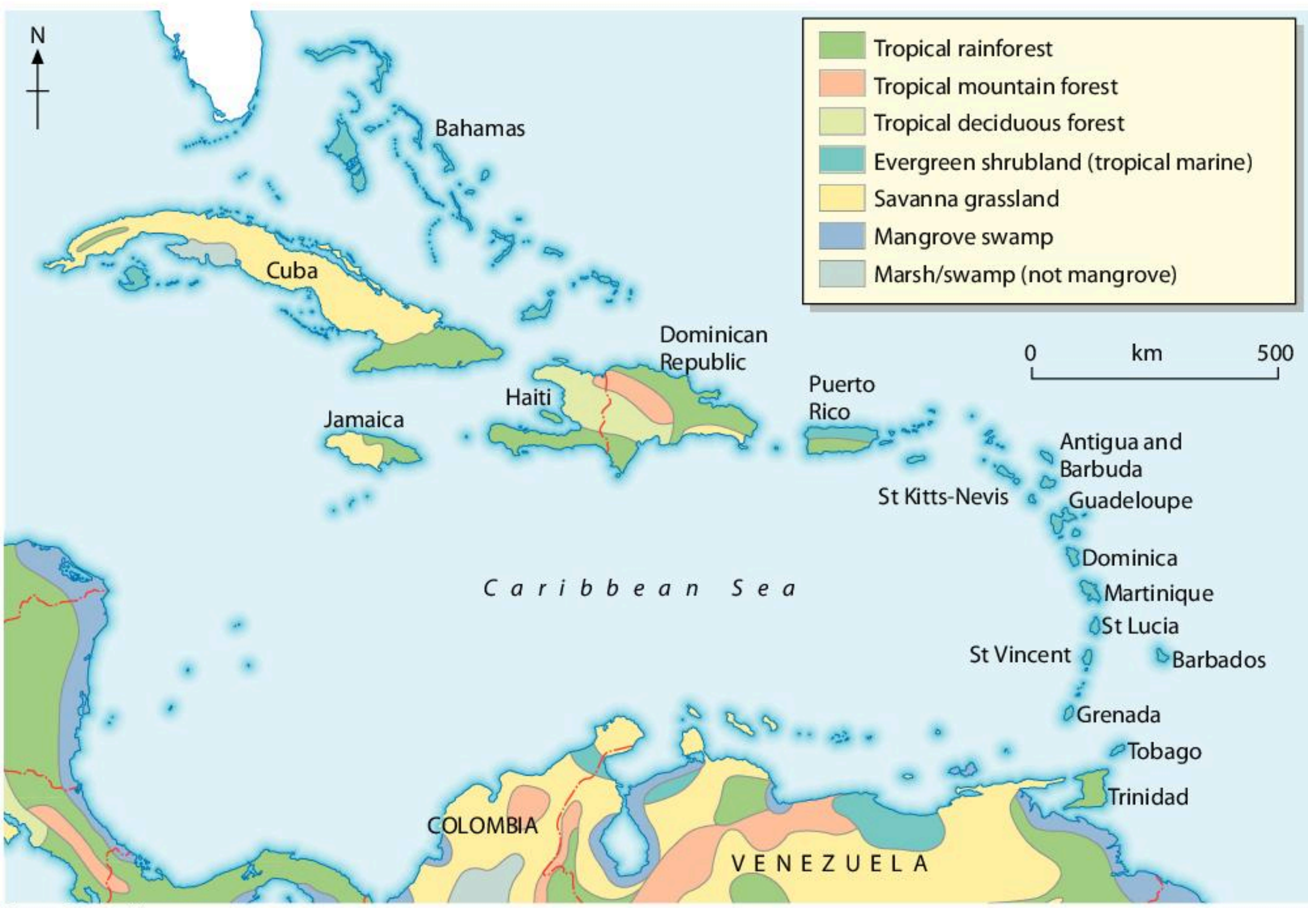


Figure 8.6 Caribbean ecosystems

Rainforest covered 15 percent of the world's land surface in 1950; today that has reduced to less than 6 percent (375 million hectares – 1 hectare = 10 000 m^2, or a square in which each side = 100 metres), mainly due to human activities, discussed later in this chapter.

Equatorial rainforest is the most productive ecosystem in the world. It supports almost 50 percent of the world's 10 million plant, insect, bird and mammal species. A single hectare can contain over 750 types of tree and 1500 species of other plants. About 80 percent of the developed world's diet originated in the rainforest, especially fruits, vegetables and spices: a few examples include avocados, coconuts, figs, bananas, citrus fruits, pineapple, yams, pepper, cayenne, chocolate, coffee, sugar, ginger, vanilla and Brazil and cashew nuts.

Twenty-five percent of modern prescription drugs use ingredients from rainforest plants, even though only one percent of these plants have ever been researched for their healing properties. There is huge potential here – the periwinkle, for example, is used to make powerful anti-cancer medication.

Rainforests are sometimes referred to as 'the lungs of the Earth' (*Figure 8.7*) because they continuously recycle atmospheric carbon dioxide into oxygen, creating 20 percent of global supply. In a world where industry and transport continuously emit large volumes of carbon dioxide, rainforest becomes increasingly invaluable in limiting climate change.

Figure 8.7 Rainforest as the 'lungs of the Earth'

Rainforest is the least understood of the world's major ecosystems because it is so very complex. This complexity also makes it the most fragile global ecosystem, the easiest to damage and the most difficult to conserve.

Activity

Study *Figure 8.7* showing 'the lungs of the Earth'. Why is the rainforest being referred to as the 'lungs of the earth'?

Rainforest climate: Constant high temperatures and regular daily heavy rainfall are typical of equatorial climate. Caribbean climate resembles that of true rainforest, but, being further from the Equator, is not identical.

Caribbean climate: The monthly temperature in Port of Spain is always around 25 °C (*Figure 8.8*). Rainfall in Trinidad from December to May (20–75 mm/month) is lower than the average, but for the rest of the year it is particularly wet (160–250 mm/month). Total annual rainfall is around 1770 mm, so Trinidad is usually described as having a tropical maritime climate. The influence of prevailing winds give less pronounced peaks in rainfall and a clearer dry season. Much of the Caribbean is classed as having a tropical maritime climate.

Equatorial rainforest climate: Guyana and Suriname are classed as having a truly equatorial climate. The sun is always high in the sky in equatorial regions, allowing more insolation (sun's energy) to reach the ground. While daily average temperatures are around 27 °C, the thermometer reads between 22° and 32° within the 24 hour period. Monthly average temperatures are consistently close to 27 °C.

True equatorial annual rainfall total is 2000 mm or more. Belem, coastal northeastern Brazil, has 2732 mm of rainfall each year and Manaus in Central Amazonia has 2104 mm. Relative humidity is high, between 80 and 100 percent, making the weather feel 'sticky'.

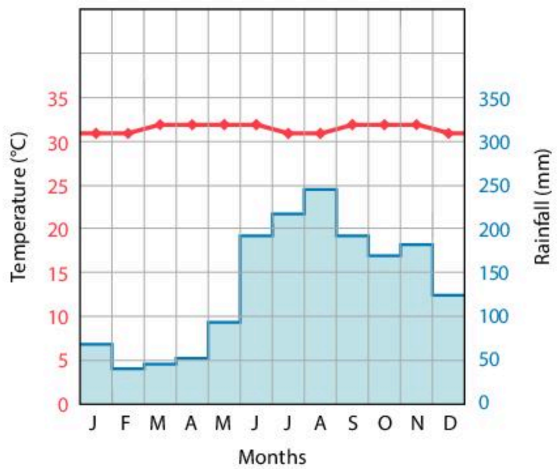


Figure 8.8 Tropical maritime climate – Port of Spain, Trinidad

Figure 8.9 shows that the **diurnal** weather pattern (weather changes throughout 24 hours) is very distinctive in equatorial regions.

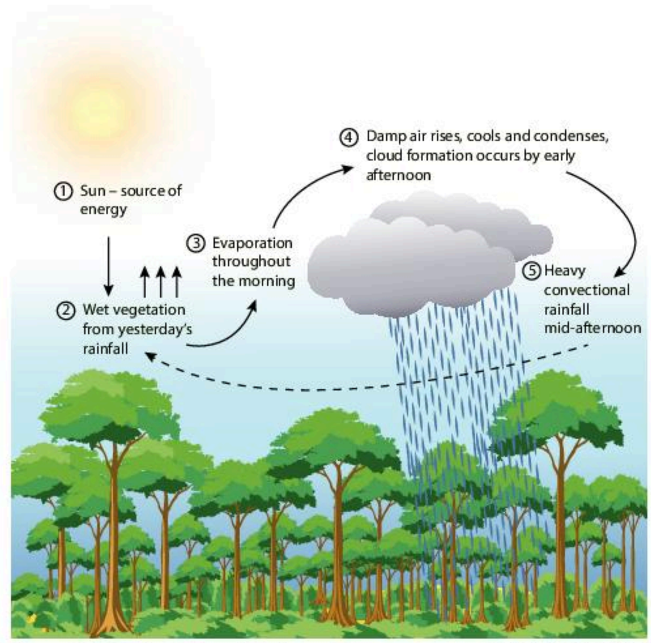


Figure 8.9 Rainforest diurnal weather pattern

Source: Alison Rae

Activities

1 Describe the pattern of temperature throughout the year in Port of Spain.

2 Why is Port of Spain's climate so consistent throughout the year?

3 Define the term *diurnal*.

4 Describe the diurnal pattern of weather in a tropical rainforest zone. *Figure 8.9* will help you. Work round it logically.

5 Identify the main differences between true rainforest climate and the climate experienced in Trinidad.

Skills

Interpreting climographs

Climographs or climate graphs (*Figures 8.10–8.12*) show details of temperature and rainfall (or, in colder regions, precipitation, which includes snow, sleet and hail). Statistics are averaged over a time period of at least 30 years, so they show a long-term pattern rather than short-term differences. This is especially important in a world affected by global warming.

Figure 8.10 shows the climate statistics for Kingston, Jamaica. Most of Kingston is of course a built-up area, but the nearby Blue Mountains and John Crow Mountains National Park are covered by tropical rainforest. Temperature is almost constant throughout the year, varying only between 30 °C and 32 °C.

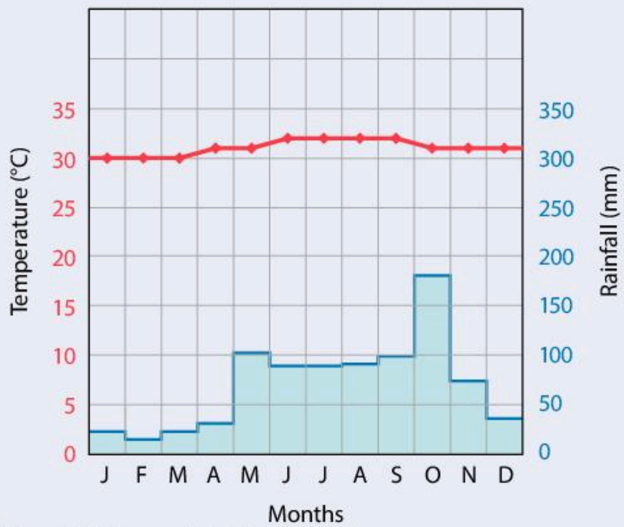


Figure 8.10 Climograph for Kingston, Jamaica

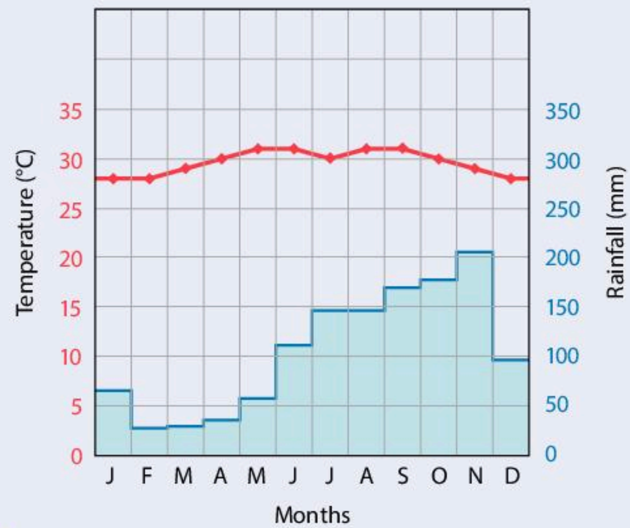


Figure 8.11 Climograph for Bridgetown, Barbados

1 Describe the climate in Bridgetown, Barbados.

2 Compare its climate with that of Kingston.

The Caribbean has some of the most stable temperatures in the world. In Port of Spain, Trinidad (*Figure 8.8*), the temperature range is only 1 °C, which is less than in Kingston.

Climographs can be drawn in different ways. Those shown here have the temperature on the left axis and rainfall on the right axis.

How to draw a climograph

Rainfall is always shown using bars, one for each month. The scale is in millimetres. Blue is used to shade the bars because it suggests water. Tall bars give a clear impression of heavy rainfall and short ones suggest dry conditions or drought.

Temperature is marked as a series of red dots, each placed in the centre of the bar for that month. Red suggests warmth but is used even for low temperatures. The dots are joined with a red line which should link to the axes at either end.

1 State how temperature is shown on the climographs on pages 164–165. Consider the way the points are plotted and how the colour is used.

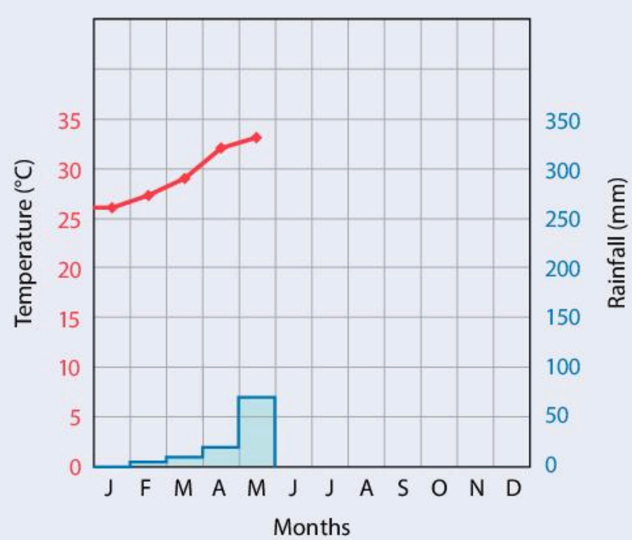


Figure 8.12 Climate figures and graph for Kano in northern Nigeria, a savanna area

2 Why is this method appropriate? (Hints: What does the colour suggest? Think about how we show continuous data.)

3 State how rainfall is shown on these graphs. Consider the colour used. Why are bars used? (Hint: Why are bars used instead of joined dots?)

4 Write two or more paragraphs to compare the climographs for Kingston in Jamaica, and Bridgetown in Barbados. Think about:
   a the patterns of temperature
   b the patterns of rainfall
   c whether there is any seasonal change.

5 a Copy and complete *Figure 8.12*, adding the values not yet marked from the table below.
   b Describe the differences between Caribbean climates and that of Kano, Nigeria.

	J	J	A	S	O	N	D
Temp.°C	32	30	28	28	31	29	26
Rainfall mm	125	220	270	145	25	0	0

Rainforest vegetation

An ecosystem is a whole community including plants, animals, insects, birds, bacteria, climate, soils, rock type and relief. Plants and wildlife species rely on each other to thrive within the community. For example, the millions of rainforest insects pollinate flowering plants and in return feed on the nectar – both are satisfied. This relationship, where each helps the other, is called symbiosis. The species in any ecosystem change and develop over time. They react to their circumstances and environment and adapt to them.

Activities

To begin studying rainforest vegetation in detail, search the internet for film clips which illustrate the rainforest ecosystem environment.

The most obvious characteristic of rainforest vegetation is its layering. Very tall trees are common in rainforest – it is well known for this. Underneath these are several other vegetation types, typically not seen in aerial photographs as the canopy (see definition, right) hides them. The five clear layers of vegetation (or stratification) are shown in *Figures 8.13* and *8.14*.

From sky to forest floor the layers are:

- **Emergents** – the very tallest trees with mushroom-shaped crowns which are around 50 metres in height and grow above all other vegetation, enjoying maximum available sunlight. This layer is the habitat for numerous birds and insects. Beneath the emergents all other plants are competing for sunlight.
- **Canopy** – the main mass of tall trees, about 30–40 metres tall. They form a closed 'top' to the forest; in other words, if you were flying over it you would see continuous treetops and no ground at all. The canopy intercepts (catches) 70 percent of sunlight and 80 percent of the rainfall available, which protects soil from rain erosion.

  The branches, which grow high up the trunk, are often home to other plants like epiphytes and lianas. Ninety percent of wildlife lives in this layer and rarely leaves the relative safety of the trees. This includes most birds, mammals like sloths and many species of monkey.
- **Lower tree layer or understorey** – this is made up of younger trees which will eventually become part of the canopy, plus

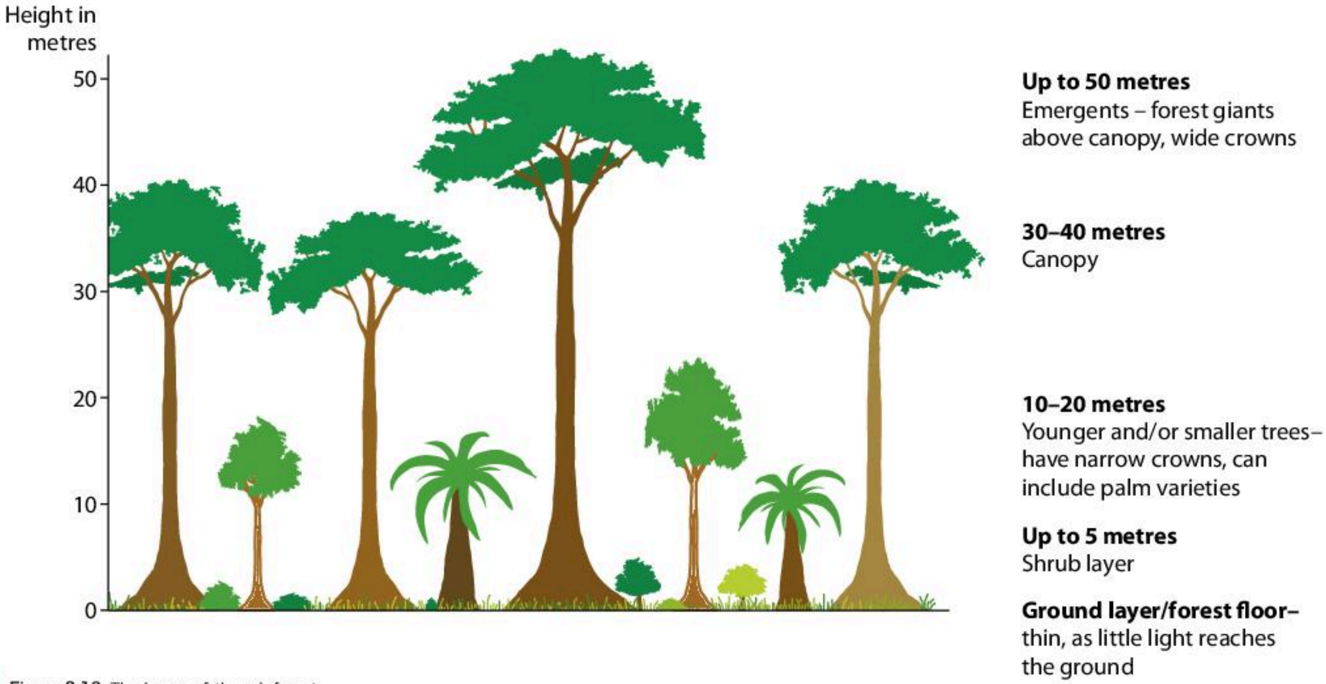


Figure 8.13 The layers of the rainforest

mature trees of smaller species, such as palms (about 10–20 metres tall). Vegetation is more open and contains young trees.

- **Shrub layer** – bushes up to 5 metres high. Only about 2 percent of the sunlight received at the canopy penetrates to this depth, so there is little photosynthesis and plant growth is slow. Nevertheless, these species are adapted to their shadier environment. Many typical house plants such as rubber and Swiss cheese plants come from this layer.
- **Ground layer** – shade-loving plants which are usually less than 1 metre in height. They do not cover the whole ground surface because few plants can cope with this degree of shade. Bare ground, with lots of **litter**, is common on the forest floor. Wildlife here eats fruit and seeds from the litter.

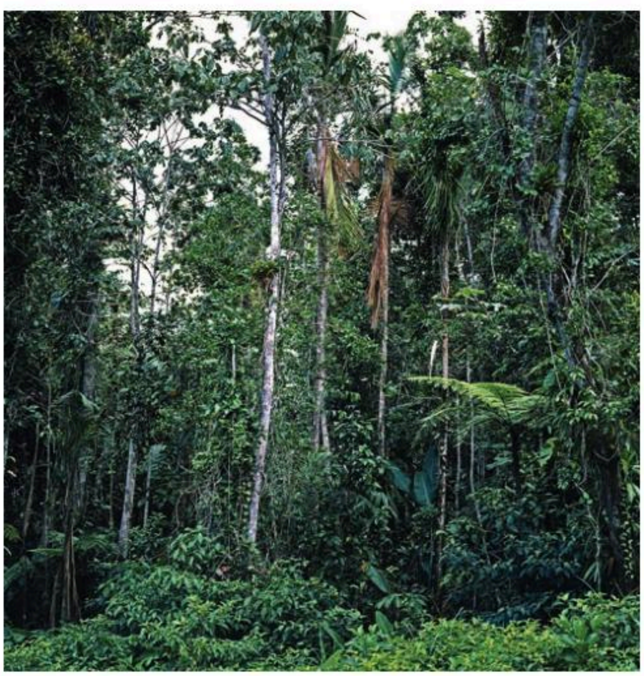


Figure 8.14 Rainforest layers

Figure 8.15 shows some of the ways in which rainforest plants have adapted to their environment. The numbers in circles link to the bullet point list below.

- Trees have slender trunks with thin, smooth bark ① to help them shed heavy rain. There is no frost, so no extra protection (such as thick bark) is needed.
- Trees are tall and the canopy ② is wide to reach maximum sunlight for photosynthesis.
- **Buttress roots** ③ at the base are especially wide to help support this great height.

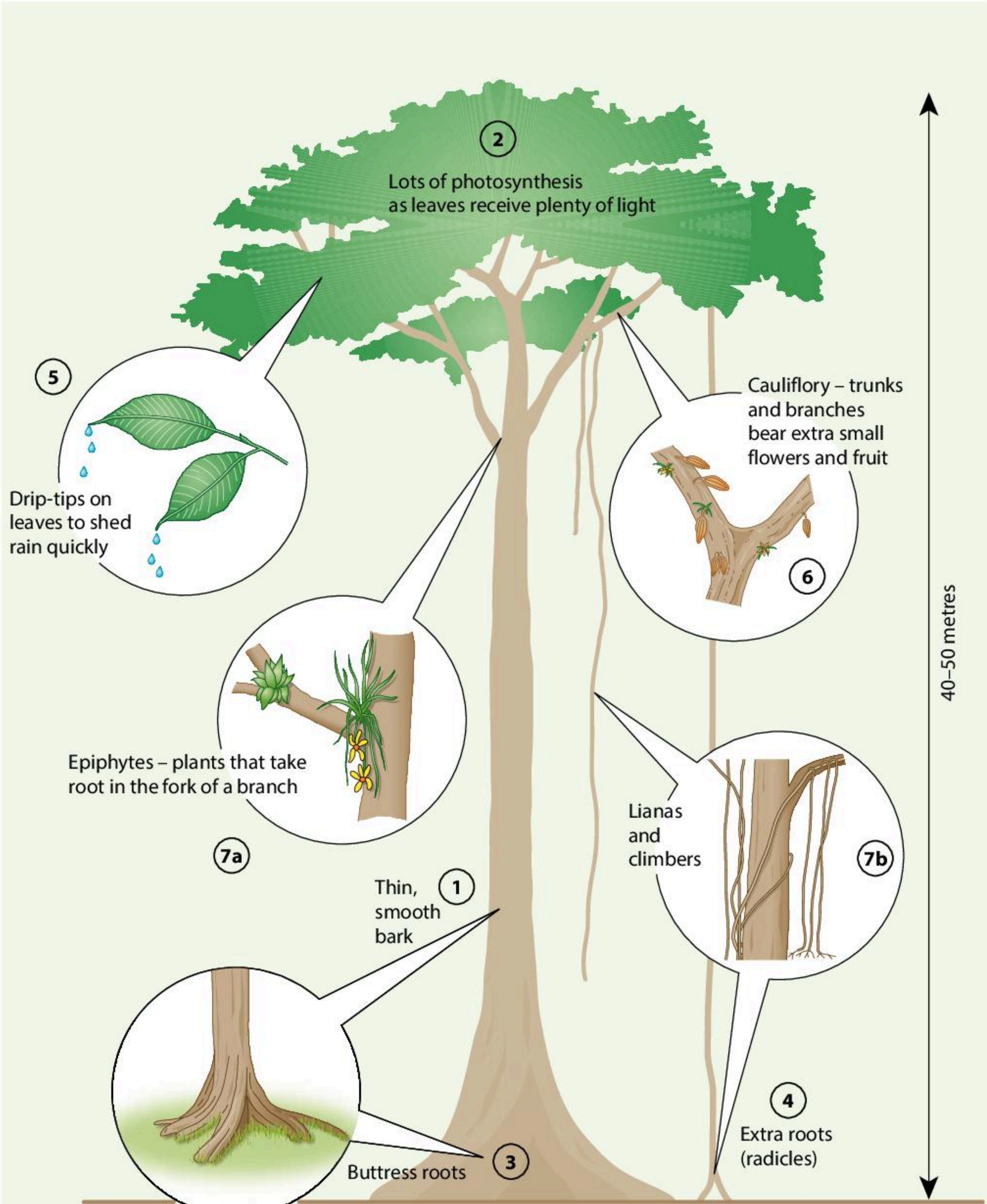


Figure 8.15 Characteristics and adaptations of rainforest vegetation

- Extra roots, or **radicles** ④, grow down from branches to make the roots more stable. (This also happens in mangrove swamps: see Chapter 5.)
- Leaves have **drip tips** ⑤, with curved ends, which help them shed excess rainwater easily.
- The leaves are leathery to protect them from the strong sun.
- The whole environment encourages productivity, so young trees have extra flowers and fruit growing directly from their trunks and branches ⑥ – this is known as **cauliflory**.
- Other plants use rainforest trees as supports ⑦ and this increases the productivity of the whole ecosystem.

  Epiphytes are plants that use dead material which has collected in the forks of trees as a place in which to root (7a). They simply use the tree for support but derive no nourishment from the tree itself.

  Lianas are climbing plants which need support and hang from the trees (7b).

Nutrient cycling: Plant nutrients are consistently moved through the ecosystem, being used and then made available once again for future plant growth and wildlife food (*Figure 8.16*). There are three main stores of nutrients: the soil, the litter and the vegetation itself. In the rainforest, the largest proportion remains in the huge plants, being recycled only when those plants die.

The rotting down of dead plant and animal material is very rapid because of the high temperatures and moist environment. When a tree dies in the rainforest, organisms like termites, fungi and bacteria decompose the material. Nutrients therefore stay only a short time in the ground litter and are quickly transferred into the soil and then taken up by the next generation of plants. The size of the circles in *Figure 8.16* indicates the size of the nutrient store and the width of the arrows show the size of the flows between them.

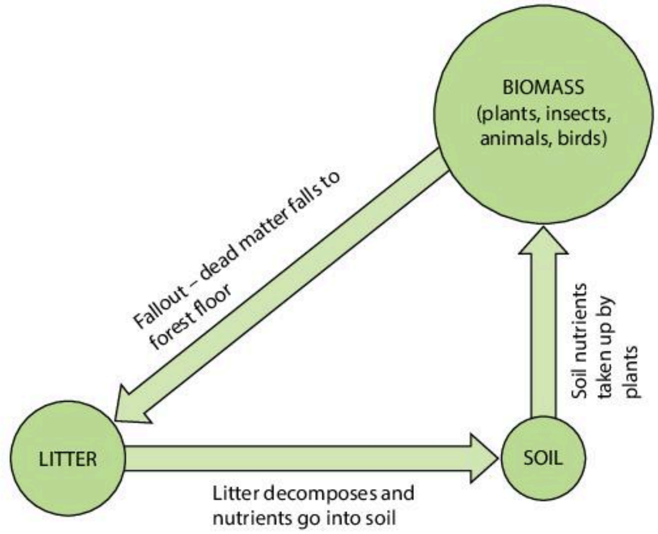


Figure 8.16 Nutrient cycling in the rainforest

Seasonality of vegetation: You have already understood the lack of variation in rainforest climate – there are no real seasons except for part of the year which tends to be drier than the rest (for example, January to May for Trinidad). In temperate zones like the UK there are distinct warm and cold seasons and plants react accordingly. Deciduous trees lose their leaves in autumn and new ones grow in one short season – spring. In contrast, all plant processes happen all the time in the rainforest – fertilisation, flowering, fruiting, seeding, leaf drop and re-growth.

Activities

1. Why does the rainforest grow in layers?
2. Which layer has the lowest density of plants? Why is this?
3. A parasite is a plant that gets its nutrients from the body of another plant. Are epiphytes parasites? Explain your answer.
4. Many visitors to the tropics are amazed by the rainforest as it is so different from the ecosystems they experience at home. In your opinion, which rainforest characteristics would impress visitors most? Give reasons for your answer.

Case Study

The Blue Mountains, Jamaica

The Blue Mountains are located in the south-east of Jamaica (*Figures 8.17* and *8.18*). They are around 45 km long and on average 19 km wide, comprising around 6 percent of the island. The original forest covered a larger area but exploitation by Spanish and British settlers reduced it. People needed land to live on and farm and there was a huge demand for hardwood from Europe. Since 1992, 776 000 hectares of land has been protected as the Blue Mountains and John Crow Mountains National Park.

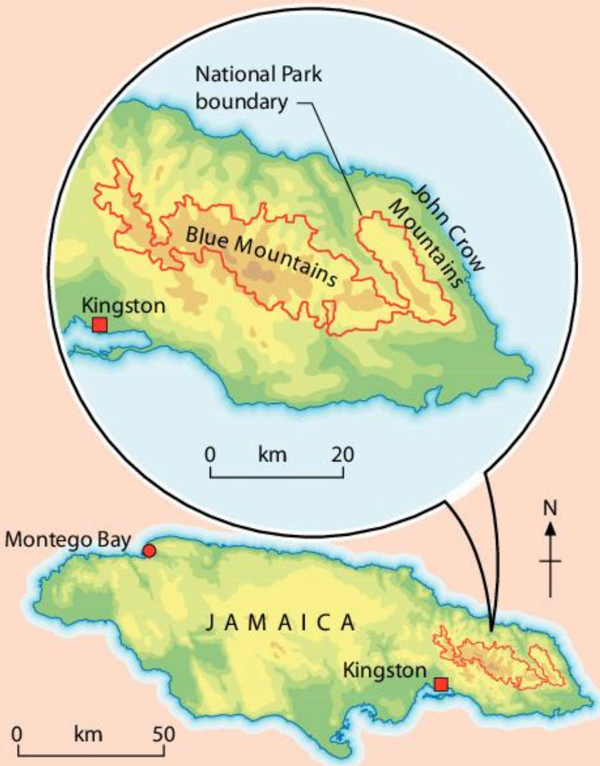


Figure 8.17 Location of the Blue Mountains and John Crow Mountains National Park

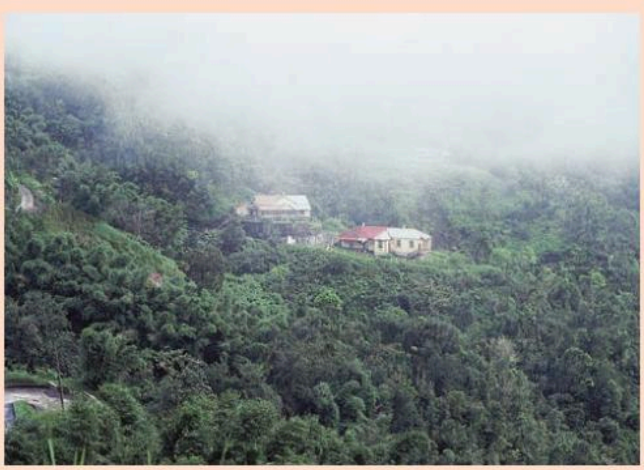


Figure 8.18 Blue Mountains rainforest

The Blue Mountains and John Crow Mountains National Park have:

- 800 species of plants native to Jamaica
- 41% of plants in the Holywell Recreation Park (within the Blue Mountains) that are found nowhere else in the world
- 256 species of resident and migrant birds, including the streamer-tail hummingbird, Jamaica's national bird
- 500 species of flowering plants, including ginger lilies, impatiens, violets and nasturtiums.

Figure 8.19 Rainforest vegetation – facts and figures

The eastern slopes are among the wettest in the world, with almost 7700 mm of annual rainfall. This results in a rich rainforest environment (*Figure 8.19*). Here there are many rare and exotic insects and plants, including the world's second largest butterfly species (*Figure 8.20*) and a Jamaican bamboo which flowers only every 33 years! (It should flower again in 2017.)

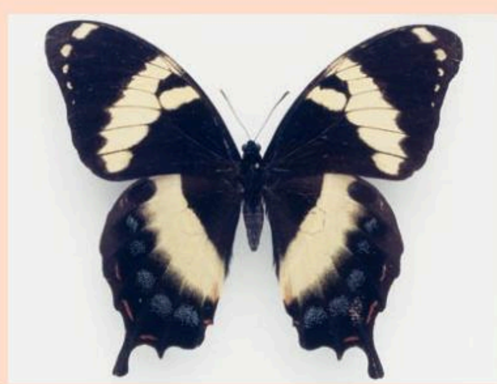


Figure 8.20 The world's second largest butterfly, found in the Blue Mountains

On the highest parts of the mountains the ecosystem changes to **cloud forest** where trees are smaller and mosses, lichens, bamboos, lianas and tree ferns dominate. With height, the vegetation adapts to the lower temperatures, higher rainfall and frequent cloud. Cloud forest can also be found in other highlands in the Caribbean, for example in the highest parts of the Northern Range, Trinidad.

Rainforest soils

Major constituents of soil

Soil is an important part of any ecosystem. *Figure 8.2* at the beginning of this chapter shows that soil directly affects vegetation and wildlife. In turn, they affect the soil, as do the bedrock below it and the climate above it. All soils have four main constituents (*Figure 8.21*) – mineral material, organic material, air and water. In most soils, mineral and organic material make up around half the body of the soil, in roughly equal quantities (therefore 25 percent each). The remainder is made up of air and water. People are often surprised that these two constituents form such a large proportion of the soil, but without air and water in large amounts, soil could not function and plants could not grow. These proportions vary from one soil to another and rainforest soils are dominated by mineral material over organic.

Soil formation

Bedrock provides the mineral material in soil and vegetation provides the organic material. Climate is also an essential factor in soil formation. Bedrock breaks down by weathering into smaller fragments called regolith. This happens particularly rapidly in tropical regions such as the Caribbean because of high temperatures and plentiful rainfall. Chemical reactions that help to weather rock happen much more quickly in warm, wet conditions. Tropical soils are therefore the deepest in the world, up to 30 metres deep (*Figure 8.23*).

As soil develops, vegetation takes a hold. When plants die, they become part of the litter layer. Continuous leaf fall in a rainforest makes sure that there is always a thick layer of litter. In the hot, wet conditions, decomposers (fungi, bacteria, ants, termites, and so on) thrive and break down the litter very quickly

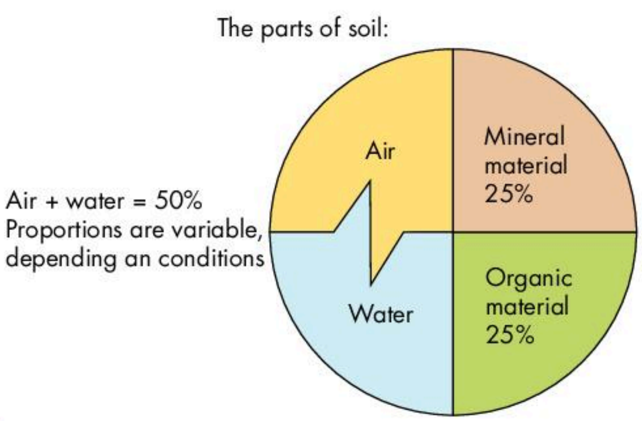


Figure 8.21 The parts of soil

Figure 8.22 Soil crumb structure

by the process of fermentation into humus. This dark brown/blackish organic material is mixed into the mineral part of the soil by small animals and insects (soil fauna) such as earthworms. Organic and mineral material together forms soil particles, or crumbs (*Figure 8.22*), and between these is air and water, which are so important for soil functioning.

Other factors affect the characteristics of a soil:

- **Slope** is important. Thicker soils form on flatter land and gentle slopes. On steeper land soil particles move downhill under the force of gravity, so, the steeper the slope, the thinner the soil.
- Another factor that is easily forgotten is **time**. Soils need time to form, usually thousands of years. The longer they have been developing, the thicker they are, although each soil type has its maximum depth – in the case of latosols, about 30 metres. The warmer and wetter the climate, the less time it takes to form a mature soil, so rainforest soils are quicker to form than many.

Ecosystems

Latosols

Chemical weathering happens particularly rapidly in tropical regions of the world such as the Caribbean because of high temperatures and plentiful rainfall. Rainforest soils have a thick layer of plant litter on the top because of the huge amount of vegetation growing on them. This suggests they are rich soils – otherwise how could they support rainforest? However, this is not really true! Tropical red earths (latosols) may support rainforest, yet they are quite poor-quality soils, because of the very rapid recycling of nutrients within the ecosystem. As soon as the plants shed their leaves, these rot down to become humus. Soil fauna mix this into the soil very quickly, and plants take up the nutrients almost immediately. The cycling of nutrients on the rainforest system is the fastest in the world.

Figure 8.23 shows little colour difference between the A (upper) and B (middle) **horizons** (layers) of tropical red earth. A lot of dark-coloured humus would show up in the colouring. Although plants take up nutrients quickly there is another reason for lack of minerals. There is so much rain in tropical regions that minerals in the A horizon, like iron, are quickly dissolved and washed down into the lower soil. This process is called **leaching**. It takes nutrients away from plants and leaves the soil acidic (low pH). On the other hand, the dense mat of roots in this soil between 20 and 30 cm deep intercepts a lot of the nutrients, retaining them for plant use. This assists rapid nutrient recycling in this ecosystem.

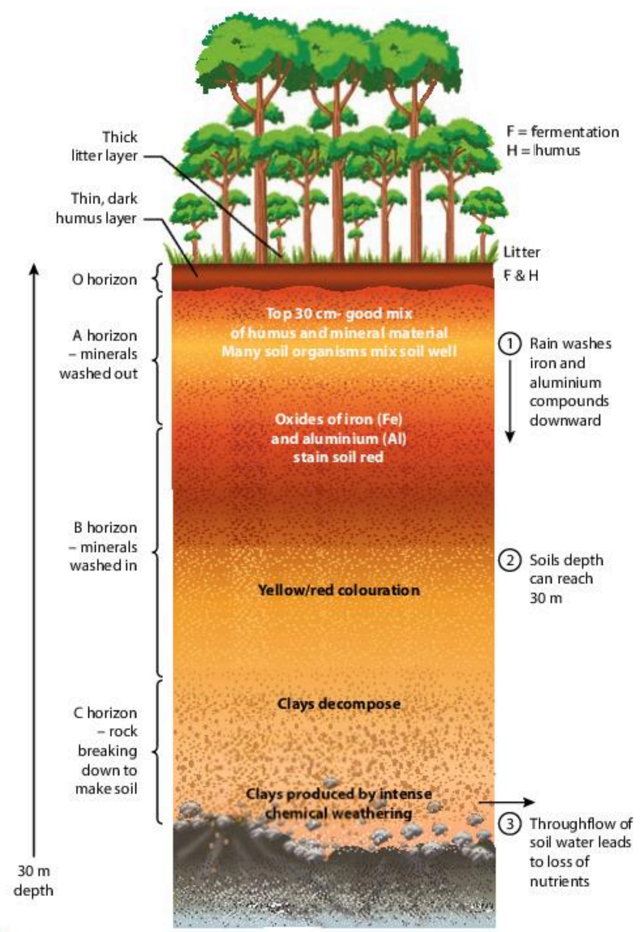


Figure 8.23 Latosol soil profile

Adapted from D. Waugh (2009) *Geography: An Integrated Approach, 4th edition*, Nelson Thornes p. 318

The low nutrient content of latosols therefore becomes a problem only when the natural vegetation is cleared, leaving the soil without its normal inputs of litter. When rainforest trees are cut down and the land is used for farming there are few nutrients left in the soil and they are used up very quickly. Harvesting crops removes the organic material that might have become litter (*Figure 8.24*). The nutrient cycle of the ecosystem has therefore been destroyed, because most of the nutrients were stored in the trees and other vegetation, not in the soil. The structure of the soil is therefore damaged and it erodes away easily.

Positive and negative impacts of human activities on tropical forest biomes

Negative impacts of people

One hectare (10 000 m^2) of rainforest is destroyed by people every second – this is the equivalent of two American football fields – but even more shocking, means that an area larger than New York City is devastated every day! That equates to the area of a country the size of Poland every year.

Causes of deforestation

1. Slash and burn

Causes of deforestation are many and various. Traditionally, rainforest people grew crops using the system of shifting agriculture or 'slash and burn'. This involves extended family groups of over 30 individuals clearing undergrowth, cutting down large trees and burning them, then spreading the ash as fertilizer (*Figure 8.25*). Such ground can be farmed for two to three years with up to three annual crops before the soil is exhausted of nutrients and needs time to recuperate (fallow periods). Clearings are small enough that even heavy rain does not erode the soil. A single group operates a few clearings at a time and then moves on to new ones, ideally returning to past land after 30 years, by which time the soil should be returned to full fertility.

Figure 8.24 Crop production on latosols limits litter input

Figure 8.25 Small-scale slash and burn land clearance

Figure 8.26 Environmental issues in Indonesia

Slash and burn is a sustainable system as long as it does not become intensive.

- New transport routes through the rainforest, in particular the Trans-Amazonian Highway, have let new settlers from the poverty-stricken regions of Brazil into the rainforest to try to earn a living through slash and burn. Lack of traditional skills has led to people failing to produce, and much rainforest destruction.
- Population increase in West Africa caused plots to be cleared too close to each other, opening up the forest and allowing rain to cause soil erosion. Fallow periods became shortened so soil was not able to regain full fertility, making it lose its structure and be more vulnerable to erosion. Serious forest destruction was the result, leaving people with no land to farm; many were therefore forced to migrate to urban areas to try to earn a living.

2. The timber industry

Commercial logging is the major cause of rainforest destruction today in Southeast Asia and Africa (*Figure 8.26*). In Amazonia there has been greater pressure to cut timber sustainably, taking the high-value trees without destroying everything else around them. Demand from the developed world drives the market in tropical hardwood timber – without that the business would not be so destructive. Indonesian rainforest has suffered harshly as the country strived to develop by exporting high-value goods to the more developed world. There is still a lack of understanding in North America and Europe over the environmental consequences of rainforest destruction.

3. Cattle-ranching and soya bean production

Ranching has been a huge cause of rainforest deforestation, being responsible for 80 percent of tree cutting in all Amazonian countries (Brazil, Peru, Bolivia) in the early years of the 21st century (*Figure 8.27*). Cattle-ranching is an extensive system of farming, using a whole hectare of cleared forest for every animal.

Figure 8.27 Deforestation in the Amazon rainforest

Demand from the wealthier world for meat has been important, but today the large, rapidly developing countries like China and India have growing middle classes who demand a diet that represents a high standard of living, with lots of protein. Carbon emissions from clearances for ranching caused 3.4 percent of global output in 2008.

Global companies like McDonalds have caused significant rainforest damage and have received public condemnation for this; public pressure has caused them to change their policy. By 2006 McDonalds claimed to have stopped clearing new rainforest for cattle and no longer bought soya beans grown on cleared forest ground for cattle feed.

Nevertheless, soya grown on cleared Amazonian rainforest is increasingly used to feed cattle and chickens. Brazil, the second largest soya producer, exports to the USA, Europe and China, who produce beef and poultry for other fast-food restaurants and people's dinner tables. An area the size of the US state of Vermont has been cleared for soya production in the Brazilian state of Mato Grosso alone.

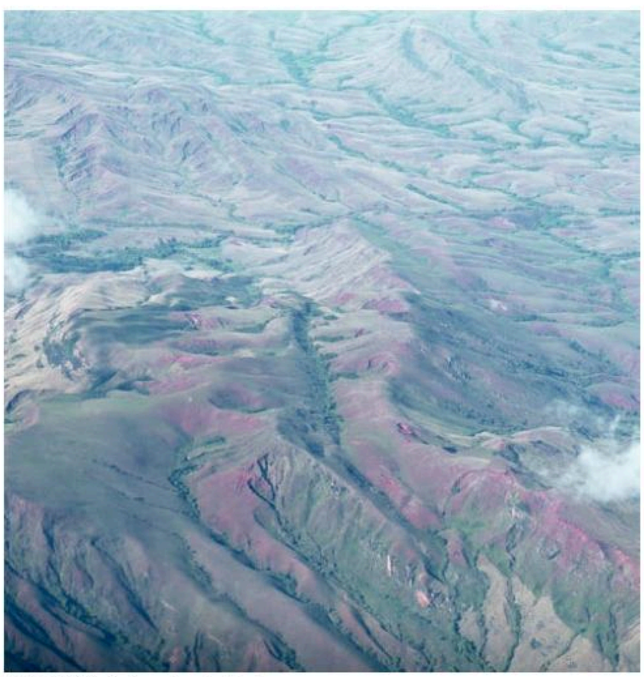


Figure 8.28 Soil erosion in Madagascar

4. Hydro-electric power (HEP)

An unlimited supply of water on the Parana River feeds Itaipu, on the Brazil/Paraguay border, said to be the largest HEP system in the world, ahead of the Three Gorges Dam in China. It supplies electricity for Brazil's largest city, São Paulo, with its population of over 21 million and expanding industries. In order to create the reservoir behind the dam, 2430 km^2 of rainforest had to be flooded, threatening several mammal species and whole ecosystems. Brazil is an NIC (Newly Industrializing Country) whose economy is growing rapidly on the back of such infrastructural developments.

Soil exhaustion and erosion

Tree roots anchor the soil, preventing erosion, but when trees are gone, soil has little protection from the heavy rains. Widespread soil erosion has occurred, and is still occurring throughout the tropics as a result of rainforest clearance. The consequences include:

- Soil loss across tropical regions has been immense, and continues.

  Costa Rica loses about 860 million tonnes of valuable topsoil every year. Most of this is washed into rivers and then into the sea.

  Madagascar loses more soil than anywhere else – 400 tonnes per hectare per year (*Figure 8.28*), turning rivers red and staining the sea far out into the Indian Ocean (*Figure 8.29*). Astronauts looking back toward the Earth have said that Madagascar looks as if it is bleeding to death.
- Crop yields decline and people must spend their limited income on expensive imported chemical fertilizers in order to produce an adequate crop.
- Offshore coral reefs are being suffocated by soil outwash into the sea. Coastal fisheries suffer not only from loss of coral reefs but also the silting up of mangrove swamps.

Figure 8.29 Soil debris in the Indian Ocean off Madagascar's Betsiboka estuary

FSC

100%

From well-managed forests

Cert no. TT-COC-XXXX

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Figure 8.30 The FSC sustainability label

Figure 8.31 Tropical hardwood, Mato Grosso, Brazil

Sustainable management

The Forest Stewardhip Council (FSC) is an international organisation which aims to increase the proportion of timber and other rainforest resources that are obtained sustainably. It aims to reduce the demand for rare, valuable tropical hardwoods through educating people of the consequences of such unsustainable exploitation. Products that have been sourced from sustainably managed forests have the FSC label (*Figure 8.30*).

Activities

1 Use an atlas to look up the sizes of New York City and of Poland to help you understand the potential consequences of current rainforest clearance.

2 Explain why population increase is a threat to the rainforest environment.

3 a Describe the ways in which fast food production can damage rainforest regions.

b Explain why global (transnational) companies have the power to put pressure on rainforest countries' governments to destroy sections of their rainforests.

4 Make two lists of the negative and the positive impacts of large-scale HEP schemes in the rainforest. Undertake some internet research and decide whether these projects can be justified.

5 a Explain why forest clearance leads to serious soil erosion.

b Make a list of the consequences of this.

6 Refer back to the case study of the Blue Mountains of Jamaica (page 170).

a List some plants and wildlife that are worth conserving in the Blue Mountain area.

b Research the cloud forests in Jamaica and Trinidad.

c Small-scale eco-tourism already takes place in the Blue Mountain National Park area. How does this economic activity help preserve the forest environment?

Case Study

Nigeria and Brazil

1. Nigeria – Cross River State

Nigerian rainforest is home to 4715 plant species and over 550 birds and mammals, but, with one of the world's fastest population growth rates, Nigeria has one of the worst deforestation records. Ninety percent has gone and a further 4 percent is lost annually. At that rate, all rainforest could be gone by 2020.

Cross River State in the south-east of Nigeria has a government which is trying to protect the remaining forest and plant more in a restoration programme. However, this is still fighting against:

- population increase causing clearance for farmland, and
- foreign logging companies sometimes breaking the law.

Figure 8.32 Locations of protected areas in Cross River State

There is a lack of central government funding for the rainforest, but species and resource protection is happening to some extent in Nigeria:

- The Cross River National Park, begun in 1991, protects half the existing forest area (*Figure 8.32*).
- The Afi Mountain Wildlife Sanctuary (AMWS) has protected endangered species, in particular the gorilla, since 2000. Despite these efforts, illegal logging and pollution remain serious problems. Logging has now been banned in Cross River State, but time will tell.
- A new focus on **ecotourism** will help bring in some foreign money which will go straight to local communities, discouraging small-scale forest clearance.

2. Brazil – Acre Amazonian rainforest conservation

This project aims to prevent deforestation in Acre State, Brazil, a region which is home to many important and endangered species – jaguars, pink river dolphins, scarlet macaws, howler monkeys, giant otters and river alligators. Deep in the Amazonian rainforest (*Figure 8.33*), Acre is larger than England and Wales (164 000 km^2). Forty percent of Acre's population are classed as extremely poor (living on less than $1 per day) and 15 percent are illiterate.

Figure 8.33 Maps to show the location of Acre state in the Amazon rainforest

Acre's state government is more progressive than most in Amazonia, so half of Acre's forests are now protected, which also improves economic opportunities for the poorest people.

The Sky Rainforest Rescue Project lasted for six years ending in September 2015. This was a partnership between WWF, the Worldwide Fund for Nature, and Sky Broadcasting, aiming to protect one billion trees. Sky customers, employees and the general public raised £9 million to fund the project. Programmes made and shown on Sky helped make people in Western countries more aware of rainforest issues. A scheme to adopt threatened wildlife like jaguars led to direct support from individuals, also increasing awareness.

The main benefits of this scheme were:

- One billion trees at risk were conserved.
- Over 1500 families were given the land and resources to make their living from sustainable rainforest agriculture.

Issues remain, however. The BR364 main road through Acre has brought in damaging development; whenever a rainforest area becomes more accessible, deforestation will increase.

Skills

Interpreting rainfall and soil maps

Figures 8.34 and *8.35* show two types of shaded map. The rainfall maps (*Figures 8.34* and *8.35b*) show shading that becomes deeper in colour as the value represented increases. Just looking at the map gives an immediate impression of the distribution pattern. The colours used are linked to each other; for example, these rainfall maps use several shades of blue. The colours also represent what they show: blue suggests water, while yellow and orange represent drier conditions.

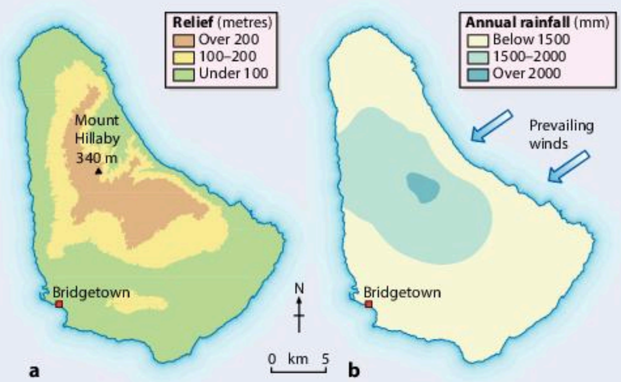


Figure 8.35 Rainfall and relief, Barbados

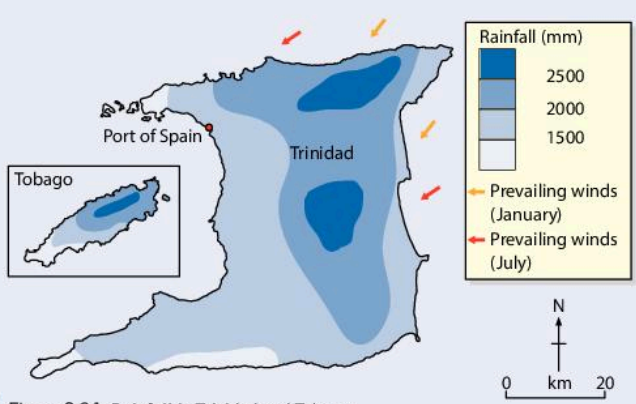


Figure 8.34 Rainfall in Trinidad and Tobago

Figure 8.36 shows the distribution of soils in a small part of Trinidad. The shading on this map is not graded. Different types of soil are shown, not different values. When interpreting such maps, use the key carefully. Some of the shades are similar, so make sure you identify the correct colour in the key.

1 Referring to *Figure 8.34*, describe the rainfall distribution in Trinidad and Tobago. State where the high and low rainfall areas are found. Use compass points and place names to describe locations and refer to values in the key.

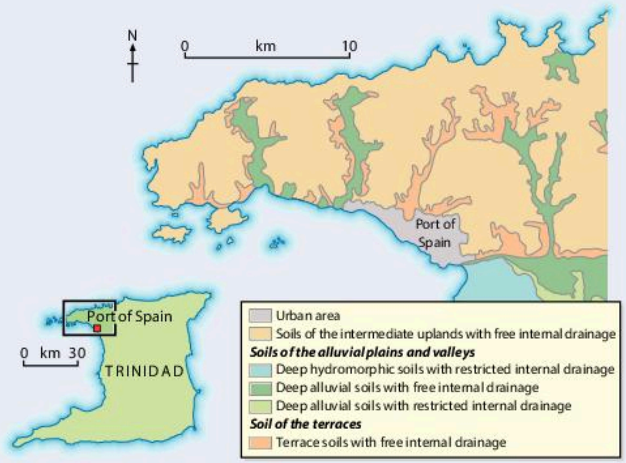


Figure 8.36 Soil types in north-west Trinidad

2 What are the differences between the rainfall patterns of Trinidad and Tobago and of Barbados?

3 a *Figure 8.35a* shows the relief of Barbados. What do you notice about the patterns of rainfall and relief? Compare the maps of Barbados (*Figure 8.35a* and *b*). Can you see any relationships?

b Look for similar maps in Chapter 7. Which island do they show?

4 List the soil types in this part of Trinidad. (Hint: There are five in total.)

5 Describe the distribution of the soils.

6 The green shading makes an unusual shape. Can you explain it?

Glossary of terms

Biomass: the weight of plant and animal material grown in a year per unit area.

Biome: a global-scale ecosystem, such as rainforest, savanna and hot desert.

Carnivore: a meat-eater.

Cauliflory: flower and fruit growing from rainforest tree branches and trunks.

Climograph: a two-part graph which shows temperature and rainfall (precipitation) figures for a particular location.

Community: a set of plants, animals and insects that operate together in an area. Each feeds on and/or is fed on by others.

Cycle: a system with flows, such as energy and nutrients.

Decomposer: fungi or bacteria which work to break down the dead matter of plants and wildlife.

Drip tips: an important rainforest tree leaf shape.

Ecosystem: a system which occupies an area on the Earth's surface, consisting of plants, wildlife, soils, climate, etc.

Energy: in the context of ecosystems, this starts as the energy from solar radiation. It cycles around plants, animals, decomposers, and back into plants again.

Epiphytes: plants which grow on rainforest trees.

Equatorial: in the latitudes close to the Equator; usually between 10° North and South.

Food chain: a sequence of nutrition in which plants are eaten by animals which may then be eaten by other animals. There are fewer individuals at higher levels in the food chain.

Herbivore: a plant eater – can be an animal/insect/bird.

Humus: rotted litter – usually of plant origin, but can also be animal – ready to be incorporated into the soil.

Inputs: for an ecosystem these are the sun's energy, rainfall, and the bedrock which adds minerals to the system and is essential for plant and animal life.

Intrazonal soil: a soil that takes its characteristics from some local feature, such as rock type.

Leaching: a chemical process in soil where soluble compounds in the upper horizon are dissolved in soil water and moved downward to lower levels.

Lianas: rainforest climbing plants.

Litter: dead plant or animal material that collects on the ground. It rots and eventually turns to humus.

Nutrient cycle: the movement of plant food (nutrients) around the ecosystem.

Nutrients: plant food; this can originate in mineral matter from the bedrock or organic matter from dead plants and wildlife.

Photosynthesis: the chemical process by which plants (producers) convert sunlight into food.

Primary consumers: herbivores (animals/insects/birds) that eat plants.

Producer: the first level in a food chain – plants. They absorb the sun's radiation and convert it into nutrients and energy which are fed into the ecosystem.

Radicles: rainforest tree roots which grow down to, and into, the ground from tree branches.

Regolith: loose rock material resulting from the weathering of rock. This is the foundation of soil development.

Secondary consumers: carnivores.

Slope: angle or gradient – the steeper it is, the thinner the soil.

Soil fauna: creatures that live in the soil – can be insects or small animals.

Soil horizon: a layer in a soil profile; each has a distinctive colour, texture, etc.

Symbiosis: a relationship between two living things that benefits them both. An example is birds in the African savanna that eat insects from the coat or skin of larger animals – the birds are fed and the animals get rid of a pest.

System: a network of flows and interacting parts, such as an ecosystem.

Time: an important factor in the development of soil and of an ecosystem. The longer the development, the more mature it is.

Tropical: between the latitudes of the Tropic of Cancer (23.5° North) and the Tropic of Capricorn (23.5° South).

Zonal soil: a soil that has developed mainly as a result of its regional climate.

Ideas for SBA

- *What can cause changes in vegetation on a mountainside?*
- *What are the features of vegetation in a tropical evergreen forest?*
- *Is there a relationship between vegetation and relief in my community?*
- *Do soil characteristics change along a slope in my community?*
- *How do changes in soil characteristics affect the vegetation on a slope in my community?*

Weblinks

1 Look up addiesrainforest.weebly.com for photos and details of rainforest plants and wildlife

2 Use www.rain-tree.com to read more on rainforest products and their potential plus rainforest destruction and the need for protection.

3 Research Greenpeace (conservation organisation) on rainforest clearance for fast food. Also WWF (www.panda.org) on unsustainable cattle ranching in Amazonia.

4 Research the Itaipu Dam on Wikipedia and other sites.

Exam-style Practice

1 a Name the FOUR main parts of soil. [4]
b Write a definition of a soil profile. [2]
c List THREE characteristics of tropical red earths. [3]
d What happens during the process of leaching? [3]
e Describe THREE characteristics of the tropical rainforest climate. [3]
f Name THREE areas in the world that have a tropical rainforest climate. [3]
g Define the term 'cloud forest'. [2]
h Describe THREE ways in which tropical rainforest vegetation is adapted to its environment. [4]

Total 24 marks

2 a Draw a well-labelled diagram to show a terra rossa soil profile. [4]
b State and explain the differences between terra rossa and tropical red earths. [4]
c Why are decomposers so important to the nutrient cycle? [3]
d On a world map, locate and label THREE equatorial rainforest biome areas. [3]
e Describe the main characteristics of the climate of an equatorial rainforest area. [5]
f Describe how a tree in the rainforest canopy adapts to its environment. [5]

Total 24 marks

3 a Explain the difference between an *ecosystem* and a *biome*. [2]
b Draw a well-labelled diagram to show the inputs, processes and outputs of an ecosystem. [6]
c Explain how a food chain operates. [7]
d Define the following terms:
i *community*
ii *soil horizon*
iii *photosynthesis*
iv *regolith.* [4]
e Explain how nutrients are recycled within the rainforest ecosystem. Use a case study to illustrate your points. [5]

Total 24 marks

9 Population

In this chapter you will study:

- population facts and figures
- world population distribution and density
- population trends
- population structure.

You will also learn how to:

- map population
- analyse population pyramids
- reduce and enlarge a map.

Population facts and figures

World population passed the 6 billion mark in 1999. Since then growth has continued, reaching 6.7 billion by 2007 and 7.4 by the end of 2015. Although this might appear very rapid (about 200000 people are added to global population daily), in fact the world growth rate is beginning to slow down. An approximate way of looking at it is to say that one baby is born somewhere in the world every second and someone dies every two seconds.

Thirty-seven percent of the world's people live in just two countries: China, the largest with approaching 1.4 billion and India with over 1.3 billion. India is currently growing faster than China and is likely to overtake it in 2022. The USA, Indonesia and Brazil are the next in population size order. Equally, there are some extremely small countries, many of which are island nations, some located in the Caribbean.

Some cities are larger than countries in terms of population. Mexico City and New York are both close to 20 million, but are outranked by the sprawl of Tokyo at 37 million.

The largest Caribbean country is Cuba with 11252000 people. Jamaica has over 2.7 million population, Trinidad and Tobago just over 1.3 million. Although these are relatively large for the Caribbean, they contain fewer people than most world cities. The British Virgin Islands have only 31000 people and the Cayman Islands, 59000. The lowest population, 5000 people, is on Montserrat.

World population distribution and density

Definitions

- **Population distribution** means the way in which people are spread out over an area.
- **Population density** is the average number of people per unit area. It relates numbers of people to the area they occupy and make their living from. Density is usually expressed as the number of people per km^2.

Activities

1. Make a list of particularly large and small countries in terms of population size.
2. What is the key difference between *population distribution* and *population density*?
3. Explain why geographers need to use both distribution and density maps.

Skills

Mapping population

Population distribution is usually shown using a dot map (*Figure 9.1*), whereas density is usually drawn as a choropleth map (*Figure 9.2*).

In a dot map, each dot is given a value, the number of people it represents (100 000 in *Figure 9.1*). A choropleth is a shaded map in which the depth of shading indicates the value represented; the darker the shading, the higher the value. The colours used are linked to each other. Population density maps often use red/orange/yellow.

Dot maps have the advantage that they show the densely and sparsely populated areas more clearly than a choropleth can. Variations within a country show up. In contrast, choropleths are better for making comparisons between countries, as each country has one value. Choropleths are also easier to draw, once the boundaries of the number categories have been decided.

Choosing the value of each dot can be difficult. If too few people are represented by one dot, then many dots are needed. They then merge and the map becomes hard to interpret. On the other hand, if too many people are shown by a single dot it is impossible to show the population in areas with few inhabitants. Greenland is an example. In *Figure 9.1* it looks empty, yet around 57 000 people do live there. The dots are each worth 100 000, so cannot show these people.

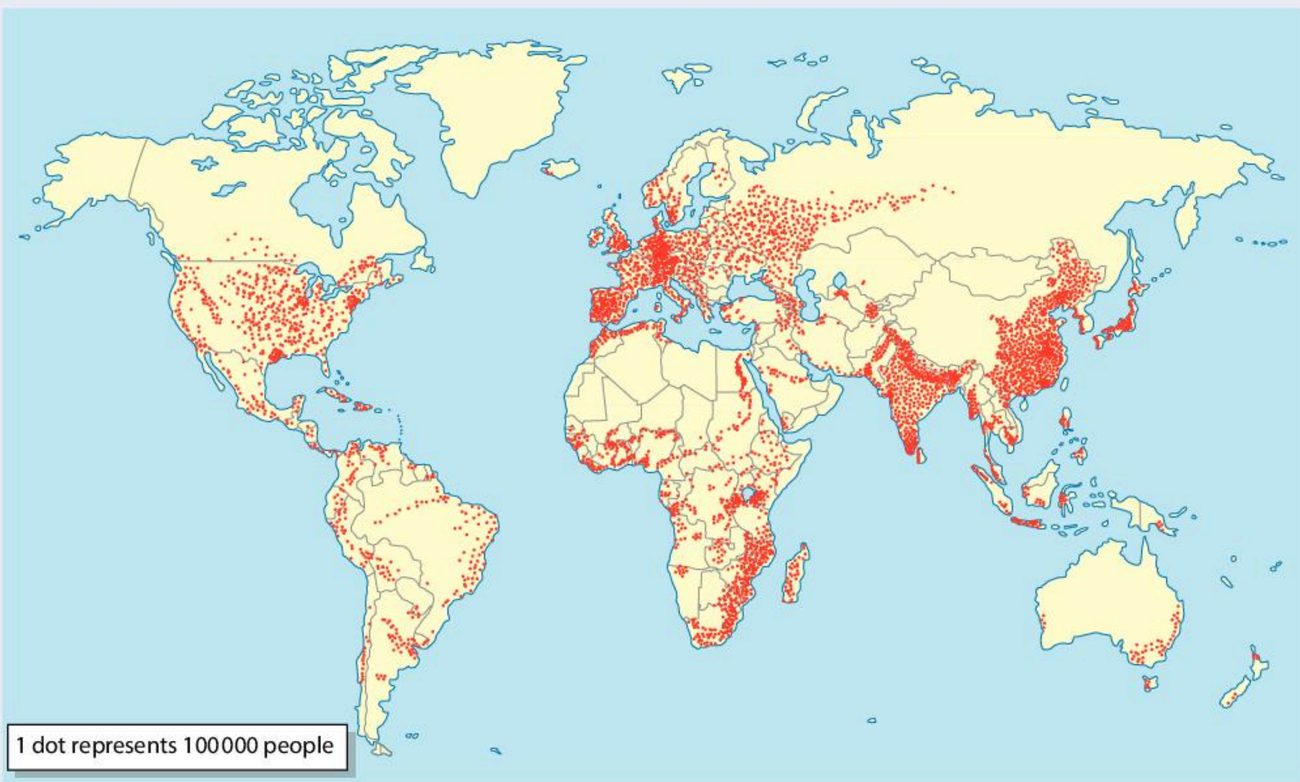


Figure 9.1 World population distribution

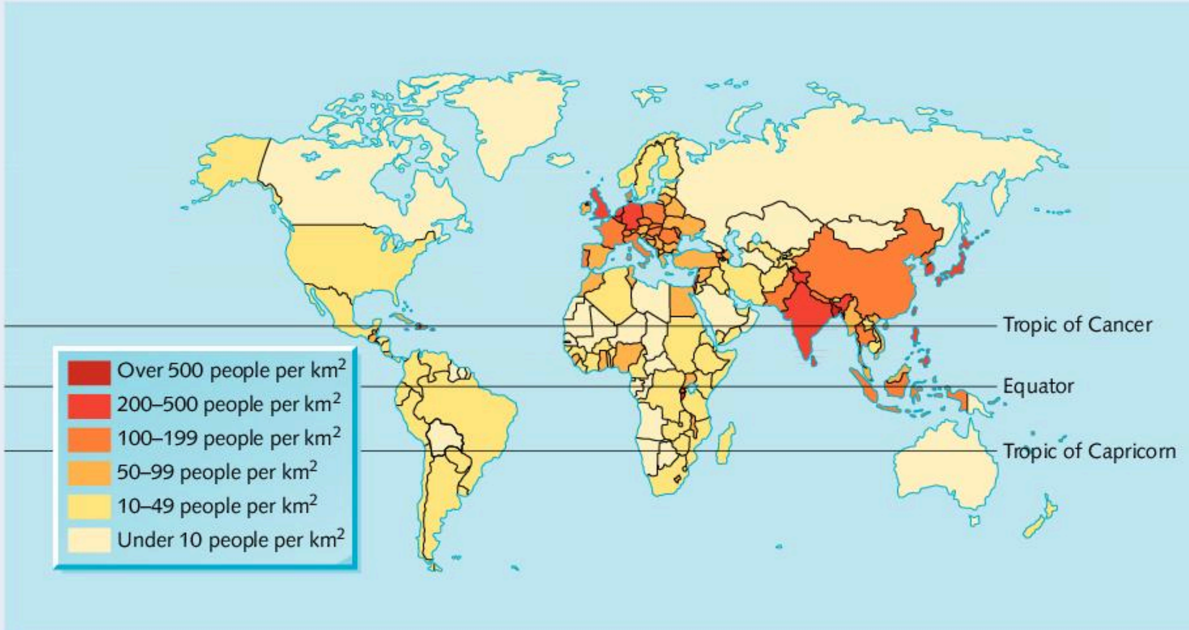


Figure 9.2 World population density (a choropleth)

Another method of mapping population is to use an isopleth (*Figure 9.3*). An isoline is a line on a map joining all places of equal value. A contour line is an isoline, joining all places of equal height above sea level, so an isopleth map looks very similar to one showing relief using contours. The lines show equal population density. These are difficult to construct and not always easy to interpret unless the spaces between them are also shaded, making them more like a choropleth.

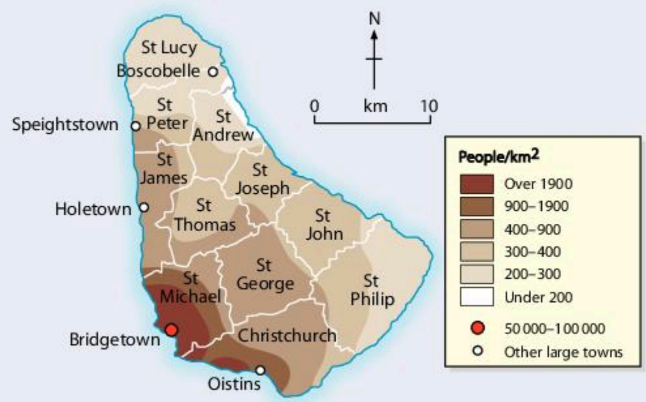


Figure 9.3 An isopleth population density map of Barbados

The pattern of world population density and distribution

Figure 9.2 shows that some countries are much more densely populated than others. Bangladesh has the highest figure at over 500/km². India, the Philippines, South Korea and Japan are all Asian countries in the next category, 200–500 people per km². In Europe, the UK, Germany, the Netherlands and Belgium also fall into this category.

If a comparison is made with *Figure 9.1*, the dot distribution map, it is clear that people in these densely populated countries are not evenly spread. India is well populated throughout but there are definite concentrations along the Ganges Valley in the north and at the southern tip. Japan's main concentration is around the cities in the south and the southern UK is more populated than the rest of the country.

China, the most populous country, has almost all its citizens in its eastern half. Sparsely populated areas of the world include Canada, Australia, Russia, Central Asia and parts of Africa. Again, people are not evenly spread over these countries. On *Figure 9.2*, the Caribbean can be divided into the denser east (200–500 people/km^2) and the less dense west (50–99/km^2).

Factors affecting population distribution and density

Everywhere in the world, the physical environment limits people's choice of where to live. Population distribution and density both change over time; different factors vary in importance over time.

Physical factors

Closeness to the coast

Two-thirds of the world's population lives within 500 km of the sea. Main concentrations of people are often on islands or at the edges of continents. On the other hand, interiors of continents tend to be sparsely populated (Central Asia was mentioned above). Many of these areas have difficult environments.

People are attracted to coasts by:

- flat land for building and for agriculture
- water supply from rivers crossing the coastal plain
- access to the sea for transport
- fishing resources.

Today many islands are particularly densely populated, including the British Isles, Japan, Indonesia, the Philippines and Sri Lanka. Within the Caribbean, Haiti, Puerto Rico and Martinique stand out as being the most densely populated.

Altitude

The number of people generally decreases with height above sea level. The greater the height, the more difficult it is to exploit the environment. Of the total world population, 56 percent live below 200 metres, occupying only 28 percent of the land.

In very high mountains like the Andes there is less oxygen in the air but people can adapt to this by developing larger lungs. More important are the physical difficulties that come with altitude:

- slopes are steeper, soils thinner and the land difficult to farm
- temperatures are lower
- precipitation is higher
- winds are stronger.

In the tropics, however, height can be positive and attractive. Lower temperatures can be more comfortable and it is possible to grow a greater variety of crops. In Kenya in East Africa, most people live on the higher plateau lands where temperatures are lower.

Rivers

Rivers usually attract people because they provide a water supply, irrigation, transport and fish. In deserts rivers are particularly attractive, for example the River Nile (*Figure 9.4*): 96 percent of Egypt's population live along the Nile, on just 4 percent of the land available in the whole country! The Amazon Basin in South America shows a similar pattern.

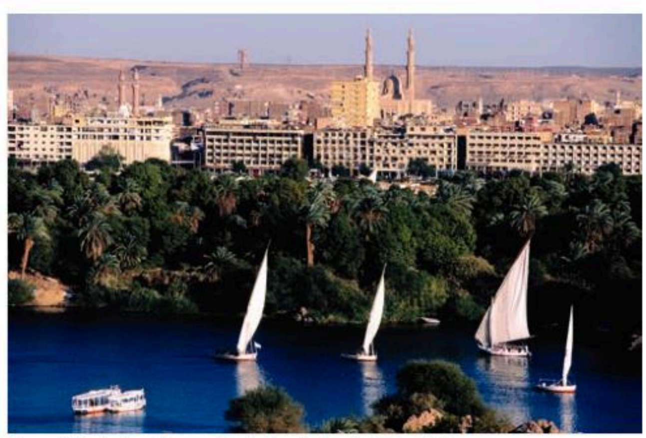


Figure 9.4 A densely populated river basin: the River Nile

Climate

The impact of climate is very important. Unfavourable climate is the main reason behind the world's empty areas (*Figure 9.5*). Half the world is almost uninhabitable because of climatic difficulties. Vast areas are too dry, such as the Sahara (a hot desert in North Africa) and the Gobi (a cool desert in western China). The whole continent of Antarctica and the extensive Arctic zones are too cold for much permanent habitation. Heat and moisture are less of a problem for people's comfort and for making a living. Some equatorial areas have quite dense populations, such as coastal West Africa and the Caribbean islands.

Natural vegetation

The only vegetation type which in itself repels human settlement is rainforest. The forest is dense and creates a difficult environment to exploit. Once the forest is removed, the land degrades so quickly that many of its resources are wasted.

Figure 9.5 A sparsely populated region in Northern Canada

Soils

Good-quality soils like alluvium (river silt) attract people. The Yangtze and Mekong valleys of China and Southeast Asia are densely populated agricultural areas. On the other hand, poor soils cannot produce enough food to support a dense population, so such areas usually have a more sparse population.

Resources

Resources attract people to settle and exploit them so long as they have the technology necessary. A material cannot be classed as a resource if people in that area have not yet learned how to use it effectively.

Many Caribbean settlements have grown recently because of the attraction of jobs in tourism. Much of the landscape in the region is a resource for tourism, and the economic circumstances are in place for tourism to develop. In the UK, most major cities grew close to coalfields, coal being vital for the development of industry in the 19th century. All over northern Canada, where the climate is cold and difficult, towns such as Port Radium and Grand Rapids have sprung up around mineral deposits or energy sources.

Historical factors

Historical migrations

Today's world population distribution has evolved through a constant pattern of migration movements throughout history and pre-history. It is believed that modern people developed in Africa and migrated from there in many stages to populate the rest of the world. The indigenous population of North and South America moved from Asia when there was a land bridge linking Siberia and Alaska. Europeans crossed the Atlantic to discover and settle in the Americas. The Caribbean islands were amongst the first to be discovered and settled.

Forced migrations – slavery

Forced migration occurs when people have no choice but to move. The Souffriere Hills volcanic eruptions caused the majority of Montserrat's people to leave or to move from the south to the north of the island. Today, 73.2 percent of Caribbean people are descended from West African slaves forcibly moved across the Atlantic as a labour supply.

Socio-economic factors

Rural-urban migration

Rural-urban migration is the process of moving home from a rural area to settle in a city, usually in order to find work and establish a higher standard of living. Opportunities in rural areas can be extremely limited. There are few opportunities to get out of poverty, but cities offer some greater employment opportunities. Usually it is the second migrant generation, the children of migrants, who improve their standard of living. They have had better educational opportunities as well as access to healthcare services. Education opens doors to opportunities and improvement.

Haiti is a good example of a rural population being attracted to urban areas. Thirty-two percent of the island's population live in the capital, Port-au-Prince (2015). The city attracted large numbers of rural people during the late 20th and in the 21st centuries, resulting in Port-au-Prince increasing from 704 000 people in 2003 to 1.9 million in 2015. In addition, the most recent migrants have settled on the edge of the urban area in the growing slums on the hillsides outside the city.

It is both rural poverty and urban opportunity which lead to people's decision to migrate. Port-au-Prince's urban population has continued to grow despite the loss of 230 000 people in the 2010 earthquake, which hit the city badly.

Resources

Resources attract people to settle and exploit them as long as they have the technology necessary. A material cannot be classed as a resource if people in that area have not yet learned how to use it effectively.

Many Caribbean settlements have grown recently because of the attraction of jobs in tourism. The landscape itself is a resource for tourism and the economic circumstances are in place for this to develop. In the UK, most major cities grew close to coal resources, vital for the development of industry in the 19th century.

Population distribution in the Caribbean

Population density varies greatly from one Caribbean island to another. The islands tend to be more densely populated than the mainland countries surrounding them.

Activities

1 Of the ten factors affecting population distribution listed above, which would you say are the most important and why?

2 This list of factors is by no means exhaustive; there are other things that attract or repel people to settle. Can you add any more to the list?

3 Choose one densely populated area and one sparsely populated area. For each, say which factors have affected its population density.

Population trends

Birth rate, death rate and natural change

Definitions

The birth rate of a country (BR) is defined as the number of babies born alive per 1000 people per year in that country.

The reason 'per 1000' is part of the definition is so that countries of different sizes can be compared. Otherwise, how could China with its population of almost 1.4 billion be sensibly compared with Jamaica, a country of 2 729 000 people? Often we record statistics as percentages. If BR was measured in this way the numbers would be small and more difficult to grasp. Using 'per 1000' is much more manageable.

Birth rates vary between 5/1000/year and 50/1000/year. These extremes are both very unusual. Most countries' birth rates are between 10 and 30/1000/year. Jamaica's BR was 18.4/1000/year in 2014; Trinidad and Tobago's was 13.8/1000 in the same year.

The death rate of a country (DR) is the number of people dying per 1000 people per year. Jamaica's DR was 6.67/1000 in 2014 while Trinidad and Tobago's was 8.48/1000.

Typically, death rates lie between 5 and 20/1000/year. Periods of national crisis such as war or epidemic disease would increase DR above this level.

Once we have these two statistics we can start to work out population change, in other words population growth or decline. This is called natural change and is calculated by simple subtraction. It is the difference between BR and DR.

Calculating natural change

Natural increase means a country has a growing population. Birth rate is higher than death rate, so the calculation is:

NI = BR – DR

Natural change (NC) is always expressed as a percentage, so the answer must be divided by ten.

Example: The UK (a developed country)

BR = 12.2/1000/year

DR = 9.4/1000/year

$$\text{NI (as a \%)} = \frac{\text{BR} - \text{DR}}{10} = \frac{12.2 - 9.4}{10} = \frac{2.8}{10} = 0.28\%\text{/year}$$

Example: Mauritius (a developing country)

BR = 13.5/1000/year

DR = 6.9/1000/year

$$\text{NI} = \frac{13.5 - 6.9}{10} = \frac{6.6}{10} = 0.66\%\text{/year}$$

Example: Singapore (a newly industrialised country)

BR = 8.1/1000/year

DR = 3.4/1000/year

$$\text{NI} = \frac{8.1 - 3.4}{10} = \frac{4.7}{10} = 0.47\%\text{/year}$$

Until recently, all countries have been in a situation of **natural increase** unless war, famine or disease has reversed this for a limited time. Today, however, some countries, mostly in Eastern Europe, are in a state of **natural decrease** (ND). To calculate ND, BR is subtracted from DR.

Example: Czech Republic (a poorer developed country, which joined the European Union in 2005)

BR = 9.8/1000/year

DR = 10.3/1000/year

$$\text{ND} = \frac{\text{DR} - \text{BR}}{10} = \frac{10.3 - 9.8}{10} = \frac{0.5}{10} = 0.05\%\text{/year } \textit{decrease}$$

BR, DR, NI and ND data give us information on the level of development of a country. Today, in all countries, whether richer or poorer, DR tends to be low. People often assume that Less Economically Developed Country (**LEDC**) death rates must be high because people are poor and life expectancy may not be very long. This is not true. Two factors affect the level of DR: improved healthcare and the youthful age structure of LEDCs (see Age Structure page 196). More Economically Developed Country (**MEDC**) death rates are often higher than those found in LEDCs due to the greater proportion of elderly people. Birth rate is a better indicator of development. In all MEDCs family size is relatively small, but LEDCs have good economic reasons for favouring larger families.

More useful definitions

Infant and child mortality rates and life expectancy are also useful indicators of development. In countries with a developing economy, the first two tend to be higher and the last tends to be lower. Countries achieve a longer life expectancy as they develop economically, but, sadly, many African countries are now seeing their life expectancy figures being reduced due to the impact of AIDS. This has happened in South Africa, Zimbabwe and Botswana.

Figure 9.6 Birth and death

The **infant mortality rate** is the number of deaths in the age group 0–12 months per 1000 live births per year. The **child mortality rate** relates to children up to their fifth birthday. **Life expectancy** is the number of years people in a particular society are expected to live. The highest life expectancy in the world is for Japan: over 80 years for both females and males. Life expectancy figures can be split by gender and it is usually higher for females than for males. Most European countries now have a life expectancy of 80+ for females, but not yet for males, though several are almost there, including Switzerland, Hong Kong and Japan.

Note: Population figures quoted in this section are from the *CIA World Factbook*, Population Trends section.

Life expectancy in the Caribbean

The data in *Table 9.1* shows average life expectancy for males and females together. As a rule, women live longer (see Weblinks suggestion). Caribbean life expectancy is fairly constant across the region with the exception of Haiti, one of the poorest countries in the world, partly as a consequence of frequent natural disasters such as the January 2010 earthquake. Life expectancy is limited by disease and very low living standards after events such as this. A comparison of Caribbean life expectancies with the rest of the world reveals the region to be only a few years behind the most economically developed countries in this respect.

A comparison of infant mortality rates

The Caribbean data is put in perspective by comparing with the United Kingdom figure of 4.4/1000 live births. Availability of health care, especially in rural areas, has a big impact on infant health. Babies are the weakest individuals physically in any society. Haiti's figure is particularly high as a result of the very poor rural and urban living standards.

Total fertility rate

Total fertility rate is a measure of family size. As a rule, the more economically developed a country, the lower its birth rate and family size. The UK statistic of 1.9 children per woman is similar to most countries in the table, suggesting Caribbean parents now favour the economic benefits of smaller families.

Net migration rate

All the countries in the table show a negative migration balance, that is, more people are emigrating than are immigrating. Better educated young adults may see more opportunities in the most highly developed nations, especially the USA and the UK. Sometimes people choose to return to their original country for retirement.

Government policy

Caribbean governments' policies have long been in favour of supporting and giving access to contraceptive facilities. Contraception has been available in state-run hospitals and clinics across the region since the 1970s. High population growth limits development potential, plus governments accept the need for families to decide on the number and the spacing of their children.

On the other hand, some Caribbean countries still have a youthful age structure and teenage fertility (teenage pregnancy rate) is relatively high. Family planning services are therefore not always being utilised. On Sunday 18 October 2015 the *Jamaica Observer* reported that:

'Jamaica's teen pregnancy rate is the fourth highest in the region despite gains in lowering the fertility rate among the demographic, according to the 2013 State of the World Population Report which turns the spotlight on girls who become mothers before their 18th birthday.

With a birth rate of 72 per 1000 adolescent girls, Jamaica lags only behind Belize, 90, Guyana, 97, and the Dominica Republic that, with a rate of 98 per 1000 teens, is the highest in the region. Rounding off the top five is St Vincent and the Grenadines with a rate of 70.'

Activities

1 Write out clearly the definitions of *birth rate, death rate, natural change, natural increase* and *natural decrease*. Make sure you keep these in your notes. Learn them and revise them regularly.

2 Do the same for *infant* and *child mortality rates* and *life expectancy*.

3 Write down an explanation of the method for calculating natural increase and natural decrease.

4 Why do most countries today have natural increase, but only a few experience natural decrease?

Table 9.1 A summary of key population data for a selection of Caribbean nations (2014)

Country	Life expectancy (in years from birth)	Infant mortality rate (deaths/1000 live births)	Total fertility rate (number of children born/ woman)	Net migration rate (number of people migrating in (+) or out (–) /1000 population
Barbados	75.0	10.9	1.7	–0.3
St Vincent and the Grenadines	74.9	13.1	1.8	–9.6
Jamaica	73.5	13.7	2.1	–4.8
Trinidad and Tobago	72.3	24.8	1.7	–6.8
Haiti	63.2	49.4	2.8	–4.1

The demographic transition model

How this theory works

Figure 9.7 shows the **demographic transition model** (DTM), or **population cycle**. This is an explanation of the patterns of birth and death rates over time, including the period of a country's major economic development. It is divided into five stages during which there is a change from a situation of high BR and DR to low rates. There is also a change from BR always being higher than DR to BR being so low it is below the DR (*Figure 9.7,* Stage 5).

Originally the model was designed to explain patterns in the developed countries but it can also apply quite well to today's developing regions of the world.

Stage 1 Known as the 'high fluctuating' stage, this stage has high BR and DR. It refers to a simpler society than we find today, with little medicine, a low life expectancy and no means of birth control. The only places where this stage still applies might be among indigenous people in remote rainforests in Amazonia or Indonesia, but even they now have some influence from the outside world.

Stage 2 The key characteristic of Stage 2 is a decreasing DR. Medical improvements and technology allow many illnesses to be cured. Life is still traditional, however, and there are still good economic reasons for the BR to stay high. The gap between the BR and DR lines on the graph (*Figure 9.7*) represents population growth. The farther apart these lines are, the greater the growth.

Stage 3 Here, DR continues to fall, but at a more gradual rate. The key change is that BR now falls, and often quite rapidly. This is due to the availability of birth control methods, but people must have an economic reason for desiring birth control. As a country develops, children become economic costs rather than economic assets. When children can work and earn they bring money into the family, but when they have to go to school (which may cost the family money) they can contribute less. It therefore becomes cost-effective to have fewer children.

Stage 4 BR and DR are now both low. The lines on the graph are close to each other and BR is still higher than DR, so there is still

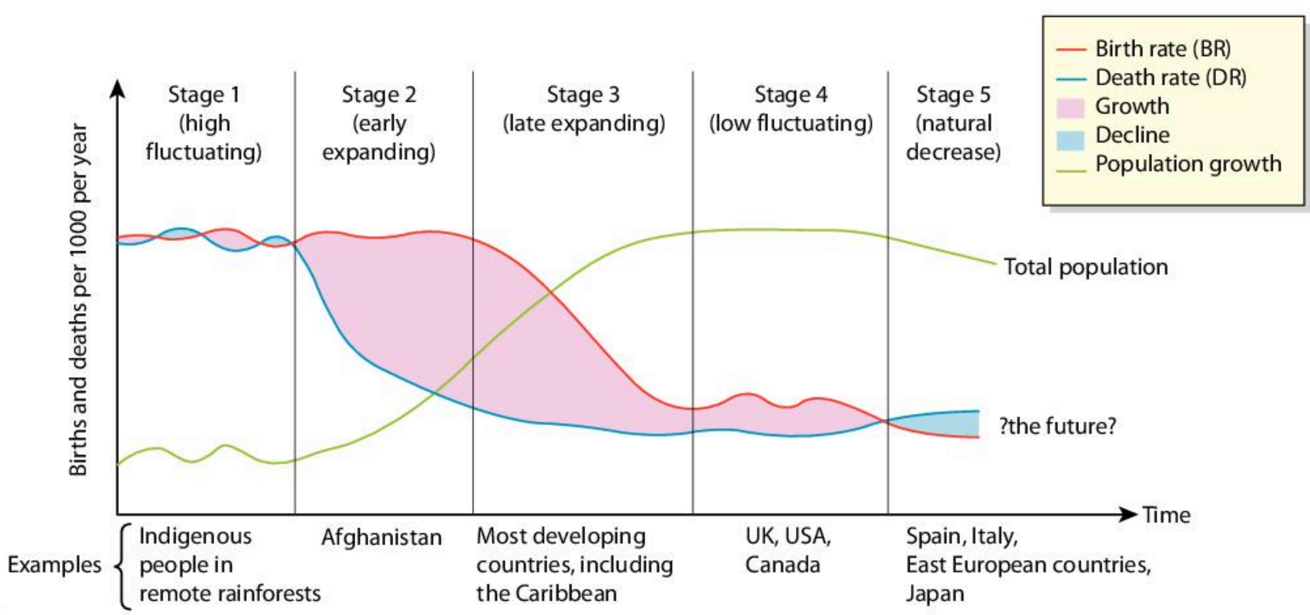


Figure 9.7 The demographic transition model of population change

population growth but it is slow. A country in this stage is developed and there are several reasons for having only a small family (see page 195).

Stage 5 The original DTM did not include this stage. It was added later to try to explain recent demographic changes in some developed countries where, for the first time in human history, BR is less than DR. More people are dying than are born each year. The reasons for this are explained on page 188. Many Eastern European countries and some western European states are now in this situation.

Activities

1. *Figure 9.7* gives examples of countries in each of the DTM stages. Suggest two more countries for each stage.
2. Why is Stage 1 of the DTM in reality a thing of the past?
3. What is likely to happen to the number of countries in Stage 5 in the near future?
4. Do you think the Caribbean countries will ever enter Stage 5? Give your reasons. (Hint: There is no right or wrong answer here; make your own decision and justify it.)

The position of the Caribbean in the DTM

Demographically, as a region the Caribbean is between Stages 3 and 4 of the Demographic Transition Model.

The region is still developing economically to some extent, and DR has been low for many years. Figure 9.7 shows Caribbean death rates lower than that of the UK with its ageing population. Stage 3 and 4 countries have low death rates.

Birth rate data for St Vincent and the Grenadines, Trinidad and Tobago and Barbados show Stage 4 levels, close to the UK figure, whilst Jamaica and Haiti's data are higher, reflecting Stage 3. The tertiary (services) sector (see Chapter 11) is growing and provides work for many in the region, a sign of continuing economic development.

Improvements in education give the next generation, boys and girls, more opportunities and will place the Caribbean countries in a situation where there is no economic need for larger families. *Table 9.2* shows that this change is underway.

The J-curve and the S-curve

Global population growth (or the growth of an individual country) can be represented by a line graph. The J-curve (*Figure 9.8*) shows gradual growth at the start and then growth rates increase until that growth becomes exponential (i.e. faster and faster and the graph becomes consistently steeper).

Table 9.2

Country	Birth rate – number of babies born/1000 population/year	Death rate – number of people dying/1000 population/year
Haiti	22.3	7.9
Jamaica	18.4	6.7
St Vincent and the Grenadines	13.9	7.1
Trinidad and Tobago	13.8	8.5
Barbados	12.0	8.4
UK, for comparison	12.2	9.3

Countries in Stages 2 and 3 of the Demographic Transition Model form this shape of graph. MEDCs behaved like this in the 19th and early 20th centuries. LEDCs have experienced this in the second half of the 20th century.

An S-curve (*Figure 9.8*) begins as a J-curve, but after rapid growth the birth rate falls sufficiently for the gradient of the curve to decrease. Eventually, the graph levels off to show zero growth (i.e. BR = DR, so no growth at all). Countries in Stage 4 of the DTM show this pattern.

World population is estimated to stop growing by the year 2150, when the total will be 10 billion.

Activities

Go through the stages of the Demographic Transition Model and say which part of the J or S curve is represented. (For example, Stage 1 of the DTM has both high BR and DR. The lines are close together on the graph and so NC is limited. BR > DR, therefore NC is NI.)

Explain your answer for each stage, as in the example above.

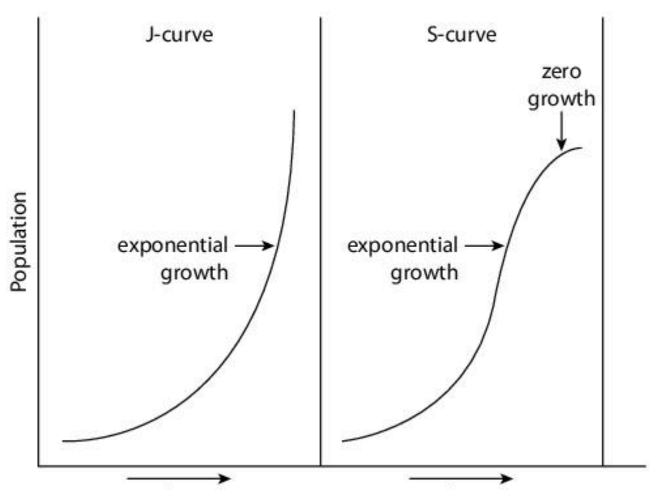


Figure 9.8 The J-curve and the S-curve

Reasons for higher birth rates in LEDCs

Hardly any part of the world does not have access to birth control today, only the most remote regions like Amazonia. In some cultures the position of women and traditional life make birth control less acceptable such as Afghanistan, which still has one of the world's highest birth rates of 38.84/1000/year. Lack of education may mean people have difficulty accepting new ideas.

Religion has also had an impact on the acceptance of birth control. The Roman Catholic faith does not agree with birth control, so Catholic countries have traditionally had larger families. This is still true in Catholic LEDCs but in MEDCs, where people have more economic choices, birth control is used and the birth rate has decreased. In Spain and Italy, for example, birth rate is now very low (1.5 children/family). In some Muslim societies the position of women is low and this encourages a high birth rate, though there is no basis for this in the Koran. Girls tend to marry young so there is a longer period in which to have children.

People's attitudes are shaped by their experience. In the past, many babies and children did die, so families were larger so that some children survived. In a peasant farming society children are needed to work on the land; they can produce more food than they eat. Even in the cities children are able to earn some money to supplement the family's income. Secondary school is not compulsory everywhere, though primary school usually is.

Some cultures prefer sons to daughters. Several children may be born to ensure at least two sons. In India, for example, a bride must bring a dowry (a payment at marriage) to her new husband's family. It is therefore expensive to have daughters. Sons also carry on the family name; if you produce only daughters, the name will die out.

This is particularly important in China. LEDCs have little state care for the elderly. Parents expect their children to look after them in their old age. This is not only a reason for having a larger family, but also for having sons, as a man is in charge of his household, not his wife. A man is more able to care for elderly parents financially. There are few pensions or services for the elderly in LEDCs. However, daughters-in-law often bear the burden of personal care for the elderly parents. People must rely on their families.

Reasons for low birth rates in MEDCs

Two factors are important in reducing the birth rate as a country develops. In an MEDC, education is compulsory for boys and girls until the age of at least 16, or higher, and many continue their education at university. Marriage is therefore later. Women have the chance to develop a career. They therefore choose to have children later or even not to have any at all. Most women have to work outside the home. It takes two incomes to buy a house and look after a family. A working mother with limited time is likely to choose a smaller family.

Children are also expensive. They cannot go out and earn money for the family but it costs a good deal to bring them up in a country with a high standard of living. People prefer to have one, two or three children and give each as much as they can afford, rather than dividing the family resources between more children.

Activities

1 Make two lists, one of the reasons LEDC families are larger than those in MEDCs, and another of the reasons for the very low birth rate in many MEDCs.

2 Will LEDCs follow MEDCs in reducing their birth rates? Give reasons for your answer. (Hint: There is no right or wrong answer here; the marks are given for the reasons.)

Case Study

The Chinese 'one child' policy

During the 1970s, the Chinese government had a severe population crisis: growth was so rapid that the country would soon face famine conditions, as had happened in the past. The 'one child' policy was therefore imposed on the Chinese people, beginning in 1980.

To some extent, the policy was not as harsh as it seemed – not everyone was limited to having only one child. Rural people, 53% of the population, were allowed a second child if their first was a girl, since boys were regarded as more useful for farm labour. Ethnic minorities, about 11% of the population, were exempt too, to preserve these groups' existence.

The policy for everyone else was not as simple as one-child-per-couple as is generally believed; it was really one successful pregnancy, and if that produced twins, triplets or more children, the parents were not penalised, rather they were considered very lucky. Parents with a disabled child were allowed to try again for a healthy child.

The policy was controversial and much criticised abroad:

- Over 15 million healthy girls were abandoned and left at orphanages. There was a demand from Europe and the USA to adopt girls from Chinese orphanages. Other daughters were even left out to die as if they had never existed, to allow the parents a second chance to have a son. Sons carry on the family name and have greater economic means to look after their elderly parents.
- Women who tried to keep a second pregnancy secret were often forced to have very late abortions when the baby was sufficiently developed to live outside the womb.
- Many women were sterilised after their first child was born without their permission. The impact of this was understood after the 2008 Sichuan earthquake in which many children died in collapsing school buildings. Their sterilised mothers had no chance of having another child.
- Salary cuts were imposed on those disobeying the rules.
- Illegal second children had no rights to healthcare, education or Chinese citizenship.
- Wealthier urban parents could pay a fine and have another child.
- The preference for boys led to a serious gender imbalance with many future consequences. Aborting a fetus after the gender was determined by scan to be female (although illegal) became increasingly common. There are now 117 boys for every 100 girls, leading to 30 million more young men than young women by 2020. Marriage is very important in Chinese society but this means many 'spare' men, and this could increase social instability and the crime rate.
- 'Little Emperor' syndrome – an only child is often spoiled, given everything he/she wants; this did become an issue when these children grew up lacking self-discipline.
- The '4-2-1 problem' – adult children look after parents and even grandparents, but, under the one child policy, two sets of grandparents have produced two parents who then have one child. That child is expected to physically and financially look after six older family members (two parents and four grandparents). Many are unable to cope, and the state has an increasing problem of financing and caring for a growing elderly population, as in the developed world.

There are also positive consequences, including:

- 250 million children were not born because of the policy, leading to the population growth rate reducing and the fertility rate decreasing to 1.4 children per woman, down from 2.8 children per woman in 1979.
- Boys were always favoured in China but, since an only child is very precious whatever their gender, girls have become more valued in Chinese society.

1 Explain what is controversial about the Chinese 'one child' policy.

2 Do you think the policy has been successful? Give your reasons.

Figure 9.10 A 'single' Chinese son

Population structure

Age structure shows the proportions of each age group within a country's population. This varies between developing countries and developed countries and within a country as it develops over time. **Gender structure** – the balance between males and females – is also important. Small differences here can tell us a lot about a country.

Population pyramids

A **population pyramid** is a bar graph diagram used to show the age and gender structure of the population of a country, city or other area. The horizontal axis is divided into either numbers or percentages. The central vertical axis is divided into age categories, either every ten years, every five years, or every one year. The lower part of the pyramid is the base and shows the younger section of the population. The upper part is concerned with the elderly group. Pyramids give us a remarkable amount of information about a population: birth and death rates, life expectancy, and the level of economic development (or stage of the DTM) (*Figure 9.11*).

The effects on a country of having a young population

The whole of Africa (except South Africa), most of South America, India and its neighbours, Mongolia and North and South Korea have over 40 percent of their people under the age of 15 years (*Figure 9.12*). This places very specific demands on the governments of these countries.

Whilst there are so many children in the population, more of the services they require will have to be provided: schools, baby clinics, vaccinations. Countries with the highest percentages of children are generally the ones that do not have the funds and so cannot supply these for their population.

As this generation grows up, some will take up places at university and in other training. They will need jobs and homes. They will begin to have their own children and, as a large generation themselves, they are likely to produce an even larger generation following them. A large family is a financial burden, so these households will find it difficult to progress economically.

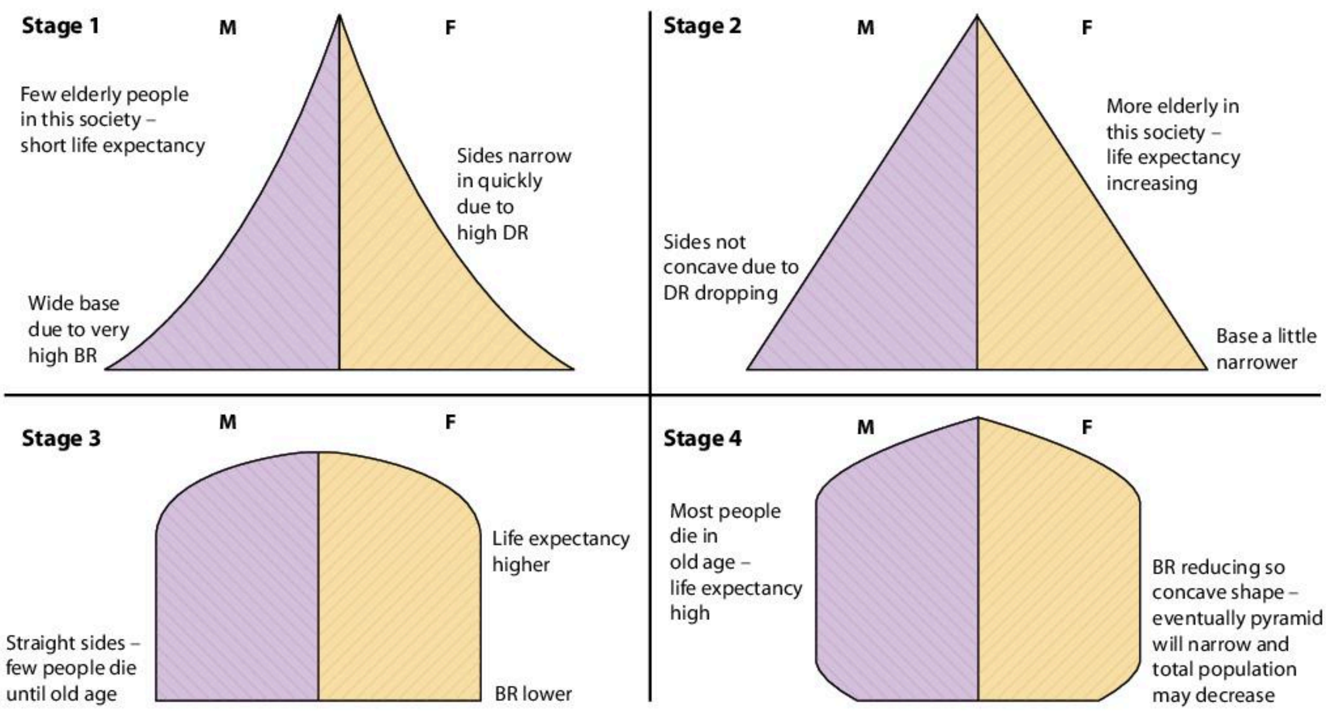


Figure 9.11 Population pyramids and the DTM

In contrast, however, it can be argued that a growing population needs services and so provides more jobs that need to be filled. Eventually more money is generated. However, there are few examples of this. Improvements tend to come when the birth rate declines and families are less pressured.

The effects on a country of having an elderly population

Life expectancy is higher in developed countries than in developing countries, so it is the developed countries that have the difficulties associated with old age. In richer countries people expect to be able to retire from work and have a pension (income) on which to live. Funds for this come from the government, from taxes paid by those of working age. If the elderly become a larger part of the population while the working age group becomes smaller, then taxes will increase and pensions and standards of living may go down.

The demand for healthcare increases because more illness occurs in old age. As people live longer and longer, even greater pressure is placed on the system. The government has to find more funds, again from taxation of present workers.

Elderly people need certain services in particular: nursing homes, day care centres and people to assist the elderly in their own homes. These special needs also put financial pressure on a country.

Activities

1 Which type of country generally has:
   a a young population
   b an elderly population?
2 Discuss the differences between the demands made on the government of these different groups of countries.

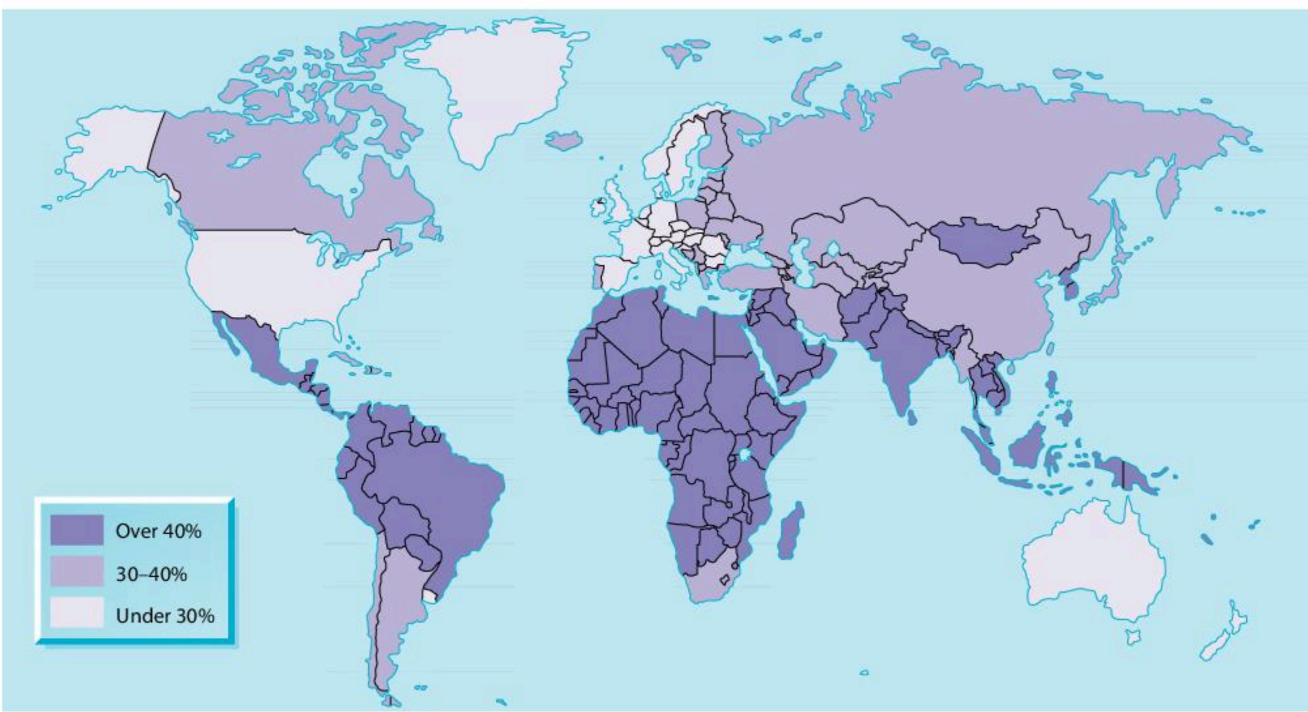


Figure 9.12 World population under 15 years

Case Study

Montserrat population structure

Population structure shows the age distribution within a population, plus the gender balance. Structure varies between LEDCs and MEDCs, changing over time as a country develops economically and socially. Small differences indicate key changes in a country's development.

Montserrat is a good example of these demographic (population) changes, with a particularly interesting population pyramid during the 20 years from 1997. This was the date of the Souffrière Hills volcanic event. In the short term, the capital, Plymouth, was devastated and the whole southern half of the island quickly became uninhabitable. Residents had a simple choice: they could either move to the north of the island, or leave Montserrat altogether. The UK offered a place of sanctuary, and many took advantage of this. In some cases children were sent away to stay with family members abroad.

Some emigrants have returned, but the risk is by no means over. By 2025 the population pyramid bars are expected to be successively wider. Hopefully, this will be based on improved economic development.

Montserrat population – key years:

Year	Population
1997	8,300
2003	4,600
2011	5,000
February 2016	5,147

Source: http://en.wikipedia.org/wiki/Demographic_of_Montserrat
countrymeters.info/en/Montserrat

Skills

Population pyramids

A population pyramid is a type of bar graph. It is rather different from most bar graphs that you see because its vertical axis is central, rather than at the left hand side. Look back at page 196 and read again about population pyramids. Answer the questions below:

1 How are the two axes of a population pyramid labelled?

2 Why is the vertical axis in the centre and not at the left hand side?

3 What is the difference in level of detail and accuracy between a pyramid showing data for every year group and one using age bands of ten years?

4 What are the advantages and disadvantages of each of these approaches?

5 *Figure 9.15* shows the 2000 pyramids for St Kitts and Nevis and the United Kingdom. For each one:

- a Make a copy. Label as many descriptive details as you can.
- b Write a paragraph to identify the differences and similarities between your two diagrams.
- c Explain the two shapes.

Figures 9.13 and *9.14* show three pyramids each, over time, for Montserrat and Japan. The questions below will help you identify what happens to a pyramid shape as a country moves through the DTM and develops economically.

Montserrat's population was only 5215 people in 2014 after around 8000 had left after the Souffriere Hills volcanic eruptions. This information will help you answer the following questions.

6 Describe the shape of the year 2000 pyramid.

7 Why do you think the age groups from age 45 upward are so small in number?

8 Suggest reasons why the number of 40–55 year olds in 2025 is predicted to be larger than the number of 15–30 year olds in 2000.

9 If Montserrat does have a pyramid shaped graph like *Figure 9.13c* by 2050, what does that suggest has happened to the economy and development of the island?

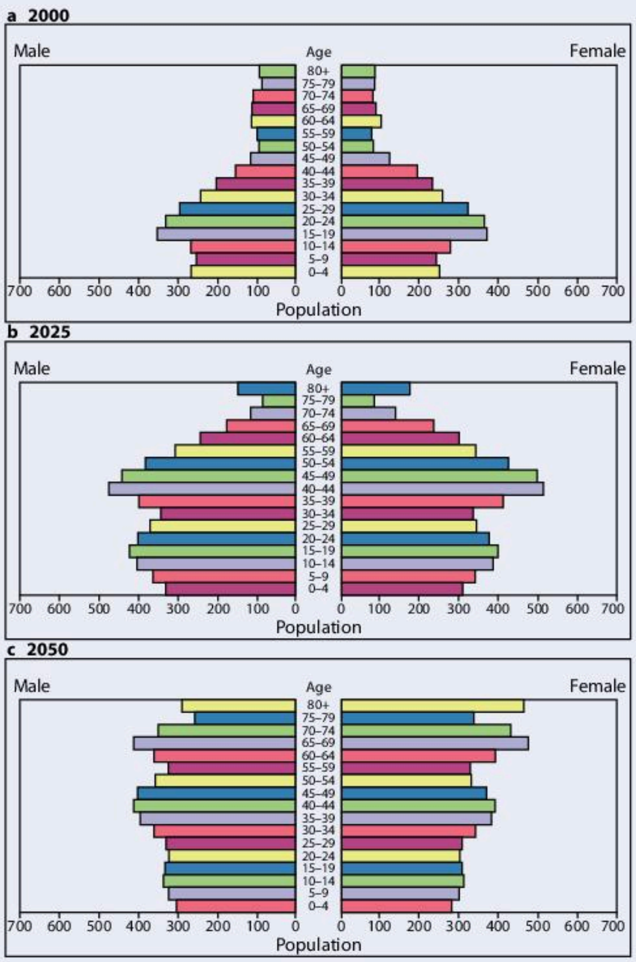


Figure 9.13 Population pyramids for Montserrat: 2000, 2025 and 2050

Source: US Census Bureau, International Database

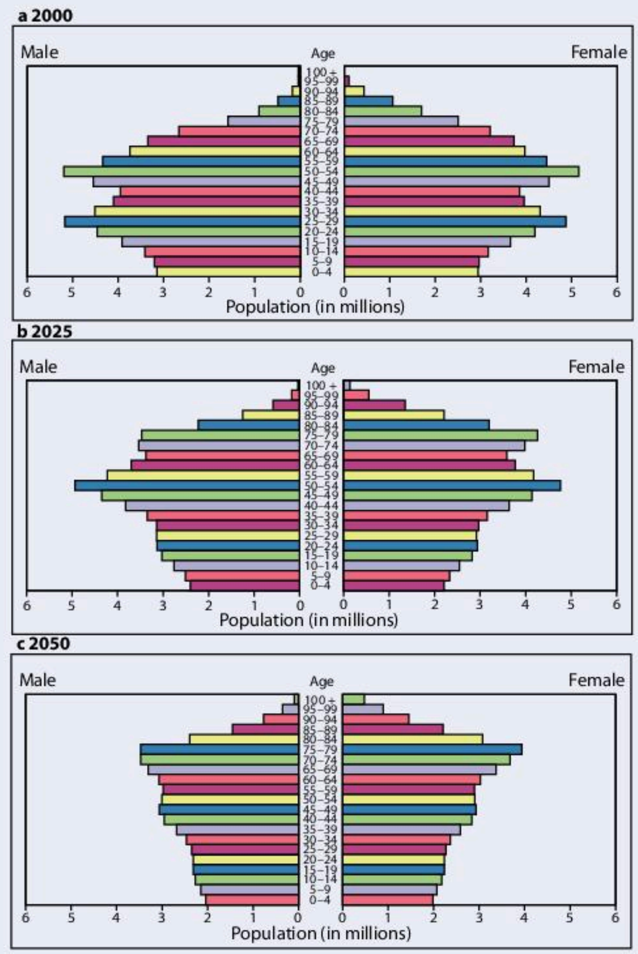


Figure 9.14 Population pyramids for Japan: 2000, 2025 and 2050

Source: US Census Bureau, International Database

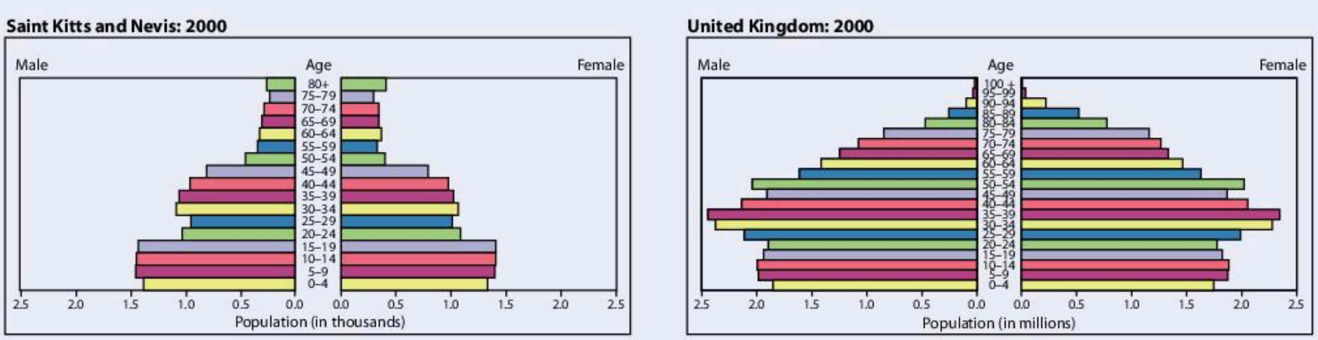


Figure 9.15 Population pyramids for St Kitts and Nevis and the UK, 2000

Source: US Census Bureau, International Database

Case Studies

Jamaica population

Table 9.3 Jamaica: facts and figures

Size	east–west 250 km north–south 90 km
Area	10 990 km^2
Population (2000): (2004):	2 680 000 2 672 000
Density (2014): 2 930 050	243 people/km^2
Natural increase 1985–2000	0.8%/year
Predicted NI (2000–2015) (2014)	0.4%/year 0.69%/year
Life expectancy (2014)	73.5 years
% urban (2010)	52
% rural (2010)	48

Source: Jamaica population census 2001

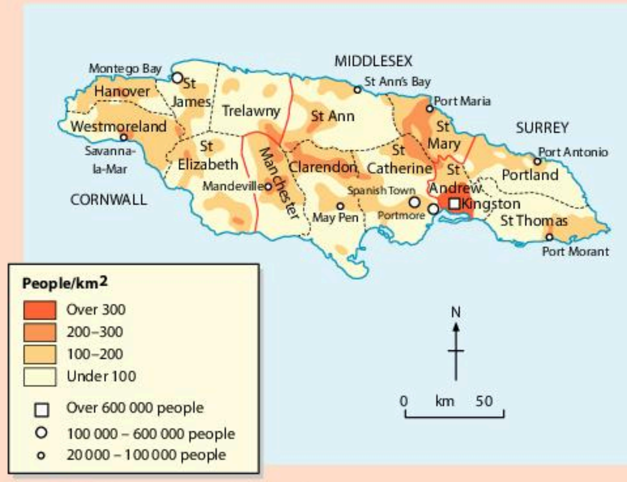


Figure 9.16 Jamaica: population density

Population distribution

Jamaica's main settlements are all on or close to the coast. To a large extent this is explained by relief. The highest point on the island is Blue Mountain Peak (2256 metres) and the Blue Mountains certainly repel population. *Figure 9.17* shows a large yellow area in the parishes of St Thomas and Portland where density is below 100 people/km^2, and this corresponds with the mountain range. Surrey is the county with the greatest variations in both density and relief. Surrey (St Andrew Parish) includes the city of Kingston (population 575 000) and its spreading suburbs, which appear on *Figure 9.16* in brown representing over 300 people/km^2. This urban zone lies on the coastal plain between the mountains and the sea.

The other two main towns on the island, Portmore (102 000) and Spanish Town (127 300), lie close to Kingston, just to the west into Middlesex County. Portmore is coastal but Spanish Town lies about 10 km inland, but still on the coastal plain. At the opposite end of the island is the other large urban area, Montego Bay (90 500), in St James Parish, Cornwall. This is another coastal site.

Outside the cities, towns and areas of denser rural settlement lie either on the coastal plain or within valleys. St Ann's Bay, Port Maria, Port Antonio, Port Morant and Savanna-la-Mar, with populations between 20 000 and 100 000 people, are all coastal. May Pen is at a key confluence in the Milk River Basin and Mandeville lies higher up this basin on the edge of the May Day Mountains at around 1000 metres above sea level. It is the highest larger settlement on the island.

Kingston/St Andrew is by far the most populous parish with a quarter of the whole Jamaican population in 2001 (*Figure 9.18*). St Catherine follows, not surprisingly as it includes both Spanish Town and Portmore. Clarendon is the third largest parish today in terms of population. Although May Pen, one of the smaller towns, is its largest settlement, Clarendon has a denser rural population well

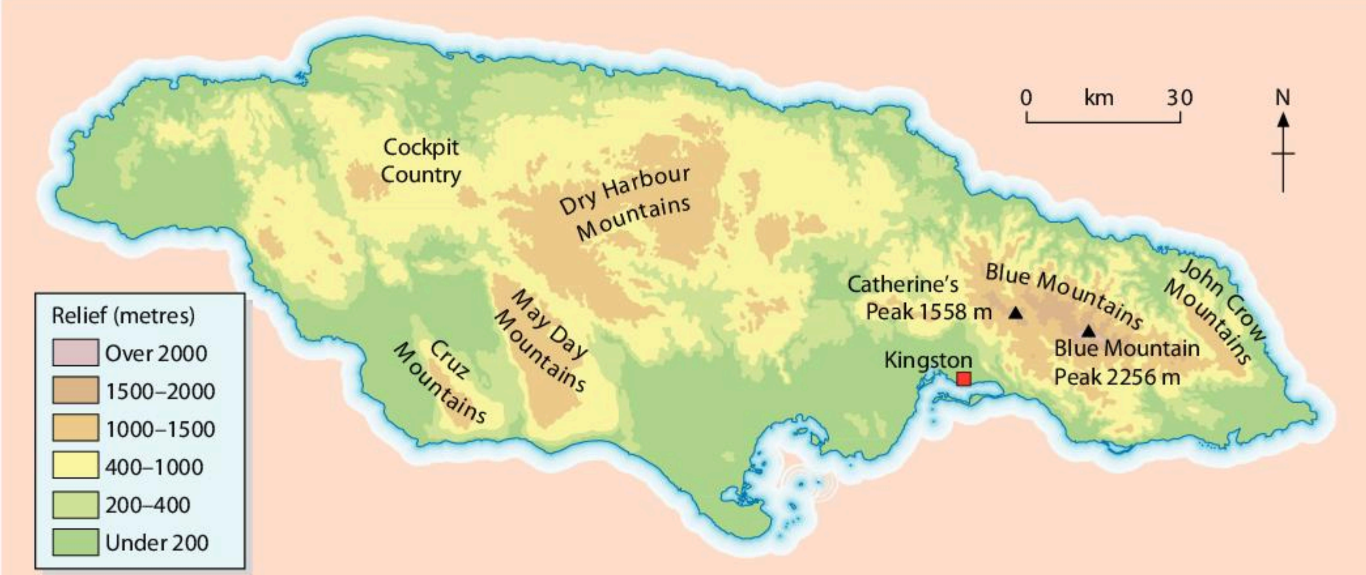


Figure 9.17 Jamaica: relief

inland in the Rio Minho valley. Manchester Parish includes Mandeville and the upper part of one branch of the Milk Valley, another relatively densely populated rural area. St James is the next most populated parish but only because Montego Bay is located there.

1 To what extent are the more densely populated parts of Jamaica on the lower-lying land? Why do you think this is so? What are the characteristics of coasts, coastal plains and river basins that attract the Jamaican population to live in these areas?

2 Explain the location of Kingston. Why should this site have led to the development of the largest settlement on Jamaica?

Population growth 1950–2000

Between 1950 and 2000, in just 50 years, Jamaica's population rose from 1.4 million to almost 2.7 million. This is almost a doubling of the population – but the situation is not as simple as it might seem. Within that period there was a great deal of emigration from Jamaica, mostly to the UK. In the 1950s Jamaica was in Stage 2 of the DTM but since then it has developed through to the end of Stage 3. The DR has decreased significantly and BR is also dropping. A rate of natural increase of only 0.8 percent is low for a developing country and it is predicted to continue to fall (*Figure 9.18*).

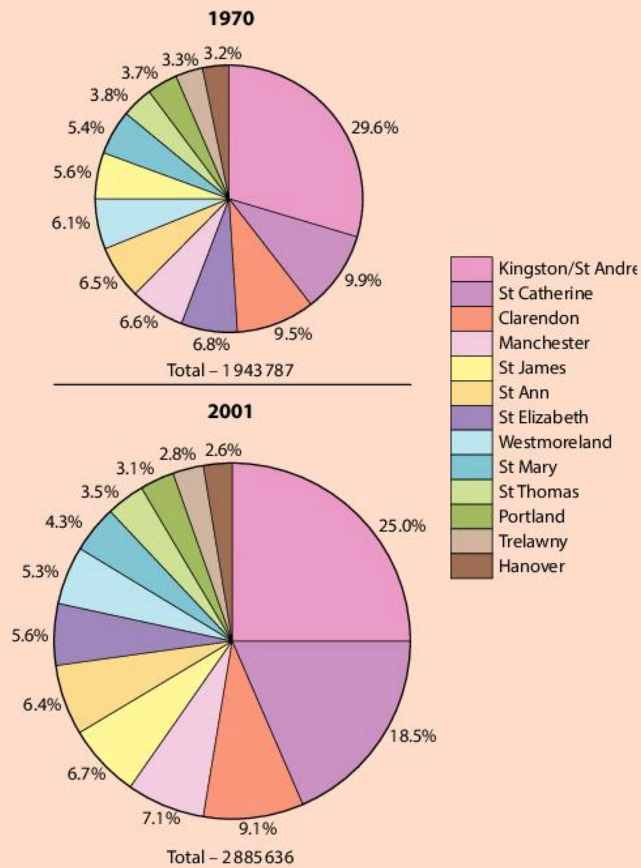


Figure 9.18 Jamaica population: total and by parish, 1970 and 2001

Source: Jamaica population census figures

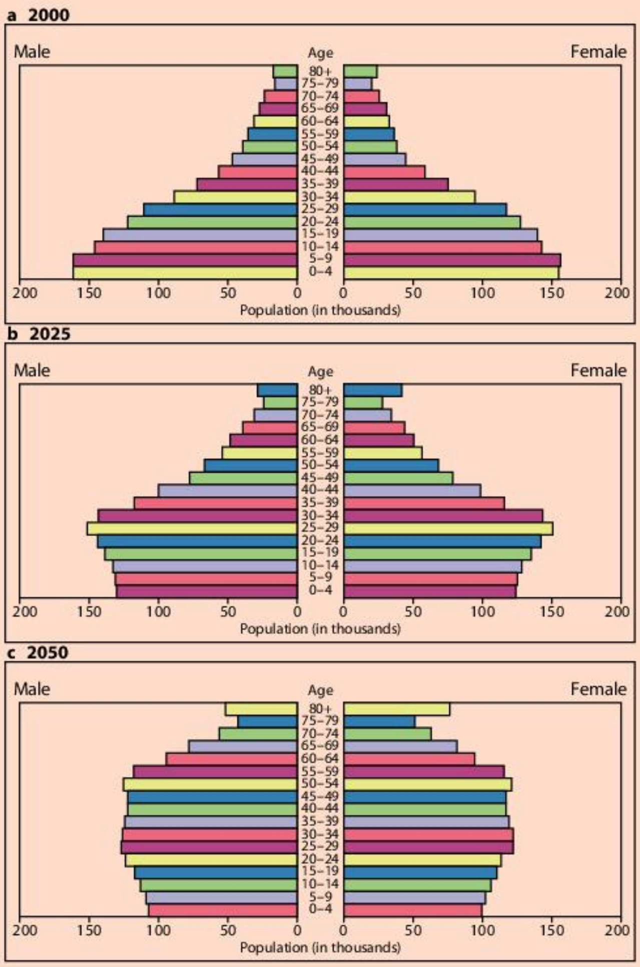


Figure 9.19 Population pyramids for Jamaica: 2000, 2025 and 2050

Source: US Census Bureau, International Database

The population pyramid for 2000 (*Figure 9.19a*) shows the typical structure for a developing country, with a wide base and rapidly narrowing sides. From the age of 35 upward the age groups are much smaller than those below. The impact of emigration on this section of the population cannot be underestimated. Migrants tend to be young adults and young families. Many in these age groups went to the UK, especially in the 1950s and 1960s. Jamaicans now in their forties and over would otherwise have been a larger sector of the population on the island. Emigration is still a significant factor. The island's population fell from 2680000 to 2672000 (that is, by 8000) in just four years, but the 2007 estimate showed a rise back up to 2780132, and then up to 2930050 by 2014.

The predicted population pyramid for 2025 (*Figure 9.19b*) shows a clear reduction in the birth rate as the base narrows. From the age of 24 downward each five-year group becomes smaller and smaller. This is a typical Stage 3 pyramid with a narrowing base. By 2050 (*Figure 9.19c*) the pattern shows a clearly ageing population, with much straighter sides. The consequences for Jamaica will be dramatic, as in the UK today! The next generation of young Jamaicans will have to do what the present equivalent generation are coping with today in developed countries: a smaller group will be paying higher taxes to maintain the elderly above them in the pyramid.

3 Describe the shape of each of the pyramids for Jamaica in *Figure 9.19*, noting the differences between them.

4 What are the main reasons for the suggested changes in shape of the pyramids between 2000 and 2050?

5 Describe Jamaica's progress through the DTM Stages 2–4.

6 What economic and social factors have encouraged these changes?

Changes in the urban and rural population, 1950–2000

Figure 9.20 represents the change in the urban–rural balance of the population of Jamaica between 1950 and 2000. The total population has increased but the urban–rural balance shows a greater variation. In 1950 urban dwellers were less than one-third of the total population, but by 2000 urban residents were over half of Jamaica's population. Urbanisation is a global trend and is linked with the economic development of a country. Primary industry (farming, mining etc.) tends to spread people out over an area but numbers employed in this sector in Jamaica have been falling. As people move into the developing tertiary sector they need to move to towns and cities to find work. Services based around tourism and serving the island community have expanded to employ 59 percent in 2001.

Agriculture, forestry, fishing and mining employ 19 percent of Jamaica's working population.

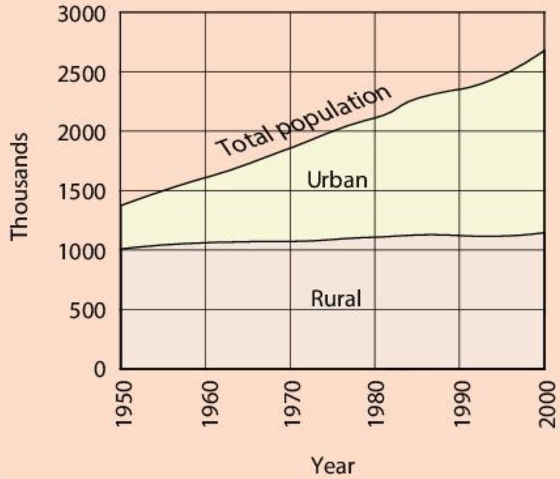


Figure 9.20 Urban–rural balance in Jamaica, 1950–2000

Race and ethnicity in Jamaica

Afro-descendants make up 90.9 percent of Jamaica's population. There are also people from the Indian subcontinent, Chinese and Europeans. **Indigenous peoples** (the earlier inhabitants of the island) still make up a small proportion of the population. They are Tainos, Jamaica's first inhabitants. They travelled by raft from Guyana about 700 BC, island-hopping up the Antilles to Jamaica. The name 'Jamaica' comes from their original name, *Xamayca*.

Children in Jamaica

Of the more than 2.9 million people living in Jamaica, 28 percent are children, but they account for more than 16.5% of people living below the poverty line (The CIA World Factbook, 2015). By 2000, enrolment in primary school was high – 95 percent for both boys and girls. However, by the end of primary school 30 percent of these children, mostly boys, still cannot read and write adequately. Only 3.6 percent of Jamaican 0–3 year-olds are lucky enough to attend a pre-school or a playgroup, which always gives a good start into primary school. About 38 516 children (6% in 2005) work and 2500 are children are forced to live on the streets (these are mostly boys).

HIV and AIDS rates are quite high in Jamaica (1.7 percent of those aged 15–49 in 2005). Of the total affected, 8 percent are children under 10 years of age; 80 percent of these affected children are from poor households, and one in four will be abandoned by their parents.

Figure 9.21 Children of Jamaica

Women in Jamaica

In 2015 women made up 9 percent of Members of the Jamaican Parliament, and held some government ministerial jobs.

Figure 9.22 Women have many roles

Illiteracy rates (inability to read and write) are low: 9 percent for females over 15 years of age. Women make up 48 percent of the total workforce of 1 million, but there is a female unemployment rate of 22 percent. Of those in work, most are in the service sector (81 percent), with 10 percent in agriculture and 9 percent in manufacturing.

7 What are the factors that attract people to live in Jamaica's urban areas? (Hint: Think about all aspects of work, education, health and other services.)

8 What effect will more women working (and in higher-level jobs) have on Jamaica's birth rate? Give reasons for your answer.

9 How does your answer to activity 2 link with Jamaica's progress through the DTM?

Trinidad and Tobago population

Population distribution

Trinidad and Tobago is similar in population density to Jamaica: 255.9 people/km^2 compared with 243.9. However, the distribution patterns are rather different. Trinidad is much less evenly populated than Jamaica. The western side of both Trinidad and Tobago is much more densely populated than the eastern side.

To some extent, as in Jamaica, high land repels settlement. The high Northern Range of Trinidad is a relatively empty area, as are the Central Range and Montserrat Hills (*Figure 9.23*). Equally, there are low-lying areas with low population densities. In the south of Trinidad, eastern Victoria and the whole of Mayaro there are fewer than 100 people/km^2. These are large, low-lying areas with relatively high rainfall (*Figure 9.24*) and largely forested. The whole of the northern and southern coastlines of Trinidad are relatively unpopulated.

Table 9.4 Trinidad and Tobago: facts and figures

Size: Trinidad:	north–south 90 km east–west 42 km
Tobago:	long axis, south-west to north-east 113 km central, widest point 13 km
Area (for both islands together)	5130 km^2
Population (2004)	1 312 854
Density	255.9 people/km^2
Natural increase 1985–2000	0.6%/year
Predicted NI 2000–2015	0.3%/year
Life expectancy	70 years
% urban (2000)	71.2
% rural (2000)	28.8

Source: Trinidad and Tobago population census 2000

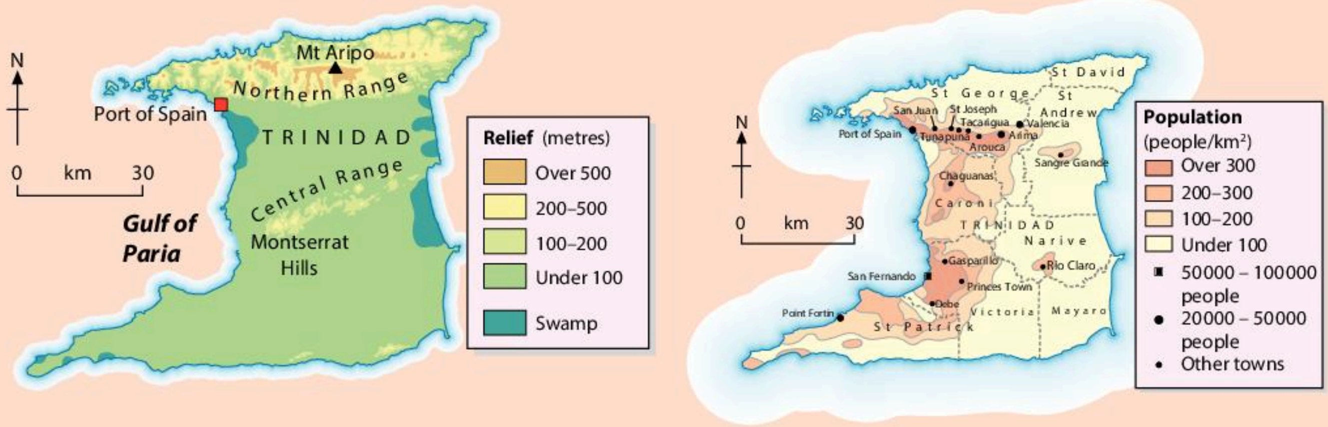


Figure 9.23 Trinidad and Tobago: population density and relief

The key zone for settlement is the Gulf of Paria coast and valleys leading toward it. These are favoured areas climatically, protected from the prevailing winds and with low rainfall. These areas are agriculturally productive: sugar cane, cocoa, rice and cattle are farmed intensively, providing jobs not only in farming but also in food processing, transport and export.

A key axis of settlement is from the capital, Port of Spain (population 49 031) inland to Valencia. Included in this sector is Arima, almost as large as Port of Spain, and several towns of between 20 000 and 50 000. On *Figure 9.23* dark shading representing over 300 people/km^2 shows this axis of settlement.

San Fernando, though not the capital, is the largest town on Trinidad, with 55 419 inhabitants. It lies at the southern end of the Gulf of Paria, surrounded by sugar cane producing areas. In contrast, eastern Trinidad has different negative landscape characteristics. Swamps occupy many lower valleys. Some parts are given over to agriculture, with which dense settlement cannot co-exist.

Tobago's population is concentrated around the town of Scarborough. The darker shading on *Figure 9.23* spreads outward from that point, becoming gradually lower in density. Main Ridge, the main line of hills on the island, accounts for the large area in the north and east of the island with a population density of less than 100/km^2. This is primarily a forested zone. The coastal plain is densely cultivated with coconuts, cocoa and other crops. Not only does relief and fertility here encourage these activities, it is by far the easiest land to build on.

1 Identify the factors affecting population distribution on Trinidad and Tobago.

2 To what extent are these factors **a** similar to and **b** different from those affecting the population distribution on Jamaica?

3 Are physical or human/economic factors more important in settlement location on these Caribbean islands? Give evidence for your decision.

Population growth

There was a clear decrease in Trinidad and Tobago's BR from 1985 onward. *Figure 9.25* shows a steady decrease from one five-year age group to the next in the four lowest age groups:

15–19 = 130 000

10–14 = 117 000

5–9 = 92 000

0–4 = 78 000.

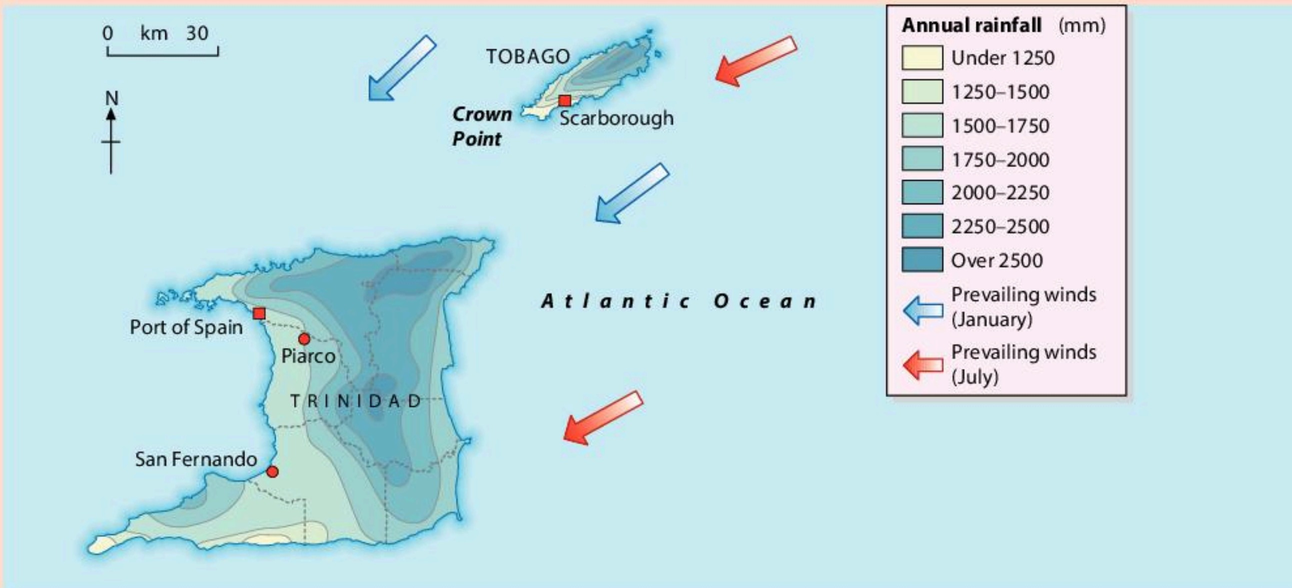


Figure 9.24 Trinidad and Tobago: rainfall and prevailing winds

The changes in the predicted age structure for Trinidad and Tobago are even sharper than those for Jamaica. By 2050 the pyramid is a 'reverse' shape; it is top heavy because as a general rule there are more people in each older group than in the five-year band below it. The young adults of 2050 will have a huge tax burden to bear. There will be more elderly than young and services will either have to be paid for out of the working population's taxes or the quality of services will decline.

The 15–19 age group in the 2000 pyramid become the 40–44 year-olds in 2025. By 2050 they will be aged 65–69. Look at the three pyramids together. What happens to this group? Clearly, their numbers are reducing. This is not just because some people die; Trinidad and Tobago's death rate is low and is likely to stay that way. Emigration is still a factor affecting the population size of these islands. It particularly helps to explain the reduction in the number of people between the years 2000 and 2025. Younger adults are the group most likely to migrate.

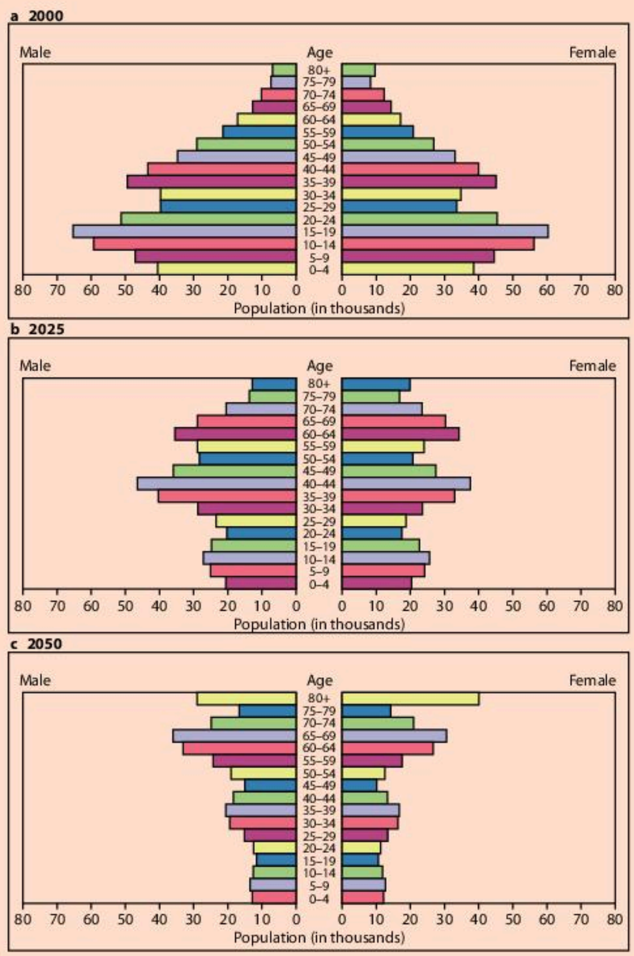


Figure 9.25 Trinidad and Tobago: population pyramids 2000–2050

Source: US Census Bureau International Database

Urban–rural population: change 1950–2000

Trinidad and Tobago is a relatively urbanised country when compared with the Caribbean as a whole, and particularly when compared with Jamaica. In 1950 a little over one-third of the national population of just over 600 000 lived in the countryside. This is a very low proportion for that time, when the majority of Caribbean people were rural-based rather than living in towns or cities. Both urban and rural populations in Trinidad and Tobago grew until 1985. Between 1985 and 2000, as population increased, the number of people living in rural areas decreased. The difference is explained by the increase in urban dwellers (*Figures* 9.26 and 9.27).

4 Describe the three population pyramids in *Figure 9.25*, taking care to point out the differences.

5 Explain the changes in age structure you have identified in activity 1.

6 The questions below are about gender structure: the differences between the male and female sides of each pyramid in each age group.
   a Which gender dominates in which age group in *Figure 9.25a*?
   b Does this domination continue through the set of three pyramids?
   c Why do you think this is so?

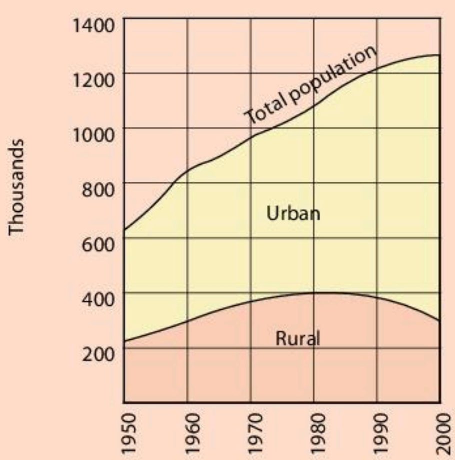


Figure 9.26 Urban–rural balance, 1950–2000

Figure 9.27 Many people in Trinidad and Tobago live in towns and cities

Race and ethnicity in Trinidad and Tobago

People of African and East Indian descent are the major groups in Trinidad and Tobago: 45.6 percent and 38.5 percent respectively in 2000 (*Figure 9.28*). Between 1960 and 2000 these two groups grew, not only in numbers, but also in percentage of the population of these islands as a whole. On the other hand, the smaller groups decreased in both number and proportion. These are Whites (1.9 percent to 0.8 percent), Chinese (1.3 percent to 0.3 percent) and Others (1.0 percent to 0.3 percent). The Mixed race group stayed almost the same in number, though reduced a little in percentage as the overall island population grew.

Included in the 'Other' category is the indigenous population. They have a more mixed background than the Tainos of Jamaica. Being closer to the mainland of South America, several tribes had easy access to Trinidad and Tobago. They are generally known as Caribs, but can be subdivided into Tainos, Yaio, Nepuyo, Chaima, Kalipuna, Carinepogoto and Garani. They lived on the islands 6000 years before any European set foot there. Many place names, such as Arima and Paria, come from the indigenous language.

Today some 12 000 descendants of these early inhabitants live in the Santa Rosa Carib Community in the north east of Trinidad.

They aim to preserve their ancestral customs and lifestyle.

7 Look back to *Figure 9.23* to see the imbalance in population distribution on these islands. A good deal of the land has a density of less than 100 people/km^2, but significant areas have over 300/km^2. How does this help you to explain the urban–rural balance in Trinidad and Tobago today?

8 What do you think is likely to happen to the urban–rural balance in the future? Give your reasons.

Children in Trinidad and Tobago

Until 1990 the infant and child mortality rates in Trinidad and Tobago were quite high (1990: 28/1000 live births). By 2004 this figure had reduced to 18/1000. Similarly, the child mortality rate has been successfully lowered from 33/1000 to 20/1000 over the same period. Nevertheless, even in 2004, 23 percent of newborn babies and 7 percent of all children below 5 years of age were underweight, an indicator of poor nutrition and health. The impact of HIV/AIDS on children has increased. In 2001 only 300 children had one of these conditions, but by 2004 this figure had more than doubled to 700.

Attendance at primary school is high. A small number of children aged 5–14 do work (2 percent), but most do so as well as going to school. The adult literacy rate is an excellent 98 percent, just 1 percent below the standard level in developed countries, and better than Jamaica's (88 percent).

Women in Trinidad and Tobago

Women occupy 19 percent of seats in the Trinidadian parliament, and 18 percent of government ministers are female. These levels are similar to those found in Jamaica.

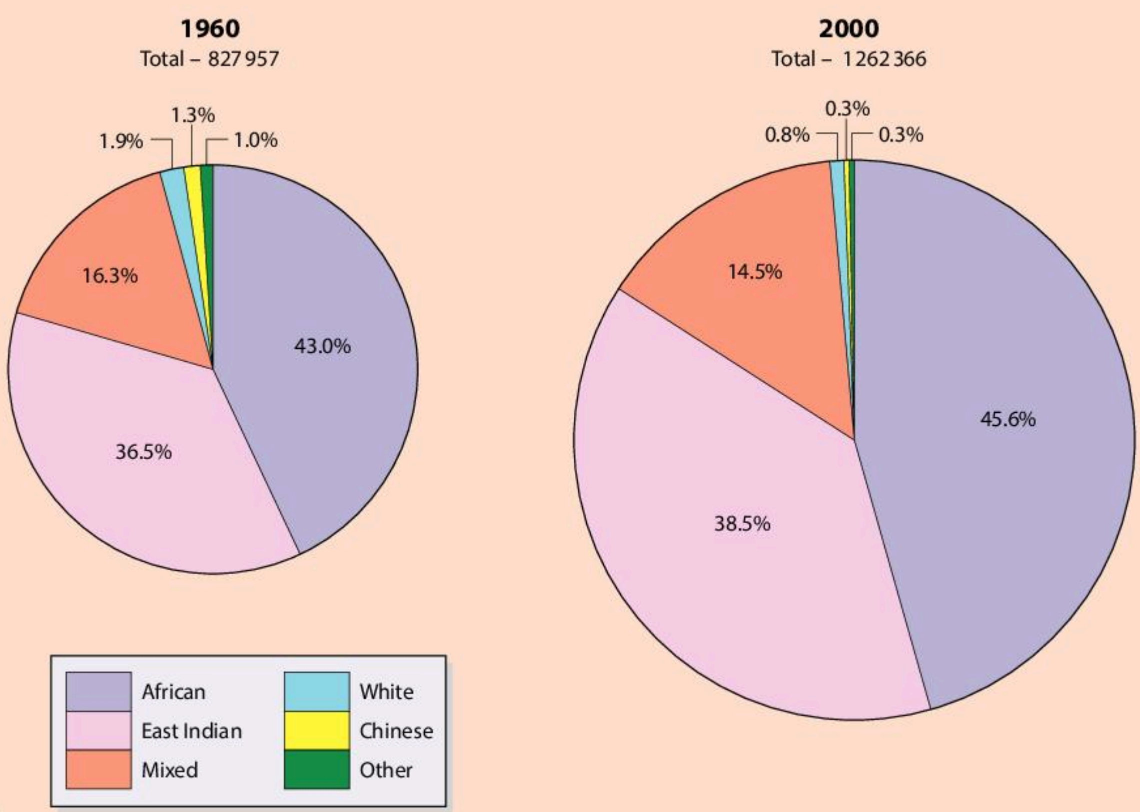


Figure 9.28 Ethnic groups, 1960–2000

Trinidad and Tobago population census 2000

There are 1 million people in the workforce but women make up only 38 percent. The majority are employed in the service sector. (Source of statistics: The State of the World's Children and Childinfo database, Unicef 2006)

9 Compare the information given on women in Jamaica and Trinidad and Tobago. Which statistics are similar and which are different?

10 Compare the circumstances of children in Trinidad and Tobago and in Jamaica. Use information on education and health to support your points.

Skills

Reducing and enlarging a map

It is sometimes useful to draw a sketch map enlarged or reduced from the original. For example, enlarging a map helps you to see fine detail more easily than it appears on the original map.

To enlarge a map you need to draw grid squares that are further apart than on the original map. For example, if you needed to double the size of a 1:50000 topographical map you could draw grid squares that are 4 cm apart instead of 2 cm apart as they appear on the original map.

Having drawn your grid squares, carefully copy onto your sketch map the details you are interested in from the original map, using the gridlines to guide you (*Figure 9.29*).

If you wish to reduce a large map to a smaller sketch map, make the grid squares smaller than the original map.

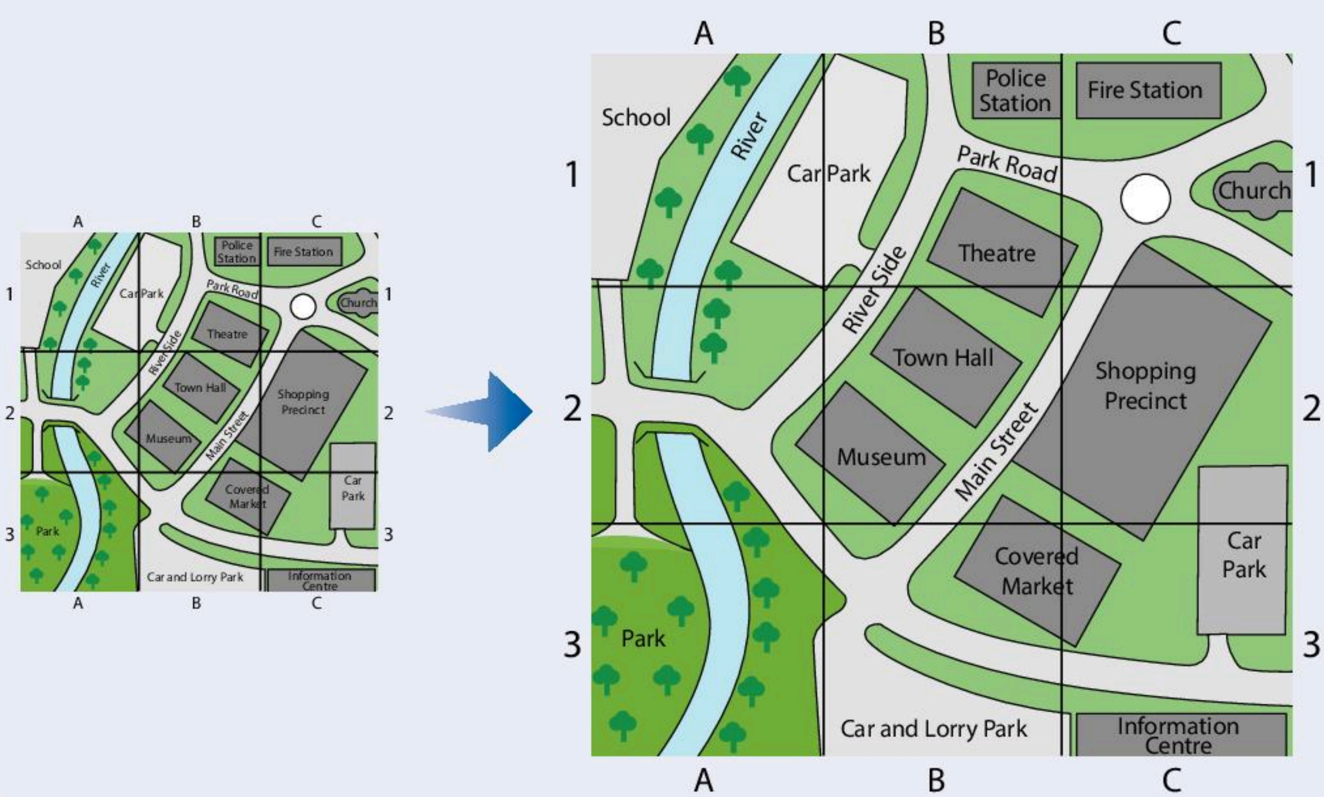


Figure 9.29 How to enlarge a sketch map

Glossary of terms

Age structure: the classification of the population of a country (or sometimes of just a city) into age groups. These age groups are either of ten years (0–9, 10–19, 20–29), or five years (0–4, 5–9, 10–14), or one year (less than 1, 1, 2, 3). Age structure is usually shown as a *population pyramid* (see below).

Birth rate (BR): the number of babies born per 1000 members of the existing population per year.

Child mortality rate: the number of children aged below 5 years who die per 1000 live births in the year in which they were born.

Choropleth map: a shaded map in which the shading represents people per unit area; the darker shades represent more people and the lighter shades represent fewer people. Population choropleth maps are usually coloured red to orange to yellow to white.

Death rate (DR): the number of deaths per 1000 members of the existing population per year.

Demography: the study of population – its distribution, density, growth or decline, age and gender structure, and migration.

Demographic transition model (DTM): a geographical theory devised to explain population growth over time (population cycle). Birth rate and death rate line graphs are drawn and the difference between them represents population growth or decrease.

Densely populated area: an area with a large number of people per unit area. People live close together, usually in urban areas.

Density of population: the relationship between the number of people and the area they live in. It is usually stated as the number of people per square kilometre (/km^2).

Distribution of population: the way in which population is spread out over an area.

Dot map: a map showing distribution by means of dots. On a population map each dot represents a certain number of people and is placed as accurately as possible in the area it represents; dots are usually red.

Ethnicity: a social group having a common national or cultural tradition.

Gender structure: the balance of males and females in a population.

Indigenous peoples: the original group of people inhabiting an area.

Infant mortality rate: the number of babies (younger than 12 months) dying per 1000 live births in the year in which they were born.

Isopleth map: a map showing population density by isolines, lines of equal density, rather like a contour map.

LEDC: Less Economically Developed Country

Life expectancy: the number of years that people in a particular location are expected to live, from birth.

MEDC: More Economically Developed Country

Migration: the movement of people from one permanent home to another; this may be within a country or between countries.

Natural change (NC): the difference between the BR and the DR.

Natural decrease (ND): the difference between the BR and the DR, where DR is greater than BR.

Natural increase (NI): the difference between the BR and the DR, where BR is greater than DR.

Population pyramid: a graph showing the age and gender structure of a country (or, less commonly, of a city). Males are on the left-hand side; females are on the right-hand side. The base (x) axis can be measured either in population numbers or as a percentage of the total population. The vertical (y) axis is divided up into age groups (1, 5 or 10 years).

Rural population: people living in a rural (countryside) area.

Sparsely populated area: an area with few people per unit area. This is usually an area with few resources and so it cannot support many people.

Urban population: people living in an urban (town/city) area.

Ideas for SBA

- *What influences population distribution in my community?*
- *How has the population changed in my community over a certain period of time, e.g. ten years?*
- *How does the population structure influence social and economic activities in my community?*

Weblinks

1 Look up the CIA World Factbook or a similar source for more Caribbean and global population statistics.
2 Research the *Jamaica Observer* (www.jamaicaobserver.com) and other Caribbean newspapers for social comment on population matters.

Exam-style Practice

1 For a Caribbean country you have studied:
a State its name. Give its location using latitude and longitude. [2]
b State FOUR factors that help to explain the distribution of population. [4]
c For ONE of the factors named above, explain its impact. [3]
d Study Table A. Some of the boxes have been left blank.
Calculate the following:
i the natural change for Barbados
ii the DR for Cuba
iii the BR for Trinidad and Tobago. [6]

Table A Birth and death rates (BR and DR) plus natural change for selected countries

Country	BR/1000	DR/1000	Natural change %/year
Jamaica	20.0	7.0	1.3
Barbados	16.7	7.8	
Cuba	16.6		1.6
Trinidad and Tobago		6.5	1.9

e What is the difference between natural increase and natural decrease? [3]
f **i** Give a reason why families in developing countries are larger than those in developed countries.
ii Give a reason for the very low birth rate in many developed countries. [2]
g Will developing countries follow developed countries in reducing their birth rates? Give two reasons for your answer. (Hint: There is no right or wrong answer here – your answer will be assessed on the reasons you give.) [4]

Total 24 marks

2 a Describe how a population pyramid is constructed. Why is it so useful? [5]
b Choose a developing country and a developed country that you have studied. Sketch the outline of the population pyramid for each country. [4]
c Explain the differences in shape between the two pyramids. [6]
d Explain THREE factors that cause these differences. [9]

Total 24 marks

10 Urbanisation

In this chapter you will study:

- global patterns and predictions
- urbanisation in the Caribbean
- the benefits and problems of urbanisation
- ways of controlling urbanisation in the Caribbean
- Caribbean international migration: patterns and consequences.

You will also learn how to:

- interpret line graphs
- interpret tables.

> *Urbanisation has the potential to usher in a new era of well-being, resource efficiency and economic growth* – The World Bank
>
> *If not managed well, urbanisation can lead to the burgeoning growth of slums, pollution and crime* – The United Nations Population Fund

Urbanisation, urban growth and urban sprawl

Urbanisation is the process whereby an increasing proportion of the population in a country or region lives in urban settlements. **Urban growth** is the actual increase in the total population of urban areas.

- If the growth of the urban population of a country increases at a faster rate than the growth of the rural population, the level of urbanisation increases.
- If the growth rate of the urban population of a country is the same as the growth rate of the rural population there will be no change in the level of urbanisation.
- If the urban population grows, but at a slower rate than the rural population, then the level of urbanisation would decrease.

Urban sprawl is the term used to describe the significant outward spread of a settlement into surrounding areas of countryside. Most of the world's largest cities, particularly in the developing world, now cover massive areas of land compared to their much more limited physical size 50 years ago. Urban sprawl has affected cities in both the developed and developing worlds with significant consequences. Virtually every country in the world has been affected to some degree. The UN report *State of the World's Cities 2012/2013* concluded:

Urban sprawl contributes to the high numbers of cars, distances travelled, length of paved roads, fuel consumption, alteration of ecological structures and the conversion of rural land into urban uses – all of which are environmentally unsustainable.

Global patterns and projections

According to the United Nations publication *World Urbanisation Prospects, 2014*:

- 54 percent of the world's population lived in urban areas in 2014 (*Figure 10.1*) compared to 30 percent in 1950. In 2007, for the first time ever, the world's urban population exceeded its rural population.

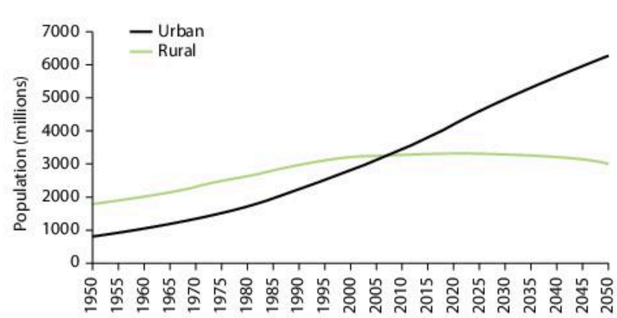


Figure 10.1 Urban and rural population of the world, 1950–2050

Source: World Urbanisation Prospects, 2014 [UN]

Figure 10.2 The inner urban area of Cairo, Egypt

- The projection for the proportion of the world's population that is urban in 2050 is 66 percent.
- The world's urban population has increased from 746 million in 1950 to 3.9 billion in 2014. This is more than a fivefold increase! The urban population of the world is expected to increase by an additional 2.5 billion by 2050.
- India, China and Nigeria are expected to account for a massive 37 percent of the projected increase in the global urban population by 2050. Other countries that are going to make significant contributions to the growth of the global urban population are Indonesia, the USA, Pakistan and DR Congo.
- The most urbanised regions of the world are northern America, Latin America and the Caribbean, Europe and Oceania (*Figure 10.3*). All four world regions have a level of urbanisation of over 70 percent. In contrast, the levels of urbanisation in Asia and Africa are below 50 percent.
- In 2014, sixteen countries had levels of urbanisation below 20 percent – most were in Africa.

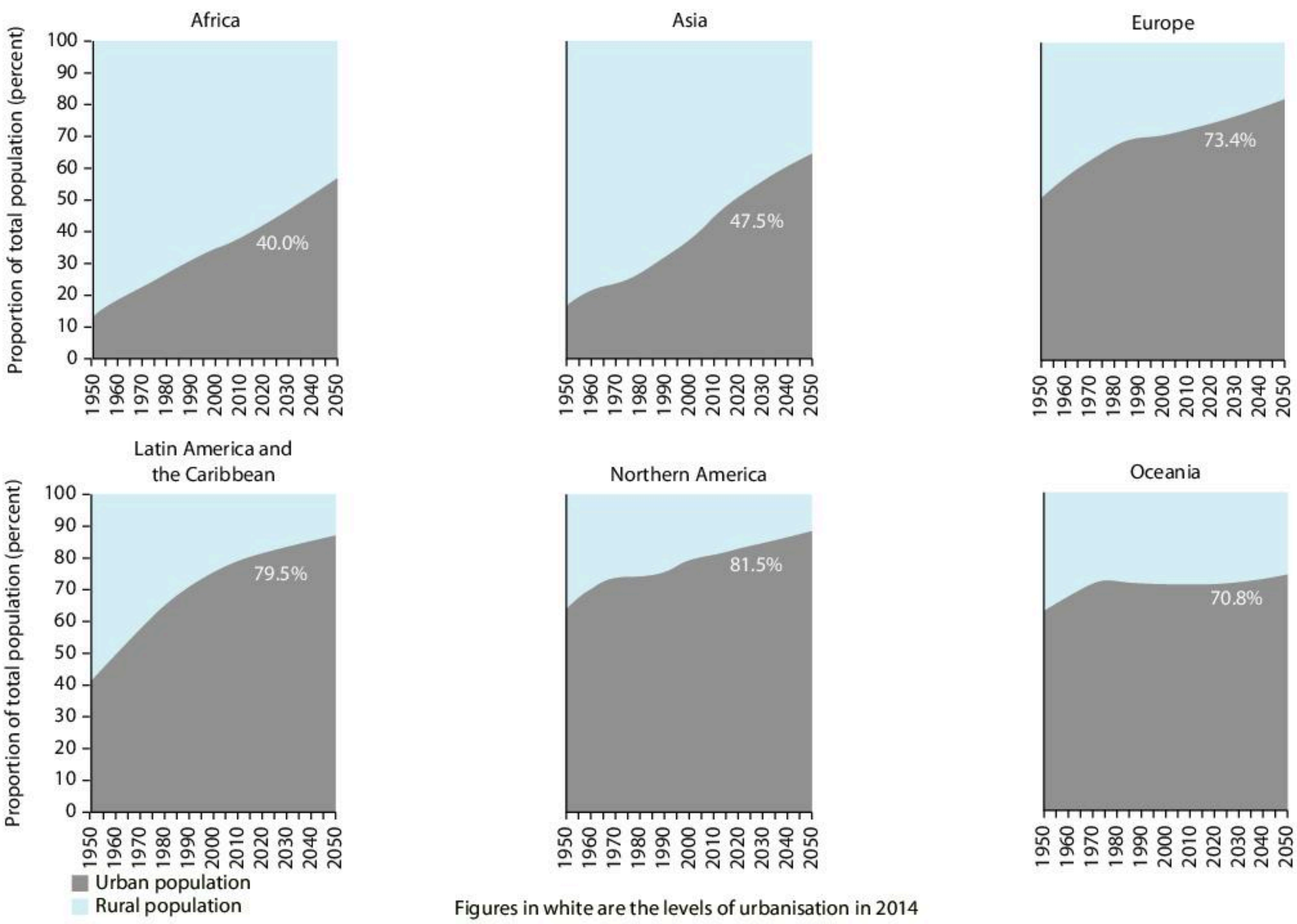


Figure 10. 3 Urban and rural population as proportion of total population, by major world regions, 1950–2050

Source: World Urbanisation Prospects, 2014 [UN]

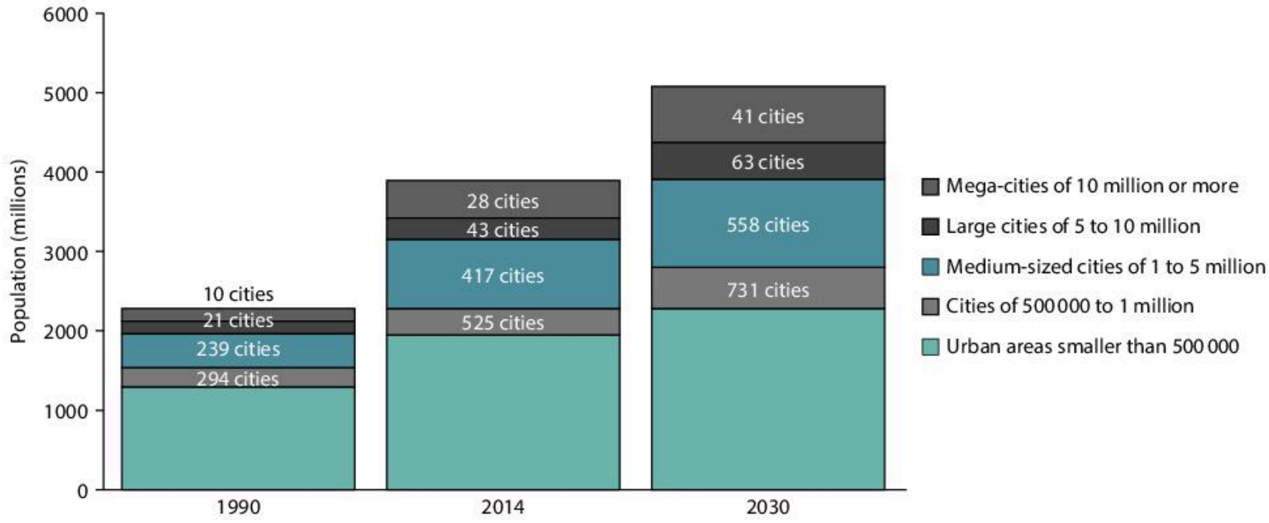


Figure 10.4 Global urban population growth is propelled by the growth of cities of all sizes

Source: World Urbanisation Prospects, 2014 [UN]

- Nearly 90 percent of the world's rural population live in Africa and Asia. India has the largest rural population (857 million), followed by China (635 million). However, Asia and Africa are currently urbanising at a faster rate than the other regions of the world. The proportion of the population classed as urban is increasing in Asia and Africa at a rate of 1.5 percent and 1.1 percent respectively.
- The world's rural population has grown slowly since the 1950s and is expected to reach its peak within the next decade.
- As the world continues to urbanise, sustainable development challenges in urban areas will increase, particularly where the process is occurring at the fastest rate. This affects issues such as water supply, transportation, energy infrastructure, pollution and waste disposal.

Mega-cities

Population growth is occuring in cities of all sizes (*Figure 10.4*). Almost half of the world's urban population live in urban areas of less than 500 000 people. In contrast, one in eight urban residents live in the 28 mega-cities with populations of more than 10 million. In 1990, there were only 10 cities worldwide in the mega-city category. By 2014 there were 28 (*Figure 10.4*), with a projection of 41 mega-cities by 2030. Tokyo, with a population of almost 38 million, is ranked the world's largest urban agglomeration for all three years (*Table 10.1*). In terms of current population, Tokyo is followed by Delhi, Shanghai, Mexico City and São Paulo. However, by 2020 Tokyo's population is projected to begin to decline, with other major world cities catching up with it rapidly.

Some urban areas have changed their world ranking in a very significant way. None more so than Shenzhen, China which increased its ranking from 308th in 1990 to 26th in 2014. In the 2014 ranking there are only seven urban agglomerations in the developed world with populations over 10 million – Tokyo, Osaka, New York, Los Angeles, Moscow, Paris and London. Apart from Tokyo, the global ranking of all of these cities fell between 1990 and 2014. For example, New York dropped from 3rd to 9th.

Table 10.1 Population size and ranking of urban agglomerations with more than 10 million people, 2014.

Urban Agglomeration	Country or area	Population (thousands) 1990	Population (thousands) 2014	Population (thousands) 2030	Rank 1990	Rank 2014	Rank 2030	Average annual rate of change (percent) 2010–2015
Tokyo	Japan	32 530	37 833	37 190	1	1	1	0.6
Delhi	India	9726	24 953	36 000	12	2	2	3.2
Shanghai	China	7823	22 991	30 751	20	3	3	3.4
Ciudad de México (Mexico City)	Mexico	15 642	20 843	23 865	4	4	10	0.8
São Paulo	Brazil	14 776	20 831	23 444	5	5	11	1.4
Mumbai (Bombay)	India	12 436	20 741	27 797	6	6	4	1.6
Kinki M.M.A (Osaka)	Japan	18 389	20 123	19 976	2	7	13	0.8
Beijing	China	6788	19 520	27 706	23	8	5	4.6
New York-Newark	United States of America	16 086	18 591	19 885	3	9	14	0.2
Al-Qahirah (Cairo)	Egypt	9892	18 419	24 502	11	10	8	2.1
Dhaka	Bangladesh	6621	16 982	27 374	24	11	6	3.4
Karachi	Pakistan	7147	16 126	24 838	22	12	7	3.3
Buenos Aires	Argentina	10 513	15 024	16 956	10	13	18	1.3
Kolkata (Calcutta)	India	10 890	14 766	19 092	7	14	15	0.8
Istanbul	Turkey	6552	13 954	16 694	25	15	20	2.2
Chongqing	China	4011	12 916	17 380	43	16	17	3.4
Rio de Janeiro	Brazil	9697	12 825	14 174	13	17	23	0.8
Manila	Philippines	7973	12 764	16 756	19	18	19	1.7
Lagos	Nigeria	4764	12 614	24 239	33	19	9	3.9
Los Angeles-Long Beach-Santa Ana	United States of America	10 883	12 308	13 257	8	20	26	0.2
Moskva (Moscow)	Russian Federation	8987	12 063	12 200	15	21	31	1.2
Guangzhou, Guangdong	China	3072	11 843	17 574	63	22	16	5.2
Kinshasa	Democratic Republic of the Congo	3683	11 116	19 996	50	23	12	4.2
Tianjin	China	4558	10 860	14 655	37	24	22	3.4
Paris	France	9330	10 764	11 803	14	25	33	0.7
Shenzhen	China	875	10 680	12 673	308	26	29	1.0
London	United Kingdom	8054	10 189	11 467	18	27	30	1.2
Jakarta	Indonesia	8175	10 176	13 812	17	28	25	1.4

Urban slums

A **slum** is a heavily populated urban area characterised by substandard housing and squalor. Thirty-two percent of the world's urban population, almost one billion people, are housed in slums. The great majority live in developing countries. However, virtually all large cities in developed countries also contain slum districts. The focus of global poverty is moving from rural to urban areas, a process known as 'the urbanisation of poverty'. Without significant global action, the number of slum dwellers will double over the next 30 years. The urban poor live in inner city slums, peripheral shanty towns and in almost every other conceivable space such as on pavements, traffic roundabouts, under bridges, and in sewers.

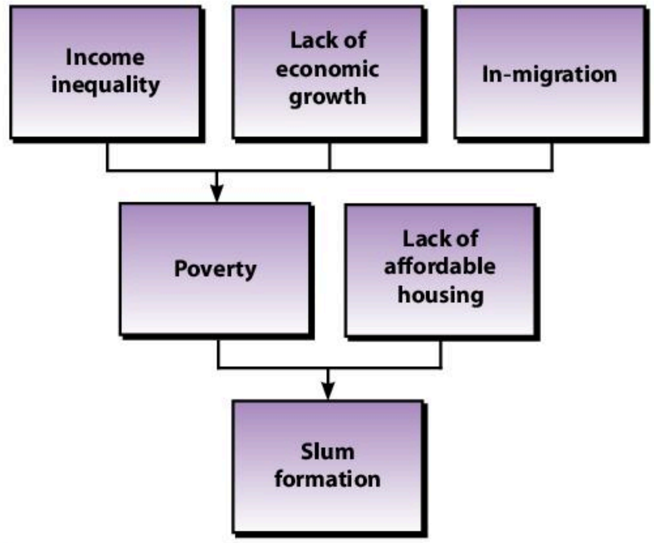


Figure 10.5 Inequality poverty and slum formation

Source: *The Challenge of Slums*, UN 2003

The United Nations regards the Kibera district of Nairobi, housing three quarters of a million people, as the largest slum in the world. The Dhavari district of Mumbai and the Orangi area of Karachi are not far behind in extent. Some slums are now as large as cities. For example, the Ashaiman informal settlement in Ghana is now larger than the city of Tema from which it grew.

The numbers of people living in urban poverty are increased by a combination of economic problems, growing inequality and population growth, particularly growth due to in-migration (*Figure 10.5*). Women, children, widows and female-headed households are the most vulnerable among the poor. In urban African slums, women head over 30 percent of all households.

Causes of urban population growth

Rapid urban population growth is the result of four factors:

- **Natural increase** – the excess of births over deaths in most urban areas, particularly in developing countries.
- **In-migration** – the perceived higher quality of life in urban as opposed to rural areas has resulted in a high rate of migration from the countryside to towns and cities. This has been at a very high rate in developing countries since the 1950s.
- **International migration** – capital cities and other large urban areas may attract significant numbers of migrants from other countries. This may include national citizens who have returned home after a period living abroad.
- **Reclassification** – rural villages which have expanded rapidly to become towns will have been reclassified as urban areas. In such cases, long-standing residents who will have previously been classed as rural dwellers become urban dwellers because their settlements have expanded in size.

The two most important factors in urban growth are natural increase and in-migration. The balance between the two has changed over time:

- Between 1960 and 1990, 60 percent of urban growth in developing countries, excluding China, was due to natural increase. In contrast, China's rural-urban migration accounted for 70 percent of urban growth.

- In 2000, the roles of natural increase and in-migration in urban growth were evenly balanced.
- The contribution of in-migration since 2000 to urban population growth has become increasingly important as fertility rates have declined in so many developing countries.

Push and pull factors

A variety of **push factors** in the countryside has encouraged out-migration. The main factors include:

- population pressure with not enough food, water and other resources to go round
- unemployment and underemployment
- the poor wages and conditions of rural employment
- poor social conditions (housing, health, education, recreation)
- environmental problems, for example, desertification.

People are attracted to urban areas (**pull factors**) because they feel life in towns and cities will provide at least some of the following:

- a higher standard of housing
- a much wider range of jobs and a greater likelihood of employment
- a better education for their children
- improved medical facilities
- the conditions of infrastructure (electricity, water, sanitation, roads etc.) often lacking in rural areas
- a wider range of consumer services such as food markets and different kinds of shops.

The scale of rural-urban migration in developing countries is not surprising given the great concentrations of wealth and economic activity in the cities compared

Figure 10.6 A shanty town in São Paulo, Brazil

to the countryside. The largest rural-urban migration in history is currently taking place in China, having begun in earnest over two decades ago.

The impact on rural areas

A high rate of rural-urban migration has led to a fall in population in many rural areas around the world, including the Caribbean. This process is called **rural depopulation**.

It can be beneficial by relieving pressure on rural areas. The impact on resources such as water, food and timber will be reduced.

However, in some rural areas, rural depopulation can create problems including:

- An ageing population: out-migration from rural areas is age selective, dominated by young adults and their children. The population left behind will be much older than that in the urban areas.
- Decreasing food production: not enough people in the working age group may be left behind to farm the land. The fall in food production can hurt the country as a whole, not just those living in rural areas.
- Loss of services: as the population falls, some public services such as schools will close because there are not enough children to justify them being kept open. Private services such as shops and bars may also

close as they lose custom. In both cases people may have to travel much longer distances to get to such services.

Activities

1 a Use data to describe the trends shown in *Figure 10.1*.
   b How do natural change and net migration cause urbanisation?
2 a What is a mega-city?
   b On an outline map of the world show the location of the mega-cities listed in Table 10.1.
   c Describe and explain the global distribution of mega-cities.
3 a What is a slum?
   b How many people around the world live in urban slums?
   c What do you understand by the term the 'urbanisation of poverty'?

Urbanisation in the Caribbean

Towns were first established in the Caribbean by European colonists after 1500. The development of trade by the colonial European powers ensured that the importance of early inland settlements declined in favour of coastal locations. For example, Kingston grew at the expense of Spanish Town in Jamaica, and in Trinidad, Port-of-Spain grew at the expense of St Joseph.

Urban primacy

People in the Caribbean are highly concentrated in:

- urban areas in general
- the largest urban areas in particular.

Urban primacy exists when one or a few cities dominate the settlement system in a country. A **primate city** is one that is at least twice the size of the second largest city. *Figure 10.7* shows the extent of urban primacy in the Caribbean. Generally over 30 percent of the population of each country live in the largest city. This is certainly the case in:

- Puerto Rico (31 percent)
- Martinique (33 percent)
- Antigua (33 percent)
- Trinidad and Tobago (40 percent)
- The Bahamas (over 50 percent)
- The Netherlands Antilles (70 percent)

Figure 10.7 also shows Miami and Caracas. Both of these cities have an important influence on the Caribbean. Because of their size they provide many functions that are not found in Caribbean cities. In fact, Miami has been referred to as 'the capital of the Caribbean', being an international banking and trade centre for the entire Caribbean region.

The main concern about urban primacy in the Caribbean is the heavy concentration of investment in capital cities which has often left little for investment elsewhere. This has led to large regional inequalities in income and quality of life.

Rapid urbanisation since 1945

The Caribbean region has experienced high rates of rural-urban migration since 1945. This has been caused by:

- the 'push' of rural poverty
- the 'pull' of real or perceived opportunities in urban areas.

The Caribbean is more highly urbanised than the developing world as a whole. In 1960, only 38 percent of Caribbean people lived in cities. By 2000, 64.6 percent of the total population lived in urban areas (*Table 10.2*), and by 2014 this figure had risen to 70 percent. This is projected to rise to 81 percent by 2050. *Table 10.3* shows the levels of urbanisation in the Caribbean in 1990, 2014 and the projections for 2050. Seven countries had levels of urbanisation of over 90 percent in 2014.

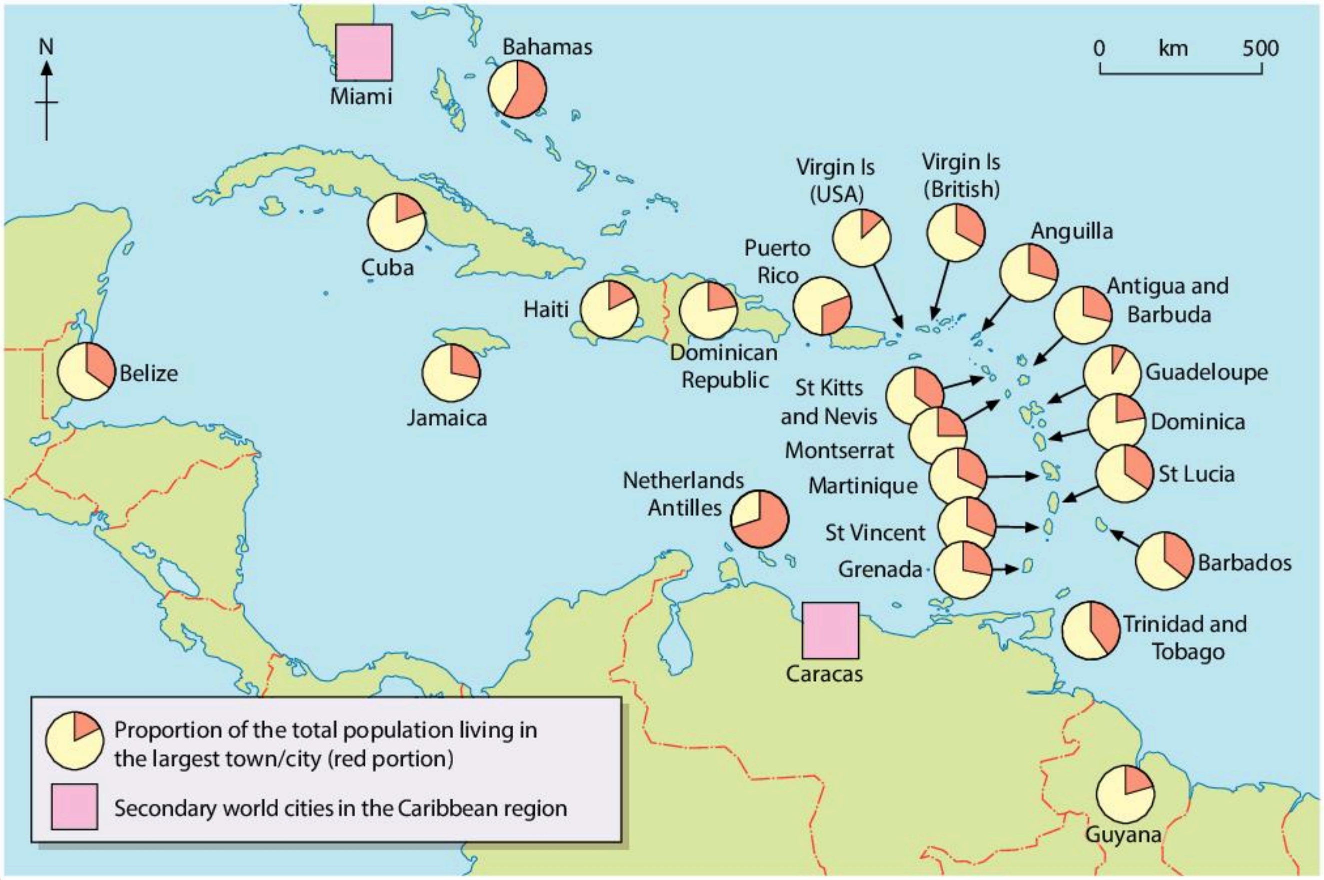


Figure 10.7 Urban primacy in Caribbean

Source: R. Potter et al. *The Contemporary Caribbean*, Pearson, 2004 Figure 7.4

A Caribbean urban land use model

Figure 10.8 is a model of land use zones in Caribbean cities. A model is a simplification of reality. It tries to show an 'average' picture of the larger urban areas in the Caribbean. This model shows the main land use zones and the population movements occurring:

- The Central Business District (CBD) is centrally located. This is the zone of maximum accessibility, at least in theory. Because of high accessibility, offices, shops, hotels, restaurants, cinemas and other commercial activities locate in the CBD. Important public buildings are also found here. Few people live in the CBD because the cost of land is so high.
- The high-density, low-income inner city surrounds the CBD. Older houses have been heavily subdivided and their condition is poor. The area may also contain old squatter settlements which have been improved over time.
- The next zone outward is occupied by the middle-income population. Housing is lower density and considerably better in quality.
- A number of high income zones form wedges from the middle-income zone outward toward the periphery. These are in certain preferential directions, sometimes on higher ground which provides good views. This is the least densely populated area.
- Beyond the city proper, squatter settlements may have grown up on vacant land. This happens particularly along main roads and near industrial areas.

The main flow of migrants from rural areas is to the tenement slums of the inner city.

Table 10.2 Increasing urbanisation in the Caribbean

		% of total population living in urban areas	
Date	**Total population of the Caribbean living in towns and cities (millions)**	**Caribbean**	**World**
1960	7.7	38.2	33.9
1970	11.1	45.1	37.5
1980	15.7	52.2	41.3
1990	21.6	58.7	45.9
2000	28.8	64.6	51.3
2014	29.9	70.0	54

Source: United Nations, 1980, in *The Urban Caribbean in an Era of Global Change*, Potter, R.B. 2000. Ashgate Publishing, in Potter R.B. et al., *The Contemporary Caribbean*, Pearson, 2004, Table 7.4

Smaller numbers head directly for the peripheral shanty towns. For most migrants, the inner city is their first destination because of the concentration of jobs and food markets in the central area. However, once they have established themselves with jobs they tend to move out to the shanty towns to reduce their living costs. They usually do this because rent will be less in the peripheral shanty towns than in the inner city, and if people build their own shacks they will pay no rent at all.

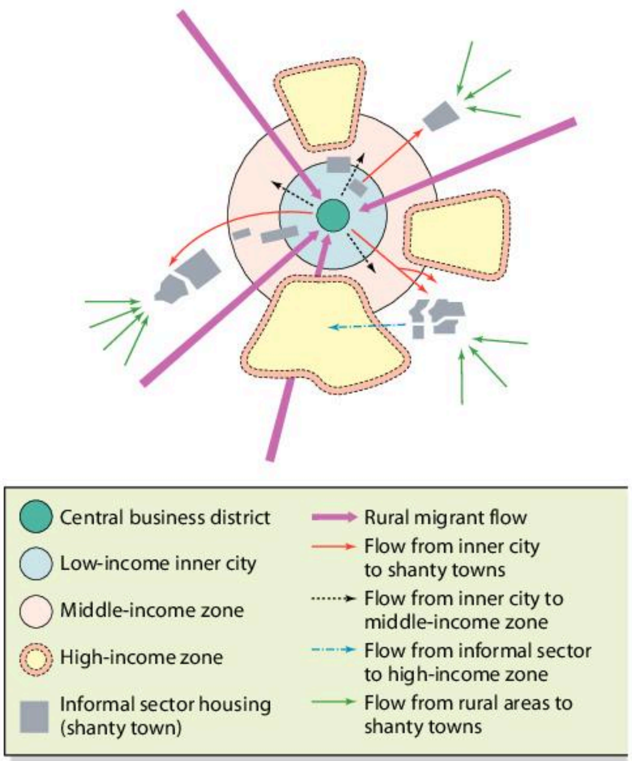


Figure 10.8 A Caribbean urban land use model

Source: Adapted from Figure 7.16, Potter R.B. et al., *The Contemporary Caribbean*, Pearson, 2004

The model also shows **social mobility**. Those who are fortunate enough to become richer move to higher income areas. Their new homes are often not far from where they used to live. This is because they are more familiar with this part of the city than elsewhere.

Urban change in the Caribbean

A number of similar changes have occurred in urban areas across the Caribbean region in the last 20 years or so. The main changes have been:

- **The development of high-rise buildings**: many urban areas have had few high-rise buildings in the past. Most buildings did not extend above two or three storeys. However, with limited available land this is changing. Examples are government office blocks, such as the twin towers of Port-of-Spain and the government building in Kingstown, St Vincent. The Kingston

Waterfront has seen considerable new high-rise development.

- **Waterfront development**: in recent decades the urban waterfront has become increasingly positively valued. New high-income housing has often replaced old warehouses and factories. New commercial development is also characteristic of waterfronts, such as in St John's, Antigua.
- **Land reclamation schemes**: the restricted sites occupied by many Caribbean urban areas has resulted in land reclamation schemes. Land reclamation is not a new feature in the Caribbean, but there has been a renewed impetus in recent decades because land is in such short supply.
- **Americanisation**: the influence of American culture and urban design has spread across the region. Classic signs are fast-food restaurants, road signs, advertising hoardings etc. Many people think that the unique character of individual cities is being lost.
- **Tourism**: the economic importance of tourism has had a growing impact on the urban landscape. The building of large hotels, marinas, tourist shops, casinos and other tourist-related facilities has changed the appearance of some urban areas considerably. For example, since the mid-1980s redevelopment in Castries, St Lucia has been based on the needs of tourism, especially cruise ships.

Figure 10.9 Urban sprawl in Barbados

Table 10.3 Levels of urbanisation in Caribbean countries, 1990, 2014, 2050

Major area, region, country or area	Population (thousands) Urban			Rural			Proportion Urban (percent)			Average annual rate of change (percent)
	1990	2014	2050	1990	2014	2050	1990	2014	2050	2010–2015
Caribbean	19 851	29 897	38 440	14 411	12 916	9207	58	70	81	0.8
Anguilla	8	14	15	0	0	0	100	100	100	0
Antigua and Barbuda	22	22	30	40	69	85	35	24	26	-2.0
Aruba	31	43	49	31	60	54	50	42	47	-0.7
Bahamas	205	317	430	52	66	64	80	83	87	0.1
Barbados	85	90	122	175	196	192	33	32	39	-0.4
British Virgin Islands	6	13	20	10	15	15	38	46	58	0.7
Cayman Islands	25	59	67	0	0	0	100	100	100	0
Cuba	7777	8666	7853	2824	2593	1559	73	77	83	0.1
Dominica	45	50	59	26	22	17	63	69	78	0.4
Dominican Republic	4001	8219	12 003	3244	2310	1318	55	78	90	1.4
Grenada	32	35	42	64	68	53	33	36	44	-0.1
Guadeloupe[20]	371	461	487	14	7	6	96	98	99	0.0
Haiti	2027	6009	10 936	5083	4453	3417	29	57	76	2.4
Jamaica	1169	1527	1900	1196	1272	908	49	55	68	0.4
Martinique	309	360	365	49	45	35	86	89	91	-0.0
Montserrat	1	0	1	9	5	5	13	9	13	-0.3
Sint Maarten (Dutch part)	29	46	61	0	0	0	100	100	100	0
Caribbean Netherlands	10	15	19	3	5	5	78	75	80	0.0
Curacao	124	145	182	22	17	17	85	89	91	-0.1
Puerto Rico	3270	3449	3424	248	234	187	93	94	95	-0.0
Saint Kitts and Nevis	14	18	29	27	37	39	35	32	43	0.2
Saint Lucia	41	34	52	98	150	155	29	18	25	0.1
Saint Vincent and the Grenadines	45	55	69	63	54	42	41	50	62	0.7
Trinidad and Tobago	104	115	123	1118	1229	1032	9	9	11	-1.5
Turks and Caicos Islands	9	31	42	3	3	2	74	92	96	0.4
United States Virgin Islands	91	102	100	13	5	3	88	95	97	0.2

Source: World Urbanisation Prospects, 2014 Revision - UN

Activities

1 a What does *Figure 10.7* show? Give figures for at least four countries.
  b Using the data in *Table 10.2*, draw bar graphs to show how urbanisation in the Caribbean has differed from the world as a whole between 1960 and 2014.

2 a What is a model?
  b What are the merits of the model in *Figure 10.8*?
  c Suggest at least one limitation of this model.

3 a What is the CBD?
  b List four types of land use found in the CBD.
  c Why is it important for these land uses to be in the CBD?
  d Suggest why so few people live in the CBD.

Case Study

Kingston, Jamaica

Location and growth

Kingston is the largest city in the English-speaking Caribbean (*Figure 10.10*). It is more than twice the size it was when Jamaica became independent in 1962. At independence it housed 20 percent of the Jamaican population. It is now over 30 percent.

Kingston became the capital of Jamaica in 1892, taking over from Spanish Town. The city lies on the coast of the Bay of Kingston in the south-east of Jamaica. It is sited on the southern section of the plains of Liguanea, south of the Blue Mountains. Approaching Kingston from the sea, the city has been likened to a giant fan sloping upward (*Figure 10.11*).

Kingston has a natural harbour protected by the Palisadoes, a long sandspit which connects Port Royal and the Norman Manley International Airport with the rest of the island.

The city is divided into two sections at a transportation focus called the Cross Roads:

- The **downtown area** to the south. This includes the harbour, industrial areas and lower-income housing.
- The **uptown area** to the north which includes the upmarket St Andrew area, 'New Kingston' and the more affluent suburbs extending up into the Blue Mountains.

The original pattern of streets and buildings followed the Spanish Law of the Indies (*Figure 10.12*). This was a central square surrounded by a grid-like street pattern. As the population grew, the city expanded. At first, growth followed the original pattern. However, later more rapid growth led to urban sprawl. This process swallowed up the surrounding villages, the affluent suburban area of St Andrew, and much agricultural land. By the early 1970s, the whole of the Liguanea Plain had been filled up by upper middle class developments and 26 government-underwritten middle-income, mass-housing schemes. Kingston can be classed as a **conurbation** due to its size and because its growth has engulfed previously free-standing towns and villages.

Figure 10.10 aerial photo of Kingston

Population change

Kingston is the largest urban area in Jamaica by far (*Table 10.4*). In 2011 its population was estimated at 937 700.

The population has increased through both natural change and net migration (*Figure 10.13*). Migration has fallen as a factor in Kingston's population growth in recent decades.

Table 10.4

Urban Area	Population (2011)
Kingston	937 700
Portmore	182 000
Spanish Town	147 000
Montego Bay	110 000

Figure 10.11 Map of Kingston Metropolitan region

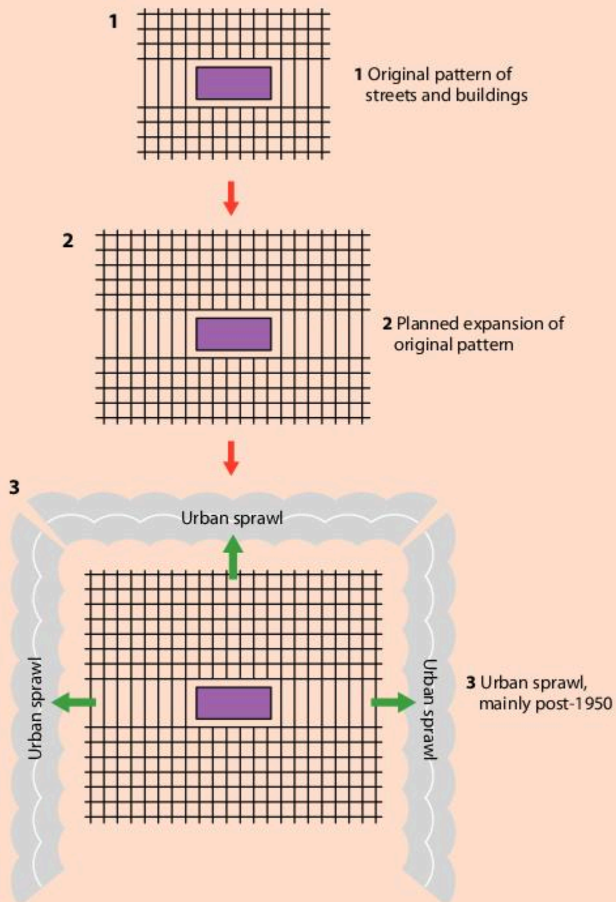


Figure 10.12 A model of the growth of Kingston

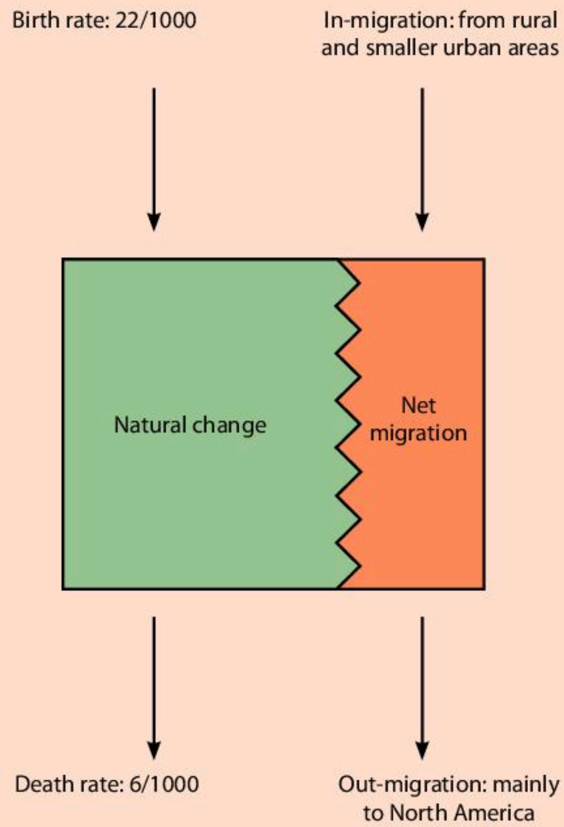


Figure 10.13 A model of population change in Kingston

While the population of Kingston has continued to grow, the downtown area has experienced population decline due to violence, arson and other negative factors in the area. Trench Town and Denham Town have lost large numbers of people through out-migration. The population of central Kingston (the parish of Kingston) declined consistently from 123 000 in 1960 to 96 000 in 2001.

1 a Describe the location of Kingston.

b Suggest two reasons why this is a good location for a large city.

2 a On an outline map of Jamaica, use located bars to show the populations of the urban areas listed in Table 10.4.

b What is a primate city?

c Why can Kingston be described as a primate city?

The Central Business District

Kingston has two central business districts (CBDs) which perform different functions:

- **Old downtown**: mainly commercial and retail with large produce markets and much **informal sector** activity. The informal sector comprises low-income, usually temporary, jobs that people often create for themselves such as selling food and drinks on the streets. Such jobs are not registered with the government and the people that do them avoid paying tax. This area is the major transport hub for the island. Many government offices are still located downtown. This area is much busier than New Kingston.

Figure 10.14 Kingston's CBD

- **New Kingston**: home to high-rise financial sector offices, banks and insurance companies. There are recently developed entertainment facilities and restaurants. Tourism is concentrated in New Kingston. Most employment here is in the **formal sector.** The formal sector is employment in shops, offices, factories and other organisations which is known to the government. Workers are liable to pay tax on their wages, but may enjoy benefits such as holiday pay and sick pay.

The offices of many transnational corporations are located in the CBD. The CBD also contains the Jamaica Stock Exchange, 35 international embassies and the International Seabed Authority. The latter is the UN body that governs the world's seas.

The inner city

Poverty is concentrated in the downtown area where the following are found:

- most of Kingston's manufacturing industries
- bauxite and alumina processing plants
- old houses which are heavily subdivided and in poor condition – renting is the main form of tenure
- close proximity to informal sector businesses, rum houses and workshops
- very low average incomes
- high unemployment
- inadequate services.

The old houses contain many families, usually rural migrants, sharing facilities. Such areas, which often have shanty towns in and around them, are called **ghettos.** Chickens, goats and other animals are often kept. Shanty towns are frequently surrounded by walls and so they may not be easily accessible to outsiders. These shanty towns are some of the oldest informal settlements. They have often experienced consolidation and upgrading. Most ghettos, such as Trench Town, have a reputation for violence. Cross Roads is a key dividing point between the north-eastern edge of Trench Town (the inner city) and the southern tip of New Kingston (the suburbs).

The suburbs

Suburbanisation is the outward growth of an urban area to engulf surrounding villages and rural areas. Middle and higher income groups have moved out from the inner core over a long period of time. They have been 'pushed' by congestion, pollution, high density living and fear of crime. They have been 'pulled' by cheaper and larger plots of land at the edge of the city. The Victorian suburbs marked the

Figure 10.15 Ghetto housing in inner city Kingston

Figure 10.16 Kingston suburbs

first major movement out, but in the post-1950 period, the middle classes moved further out. The Victorian suburbs became 'urban ghettos' with much increased population densities.

The increase in population in the post-1950 period resulted in:

- the suburbanisation of the Liguanea Plain to the north of the Washington Boulevard
- subsequent overspill to the new dormitory suburbs at Portmore
- creation of the suburbs and squatter settlements around Spanish Town.

To the north and north-west, rising up into the Blue Mountains, are the affluent residential neighbourhoods of Hope, Mona and Beverly Hills.

1 a List four functions that you would expect to find in the CBD.
  b Suggest why Kingston has developed two CBDs.
2 Discuss three differences between the inner city and the suburbs of Kingston.
3 Explain the difference between the formal and informal sectors of the economy.

The benefits and problems of urbanisation

Benefits

There are many benefits or perceived benefits to urbanisation. This is why so many people have moved from rural to urban areas over a long period of time. The reasons are the push and pull factors noted above. It is all about people trying to improve their **quality of life**. So, to a certain extent, urbanisation can be seen as a positive response to economic development.

Large urban areas are more likely to attract new businesses. This is because cities have better facilities and more highly skilled workforces than smaller settlements. Rural to urban migration, as well as natural increase, increase the **labour supply.** A large labour supply is an attractive pull factor to

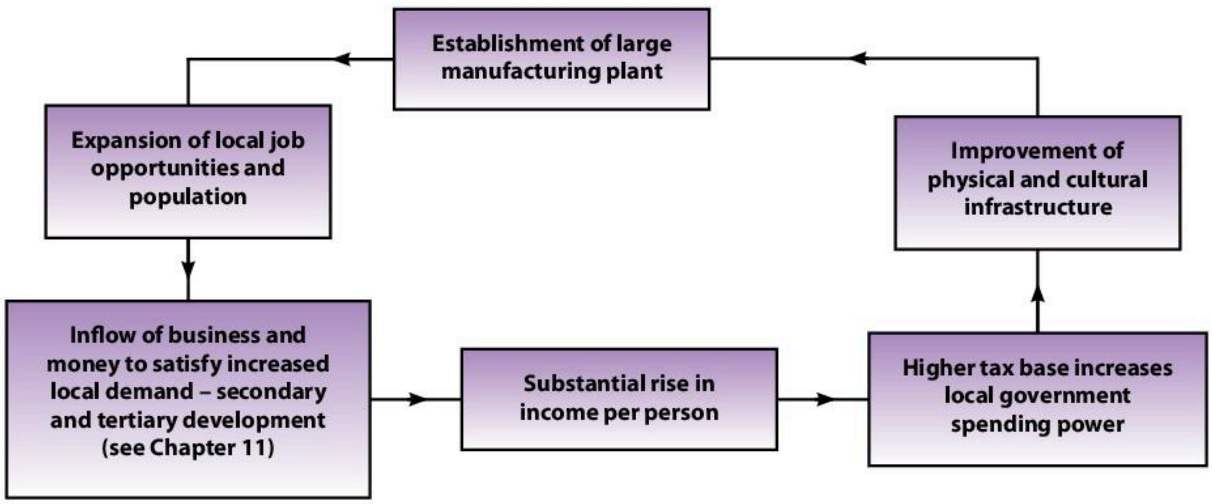


Figure 10.17 Model of cumulative causation

business, making it more likely that they can recruit workers with the variety of skills they need.

If these businesses are owned by foreign companies, the money spent on new development is known as **foreign direct investment (FDI).** Such investment by big companies can create large numbers of jobs and be a major factor in **economic growth**. The building of a new large factory can set off a chain of economic growth. This is called the process of **cumulative causation** (*Figure 10.17*).

A larger urban population can:

- attract new privately owned services such as major hotel chains and specialist shops
- justify investment in new public services such as roads, public transport and hospitals.

Problems

The problems of urban growth include:

- overcrowding
- insufficient and substandard housing
- inadequate transport infrastructure
- environmental degradation
- crime.

Very often, urban areas are growing at a faster rate than the ability of urban governments to provide roads, housing and other important infrastructure. The investment required for such infrastructure is considerable and frequently well beyond the financial resources available. Even when sufficient money is available, key infrastructure often takes a long time to build.

Urban problems in Kingston, Jamaica

Housing and infrastructure

The Global Housing Policy Indicators (2011 assessment) for Kingston identified the following infrastructure and services coverage in 2010:

- water 92 percent
- waste collection 75 percent
- public transportation 42 percent
- sanitation 25 percent

This report stated that 20 percent of households in the Greater Kingston municipality lived in informal squatter settlements. Housing is a major problem for the urban poor. After buying food and other necessities, many people are unable to afford to live in the formal housing sector.

The report noted a number of government initiatives to improve Kingston's housing problems:

- The Housing Agency of Jamaica budgeted J$387 million for a squatter upgrading programme in 2011/12.
- The National Housing Trust provides a mortgage subsidy for households who earn less than J$10 000 a week to purchase or build a unit.
- An interest rate subsidy is available to private developers to construct affordable housing.

However, critics have argued that total government resources available to improve the housing situation are very limited compared to the extent of the housing problem. In 2013, a government statement said that there was a deficit of 450 000 housing units in the country as a whole, with fewer than 3000 units being built per year. The report stated that an annual construction rate of 12 000–15 000 was needed to bridge the current gap.

A chain of deprivation has been recognised (*Figure 10.18*), beginning with low-class status. Many people living in poor-quality rented housing have only been able to find work in the informal sector of the economy.

The expansion of metropolitan Kingston has witnessed the development of new shanty towns, following the route of the bypass and other major roads on the outskirts of Spanish Town and at Portmore. Shanty towns are characterised by:

- makeshift building materials
- high population density
- lack of services (water, sanitation, electricity etc.)
- a very young population
- high fertility
- high unemployment
- low educational and skill levels.

Although many people still live in poor-quality dwellings, housing conditions in Kingston have improved over the past 30 years. Improvements have been due to:

- Funding by local building societies, along with some government help in keeping down interest rates.
- International aid after Hurricane Gilbert in 1987. The hurricane destroyed 20 percent of Jamaica's housing and damaged another 50 percent.
- Investment in home loans by the National Housing Corporation and the National Housing Trust.
- The increase in the number of people classed as middle and higher income. This means that more people have been able to pay for better housing.

Urban decay and renewal

Faced with many poorly maintained and deteriorating buildings, attempts have

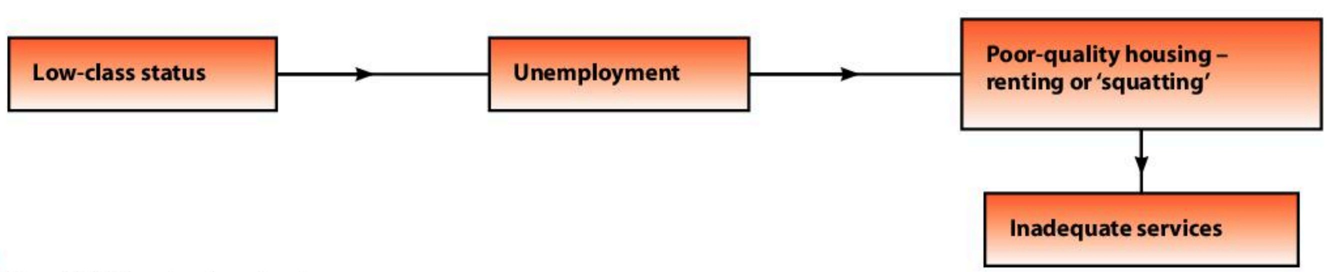


Figure 10.18 The urban deprivation chain

been made to improve the downtown area. The first large-scale improvement scheme began in 1967 when the Kingston Waterfront Redevelopment Company (KWRC) was formed. It was the forerunner to the Urban Development Corporation (UDC) established in 1968. The Kingston Waterfront development was completed in 1975.

Urban redevelopment involves complete clearance of existing buildings and site infrastructure and construction of new buildings, often for different purposes, from scratch. In contrast**, urban renewal** keeps the best elements of the existing urban environment (often because they are safeguarded by planning regulations) and adapts them to new usages. Simple examples are where a bank has been turned into a restaurant, keeping the former's facade, but altering the inside of the building to suit its new purpose. Urban renewal helps to maintain some of the historic character of urban areas.

In the 1980s, the UDC upgraded Parade Square, including St William Grant Park and the Ward Theatre. The Kingston Restoration Company completed façade improvements along King Street, Duke Street and in other areas.

The Government introduced the Urban Renewal (Tax Relief) Act in 1995. The aim was to improve significant parts of the city. The first phase of this Tax Incentive Programme (TIP) was launched in August 1995. A variety of companies, small and large, have been making use of the incentives. A Special Development Area (SDA) has been identified in downtown Kingston.

Transport

Traffic congestion and pollution have been growing problems for some time. As incomes have increased, more people have been able to buy cars. Also, the import of a large number of cheap second-hand cars has given many people on modest incomes a chance to buy their own vehicles.

Figure 10.19 Kingston Waterfront redevelopment

As Kingston has sprawled outward, more people are commuting longer distances to work in the centre of the city. Although new roads have been built, this seems to have encouraged more traffic. Some commuters live as far away as May Pen and Mandeville – 65 miles to the west. As more cars enter the central area parking becomes more and more difficult.

Public transport could provide a partial solution but the system is at saturation point. Only a huge investment of new money can solve the problem, but because the economy is weak such large sums of money are not available.

Pollution

Data from the World Health Organization shows that air pollution in Kingston is high, while drinking water pollution, and noise and light pollution are classed as moderate. Heavy pollution in Kingston Harbour has been a long-standing problem. The sources of this pollution have included sewage, domestic waste and oil spills.

Crime

The Jamaica 2013 Crime and Safety Report stated that the crime situation in Kingston was 'critical'. Kingston had one of the highest murder rates in the world. In 2012, in Kingston, there were:

- 1083 murders
- 1218 shootings
- 833 rapes
- 2679 robberies.

The report stated that 'Crime may be as a result of several factors: poverty, retribution, drugs, gangs, and politics.' It is difficult to assess the impact of crime on economic growth in Kingston, but there can be no doubt that it has a major impact on the quality of life of the population.

Figure 10.20 Traffic congestion in Kingston

Activities

1 Look at *Figure 10.17*. Explain in your own words what the diagram shows.

2 Comment on the coverage of key infrastructure and services in Kingston.

3 Describe the sequence of deprivation illustrated by *Figure 10.18*.

4 Suggest how a high crime rate might impact on economic activity.

Controlling urbanisation in the Caribbean

Most Caribbean countries have recognised the problems caused by urbanisation. In particular, there has been great concern about the large size of capital cities compared to other urban areas. There have also been attempts to encourage people to remain in rural areas but this has proved difficult. Strategies for reducing urbanisation and urban growth in developing countries include:

- decentralisation of services
- land use zoning, including green belts
- development of housing away from the larger urban areas
- the upgrade of rural areas
- the diversification of agriculture
- encouraging fertility decline.

All these strategies require significant resources which are usually in short supply in developing countries.

Decentralisation

To combat the growth of large cities, attempts have been made to encourage development away from capital cities. The first Physical Development Plan for Barbados (1970) aimed to spread employment, population and government offices more evenly around the country. The aim was to limit the growth of Bridgetown, the capital city. Little progress was made because the policy was too ambitious. The second and third national Physical Development Plans of 1986 and 1998 focused on the idea of a linear urban corridor. To counter the dominance of Bridgetown, the importance of the urban areas of Speightstown, Holetown, Oistins and Six Cross Roads was to be enhanced.

Trinidad and Tobago produced a Physical Development Plan in the early 1980s, aiming to reduce regional imbalance. A major aim was to direct development toward the rural east and south of the country. However, for both Barbados and Trinidad and Tobago limited progress has been made, as people and businesses may not want to do what the government thinks is best. At present, 40 percent of the population of the country live in the conurbation that stretches across the foothills of the Northern Range, from Port-of-Spain to Arima.

In Cuba, things have been very different. Here the government controls almost everything. After 1963 the government adopted the 'Havana strategy'. The idea was to stop Havana growing so that the rest of the country could catch up. Great efforts were made to improve education and health particularly in rural areas. This would lessen the impact of additional push factors in rural areas. This strategy has had a good degree of success.

Land use zoning laws

In a number of large cities a green belt policy has been adopted to protect farmed or wooded areas at the edge of cities from development.

Green belts:

- limit urban sprawl
- provide recreational opportunities for the urban population
- prevent loss of farmland
- protect wildlife.

Upgrading rural areas and the diversification of agriculture

Improving employment prospects and the overall quality of life in rural areas helps to reduce migration to large urban areas. Schemes to diversify agriculture can help to stem the loss of jobs on the land and may even provide new employment opportunities. Assistance to small and medium-sized rural businesses can also help the employment situation. Investment in public services can do much to improve the quality of life in rural areas.

Activities

1 Why have attempts been made to control urbanisation in the Caribbean?

2 Research in more detail one of the examples mentioned in this section on controlling urbanisation in the Caribbean.

Case Study

China: Strategies for reducing urbanisation

Restricting rural–urban migration: China's Hukou system

For many years the Chinese government followed a relatively restrictive policy toward urbanisation, in part by means of policies that sought to limit rural–urban migration. One explanation for this centres on communist ideology. Another focuses on the interaction of China's development strategy with urbanisation. As the government sought to maximize the pace of industrialisation, limiting urbanisation was seen as having the advantage of reducing the need for large investments in urban housing infrastructure, thus allowing more investment to flow to industry. However, in more recent years, restrictions on migration to urban areas have been gradually eased to satisfy the growing demand for labour in China's rapidly expanding industries.

For some time China has had a fear of uncontrolled population movement. Since the Chinese Communist Party came to power in 1949, regulating and controlling migration has been one of China's most consistent development policies. From the 1950s, the main instrument used to control rural to urban migration has been the population register system (the Hukou system), which identified people as either 'urban' or 'rural'. Permission was required to leave the countryside and was only given if potential migrants could produce documentary evidence that they had an urban job to go to. Food rationing was also used to restrict movement from the countryside. Grain and oil rations in the cities were made available only to people in possession of urban household registration documents.

Alongside these measures, since the 1950s the authorities have periodically encouraged large numbers of people to leave the cities, some voluntarily, others very reluctantly. In the 1950s and 1960s significant numbers of people were sent from urban areas to develop oil-fields in northern and north-eastern China, and to colonise new land for cereal cultivation. The government was also keen to increase population in the sparsely-peopled western provinces, in an effort to achieve more balanced regional development and for reasons of national security. In total, the main migratory direction in China at this time was from the densely populated central and eastern provinces to the sparsely populated and remote border provincial regions in the northern and western parts of the country. Heilongjiang, Inner Mongolia, Xinjiang, Qinghai and Ningxia in particular received large numbers of migrants.

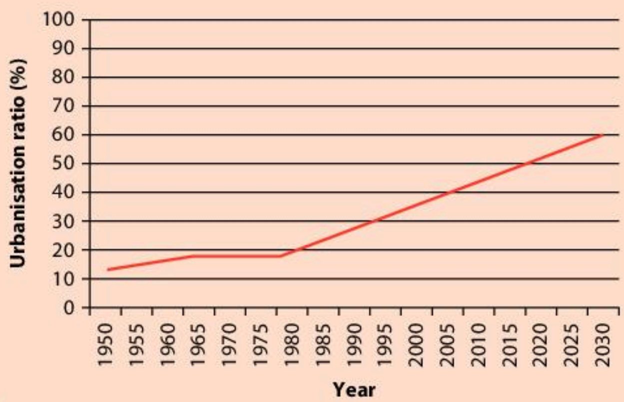


Figure 10.21 Urbanisation in China

Source: International A and AS Level Geography G. Nagle, P. Guinness Cambridge, p. 189

The 'back to the villages' movement in the early 1960s saw 20 million people leave large cities to return to their rural origins. Alongside this counter-stream, large-scale deportations of urban youth to the countryside occurred from the mid-1950s onward. Between 1969 and 1973 alone, an estimated 10 to 15 million urban school leavers were resettled in rural areas. The twin objectives were to relieve urban pressure and to improve rural productivity. The latter would be achieved by the higher level of education the young urbanites would bring to the countryside. Thus, in contrast to the situation in many developing countries, in-migration accounted for only about 30 percent of urban growth in China during the 1950s, 1960s and 1970s.

This unpopular process continued until the late 1970s, after which it was reversed in support of China's industrialisation strategy. Now the emphasis on regional development shifted to the coastal regions to speed up economic development. As a result, many coastal regions, such as Jiangsu, Zhejiang and Guangdong, experienced rapid population and economic growth. The relaxation of controls on rural to urban migration in the 1980s resulted in rapid urbanisation. The huge increase in construction projects attracted many rural migrants but there was big competition for every job in the formal sector, leaving many disappointed and forced to scratch a living in the informal sector.

Although considerable changes in migration restrictions were introduced in the early 1980s, the household registration system was not dismantled and it continues to provide the framework within which migration takes place. Local authorities in rural areas continue their efforts to limit out-migration while local governments in city destinations have erected barriers in terms of employment discrimination and the 'deportation' of migrants back to their areas of origin. Without urban household registration migrants cannot get access to schooling, healthcare and housing.

Balanced development

China's urbanisation strategy emphasises balanced development. Large-scale urbanisation leads to an influx of rural population to the urban areas, bringing immense pressure to the large cities. In order to reduce urbanisation's impact on the large cities, China's urbanisation strategy focuses on promoting the development of small and medium-sized cities, ensuring multi-faceted development of regional economies. The objective is that if rural dwellers decide to migrate to an urban area they will look closely at smaller urban areas within their own region as an alternative to longer migrations to the largest cities in China.

In situ urbanisation

The emergence and development of ***in situ* urbanisation** has been one of the major characteristics of urbanisation in China since the 1980s. This process occurs when rural settlements transform themselves into urban or quasi-urban entities with very little movement of population. Over 20000 small towns in China have developed in this way. The advantages of this process are seen as:

- benefiting significant numbers of the rural population who are often neglected in the development process
- diverting many potential rural–urban migrants who would otherwise head for slum areas in established cities.

On the other hand, critics have argued that the process lacks the benefits of agglomeration economies in large cities and has serious negative effects on the environment. However, in terms of the latter, this has to be balanced against the environment implications of very large cities.

Migration

Migration is defined as the movement of people across a specified boundary, national or international, to establish a new permanent place of residence. The United Nations defines permanent as a change of residence lasting more than one year. Movements with a timescale of less than a year are termed 'circulatory movements'.

It is customary to subdivide the field of migration into two areas: **internal migration** and **international migration.** International migrants cross international boundaries; internal migrants move within the frontiers of one nation. The terms **immigration** and **emigration** are used with reference to international migration. The corresponding terms for internal movements are **in-migration** and **out-migration.** Internal migration streams are usually on a larger scale than their international counterparts. Much internal migration is from rural to urban areas. **Net migration** is the number of migrants entering a region or country less the number of migrants who leave the same region or country. The balance may be either positive or negative.

Migrations are embarked upon from an area of **origin** and are completed at an area of **destination.**

Migrants sharing a common origin and destination form a **migration stream.** For every migration stream, a **counter-stream,** or reverse flow, at a lower volume usually results as some migrants dissatisfied with their destination return home. Push and pull factors encourage people to migrate. **Push factors** are the observations that are negative about an area in which the individual is presently living, while **pull factors** are the perceived better conditions in the place to which the migrant wishes to go. Push and pull factors have been discussed in more detail earlier in this chapter. Once strong links between a rural and an urban area are established, the phenomenon of **chain migration** frequently results. After one or a small number of pioneering migrants have led the way, others from the same rural community follow.

The most basic distinction drawn by demographers is between voluntary and forced migration. **Voluntary migration** is where the individual or household has a free choice about whether to move or not. **Forced migration** occurs when the individual or household has little or no choice but to move. This may be due to environmental or human factors. *Figure 10.22* shows that there are barriers to migration. In earlier times, the physical dangers of the journey and the costs involved were major obstacles. However, the low real cost of modern transportation and the high level of safety has reduced these barriers considerably. In the modern world it is the legal restrictions that countries place on migration that are the main barriers to international migration. Most countries now have very strict rules on immigration, and some countries restrict emigration.

Activities

1 Define migration.
2 Distinguish between (a) immigration and emigration and (b) in-migration and out-migration.
3 Explain the terms (a) origin and destination and (b) stream and counterstream.
4 What is the difference between voluntary and forced migration?

Currently, about 3 percent of the world's population live outside the country of their birth. This amounts to about 213 million people; higher than ever before. Recent migration data shows that:

- With the growth in the importance of labour-related migration and international student mobility, migration has become increasingly temporary and circular in nature. The international mobility of highly skilled workers increased substantially in the 1990s and 2000s.
- The spatial impact of migration has spread, with an increasing number of countries affected either as points of origin

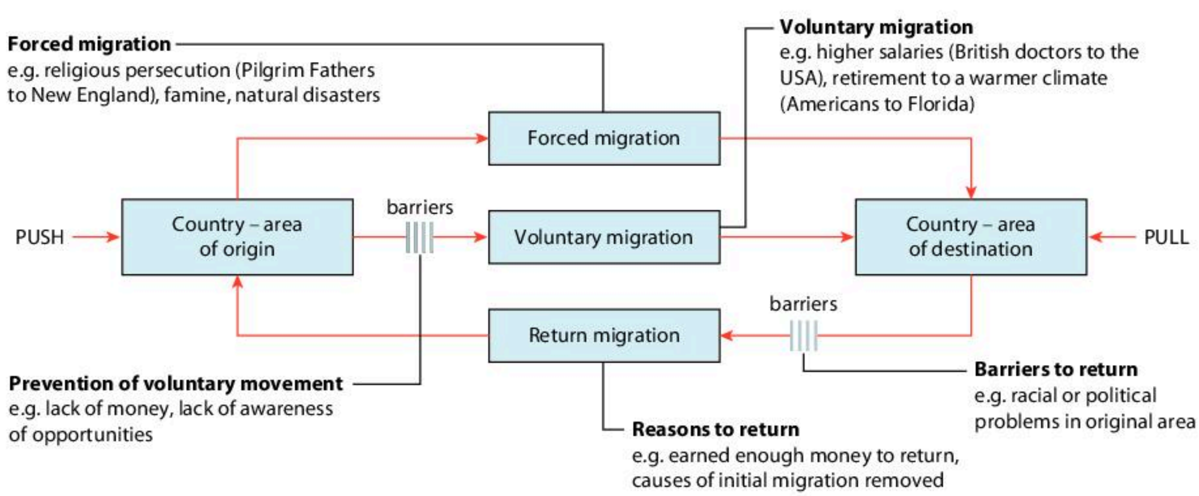


Figure 10.22 Barriers to migration

Source: IGCSE Geography — P. Guinness/G. Nagle, Hodder, p. 19

or destination. While many traditional migration streams remained strong, significant new streams have developed.

- The proportion of female migrants has steadily increased (now almost 50 percent of all migrants). For some countries of origin, for example the Philippines, Sri Lanka, Thailand and Indonesia, women now make up the majority of contract workers.
- The great majority of international migrants from developed countries go to other affluent nations. Migration from developing countries is more or less equally split between the developed and developing world (*Figures 10.23* and *10.24*). However, there is an important qualification here in that the movement between developing countries is usually from weaker to stronger economies.

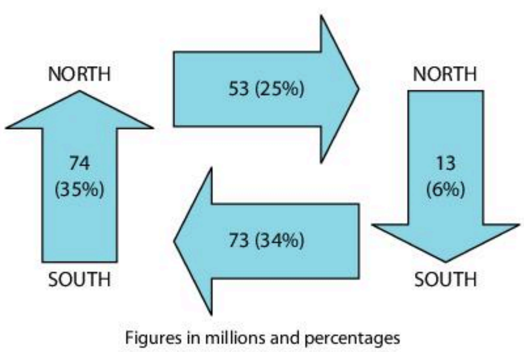


Figure 10.23 International migrant stock by origin and destination, 2010 Source: Cambridge IGCSE Geography, p. 21 Hodder Education

- Developed countries have reinforced controls, in part in response to security issues, but also to combat illegal immigration and networks that deal in trafficking and exploitation of human beings.

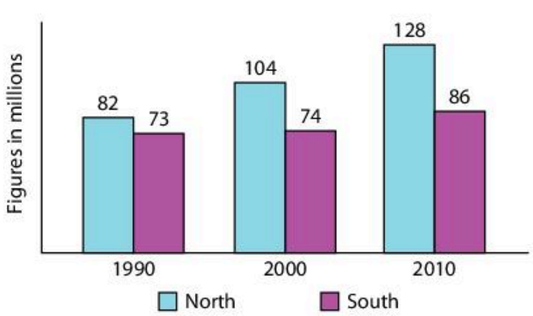


Figure 10.24 International migrant stock in the North and South, 1990–2010 Source: Cambridge IGCSE Geography, p. 21 Hodder Education

Globalisation, in all its aspects, has led to an increased awareness of opportunities in other countries. With advances in transportation and communication and a reduction in the real cost of both, the world's population has never had a higher level of potential mobility. Also, in various ways, economic and social development has made people more mobile and created the conditions for emigration.

Each receiving country has its own sources; the results of historical, economic and geographical relationships. Earlier generations of migrants form networks that help new ones to overcome legal and other obstacles. Today's tighter rules tend to confine immigration to family members of earlier 'primary' migrants.

The consequences of migration

'*The overall economic gains from international migration for sending countries, receiving countries, and the migrants themselves are substantial.*'

The World Bank, 2012

Migration has played a major role in shaping the global cultural map. In some parts of the world international migration is a long-established process. The truly cosmopolitan nature of major cities such as London, New York and Paris is clear evidence of this. In other parts of the world there is little evidence of cultural diversity because international migration has never been significant in these regions.

Figure 10.25 is a summary of some of the possible impacts of international migration. Many of these factors are also relevant to internal migration. Because migration can be such an emotive issue you may not agree with all these statements, and you may consider that some important factors have been omitted.

Impact on countries of origin

Remittances (money sent back to families by migrants working in other countries) are often seen as the most positive impact on the

The impact of international migration		
Impact on countries of origin	**Impact on countries of destination**	**Impact on migrants themselves**
Positive • Remittances are a major source of income in some countries. • Emigration can ease the levels of unemployment and underemployment. • Reduces pressure on health and education services and on housing. • Return migrants can bring new skills, ideas and money into a community.	• Increase in the pool of available labour may reduce the cost of labour to businesses and help reduce inflation. • Migrants may bring important skills to their destination. • Increasing cultural diversity can enrich receiving communities. • An influx of young migrants can reduce the rate of population ageing.	• Wages are higher than in the country of origin. • There is a wider choice of job opportunities. • A greater opportunity to develop new skills. • They have the ability to support family members in the country of origin through remittances. • Some migrants have the opportunity to learn a new language.
Negative • Loss of young adult workers who may have vital skills, e.g. doctors, nurses, teachers, engineers (the 'brain-drain' effect). • An ageing population in communities with a large outflow of (young) migrants. • Agricultural output may suffer if the labour force falls below a certain level. • Migrants returning on a temporary or permanent basis may question traditional values, causing divisions in the community.	• Migrants may be perceived as taking jobs from people in the long-established population. • Increased pressure on housing stock and on services such as health and education. • A significant change in the ethnic balance of a country or region may cause tension. • A larger population can have a negative impact on the environment.	• The financial cost of migration can be high. • Migration means separation from family and friends in the country of origin. • There may be problems setting into a new culture (assimilation). • Migrants can be exploited by unscrupulous employers. • Some migrations, particularly those that are illegal, can involve hazardous journeys.

Figure 10.25 Matrix showing the impacts of migration

Source: Paul Guinness

country of origin. Remittances to developing countries are estimated to have totalled just over $400 billion in 2012. Remittances exceed considerably the amount of official aid received by developing countries. The major sources of remittances are the USA, countries in western Europe, and the Persian Gulf. In 2012, the top recipients of remittances were: India ($69 billion), China ($60 billion), the Philippines ($24 billion) and Mexico ($23 billion).

Other possible advantages of emigration include reducing population pressure on resources such as food and water, and lowering levels of unemployment. Emigration can also reduce pressure on the housing stock, and on health and education services.

In terms of disadvantages, the loss of workers with important skills is of concern in many countries of origin. In extreme cases, there may not be enough people left to continue to farm effectively in some communities. The loss of many young people can advance the ageing of a population.

Impact on countries of destination

An increase in the labour force is generally welcomed by businesses, particularly if migrants have skills that are in very short supply. Greater competition in the labour force tends to limit wage rises and keep inflation low. Many people value an increase in cultural diversity which can enrich communities. An influx of young migrants can help to reduce the rate of population ageing and lower the dependency ratio. This has a positive financial impact on countries.

The negative impact of immigration is more contentious. A significant influx of migrants can put pressure on the available housing stock. It will also increase demand on health, education and other services. In areas where there has been a big change in the ethnic balance, tension between ethnic groups may increase.

Caribbean international migration: patterns and consequences

Caribbean people have a history of going abroad to find work or for educational opportunities. In recent decades, emigration has been a major process in the Caribbean. However, there are some examples of migration within the region. The Cayman Islands and the Bahamas have increased their populations considerably due to this process.

Emigration has been caused by:

- economic hardship
- limitations to professional advancement
- outbreaks of civil unrest and violence
- natural disasters
- alienation with island society
- recruitment efforts by United States agencies.

All of these issues can be classed as push factors.

Changes to immigration laws in both the USA and Canada in the 1960s made migration from the Caribbean to these countries easier. However, at about the same time it became more difficult to migrate to Britain. The USA is the major destination for Caribbean emigrants (*Figure 10.26*). There are well-developed networks between Caribbean communities and immigrant areas in the United States and Canada in particular.

It is not uncommon for individuals to emigrate to the USA or other countries and leave their spouses and dependent children behind. Women have played an increasing role in emigration from the Caribbean, now accounting for almost 50 percent of emigrants. This has been called the **feminisation of migration**.

The Cayman Islands: high immigration

The Cayman Islands has a relatively small proportion of its population born within the islands. Economic growth, particularly in tourism and financial services, has resulted in a rapid expansion in employment which has attracted immigrants from many different countries. The construction industry is a big employer of foreign labour. The largest source of migrants has been Jamaica. Almost one-fifth of the present population of the Cayman Islands was born in Jamaica. Migration into the Cayman Islands is controlled by a system of work permits. This is the same for most countries in the Caribbean. In 2013, 56 percent of the workforce in the Cayman Islands had work permits, with 36 percent of the total population being permit holders. Between 2008 and 2014, more than 12000 people gained permanent residence in the Cayman Islands.

The population of the Cayman Islands increased over six-fold between 1960 and 2013 (*Table 10.5*). The estimated population for 2013 was 56700. While the increase in population has brought benefits, there have also been problems. Economic success and population growth has taken a toll on the environment. Deforestation to make way for new buildings has been the major problem.

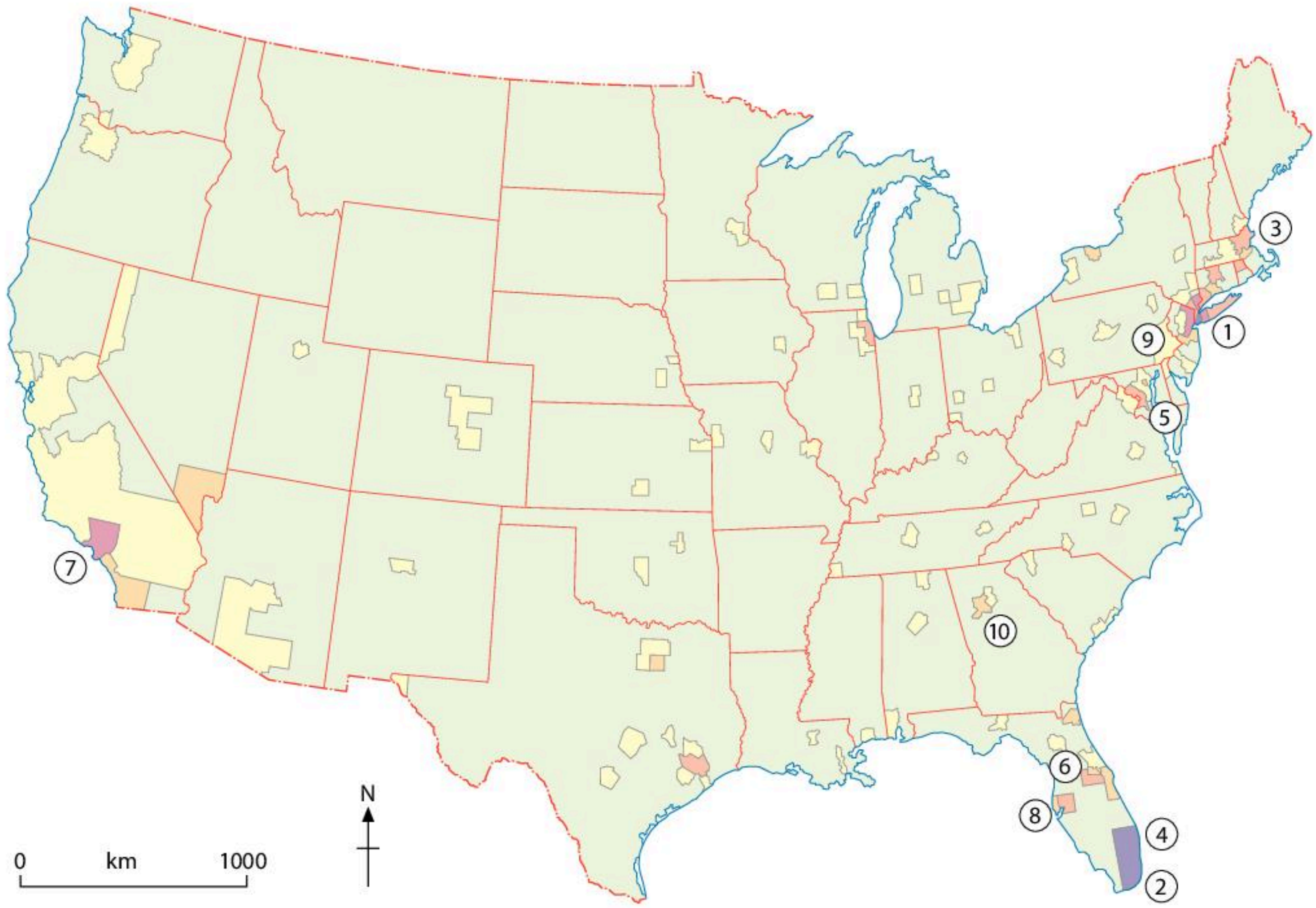
Jamaica: high emigration

The Jamaican **diaspora** is vast, with communities in North America, Europe, Latin America, Africa and Asia. The word 'diaspora' means the dispersal of a people around the world. The number of Jamaicans living abroad is estimated to be about 2.5 million. This is just lower than the population living in Jamaica at present (2.7 million).

The peak period of Jamaican migration to Britain was from 1955 to the early 1960s. The 1962 Immigration Act in Britain restricted the number of West Indian migrants to a lower number than previously. By the late 1960s more migrants were returning to the West Indies than going to Britain. However, by 1970 there were still 300000 Jamaicans living in Britain. This was equivalent to 15 percent of Jamaica's population. Although migration to Britain continues, since the 1962 Act more Jamaicans have emigrated to the USA and Canada than to Britain.

The USA has been the main destination for Jamaican emigrants. Jamaican migration to the USA began in 1920. In 2009, Jamaicans accounted for 18.8 percent of the Caribbean-born population in the USA, after Cuba (28.6 percent) and the Dominican Republic (22.9 percent).

There are sizeable concentrations of Jamaicans in New York City, Miami, Atlanta, Orlando, Tampa, Los Angeles, Philadelphia and



Number of Caribbean-born
- 67 001–689 000
- 29 001–67 000
- 13 001–29 000
- 4501–13 000
- 41–4500

Top 10 metropolitan areas of residence for Caribbean people born in the USA, 2000		
		Number
1	New York/North New Jersey/Long Island	1 238 902
2	Miami/Fort Lauderdale	859 405
3	Boston/Worcester/Lawrence	109 154
4	West Palm Beach/Boca Raton	75 832
5	Washington/Baltimore	67 001
6	Orlando	65 480
7	Los Angeles/Riverside/Orange County	56 137
8	Tampa/St Petersburg/Clearwater	51 095
9	Philadelphia/Wilmington/Atlantic City	44 395
10	Atlanta	41 870

In 2000, there were 2 953 066 Caribbean-born individuals living in the USA.

The states with the largest Caribbean-born population were Florida (1 105 079), New York (1 004 344) and New Jersey (238 572).

Two in every five of the Caribbean-born population lived in the New York metropolitan area.

Figure 10.26 Map of the USA showing destinations of Caribbean migrants

Baltimore. New York City has by far the largest Jamaican community abroad. *Figure 10.28* shows the ages of Jamaican migrants to the USA in 2002.

In Canada, the Jamaican population is concentrated in Toronto. In England, about four percent of Londoners are of Jamaican origin. A further two percent are of mixed

Table 10.5 Population of the Cayman Islands

Year	Population
1960	8511
1970	10068
1979	17030
1989	25350
2000	40000
2013	56700

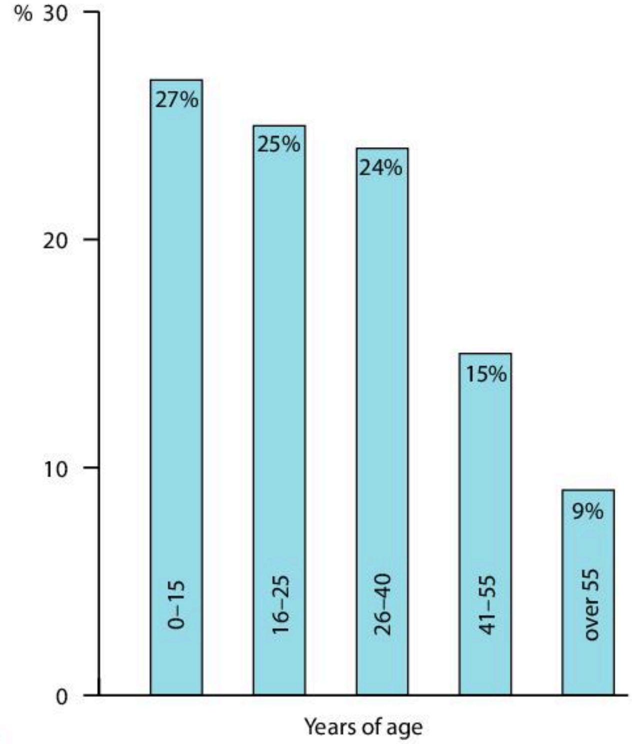


Figure 10.28 Bar graph showing ages of Jamaican migrants to USA in 2002

Jamaican and British origin. One of the largest and most famous Jamaican communities is in Brixton, South London.

The emigrants would have greatly increased the pressure on employment and social services had they remained in Jamaica. This is an indirect impact. A direct impact is the positive effect that they have on the country's economy. In Jamaica, remittances are an important source of income for thousands of people. In 2013, remittance inflows amounted to $2.06 billion. With a low level of remittance outflows, net remittances totalled $1.8 billion.

About 15 percent of Jamaica's GDP comes from remittances. This is a significant amount of money. Such money can be important in establishing new small businesses. Apart from direct cash remittances, Jamaican communities abroad also help with:

- education
- youth and community development
- healthcare
- contributions in times of natural disasters.

An increasing number of Jamaicans overseas take holidays in their own country, which benefits the tourist industry. Also, people who return home permanently from abroad often bring back skills which are beneficial to the country. Others have made money abroad which they may invest in new businesses in Jamaica.

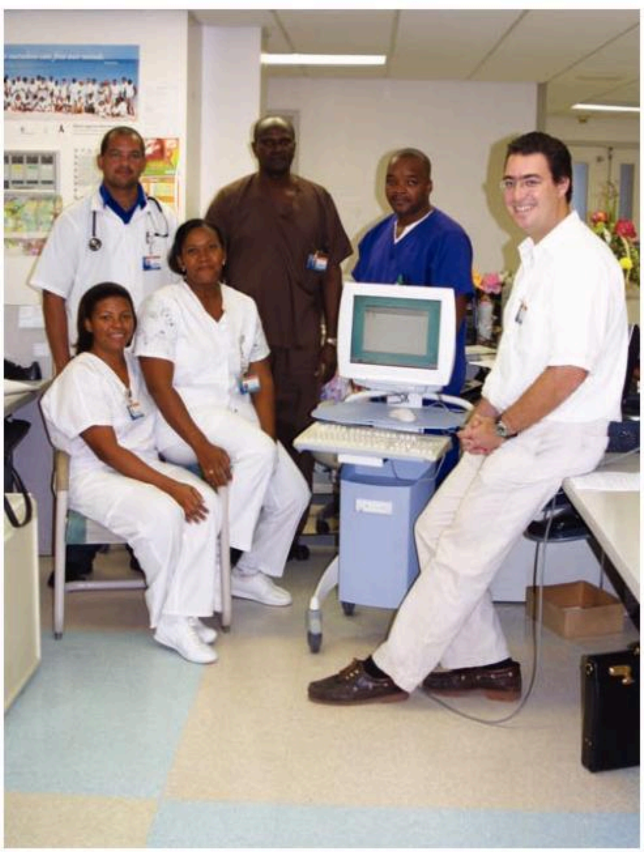


Figure 10.27 Healthcare professionals in the Cayman Islands

A major problem caused by emigration is that significant numbers of children are left with relatives as their parents seek a better life abroad. They are sometimes known as 'barrel children', as in the past, parents working abroad shipped money, clothes, toys and other things back to their children in barrels. Children who do not live with their parents on a regular basis tend to develop more social problems than the average child. For example, their education is likely to suffer and they are more likely to be involved in crime.

Return migrants

Many Caribbean emigrants leave their countries with the intention of returning for good at some stage in the future. This may happen because of:

- retirement
- disappointment with conditions abroad such as poor weather and under-achieving schools
- returning to build a house or start a business after gaining skills and saving money abroad
- people who have been deported and sent home because they migrated illegally or were convicted of a criminal offence.

Activities

1 Draw a bar graph to show the increase in population of the Cayman Islands between 1960 and 2013.

2 **a** What is the meaning of the word 'diaspora'?
b How wide is the Jamaican diaspora?
c Explain why the USA is the main destination for Jamaican emigrants.

3 Why are remittances so important for many developing countries?

Skills

Interpreting tables

There are a number of tables in this chapter. *Table 10.5* is an example. Always check the following:

- read the title of the table carefully
- read the column headings (across the top of the table)
- read the row headings (along the right-hand side)
- note the units for any figures given (thousands, millions etc.).

Now study the information carefully. Note in particular the highest and lowest figures. If data is provided for different time periods, are there any trends you can recognise?

Write a detailed paragraph analysing *Table 10.5*.

Interpreting line graphs

Figure 10.28 is an example of a bar graph. Always check the following:

- Read the title of the graph carefully.
- What does the X-axis show?
- What does the Y-axis show?
- Be clear about the units used (thousands, millions etc.).
- How many lines are shown on the graph?

You should now be ready to study the line graph carefully. Note in particular the figures for:

- the starting time
- the finishing time
- the time(s)when there are any significant changes on the graph.

Write a detailed paragraph analysing *Figure 10.28*.

Glossary

CBD: Central Business District. This is the commercial and geographical heart of a city.

Diaspora: the dispersal of a people around the world.

Forced migration: occurs when the individual or household has little or no choice but to move.

Formal sector: Employment in offices, shops, factories and other organisations, which is known to the government. Workers are liable to tax on their incomes but may enjoy benefits such as holiday pay and sick pay.

Ghetto: a highly segregated area often dominated by one racial group. Ghettos are characterised by substandard housing, high unemployment, poverty and high levels of crime. Housing may be a mixture of deteriorating properly built houses and shanty-style development.

Informal sector: low-paid, usually temporary jobs that people often create for themselves such as selling food and drinks on the streets. Such jobs will not be registered with the government and will not attract tax.

Mega-city: a city with a population of 10 million people or more.

Migration: the movement of people across a specified boundary, national or international, to establish a new permanent place of residence.

Primate city: a city that is at least twice the size of the second largest city.

Remittances: money sent home to families by migrants working in another country.

Shanty town: an area of makeshift housing usually built by the occupants themselves. Shanty towns are unplanned and often illegal, having been built on land owned by other people.

Slum: a heavily populated urban area characterised by substandard housing and squalor.

Urbanisation: the process whereby an increasing proportion of the population in a geographical area lives in urban settlements.

Urban growth: the absolute increase in physical size and total population of urban areas.

Urban primacy: when one or a few cities dominate the settlement system of a country.

Urban sprawl: the rapid outward expansion of an urban area by low-density suburbanisation.

Voluntary migration: where the individual or household has a free choice about whether to move or not.

Exam-style Practice

1 *Figure 1* shows the results of a survey of seven groups of people regarding urban environmental problems in Kingston, Jamaica.

- **a** What are TWO important findings of the survey? [2]
- **b** How did the following problems rank in the survey?
  - **i** electricity
  - **ii** sewerage
  - **iii** unemployment. [3]
- **c** How might THREE of the problems affect people living in the area? [9]
- **d** To what extent has the population added to TWO of the problems? [6]
- **e** Which of the problems do you think needs to be addressed most urgently? Explain your answer. [4]

Total 24 marks

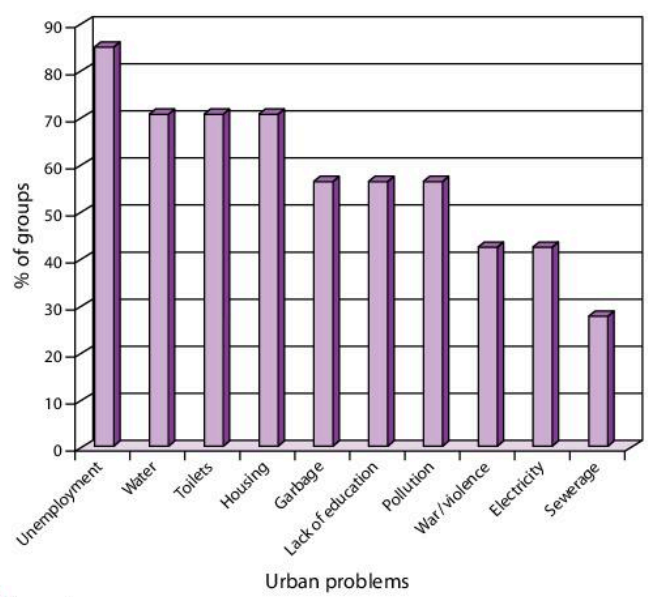


Figure 1 Bar graph showing urban environmental problems in Kingston

2 *Figure 2* shows the relationship between GDP (Gross Domestic Product) and remittances per capita for a number of countries in Latin America and the Caribbean.

a Which country has:

i the highest GDP per inhabitant (state the value)

ii the lowest GDP per inhabitant (state the value)

iii the highest remittances per inhabitant? (state the value) [3]

b Describe the relationship between remittances and GDP. [3]

c List THREE factors that contribute to the relationship between remittances and GDP. [3]

d Describe how a government can improve the flow of remittances through:

i technology

ii financial regulations [6]

e What are THREE causes of urbanisation? Support your answer with examples. [6]

f Discuss and describe the impact of urbanisation on rural areas. [3]

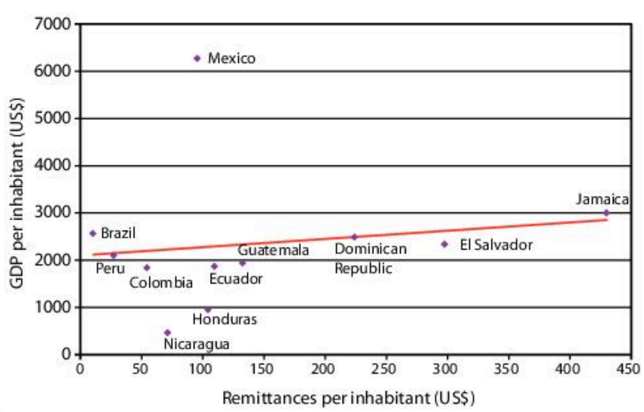


Figure 2 Scatter graph showing relationship between GDP and remittances

Total 24 marks

3 a State THREE reasons many cities in the Caribbean are increasing in size. [3]

b Explain how the problem of over-population experienced in the cities mentioned can be solved. [5]

c Define the following terms:

i rural-urban migration

ii mega-cities

iii urban primacy decentralisation [6]

d Using the photograph in *Figure 3*, explain the negative effects of urbanisation on the environment. [6]

Figure 3 An effect of urbanisation

e Explain FIVE benefits Caribbean countries can derive from urbanisation. [5]

Total 25 marks

11 Economic Activity

In this chapter you will study:

- the classification of industry
- economic development
- the importance of economic activity in the Caribbean
- factors influencing industrial location
- economic activity in the primary, secondary, tertiary and quaternary sectors
- challenges to the economies of the Caribbean.

You will also learn:

- how to draw a pie chart.

This chapter looks at **economic activity** – industry and jobs, how people earn a living and how wealth and money is produced, both for individuals and countries. There are huge changes taking place in industry as a result of **globalisation** – that is, the way in which people around the world are more connected to each other than ever before. Many of these changes have significant effects on the people of the Caribbean.

Industry is the way that products and services are made or created – for instance, the fashion industry includes all those businesses and people involved in making clothes, from designers to factory workers and retailers.

Geographers tend to group, or **classify**, all economic activities into four different types of industry, also known as **sectors**. These are primary, secondary, tertiary and quaternary (*Figure 11.2*).

Classification of industry

Primary sector

Primary activities, or **primary industries**, are those that take **natural resources** out of the Earth. Because of this they are also known as **extractive** industries. Examples include farming, fishing, forestry, mining and quarrying.

Some primary industries produce goods that can be used just as they are. In the Caribbean, a good example is the fishing industry. The fishermen go to sea and come back with the fish they sell directly to market.

Other primary industries, however, produce **raw materials** that are used by other industries. For instance, oil from Trinidad and Tobago is exported to companies in the USA where it is used to make petroleum products.

Most developed countries, for example the UK, have very few people involved in primary industries but in many developing countries, such as Ethiopia in Africa, primary industries employ more people than any other type of industry. In the case of Ethiopia, 80 percent of the population work in agriculture.

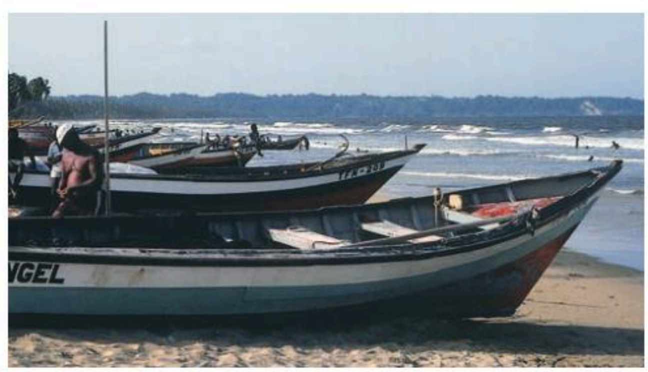


Figure 11.1 Fishing in Trinidad: a primary economic activity

- **Primary industries** extract raw materials directly from the Earth or the sea.
- **Secondary industries** process and make (manufacture) things from the products of primary industries.
- **Tertiary industries** provide a service.
- **Quaternary industries** provide information and expertise.

Figure 11.2 The classification of industry and economic activity

Figure 11.3 Extracting raw materials in the USA

Secondary sector

Secondary activities, or **secondary industries**, are involved in the production of processed goods such as clothes. Many take raw materials from the primary sector and use them to make products for sale. Others use goods provided by other secondary activities and process them to complete their finished product. For example, in car manufacture the factory where the car is put together is supplied with parts by other factories that specialise in making wheels or seats or windscreens. Secondary industries are also known as **manufacturing industries** and almost always use some kind of factory.

Secondary activities are good for a country's economy because the things they produce, when sold abroad as **exports**, make more money than raw materials. A country with a large fishing fleet such as Haiti may never become rich because it has to sell the fish to local markets, probably at quite low prices. However, if a country sets up a successful fish processing factory, it can freeze or can or dry the fish and sell the products all over the world. This brings money into the country as **export revenues**.

Some developed countries have a fairly strong manufacturing base and are heavily involved in secondary industries. In Japan, steelmaking uses raw materials brought in (**imported**) from other countries and provides the steel for the shipbuilding and car-making industries. It brings a lot of money into the country but, because factories use a lot of high-technology machinery, it may not employ many people. Developing countries, for a number of reasons, may not have the factories capable of processing their raw materials and their economies suffer as a result.

Figure 11.4 A food processing plant in Jamaica

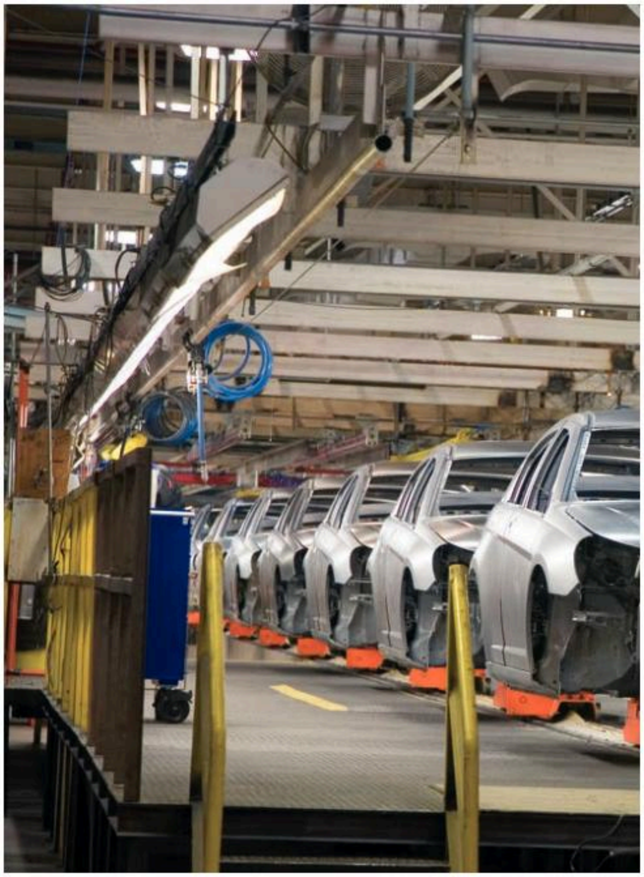


Figure 11.5 Secondary economic activity in a developed country – making cars in the USA

Tertiary sector

Tertiary activities, or **tertiary industries**, are those that provide a **service**. Because of this, they are also known as **service industries**. Unlike primary and secondary industries, they do not make goods that can be seen or handled. Instead they include employment in education, health, the police and fire brigade, public transport, local government, banking and finance. Two of the biggest Caribbean employers, tourism and retailing (which includes all types of selling), are included in the tertiary sector.

In many countries it is the tertiary industries that now employ the majority of the population. In Jamaica, 64 percent of people work in the service sector, while in the UK the figure is 82 percent – but the services provided by the two countries are very different. Jamaica's tertiary activities are very much based on tourism while those in the UK are largely in the retail, distribution and services industries, for example health, education, retail, catering and the financial sector.

Most developing countries, unless they have a highly developed tourist industry, have a low percentage of people working in the tertiary sector.

Figure 11.6 Providing an educational service in Jamaica

Figure 11.7 Tourism: the most important tertiary industry in the Caribbean

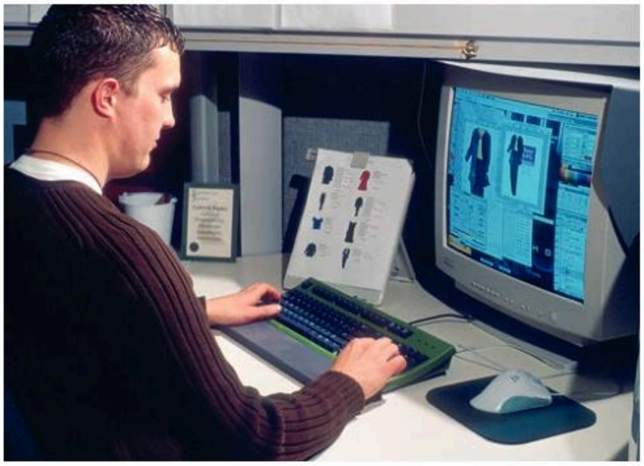


Figure 11.8 Quaternary industry worker

Quaternary sector

Quaternary activities, or **quaternary industries**, are a fairly new addition to the classification of economic activities. They are often thought of as just another part of the tertiary sector because they also provide a service. The difference is that the quaternary sector mainly concentrates on those industries that provide information and expertise. This includes activities such as training and research and development and includes high-technology industries such as internet-based companies.

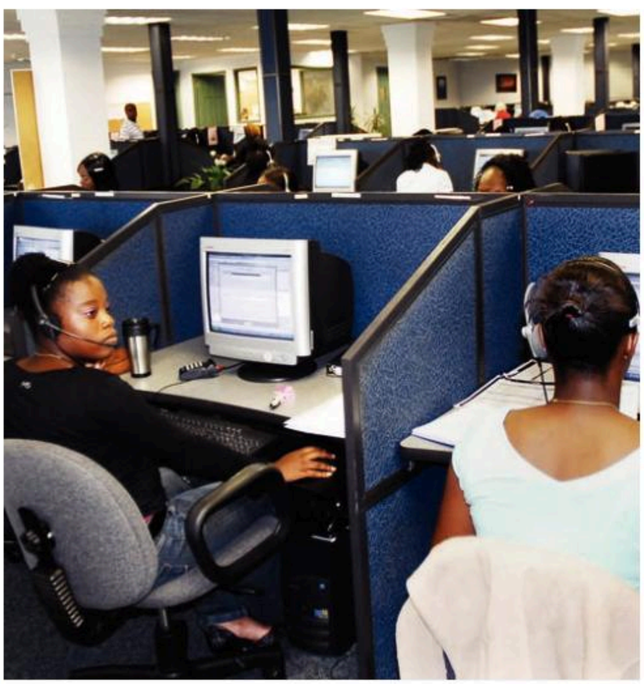


Figure 11.9 Call centres are a growing industry in the Caribbean

Because many of the quaternary industries rely on new technology such as satellites and computers, they do not have to be located near to their raw materials in the same way as drilling for oil has to be. They can, therefore, move to areas either where wages are lower or where there is a pleasant environment for their employees to live and work.

Several companies in the quaternary sector are now setting up in the Caribbean for these reasons. **Call centres**, where people ring up for advice on their bank accounts or for help in booking airline flights, are a good example. The customer never comes into direct contact with the employee they talk to on the phone, so it makes no difference whether the company is located in Guyana, India or the UK.

Activities

1. Look at the pictures of various workers and industries in *Figures 11.2* to *11.9*.
   - **a** Classify the pictures by economic activity and identify whether they are from a developed or a developing country.
   - **b** Write down the similarities and differences between developed and developing countries for each of the economic activities.
2. Give an example of each classification of economic activity:
   - **a** in your own country
   - **b** for a country outside the Caribbean region.
3. Which type of economic activity do you think helps the economy of your country the most? Give reasons to justify your answer.

Economic development

Over time, economists, who study the wealth of the world, have thought up many different ways to measure how rich a country is. The most widely accepted statistic, or **indicator**, of wealth is **GDP**, or **gross domestic product**, per capita (per person). Other commonly used indicators you may hear of that measure similar things include GNP (gross national product) and GNI (gross national income).

$$\text{GDP per capita} = \frac{\text{the total value of goods and services produced by a country}}{\text{the total population of a country}}$$

So economists add up all the profits from tourism, fishing, clothing factories and any other economic activity that a country carries out, then divide the total by the number of people living in the country. GDP is almost always measured in US dollars (US$). It should be remembered, however, that GDP is an *average* figure, which is distorted by the extremely high incomes of some and low incomes of others within a particular country.

The use of GDP has been criticised because it tells us nothing about what people can actually buy with their money. For instance, even though GDP per capita is much higher for the UK than it is for Jamaica, 1 kg of sugar is much cheaper to buy in Jamaica. Despite this, GDP per capita is seen as being a very useful way of comparing how rich various countries are. Some GDP figures for countries in the Caribbean are shown in *Table 11.1*.

It can also be useful to look at other economic statistics such as the growth rate of a country's GDP. This tells us how well the economy of a country is growing. Most countries would hope to see their economies grow by at least 2 percent per year. As *Figure 11.10* shows, economic growth is not consistent across the Caribbean: the economy of Trinidad and Tobago is based on oil and gas and a well-developed manufacturing industry. It is much healthier than that of Haiti which has had lots of political problems and, because it is quite poor, fails to attract industries and investment from other countries.

Table 11.1 GDP per capita figures for selected Caribbean countries, 2012

Country	GDP per capita (US$)
Bahamas	32 000
Barbados	25 000
Grenada	13 800
Guyana	8500
Haiti	1300
Jamaica	9000
Dominican Republic	9700
St Kitts and Nevis	16 300
St Lucia	13 100
Trinidad and Tobago	20 300

Source: *Philip's School Atlas*

Trade

Countries that have something valuable or unique to sell are in a much better position to

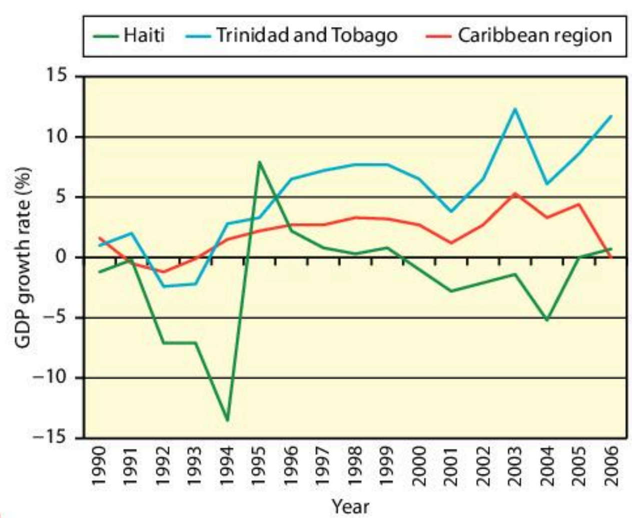


Figure 11.10 GDP growth rates for Trinidad and Tobago, Haiti, and the Caribbean

Source: Economic Commission for Latin America and the Caribbean, 2006 get rich than those that do not. In the example of *Figure 11.10*, Trinidad and Tobago's oil and gas industry brings in a considerable revenue. By contrast, Haiti has few natural resources and its main industries, like clothing manufacture and sugar harvesting, do not generate much income. No country is entirely **self-sufficient** – that is, producing all the goods it needs by itself. For instance, Trinidad and Tobago exports ammonia and methanol but needs to import food and animals from other countries in the Caribbean and from the USA. One of the most important things for a country's economy is to try to balance its imports and exports:

- If a country spends more on imports than it gains from exports, then the economy will show a **trade deficit**.
- If a country gains more money from exports than it spends on imports, then the economy will show a **trade surplus**. Examples of import and export figures for some Caribbean countries are shown in *Figure 11.11*.
- A country with a trade deficit may still be quite rich if it has other means of making money such as tourism or a big financial services industry.

Many factors can affect how a country trades. A number of Caribbean countries have one or two major agricultural crops they sell all around the world, such as sugar or coffee. They do not set the price they get for their crops, however, because there are many other countries selling the same things. If one country tries to increase the price of the crop, then buyers will get it from another country that is selling it more cheaply.

Countries only selling one or two types of crop also suffer more from problems such as disease or natural disasters, like hurricanes, which can destroy a whole season's crop. In 2005, Hurricane Ivan destroyed 60 percent of the Jamaican Blue Mountain coffee crop – one of the world's most sought-after coffees – just as the year's harvest was about to begin. In the short term this can mean a big price increase for the product that is left but it may also mean that buyers give up on a country where the harvest is uncertain and this can have long-lasting effects on the economy.

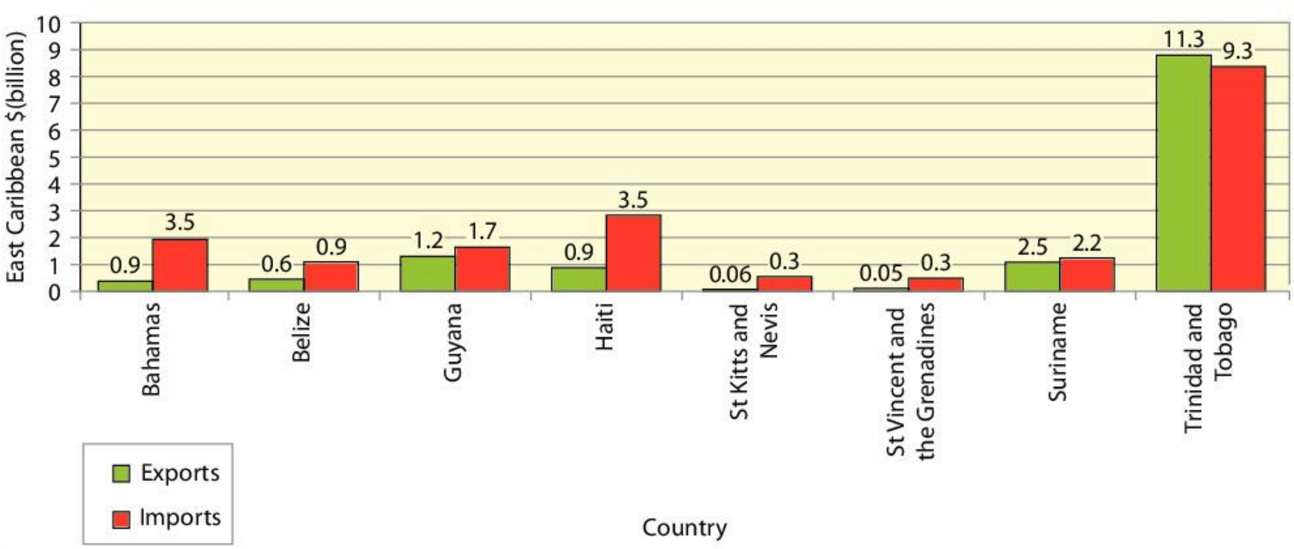


Figure 11.11 Import and export figures for selected Caribbean countries

Source: Economic Commission for Latin America and the Caribbean, 2014

Activities

1 Draw a bar graph to illustrate the information shown in *Table 11.1*.

2 Many different factors can affect a country's trade balance. Think of your own country, or a neighbouring country, and write down examples of such factors. How might they affect trade?

The importance of economic activity in the Caribbean

All four types of economic activity are important to the islands of the Caribbean but their relative importance varies from place to place and changes over time. Nowadays, almost all the Caribbean islands have a well-developed tourist industry in the tertiary sector. However, a hundred years ago, only a few very rich visitors from Europe and North America would have contributed to this part of the economy.

Up until the middle of the 20th century, most of the Caribbean's income came from the primary sector, mainly from agriculture and large estates producing valuable crops such as sugar, bananas and nutmeg. Within the primary sector, most of the population were involved in **subsistence** farming – producing crops for themselves and their families to eat. They contributed little wealth to their country's economy.

Nowadays, while many farmers are still trying to grow crops to feed their families, many are also hoping to sell extra crops, called a **surplus**, to bring in extra cash (see Chapter 12).

As countries become more economically developed, fewer people work in agriculture and secondary and tertiary activities become more important. In the Caribbean, these include:

- garment manufacturing in St Kitts and Nevis, food processing and the drinks industry in Jamaica, electrical goods in Barbados and cement manufacture in Guadeloupe
- tourism in Jamaica, Puerto Rico, Dominican Republic, Cuba and many other Caribbean islands
- financial services in Bermuda, the Cayman Islands and the Netherlands Antilles.

Most countries also develop their health and education services as they become richer.

Increasingly, quaternary activities are responsible for more wealth in Caribbean countries. The contributions of different industries to the economies of Trinidad and Tobago and Jamaica are shown in *Figure 11.12*.

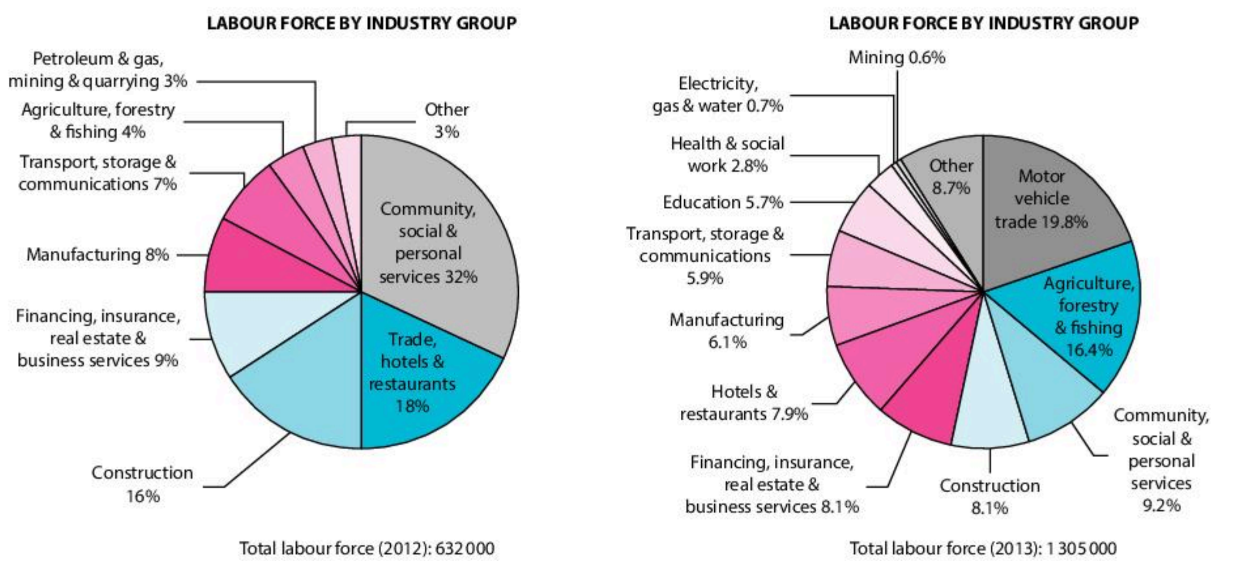


Figure 11.12 Employment in economic activities in Trinidad and Tobago and Jamaica, 2012

Source: *Philip's Certificate Atlas for the Caribbean* (5th edition) 2004

Economic benefits

Economic activities are important for a number of reasons but mainly because:

- they create jobs
- they earn **foreign exchange** money, such as US dollars, euros and UK pounds
- they gain money for the government.

Keeping a country's population in work is one of the main aims of any government. People with jobs pay taxes to the government which uses this money for services such as health and education. Unemployed people may have to be supported by the state through payments or through providing services at subsidised rates. Working people, on the other hand, help to build the society by the work that they do and they help to pay for the services by their contribution of personal income taxes.

All governments need foreign exchange to pay for goods and services from overseas. Money paid for exports will often be in US dollars and this is useful for governments that want to buy things from other countries.

Governments also take money in taxes from companies and businesses operating in their country. This money can be spent on the **infrastructure**, such as roads, port services and education for the people. A better infrastructure will attract more foreign investment into the country.

Employment structure

Different countries have very different numbers of people in each sector of their economy, as *Tables 11.2* and *11.3* show for agriculture, industry and services.

The importance of tourism to the whole Caribbean means there are very large numbers of people working in the service sector. In much of the rest of the world, service industry jobs are normally concentrated in what is called the **public sector** – jobs provided by government in, for example, education, health, tax collection and local government. While these jobs are also available in the Caribbean, many people are employed selling goods in gift shops, working in hotels (*Figure 11.13*) and providing services such as guided tours for visiting cruise ships.

Everybody who has a job needs somewhere to spend the money they earn on food and manufactured goods and other services. They will often spend money locally, contributing to the economy of their own country and giving money to retailers who then employ other people.

Table 11.2 Numbers employed in various economic sectors in selected Caribbean countries as a percentage of the total workforce

Country	Agriculture	Industry	Services
Antigua and Barbuda	2.8	15.6	81.6
Bahamas	3.7	12.9	83.4
Barbados	2.7	18.9	78.5
Dominican Republic	14.5	16.7	69.1
Guyana	23.1	18.8	58.1
Montserrat	6.6	5.6	87.8
St Vincent/Grenadines	24.9	8.7	66.4
Trinidad and Tobago	3.7	29.4	66.9

Source: International Labour Organization, 2015

Figure 11.13 A receptionist helps tourists in the hotel

This situation, where employment in one sector increases employment in others, is called the **multiplier effect**. The more people there are in work, the greater this effect is.

The informal economy

While most people try to find work in what is known as the **formal sector** (including factory workers, professionals, shop and office workers) many others work in the **informal sector**.

Informal sector workers do a huge variety of jobs including selling goods to people at traffic lights, setting up market stalls (*Figure 11.14*), cleaning shoes and making repairs to furniture in backstreet shops. The workers often have limited education and contribute little, if anything, in the way of taxes. However, as they make a success of their small businesses, many try to get an education, find a better job and so enter the formal sector.

Developing countries often have high rates of unemployment and underemployment (where there are not enough jobs for people to work full-time). With many people migrating from the country areas to the towns and cities, many become self-employed, often working in the informal sector. A comparison of the formal and informal sectors is shown in *Table 11.4*.

Figure 11.14 Street sellers in St Lucia working in the informal sector

Table 11.3 Numbers employed in various economic sectors in selected developed and developing countries as a percentage of the total workforce

Country	Agriculture (and fishing)	Industry	Services
Canada	1.7	20.2	78.1
France	2.8	20.5	76.7
Hong Kong*	0.2	11.7	88.1
Netherlands	2.1	14.9	83.0
Maldives (2000)	14.6	15.7	69.7
Mauritius	7.5	28.0	64.5
Singapore	0	19.9	80.1
United Kingdom	1.3	18.8	79.9

* a Special Administrative Region of China

Source: International Labour Organization – 2015

Table 11.4 Differences between the formal and informal economic sectors

Formal	Informal
Type of job	
Retailing – department stores and food franchises	Distribution, such as street sellers and small market stalls
Government-created jobs including the police, army and civil service	Services, e.g. shoe cleaners, selling clothes and fruit
Manufacturing – both local companies and companies from overseas	Small-scale industries, such as food processing and dress repairs
Description	
Mainly employees	Self-employed
Regular hours and wages	Irregular hours and uncertain wages
Fixed prices	Prices negotiable (bartering involved)
Jobs done in factories or organised shops and offices	Jobs often done in the street or in homes
Legal	Sometimes illegal
Use foreign investment and expensive raw materials	Little money invested and uses cheap or recycled materials
Advantages	
Uses some skilled and unskilled workers	Uses many unskilled workers
Provides permanent jobs and regular wages	Jobs may provide training and skills that lead to better jobs in future
Waste materials provide raw materials for the informal sector	Uses local and waste materials

Employment of children A large number of workers in the informal sector are children, many of them under 10 years old (*Figure 11.15*). Few of them go to school and, instead, they work the streets from a very early age to add to their family's income. For some, the money they earn helps to pay for their education and they will work hard during the day and study hard at night to find better employment in the future.

Activities

1 Think about the development of the economy of your own country. What changes in economic activity have taken place over the last hundred years?

2 Compare the employment structures of Jamaica and Trinidad and Tobago shown in *Figure 11.12*. What do the figures tell you about the economic activities in each of these countries?

As soon as the department stores close, the street vendors open for business. They hang their imported jeans and T-shirts on the protective rails installed by the store owners. Soon the street is transformed into a gallery of displayed apparel. Large suitcases and display cots obstruct passage on the pavements, so customers are obliged to amble slowly along the street. Among the sellers are children who at first glance appear to be kept there by their parents (the seller) for supervision. However, when the adult goes to find change for a sale the child is left to tend the stall and conducts business with as much skill and financial acumen as the parent.

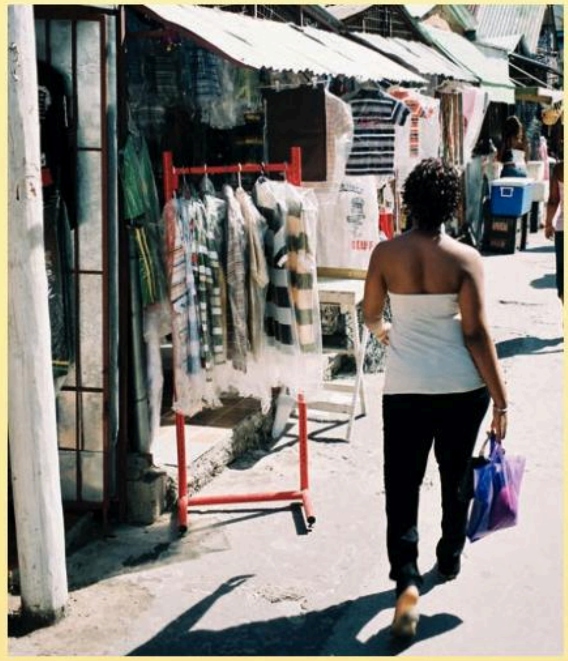


Figure 11.15 Personal observations on street vending in Trinidad

Source: author's notebook

Skills

How to draw pie charts

Pie charts, also known as divided circles, are an excellent way of displaying geographical and statistical information. They show a circle, or 'pie', divided up into sections, or 'slices'. Any data that can be converted into a percentage can be displayed using a pie chart and they add dramatic visual impact to your field studies and essays.

The example set out here uses the data in *Table 11.5*.

1 The first task is to calculate the size of each slice in the pie. To do this we need to know the total expenditure – the sum of the items in the second column:

Total expenditure
= 3193 + 2415 + 2614 + 170 + 450
= US$8842

Table 11.5 Expenditure per tourist in selected Caribbean countries

Country	Expenditure per tourist (US$)
Puerto Rico	3193
Bahamas	2415
Cuba	2614
Haiti	170
Trinidad and Tobago	450

Source: *Philip's Certificate Atlas for the Caribbean* (7th edition) 2015

2 To draw a pie chart, each part of the data must be represented as a proportion of 360 (because there are 360 degrees in a circle). Each tourist to Puerto Rico spends US$3193 out of a total of US$8842, so the

calculation to find the number of degrees needed to represent that information is:

(3193 ÷ 8842) × 360 = 130°

Calculations for the other countries:

- Bahamas = (2415 ÷ 8842) × 360 = 98°
- Cuba = (2614 ÷ 8842) × 360 = 106°
- Haiti = (170 ÷ 8842) × 360 = 7°
- Trinidad and Tobago = (450 ÷ 8842) × 360 = 19°

It is easier to draw in whole degrees, so you need to round up (or down) some of the degrees calculated to get a whole number. You should make sure the total number of degrees adds up to 360.

3 Now you are ready to draw your pie chart (*Figure 11.16*).

4a Look through this chapter and find data that can be converted into pie charts. For example, *Table 11.2* shows the percentage of people employed in various sectors of economic activity for selected Caribbean countries. To draw a pie chart from this example, read the figures across the row. As the figures are percentages, you need to divide each by 100. So, using the Bahamas as an example:

- Agriculture = (3.7 ÷ 100) × 360 = 13°
- Industry = (12.9 ÷ 100) × 360 = 46°
- Services = (83.4 ÷ 100) × 360 = 301°

Draw the pie chart to illustrate this data. Pick one more country and construct a similar pie chart for that country. Don't forget to add labels and a title.

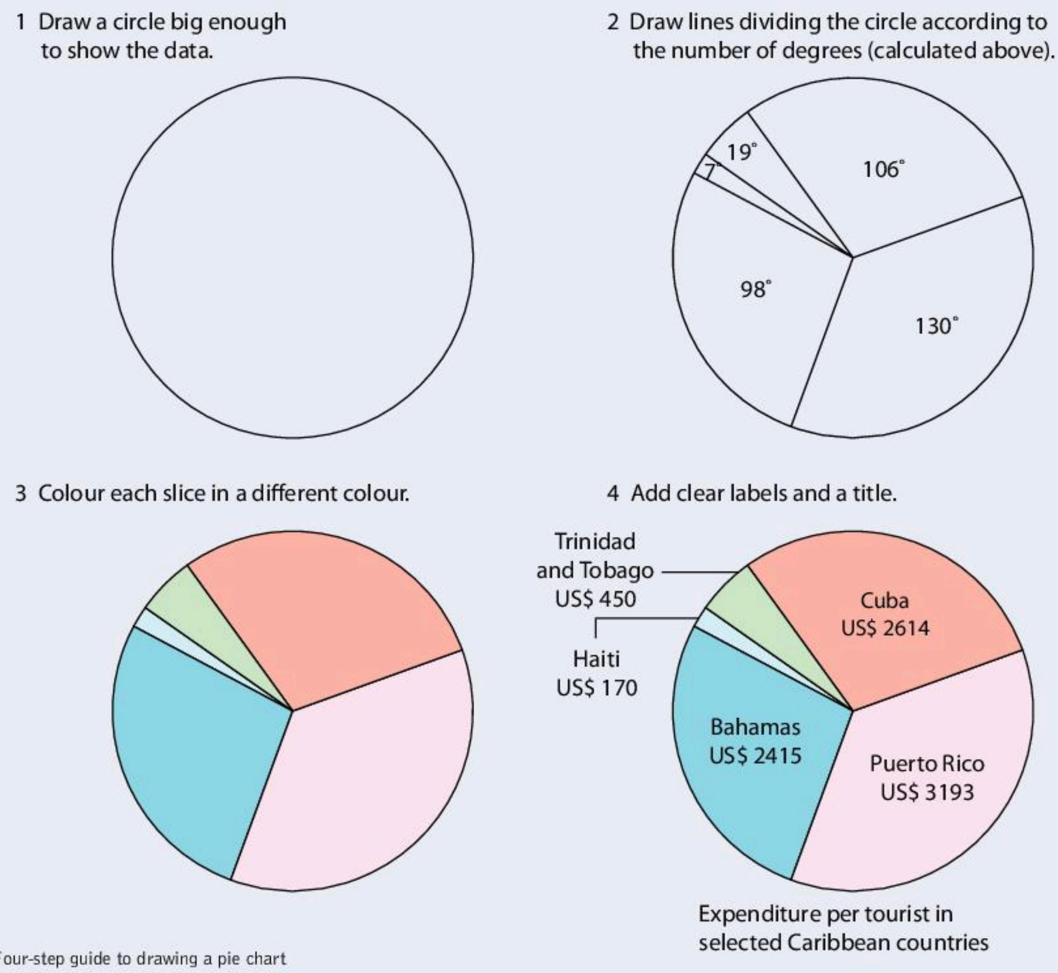


Figure 11.16 Four-step guide to drawing a pie chart

Table 11.6 Jobs by economic activity in Grenada and Suriname, 2013

	Jamaica (%)	Suriname (%)
Agriculture, hunting, forestry and fishing	15	4
Mining and quarrying	1	7
Manufacturing	18	31
Construction	8	11
Wholesale and retail trade	20	18
Transport, storage and communication	7	7
Finance, insurance and real estate	6	2
Community services	25	20

Source: International Labour Organization (Caribbean Office), 2015

b Now you have two pie charts showing the same kind of data for two different countries, so you can analyse them. Describe the differences between the two charts and try to come up with reasons for the differences.

5 Pie charts can be used to show quite complex sets of data in a simple form that can often be understood more easily than if the data is presented as a table. Construct a pie chart to show the jobs by economic activity for Suriname using the data in *Table 11.6*. There is a lot more information to consider here and much more work involved, but the basic principles for the construction of the pie chart remain the same.

Factors influencing industrial location

Most industries and major economic activities have very specific needs, which affect where they are set up. Older, or traditional, industries in developed countries needed to:

- be near to raw materials
- have a reliable power source (originally water and then, later, coal)
- be close to the market where the goods were sold, as transporting them by horse and cart or by canal would have been difficult (road and rail transport was not developed at that time).

The coalfields of Western Europe provided a huge source of energy, from central Scotland across Germany to Poland. Because of this, these countries became very wealthy through industries such as iron- and steel-making.

In the Caribbean, many of the factors that influenced industrial location in developed countries are less important. For instance, as islands are generally quite small, there is often

Table 11.7 Factors influencing industrial location

Physical factors (related to the natural environment)	Human and economic factors
Raw materials: the bulkier and heavier these are to transport, the nearer a factory should be located to the raw materials. This was even more important in times when transport was less developed. **Power (energy)**: this is needed to work the machines in the factory. Early industry needed to be sited near to fast-flowing rivers or coal reserves but, today, electricity can be transported long distances. **Natural routes**: in the days before the railway, car or lorry, transport was by river or horse and cart, so flat areas and river valleys were essential. **Site and land**: although early industry did not take up much space at first, it did need flat land for building. As the size of factories increased, more land was needed. Ideally such sites were on low-quality farmland as it cost less.	**Labour**: factories, and some other sectors of industry, need large numbers of workers. Others need skilled employees, e.g. technology-based industries often need university graduates. **Capital (money)**: early industry depended on wealthy people willing to risk their own money but investment now also comes from banks and governments. **Markets**: the size and location of markets has become more important than the source of raw materials. **Transport**: costs increase when items being moved are bulky, fragile or heavy, or lose quality quickly. **Economies of scale**: small units may become unprofitable and so merge with, or are taken over by, larger firms. **Government policies**: as governments tend to control most wealth, they can influence industrial location by giving grants to help certain parts of their country. **Improved technology**: examples include facsimile (fax) machines, electronic mail and satellite communication. **Leisure facilities**: in the town and countryside, leisure facilities for employees are becoming more important.

easy access to a port where goods can be taken for export. However, many of the factors shown in *Table 11.7* are common throughout the world.

In the countries of the Caribbean, the significance of different industrial location factors depends on the local situation. For instance, the setting up of free trade zones by the government of Dominican Republic has helped to increase trade. How the various factors work together is highlighted in the case studies that follow.

Case Study

Industrial location in Jamaica

Bauxite mining in Jamaica is by far the biggest contributor to wealth in the primary sector. However, other economic activities including clothing manufacture, drinks production and the export of sugar and bananas add to the country's GDP. The location of these industries (*Figure 11.17*) is a result of the physical landscape, historical influences and current world trading patterns.

- **Bauxite mining**: The rocks of Jamaica are rich in bauxite – the raw material used to make aluminium – and the industry has had heavy investment from the government and from North American companies. Roads and railways have been built to transport the raw material to alumina processing plants from where it is taken to ships waiting in Jamaica's natural harbours. The product is then shipped the short sea distance across the Gulf of Mexico to markets in the USA.

- **Sugar and rum manufacture**: Once dominant in large plantations set up by European businessmen, the importance of sugar has declined but it still plays a part in the Jamaican economy. As sugar exports have decreased, partly due to competition from other countries, the manufacture of rum, using sugar as its raw material, has increased. On the world market, rum costs much more than sugar, weight for weight, so it is known as a **value-added** product.
- **Clothing manufacture**: A relatively large workforce, good ports and closeness to the USA led to an expansion in the Jamaican clothing business in the 1980s, as it did in many other Caribbean countries.

Obviously tourism, discussed later in this chapter, also has a major impact on Jamaica's GDP.

Referring to the factors shown in *Table 11.7*, write a short essay outlining what has influenced the industrial location in your own country, or any other country in the Caribbean that you are familiar with.

Figure 11.17 Industrial location in Jamaica

Economic activity in the primary and secondary sectors

Many countries in the Caribbean, along with many others in the developing world, rely on primary sector activities to bring in money.

Some of the region's most important and widespread primary industries are shown in *Table 11.8*. Apart from bauxite mining, these activities don't bring in much export revenue, but some other primary activities, for example the oil and gas industry, generate a huge income.

Table 11.8 Primary sector activities of major importance to the Caribbean

Forestry	
Location	Guyana, Belize, Bahamas, Dominica, Trinidad and Tobago
Factors in location	• tropical climate • large forests – originally full of tropical hardwoods but now including many faster growing species • port facilities to export tree products • wood processing factories
Trends	Traditional products using tropical hardwoods, such as furniture, are being replaced by woodfuel and tree products used in industry from non-native, introduced species.
Challenges	• changing tastes from Western buyers concerned about the use of traditional tropical hardwood species • over-foresting of old species, almost to extinction – use of trees now needs to be sustainable • competition from other countries, especially those in Southeast Asia with large forests of tropical hardwoods, e.g. Indonesia • coping with international pressure to stop deforestation because of the effects on global climate change.
Fishing	
Location	Cuba, Belize, Guyana, Netherlands Antilles
Factors in location	• shallow coastal waters rich in nutrients washed out to sea from rivers • abundant marine life in coral reefs • productive deeper waters with important fish species • mangrove swamps for shrimp and other high-value fish • natural harbours for fishing boats and port facilities to export products • historically, communities very involved in fishing for food and trade

continues →

Trends	Communities have often organised themselves into cooperatives and own their own fish-processing plants in order to export a wide range of fisheries products on a large scale. Per-capita consumption of fish in the Caribbean is amongst the highest in the world and the industry is worth around US$6 billion per year, employing over 180 000 people.
Challenges	• over-fishing, so young fish cannot mature and breed, leading, in time, to decreasing catches • global competition from big fishing businesses from countries such as Japan with high-tech equipment used, for instance, to track fish by satellite • pollution, both in rivers and in the sea, that kills off fish stocks • the removal of mangrove swamps and the destruction of other coastal breeding grounds for housing and tourism development • an increasing lack of labour as young people do not want to enter the fishing industry • disputes between countries over international boundaries in marine waters • the effects of climate change leading to changes in the eco-systems traditionally used for fishing.
Bauxite	
Location	Jamaica, Guyana, Suriname
Factors in location	• presence of easily mined bauxite mineral • nearby processing factories to turn bauxite into alumina for export • railways and decent roads for alumina and bauxite to be transported to ports and adequate port facilities for export • closeness to huge markets for alumina in the USA
Trends	Jamaica: still large reserves of bauxite that are easily mined and cheap to transport. Guyana: bauxite is hard to get at and expensive to bring out of the forests. Suriname: new reserves being developed.
Challenges	• increasing global competition from countries including Australia and Guinea in West Africa • an over-reliance on selling to the USA • concerns from importing countries about the environmental-friendliness of Caribbean bauxite mining • shipping costs are getting cheaper so higher mining costs in the Caribbean make the region's bauxite relatively expensive • even with the possibility of a new aluminium smelter in Suriname, there are not enough to cope with demand in the Caribbean region.

Case Studies

Primary sector: the oil and gas industry in Trinidad and Tobago

Trinidad and Tobago is one of the richest countries in the Caribbean because it has large reserves of oil and gas. The use, or **exploitation**, of these natural resources dominates the economy and, while employing only 3 percent of the workforce, it brings in 71 percent of foreign exchange and accounts for 23 percent of the country's GDP.

GDP per capita reached US$32 100 in 2014 (by comparison, the UK's GDP per capita is US$39 500 and Guyana's is US$6900). Although there was a slight decline in the country's economic fortunes in the late 1980s and 1990s as world crude oil prices fell, the growth of the petrochemical and liquefied natural gas (LNG) industries has more than made up for this in recent years.

Exploiting oil and gas

Millions of years ago, plants and animals died and were slowly buried under layers of other rocks. Over time this **organic matter** was transformed into crude oil and natural gas by heat and pressure and, if not blocked by the rocks above, would come straight to the surface. However, when trapped underground by other rock layers, huge oil and gas fields form. These can be identified by geologists.

In 1857, the first well was drilled for oil in Trinidad and since then a vast number of oil and gas fields have been discovered (*Figure 11.18*). The oil discoveries on the island were followed by offshore drilling under the sea off the west coast in the Soldado field in 1954. While the offshore oil fields are huge, it is much more expensive to drill for oil under water than on land (*Figure 11.19*). In 1968, drilling started off the east coast and, in 1971, in the gas fields in the sea to the north. *Figure 11.18* also shows the major gas pipelines that pump the precious fuel to processing plants on the island.

Oil in the land-based fields is now becoming **depleted** (running out) and the oil that is left is difficult and expensive to extract. No new oil is being created, which means it is a **non-renewable** resource. The calm, shallow waters off the west coast are easier to exploit, while deep drilling of up to 6000 metres takes place in the oil and gas fields to the east.

Products and markets

The government of Trinidad and Tobago has invested the revenue it has gained from oil and gas products (these products are shown in *Figure 11.20*) in other parts of the economy. An iron and steel company was set up in 1980 to make sure that Trinidad and Tobago had other products, such as wire rods and steel billets, which it could export in addition to oil and gas. The construction of cross-country gas pipelines made sure that industry across Trinidad had a reliable power supply.

The largest market for oil is the USA. Oil from Trinidad and Tobago costs less to import into North America than that from the Middle East because the shorter distance makes transport cheaper. Political problems in the Middle East since the 11 September 2001 terrorist attacks in New York have also favoured Caribbean oil. Natural gas is more difficult to transport than oil but gas products and liquefied natural gas (LNG) are being exported to the USA, Europe and around the world.

Benefits of oil and gas for the economy of Trinidad and Tobago

- **Employment**: about 20 000 workers are employed directly in the energy sector and many more workers are employed

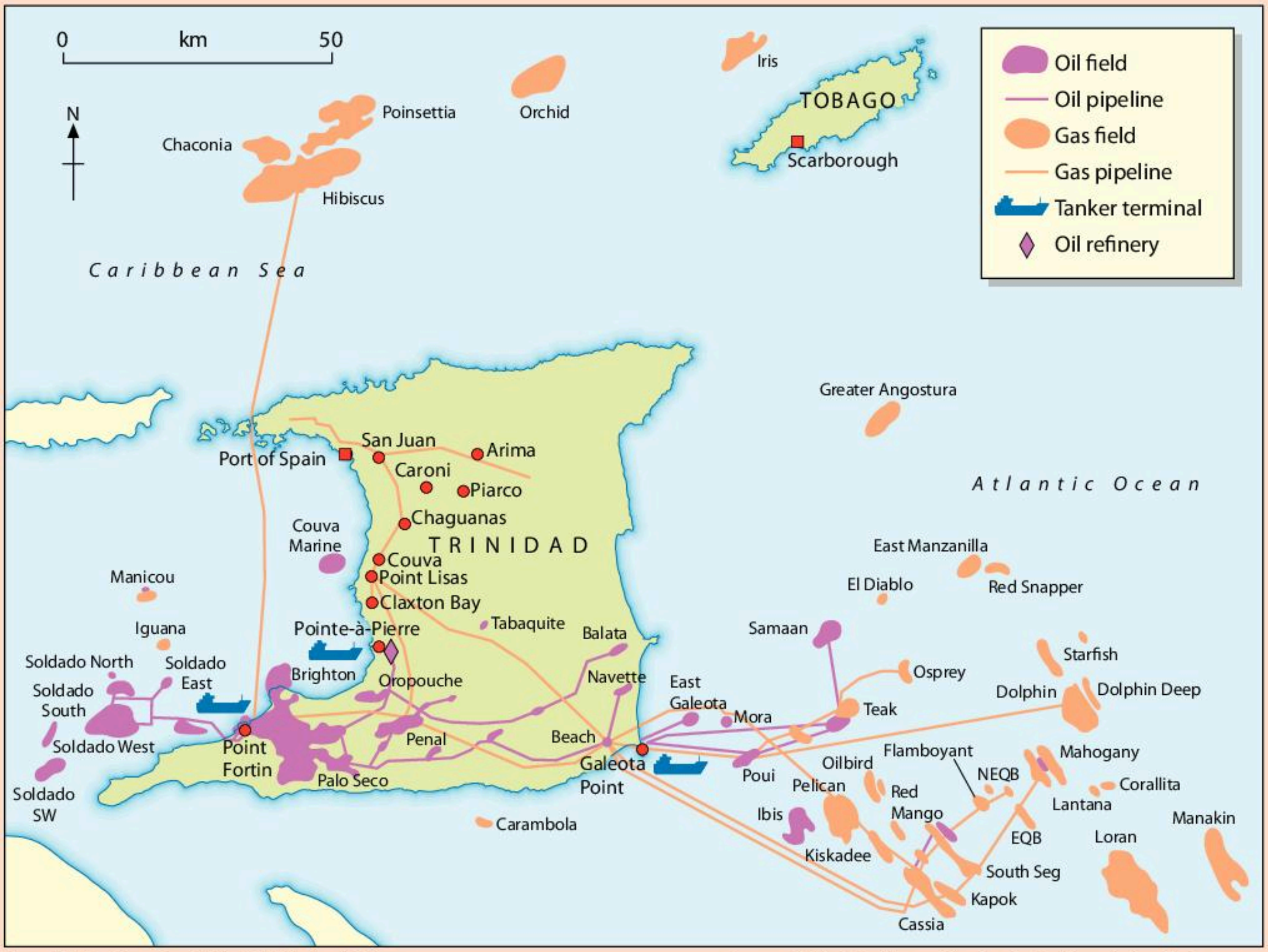


Figure 11.18 Oil and gas fields in Trinidad and Tobago

Source: *Philip's Certificate Atlas for the Caribbean* (5th edition), 2004

in manufacturing industries that use the cheap power supplied by the energy sector.

- **Skills training**: workers from Trinidad and Tobago have developed important skills by working in industry and many earn high wages in Canada, England and the Gulf States. Many of these workers send part of their income to their families back home.

Figure 11.19 Drilling for oil on land and sea in Trinidad

Crude oil is used to make:

- gasoline
- diesel
- kerosene.

Natural gas is used for:

- generating electricity
- fuel in cement and glass production
- fuel in iron and steel production.

Natural gas is also used to make:

- propane, butane and cooking gas
- methanol and ammonia for plastics and fertilizers
- liquefied natural gas (LNG).

Figure 11.20 Products made in Trinidad and Tobago from oil and gas

- Increased wealth means the government can pay for **improvements in services** in the country, such as education and health. It can build roads, schools and hospitals, develop its industry and save money for hard times in the future.
- Increased wealth also has **economic effects**, as people have more money to spend in shops and on leisure activities, increasing employment in the tertiary and quaternary sectors of the economy.
- **Stability**: Trinidad and Tobago is seen as a good place for overseas companies to locate and the government has worked hard to encourage foreign investment. The CIA World Factbook 2007 states that the country 'has earned a reputation as an excellent investment site for international businesses'.

Challenges for the future

Trinidad and Tobago has done very well in managing its oil and gas reserves but they will not last forever. New natural gas fields are being discovered but it is unlikely that current production rates will be the same after 2050

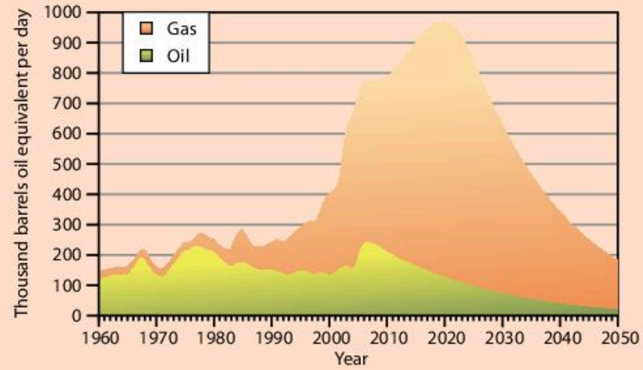


Figure 11.21 The future of oil and gas in Trinidad and Tobago Source: Energyfiles Ltd

(*Figure 11.21*). New techniques are being invented which means fields that were not seen as profitable may soon be worked and make money.

The increasing affluence in the country has come with some unforeseen consequences. Social ills such as gambling, drug use, kidnapping for ransom and juvenile delinquency have increased. There is a high murder rate due in large part to criminal activities such as the sale and transfer of illegal drugs and gang-related violence. Many people have expressed dissatisfaction and a loss of faith in the ability of the authorities to enforce the law and to do anything to curb the violence and ensure personal safety. The worsening crime situation has threatened the tourism industry, and some owners of manufacturing and service sector companies are now seriously reconsidering their continued involvement in the country's economy.

1. What are the location factors – physical, human and economic – behind the development of industry in Trinidad and Tobago?
2. What are the advantages for a foreign investor of setting up a business in Trinidad and Tobago rather than any other Caribbean country?
3. What should the government of Trinidad and Tobago be doing now to make sure the country has a strong economic future when the oil and gas reserves are depleted?

Secondary sector: food processing in CARICOM countries

People of the Caribbean have always taken part in food processing. The production of jams and jellies, fruit drinks, wines and beers, sauces (*Figure 11.22*) and snacks (such as dried fruit) has been part of family life for generations. Recently, many family businesses have grown in size and there has been an increase in the amount of money gained through exports. Larger multi-national companies have also set up factories but 80 percent of the businesses in the Caribbean are still 'cottage industries' – small and medium-sized units mainly owned and operated by women. In some countries the potential for the industry to expand is huge.

Turning raw materials into processed products

Much of the food processing in the Caribbean is based on fruit and seeds but other products include poultry, seafood, vegetables and confectionary. More than 50 percent of the total manufacturing output in Trinidad and Tobago comes from food processing and businesses in the sector contribute around three percent of the country's total GDP. Around 13000 people work for 500 companies ranging in size from large multi-nationals like Nestlé to small family run businesses.

Figure 11.22 Processed sauces produced in the Caribbean

Guyana has recently looked at ways of copying the success of Trinidad and Tobago. The country has made large investments in the food processing industry to produce and export its own canned products including sausages, corned beef and corn. It is one of the few countries in the Caribbean which has sufficient land to grow enough food for its own people and, because of this, the government has come up with a seven-year plan to grow surplus crops and to increase export revenues from processed food.

Advantages of Caribbean countries for food processing

A long tradition of turning raw materials into processed food has given many countries an in-built advantage in setting up their industries, but there are other good reasons why they can be successful:

- The small size of many countries means that factories can be located in large cities and towns giving ready access to nearby markets.
- Raw materials are easily available on agricultural land and from rich fishing-grounds offshore. In addition, semi-processed food can be easily imported from, for instance, the USA and Canada and finished off in Caribbean factories.
- There is a readily available and experienced labour supply.
- Many countries have dense and efficient networks of roads and port facilities to transport raw materials and finished products.
- Some countries have invested in technologies such as the use of high temperature and pressure to keep food fresh.
- Governments have been supportive of local industry and, in some cases, have put high taxes on imported food that competes with local products.

The challenges facing food processing in the Caribbean

Despite the potential for the industry to expand there have been problems with building up food processing businesses.

Many fruits and other crops are grown in backyard gardens or small mixed or single orchards. Attempts at large-scale agriculture have not always been successful so factories often rely on many different local suppliers. Not all of these suppliers can send fruit on a regular basis so, occasionally, factories are unable to work.

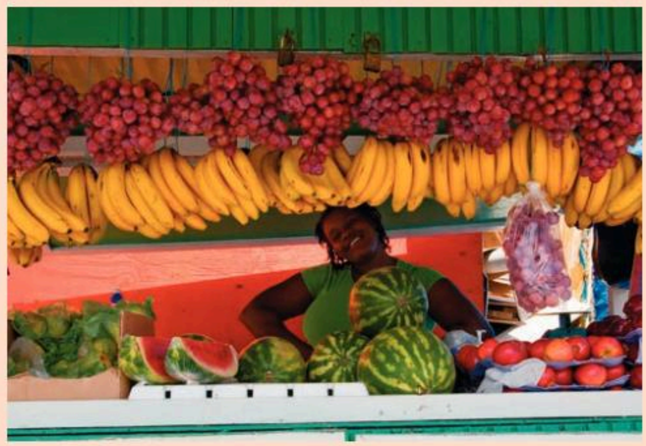


Figure 11.23 Tropical fruit stand, Tobago

Diseases in recent years have affected fruit crops and stopped processing of certain foods in some countries:

- The pink hibiscus mealybug has attacked pineapples and affected exports of processed foods in Guyana and the Dominican Republic.
- The mango seed weevil has affected food production in some countries.
- Across the region, fruit flies have resulted in exports of many fruit products to the USA being restricted.
- The citrus processing sector in Jamaica and Trinidad and Tobago has been affected by outbreaks of Citrus Tristeza Virus.

Historically (although this is now changing) there has also been a lack of investment in the food processing sector so that research and development and staff training have not been seen as priorities. This has seen the industry fall behind some of its competitor countries.

The future of food processing in Caribbean countries

Many Caribbean countries are looking to develop their food processing industries in the future. With expanding populations it is important that many of them look to increase the amount of food they produce. Processing food is an efficient way of reducing waste so that, for instance, mangoes and tomatoes which are thought not good enough for export can be tinned and sold locally. Food processing is also seen as a way to reduce the CARICOM countries' huge spending on imported food. This stood at US$4.25 billion in 2011 with only 12.7 percent of total food imports coming from within the Caribbean.

There is a high level of government support ready to develop the industry and, combined with available raw materials and good transport networks, it should be possible for much more to be made of food processing within the Caribbean.

Secondary sector: food processing in Singapore

On a completely different scale altogether from what occurs in the Caribbean is the food processing industry of Singapore (*Figure 11.24*). This small country – slightly larger than St Lucia – has more than 800 different food processing factories. Together they made more than US$8.4 billion in 2011 and contributed 0.7 percent of the country's GDP.

Food processing was one of the earliest industries in Singapore and, similar to the Caribbean, is closely related to culture, habits and tradition. Businesses have grown massively from small home-based industries where mainly women made sauces, jams and other products. By the 1970s the sector had grown to be the third biggest industry in the country. It has since survived:

- the economic recession of 1986
- the Asian financial crisis of 1997
- the bird-flu epidemic of 2003
- the worldwide financial recession from 2008.

Despite these problems it is still the country's seventh largest industrial sector in terms of the money it brings in.

Food processing in Singapore falls into two different categories. The first – known as small and medium-sized enterprises (SMEs) – makes up about 95 percent of the total business, employing anything from a few workers up to around 200 employees. The rest are very large enterprises, often run by multi-national companies.

Products are exported from the country and used for local consumption. They include dairy products, vegetable oils, beer and non-alcoholic drinks, bakery products, processed meat and chocolate.

Figure 11.24 High technology in the Singaporean food processing industry

Factors affecting food processing industries in Singapore

Location: companies are mainly located in industrial estates scattered all over the small island with a dense road network connecting them to ports and markets.

Labour supply: originally, employees were provided by local towns and villages but, increasingly, the 19 000 employees include migrant workers. Local employees in particular are highly skilled and well-educated.

Raw materials: local farming is only done on a very small scale so many of the materials used in the food processing industry come into the country as imports.

Technology: the industry has a lot of investment in technology (*Figure 11.24*) and in research and development.

Government: government influence is very high in all industries in Singapore, making sure there are enough industrial estates for businesses to develop, helping with export markets and ensuring taxes are kept low or products are duty-free.

The challenges for the Singapore food processing industry

The industry in Singapore has a very strong international image, especially in the rest of Asia, for good quality products sold at competitive prices. However, it does face challenges including increasing competition from other countries close by. Many of these countries do not pay the high wages which Singaporean nationals expect and can keep their prices lower as a result.

With a population of just over five million, there is also a limited market for buying processed food at home and companies have to be continually on the lookout for other markets where they can sell their goods. The major export markets are shown in Table 11.9 but many of these are now demanding changes to the food they buy: customers want to know more about health and nutrition, for instance, and there have been many concerns in western countries about the problems associated with eating processed food.

There is also increasing demand from other countries for the raw materials that Singapore has traditionally used in its industry, meaning increased competition and increasing prices. To help combat this, some companies in Singapore have begun buying up land in other countries, including China, and developing huge farms that will keep them supplied with the food they need.

Although there are very significant challenges facing the country's food processing businesses, industry in Singapore has a long history of being able to cope with similar challenges and has the finances and infrastructure to react quickly to competition when it needs to.

Table 11.9 Top ten Singaporean export markets.

• Japan	• Australia
• Malaysia	• Hong Kong
• Indonesia	• USA
• China	• Taiwan
• Thailand	• Vietnam

Other types of economic activity

Tertiary sector: 21st-century tourism

Tourism – travel for pleasure – has been around for a long time but it is only in the last hundred years or so that many more people have become tourists. Before that only very wealthy people could afford to travel.

Tourism really began to develop in the 18th and 19th centuries when rich Europeans and Americans travelled on the 'Grand Tour', visiting Paris and the major Italian cities. By the beginning of the 20th century, Europeans wanted to travel further, and many chose sunny countries, which at that time were their own colonies. In the Caribbean:

- the British went to Jamaica and Barbados
- the French went to Martinique
- the Dutch visited Curaçao, and
- North Americans went to Cuba and the Bahamas.

The long sea journey from Europe meant that many of these tourists stayed for weeks or months or even for the whole winter. In 1900, tourism was already an important contributor to the economy of Barbados, with 11 steamships visiting the island each year.

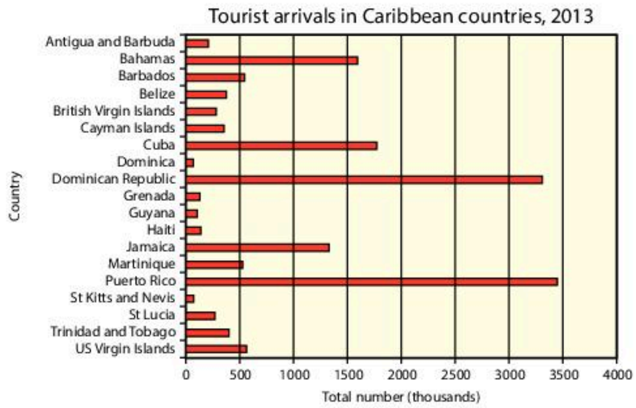
The growth of mass tourism

As people in developed countries got richer, more and more of them wanted to go on holiday abroad although the holidays they took were very different from those of today. There were few hotels and tourists stayed in guest houses or expensive country clubs. Nobody spent much time on the beach although some would swim in the sea as they thought it was good for their health. In the 1920s, the trend for getting a tan began and beach holidays became popular but it wasn't until the 1960s, when airplane flights became more widespread, that Caribbean tourism really took off. Long-haul flights from Europe meant the islands could be reached in eight hours instead of three weeks by sea. Jobs included time off for holidays, so people flocked to the Caribbean for the:

- spectacular landscapes and fine, sandy beaches
- warm year-round climate with dry winter months
- freedom from insects and diseases that were widespread in other 'exotic' holiday locations
- widely-spoken European languages including English, French and Spanish
- friendliness and relaxed attitude of the Caribbean people
- 'paradise' image helped by books and films such as the James Bond series (*Figure 11.25*) and lately, *Pirates of the Caribbean*.

As more people came to the islands, hotels, restaurants and other facilities sprang up to serve them. Whereas 50 years ago 'Sugar is King' was the phrase that summed up the region's dominant industry, today tourism is the undisputed champion.

Figure 11.25 'James Bond' has portrayed a positive image of Jamaica to tourists



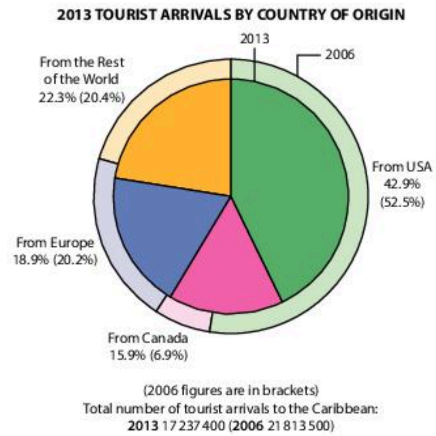


Figure 11.26 Tourist arrivals in the Caribbean

Source: *Philip's Certificate Atlas for the Caribbean* (7th edition), 2005, page 24

The biggest business in the Caribbean

In 2013, almost 20 million tourists visited the Caribbean. The graphs in *Figure 11.26* show that most of them came from the USA and that Dominican Republic had the largest number of visitors.

Tourists spend very different sums of money depending on which island they visit. While Dominican Republic earned almost US$5 billion from tourists in 2001, some of the smaller islands, which attract wealthier visitors, receive more money from each person (*Figure 11.27*).

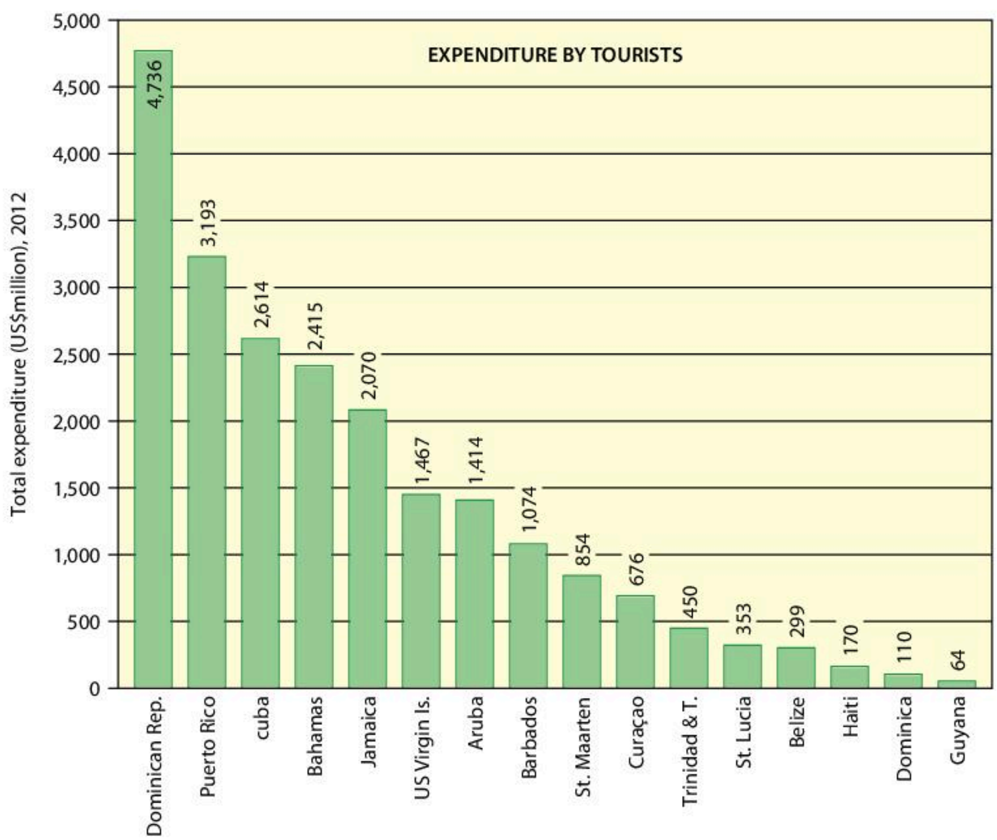


Figure 11.27 Money spent (expenditure) by tourists in the Caribbean, 2012

Source: *Philip's Certificate Atlas for the Caribbean* (7th edition), 2015

Some countries, such as Belize, do not benefit much from tourism because many of their visitors come by cruise ship and only have a brief stop in Belize City, instead of staying overnight and spending money in hotels and restaurants. Figures from the Bahamas in 2003 showed that the average spending by cruise passengers was only US$53 compared with US$1058 spent by hotel tourists. Numbers of cruise ship visitors to the islands are shown in *Figure 11.28*.

Economic benefits of tourism

All tourists, whether they arrive by boat or plane, bring benefits to the country they visit:

- **Jobs**: many people are employed to serve tourists, from waiters and receptionists to shopkeepers and tour guides. In Antigua and Barbuda, for instance, 30 percent of the employed population works in tourism.
- **Foreign exchange**: tourists spend their money in US dollars, euros and British pounds. This foreign exchange can then be used to buy goods and services from overseas.
- **Government revenue**: many countries charge a head tax or a departure tax for visitors and this money goes to the government to help pay for things such as electricity and water services, roads, health and education.
- **Agriculture**: hotels often buy fruit, vegetables and fish from local suppliers.
- **Multiplier effect**: many small businesses are linked to tourism. Taxis, bars and restaurants all benefit from the money spent. Larger businesses involved in the construction of hotels, for example, are also kept busy.

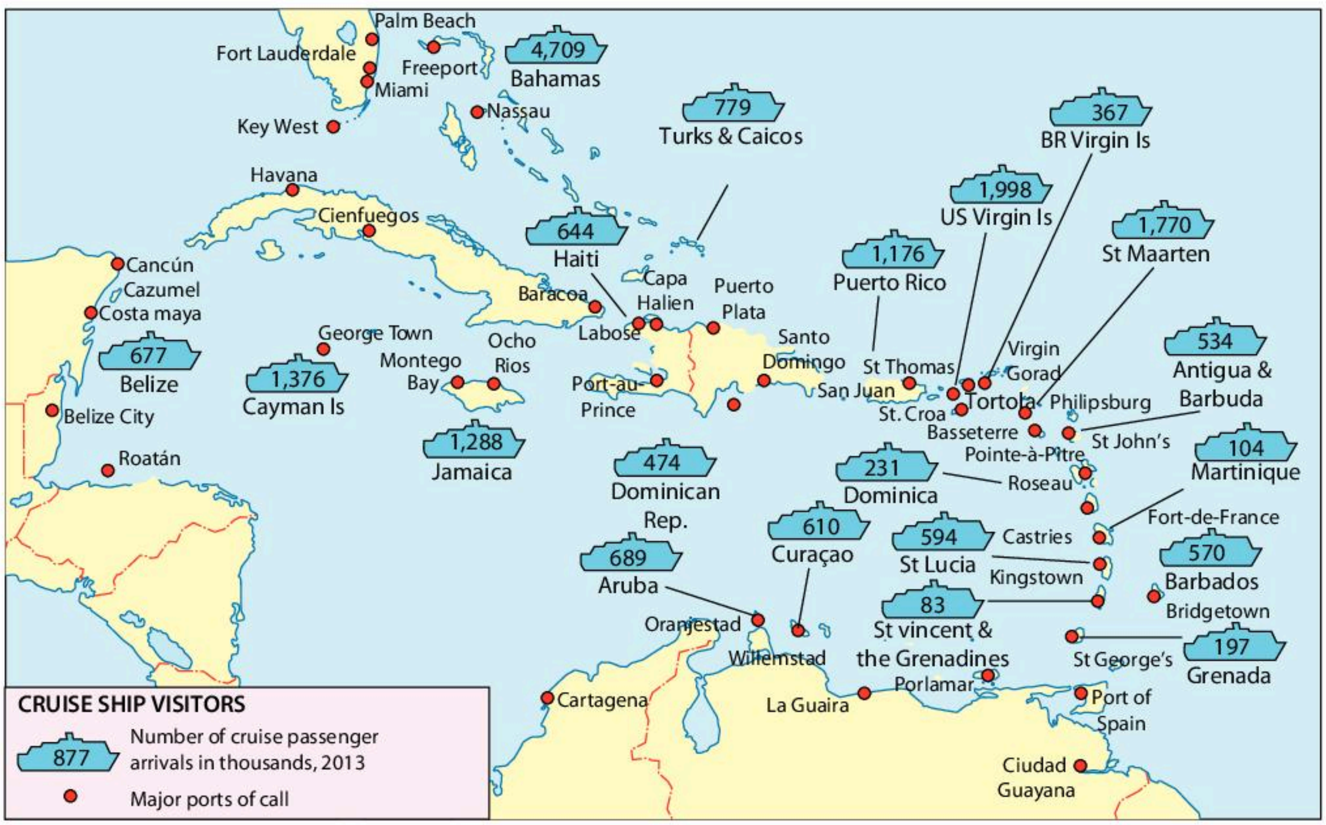


Figure 11.28 Cruise ship visitors to the Caribbean

Source: *Philip's Certificate Atlas for the Caribbean* (7th edition), 2005, page 24

Case Study

Tourism in Jamaica

Jamaica has long been one of the Caribbean's main tourist destinations and tourism is the country's second biggest earner of foreign exchange after bauxite mining.

The first tourist hotels were built in Montego Bay and Port Antonio in the late 1800s to look after rich invalids from Britain and North America who wanted to escape to warmer winter weather. With improved transport after the First World War, tourist numbers began to increase and the development of relatively cheap and easy air travel meant a boom period from the 1960s to the 1990s (*Figure 11.29*). Obviously, many people came for the white sand beaches and good weather but, as *Figure 11.30* shows, Jamaica has a number of attractions that have kept visitors coming.

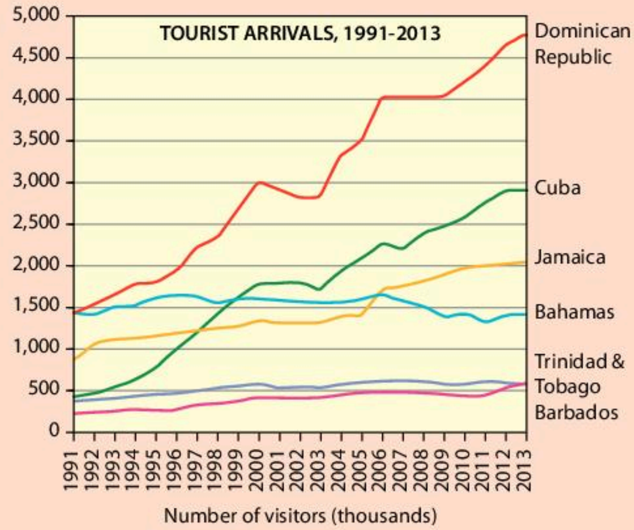


Figure 11.29 People visiting Jamaica, 1991–2013

Source: *Philip's Certificate Atlas for the Caribbean* (7th edition) 2015

As well as around 220 000 Jamaicans who work directly in tourism businesses such as shops, restaurants and hotels, many more

Jamaican tourism facts and figures	
Total number of tourist arrivals	1 986 100
Population employed in tourism	23%
Tourist expenditure (per person)	US$2070 million
Total foreign exchange earnings	US$875 million
Contribution to GDP	20%
Cruise ship arrivals (2002)	1288
Rooms available to tourists (2002)	30 000
Visitors from USA and UK (% of total)	70% and 10%

Figure 11.30 Jamaican tourism attractions

Source: *Philip's Certificate Atlas for the Caribbean* (5th edition), 2004 are employed in other economic activities which earn part of their income from tourism. For example, farmers supply food to hotels and carpenters make the furniture the tourists use.

Jamaican tourism has recently been faced with two particular problems:

- more competition from other tropical tourist destinations both within and outside the Caribbean region
- reports in the newspapers in the UK, USA and Canada of violence and tourist muggings.

To keep visitors coming, some businesses in Jamaica have now started to **specialise**, that is, to offer holidays aimed at a particular type of tourist such as ecotourists or adventure seekers.

Adventure tourism in the caves, cliffs and hills

Jamaica's dramatic scenery with its mountainous landscape, cliffs, caves and bays is ideal for the development of **adventure tourism** which includes activities such as biking, hiking, surfing, caving and diving.

One of the fastest-growing types of tourism in the world is adventure tourism. The adventure tourist is on the lookout for physical challenges and risk-taking holidays. Often around 30 years old, unmarried, with a good job and a high income, adventure tourists can contribute a lot of money to a country's economy. Jamaica has some top high-adrenalin activities to tempt them, including:

- the 200-metre waterfall at **Dunn's River Falls** (*Figure 11.31*) where visitors can climb the slippery slopes and use the boulders as water slides
- mountain biking tours of **Cockpit Country** limestone scenery, exploring the hidden trails and climbing down ladders into some of the deepest caves
- cliff diving in **Negril** where tourists can leap 12 metres into the sea below.

Figure 11.31 Adventure tourist destination: Dunn's River Falls

While Belize is currently the adventure tourism capital of the Caribbean, many companies in Jamaica are challenging that country's dominance.

Looking after the environment with ecotourism

As environmental issues become more important, especially in developed countries, another new brand of tourism has sprung up for people who think of themselves as 'green'. Environmental tourists, or **ecotourists**, tend to be older than adventure tourists but also have a high income and, again, are the kind of big spenders that tourism businesses want to attract (*Figure 11.32*).

Jamaican companies have been quick to offer ecotourism holidays, taking advantage of the dramatic natural environment and the tropical bird, animal and plant life that lives on or visits the island. Examples of such trips include:

- wildlife-watching walks on the way to waterfalls in the **Blue Mountains**
- building bamboo rafts to see the rainforest along the **Rio Grande**
- island-wide birdwatching trips to find all 27 of Jamaica's native bird species, including the Jamaican owl, Jamaican mango and Jamaican tody.

The ecotourist

... wants to get to know the natural environment better by taking part in activities such as birdwatching, tracking wildlife or enjoying mountain views

... also wants to minimise their **environmental footprint** – this means they do not want their holiday to spoil the natural environment and they want the companies they use to cut down on waste, use less energy

... does not want to stay in a large hotel but likes to get 'close to nature' in small lodges in quiet surroundings

... wants to get to know local people and to be taken around by educated local guides.

Figure 11.32 Characteristics of the ecotourist

Figure 11.33 An ecolodge in Jamaica

Ecotourism often involves the setting up of **ecolodges** (*Figure 11.33*) in nature reserves, rainforest areas or isolated beaches where they are built to fit in with the natural environment. Instead of huge hotel complexes, guests normally stay in small cabins, often with no electricity, and eat local food. Guides may take them on walks to help them understand the local environment. Ecolodges are often seen as a benefit to the local economy because they employ a large number of local staff and only have a small impact on the environment. Prices here are usually much higher than in a standard tourist hotel.

Getting close to communities

Another new and increasingly popular type of tourism is **community tourism**. Many visitors do not wish to stay in large hotels and want to get to know the people of the countries they are visiting. Cuba has been a pioneer in this type of business, encouraging local people to open their homes – known as *casas particulares* – to tourists from overseas.

In Jamaica, guests stay in bed and breakfast accommodation in rural areas or in private homes to get to know a family's way of life. The wider local community is likely to include businesses such as arts and crafts shops and local restaurants and bars where more money will be spent.

Benefits of community tourism for the visitor include:

- a greater connection with the natural attractions, local resources and people of an area
- much more interaction with the local people and their culture
- a feeling that their money is going to the people who need it most.

Benefits for the community include:

- sharing culture with people from overseas
- more money from the tourist industry
- money given directly to communities and rural villages, rather than to big tourism businesses.

Community tourism could be a big feature in the future of Jamaican tourism and organisations promoting the industry are increasing.

Activity

1 Refer to the information in *Figures 11.29* and *11.30* and think about the size and populations of the countries involved. Whose economy do you think benefits most from tourism in the Caribbean? Why?

2 Discuss the benefits of the different types of tourism on offer in Jamaica. Is there any one that is best for the economic development of the country?

3 What are the characteristics of the tourist industry in your own country? In what ways could adventure tourism, ecotourism and community tourism be developed?

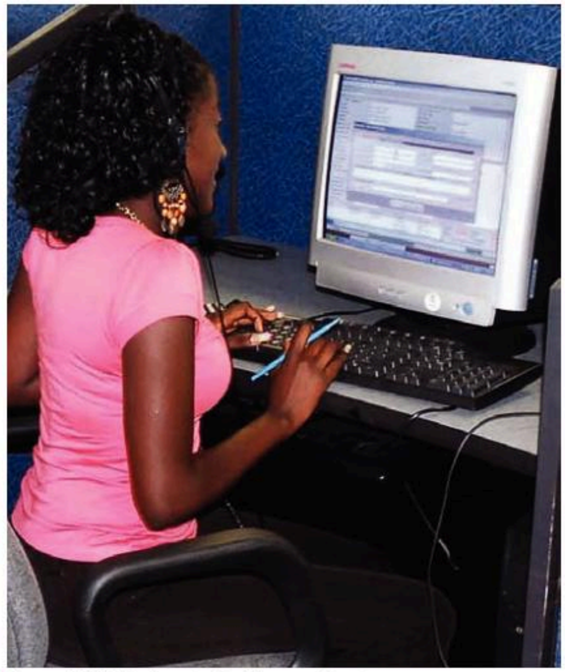


Figure 11.34 Worker at a Caribbean call centre

Quaternary sector: Caribbean call centres

Although they are still quite new to the Caribbean, there has been an increase in quaternary industries in the region in recent years. Companies that rely on technology can set up almost anywhere in the world and many of them – such as those involved in medical research and the development of computer systems – are moving to Asia where there is an educated workforce but wages are cheaper than in the USA and Europe.

The Caribbean workforce is also relatively cheap and educated but some countries in the region are limited by high energy costs, an irregular electricity supply due to disasters such as hurricanes, and expensive equipment (because computers have to be imported).

However, the call centre business is on the increase. Customers can ring helplines to ask for information on anything from computer problems to booking a holiday to advice about their bank account.

Calling the Caribbean

In 2001 there were 44 call centres operating in the Caribbean with 11 000 phone operators. This number had risen to 55 000 by 2008. Most companies were from the USA and based their centres in Jamaica, Trinidad and Tobago, Dominican Republic, Barbados and Puerto Rico. In 2008 in the Dominican Republic, 18 000 operators worked for 35 different call centres while Jamaica had centres with more than 14 000 operators. The advantages and disadvantages of Caribbean locations are shown in *Table 11.10*.

Recently, call centres in India have caused problems for some US companies: there have been complaints from North American customers that the Indian employees are difficult to understand.

Meanwhile the Caribbean is becoming more attractive to businesses from the USA. Local staff training can be carried out quickly due to the short flying time between the two places. In 2008 this put the hourly rate of using an operator in Jamaica, for example, at a maximum of US$16.50 – the same as in India and cheaper than in the USA (US$29).

Activity

Look back to the section on industrial location factors (page 256). What factors – physical, social and economic – are important for quaternary industries?

Table 11.10 Factors for and against locating call centres in the Caribbean

Advantages	Disadvantages
• In 2008 the average wages were around US$3 per hour (compared with US$9 in the USA). • Employees trained in tourism are accustomed to dealing with the public. • Literate and educated English-speaking workforce. • Close to company headquarters in the USA (average 2 hours' journey time compared with 20 hours to Asia). • Possibilities for Spanish-speaking call centres to serve US and Latin American markets.	• Phone call charges used to be up to 15 times more in the Caribbean than in the USA, although these have dropped as competition between telecommunications companies has increased. • North American callers often like to deal with other North Americans. • Strong accents may be difficult to understand. • Cultural differences can lead to problems in dealing with customers.

Challenges to the economies of the Caribbean

As we have seen, the Caribbean is home to many different industries and economic activities. No two countries have the same mix, although many have a large tourism sector. The case studies have shown some of the challenges that the economies currently face, and some of the ways in which governments and companies are responding.

This final section looks more closely at how businesses in the region plan to cope with increased globalisation and technology, and how they will sell themselves in the future.

Increased competition as globalisation takes hold

In the middle of the 20th century (1950s), the world was a very different place. Most countries specialised in certain products and their traditional markets – the countries they sold their goods to – had been the same for a long time. The UK made cars and sold them to British people and British colonies. Sugar and bananas from the Caribbean were sold to Europe and the USA – Europe did not think of getting its bananas from anywhere else.

Many people argue about what globalisation is but most definitions say it involves increased connections, economically and socially, between different countries and parts of the world. It also means increasing **interdependence** so that countries help each other and work with each other.

Some people see globalisation as a good thing, helping to make everyone richer, while others say it is just a way of trying to make all the countries of the world the same as the USA and Europe, with McDonalds and Burger King, for example, on every street whether it is in Kingston, London or Hong Kong.

Figure 11.35 What is globalisation?

All this has now changed as many parts of the world have become more developed and, as globalisation (*Figure 11.35*) has taken hold, more and more countries are trading with each other.

This could be bad news for the Caribbean. Already, many countries have been forced to abandon the **preferential trade deals** they used to have with the region. For instance, exporters selling bananas to Europe have to pay added taxes but, ten years ago, African, Caribbean and Pacific countries had a trade agreement called the Lomé Convention which arranged for fewer taxes on imports into Britain of bananas, sugar and rum than on goods from the rest of the world, including Latin America. In 2005 the World Trade Organization (WTO) ruled this as unfair and now all bananas are imported into Europe with the same added taxes and quota restrictions. This has meant increased competition and the Caribbean, where wages and prices are higher, has seen its exports to Europe fall.

There are various ways for the Caribbean countries to cope with the competition, including investment in industry, improved marketing, taking advantage of new technology, and joining together in large trading organisations.

Investing in new industries

Many Caribbean countries get a high proportion of their income from one or two products or industries:

- agriculture in Cuba and Guyana is concentrated on sugar exports
- more than 50 percent of Jamaica's export money comes from bauxite
- bananas are key to the success of food exports from the Windward Islands.

Relying on one product means that a country is at the mercy of world demand, world prices and other factors. As we have seen, the garment manufacturing industry in Haiti has suffered because China now produces the same thing more cheaply and customers have started to buy from Asian countries. One major natural disaster, such as a hurricane, can wipe out an agricultural crop. Investment is needed so that:

- Countries can set up new industries and **diversify** – that is, have lots of different ways to make money. In Trinidad and Tobago, oil money was invested in other industries to make sure that not all the country's income came from the same place.
- Countries can **process** the resources they have because this adds value. For example, converting sugar into rum produces a much more expensive, but still desirable, product. Canning fish means it can be sent all over the world at a relatively high price.
- Countries can take advantage of new **technologies** such as satellite and internet communication. Reducing the cost of these to outside companies will encourage businesses such as call centres to set up operations.

The main problem is that small countries often have little money to invest but they can work with other countries (through trade organisations) or try to attract money from foreign companies.

Selling old things in new ways

People still want to take holidays in the Caribbean but they also want to visit the Maldives, Madagascar, the Canaries and many other tropical islands. Cheap airline flights from Europe mean that many of these destinations now cost less to get to. Caribbean countries therefore have to make sure they can still attract large numbers of visitors, or small numbers of visitors who spend lots of money.

Specialising in certain types of holiday is one way to attract new holidaymakers so the Caribbean has seen a growth of:

- ecotourism, community tourism and adventure tourism
- birdwatching and wildlife tours
- honeymoon and wedding trips
- party holidays for groups of young and single men and women.

Caribbean countries have also started to sell themselves using the internet. The Caribbean Tourist Organization has a user-friendly website where potential tourists can find lots of information about where to go and what to do (*Figure 11.36*). Sitting on a cold day in wintry England and looking at pictures of

Figure 11.36 Website promoting Caribbean tourism

sun-drenched Caribbean beaches, this new way of selling can be very powerful.

Trading groups

A hundred years ago, most countries dealt with those countries they had colonised or been colonised by. The last 50 years have seen the growth of **transnational** (or **multinational**) **corporations** (TNCs) – companies that work in many different countries. Examples include, General Motors, Ford, Shell and Toyota. TNC headquarters are usually in a developed country with factories and branches in many developing countries. In 1966 such companies controlled one-fifth of the world's manufacturing; by the late 1990s the proportion was more than a half.

As TNCs grew bigger, governments realised they had to join with other governments to compete and deal with them. Many countries have formed **trading blocs** and these groups have come to dominate world trade – the two largest are the European Union (EU) and the North American Free Trade Association (NAFTA) (*Figure 11.37*).

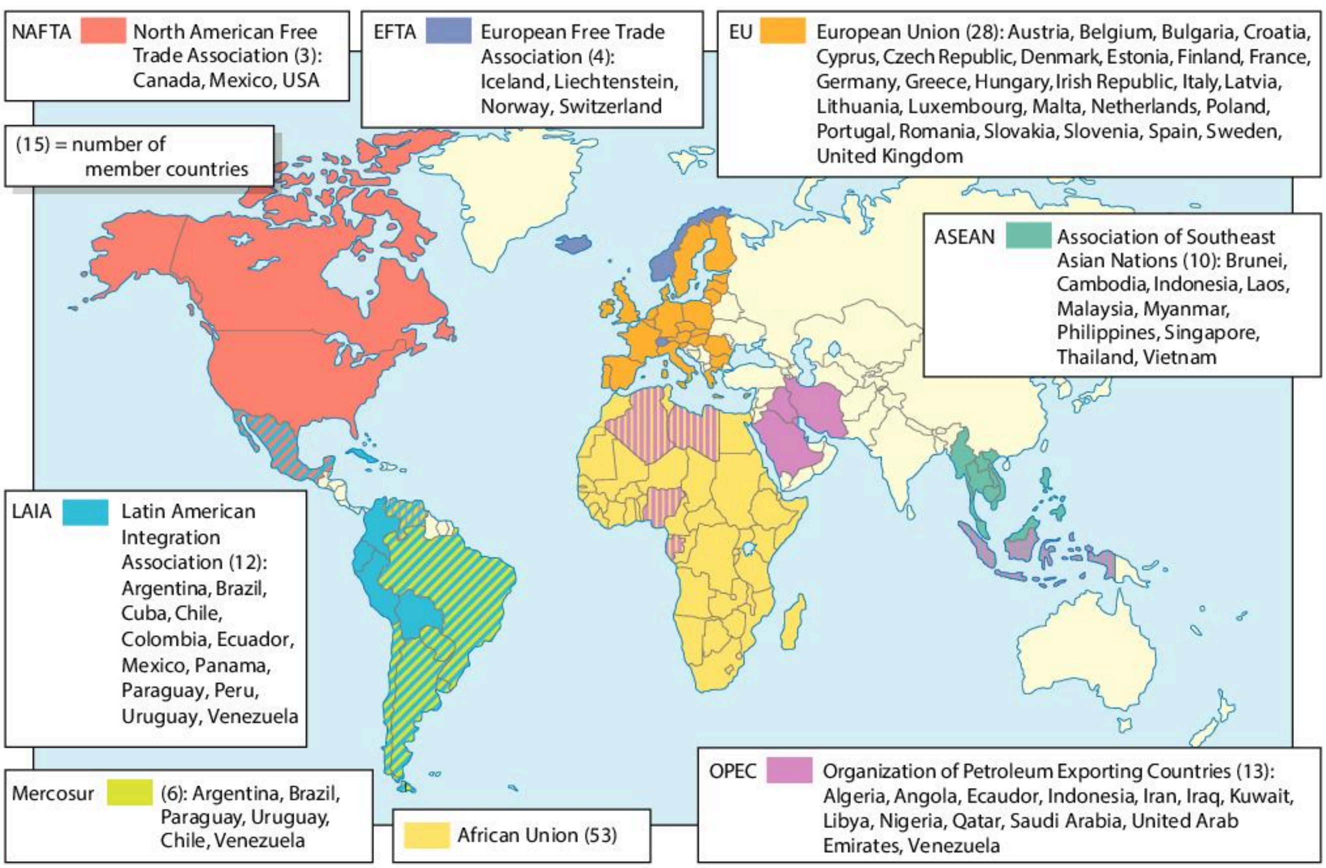


Figure 11.37 World trading groups excluding CARICOM

West Indies Federation

1958–62

Antigua and Barbuda
Barbados
Dominica
Grenada
Jamaica
Montserrat
St Kitts-Nevis-Anguilla
St Lucia
St Vincent
Trinidad and Tobago

CARIFTA

Caribbean Free Trade Association

1965

Antigua and Barbuda
Barbados
Guyana
Trinidad and Tobago

1968

Dominica
Grenada
St Kitts-Nevis-Anguilla
St Lucia
St Vincent and Grenadines
Montserrat
Jamaica

1971

Belize (British Honduras)

CARICOM

The Caribbean Community

1973

Antigua and Barbuda, Bahamas, Barbados, Belize, Dominica, Guyana, Grenada, Haiti, Jamaica, Montserrat, St Kitts and Nevis, St Lucia, St Vincent and the Grenadines, Suriname, Trinidad and Tobago

Associate members

Anguilla, Bermuda, British Virgin Islands, Cayman Islands, Turks and Caicos Islands

OECS

Organisation of Eastern Caribbean States

1971

Antigua and Barbuda, Commonwealth of Dominica, Grenada, Montserrat, St Kitts and Nevis, St Lucia, St Vincent and the Grenadines

Associate members

Anguilla, British Virgin Islands

Figure 11.38 History and membership of CARICOM

By being members of trading blocs, countries can:

- club together to make rules that favour their members
- tax the products of non-members that want to export to member countries – these taxes are called **tariffs**
- impose **quotas** on another country's products, limiting the amount that can be sold to member countries.

The small states of the Caribbean realised a long time ago that they would be stronger in trading with other, larger countries if they joined together. The West Indies Federation was originally set up by the British authorities in 1958 but it collapsed as more countries gained independence. Eventually, it became the Caribbean Community (CARICOM) (*Figure 11.38*), including a smaller trading bloc, the Organisation of Eastern Caribbean States (OECS). CARICOM exists to 'expand trade with third states, enhance levels of international competitiveness and achieve greater effectiveness in dealing with third states and trading blocs' for its members. These are all things the member countries would not be able to do on their own.

CARICOM and the Caribbean Single Market

CARICOM has tried to make sure that development is spread equally around the member countries by:

- increasing trade between member states
- encouraging industrial and agricultural businesses
- increasing the type of goods and services being traded
- removing tariffs and quotas on goods traded within CARICOM.

It has also tried to set up the CARICOM Single Market and Economy (CSME) to develop free trade within the region, with no quotas or tariffs, and to give companies and workers freedom to set up in any country in the region.

Most of CARICOM's export trade (83.6 percent in 2004) is with other countries and trading blocs in the Americas including Mercosur and the Latin American Integration Association (*Figure 11.38*) but there are still a number of countries selling to the EU and there is an increasing amount of trade with Asian countries.

Sustainable development

One increasingly important factor in world trade is the idea of **sustainable development** which should, according to the United Nations:

> '… meet the needs of the present without compromising the ability of future generations to meet their own needs'.

The idea is that countries should improve the quality of life and standard of living for their people so that they get richer without destroying the environment needed to keep developing in the future. The UN says countries should aim for:

- economic development at a speed the country can afford and manage without getting into debt
- technology that is appropriate to the skills, wealth and needs of local people and that develops local skills
- use of natural resources without harming the environment and in a way that will make them last longer.

The small countries of the Caribbean, many of them with an increasing population and only small amounts of natural resources, need careful management of their many types of economic activity to make sure they have a healthy, sustainable future.

Activities

1 What is the main export or industry in your country? What challenges does this industry face and from what parts of the world? How could these challenges be tackled?

2 Are there any TNCs operating in your country? Write a list of all those you can think of and try to identify what country their headquarters are in.

3 Think again about the businesses of your own country and look again at *Figure 11.37*. What products does your country sell to the main trading blocs?

4 Do you think development in your own country, and in the Caribbean region, is sustainable? Give reasons for your answer.

Glossary of terms

Economic activity: all the businesses and industries in a country that make money.

Exports: products that are made to be sold to another country.

GDP per capita: the total value of all goods and services produced in a country divided by the population of that country.

Globalisation: the increasing social and economic connections between countries around the world.

Imports: goods bought from one country by another country.

Multiplier effect: employment in one sector or area increases and as a result employment in other sectors increases too.

Newly industrialised countries (NICs): countries that have had rapid growth in their manufacturing industries since the 1950s – they are mainly in Asia.

Primary industry: economic activity concerned with the extraction of natural resources such as mining, fishing and agriculture.

Quaternary industry: economic activity like research and development that has a high use of technology such as computers. It is sometimes included as part of the tertiary sector.

Raw materials: the things used by an industry to make a product. They can be either natural resources like oil or already processed goods, for example: wheels sent to a car manufacturing factory.

Secondary industry: economic activity that processes raw materials and produces manufactured goods, for example car manufacture and shipbuilding etc.

Tariff: a tax that a government charges to importers of foreign goods. Tariffs raise the prices of imported goods and make them less competitive in the importing country.

Tertiary industry: economic activities that provide a service including police forces, shopkeeping, education and health services.

Trade: the flow of goods and services from producers to consumers.

Ideas for SBA

- *What factors influence the location of an economic activity in my community?*
- *What are the major problems faced by an economic activity in my community and what is done to minimise these problems?*

Exam-style Practice

1 a What do the initials GDP stand for? [1]
b Draw a bar graph to illustrate the information in Table A. [4]
c For TWO of these countries, name two of their manufacturing industries. [4]
d Compare the food processing industry in the Caribbean with the same industry in Singapore. Use the following headings:
  i location, markets and labour supply
  ii raw materials
  iii prospects for the future. [6]
e Describe THREE factors that contributed to the development of the quaternary sector in a named Caribbean country. [6]
f Compare the value of the contributions of this sector to GDP in the named country and the USA. [3]

Total 24 marks

Table A Total GDP from manufacturing and construction industries in a selection of Caribbean countries, 2012

Country	Percentage of GDP from manufacturing 2012
Barbados	7
Cuba	12
Dominican Republic	23
Puerto Rico	49
Jamaica	9
Trinidad and Tobago	6

Source: *Philip's Certificate Atlas for the Caribbean* (7th edition), 2015

2 a What does the acronym CARICOM stand for? [1]
b Name TWO trading blocs in the Caribbean that were formed before CARICOM. [2]
c Draw a pie chart to illustrate the information in Table B. [4]
d Explain the economic challenges to the Caribbean in terms of:
  i increased competition from other countries
  ii the abandonment of traditional trade deals
  iii new technology. [9]
e Explain THREE policies adopted by CARICOM in order to cope with these challenges. [8]

Total 24 marks

Table B Trade by CARICOM countries in terms of the types of goods being sent to other countries

Type of goods exported	Percentage of total exports
Petroleum and petroleum products	39
Sugar	14
Chemicals	14
Miscellaneous manufactured articles	4
Iron and steel	3
Clothing and accessories	3
Beverages and drinks production	3
Other	20

Source: CARICOM, 2007

12 Agriculture

In this chapter you will study:

- historical, physical, human and economic factors associated with agriculture
- areas in Caribbean countries where commercial farming (both large-scale and small-scale) and subsistence farming are important
- characteristics of commercial farming in a named Caribbean country (size of farm, ownership, labour, farming practices, products, markets, technology)
- characteristics of sugarcane farming – area, farming practices, labour, technology (for example, the use of materials, tools, techniques and sources of power to improve productivity), and markets
- changes in commercial farming – for example, government policies (including issues of food security), biofuels, value-added products, technology, shade houses, new markets
- impact on economic development – for example, cost and availability of traditional products, income, government revenue, job opportunities, and diversification.

You will also learn how to:

- interpret tables, maps and charts
- describe a pattern.

We have seen in Chapter 7 how the climate of the Caribbean, with its high temperatures and seasonal rainfall has given it great potential for tourism. It has also given it great potential for agriculture. Indeed, the economies of Caribbean countries have long been associated with the production of export-oriented agriculture, such as sugar and bananas. However, there is great variety in Caribbean agriculture – Grenada has specialised in nutmeg, Dominica in limes and Jamaica in pimento. In contrast, on the smaller drier islands, such as the Turks and Caicos, commercial farming never really took off, and farming was mainly subsistence (for household consumption). Each Caribbean country has a unique set of environmental, cultural and socio-economic factors which give rise to a mosaic of agricultural land uses.

On most Caribbean islands a dual agricultural economy has developed, with a large-scale, export-oriented plantation sector (*Figure 12.1*) and a small-scale farming system geared to production for the household and for sale on the domestic market (*Figure 12.2*).

Figure 12.1 A banana plantation on Barbados

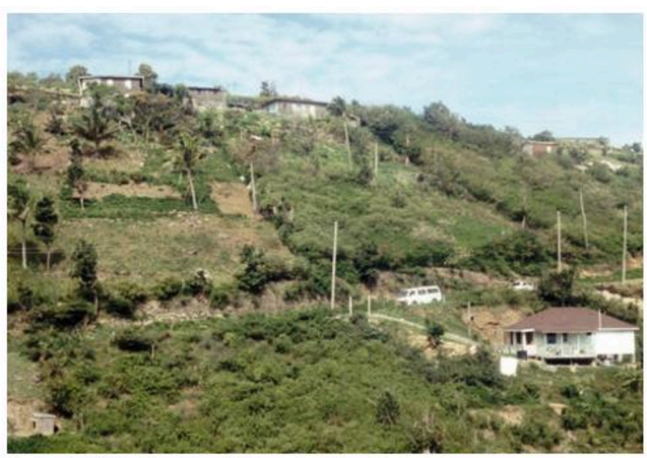


Figure 12.2 Small-scale subsistence farming, Montserrat

On the more mountainous islands, such as St Kitts, elements of this have persisted, giving a distinctive spatial pattern. Traditionally, farming has been one of the most important economic sectors in the Caribbean, and many countries have depended on farming for their livelihood. Some countries have even depended on just one farm product. However, in recent decades this has begun to change. There has been a shift away from a dependence on primary export crops such as sugar, and agriculture has tended to decline. Even so, primary (farm) products constitute over 40 percent of the exports of all Caribbean countries, except Dominican Republic, Antigua and Barbuda and St Kitts and Nevis.

Caribbean agricultural landscapes reflect diverse cultural influences. Farmers with African ancestry grow crops such as pumpkins and cassava, which would have been familiar to the indigenous Arawak. They also grow yams, which come from Africa, carrots, cabbages and onions from Europe, mangos (India) and breadfruit (Pacific Islands). Some Guyanan farmers are descended from Indian labourers, and rice, buffalo, Hindu temples and Islamic mosques are all part of the rural landscape.

The plantation system

The most important factor underpinning contemporary farming in the Caribbean is the legacy of the colonial plantation system. Historically, the plantation dominated the agricultural, economic, social, political and colonial organisation of the Caribbean. The labour force (slaves and, later, wage earners) were carefully controlled and supervised, to the extent that plantations dominated the lives and livelihoods of the people they embraced. As an economic system, it was geared to the commercial production of export crops for an overseas market, and the bias toward export crops over domestic food crops still persists among those involved in large-scale commercial agriculture.

Figure 12.3 Plantation and woodland, Barbados

Modern sugar plantations are large-scale operations requiring good, relatively flat, arable land, and a large labour force for cultivation and processing (*Figure 12.3*). Field layout generally reflects the need to process the harvested cane quickly and a factory is usually located centrally within a sugar estate.

Sugarcane is also a cash crop for small and medium-sized farmers. The linkages between the sugar factory and surrounding cane farmers still defines a 'catchment area' whose size is partly determined by transport costs and perishability (since sugar quality deteriorates rapidly 24 hours after reaping).

Trends in Caribbean agriculture

Some of the main trends in Caribbean agriculture are shown in *Figure 12.4*. These include:

- a steady decline in the workforce, from just under 50 percent to under 25 percent
- a rise and subsequent fall in agricultural exports from one million tonnes to a peak of over six million tonnes in 1986, and a decline to just over two million tonnes in 2001
- fertilizer use rose from just under 0·25 million tonnes in 1960 to a peak of nearly one million tonnes in the 1980s, and then fell back to just under 0·5 million tonnes in the 1990s
- the number of tractors in use increased from about 200 in 1961 to about 1000 in 2000–01.

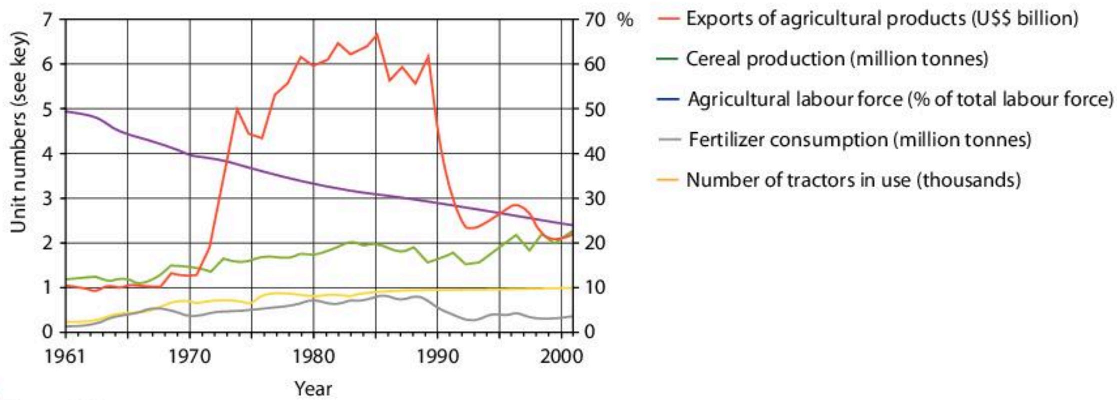


Figure 12.4 Changes in agriculture in the Caribbean, 1961–2001

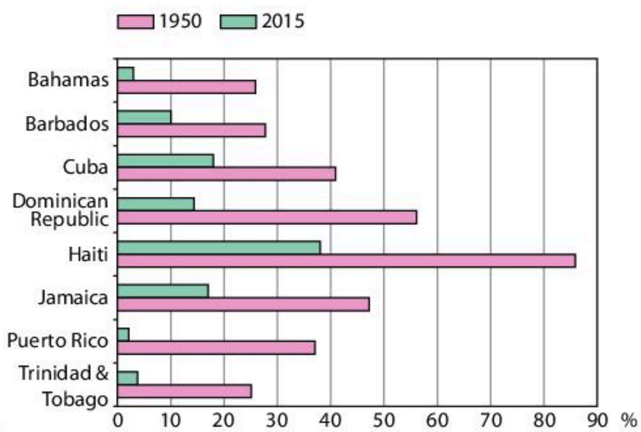


Figure 12.5 Percentage of total population employed in agriculture, 1950 and 2015

Figure 12.6 Untapped land in St Lucia

There have also been reductions in the number of people employed in farming (*Figure 12.5*). Nevertheless, agriculture, both commercial and subsistence, remains important in the Caribbean as a source of food, fodder, income and livelihood for farmers, as a land-use, and as a source of foreign exchange.

Activities

1 Referring to *Figure 12.5*, copy and complete *Table A* on page 285.

2 Work out:

a the average for the percentage of total population employed in agriculture, for 1950 and 2015

b the average change in employment for these countries

c which countries declined by more than the average decline 1950–2000.

3 Suggest why the expansion of farming is limited in the area shown on *Figure 12.6*.

Table A

	% in 1950	% in 2015	% change 1950–2015
Bahamas	26	4	22
Barbados	28	4	24
Cuba	41	13	28
Dominican Republic	73		
Haiti	86		
Jamaica	47		
Puerto Rico			
Trinidad and Tobago			

The importance of agriculture to the Caribbean region

Agriculture benefits Caribbean economies in a number of ways:

- it contributes to gross domestic product (*Table 12.1*) and to export earnings
- it contributes to the domestic food supply
- it provides employment (*Table 12.2*)
- it is a source of industrial raw materials (for example in the manufacture of rum)
- the income from farming generates income for families living in rural areas.

Table 12.1 Contribution to GDP by sector

	Agriculture (%)	Industry (%)	Services (%)
Anguilla	2.6	24.4	73.0
Antigua and Barbuda	1.9	18.5	79.6
Bahamas	2.1	7.3	90.6
Barbados	3.1	12.0	85.0
Cayman Islands	0.3	28.4	71.0
Cuba	3.8	14.3	81.9
Dominica	14.8	14.1	71.1
Dominican Republic	6.3	32.1	61.6
Grenada	5.9	11.0	83.2
Haiti	24.7	20.0	55.3
Jamaica	6.9	21.1	72.0
Montserrat	1.6	21.9	76.6
Puerto Rico	0.7	48.5	50.8
St Kitts and Nevis	1.5	23.0	75.4
St Lucia	3.0	14.5	82.5
St Vincent and the Grenadines	8.5	20.9	70.6
Trinidad and Tobago	0.5	15.2	84.3
Virgin Islands	2.0	20.0	78.0

Source CIA World Factbook, 2015

Table 12.2 Contribution to the workforce

	Agriculture (%)	Industry (%)	Services (%)
Anguilla	4.0	21.0	75.0
Antigua and Barbuda	7.0	11.0	82.0
Bahamas	3.0	11.0	86.0
Barbados	10.0	15.0	75.0
Cayman Islands	1.9	19.1	79.0
Cuba	18.0	10.0	72.0
Dominica	40.0	32.0	28.0
Dominican Republic	14.4	20.8	64.7
Grenada	11.0	20.0	69.0
Haiti	38.1	11.5	50.4
Jamaica	17.0	19.0	64.0
Puerto Rico	2.1	19.0	79.0
St Lucia	21.7	24.7	53.6
St Vincent and the Grenadines	26.0	17.0	57.0
Trinidad and Tobago	3.8	33.2	63.0
Virgin Islands	1.0	19.0	80.0

Source: CIA World Factbook, 2015

Farming is the major economic land use activity on most Caribbean islands. Agriculture contributes about 24 percent of GDP in the Caribbean, being highest in Haiti (*Table 12.1*). There is a declining regional trend; for example, in St Kitts and Nevis, agriculture has fallen from 40 percent of GDP in 1964 to less than 2 percent, and in Barbados from 38 percent in 1958 to 3 percent. In the Caribbean, agriculture now generally accounts for less than 10 percent of GDP in most of the countries listed in *Table 12.1*. However, the decline in employment in agriculture in the region has been matched by a rapid growth of employment in the service sector.

As primary exports like sugar and bananas have stagnated or declined, tourism, light manufacturing and offshore financial and IT services have become more important. In the smaller, drier Leeward Islands, this process came faster than in the more agriculturally favoured Windward Islands. In 9 of 15 CARICOM states, food exports exceed 20 percent of total exports – a threshold used by the UN Food and Agricultural Organization (FAO) to define those countries it considers too dependent on agricultural exports. In Dominica, agriculture accounts for 60 percent of export earnings. Dominica's exports are dominated by bananas. The growth of tourism was expected to stimulate local farming by generating demand for fresh food in hotels and restaurants, leading to a diversification away from commercial export crops. However, a 2000 World Bank study showed that food imports for the tourism sector represented 20–25 percent of total agricultural imports and cost US$366 million.

Most Caribbean countries have high levels of food imports, both for the local population and for the tourist sector. Around the year 2000, CARICOM countries produced a net agricultural surplus of about US$3 billion. By 2015, the food import bill was about US$3.5 billion/year.

Employment in agriculture as a percentage of the labour force has declined in recent years. It varies across the region, from a low of 1 percent of the labour force in the Virgin Islands and 2 percent in Puerto Rico, to between 20 and 40 percent in Dominica and St Lucia (*Table 12.2*). Nevertheless, agriculture supports nearly one-quarter of the Jamaican population, and over half a million people (mostly small farmers) work in agriculture in Dominican Republic.

Agriculture is a major land use (*Figure 12.8*). The Caribbean has less than 0.25 percent of the world's total farmland. Half of all Caribbean farmland is in Cuba and, with Dominican Republic and Haiti, these three countries account for over 90 percent of the region's farming area. Farming still occupies 44 percent of Barbados and Jamaica, even though land is being converted to urban and tourist-related activities. Over the last 50 years the farmland has expanded in some countries and contracted in others. The largest loss (around 50 percent) occurred in Puerto Rico, with smaller declines in Grenada and St Kitts and Nevis. The largest increase was in Cuba, where three million hectares have been brought into production since 1961.

Skills

How to interpret a table

Table 12.1 is a set of data relating to employment characteristics in the Caribbean. Tables provide data in an accurate and accessible way. The information in the table could be shown graphically by 18 pie charts (one for each country) or in the form of a divided bar chart (like the one in *Figure 12.7*). However, that would be a great many pie charts, and divided bar charts can sometimes be difficult to read.

When interpreting tables you should look out for particular information, for example:

- the highest value (and what it relates to)
- the lowest value (and what it relates to)
- the range of values (highest to lowest)
- the average value.

Study *Table 12.1*.

1. In which country does agriculture contribute the highest proportion of GDP?
2. In which countries does agriculture contribute the least to GDP?
3. What is the average contribution of agriculture to GDP in the countries listed? (Hint: Add up all the values in the 'Agriculture' column and then divide by 18.)
4. *Figure 12.7* is a partly completed divided bar chart. Copy and complete the chart using data from *Table 12.2*.

Note: To plot the line dividing Industry from Services, add the percentage employed in Industry to the percentage employed in Agriculture. For example, in Anguilla the 21 percent employed in Industry is added to the 4 percent employed in Agriculture, and the line is drawn at 25 percent (4 percent in Agriculture and 21 percent in Industry). The remaining 75 percent (100 percent – 25 percent) is the percentage employed in Services.

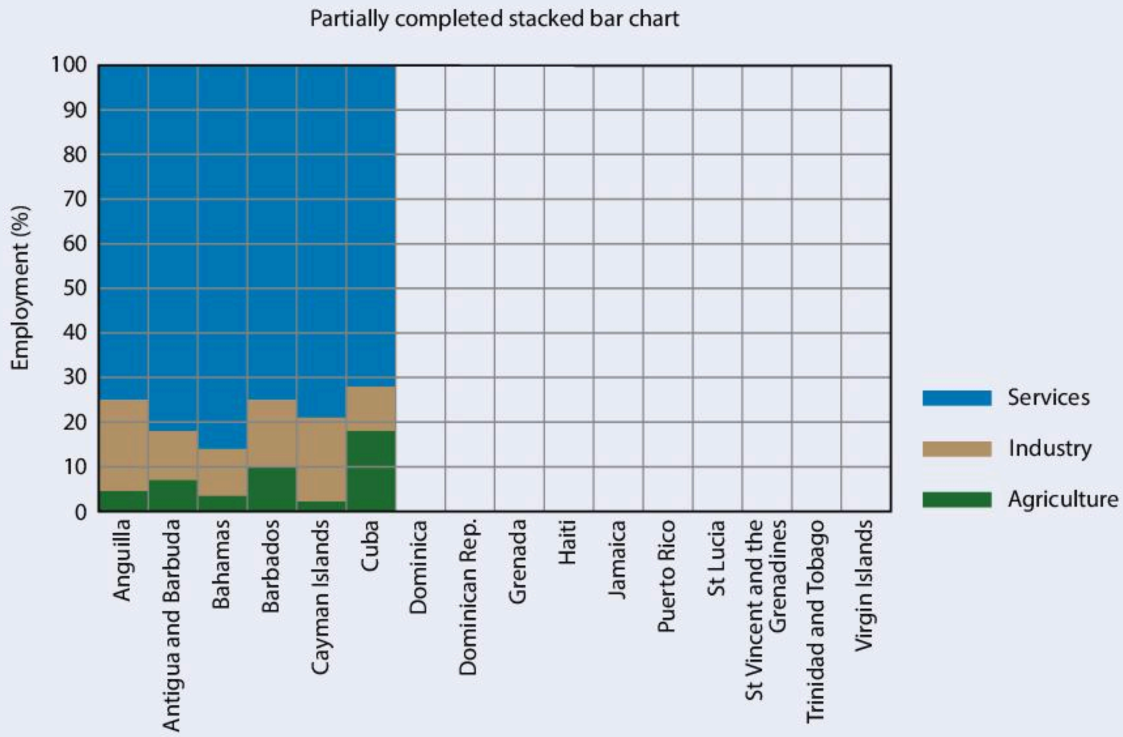


Figure 12.7 Drawing a divided bar chart

Skills

How to interpret a chart

A chart is an outline map showing specialised information, or a diagram or list giving information in an ordered way. *Figure 12.8* has two keys: one for land use and one for agricultural exports.

1 Which country has the largest total land area in hectares?

2 Which country has the smallest land area in hectares?

3 Which country has the highest percentage of arable land?

4 Which country has the highest percentage of permanent pasture?

5 Which country has the highest percentage of forest and woodland?

6 What is the dominant land use in:
  a Dominican Republic
  b St Lucia
  c Cuba
  d Jamaica?

7 What is the proportion of agricultural exports as a percentage of total exports in:
  a Haiti
  b Dominican Republic
  c Grenada?

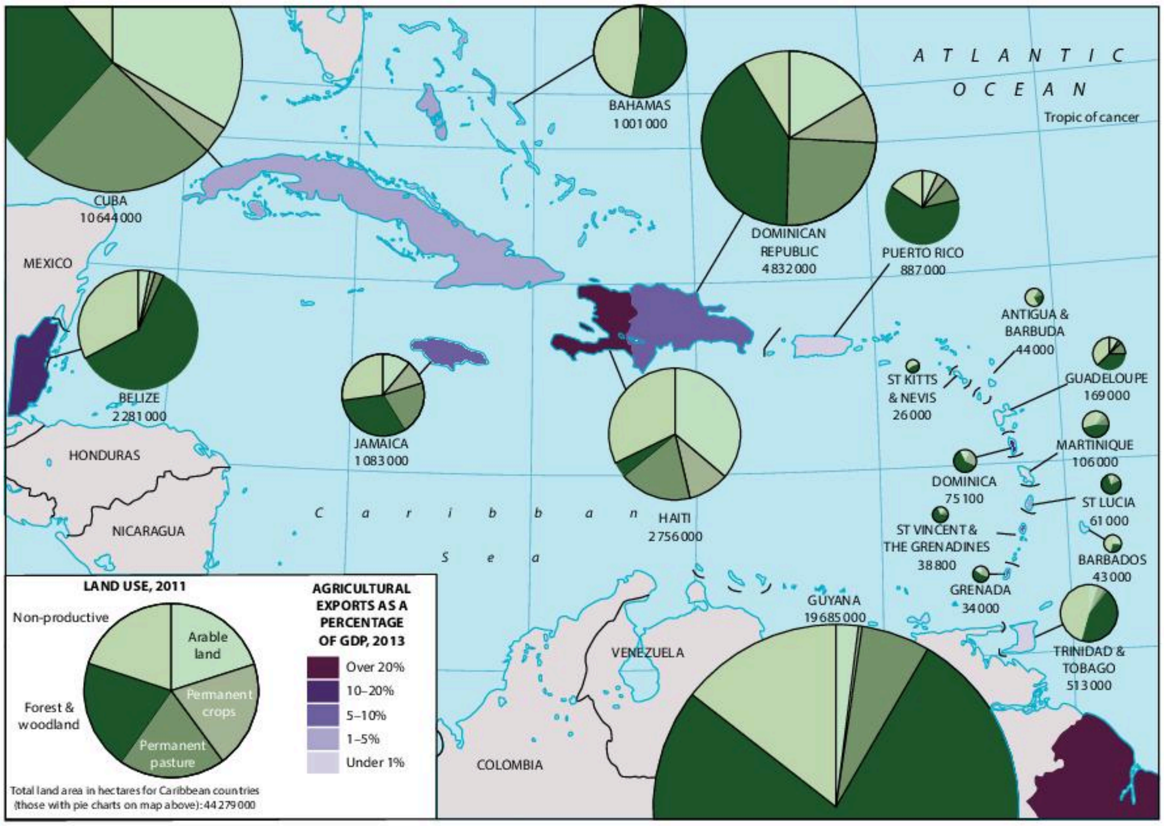


Figure 12.8 Land use in the Caribbean, and agricultural exports

Table 12.3 Changes in agricultural land, 1961–2011

	1961 Ha (thousands)	1961 % of total	1981 Ha (thousands)	1981 % of total	2001 Ha (thousands)	2001 % of total	2011 Ha (thousands)	2011 % of total
Antigua and Barbuda	10	23	11	25	12	27	9	20.5
Bahamas	10	1	11	1	13	1	15	1.5
Barbados	19	44	19	44	19	44	15	34.9
Belize	79	3.5	97	4	139	6	157	6.9
Cuba	3550	32	5938	54	6665	61	6570	61.7
Dominica	17	23	19	25	17	23	26	34.7
Dominican Republic	3082	64	3517	73	3696	76	2447	50.6
Grenada	22	65	16	47	12	35	11	32.4
Guyana	1359	7	1715	9	1726	9	1677	8.5
Haiti	1255	46	1403	51	1400	51	1770	64.2
Jamaica	533	49	497	46	503	46	449	41.5
St Kitts and Nevis	20	56	15	45	10	28	6	23.1
St Lucia	17	28	20	33	19	31	11	18
St Vincent and the Grenadines	10	26	12	31	13	33	10	25.6
Trinidad and Tobago	102	20	127	25	133	26	54	10.5

Source: FAO.ORG in Potter R.B. et al., *The Contemporary Caribbean*, Pearson, 2004, Table 3.2, and www.fao.stat 2015

Activities

1 Study *Table 12.3*.
  a In which countries was there an increase in the percentage of agricultural land between 1961 and 2011?
  b Which country had the biggest increase in percentage of agricultural land use after 1961?
  c Which country had the biggest increase in agricultural area after 1960?
  d Which countries saw a decrease in the percentage of agricultural land between 1961 and 2011?
  e Which country had the biggest decrease in the percentage of agricultural land use after 1961?
  f Which country had the biggest decrease in hectares after 1960?

Large-scale and small-scale commercial farming: Agricultural systems in Jamaica

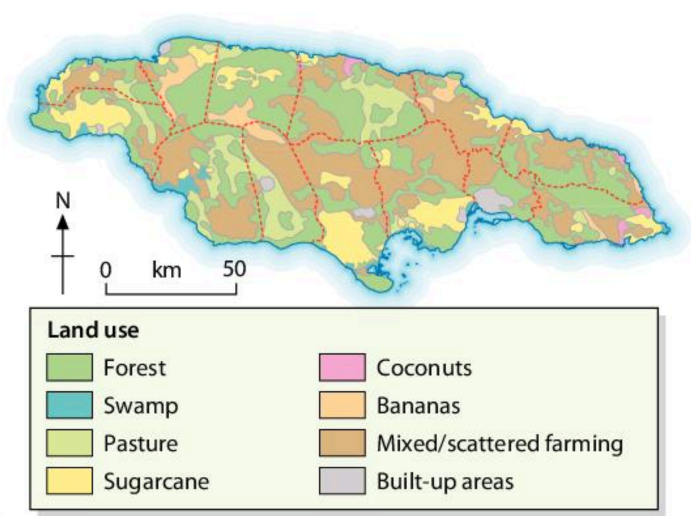
Distribution of land use

Less than one-third of Jamaica is suitable for farming (*Table 12.4 and Figure 12.9*). This is because half of the country is over 300 metres in height and about one-third of it has steep slopes of more than 20 percent (one in five, or 20 degrees). In Jamaica, slopes over 20 degrees cover half the island, and as much as a quarter of the surface area has slopes over 30 degrees, yet these same hillsides are the principal sites of small-scale farming occupied by about a quarter of the island's population. In the limestone areas the soils are thin and there is a lack of surface water. All of these factors make farming difficult. In addition, large areas of forest have been cut for timber and charcoal. In some areas soil erosion has been severe and there have been a number of attempts to protect the upper parts of watersheds.

Table 12.4 Percentage of land uses in Jamaica

Land use	% of area
Agricultural land	44.2
Arable land	12.9
Permanent cropland	10.2
Forest area	31.1

Source: The World Bank



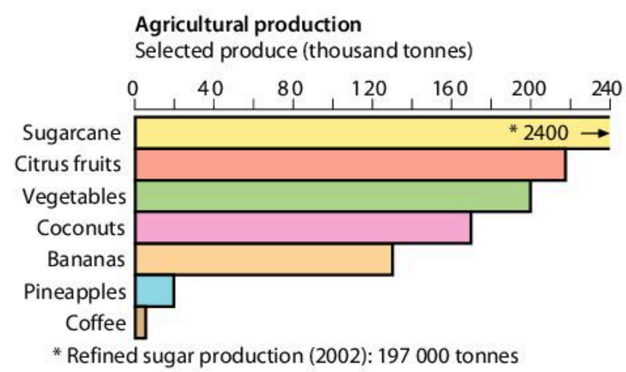


Figure 12.9 Agricultural land use and production, Jamaica

Skills

How to describe a pattern

- First of all, try to get an overview of the situation. Decide whether the pattern is even or uneven, regular or irregular, linear or random.
- Then, state roughly how many regions there are with the named characteristics. Try to locate them – are they mostly in the north, south, east, west or centre? Are they coastal or inland? Are they located on high ground or low ground? Are they close to or far away from urban areas or major transport routes?
- Can you think of any other geographic factors that might be important in describing a pattern?

1 Describe the distribution of pasture land shown in *Figure 12.9*.

2 a Describe the distribution of areas that produce sugarcane.
b How does this compare with areas producing coconuts?

3 Suggest why there is so much forest in Jamaica.

4 Using the data in *Table 12.4*, construct a pie chart to show the proportion of land uses in Jamaica. (Look back to pages 254–255 to check how to draw a pie chart.)

Characteristics of commercial arable and peasant farming

The Brundtland Commission (1987) suggested that there are three main types of farming:

- commercial (large-scale) agriculture
- resource-poor agriculture
- Green Revolution agriculture.

Industrial or large-scale **commercial agriculture** is technology-dependent and capital-intensive, and is based on the widespread use of mechanised oil-driven tractors and other farm equipment (*Figures 12.10* and *12.11*). Traditional **subsistence farming** has low levels of technology and food output and, worldwide, supports two billion people in marginal semi-arid lands, highlands and forests (*Figure 12.12*). **Green Revolution agriculture** is a separate category, since the developing regions affected (especially in Asia) have experienced dramatic transformations in farming and food output.

Figure 12.10 A commercial farm in the Caribbean

The main type of farming in the Caribbean, traditional small-scale peasant farming is, in many ways, 'resource-poor'.

However, there is also a long tradition of commercial production by small farmers. Today, small farmers dominate exports in crop sectors such as bananas in the Windward Islands, yams in Jamaica and rice in Guyana.

Commercial agriculture	'Resource-poor' small-scale peasant farming
Increased food output	Low levels of food output
Increased farm size	Subsistence production and some cash crops
Reduced demand for labour	Small farm size
Monoculture	High demand for labour
Production for profit	Mixed cropping and polyculture
Intensification of capital inputs	Production for home consumption
High energy use from unsustainable fossil fuel sources	Low level of capital inputs
Demise of family farm	Reliance mainly on renewable human, animal and solar sources of energy
Increasing role of corporate business	Farm based on household unit
Development of industrial substitutes for many agricultural products	Variety of tenure arrangements, some insecure

Figure 12.11 Characteristics of commercial agriculture and small-scale peasant farming

Activities

1. Describe the main characteristics of the farm shown in *Figure 12.10*.
2. Describe the landscape in *Figure 12.12*.
3. Suggest three ways in which the farms in these two pictures differ.
4. To what extent do you think they typify the types of farming described in *Figure 12.11*?

Figure 12.12 A subsistence farm in Barbados

Plantations and the dual agricultural economy

Table 12.5 illustrates the farm size distribution for Jamaica in 1996. Over 60 percent of the country's 188 000 holdings were less than one hectare, yet the 77 percent of holdings under two hectares occupy only 20 percent of the country's farmland. Conversely, the 1400 large holdings (over 20 hectares) account for 54 percent of all agricultural land.

The present inequalities in land ownership patterns are a legacy of the colonial period. Plantations and large estates were owned by the wealthy class and geared to commercial export crops. They occupied the best and largest proportion of agricultural land, whilst small farmers usually cultivated small plots of poorer-quality land under insecure forms of tenancy, yet they constituted the majority of the rural population. This division of agriculture into large-scale and small-scale sectors is known as a **dual agricultural economy**.

Table 12.5 Size distribution and fragmentation of farm holdings in Jamaica

Size category (ha)	Total number of holdings	Total area (ha)	Total number of plots
Less than 0.4	71 753	9401	61 274
0.4–2	87 273	73 205	114 798
2–4	18 256	46 807	30 987
4–10	7746	42 998	15 285
10–20	1339	17 642	2718
20–40	624	16 468	1020
40–80	349	18 482	529
80–200	248	30 681	371
Over 200	203	152 393	413
Total	187 791	408 077	227 395

Source: Census of Agriculture 1066, Vol 3, Statin Table 6.4 in Potter R.B. et al., *The Contemporary Caribbean*, Pearson, 2004, Figure 7.9

Activities

1 Study *Table 12.5*.
  a **i** How many farms are less than 0·4 hectares in size?
    ii How much land do they account for?
  b **i** How many farms are larger than 80 hectares?
    ii How much land do they account for?

2 Study *Figure 12.12*. Suggest reasons for the location of the plantation and of the rainforest in the photograph.

Small farming traditions

Traditional small farmers in the Caribbean are generally 'resource-poor' with a low level of education. Small farmers use family labour wherever possible, and little technology. In the Caribbean, most farms are broken up into several small parts (**fragmentation**). Barbados is an exception, but in Jamaica the average number of plots per farmer is 1·21. Larger farms are more fragmented than smaller ones and the average number of plots for farms over 10 hectares is 1·64 compared with an average of 1·11 for farms less than two hectares (*Table 12.5*).

Cropping systems are ecologically complex and techniques like intercropping require the skilful use of several crops at the same time and in a limited space. Crop rotation cycles incorporate legumes to help replenish depleted soil nutrients.

Kitchen gardens and food forests

A kitchen garden is the area around a house that is cultivated **intensively**, mainly to produce food for the household. It is widespread in the tropics. A multi-layered food garden is called a **food forest** (*Figure 12.13*). The different biological cycles of food plants ensure a continuous food supply throughout the year.

GENERAL FUNCTIONS

Subsistence; boundary markers; decorative; beverages; construction; commercial; protective; religious; medicinal; furniture

STRUCTURE

Tall trees (15–30 metres): breadfruit, breadnut, cedar, cinnamon, mahogany, mango, palms

Medium trees and bushes (10–15 metres): ackee, coconut, pimento, star apple

Small trees and bushes (5–10 metres): avocado, banana, papaya, plantain, sugar apple

Small bushes and shrubs (2–5 metres): cocoa, coffee, cashew, castor bean, citrus, okra, pigeon pea, tree tomato

Tall grasses (1–2 metres): sugarcane, corn, guinea grass, elephant grass, napier grass, guinea corn

Legumes (bushy creepers): broad bean, butter bean, cowpea, French bean, haricot bean, peanut

Rosette type: pineapple, sisal

Spreading plants: pumpkin, melon, squash, christophene (cho cho)

Roots and tubers: sweet potatoes, eddoe, yams, dasheen

Vegetables: beetroot, carrot, celery, lettuce, shallot, radish, calalloo, cauliflower, aubergine, onion, spinach, tomato

Vines: granadilla, black pepper

Beverages: mauby, sorrel

Medicinal: aloe, physic nut, sarsaparilla

Herbs and spices: basil, dill, thyme, bayleaf, garlic, tamarind

PRODUCTS

Human foods: cereals, fruit, nuts, oil seeds, pulses, roots, spices, tubers, vegetables

Animal foods: corn, cowpea, guinea corn

Beverages: *non-alcoholic:* coconut, ginger, fruits, sorrel, vines; *alcoholic:* banana, sugar, cassava

Medicines: 75 percent of plants serve some medicinal purpose

Thatching: banana, coconut, plantain

Fibre: coconut (coir fibre), sisal

Timber: for bearings, construction, flooring, furniture, mallets, ornaments, propeller shafts, pulleys, walking sticks

Containers: calabash, coconut (shell)

Miscellaneous uses: boat caulking (breadfruit bark), cosmetics (bixa, ganja), dyes (jackfruit, guinep), fish poison (pulverised ackee), flowers, gums, indelible ink (cashew), mulch, musical instruments, ornamentals, preservatives (papaya, cassava), resinous latex (jackfruit), soap starch (cassava), waterproofing (cashew)

Figure 12.13 The functions, structure and products of Caribbean food forests

Recent changes in Jamaican farming

Farming has suffered in Jamaica in recent years: partly because of natural hazards, partly because of the lower prices received by Jamaican farmers from the European Union. As a result, the Jamaican government announced a new policy for a sustainable local sugar industry. The two main points of the Jamaican government's policy were that the industry will be centred around three products – raw sugar for export and domestic markets, molasses for the manufacture of rum, and ethanol for fuel – and the production target will be 200 000 tonnes of raw sugar per year.

Case Study

Jamaican farms

A commercial arable farm: Kew Park Farm

Kew Park Farm is in the west of Jamaica, close to the north-east boundary of Westmoreland parish, on the edge of Cockpit Country (*Figure 12.14*). It is an area of about 385 hectares and is run along with Copse Mountain Farm (about 425 hectares) – the two farms together form one unit, Kew Park. This is a very hilly part of the country; about 30 percent of Kew Park Farm can only be accessed on foot, and about 15 percent of the total area is not farmed at all.

Most of the farmed area is allocated to beef cattle; much of the breeding research for the Jamaican Red Poll was conducted here (*Figure 12.15*). At present, there are five pedigree Jamaica Red Poll herds and two commercial herds on the farm: a total of about 700 animals. The cattle are raised extensively, but are confined in grass pastures by either barbed-wire fences or dry-stone walls. Other parts of the farm support a variety of agricultural activities:

- Above about 400 metres, an area of 16 hectares is planted with arabica coffee, producing the 'Estate' brand. Much of the primary processing of the coffee is done on the property but it is sent to Kingston to be graded, roasted and packed. Kew Park has a licence to export the processed coffee, although much of it is sold locally.
- Two hectares of the farm are given over to citrus fruits (ortaniques). However, the fruit are not of prime quality as the climate is rather too wet and the trees are not very well maintained.

Figure 12.14 Kew Park and Windsor farms in western Jamaica

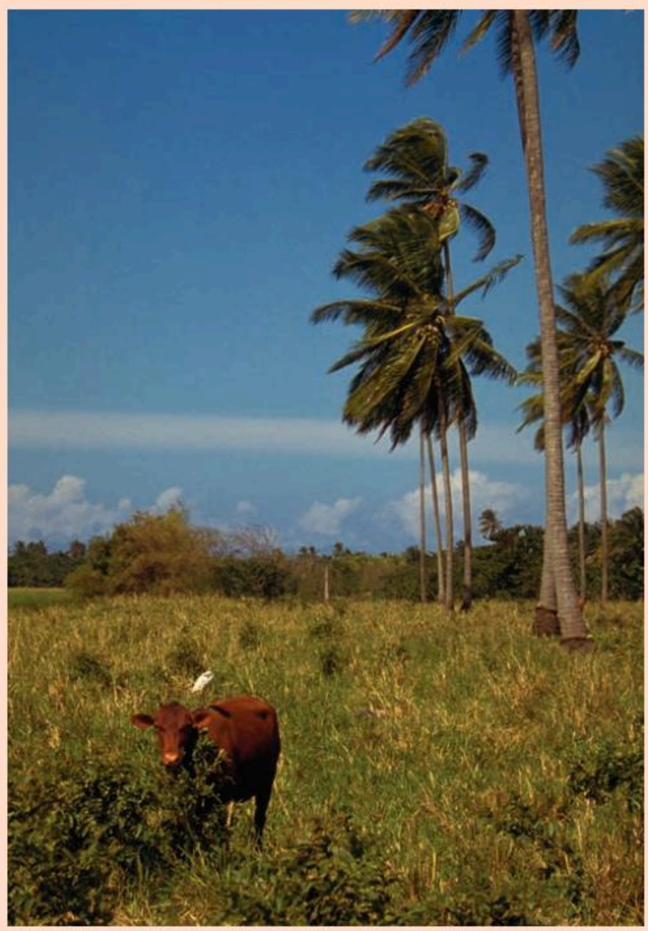


Figure 12.15 Red Poll cattle

- There are two hectares of lychees, which is a difficult crop to grow but there is a good local market for the fruit.
- The farm supports some 2000 free-range chickens; the eggs are washed and packed on the property and sold locally.
- Five pig units comprise a total of 120 sow units (breeding animals) and 2500 fatteners. Kew Park has a contract to provide a local processor (Grace Food Processors) with 120–150 pigs a week.

The farm employs some 40 full-time workers. The number of part-time staff taken on depends largely on the demands of the coffee crop, but it can be as many as 100.

While the farm is run as a commercial enterprise, as on most farms money earned is ploughed back into the farm and its staff – life in rural areas is not easy and Kew Park provides the only full-time employment in the area. Wages are low. Some staff live in houses owned by the estate but most travel from their own homes nearby.

Small-scale commercial farms in Cockpit Country

Less than 40 km from Kew Park is the small settlement of Windsor, located within Jamaica's Cockpit Country (*Figure 12.14*). Here a number of small peasant farmers work the land (*Figure 12.16*).

Most of the farmers are elderly. Surveys have shown that over 60 percent of the farmers in this area are aged over 50 years and that 43 percent are aged over 60. In contrast, the proportion of young farmers is very low – less than 3 percent of the farmers are younger than 25 years of age.

Farm sizes are generally small, the majority being less than one hectare, and most are broken up into many fragments – most farms are made up of at least two or three parcels of land, and some as many as ten. Being fragmented has its advantages: it allows farmers to farm in different environments and to spread their risk among many different types of crops. For instance, the forested areas (cockpits) contain rich, fertile soils, and are moister and cooler than the rocky slopes and high ground. On the other hand, some farmers can spend up to two hours cycling to one piece of land, representing a considerable waste of the farmer's time.

Figure 12.16 Working the land on a smallholding in Cockpit Country

Small farm production is characterised by a variety of crops. Sugarcane is the most important cash crop. This is collected by truck and processed at the Long Pond factory. Other important cash crops include coffee and bananas. Other crops are used for a mix of subsistence needs and for sale at the market at Falmouth, some 16 km away. Field crops include yams, dasheen, maize, sweet potatoes and cabbage while tree crops include breadfruit, coconuts and avocado pears. On some of the rocky slopes farmers grow 'creeping crops' which are able to spread over the bare rock. These include pumpkin, cucumbers and yams. Many farmers also keep livestock – cattle and goats are the most important in the region.

To sustain their farming, most farmers use a variety of measures such as intercropping, crop rotation and fallow.

The main problem is an economic one – that of being able to market the farm products. The area is relatively isolated and there are few good roads to the nearby towns. The future for these small farmers appears bleak. Farmers need more land to farm effectively, but there are competing claims for the land from mining companies, environmentalists and forestry companies.

1 Outline two similar factors experienced by the farmers at Kew Park and the farmers near Windsor, Cockpit Country.

2 In what ways is the fragmentation (breaking up into small pieces) of farms:
i a good thing
ii a bad thing?

3 How might the problems that face Kew Park be different from the problems that face farmers near Windsor?

Jamaica also has a **New Agricultural Development Plan** that is aimed at transforming the farming sector by 2020. The main aims of the plan are:

- to halt the decline of the agricultural sector
- to restore productivity to agricultural resources
- to ensure that farming communities provide meaningful livelihoods and living environments for those who depend on the agricultural sector.

The New Agricultural Development Plan aims to increase production in eight key areas:

- Small Ruminant Industry Development Project
- National Organic Agriculture Project
- Protected Cultivation (Hydroponics)
- Beekeeping Enhancement Project
- Marketing (Agribusiness Enhancement Project)
- Fruit Tree Crop Development Project
- Ornamental Horticulture
- Fisheries Development Project.

Production in the Traditional Export Crops sub-sector fell by over 32 percent between 2004 and 2005 (*Table 12.6*). This was due to the impacts of drought and hurricanes. The banana industry was totally devastated in September 2004. In addition to the climate hazards, the decline in the volume of milled sugarcane was due to industrial disputes and mechanical stoppages at some factories. Coffee trees were also affected by Hurricane Ivan: about 5 percent of coffee trees were destroyed and some 40 percent of the crop was lost. New coffee trees require three to five years to mature, so the impact is long-term.

Activities

Study *Table 12.6*.

1 Describe the trend in export crops since 1996.

2 Which farm sector is the only one to have increased since 1996?

3 Suggest why export crops and domestic crops fell between 1996 and 2005.

However, the outlook for farming in Jamaica is positive. The sector is expected to grow, although this is very much dependent on the weather. In addition, the New Agricultural Development Plan is expected to have a positive impact, as it invests US$3 million into the farming sector.

Table 12.6 Trends in commercial agriculture in Jamaica, 1996–2005 (1996 production = 100)

Year	Export crops	Domestic crops	Livestock	Total
1996	100.0	100.0	100.0	100.0
1997	84.5	79.3	105.2	84.3
1998	73.8	77.4	100.2	80.3
1999	78.0	79.4	119.1	83.9
2000	69.1	64.7	120.7	72.7
2001	68.9	70.2	123.7	76.3
2002	63.7	61.9	134.4	71.9
2003	59.5	70.5	135.4	76.4
2004	56.1	59.5	133.0	68.7
2005	38.1	57.5	139.0	64.1
% change 2004/2005	–32.1	–3.4	4.5	–6.7

Source: *Economic and Social Survey, Jamaica 2005*, Planning Institute of Jamaica, 2006

Trends in commercial arable farming in the Caribbean

The decline of the sugar plantation

In 1961 Caribbean sugarcane accounted for 20 percent of world production but has since declined to less than 4 percent. Cuba is by far the region's largest producer, accounting for 75 percent of Caribbean production in 2001. Declines in output and area planted in cane have occurred across the region, the most dramatic decline being in Martinique and Guadeloupe.

Nevertheless, sugar is still an important source of foreign exchange for the remaining producers, generating US$338 million in 1998/99. The sugar industry employs some 150 000 unskilled and semi-skilled workers in the English-speaking region. In Barbados it still contributes 16 percent to export earnings and one-third of agricultural production by value. The enduring problem, however, is the high cost of production, which is partly due to the lack of capital investment.

Activities

Study *Table 12.7*.

1 In which countries has sugar production increased most since 1960?
2 In which countries has sugar production decreased most since 1960?
3 Which were the three largest producers of sugar in 2001?
4 Suggest why the sugar industry is still an important industry in the Caribbean.

Table 12.7 Sugar production in the Caribbean and Latin America, 1961–2001 (million tonnes)

	1961	1971	1981	1991	2001
Antigua and Barbuda	183 820	134 100	2801	0	0
Bahamas	0	2000	52 000	45 000	45 000
Barbados	1 400 117	1 233 500	966 000	587 000	520 000
Belize	247 367	642 783	985 670	1 131 880	1 150 000
Cuba	55 885 920	54 700 000	66 678 496	79 700 000	35 000 000
Dominica	6400	4000	4600	4400	4400
Dominican Republic	7 811 195	9 973 725	9 629 000	6 930 457	4 645 332
French Guiana	11 700	5000	11 250	4000	5300
Grenada	10 400	10 535	9300	6500	6750
Guadeloupe	1 914 000	1 733 319	834 045	645 000	798 072
Guyana	3 618 829	4 310 606	4 192 220	2 935 000	3 000 000
Haiti	2 850 000	2 792 400	3 000 000	1 500 000	1 008 100
Honduras	804 300	1 407 112	2 920 360	2 730 136	4 117 000
Jamaica	4 438 093	4 1045 846	2 492 370	2 732 000	2 400 000
Martinique	1 140 218	514 275	244 148	189 708	207 000
Puerto Rico	9 755 814	4 156 717	1 848 830	843 061	320 000
St Kitts and Nevis	419 595	276 352	337 500	200 000	188 373
St Lucia	66 700	0	0	0	0
St Vincent and the Grenadines	34 395	0	30 000	23 000	20 000
Suriname	138 782	195 000	146 327	70 000	120 000
Trinidad and Tobago	2 517 954	2 349 221	1 289 521	1 300 900	1 500 000
Virgin Islands (US)	104 000	0	0	0	0

Source: Apps1.fao.org in Potter R.B. et al., *The Contemporary Caribbean*, Pearson, 2004, Table 3.4

Plantations able to invest in higher-yielding varieties of cane were generally foreign-owned. Some plantations survived by intensifying cane production, whilst others tried to survive by bringing more land into production, even though it was marginal to cane cultivation (*Figure 12.17*). Barbados and Jamaica each had 20 working factories in the 1950s, but there are only three factories left in Barbados and eight in Jamaica.

Sugarcane production in Guyana

Guyana has traditionally been one of the most important sugarcane producers in the Caribbean. Several areas along the narrow coastal belt produce sugarcane. The area has an equatorial climate with high temperatures year round and with two distinct rainy seasons. This allows two crops a year to be grown. The soils are generally fertile and there is a large supply of labour, necessary since sugarcane is a labour-intensive form of farming. Most of the crop is exported, so the coastal location is a benefit.

Prior to planting, the fields are flooded with water to provide fertile silt, and to kill off weeds and pests. Planting is normally done by hand. The canals are also used to transport the harvested cane to the factories in punts (boats).

Guysuco is the state-owned sugar company. In 2013 Guyana produced around 220 000 tonnes of sugarcane, largely for the European market. One of its niche products is demerara sugar, which comes from the Demerara River basin. Sugarcane has become less profitable over time. The crop is subject to poor weather and plant diseases, and the industry has been hit by labour unrest and a shortage of skills and capital. As international competition has increased, Guyana has become increasingly reliant on the European market. However, reform of the European market (reduced costs for sugarcane) are likely to have a major impact on countries such as Guyana.

Figure 12.17 Sugarcane plantation, south-east Barbados

Guyana's economy is dominated by the production of primary products and trade. Sugar is a significant part of the national and local economy. However, in its current form the sugar industry is uncompetitive, with low cane yields and low sucrose content. Cane supply has fallen, pushing up the industry's costs of production. Guyana also faces the largest reduction in the selling price of sugar for any ACP (Africa-Pacific-Caribbean) sugar producers. Households linked to sugar production tend to have lower educational qualifications and are more vulnerable to slipping into poverty. Many of the services – education, healthcare, pensions and sports facilities – provided by the sugar sector, are vulnerable to EU reforms regarding sugar pricing.

There are a number of options to improve the competitiveness of Guyana's sugar industry:

- cost-reduction measures by improving technical performance, achieving economies of scale, and making better use of milling capacity
- diversification within the sugar sector, for example by producing ethanol or cogenerating electricity
- diversification of sales into different markets, by supplying regional markets rather than exports to the EU.

The future for Guyana's sugar farmers is uncertain.

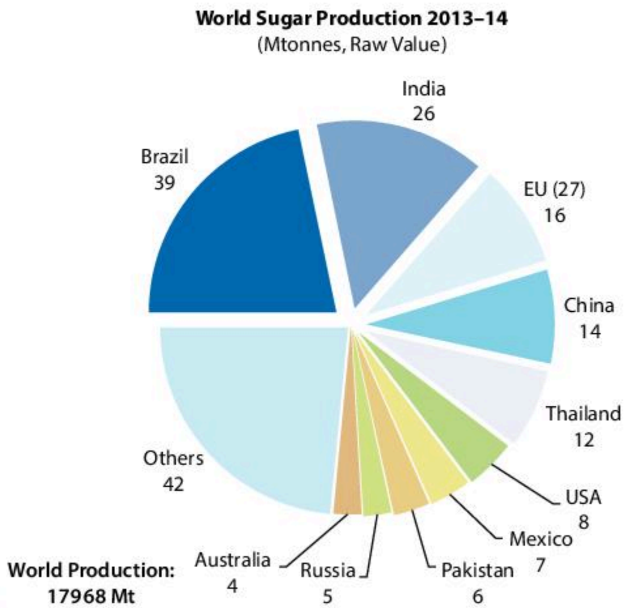


Figure 12.18 World sugar production, 2013–14

Brazilian sugarcane industry

Sugarcane is a plant that provides sugar and alcohol, and its cultivation originated from Southeast Asia. It was introduced in Brazil five centuries ago, when the country was a colony of Portugal.

Brazil first became the largest producer of sugar in the mid-17th century. In 1975 the Brazilian government introduced a project called ProÁlcool or Programa Nacional do Álcool (National Program of Alcohol). This was created to promote the use of the alcohol from the sugarcane as an alternative fuel for automobiles. The use of ethanol in vehicles began following the 1973 oil crisis, when oil prices quadrupled. Since then, the production of sugarcane increased very quickly in Brazil, and by 1976/1977 it had already reached 100 million tonnes per year.

In the 2010–11 crop, there was a record production of 623 905 million tonnes of sugarcane. São Paulo produces 60 percent of the country's crop. Paraná, Triângulo Mineiro (Triangle Region of Minas Gerais) and Zona da Mata Nordestina (Forest Zone of the Brazilian Northeast) are the other production areas.

Nevertheless, the sugar/alcohol sector has been facing difficulties. In the 2011/2012 crop, the debts reached BRL 48 billion. The cost of production increased due to the lack of competitiveness of ethanol and late investments in the recovery of sugarcane plantations and mechanisation.

Brazil is the world's largest producer of sugarcane, producing almost 40 percent of world sugar. The South-Central region accounts for almost 90 percent of the country's harvest. Sugarcane occupies about 2·5 percent of Brazil's arable land and produces about 600 million tonnes per year.

Brazilian sugar accounts for around 25 percent of the world's production of sugar, 40 percent of the world exports of sugar, six billion gallons of ethanol (equivalent to 50 percent of US production) and 1500 MW of electricity (about 3 percent of Brazilian demand). Sugar earns Brazil around $16 billion in export earnings.

There are some 70 000 sugarcane growers in Brazil, and over one million people are employed in the sugar industry. Sugar is used in the domestic market and in the export market, for ethanol, detergents, solvents, lubricants, diesel and in the production of bioelectricity. Bioelectricity is a clean and renewable energy, made by biomass – in Brazil, 80 percent is made from the bagasse (fibre) of the sugarcane. While ethanol is an alternative to the use of oil, bioelectricity is the alternative to supplement the hydroelectric system. Brazil has a potential production of this energy, since its main producers of sugarcane are concentrated in the region of the main energy consumer centres. Nowadays, this energy represents the consumption of five million people, 2 percent of the national share.

The sugarcane industry expanded rapidly between 2000 and 2001 to 2008/09 at about 10 percent per annum. It has plateaued at around 550–600 million tonnes per annum since 2008–09.

Table 12.8 Brazil's sugarcane land use

Brazil's total land	850 million ha
Farmland	330 million ha
Sugarcane	8.5 million ha

Changes in commercial farming

Guyana has potential for agricultural growth. Caribbean countries currently spend $3·5 billion on food imports each year. The Jagdeo Initiative sets out the constraints hindering agricultural development in the Caribbean. Guyana is the only Caribbean country that is a net exporter of food.

Government policy: The Jagdeo Initiative

The Jagdeo Initiative is an attempt to speed up the Regional Agriculture Development Process by identifying a set of pressing and binding constraints and developing a corresponding set of interventions to address these constraints.

The constraints include:

- limited financing and inadequate investment
- deficient and uncoordinated Risk Management Measures including praedial larceny (farmers robbed of their produce)
- inefficient land, water distribution and management systems
- inadequate research and development
- outdated and efficient agricultural health and food safety systems
- inadequate transportation system particularly for agricultural products
- fragmented and unorganised private sector
- lack of skills and quality human resources in agriculture
- market infrastructure including market information and market linkages.

The aim of the Jagdeo Initiative is to have:

- more private and public investment in agriculture
- increased employment in the sector
- increased intra-regional agricultural trade
- increased extra-regional trade and hence foreign exchange
- improved food security and nutrition.

To achieve these goals, the Jagdeo Initiative requires:

- increased investment in agriculture
- an increase in agriculture production
- an increase in intra-regional trade.

The government is spending up to $6 million per annum on drainage and irrigation and will need to spend up to $100 million to adapt the drainage to cope with climate change.

The world's agricultural markets were affected by the global financial crisis. Some governments have increased protectionism and subsidies for their own producers. Access to the EU market ended abruptly and has been replaced by an Economic Partnership Agreement (EPA) which is a comprehensive free trade agreement. This gives all producers equal access to the EU food market.

Food security

Food security is a condition where all people at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life. Four broad dimensions of food security are usually identified:

- availability – the supply of food in an area
- access – the physical and economic ability of people to obtain food
- utilisation – the proper consumption of food
- stability – the sustainability of food supplies.

CARICOM has been experiencing declining agricultural productivity, decreasing earnings from traditional export crops, a high and growing dependence on imported food, increasing levels of poverty and increases in diet-related diseases. Smallholder farmers supply 90 percent of the food for developing countries and feed one third of the world. Hence, building the capacity of small-scale food producers to increase agricultural output is fundamental. Greater attention is needed to increase women's participation in food production and marketing and improve their food security, nutrition and economic livelihoods. In addition, local/traditional knowledge should be used to help small-scale farmers. Participation of women in food production could be an effective strategy for addressing food security at the household level. This can be done through a Kitchen Garden Project or Backyard Garden Project in which women receive training in growing organic foods especially fruits and vegetables mainly for home consumption.

Biofuels

The expansion of biofuels from agricultural biomass has increased significantly over the last years. It is seen as a way to reduce dependence on fossil fuels and a way to revitalise the agricultural sector in many countries. The best crops on which to base biofuel expansion will continue to be sugarcane and palm oil. Energy security through biofuels has a knock-on effect on food security as countries dedicate higher shares of their agricultural land to biofuel expansion.

Brazil will continue to be the major player in the ethanol market in the future. Brazil will expand its ethanol exports to meet growing demand in other countries including some in Latin America. Brazil will continue to be a net exporter of sugar to world markets.

Diversification

Diversification is limited by the small size of economies in the region. Diversification within the agricultural sector and away from traditional crops would depend on the availability of suitable land for specific crops, infrastructure, markets, committed farmers and access to finance.

The availability of suitable land is a critical issue as the most suitable agricultural land has been plantation land under sugar cultivation. In addition, fertile land has been allocated to non-agricultural activities such as tourism and real estate development. Alternative crops such as fruits and vegetables could be developed but will require a significant amount of land in order to be commercially viable. If directed toward export markets then market access would have to be secured. If production is oriented toward domestic markets then the produce will have to be competitive both in terms of price and quality.

Value-added

There are two levels of processing that could be pursued. One is a primary level or first stage processing and involves the preparation of the produce (e.g. cleaning and cutting) for further processing in other countries. Agro-processing would drastically reduce post-harvest losses, preserve food, and add value, thus increasing farm incomes. Cottage industries based on locally produced fresh farm produce should be promoted, encouraged and supported. In this regard, there should be efforts to establish properly constituted cooperatives but household level industries should also be pursued. The marketing and distribution of domestic food crops should be organised more formally.

Small farmer sector

Caribbean producers, in particular small-scale farmers, tend to produce products of erratically variable quality. This has forced processors to rely on imported inputs for their processing operations. The small-scale farmer may be the loser from the changes taking place at both the international and domestic levels. Size is critical in enhancing competitiveness so that countries will tend to focus on large-scale farming operations. Access to limited resources, in particular land and finance capital, will also pose a challenge to the small-scale producer. Government assistance will be crucial to the development of the agricultural sector in the region if that sector is to remain viable and provide a sustainable livelihood for the rural communities that depend on it. Most governments in the region have expressed commitment to preserving the sector.

Technology

The use of technology in many Caribbean farms is limited due to the steepness of terrain and affordability. Many small farmers are poor and cannot afford the high costs of new technology. One technology that can be affordable is a shade house – this is a house or construction that protects plants from the direct glare of the sun. Some of these can be made from darkened plastics to reduce the glare, and these are relatively cheap.

New markets

The preferential access for ACP countries to the European Union market has been replaced with an EPA (Economic Partnership Agreement) that allows comprehensive free trade between all countries. Caribbean producers should therefore look to provide for the domestic market and try to access the North American market – although there are doubts as to whether this would be possible or economic.

Changes in Brazilian farming

Even up until the 1980s, Brazil was still a large food importer. Changes in Brazilian agriculture were prompted by state-led industrialisation that occurred between the 1960s and the early 1980s. This led to a growing urban population with a larger income and increased demand for food.

In Bahia state, in north-eastern Brazil, new farms are being created in the *cerrado*

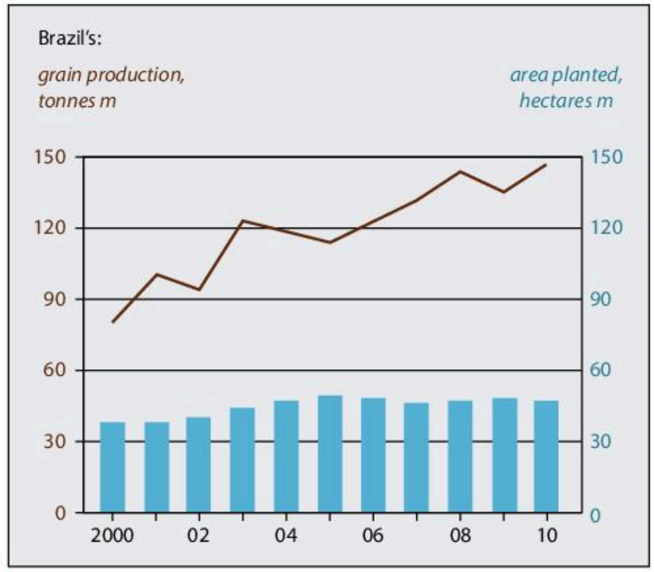


Figure 12.19 Grain production and area planted, 2000–2010

(savanna). Some of the farms are vast – one at Jatoba is 24 000 hectares – and this move is set to transform part of Brazil's poorer regions. Another farm, in the state of Piauí, uses radio transmitters to keep track of the weather; runs SAP software; employs 300 people; has 200 km of new roads crossing the fields; and, at harvest time, resounds with the thunder of lorries which, day and night, carry maize and soya to distant ports. Some of Brazil's farms are undergoing agro-industrialisation on a massive scale.

In under thirty years Brazil has turned itself from a food importer into a major exporter. It is the first country to have caught up with the traditional 'big five' grain exporters (USA, Canada, Australia, Argentina and the European Union). It is also the first tropical food-giant.

The increase in Brazil's farm production has been stunning. Between 1996 and 2006 the total value of the country's crops rose from 23 billion reais ($23 billion) to 108 billion reais, or 365 percent. Brazil increased its beef exports tenfold in a decade, overtaking Australia as the world's largest exporter (*Figure 12.20*). It has the world's largest cattle herd after India.

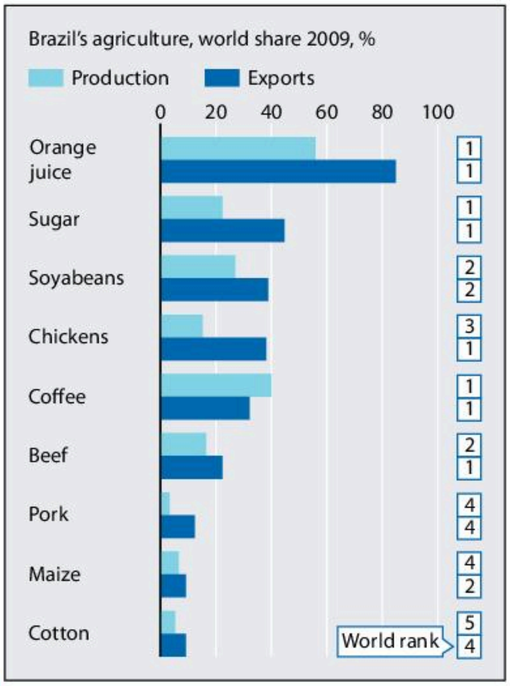


Figure 12.20 Brazil's share of selected products

It is also the world's largest exporter of poultry, sugarcane and ethanol (*Figure 12.20*). Since 1990 its soyabean output has risen from barely 15 million tonnes to over 60 million.

Brazil accounts for about a third of world soya bean exports, second only to America.

Brazil has done all this without much government subsidy. State support accounted for 5·7 percent of total farm income in Brazil during 2005–07, compared with 12 percent in the USA and 29 percent in the European Union.

Brazil has more spare farmland than any other country (*Figure 12.21*). It has between 300 million and 400 million hectares of total potential arable land, but only about 50 million hectares are being used. Most of the spare land is not in the rainforest but in the *cerrado*. The *cerrado* is the country's second largest biome, occupying about 204 million hectares, 24 percent of the country. It is one of the world's most biologically rich savannas. Land suitable for agriculture covers some 139 million hectares. Brazil also has more than 8000 billion cubic kilometres of renewable water each year.

Since 1996 Brazilian farmers have increased the amount of land under cultivation by

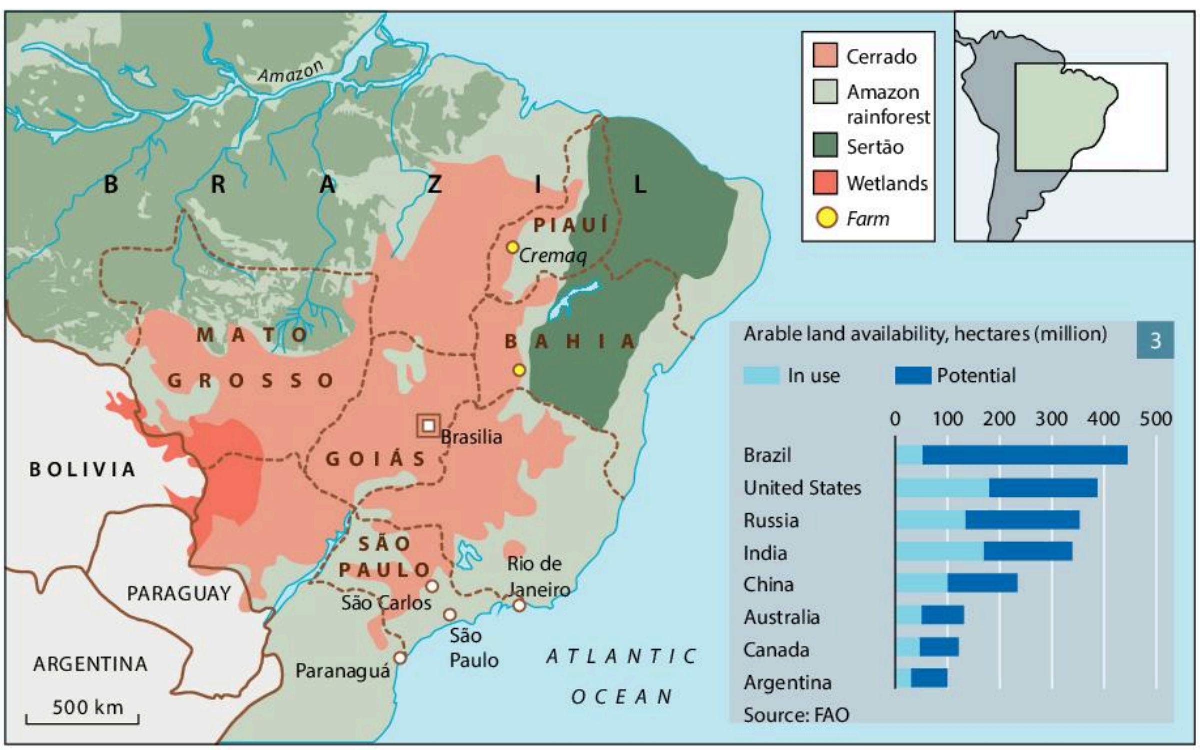


Figure 12.21 The location of Brazil's Cerrado

a third, mostly in the *cerrado*. They have also increased production by ten times that amount.

More food without deforestation

Embrapa (Empresa Brasileira de Pesquisa Agropecuária), or the Brazilian Agricultural Research Corporation, was set up in 1973. At the time, escalating oil prices were making Brazil's high levels of agricultural subsidy unaffordable. Embrapa set about to make Brazil's agriculture competitive, productive and modern.

When Embrapa started, the soils of the *cerrado* were regarded as too acidic and too poor in nutrients. Embrapa did four things to change that. First, it poured industrial quantities of lime onto the soil to reduce levels of acidity. Approximately five tonnes of lime per hectare were used, sometimes more. Embrapa scientists also bred varieties of bacteria that helps fix nitrogen in legumes and which were adapted to the soil of the *cerrado*, hence reducing the need for fertilizers. Today the *cerrado* accounts for 70 percent of Brazil's farm output.

Second, Embrapa brought back a grass from Africa called *brachiaria*. Patient crossbreeding created a variety which produced 20–25 tonnes of grass feed per hectare, many times what the native *cerrado* grass produces and three times the yield in Africa.

Third, Embrapa turned soya beans into a tropical crop. By cross-breeding, Embrapa worked out how to make it also grow in a tropical climate. Brazil is now the world's second-largest user of GM after the United States. It has also developed 'short cycle' plants which make it possible to grow two crops a year. The variety of soya now being planted there did not exist ten years ago!

Fourth, Embrapa pioneered and encouraged new operational farm techniques. Brazilian farmers pioneered 'no-till' agriculture, in which the soil is not ploughed nor the crop harvested at ground level. Rather, it is cut high on the stalk and the remains of the plant are left to rot into a mat of organic material. Next year's crop is then planted directly into the mat, retaining more nutrients in the soil. This avoids erosion and saves inputs, like watering. It also spares equipment and machines, protects the soil, cuts expenditure on fuel and promotes carbon sequestration. In 1990 Brazilian farmers used no-till farming for 2·6 percent of their grains; today it is over 50 percent.

Another model adopted in Brazil – called Farming-Livestock-Forestry – sets new technological standards for agriculture and livestock and allows damaged pastoral and cultivated areas with sustainability problems to recover. It involves grains, fibre, meat, milk, energy, and other crops and aims at maximum exploitation of the biological cycles of plants and animals.

Size matters

Nevertheless, Brazil is divided between productive giant operations and inefficient smallholder farms. Half the country's five million farms earn less than 10 000 reais a year and produce just 7 percent of total farm output; 1·6 million are large commercial operations which produce 76 percent of output.

However, the success of this sector has been associated with widespread destruction of Brazilian ecosystems, especially the *cerrado* and the Brazilian Amazon rainforest, as well as environmental degradation. Brazil's status as one of the world's most unequal countries in terms of income distribution makes it difficult to achieve sustainable development. To be sustainable, Brazil must balance its increasingly productive, modern tropical agricultural system with environmental preservation, social equity, and poverty alleviation in rural and urban areas.

Ideas for SBA

- *Why is agriculture practised in my community?*
- *What are the problems faced by farmers in my community? How can they be solved?*
- *How has the agriculture practised in my community changed in the last 20 years?*

Glossary of terms

Agribusiness: commercial farming on an industrial scale, often run and financed by large companies; farms are mechanised, large in size, and demand large inputs.

Arable: cultivation of crops such as cereals and vegetables, and plants used for making oils or cloth.

Extensive: type of farming system in which the area of the farm is large but inputs (such as labour or fertilizers) are low, so there is a low input (and output) per unit area.

Fragmentation: the division of a farm into several separate plots of land.

Gross domestic product (GDP): the value of all the goods and services produced within a country in a given year.

Intensive: type of farming system in which large quantities of inputs, such as labour or fertilisers, are used on a small area of land, to produce a high yield or output per unit area.

Pastoral: the rearing or keeping of animals in order to obtain meat or other products, such as milk and leather.

Plantation: a large farm or estate where commercial production of one crop is carried out. Many plantations were established under colonial rule using slave labour.

Subsistence: type of farming that produces enough to feed only the farmer and the family – there is no surplus to sell.

Exam-style Practice

1 a What is meant by the terms *pastoral farming* and *arable farming*? Name an example of each type of farming. [2]

Study Figures 1 and 2.

b Identify the type of farming shown in each photograph. [2]

c Describe the shape and size of the fields in Figure 1. [2]

d Suggest reasons for the fields being like this. [3]

e Compare the TWO types of labour that would be needed on the farms shown in Figures 1 and 2. [2]

f Describe and explain the recent changes in employment in agriculture in the Caribbean. [6]

g For a country that you have studied, outline the ways in which it is possible to increase farm productivity. [8]

Total 25 marks

Figure 1 Large rectangular farms in north-east Barbados

Figure 2 A smallholding in Antigua

2 a Explain the difference between intensive farming and extensive farming. Name an example of each type of farming. [2]

Study Figure 3.

b In which country was agriculture the most important contributor to the economy in 1970? [1]

c In which country was agriculture the most important contributor to the economy in 2000? [1]

d What was the approximate contribution of agriculture to GDP in St Lucia in **i** 1978 **ii** 2000? [2]

e Describe how the contribution of agriculture to GDP changed between 1970 and 2000 in **i** Jamaica **ii** Guyana [4]

f Use the data in Table A to draw a pie chart for land use in Jamaica. [6]

g Describe the main characteristics of smallholder (peasant) farming in the Caribbean. [4]

h What are the main characteristics of farming in Brazil? [4]

Total 24 marks

Table A Land use in Jamaica

Land use	%
Major crops	18
Grassland	13
Forest	24
Scrub and woodland with patches of subsistence farming	20
Unused – potentially productive for farming	8
Permanently unproductive	12
Built-up areas	5

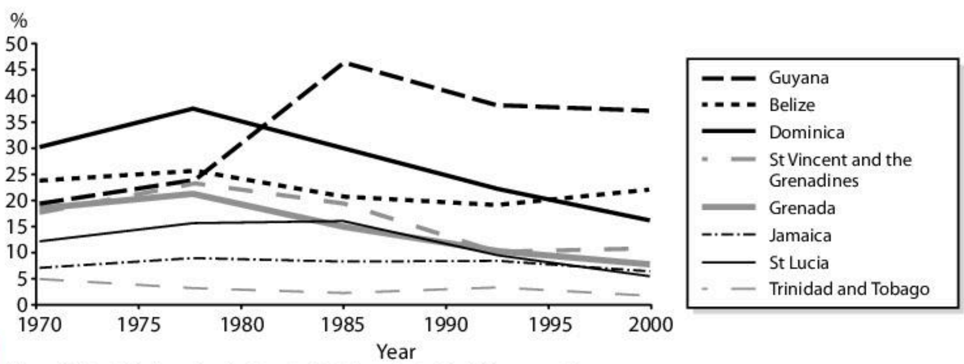


Figure 3 Contribution of agriculture to GDP in selected Caribbean countries, 1970–2000

13 Natural Hazards

In this chapter you will study:

- the distinction between a natural hazard and a natural disaster
- the impact of hazards including earthquakes, hurricanes, volcanoes, landslides and flooding on the physical and human environments in the Caribbean
- responses of individuals, national and regional agencies in the Caribbean to reduce the effects of natural hazards and disasters.

You will also learn how to:

- interpret maps, charts and photographs
- locate and map places where disasters have struck.

The start and end of the 20th century were marked by intense volcanic activity in the Caribbean region. In 1902 Mt Pelée on Martinique erupted, killing almost 30 000 people. Pyroclastic flows (superheated clouds of ash and dust) devastated the town of St Pierre, and there were just two survivors; one of them, Ludger Sylbaris, was protected by his windowless prison cell.

Since July 1995 the continuing eruption of the Soufrière Hills volcano on Montserrat has produced a number of hazards (*Figure 13.1*) including pyroclastic flows (*Figure 13.2*).

Figure 13.1 Hazards sign at Plymouth, Montserrat

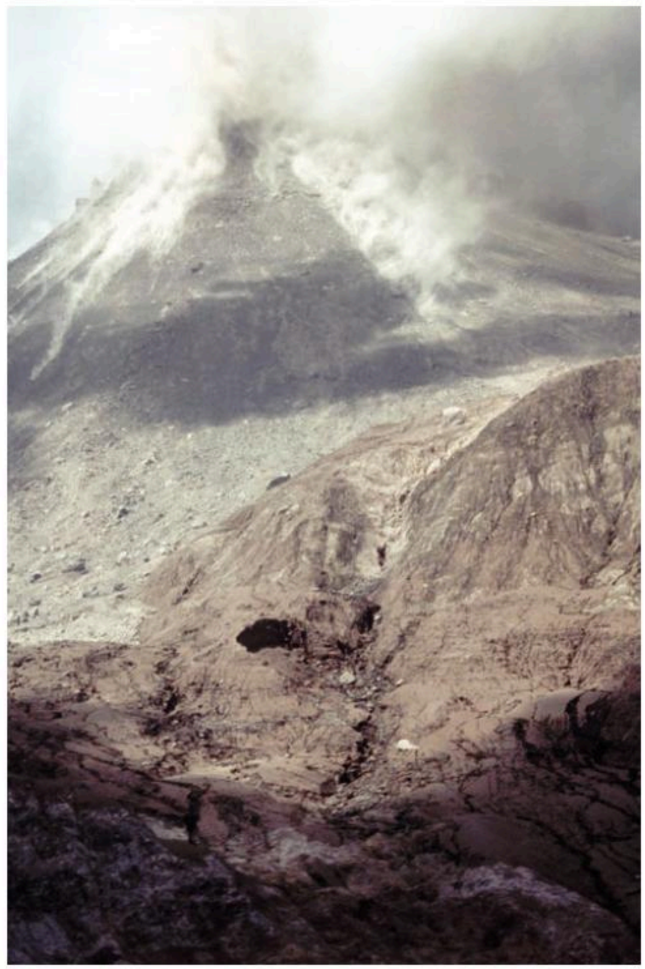


Figure 13.2 Pyroclastic flows on the Soufrière Hills, Montserrat

Now, however, scientists' understanding of volcanoes is much better and they have been able to evacuate most villagers to safety. The 21st century has continued to produce a number of hazards in the Caribbean. The Haiti earthquake, Hurricanes Ivan and Jeanne, and Superstorm Sandy illustrate the fact that the Caribbean is one of the most hazard-prone regions in the world.

Various types of hazard are experienced in the Caribbean. One study showed that up to two-thirds of the hazards are hurricanes and tropical storms. However, volcanoes and earthquakes account for the greatest loss of life. The impact also varies by area: Haiti and Jamaica were the most vulnerable locations in the 20th and 21st centuries.

Natural hazards can also devastate a country's economy. Hurricane Gilbert cost Jamaica almost US$1 billion. In 1995 Antigua and Barbuda were struck by Hurricanes Luis and Marilyn; the damage was equivalent to 65 percent of the country's wealth, and between 15 and 25 percent of the country's workforce lost their jobs.

Activities

1 What types of hazard are indicated in *Figure 13.1*?

2 Suggest how the type of hazard shown in *Figure 13.2* might endanger people's lives and livelihoods.

Trends in natural hazards and natural disasters

Natural hazards involve hydrological, atmospheric and geological events. A **natural hazard** is a natural event that causes damage to property and/or disruption to normal life, and it may cause loss of life. Some groups of people are more vulnerable to natural hazards and have greater exposure to them.

Exposure to hazards varies over time and by place. Some locations are more hazardous than others. The Greater Antilles, for example, has no active volcano but in the Lesser Antilles, Soufrière Hills in Montserrat and Kick 'em Jenny, off Grenada, are both currently active. Coastal areas tend to be more vulnerable to coastal surges while upland areas, such as Upper St Andrew in Jamaica, are at greater risk of landslides. Some cities, such as Kingston in Jamaica, are subject to various hazards, such as earthquakes (1692, 1907 and 1993), landslides (1963 and 1988), hurricanes (Charlie 1951 and Gilbert 1988) and coastal flooding.

Since the 1960s, more people have been affected by natural hazards. Reasons for this include:

- a rapid increase in population, especially in developing countries
- increased levels of urbanisation, including more shanty towns which are often located in hazardous environments
- changing land use in rural areas which results in flash floods, soil erosion and landslides
- increased numbers of people living in poverty who lack the resources to cope with natural hazards
- changes in the natural environment causing increased frequency and intensity of storms, floods and droughts.

A **natural hazard** refers to a potentially dangerous event or process. It becomes a **natural disaster** when it affects people and their property. **Risk** suggests that there is a possibility of loss of life or damage. **Risk assessment** is the study of the costs and benefits of living in a particular environment.

There are two very different ways of looking at people's vulnerability:

- One view is that people choose to live in hazardous environments because they understand the environment. In this situation, people decide to live in an area because they feel the benefits outweigh the risks.
- Another view is that some people live in hazardous environments because they have very little choice over where they live, because they are too poor to move.

Activities

1 What is a natural hazard?

2 Suggest reasons why natural hazards appear to be increasing in frequency.

Earthquakes and seismic hazards

The Caribbean plate is one of the smaller surface plates of the Earth (*Figure 1.6* on page 10). Earthquakes occur all around its periphery, and volcanoes erupt on its eastern and western sides. The Caribbean plate moves more slowly, at about 1–2 cm a year, while the North American plate moves westward at about 3–4 cm a year. Many earthquakes and tsunamis have been experienced in the north-eastern Caribbean region, where the movement of plates is rapid and complicated.

Earthquakes can be divided into deep-focus earthquakes and shallow-focus earthquakes (*Figure 1.19* on page 18). Deep earthquakes (more than 200 km below the Earth's surface) are commonly found in subduction zones and so are most common in the eastern Caribbean. Shallow earthquakes (less than 70 km below the Earth's surface) occur along the transform (conservative) boundary of the northern Caribbean, and near marine trenches such as the Puerto Rican Trench (*Figure 13.3*). Shallow earthquakes are potentially more dangerous than deep-focus earthquakes, and occur throughout the Greater Antilles. Puerto Rico is especially vulnerable. Major historical earthquakes occurred in Puerto Rico in 1670, 1787, 1867 and 1918. In Kingston, Jamaica, major shallow-focus earthquakes occurred in 1692, 1907 and 1993. In the 1993 earthquake, 518 families were affected, 450 of them in Kingston and St Andrew. Following that event, a total of 7871 insurance claims reported J$152 million in damage/losses. Experts believe that another major earthquake in Jamaica is imminent – and the population and infrastructure have grown significantly in recent years.

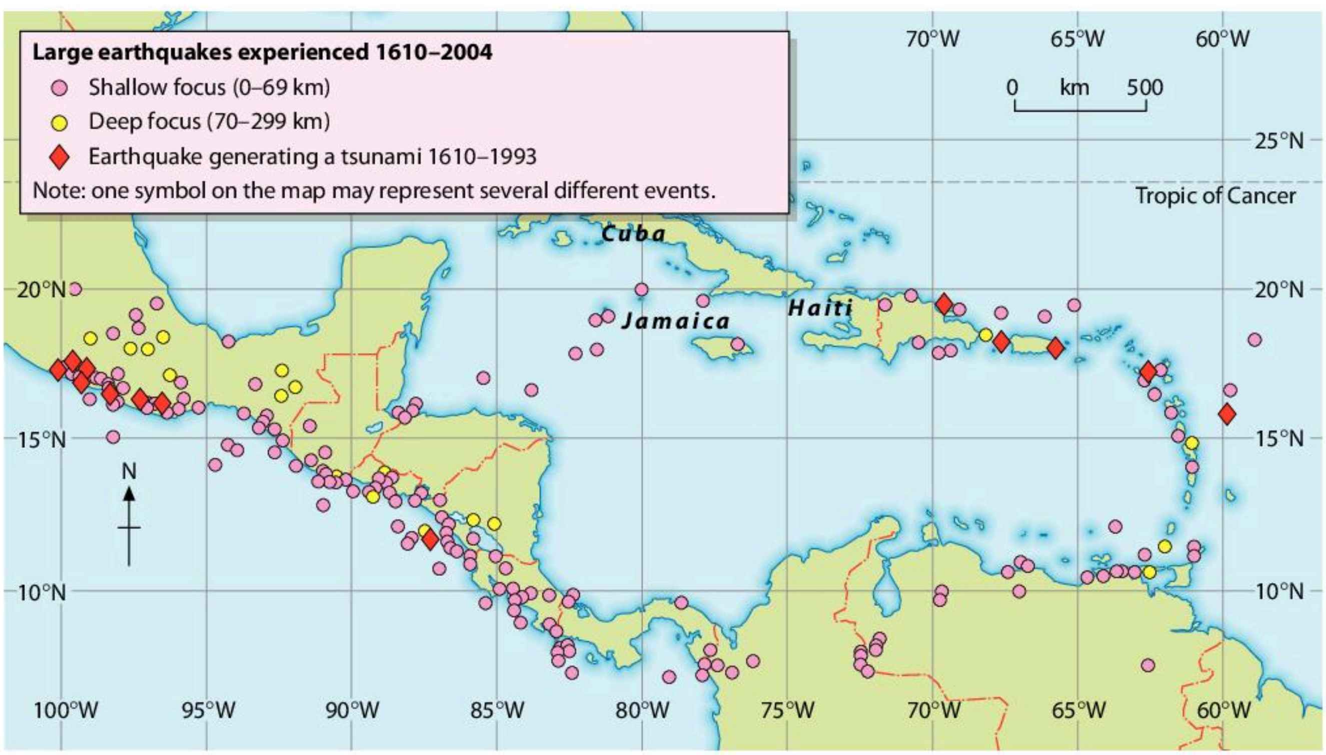


Figure 13.3 The distribution of deep and shallow earthquakes in the Caribbean

Measuring the strength of earthquakes: the Richter and Mercalli scales

The Richter scale measures the magnitude (strength or force) of earthquakes. *Table 13.1* shows the world's largest earthquakes in the 20th century and the 21st century. These are measured on a seismometer and shown on a seismograph. By contrast, the Mercalli scale (*Figure 13.6*) relates ground movement to things that you would notice happening around you. Its advantage is that it allows ordinary eye-witnesses to provide information on the strength of the earthquake. The Richter scale is logarithmic – this means that an earthquake of 6.0 is ten times greater than one of 5.0, and one hundred times greater than one of 4.0 (*Table 13.1*).

Table 13.1 The world's largest earthquakes in the 20th and 21st centuries

Place	Date	Strength on the Richter scale
Indonesia	2004	9.1
Tōhoku, Japan	2011	9.0
Chile	1960	8.9
Kansu, Japan	1920	8.6
Tokyo, Japan	1923	8.3
San Francisco	1906	8.3
Chile	2015	8.3
Mexico City	1985	8.1
Tangshen, China	1976	8.0
Erzincan, Turkey	1939	7.9
Gorkha, Nepal	2015	7.8
North Peru	1970	7.7
Izmit, Turkey	1999	7.2

Source: adapted and updated from R. Kovach and B. McGuire, *Guide to Global Hazards*, Philip's, 2003

Hazards related to earthquakes

There are a number of hazards and impacts associated with earthquakes (*Figure 13.7*). These include ground shaking (liquefaction) and failure (landslides), and tsunamis. Earthquakes vary greatly in terms of their magnitude and duration (length of time of shaking).

Up to 95 percent of deaths in earthquakes are related to building collapse. Many buildings in developing countries do not conform to earthquake-proof standards (*Figure 13.4*). Secondary hazards include fire, caused by the rupture of electricity cables and gas pipelines.

How a site reacts to shaking depends on a number of factors, including:

- depth of soil
- moisture content of the soil
- the nature of the rock – is it hard or soft?

Steep slopes and landforms formed by deposition are especially vulnerable to shaking.

Liquefaction is a process in which sediments containing large amounts of water lose their strength and begin to behave like a fluid. Waves occur in the sediments and can cause foundations to crumble and pipes to split. Deltas and alluvial fans (deposits formed when a river leaves an upland area and spreads out into a lowland area) are especially vulnerable. Kingston (Jamaica), Port-au-Prince (Haiti) and San Juan (Puerto Rico) are all located on such sites.

It is difficult to predict earthquakes although in some cases there may be a 'recurrence interval' – that is, an average time in years between large events.

Tsunami hazards

Tsunami waves form when large pieces of the sea floor undergo abrupt vertical movement due to submarine earthquakes, landslides or volcanic activity. Eye-witness reports of a tsunami in the Virgin Islands in 1867 give a maximum wave height of more than seven

Figure 13.4 Substandard housing in the Caribbean

metres in Frederiksted, St Croix, where a large naval vessel was left on top of a pier. In 1918, the magnitude 7.5 earthquake caused a tsunami that killed at least 91 people in north-western Puerto Rico. Immediately after the 1946 earthquake, a tsunami struck north-eastern Hispaniola and travelled inland for several kilometres; some reports indicate that nearly 1800 people drowned.

There have been about 50 tsunamis in the Caribbean since 1530. One of these, in Puerto Rico in 1918, caused 40 deaths, while another in Dominican Republic caused 100 deaths. There is also a potential threat of tsunamis being caused by a submarine explosion of Kick 'em Jenny, the volcano north of Grenada (page 324). Coastal development including tourism and urban growth is placing more people in the coastal zone, and increasing the potential impact of a tsunami.

The US Geological Survey is studying the geology of the region and mapping earthquakes, in order to estimate where earthquakes and tsunamis are likely to occur. A problem for Puerto Rico and the Virgin Islands is that sites of tsunami generation are likely to be very close to the coast, and so warning time would be short.

Case Study

Haiti 2010

On 12 January an earthquake measuring 7.0 on the Richter scale occurred just 25 kilometres west of Port-au-Prince, at a depth of only 13 kilometres below the surface. Further aftershocks were as strong as 5.9, and occurred just nine kilometres below the surface, 56 kilometres south-west of the city. A third of the population was affected: about 230 000 people were killed, 250 000 more were injured and around a million people were made homeless.

The island of Hispaniola (shared by Haiti and the Dominican Republic) sits on the Gonave microplate, a small strip of the Earth's crust squeezed between the North American and Caribbean tectonic plates. This makes it vulnerable to rare but violent earthquakes.

The city and the region around it are mainly shanty settlements of overcrowded, badly constructed buildings, hopelessly ill-suited to withstanding a shaking. Most of Port-au-Prince's two million residents live in tin-roofed shacks perched on unstable, steep ravines. After a school collapsed in the suburb of Pétionville in 2008, the capital's mayor said that 60 percent of its buildings were unsafe even under normal conditions.

Doctors, trained sniffer dogs, and tents, blankets and food were pledged from other countries, including Mexico, Venezuela, China, Britain, France, Germany, Canada and Cuba. Crews of Dominicans, including engineers, telecoms technicians and the Red Cross, were among the first to join the relief effort (*Figure 13.5*).

Financial assistance also poured in. The World Bank led with a US$100 million commitment,

Figure 13.5 Cleanup efforts in Haiti after the 2010 earthquake

pending the approval of its board. The UN released US$10 million from its emergency fund and European countries pledged US$13.7 million. Yet most of this aid arrived too late for the thousands who were trapped in rubble or awaiting treatment for their injuries.

One of the world's poorest countries, Haiti was overpopulated and vulnerable even before the disaster. The country had only two fire stations and no army – the Haitian army was abolished in 1995 – and was powerless to do anything for itself. The earthquake degraded an already feeble health service by destroying many hospitals and clinics, including all three aid centres run by Médecins sans Frontières. Crowded Haiti has long suffered from squabbling and venal politicians, extreme inequality and ecological stress.

A month after the disaster, hospitals were working again, though not before thousands of survivors had died of their injuries. The World Food Programme handed rice to 2.5 million people in the capital and nearby areas. Most streets in Port-au-Prince were cleared of rubble.

After the rescue and relief phase, the focus of aid changed to providing shelter robust enough to withstand the rains (and landslides) that normally begin in earnest in May, and the hurricanes that may follow from June onward. Around 550 000 people gathered in hundreds of makeshift camps; almost as many were sleeping rough. With aftershocks continuing, many were too scared to venture back into their houses even when these survived. Some were issued with tents. But relief workers reckoned that simple plastic tarpaulins, suspended on poles, were a more durable option. Months after the disaster the camps were still crowded, and for most people proper housing is still years away.

The 1989 earthquake near San Francisco in California was of similar magnitude to Haiti's but killed just 63 people, mainly because most buildings there are designed to withstand the shock. There are plenty of ideas for cheap earthquake-proofing: one is to fit rubber pads from recycled tyres between concrete blocks as shock-absorbers. But the Haitian government has rarely enforced building codes.

Rebuilding Haiti's homes, schools, roads and other infrastructure will take between US$8 and $14 billion. Many Dominicans fear a flood of illegal migrants into their country unless reconstruction is swift and effective.

Long-term rebuilding

A long-term strategy for rebuilding Haiti is vital. Even before the earthquake, Haiti was poor, environmentally degraded, aid-dependent and had few basic services. 'Building back better' must be more than just a slogan.

Fortunately, a blueprint drawn up by Haiti's government was presented to donors in 2009. It calls for investment to be targeted on infrastructure, basic services and combating soil erosion to make farmers more productive and the country less vulnerable to hurricanes. However, rural areas are now under increased pressure, as many Haitians have left Port-au-Prince and returned to rural regions. The country needs a strong government to put it right.

Strength	Observation
1	Rarely felt.
2	Felt by people who are not moving, especially on upper floors of buildings. Hanging objects may swing.
3	The effects are noticeable indoors, especially upstairs. The vibration is like that experienced when a truck passes.
4	Many people feel it indoors, a few outside. Some are awakened at night. Crockery and doors are disturbed and standing cars rock.
5	Felt by nearly everyone; most sleeping people are awakened. Some windows are broken, plaster becomes cracked and unstable objects topple. Trees may sway and pendulum clocks stop.
6	Felt by everyone; many are frightened. Some heavy furniture moves, plaster falls. Structural damage is usually quite slight.
7	Everyone runs outdoors. Noticed by people driving cars. Poorly designed buildings are damaged.
8	Damage to ordinary buildings; many collapse. Well-designed structures survive but suffer slight damage. Heavy furniture is overturned and chimneys fall.
9	Damage occurs even to buildings that have been well designed. Many are moved from their foundations. Ground cracks and pipes break.
10	Most masonry structures are destroyed, wooden ones survive. Railway tracks bend and water slops over banks. Landslides and sand movements occur.
11	No masonry structure remains standing, bridges are destroyed. Large cracks occur in the ground.
12	Total damage. Waves are seen on the surface of the ground, objects are thrown into the air.

Figure 13.6 The Mercalli scale

Hazards	Impacts
Primary hazard Ground shaking Surface faulting **Secondary hazard** Ground failure and soil liquefaction Landslides and rockfalls Debris flows and mud flows Tsunamis	**Impacts** Total or partial destruction of building structures Interruption of water supplies Breakage of sewage disposal systems Loss of public utilities such as electricity and gas Floods from collapsed dams Release of hazardous material Fires Spread of chronic illness

Figure 13.7 Caribbean earthquake hazards and impacts

Activities

1 Why do earthquakes occur in the Caribbean?

2 What are the potential impacts of an earthquake in the Caribbean?

3 Study *Figure 13.4* on page 313. Suggest how human activity can increase the risk of hazards from earthquakes.

4 a What are the advantages of the Richter scale over the Mercalli scale?

b What are the advantages of the Mercalli scale over the Richter scale?

5 Look at *Table 13.1*. For each earthquake listed, suggest what scale it would have reached on the Mercalli scale (*Figure 13.4*). Give reasons to support your choice.

Hurricanes

Measuring hurricanes

Hurricanes are the most violent and frequent hazard to affect the Caribbean. Damage is the result of high wind speeds, driving rain and storm surges, which often cause floods. These are measured on the Saffir-Simpson scale (*Figure 13.8*). The scale is a 1–5 rating based on the hurricane's intensity.

Category 1
Winds 119–153 km/hr. Storm surge generally 1.2–1.5 metres above normal
No real damage to building structures. Damage primarily to unanchored mobile homes. Also some coastal road flooding and minor pier damage.

Category 2
Winds 154–177 km/hr. Storm surge generally 1.8–2.4 metres above normal
Some damage to roofing material, doors and windows. Considerable damage to vegetation, mobile homes, and piers. Coastal and low-lying escape routes flood two to four hours before arrival of the hurricane eye. Small craft in unprotected anchorages break moorings.

Category 3
Winds 178–209 km/hr. Storm surge generally 2.7–3.6 metres above normal
Some structural damage to small residences and utility buildings. Mobile homes destroyed. Flooding near the coast destroys smaller structures; larger structures damaged by floating debris. Land below 1.5 metre above sea level may be flooded. Evacuation of low-lying residences close to the shoreline may be necessary.

Category 4
Winds 210–249 km/hr. Storm surge generally 3.9–5.5 metres above normal
Some complete roof structure failures on small residences. Destruction of mobile homes. Extensive damage to doors and windows. Land below 3 metres above sea level may be flooded, requiring massive evacuation as far inland as 10 km.

Category 5
Winds greater than 249 km/hr. Storm surge generally greater than 5.5 metres above normal
Complete roof failure on many residences and industrial buildings. Some complete building failures with small utility buildings blown over or blown away. Complete destruction of mobile homes. Severe and extensive window and door damage. Low-lying escape routes are cut off by rising water 3 to 5 hours before arrival of the hurricane. Major damage to lower floors of all structures located less than 4.5 metres above sea level and within 500 metres of the shoreline. Massive evacuation of residential areas on low ground within 8–16 km of the shoreline may be required.

Figure 13.8 Saffir-Simpson scale of hurricane strength

It is used to give an estimate of the potential property damage and flooding expected along the coast. Wind speed is the main determining factor in the scale. Storm surge values are also included but they are highly dependent on the slope of the continental shelf and the shape of the coastline in the region where the hurricane strikes land.

Hurricanes can cause considerable loss of life. For example, Hurricane Georges (1998) killed more than 460 people, mainly in Dominican Republic and Haiti.

Figure 13.9 Effects of Hurricane Dean, 2007

Case Study

Hurricane Jeanne

Jeanne was the sixth major hurricane in the Caribbean in 2004. It was also the deadliest, with over 3000 deaths in Haiti, and five in the USA. Around the same time that Hurricane Ivan left the Caribbean (pages 143–146) and began to batter Florida, the wider region experienced a new tropical storm, Jeanne.

Jeanne and Haiti

Jeanne showed that the strongest natural hazard events do not necessarily cause the greatest damage. Tropical Storm Jeanne brought mudslides and flooding to Haiti. A high population density, poor building standards – especially in poorer communities – and a low level of hazard planning measures also helped to determine the outcome of the hazard. Haiti has very poor levels of preparedness for natural hazards, which is unsurprising given that it is the poorest country in the western hemisphere – 80 percent of its people live below the poverty line.

Two days of rain sent torrents of water down mountains in the country's Artibonite and North-West provinces, causing rivers to burst their banks. Heavy rainfall and rising sea levels submerged poorly defended urban areas, causing massive loss of life through drowning. The floods tore through the coastal town of Gonaives and outlying districts, covering crops and roads. Much of Gonaives was under waist-deep water and aid workers found it difficult to evacuate all those in need. At least 550 people died when a three metre wall of water and mud destroyed large areas of the town. More than 100 other people died in the region, and many residents lost their homes and their livelihoods. Gonaives, a city of 250 000 people, was declared a disaster area and an appeal went out for international aid. Over 100 000 people in Gonaives needed shelter, food or medical aid. The government of the USA pledged an immediate US$60 000 in aid. The economic cost of the storm damage on Haiti in 2004 was estimated to be US$296 million.

The scale of the disaster was blamed on deforestation, which left communities vulnerable to flash floods. This mountainous country which was once heavily forested now has less than two percent tree cover. This has led to severe soil erosion which allows water to rush off the steep slopes. Most trees have been cut down to make charcoal for cooking. A recent UN environmental report described Haiti as 'one of the most degraded countries in the world'.

With soil in some areas eroded beyond repair, the government has been looking into relocating communities, particularly away from flood-prone areas. After the floods, reforesting the country was declared a priority. The USA promised aid to help build water catchment areas and to plant more trees, but restoring Haiti's ecology is a massive task. In the past 20 years, more than 60 million trees have been planted to try to avoid soil erosion and desertification, but an estimated 10–20 million are cut down each year for firewood and charcoal.

After the storm left Haiti, the United Nations organised a relief effort to send emergency supplies of food and medicines to the area. Aid agencies such as Oxfam and the Red Cross sent emergency aid, but there was not enough for everyone. There was looting in the wake of the storm as many local people became desperate. Eventually a UN peacekeeping force consisting of troops from Argentina, Uruguay and neighbouring Caribbean islands was brought in to restore order, and to help aid workers continue the relief effort. In 2007 the World Food Programme was continuing to provide food aid in Haiti.


Figure 13.10 Deforestation in Haiti

Jeanne and Florida

The tropical storm was tracked and monitored by the National Hurricane Center in Miami as it moved north-westward, and was upgraded to a hurricane. By 24 September, hurricane watches were issued for Florida's east coast from St Augustine in the north to Miami in the south. After strengthening to a Category Three hurricane, Jeanne came ashore along the coast of Florida, which was still recovering from the effects of the three previous hurricanes. This time, up to three million people in Florida were told to evacuate the area, breaking evacuation records for the third time in a month. However, the regularity of hurricane warnings now meant that 'hurricane fatigue' was beginning to set in, and many people decided to stay put. Consequently, three lives were needlessly lost to this, the weakest of the four hurricanes to hit Florida that year. Two other people were killed by this storm in the USA: one in South Carolina and one in Virginia.

The Governor of Florida requested aid from the US Government to help speed up the recovery and nearly 3500 members of the National Guard were deployed around the region to respond in the aftermath of the hurricane.

The storm came ashore near Stuart, Florida – the same area that Hurricane Frances had hit several weeks earlier. Jeanne rolled across the peninsula, knocking out electricity to some 2.3 million people in Florida as it did so. As it wound down to the level of a tropical storm, Jeanne moved northward into Georgia, where it toppled trees and flooded roads. Further north, Jeanne produced tornadoes in South Carolina and some 76 000 residents in Peach State were left without electricity. Even after the storm was downgraded to a depression, it brought torrential rains and flooding to the mid-Atlantic and north-east states, where the ground was already saturated by the earlier remnants of Ivan and Frances.

In the short term, FEMA (the Federal Emergency Management Authority) ordered over 600 000 blue tarpaulins (covers) for home owners to place over their roofs. In the longer term it provided assistance for rebuilding homes and grants for bringing in measures to reduce the impacts of natural hazards.

Although it was certainly very destructive, Hurricane Jeanne was not as damaging as some of the hurricanes that had hit Florida earlier that year (notably Charley and Frances). Fewer lives were lost in Miami, and it caused less destruction than it had on Haiti in its less powerful form, Tropical Storm Jeanne. Even so, the economic cost of this hurricane in the USA was estimated to be US$6.9 billion.

1 Create a table to show how Jeanne affected Haiti and Florida in different ways.
2 Suggest how hurricane preparedness is likely to have been different in Haiti and Florida.
3 In what ways was the response to Hurricane Jeanne likely to have been different in Haiti and Florida? Give reasons for your answer.

Skills

Locating and mapping places where disasters have struck

The data in *Table 13.2* shows the path of Hurricane Jeanne. The first part of the track has been plotted for you on *Figure 13.11.* Note that the strength of the hurricane is colour-coded.

A **chart** is an outline map showing specialised information, or a diagram/list giving information in an ordered way. *Figure 13.11* shows part of the track for Hurricane Jeanne, and the strength of the hurricane. In this example we need to describe its path, and state how the hurricane changes in strength.

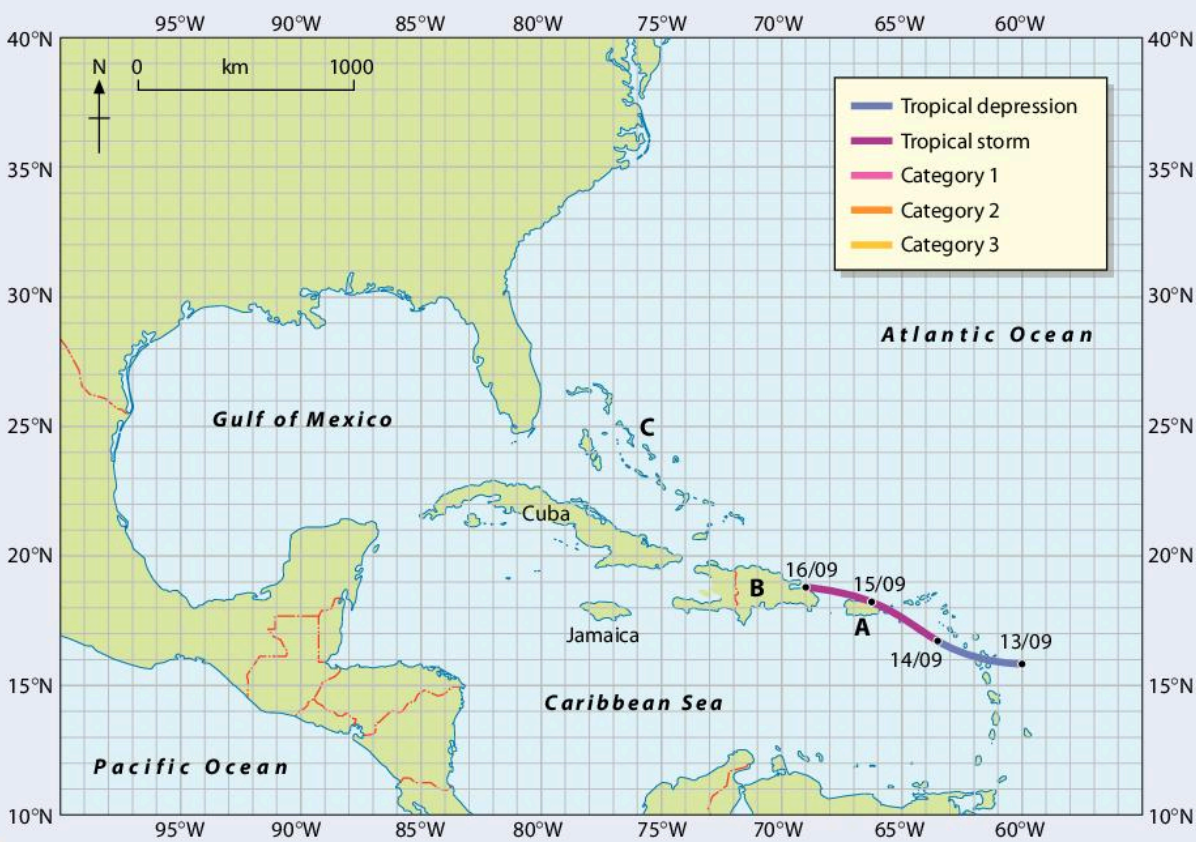


Figure 13.11 The path of Hurricane Jeanne

We can also predict where the hurricane might move next, and how its strength might vary (stronger over ocean, weakening over land). However, hurricanes are very difficult to predict!

1 Copy and complete *Figure 13.11* using the data provided in *Table 13.2*.

2 Using an atlas, identify the islands labelled A, B and C on *Figure 13.11*.

3 Suggest where you think the hurricane might go over the next seven days.

4 Describe the course of Hurricane Jeanne as it passed through the Caribbean and into the USA. Note how its strength varied as it moved through the area.

Table 13.2 Data for Hurricane Jeanne, 13–29 September 2004

Latitude °N	Longitude °W	Date	Status
15.90	60.00	13	Tropical depression
16.70	63.50	14	Tropical storm
18.10	66.20	15	Tropical storm
18.80	69.00	16	Category 1
20.00	71.60	17	Tropical depression
21.70	72.30	18	Tropical storm
24.20	72.30	19	Tropical storm
27.20	71.40	20	Category 1
27.40	69.20	21	Category 1
26.20	68.80	22	Category 2
25.80	70.00	23	Category 1
26.40	73.10	24	Category 2
26.90	78.20	25	Category 3
28.30	82.30	26	Tropical storm
32.50	83.60	27	Tropical depression
37.30	78.40	28	Tropical depression

Volcanoes

There are 25 potentially active volcanoes in the Caribbean, all of them in the eastern Caribbean (*Figure 13.12*). There have been 17 eruptions in recorded history: Mt Pelée (1902) in Martinique accounted for most deaths, and the Soufrière Hills volcano in Montserrat has been active since 1995. Kick 'em Jenny is an active submarine volcano, north of Grenada. All of the volcanoes are associated with subduction zones (Chapter 1, page 12).

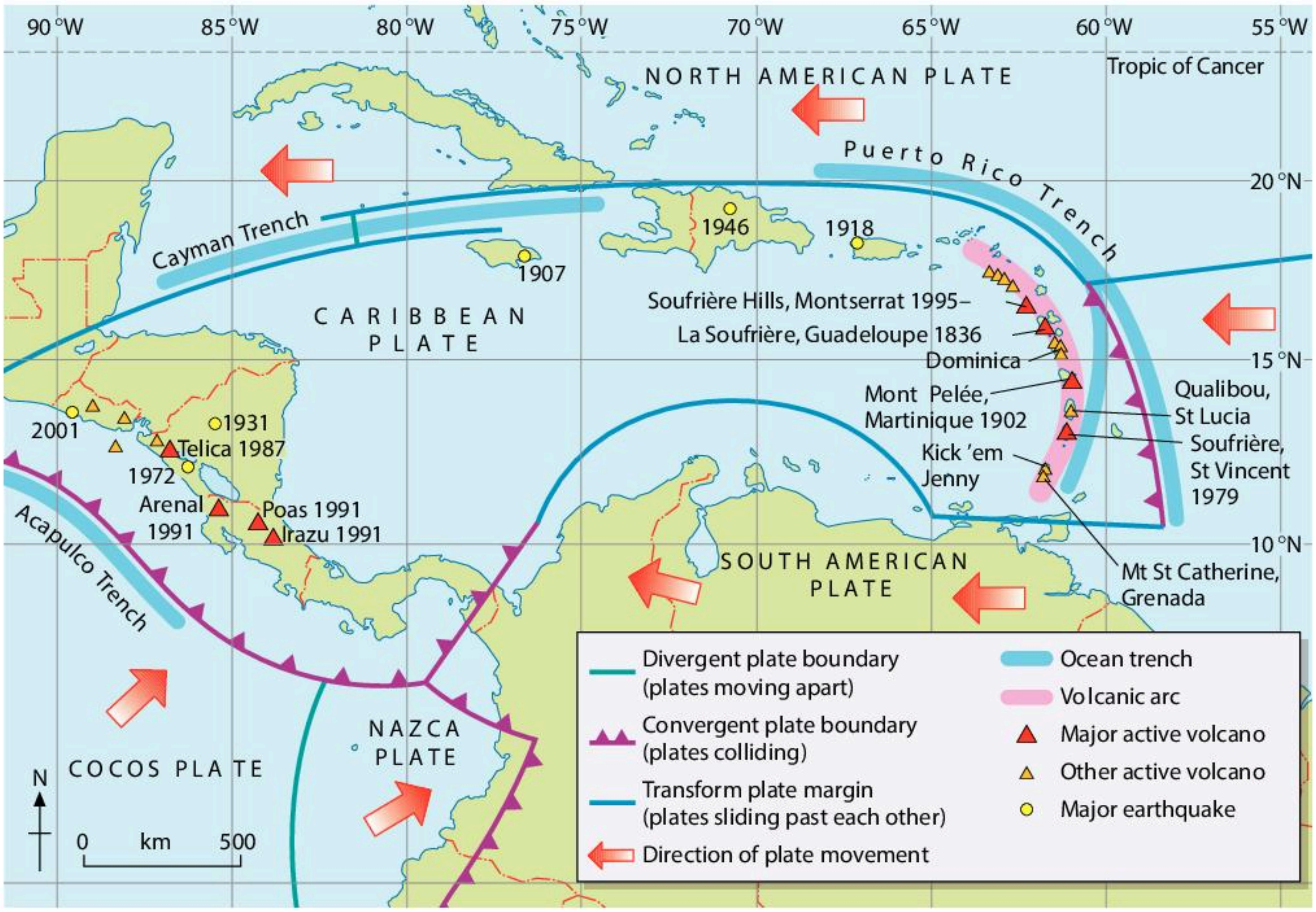


Figure 13.12 Hazard map of the Caribbean

Skills

How to interpret a map

Figure 13.12 shows the potentially active volcanoes in the Caribbean. Any interpretation of a map of this type requires questioning:

- **Where is it?** Name some of the main features shown on the map.
- **Is there a pattern?** Describe whether it is even or uneven, regular or irregular, linear or random.
- **Are there exceptions to the pattern?** Name one or two examples that do not seem to fit the general pattern.
- **Why is it there?** Give a brief explanation of why that pattern might exist.

Caribbean volcanoes are of the explosive type (*Figure 13.13*). There is a wide range of hazards associated with volcanic activity in the eastern Caribbean (*Figure 13.14*). Pyroclastic flows – superheated clouds of fine ash and small rocks – may reach temperatures of up to 1000ºC and achieve speeds of around 720 km/hour. A pyroclastic flow on the Soufrière Hills volcano in 1997 was responsible for the formation of a new delta (*Figure 13.15*); it also caused a small tsunami.

Figure 13.13 Explosive volcanic activity in the Caribbean: Soufrière, Montserrat

Direct hazards	Indirect hazards	Socio-economic impacts
Pyroclastic flows	Atmospheric ash fallout	Destruction of settlements
Volcanic bombs (projectiles)	Landslides	Loss of life
Lava flows	Tsunamis	Loss of farmland and forests
Ash fallout	Acid rainfall	Destruction of infrastructure – roads, airstrips and port facilities
Volcanic gases		Disruption of communications
Lahars (mudflows)		
Earthquakes		

Figure 13.14 Hazards associated with volcanic activity in the eastern Caribbean

Figure 13.15 The new delta formed in Montserrat as a result of a pyroclastic flow, Boxing Day 1997

Activities

1 Study *Figure 13.12*. Why is there volcanic activity in the Caribbean?

2 How may volcanic activity be a benefit to people in the Caribbean? (*Figure 13.15* may suggest one reason.)

3 Describe the direct and indirect hazards associated with volcanic activity in the Caribbean.

4 What are the potential impacts of volcanic activity on people's lives and livelihoods?

Managing the impacts of volcanoes: Montserrat

Volcanic activity has made over 60 percent of southern and central parts of Montserrat uninhabitable. Plymouth was evacuated three times in 1995 and 1996. The volcano was responsible for 19 deaths – all of them farmers – caught out by an eruption during their return to the Exclusion Zone. Volcanic dust is another hazard, as it is a potential cause of silicosis and can aggravate asthma.

Redevelopment has been centred around the Davy Hills (*Figure 13.16*). Much of the northern third of the island has seen considerable development – housing, schools, hospital, infrastructure – as people attempt to learn to live with the volcano in the south.

Volcanic management includes **monitoring** (*Figure 13.17*) and **prediction**. The Geographical Positioning System (GPS) is used to monitor changes in the surface of the volcano (volcanoes typically bulge and swell before an eruption). The development of 'risk maps' can be used to good effect (*Figure 13.20* on page 327). There are risks from volcanoes on other Caribbean islands too. St Vincent and St Kitts are high-risk islands whereas St Lucia, Grenada and Nevis are at lower risk from volcanic activity.

1 What are the main hazards related to volcanic activity in Montserrat? (*Figure 13.12*)

2 Why has most of the redevelopment of Montserrat been in the north of the island?

3 Suggest why Montserrat has seen a growth in population since 2000.

Figure 13.16 Redeveloping Montserrat

Figure 13.17 The Montserrat volcano observatory

Case Study

Kick 'em Jenny, Grenada

Kick 'em Jenny is a submarine volcano located between Grenada and St Vincent and the Grenadines (*Figure 13.18*). The volcano is about 1300 metres high, and its summit is currently thought to be about 180 metres below the surface of the sea. Kick 'em Jenny is the only 'live' (likely to erupt again) submarine volcano in the eastern Caribbean. It is also the most frequently active volcano in the region, erupting at least 12 times since it was discovered in 1939. The 1939 eruption sent a black cloud up to 270 metres above sea level.

The crater rim of Kick 'em Jenny has remained at the same depth below the surface (180–190 metres) since at least 1966. A dome grew in the crater between 1976 and 1978 but collapsed in either 1988 or 1990 and there is now no trace of it. Kick 'em Jenny did not, therefore, grow any closer to the surface between 1962 and 2003. The last major eruption was in December 2001.

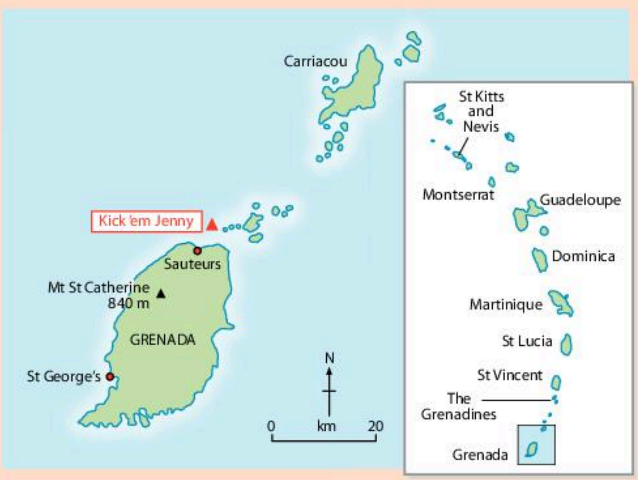


Figure 13.18 The location of Kick 'em Jenny

All the volcanoes in the Windward and Leeward island arc are associated with a subduction zone where the oceanic plate created at the Mid-Atlantic Ridge is pushed under the Caribbean plate (see Chapter 1). Kick 'em Jenny is probably the most intensively monitored submarine volcano in the world. Scientists have discovered that Kick 'em Jenny is continuously releasing gas bubbles from numerous fumaroles (steam vents) within the inner crater. This degassing can occur during or between eruptions and it can significantly lower the density of the water, which poses a serious danger to shipping. In March 2003, scientists discovered three volcanic craters and two cones near Kick 'em Jenny. The largest of these previously unrecognised volcanoes has been tentatively named 'Kick 'em Jack'.

1. Which crustal plates are responsible for the formation of Kick 'em Jenny?
2. Why might this volcano be considered a potential hazard in the region?

Landslides

Landslides are a common natural event in unstable, steep areas. Landslides may lead to loss of life, disruption of transport and communications, and damage to property and infrastructure. The annual repair costs for roads in the Caribbean is estimated to be US$15 million, much of it resulting from landslides.

Hurricane activity may cause landslides. In Jamaica in 2001, Hurricane Michelle triggered a number of debris flows, many 2–3 km in length. Similarly, Hurricane Mitch (1998) caused a mudflow 20 km long and 2–3 km wide which killed more than 1500 people in the town of Posoltega in Nicaragua and surrounding villages.

The two main forces that trigger landslides in the Caribbean are:

- seismic activity, and
- heavy rainfall.

Jamaica is subject to frequent landslides. In the Blue Mountains, over 80 percent of the slopes are over 20 degrees. The area is also geologically young, heavily fractured, and the bedrock is deeply weathered, making it unstable. The largest historic landslide in the region occurred on Judgement Cliff, eastern Jamaica (pages 48–49), when an estimated 80 million cubic metres of material was moved.

Human activities can increase the risk of landslides, for example by:

- increasing the slope angle, for instance cutting through high ground
- placing extra weight on a slope, for instance new buildings
- removing vegetation
- exposing rock joints and bedding planes.

Activities

1 Suggest why hazards are common throughout many parts of the Caribbean.

2 How can human activity increase the risk of landslides?

Case Study

Landslides in Puerto Rico

Approximately 70–80 percent of Puerto Rico is hilly or mountainous (*Figure 13.19*). The country can be divided into three distinct physiographic provinces: Upland, Northern Karst and Coastal Plains. The Upland province includes three major mountain ranges and is covered by dense tropical vegetation. Slopes as steep as 45 degrees are common. The Northern Karst province includes most of north-central and north-western Puerto Rico north of the Upland province. The Coastal Plains province is a discontinuous, gently sloping area.

Puerto Rico's major cities are built primarily in the Coastal Plain province, although population growth has pushed development onto adjacent slopes of the Upland and Northern Karst provinces.

Average annual precipitation in Puerto Rico ranges from less than 1000 mm along the southern coast, to more than 4000 mm in the rainforest of the Sierra de Luquillo on the north-eastern part of the island. The mountainous Cordillera Central receives considerable rainfall. Rain in Puerto Rico falls throughout the year, but about twice as much rain falls each month from May to October – the hurricane season – as falls from November to April. In October 1985, a tropical wave, which later developed into Tropical Storm Isabel, struck the south-central coast of Puerto Rico and produced extreme rainfall.

Some 60 percent of the 3.35 million population lives in the four largest cities – San Juan, Ponce, Mayaguez and Arecibo – which are located primarily on flat or gently sloping coastal areas. Continuing growth of these urban centres, however, is pushing development onto surrounding steep slopes.

Most of the Upland province and the Northern Karst province have continuing landslide problems, on account of their high relief, steep slopes and abundant rainfall. The drier south-western part normally experiences landslides only during exceptionally heavy rainfall. Debris slides and debris flows – rapid downslope sliding or flowing of disrupted surface rock and soil – are particularly hazardous because they happen with little or no warning. Rock falls are common on very steep natural slopes and especially on the numerous steep roads on the island – the cost of road maintenance following landslides is high.

A major tropical storm in October 1985 triggered thousands of debris flows and the disastrous rock slide that destroyed the Mameyes district of Ponce, killing at least 129 people. Statistics on fatalities and damage from landslides in Puerto Rico are not systematically recorded, so estimating losses is difficult. However, the Mameyes landslide was definitely the worst ever experienced in Puerto Rico. More than 100 homes were destroyed, and many more were later condemned and removed because of continuing risk from landslides. The recorded frequency of serious storms in Puerto Rico suggests that loss of property, homes and even lives as a result of landslides is likely to continue.

1 Suggest why Puerto Rico is particularly vulnerable to landslides.

2 How could the threat of landslides be reduced there?

Figure 13.19 Relief of Puerto Rico

Floods and flood hazards

Flooding in the Caribbean is generally small-scale but frequent and recurring. It tends to affect poorer communities in both rural and urban environments. The region is affected by three main types of flooding: river, coastal and flash floods. Flooding is related to hurricanes and tropical storms in summer, and to cold fronts (northers – see Chapter 7) in the northern Caribbean in winter.

The flood hazard is intensified by human activities. Deforestation in drainage basins and the removal of coastal forests, notably mangrove, has increased the risk of floods. Urbanisation also increases the risk of flooding by increasing the amount of impermeable surfaces and decreasing the number of drainage channels.

Hazard reduction processes

Reducing the impact of hazards includes a mix of engineering and building design, land use planning, and improving information to those at risk and those providing relief.

Risk assessment involves consideration of:

- the likely size and range of natural processes involved
- the extent of the impacts
- ways in which the impacts can be reduced.

Most risk assessment involves statistical analysis to assess the likelihood of the size and impact of the event. It is also possible to map the distribution of risk and impact (*Figure 13.20*) and to identify vulnerability, by social group, by type of building and by land use. (See Chapter 1, pages 26–27 for a case study on Montserrat.) However, in many parts of the Caribbean, hazard management has moved on from post-disaster relief to hazard preparedness (*Figures 13.21* and *13.22*).

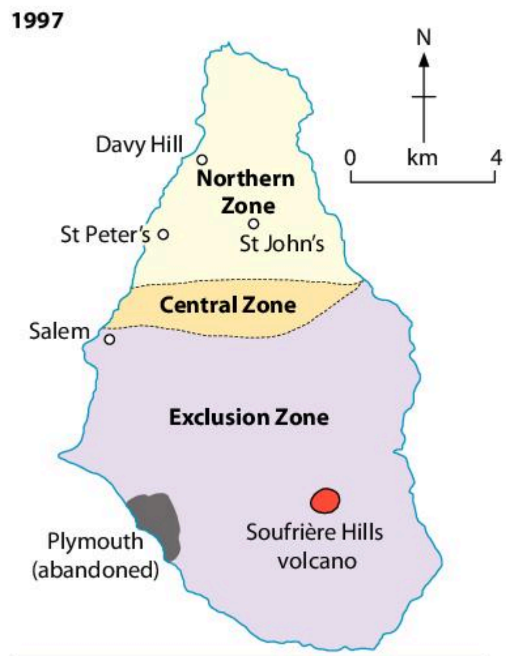
All countries in the Caribbean have adopted the concept of disaster reduction through:

- hazard mitigation
- disaster management
- establishing national disaster agencies to cope with natural disasters.

Activities

1 Study *Figure 13.20*. Where are the greatest risks from volcanic hazards on Montserrat?

2 Study *Figures 13.21* and *13.22*. Describe how the ways of dealing with a disaster change over time.



Exclusion Zone	No admittance except for scientific monitoring and national security matters.
Central Zone	Residential area only. All residents in state of alert. All have rapid means of exit 24 hours a day. All residents must have hard hats and dust masks
Northern Zone	Significantly lower-risk, suitable for residential and commercial occupation.

Figure 13.20 Hazard risk map for Montserrat

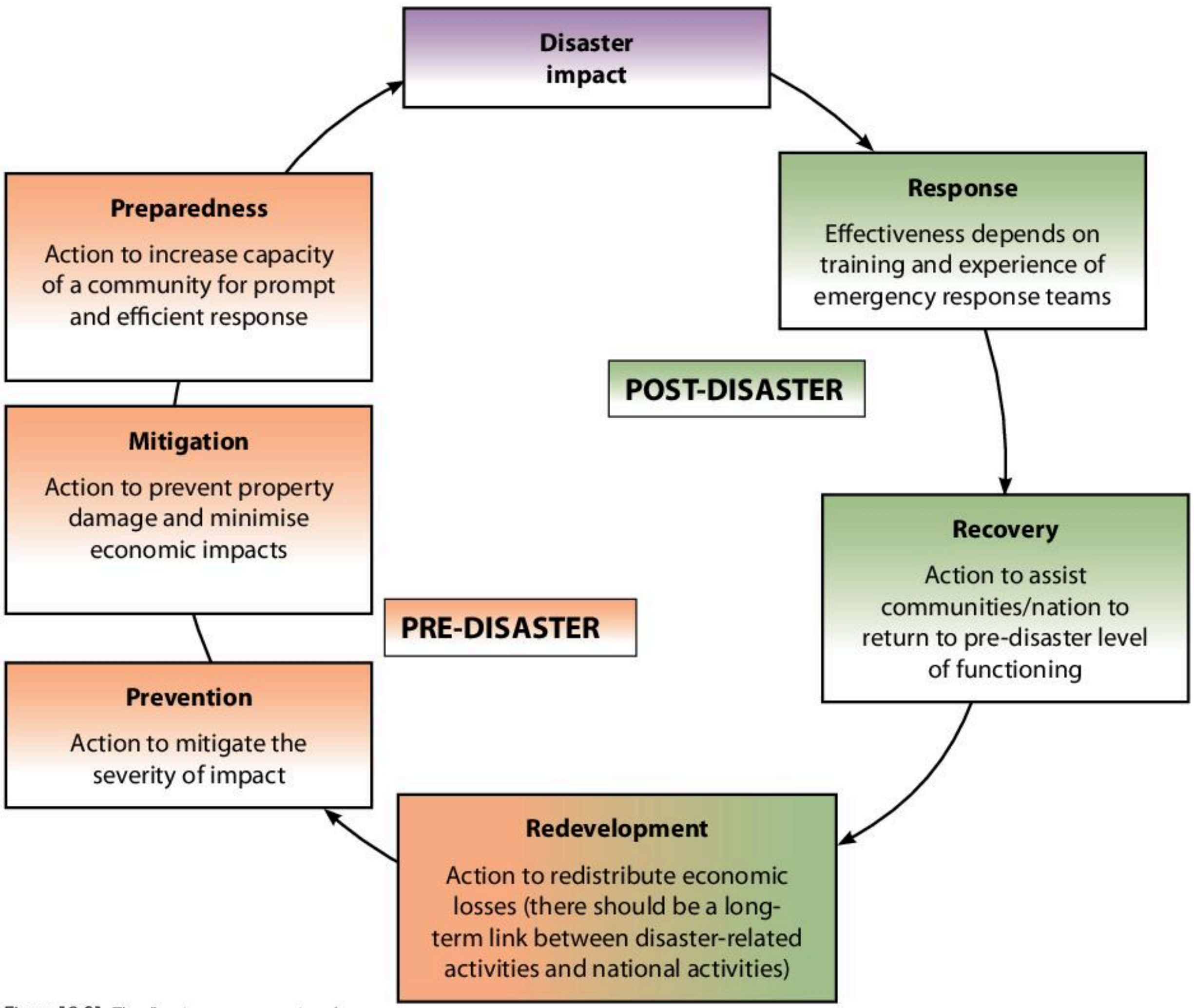


Figure 13.21 The disaster management cycle

Physical adjustments include:

- building and construction techniques to withstand a hazard
- identifying (mapping) and avoiding sites where hazards are likely to occur
- predicting the occurrence of a hazard
- preventing or altering the characteristics of a hazard.

Social adjustments include:

- land use zoning and restrictions for hazardous sites
- establishing minimum building standards for hazardous sites
- public awareness through public education
- issuing early warnings of imminent threats
- evacuation plans, preparations for emergency food and shelter
- emergency preparedness programmes to protect life and property
- spreading economic loss more fairly through insurance, taxation and grants
- reconstructing a community so that it is less vulnerable.

Figure 13.22 Possible physical and social adjustments to hazards

Managing natural hazards

Caribbean Disaster Emergency Management Agency (CDEMA)

The Pan Caribbean Disaster Prevention and Preparation Project (PCDPPP) was established in Antigua in 1981 following severe floods and hurricanes. It was followed by the Caribbean Disaster Emergency Management Agency (CDEMA) in 1991. The University of the West Indies is also actively involved in hazard and disaster management.

CDEMA is a regional inter-governmental agency responsible for disaster management, whose motto is 'Managing Disasters with Preparedness'. There are 16 participating states within CDEMA's membership. These are organised into four sub-regional groups:

- **Jamaica** including Belize, the Bahamas, Turks and Caicos Islands
- **Antigua and Barbuda** along with the British Virgin Islands, Anguilla, St Kitts and Nevis, Montserrat
- **Barbados** including Dominica, St Lucia, St Vincent and the Grenadines
- **Trinidad and Tobago** with Grenada and Guyana.

Within each country there is an Office of Disaster Preparedness.

CDEMA's main function is to make an immediate and coordinated response to any disastrous event affecting any participating state, once the state has requested such assistance.

Other functions include:

- acquiring and channelling comprehensive and reliable information on disasters affecting the region to interested governmental and non-governmental organisations
- reducing, as far as possible, the consequences of disasters
- mobilising and coordinating disaster relief from governmental and non-governmental organisations for affected countries.

With more than US$5 billion in losses to the Caribbean in the last two decades of the 20th century, in the 21st century CDEMA has refocused its attention on comprehensive disaster management. It focuses on all cycles of a hazard, involving all sectors of the society and concentrating on all hazards.

A participating state may request assistance in responding to any type of disaster as long as that state has determined that control of the situation is beyond its own capability. This includes disasters resulting from natural hazards such as hurricanes, floods, earthquakes and volcanic eruptions as well as 'human-made' disasters such as oil spills, chemical accidents, aircraft crashes and industrial fires.

The extent of CDEMA's involvement in disaster response operations in participating states depends on the severity of the situation and the type of assistance required. Three levels of regional response have been defined (*Table 13.3*).

The Office of Disaster Preparedness and Emergency Management (Jamaica)

The Office of Disaster Preparedness and Emergency Management is committed to taking positive measures to prevent or reduce the impact of hazards on Jamaica, on its people, natural resources and economy. It achieves this through its trained and professional staff, by the use of appropriate technology and through collaborative efforts with national, regional and international agencies.

Following the 1979 floods, which devastated parts of western Jamaica, the Jamaican Government recognised the need to establish a permanent disaster management organisation. The Office of Disaster Preparedness and Emergency Relief Coordination (ODIPERC) was established in July 1980. In 1993, the name ODIPERC was changed to the Office of Disaster Preparedness and Emergency Management (ODPEM). ODPEM operates

Table 13.3 CDEMA's regional response levels

Level	Description	Extent of regional involvement	Examples
I	Local incidents within a participating state are dealt with in the regular operating mode of the emergency services. The local national focal point is required to submit information on the event in order to consolidate regional disaster records.	No regional response required	Jamaica earthquake, January 1993 Jamaica floods, May 2007
II	Disasters taking place at the national level which do not overwhelm the socio-economic structure or capacity to respond within the affected state. In such cases, the primary assistance at the regional level will be limited to providing technical expertise to national disaster organisations or facilitating their access to specific resources that may be required for the particular disaster event. The whole operation is still managed by the national disaster focal point.	Limited or specialised	Hurricane Andrew, Bahamas, 1992 Tropical Storm Debby, St Lucia 1994 Tropical Storm Emily, Grenada 2005
III	Disasters that overwhelm the capacity of the affected state(s) to respond. In such instances the Regional Response Mechanism is activated. This includes the activation of the Caribbean Disaster Relief Unit (CDRU) which is the operational arm of the Regional Response Mechanism. The CDRU comprises representatives from the military forces within CARICOM and its main responsibility is logistical support for the receipt and dispatch of relief supplies.	Full activation	Hurricane Luis, eastern Caribbean 1995 Hurricane Georges 1998 Hurricane Ivan 2004

out of the Ministry of Land and Environment. ODPEM has had a number of achievements to date. These include:

- implementation of the Community and Vulnerability Reduction Programme in Portland
- development of a National Disaster Management Plan and Policies
- relocation of vulnerable people where necessary
- coordination of response, assessment and clean-up activities for disasters and major incidents
- establishment of a National Zonal Programme of community-based disaster management structures and procedures
- completion and maintenance of a National Disaster Catalogue and Hazard Database
- completion of damage assessment reports for disaster incidents
- establishment of a National Emergency Operations Centre
- establishment of a National Shelter Programme
- establishment of community flood warning systems

- establishment of a National Relief and Procurement Policy
- the development of websites, including one specifically dedicated to children.

Activities

1 Describe the work of CDEMA.

2 How does CDEMA help to manage hazards in the Caribbean?

3 What are the aims of the Office of Disaster Preparedness and Emergency Management (ODPEM)?

4 List some of the ways in which Jamaica's ODPEM has helped to reduce the risk of hazards in Jamaica.

Reducing the impact of earthquakes

The impact of earthquakes can be reduced in a number of ways, by:

- land use zoning
- building design
- stabilisation of steep slopes
- redevelopment of vulnerable sites
- improvements in warning and prediction.

Although there are building codes, in some places they are difficult to enforce.

Managing the risk of hurricanes

Tracking hurricanes

Most hurricanes are tracked by the US National Hurricane Centre in Miami, USA and by the Meteorological Office (Met Office) in the UK. The National Hurricane Centre in turn warns countries if they are at risk of a hurricane. Active hurricane satellite images are available on the internet, so organisations such as the Office of Disaster Preparedness are able to monitor these and issue warnings.

Information regarding hurricanes is received from a number of sources:

- satellite images
- aircraft that fly into the eye of the hurricane to record weather information
- weather stations at ground level
- radar which monitors areas of intense rainfall.

Hurricane management

Housing is particularly vulnerable to hurricanes. Hurricane Luis (1995) caused damage to 90 percent of Antigua's houses, while Hurricane Gilbert (1988) made 800 000 people temporarily homeless in Jamaica. To limit damage to houses, owners are now encouraged to fix hurricane straps to roofs and put storm shutters over windows (*Figure 13.23*). Houses built on stilts allow flood waters to pass away safely.

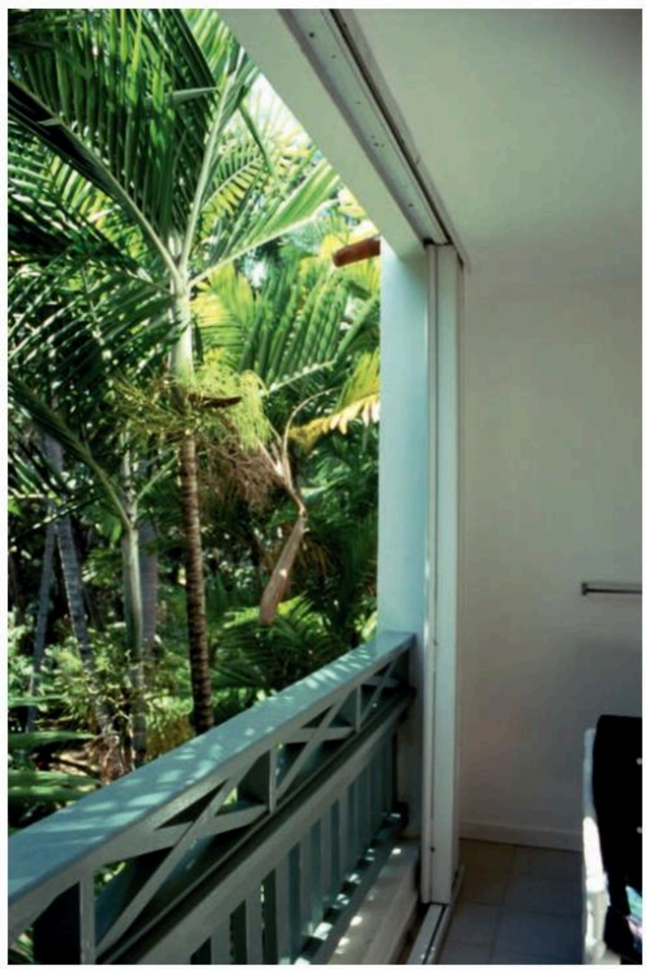


Figure 13.23 Storm shutters to protect against a hurricane

National governments and local agencies can help people to prepare for a hurricane in a number of ways.

- **Risk assessment**: The evaluation of risks of hurricanes can be shown on a hazard map. The information on the map may be used to estimate the probability of a hurricane striking a particular country. This information includes:
  - analysis of climate records to determine how often hurricanes have struck, their intensity and locations
  - history of wind speeds, frequencies of flooding (height and location) and storm surges, and hurricane activity over a period of about 50–100 years.
- **Land use zoning**: The aim is to control land use so that the most important facilities are placed in the least vulnerable areas and the least important facilities in the more vulnerable areas. Policies on future development may regulate land use and enforce building codes in areas that are particularly vulnerable to the effects of hurricanes.
- **Flood plain management**: A plan for flood plain management should be developed to protect important assets from flooding (by heavy rain, swollen rivers or the sea).
- **Reducing vulnerability of structures and infrastructure**:
  - New buildings should be designed to be wind and water resistant.
  - Communication and utility lines (telephone and electricity lines, for example) should be located away from the coastal area or installed underground.
  - Building sites should be improved by raising the ground level in order to protect buildings from flood and storm surges.
  - Protective river embankments, levées and coastal defences should be inspected regularly for breaches due to erosion.
  - Planting trees and other vegetation helps to reduce the impact of soil erosion and landslides and enables the absorption of rainfall, which in turn helps to reduce flooding. Where appropriate, mangrove trees can be planted to reduce the energy of breaking waves.

There are also many things that individuals can do to prepare for a hurricane. Everyone can learn how to act during such an event, and know what to do afterward (*Figure 13.24*).

- A *tropical storm warning* is issued when there are risks of tropical storm winds within 24 hours.
- A *tropical storm watch* is issued when tropical storm winds are expected within 36 hours.
- A *hurricane watch* is issued when there is a threat of hurricane conditions within 24–36 hours.
- A *hurricane warning* is issued when hurricane conditions (winds of 120 km/hour or greater, or dangerously high water and rough seas) are expected in 24 hours or less.

The emergency relief offered after a hurricane can take many forms: food supplies, clean water, blankets and medicines. Much of this is provided in hurricane shelters.

Figure 13.24 Safety tips for living through a hurricane

Source: Office of Disaster Preparedness and Emergency Management, Jamaica

Before a hurricane

- Know your emergency shelters – contact the National Disaster Office for your closest shelter.
- Make sure you have disaster supplies on hand:
  - flashlight and extra batteries ☐
  - portable, battery-operated radio and extra batteries ☐
  - first aid kit ☐
  - non-perishable (canned) food and water ☐
  - non-electric can opener ☐
  - essential medicines ☐
  - cash and credit cards ☐
  - sturdy shoes. ☐
- Protect your windows – permanent shutters are the best protection (a lower-cost alternative is to put up plywood panels).
- Trim tree branches away from your home and cut off all dead or weak branches on any trees on your property.
- Check your home and car insurance – confirm that policies are valid and coverage is appropriate.
- Make arrangements for pets and livestock – pets may not be allowed into emergency shelters for health and space reasons. Contact your local humane society for information on animal shelters.
- Develop an emergency communication plan – make sure that all family members know what to do. Teach family members how and when to turn off gas, electricity, and water.

During a hurricane

- Listen to the radio or television for hurricane progress reports.
- Check emergency supplies.
- Ensure there is fuel in the car.
- Bring in outdoor objects such as lawn furniture, toys and garden tools and firmly anchor objects that cannot be brought inside.
- Secure buildings by closing and boarding up windows.
- Remove outside antennas and satellite dishes.
- Turn refrigerator and freezer to coldest settings. Open only when absolutely necessary and close quickly.
- Store drinking water in clean jugs, bottles and pans.
- Store valuables and personal papers in a waterproof container at the highest level of your home.
- Stay inside, well away from windows, skylights and glass doors.
- Keep a supply of flashlights and extra batteries handy. Avoid open flames, such as candles and kerosene lamps, as a source of light.

After the hurricane

- Assist in search and rescue.
- Seek medical attention for anyone who is injured.
- Clean up debris and effect temporary repairs.
- Report damage to utilities.
- Assist in road clearance.
- Watch out for secondary hazards, fire, flooding, etc.
- Assist in community response efforts.
- Avoid sightseeing.
- Cooperate with damage assessors.

Figure 13.25 What to do before, during and after a hurricane

In some communities emergency electricity generators may be needed. The community usually becomes involved in the clean-up operation, and electricity and phone companies work to restore power lines and communications.

Long-term redevelopment may include construction of new buildings in areas away from the coastline and on high ground. Long-term reconstruction in Grenada following Hurricane Ivan (pages 143–146) concentrated on:

- housing and community projects
- water supply and sanitation
- transport and communications
- agriculture, fisheries and small businesses
- schools.

Most parts of the Caribbean are affected by hurricanes at some time, although Trinidad experiences them only rarely as it is so far south. The hurricane season is generally from June to November, with a peak in September. In the early part of the season the main source area is the western Caribbean and Gulf of Mexico. By mid-season the main source region is the Atlantic, and by the end of the season it is back in the Gulf of Mexico and western Caribbean. All hurricanes are now named and tracked, so it is possible to predict likely paths and issue warnings to people. However, each hurricane track is unique (*Figure 7.22*, page 141).

There have been long-term variations in hurricane activity. For example, activity was low in the 1870s, 1910s and 1960s but high in the 1890s, 1930s–1950s, and since the late 1990s. The impact of global warming on hurricane activity is not fully understood – it may make them more frequent and/or intense, or it could be a part of long-term variations.

Managing landslides

There have been various attempts to manage the landslide risk, and a number of landslide hazard maps have been produced for the region. Methods to combat the landslide hazard are largely labour intensive and include:

- building restraining structures such as walls, piles, buttresses and gabions
- excavating and filling steep slopes to produce gentler slopes
- draining slopes to reduce the build-up of water
- watershed management, for example, afforestation and agroforestry ('farming the forest').

Activities

1 a In what ways is it possible to prepare for hurricanes?
b How can governments help people prepare for hurricanes?
c What are the main actions that should be taken during a hurricane?

2 When is the Caribbean hurricane season?

3 How has hurricane activity varied over time?

4 Describe the conditions of a Category Five hurricane.

Retaining walls
Stone and concrete structures to protect against erosion on steep slopes.

Check dams
Small dams of variable height built across the width of small gullies. They are usually formed of rock and wire but wood and old tyres can also be effective.

Gabions
Galvanised wire baskets filled with rocks or stones to protect river banks and slopes against erosion.

Paved drains and culverts
U-shaped concrete structures designed to move water quickly from roadsides, and areas susceptible to erosion and flooding.

Levées
Concrete or earth embankments on the side of a river to prevent flooding.

Figure 13.26 Small-scale construction techniques used in flood control in the Caribbean

Figure 13.27 Gabions in Barbados

Figure 13.28 Paved drain in St John, Antigua

However, many settlements are located on unsuitable land because no one else wants that land. There may also be relocation following a disaster. For example, in the Mameyes Portones area of Ponce, Puerto Rico, the site was cleared following a landslide. Similarly, the Preston Lands landslide in 1986 in Jamaica resulted in the local community being relocated.

Managing the impacts of flooding

Most of the techniques adopted for flood control are labour-intensive, low-technology solutions (*Figure 13.26*). **Land use zoning** – that is, avoiding building in hazardous areas – is not often practised, as many people choose to build temporary or even illegal settlements in these places. **Weather forecasts** warn of the potential hazards of flash floods and possibly of longer-term weather systems.

Skills

Interpreting a photograph

Study *Figures 13.27* and *13.28*. Ask lots of questions about them. We know that they are something to do with flood control – but …

- What do they show?
- Where are they likely to have been taken?
- Who decided to have these structures built?
- How do they work? What would the impacts be if they did not work properly?
- How costly are they? Are there more expensive and better methods used in developing countries?
- Why are they needed – what are the human and natural causes of flooding?
- What is the scale – are we talking large-scale or small-scale?

In interpreting any photograph we can think about the natural environment (physical geography), the social environment (people), the economic environment (cost) and the political environment (who decides what is done). Thinking up lots of questions may help channel your ideas.

1 What are the main causes of floods in the Caribbean?

2 Suggest how *Figures 13.27* and *13.28* work as methods of flood control. Which do you think is best? Give reasons for your answer.

Idea for SBA

- *What is done in my community to reduce the effects of a specific hazard?*

Glossary

Disaster: a situation in which a natural hazard has a serious effect on people, their property and livelihoods.

Earthquake: a sudden movement of the Earth's crust. Most earthquakes occur at plate boundaries (especially at convergent and transform ones, but in other places too).

Hazard: a natural event that puts people, property and livelihoods at risk.

Landslide: rapid movement of a large section of land – common in areas that are steep, experience high levels of rainfall and are tectonically active.

Risk: a possibility of loss of life or damage.

Risk assessment: the study of the costs and benefits of living in a particular environment.

Tsunami: a giant sea wave usually generated by tectonic activity. Most are caused by submarine earthquakes, volcanic eruptions or landslides.

Volcano: a cone-shaped mountain formed by material erupted from below the Earth's surface.

Exam-style Practice

1 Study Figure 1.

a What is the first action to be taken after a disaster? [2]

b How might it be possible to reduce the impact of a natural hazard? [3]

c Identify ONE short-term response and one long-term response on Figure 1. [2]

d Explain the difference between a *hazard* and a *disaster*. [3]

e Describe THREE hazards associated with tectonic activity in the Caribbean. [6]

f For a named hazard, describe how some islands are more at risk than others. [3]

g Using THREE examples, show how human activities can increase the risk of natural hazards in the Caribbean. [6]

Total 25 marks

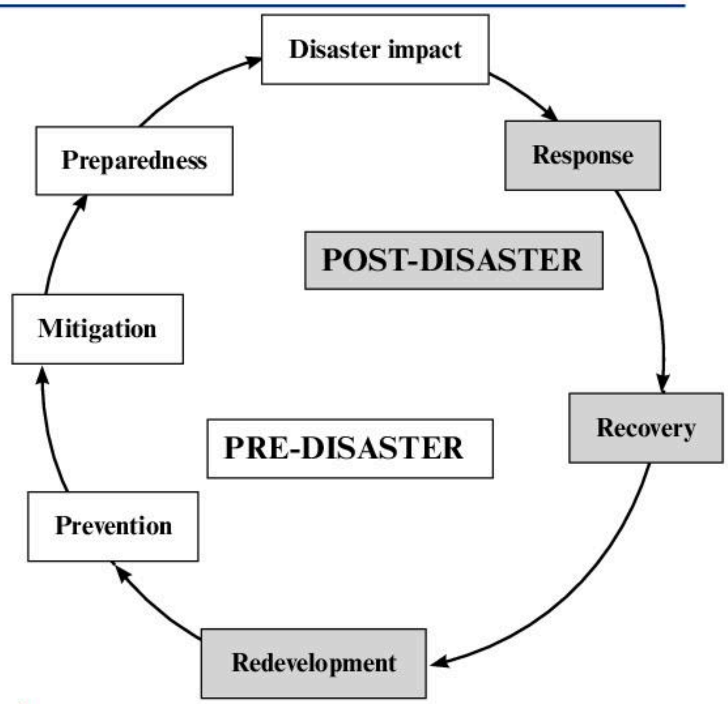


Figure 1 The disaster management cycle

2 a List THREE areas where hurricanes originate. [3]

b Describe THREE growth stages of a hurricane, using illustrations where necessary. [6]

c What are TWO conditions necessary for the formation of a hurricane? [2]

d Explain the importance of CDEMA as it relates to disaster management in the Caribbean. [6]

e What is the role and responsibility of a named national agency in disaster preparedness? [8]

Total 25 marks

14 Environmental Degradation

In this chapter you will study:

- the types of pollution that affect air, land and water
- destruction of the forests
- destruction of coastal mangroves.

You will also learn how to:

- locate places using maps and aerial photographs.

Our threatened planet

Deforestation, climate change and sea level rise are all forms of the **environmental degradation** which takes place when the natural world suffers because of human activity. One cause of environmental degradation is **pollution** – the damage caused by harmful substances – which affects the Earth and everyone living on it. Some **pollutants** (the gases, liquids and solids that cause pollution) are natural, such as the dust and ash given off by volcanic eruptions. Many are produced by the activities of humans.

The environmental problems caused by pollution can be on a local, regional and global scale. Solutions are more difficult to find when the pollution is on a large scale. Local problems such as water pollution are easier to see and solve than large-scale ones like global warming. However, if the local and regional problems are not sorted out they may, in the end, cause environmental degradation on a global scale. Five main types of pollution are shown in *Figure 14.1*.

Air pollution

We need air to breathe and without the mixture of gases that make up the air, animals and plants would not survive. There is now nowhere on Earth where the air is completely free from atmospheric pollutants – the

- **Air pollution** includes invisible gases, such as carbon dioxide, and dust which can be seen and settles on people and objects.
- **Water pollution** includes chemicals that are often invisible, and solid objects that we can see and that float in our rivers, lakes and seas.
- **Noise pollution** includes the sounds that come from mechanical industry and can be damaging to hearing.
- **Land and soil pollution** includes chemicals that poison the soil as well as industrial sites such as waste dumps and quarries.
- **Visual pollution** makes the landscape look less attractive and can damage a country's economy by, for example, discouraging tourists from visiting an area and also dissuade foreign investors.

Figure 14.1 The five main types of pollution harmful substances, mainly produced by industry and motorized vehicles, that are carried around the planet on the wind.

In some big cities in both developed countries and developing countries the air pollution is so bad that people suffer and can die from lung diseases. One of the main sources of air pollution is petrol because it contains carbon monoxide, carbon dioxide, nitrogen oxide, soot, oil vapour and, occasionally, lead.

Similar gases come from industry. Some factories produce the pollutants themselves, such as the iron and steel industry, but all industries use energy produced by power stations. Many power stations use oil or liquefied natural gas and give off pollutants when the raw materials are burnt. Two of the biggest diesel power stations in the world are Clifton Pier in the Bahamas (*Figure 14.2*) and Pembroke East in Bermuda.

Figure 14.2 Clifton Pier diesel power station in the Bahamas

Acid rain

In some parts of the world, moisture in the air is contaminated by chemicals released into the air, largely by industrial processes and the burning of fossil fuels. These chemicals dissolve in rainwater which falls to Earth as **acid rain** (*Figure 14.3*). Since the 1950s many countries have been affected by acid rain in various ways, for example:

- increased acidity in lakes, killing plants and fish
- increased acidity in soils, reducing the amount of crops that can be grown
- destruction of forests as the pollutants stop roots growing
- drinking water supplies becoming more acidic, creating health problems for people in the future
- buildings being destroyed by the chemical action of the acids.

In Montserrat, gases from the eruptions of the Soufrière Hills volcano have also caused acid rain, killing plant life and having an effect on how much food can be produced in the country. However, it is now mainly in places like China, where industry is developing very rapidly, that acid rain is a problem. It is thought that up to a third of

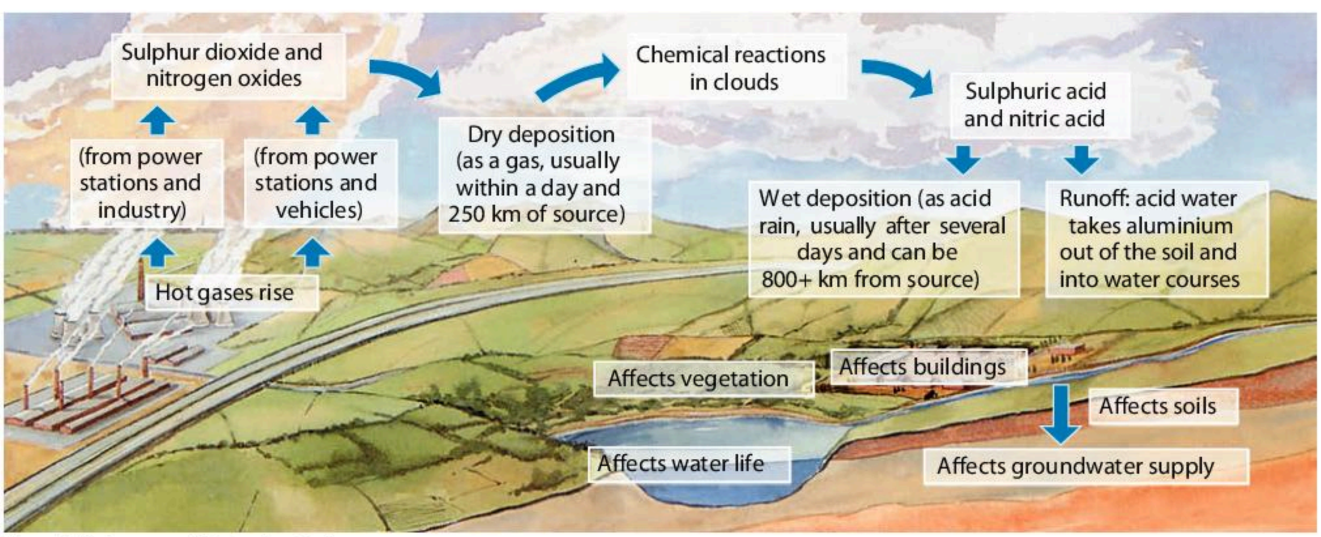


Figure 14.3 Causes and effects of acid rain

China's agricultural land is being damaged by chemicals in air pollution. In the Caribbean, any country that develops its industry and builds more power stations by burning **fossil fuels** (such as oil and gas) risks causing acid rain which may fall not only on that country but also on its neighbours.

Water pollution

Water is crucial to the Caribbean. Apart from the clean, fresh water that everybody needs to drink, the sea needs to be unpolluted to continue to produce the fish that form such an important part of the Caribbean diet and economy. We have already seen the damage that pollution can cause to coral reefs (Chapter 5).

Some pollutants in acid rain can kill sea life in small areas such as bays and harbours, and industry can pollute the sea by pumping chemicals directly into it (see case study on Kingston Harbour on pages 341–343).

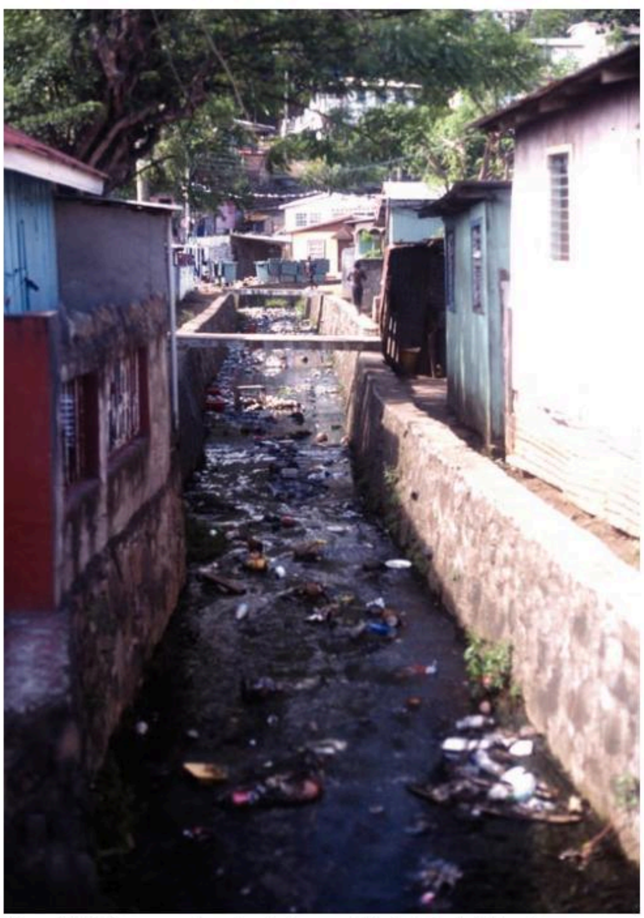


Figure 14.4 Open sewer in a shanty town outside Castries in St Lucia

One of the biggest money earners in the region – the exploitation of oil and gas in Trinidad and Tobago – also causes water pollution problems. In July 1979 two ships, the *Atlantic Empress* and the *Aegean Captain*, collided 16 km off the coast of Tobago. The *Aegean Captain* was towed safely to Curaçao losing only small quantities of oil on the way, but the *Atlantic Empress* sank out at sea in the middle of a burning oil slick. Even though 300 000 tonnes of oil were spilled, very little washed up onto the shores of the surrounding islands. Much of the oil may have burned in the slicks at sea, adding to the local air pollution at the time, but nobody knows how much sank with the ship or whether it could still cause damage to the environment.

Polluting water on the land

More significant for most people than the large-scale pollution incidents at sea is the damage being done to sources of drinking water on land.

In some **shanty towns** – the poor-quality housing on the outskirts of towns and cities – open sewers run through the streets. People throw their garbage in the sewers and they may even be used as open-air toilets (*Figure 14.4*).

Pollution of water sources in this way can cause diseases such as cholera and typhoid while parasitic worms and other bacteria lead to diarrhoea. Much of the polluted water is washed out to sea by rivers where poisons can affect fish and shellfish that are harvested and then sold in markets. Some of the ways in which water is polluted in the Caribbean are shown in *Table 14.1*.

Land pollution

Although it is generally less harmful to health than air and water pollution, land pollution such as waste dumps can affect a country's economy. Tourists, in particular, come to the Caribbean to see a tropical paradise and do not expect to see landfill sites (*Figure 14.5*) or roadside garbage dumps (*Figure 14.6*) even though they – the tourists – help to create the waste in the first place. Many of the countries in the region are small and have an increasing population and do not have space to bury large quantities of waste. Landfill sites also give off gases such as methane, adding pollutants to the air. Careful management is needed to make sure disposal of waste does not become a huge problem.

Table 14.1 Common ways in which water is polluted in the Caribbean

Sewage – Building and looking after sewage treatment plants is very expensive and most Caribbean countries do not have enough plants to serve their population. A recent World Health Organization report showed around 51 percent of Caribbean households were connected to a sewer. The problem is likely to get worse as the number of people living on the coast increases and more sewage is pumped straight into the sea.
Oil – Although accidental oil spills that occur in collisions make news headlines, far more oil is released into coastal waters by ships deliberately emptying oil when washing their tanks. Exploitation of oil and gas also involves pumping chemicals into sea water; oil can be released when pipelines and other types of equipment break.
Sediments, nutrients and pesticides – Human activities such as cutting down forests and building towns and cities add sediments (from soil) to rivers and these are washed out to sea. It has been estimated that 12 percent of the total worldwide sediment input into the oceans comes from the Caribbean. Agriculture adds nutrients such as phosphorus from fertilizers to river water, and poisonous chemicals from pesticides. Nutrients in the water can cause **eutrophication** – the process where plant growth increases and oxygen in the water decreases, causing problems for animals living in the water. Pesticides kill marine life and poison food such as fish and shellfish.
Solid waste – Objects thrown from ships and by fishermen wash up on shore or can be swallowed by sea creatures, while similar products thrown in rivers also end up in the oceans. Some, like needles and glass, are health hazards but all cause visual pollution that can affect the tourist trade as well.
Toxic (poisonous) substances – Oil refineries, petrochemical plants, chemical industries, paper-making and pesticide production all add poisons to water sources in the Caribbean. Many of these poisons last a very long time. However, not all of the sources of the pollution are in the Caribbean and much of it comes from industrial centres in the Americas, for example, Havana Bay in Cuba, Cartegena Bay in Colombia, and the Texas and Louisiana regions of the US Gulf Coast. On a local scale, residents in some parts of Jamaica have been concerned that emissions from bauxite plants have affected local drinking water sources and tank water used to irrigate crops.

Source: Caribbean Environment Programme/United Nations Environment Programme, 2007

Figure 14.5 A landfill site

Figure 14.6 Abandoned roadside garbage in Jamaica

Noise and visual pollution

While noise and visual pollution are often associated with industry, there can also be a lot of noise and destruction of the landscape by activities like quarrying or mining. This can be very annoying for people who live nearby, but rarely threatens health in the way that air and water pollution can. There can be consequences for a country's economy as tourists will be put off returning if there is excessive noise or if the industry spoils the natural environment. Tourists themselves can cause visual pollution as the light from big hotel resort complexes can interfere with economic activities such as night fishing.

Activities

1 Think about your local area. What kinds of pollution can you identify where you live? Write a list and beside each type state the source of the pollution.

2 What is the most damaging source of pollution in your country? How does it affect **a** the local people and **b** the tourists who visit?

3 What can be done to combat pollution in your country? Do you know of any action the people or the government are taking to stop pollution incidents?

Case Study

Pollution in Kingston Harbour, Jamaica

Kingston Harbour is a very large, well-protected harbour in the south-east of Jamaica, which is almost entirely surrounded by land. It is the world's seventh largest natural harbour and the third biggest in the Caribbean and Latin America. The harbour was formed as sediment was deposited parallel to the coastline, creating a tombolo (see Chapter 4). Ships enter its sheltered waters through a small gap in the coastline (*Figure 14.7*).

Many communities around the harbour rely on the activities there for jobs and money. According to Jamaica's National Environment and Planning Agency, around 800 000 of Jamaica's 2.7 million people live in areas that have an impact on water quality in the harbour. The value of the harbour to the country is estimated at over US$500 million per year through the following economic activities:

- Over 3000 fishermen work from 7 fishing villages including Port Royal, Harbour Head and Rae Town, landing an annual total of more than 1000 tonnes of fish.
- The port facilities enable more than 1500 ships to transfer their goods through Kingston every year.

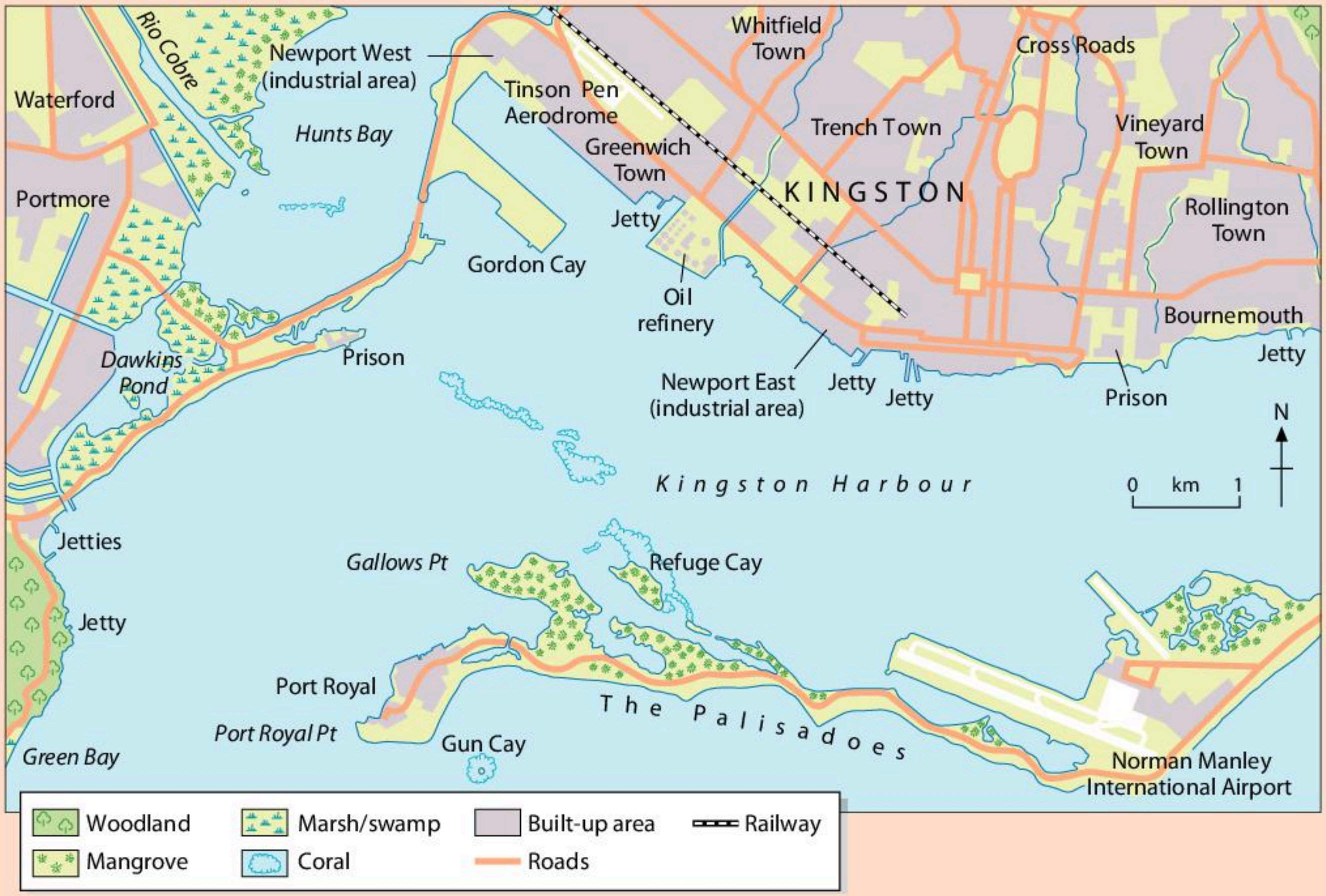


Figure 14.7 Kingston Harbour, Jamaica

- Surrounding the harbour is Kingston's industrial estate, with large oil refineries and cement production plants.
- Yachting takes place from sites like Morgan's Harbour on the Palisadoes but other, previously popular, recreational pursuits such as water-skiing and swimming have stopped because of the high pollution levels in the harbour.
- Reclaimed land, taken back from the sea, has been converted into industrial land and has also provided a base for Jamaica's main airport, Norman Manley International.

Despite the high value and heavy use of the area, little thought has been given to how to manage the environment and, with the very large numbers of people nearby, water quality has reached a very low standard with little marine life left in some parts and sea life completely dead in others.

Pollution problems

1 The main source of pollution in the harbour is poorly treated sewage, with an estimated 90 million litres of improperly treated sewage being deposited every day (only about a third of the households in the Kingston Metropolitan Area are connected to a sewerage system). The partly-treated sewage contains nitrate and phosphate nutrients that cause eutrophication (*Table 14.1*) and cut off oxygen to fish and plants. Some plants, known as algae, feed off the nutrients and cause massive **algal blooms** that turn the sea red.

2 The main industrial zone, with breweries, distilleries and food processing plants, lies on the northern boundary of the harbour (*Figure 14.8*). Many of these dump chemicals straight into the harbour, adding high levels of heavy metals such as lead

Figure 14.8 In Kingston Harbour's industrial zone

and pesticides to the water. Ships add to this pollution by emptying their tanks and throwing garbage into the sea.

3 All rivers from the Kingston Metropolitan Area flow into the harbour, bringing large amounts of solid and other waste. Much of this is difficult to get rid of and causes visual pollution with styrofoam, plastics and paper floating on the water and piling up on the coastline (*Figure 14.9*).

Waste disposal for local people is not good and many have little option but to dump household garbage into the rivers and let it be washed away by the rain. Construction and deforestation around Kingston have also


Figure 14.9 Solid waste on the Kingston Harbour shoreline

added to the sediment being carried by rivers out into the harbour.

The problems of Kingston Harbour are made worse by its narrow entrance and the small tides which mean that very little water from the open sea mixes with that inside the harbour.

Solutions to the harbour's pollution problems

Efforts are being made to tackle the pollution problems although, for many areas where the water lacks oxygen, it may already be too late. In 2003 the government said it would be spending US$620 million to save the harbour by:

- coming up with a zoning plan to make sure some polluting activities are carried out only in certain areas
- cracking down on industries polluting the harbour
- building a separate facility for ships to get rid of their waste and empty their tanks without polluting
- educating the public to encourage them to pollute less.

By 2007, the importance of caring for the environment and protecting the harbour was being taught in Jamaican schools and in 2008 a new US$50 million sewage plant, built to treat at least 5 million tonnes of sewage every day, was completed at Soapberry, close to Hunt's Bay. In 2013, a new Environmental Management Plan aimed to improve wastewater and hazardous waste systems. However, there had been little progress on some of the other large-scale projects. It remains to be seen whether the measures being taken are enough to save the harbour after so many years of environmental degradation.

Using *Figure 14.7*, draw a detailed, labelled sketch map showing the causes of pollution in Kingston Harbour, and some of the ideas being put forward to solve the problem.

The destruction of the forests

Forests covered about 40 percent of the Earth before people settled down and started farming 8000 years ago. At first, much of the forest was removed in Europe and Asia as these were the areas where most people lived. However, with the arrival of Europeans in the Americas 500 years ago, **deforestation** and **forest degradation** (*Figure 14.10*) began here too.

Although there has been a decline in the world's forest for centuries – 15 percent was removed between 1850 and 1980 – the big changes have taken place since 1950 and around half the total forest cover has now been destroyed.

Loss of the tropical forests found in many Caribbean countries has been even more severe and the total tropical forest cover worldwide dropped from 15 percent in 1950 to only 6 percent in 2000. The most dramatic changes have been in countries with the largest amount of forest. Between 2000 and 2005, for instance, Brazil lost 17.5 million hectares of rainforest – an area roughly the size of Haiti and Jamaica combined – each year.

Some countries in the Caribbean, such as Suriname and Guyana, have managed to cling on to their forests but, as can be seen in *Figure 14.11*, many others that were almost completely covered when the Europeans first arrived are now almost treeless.

A forest can be destroyed in one of two ways:

- **deforestation** is the total removal of trees and forest cover
- **forest degradation** is a negative change in the forest cover, for example when primary rainforest is removed and less natural forest grows in its place.

Figure 14.10 Forest destruction

Causes of forest destruction

There are many reasons behind the removal of tropical forests in the Caribbean, including the following:

- **Large-scale agriculture** – many of the forests in Caribbean countries were cleared by European settlers to make way for plantations growing tropical export crops such as coffee and cotton. In Cuba, sugar and cattle ranches needed large open spaces and so the tree cover was removed. Many plantations remain to this day. Often the forest in the interior of the islands was left untouched because it would have been too difficult and expensive to get crops out to a country's ports.
- **Subsistence agriculture** – farming operated on a small scale in many forests in the Caribbean for years (*Figure 14.12*). However, as population increased and

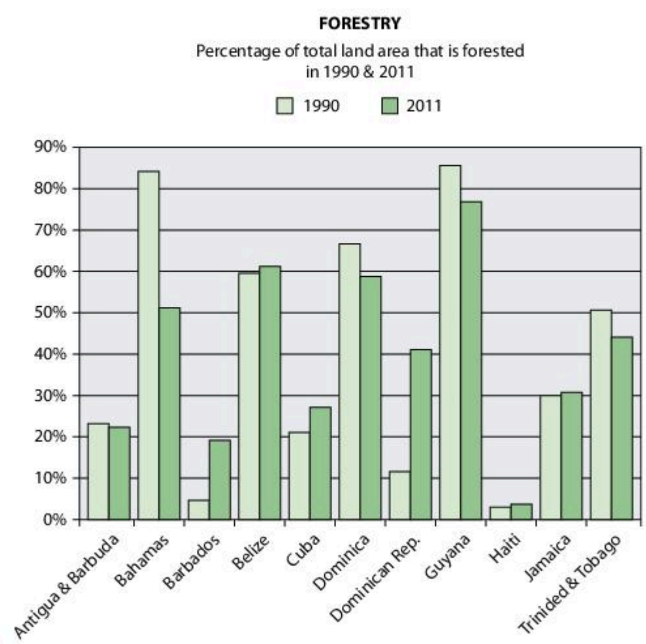


Figure 14.11 Forest cover in the Caribbean

Source: FAO


Figure 14.12 Subsistence agriculture in cleared forest in Trinidad

good-quality farmland became more expensive, people cleared plots of land and planted crops in the forest. The southern slopes of Jamaica's Blue Mountains have been cleared of forest by settlers, some of them illegal **'squatters'**, to make way for farming. On a global scale, the problem is at its worst in Brazil where thousands of people have cleared huge areas of land in the Amazon. When the land becomes degraded and impossible to farm, they move on to other areas and this leads to the permanent degradation of the forest and the land they leave behind.

- **Fuelwood and charcoal** – in some of the poorest countries in the region, people are forced to collect wood, some of it to be converted into charcoal, as the only way to heat their homes and to cook. As Haiti has become poorer, deforestation has increased so that now only 1–2 percent of the country has any dense forest left. Deforestation for woodfuel is also a major problem in Guadeloupe, Martinique and Dominican Republic.
- **Logging** – countries including Belize and Guyana still make money from logging, or lumbering, and selling wood products. This leads to degradation as the trees that grow in place of the ones removed are never the same as natural forest. Over-harvesting of trees is also becoming a problem as more businesses try to take advantage of the forests.
- **Mining** – the discovery of valuable minerals in forested areas often leads to permanent deforestation, both to dig the mines and to build roads and airstrips to serve them (*Figure 14.13*). When the mineral discovered is very valuable, such as the recent finds of gold in Guyana, environmental regulations are often forgotten as companies try to get the resources out as quickly as possible. In Jamaica, bauxite mining is considered the largest cause of deforestation in the country.
- **Building and tourism development** – while visitors to the Caribbean come to look at the forests and the natural beauty, many are staying in hotels built on land that used to be forest. As the population of many countries increases, towns and villages are also expanding outward and being built on hillsides that used to be covered by lush forest.


Figure 14.13 Mining for gold in the rainforests of Guyana

The causes of deforestation are similar across the world, from the Caribbean to Indonesia and Papua New Guinea, and have effects that are felt at both local and global levels.

The consequences of forest destruction

There can be positive effects of forest destruction with farmers opening up new land and producing more crops. However, most deforestation and forest degradation has a negative impact on individual countries and on the whole world.

Local effects of deforestation

- Forests help to control how much water flows in streams and rivers. Tree roots hold soil in place and tree canopies reduce the impact of raindrops, wind and water on the soil. Without them, the soil can easily be worn away, or **eroded**, causing **landslides**, and water can very quickly enter rivers, causing **floods**. The removal of forests in Haiti was considered responsible for the loss of 700 lives due to flooding and mudslides following Tropical Storm Jeanne in 2004.
- After the vegetation cover is removed, soil can be washed into streams and rivers and eventually settles on the floor of the sea. It covers reefs, kills coral and affects the whole food chain. Reefs in Jamaica, Dominican Republic and Puerto Rico are all at risk following deforestation.
- Wildlife is lost when trees are cut down, and a number of endangered species, such as the Puerto Rican parrot, are threatened by deforestation. Evidence from Guadeloupe shows that fewer male Hawksbill turtles (*Figure 14.14*) are born when coastal forests are removed.
- Many tourists come to the Caribbean to see wildlife and, in countries including Antigua and Barbados, the lush tropical forest. Further deforestation could have a serious effect on the tourist economy of these countries.
- Other negative economic effects include the loss of yam product exports in Jamaica (*Figure 14.15*). There are many other forest products, food and medicines that can bring in a lot of money if they are collected in the right way.

Figure 14.14 A Hawksbill turtle, which uses coastal forests as its breeding ground

Deforestation and global warming

Perhaps the greatest threat from deforestation is increased global warming. Forests, especially the huge tropical areas such as Brazil and Indonesia, act as **carbon sinks**. That is, they soak up damaging carbon dioxide. Cutting down the trees means more carbon dioxide in the atmosphere and this is added to when the felled trees are set on fire. As we have seen, more carbon dioxide could mean increased global temperatures and sea-level rises.

Brazilian scientists recently claimed that deforestation in the Amazon would mean cooler air in the atmosphere and more heat in the waters of the southern North Atlantic – conditions that would be ideal for more extreme and more frequent hurricanes in the Caribbean.

Deforestation threatens yam export industry in Jamaica

The watershed area in the Cockpit Mountains of Trelawny continues to suffer serious environmental degradation through the practice of harvesting trees for the provision of yam sticks. Some 16000 hectares of yam cultivation presently exist with an estimated 55 million yam sticks used by farmers and about 30 million replacement yam sticks needed annually.

Farmers use yam sticks to help expose yam vines to produce larger tubers. However, this cultural practice can only further threaten the US$15 million yam export industry. This will happen as soil loss due to deforestation will affect the productivity of the land and farmers will therefore have to increase their inputs over time in order to achieve the same yield.

A yam crop

Figure 14.15 Deforestation and the Jamaican yam industry

Source: *Government of Jamaica Handbook on Environment and Sustainable Development*

Case Study

Tackling deforestation in Guyana

Almost 75 percent of the land area of Guyana is covered in forest but this figure has decreased rapidly over the last ten years or so and, according to the FAO, is down from 94 percent in 1995. Some Amerindians – the original inhabitants – still live in the forest in the interior of the country but 90 percent of the population lives on the coast. Historic and current reasons for deforestation include plantation agriculture, mining, logging, fires, road building and fuelwood collection but there are an increasing number of projects in the country trying to save the forest that remains.

Iwokrama

Iwokrama project (*Figure 14.16*) has been set up to promote the conservation and sustainable use of a tropical forest 'in a manner that leads to lasting ecological, economic and social benefits to the people of Guyana and to the world in general' (Iwokrama Mission Statement). Since 1989 the area has been used as a research station for scientists and as a holiday destination for eco-tourists (*Figure 14.17*). The forest authorities are now looking to exploit timber and other forest products including honey and aquarium fish as a way of bringing in money. This exploitation will be sustainable and provide an example that other countries suffering deforestation can follow.

Figure 14.16 The Iwokrama project in Guyana

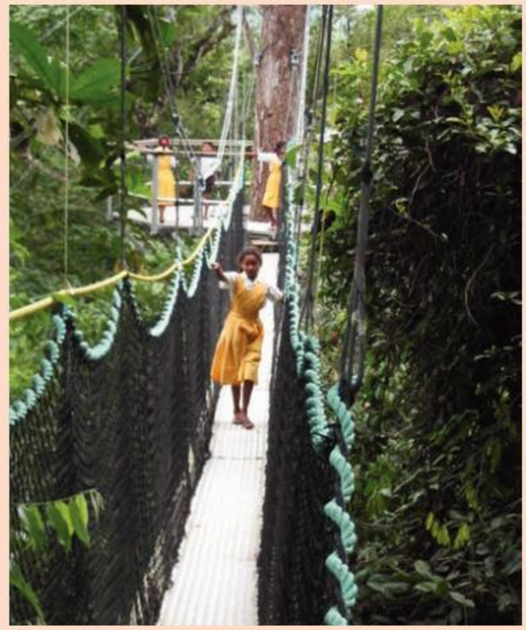


Figure 14.17 Ecotourism: the Iwokrama rainforest walkway

Forest Stewardship

The Barama Company's forests in the west of Guyana were given an internationally respected certificate by the Forest Stewardship Council (FSC) in 2006. The company, which employs 1500 people, uses low-impact logging measures to make sure damage to the forest is kept very small. People buying from the company know that the products they buy are environmentally friendly and that the company's workers get better pay and conditions. Other logging companies in Guyana are expected to apply for FSC certification.

Reafforestation projects

The Guyanan government has also set up a number of reafforestation (replanting) projects with money from aid agencies such as the Worldwide Fund for Nature and the World Conservation Union. These are replanting local species of trees that have been lost because of deforestation. One example is in the Barima region of the country where six Amerindian communities are growing *Euterpe oleracea*, a type of manicole palm that will be replanted in their communities.

1 How much forest is left in your own country? What are the causes of deforestation? Are there any obvious positive or negative effects?

2 Would the actions of the Guyanan government to tackle deforestation work in a country with much more tropical forest, like Brazil? Give reasons for your answer.

The environmental degradation of mangrove swamps

Many countries of the Caribbean have substantial areas of mangroves – salt-adapted trees and shrubs that line the coast. These ecosystems act as filters for water supplies, provide a barrier to erosion and are used extensively for recreational purposes. It is a matter of some concern to many countries, therefore, that mangroves seem to be disappearing faster than virtually any other ecosystem on Earth. Some scientists have suggested they are disappearing three to five times faster than other types of global deforestation.

The destruction and degradation of the mangroves will have significant consequences for many coastal communities because they play a crucial role as a nursery ground for many economically important fish species. In Jamaica it is estimated that 75 percent of game fish and up to 90 percent of commercial fish rely on mangrove forests at some stage in their lives. The rainbow parrotfish (*Figure 14.18*), for instance, has disappeared from many areas of the country following removal of the plants.

Mangroves are responsible for reducing the impact of waves on coastlines during heavy storms by absorbing some of the power of the sea. They also act as floodplains for river deltas, preventing flooding by taking much of the excess water during periods of heavy rain (*Figure 14.19*). In addition they can protect coral reefs from damage from algae, chemicals and sediments and they provide large areas of wetlands for important bird species popular with tourists. Indeed, many mangrove areas are economically important in their own right as tourist destinations.

Figure 14.19 Mangrove swamps reduce the impact of waves on the coastline

There are a number of environmental threats to the mangrove swamps in the Caribbean:

- the clearing of large areas for the development of resorts, marinas and residential areas associated with the growth of tourism (*Figure 14.20*)
- propellers and anchors on boats responsible for local damage to the trees
- coastal developments, both for tourism and for housing, increasing the amount of sand and other suspended material carried in coastal waters – this material can smother mangroves and stop them from growing

Figure 14.18 The rainbow parrotfish

Figure 14.20 A tourist resort built on a cleared mangrove swamp

- dredging and reclamation of land around ports and harbours disturbs sand and smaller particles which then settles on the mangroves and kills the plants
- sewage, chemicals from industry and oil pollution which destroys the swamps
- power plants located along coastlines (such as the JPD Power Plant in Jamaica's Old Harbour Bay) responsible for raising the temperature of the water and causing damage to the ecosystem
- pollution from fertilizers and pesticides washed off farmland
- mosquito control projects which involve clearance of mangrove swamps because they are often ideal breeding grounds for the insects.

All of the above threats are increasing due to the high population growth rates found in some Caribbean islands.

There are further threats to areas of mangroves associated with global climate change. Sea-level rise and higher sea surface temperatures will have an effect on the delicate ecosystems which may not be able to adapt quickly enough to the higher and warmer waters. The loss of the mangroves also leads to a loss in the 'carbon sink' which absorbs carbon dioxide and reduces greenhouse gas emissions. Finally, there are secondary effects because of the potential for increased hurricane activity that may come from global warming. Higher storm surges and the potential for more damage will almost certainly affect the vegetation lying along Caribbean coastlines.

One country taking action to manage and protect its mangrove coastlines (especially from the threat of climate change) is Guyana.

Sustainable mangrove management in Guyana

The government of Guyana has been looking at ways to restore and plant new mangrove forests, both as a way to decrease the amount of greenhouse gases the country produces and to strengthen sea defences from the possible effects of climate change.

In particular, the Mangrove Action Plan for the country has:

- identified sites that currently protect the coastline and planted more than 400 000 new seedlings to increase this protection
- mapped the whole area of the country's mangrove forests using satellite imagery and geographical information systems
- set up a mangrove ranger unit with eight rangers who patrol and protect 36.5 km of mangrove coastline
- improved community awareness by establishing village mangrove action committees
- set up the first Mangrove Reserve – winner of a major environmental tourism award in 2011 – and a Mangrove Visitor Centre with 3000 students and around the same number of tourists visiting each year
- started an education programme, both on television and in schools, to increase awareness of the need to protect the mangrove ecosystems.

Other countries with substantial areas of mangrove in the Caribbean have been watching the developments in Guyana and many have already started planning their own actions to help stop the environmental degradation of this precious resource.

Glossary of terms

Acid rain: air pollution resulting from acidic chemicals mixing with rain.

Algal bloom: when algae grow quickly in the sea and in rivers because of nutrients added from farm fertilizers and detergents.

Carbon sink: an area, such as a forest, that soaks up carbon dioxide released from other areas.

Deforestation: the total removal of trees and forest cover.

Environmental degradation: when the environment's ability to cope with the needs of people, animals and plants is reduced – usually by the actions of people.

Eutrophication: when a body of water receives too many nutrients and excessive plant growth takes place.

Forest degradation: a negative change in the forest cover, for example when primary rainforest is removed and less natural forest grows instead.

Fossil fuel: oil, coal and natural gas formed millions of years ago from decaying plants and animals.

Global warming: the increase in the average temperature of the Earth's atmosphere and oceans.

Green: an informal term to describe someone who cares about the environment.

Greenhouse effect: the trapping of heat within the Earth's atmosphere.

Greenhouse gases: the gases that trap heat within the Earth's atmosphere, such as carbon dioxide, methane and water vapour.

Pollution: damage caused to the Earth, often by harmful and toxic (poisonous) substances.

Recycling: processing items like cans, paper and glass so that they can be used again.

Renewable energy: energy produced from sources that, unlike fossil fuels, will not run out. Examples include tidal power, solar power and wind power.

Ideas for SBA

- *What causes pollution in my community and what measures are taken to reduce the harmful effects of this pollution?*
- *What are the causes and effects of coral reef destruction?*
- *What are the causes and effects of deforestation?*

Exam-style Practice

1 a What is pollution? [1]

b Give TWO ways in which water can be polluted. [2]

c Suggest TWO ways in which the pollution can be avoided. [2]

d Look at Figure 1. Name a source on the map where you might find each of the types of pollution listed below:

- **i** air pollution
- **ii** water pollution
- **iii** noise pollution
- **iv** visual pollution. [4]

e Give THREE benefits provided by mangrove swamps in the Caribbean. [3]

f Outline the environmental threats currently affecting the mangrove swamps in the Caribbean. [8]

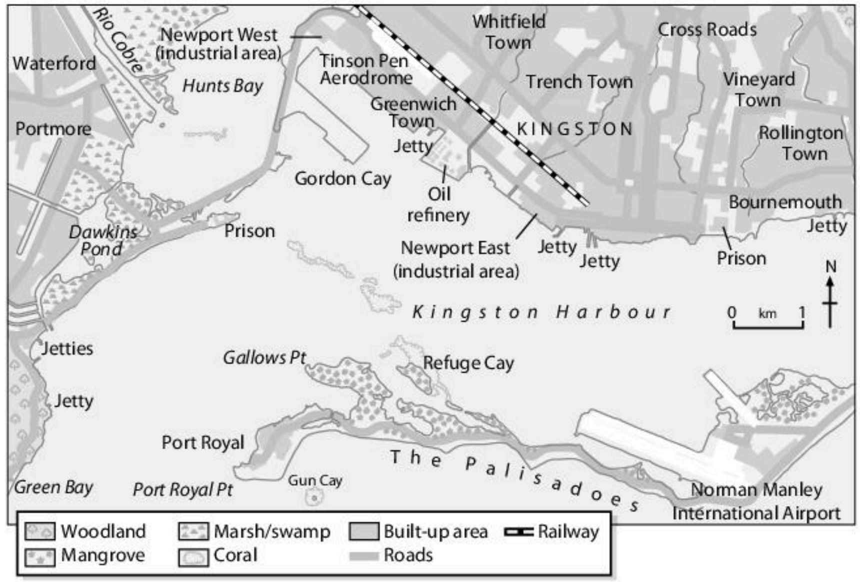


Figure 1 Kingston Harbour, Jamaica

g Using a named example, explain how the problem of environmental destruction of the mangroves is being tackled. You should outline at least THREE different methods in your answer. [6]

Total 26 marks

2 Study Table A.

a Explain how acid rain occurs. [4]

b Draw a bar graph to illustrate the figures in Table A. [4]

c Outline TWO possible impacts of acid rain on the island of Montserrat. [2]

d Explain the difference between deforestation and forest degradation. [2]

e Referring to named Caribbean countries, describe THREE effects of deforestation. [6]

f Give details of THREE ways in which the problems of forest destruction are being tackled in a named Caribbean country. [6]

Total 24 marks

Table A Per capita carbon dioxide emissions for Montserrat

Year	Carbon dioxide emissions (in thousand metric tons)
2000	13
2002	16.5
2004	18
2006	18
2008	22

Source: Carbon dioxide information analysis center

School-Based Assessment

Introduction

Geography means 'the study of the Earth'. Our knowledge of the Earth is based on descriptions by travellers who describe what they see in unique places. Additionally, we can collect information on many specific examples of a particular feature or phenomenon on the Earth. Geographers then try to explain the general pattern that emerges. They may be able to state the frequency with which the pattern will recur. They may also predict where other examples of the phenomenon are located. For example, an earthquake strikes at one place and does damage locally. Geographers study several of these earthquakes and record their locations on regional maps. They can then identify a pattern which shows that earthquakes occur at the edges of crustal plates.

Fieldwork describes what we encounter in the real world and is probably the most important work of geographers. Information is gathered and mapped so that spatial patterns can be interpreted.

The purpose of the School-Based Assessment

The School-Based Assessment (SBA) will help you to understand the knowledge that is presented to us in textbooks and other publications. You will be applying/checking all of the information, concepts and understandings that you had studied in your Geography classes in the field. The SBA also allows you to earn marks which are added to those you earn in the written examination.

You are expected to design a simple study, collect and present information that is relevant and arrive at a conclusion about your study, using no more than 1000 words.

Terms of a Geography SBA defined

Table of contents – list of chapters or sections in sequence and the page number at which each starts

Introduction – provides a clear focus for the study

Aim of study – the question that is being studied

Location – where the study is made which includes sketch maps and description of the location

Methodology – methods of gathering primary data and secondary data to support the study

Presentation of data – illustration of the data: maps, graphs, diagrams, photographs

Analysis of data – examination of the data used to find an answer to the question set in the Aim

Discussion of findings – well organised points using the data collected as evidence to answer the question set in the Aim of the study

Conclusion – your answer to the question that is being studied

Bibliography – the list of all sources of information that are used to support the study

Basis for SBAs

The SBA is included in your study of Geography to give you an opportunity to study a topic from the syllabus in more detail. You should choose a topic that will allow you to investigate a geographic feature to apply your geographic understanding and to demonstrate skills obtained in the course.

In selecting a topic for your SBA you must *read the syllabus*. Your school should provide a copy or you can obtain a copy at the CXC website. Use the following link: http://cxc-store.com/syllabuses-subject-reports/csec/humanities/geography.

Examine the objectives in the syllabus and select a feature of geographic interest in your community or in a place that you can reach easily to collect primary data. This is important. The SBA is being done to improve your understanding of geographic features near to you.

It is important to make sure that your topic of study is included in the syllabus. Decide on a topic that can be examined through fieldwork and additional reading. Perhaps there is a part of the syllabus that you are interested in studying. Ask yourself what is the most interesting section of the course. Are you most interested in physical geography or human geography? Go to one of the relevant chapters in this textbook and examine the SBA ideas at the end of the chapter. Is there a study that you find interesting? Do you have another idea based on the specific objectives in the Geography syllabus that you can relate to a feature in your community?

How to plan for the SBA

Now that you have selected a topic for study, how is the study to be done?

Planning with the Strategy Sheet

You will be asked to complete a Strategy Sheet because this exercise will help you to focus on planning to conduct the study. You have to make a simple plan of how you will conduct and present the study. Make sure you select a topic that you can complete on time. Then fill in the Strategy Sheet provided by the teacher. Your Strategy Sheet should be approved by your teacher before you go into the field.

What question is the basis of your topic?
Perhaps discussing the topic with a classmate can help you to identify a suitable question. Talk to your teacher for further assistance and check to make sure that the topic is in the syllabus. You may select from among the project ideas listed at the end of each chapter in this book. You could also study the specific objectives in the syllabus and create a question using one of these objectives. Make the idea specific by including the name of the particular feature and the village or town in which the study will take place.

What characteristics of the geographic features will you examine in your study?

- Read the chapter that is most closely related to your topic. Note the key geographic terms used which explain features associated with the topic.
- Examine the techniques that are used to present the data in that chapter. Are any special types of map, diagram, table or photograph used?
- With the help of your teachers, learn how to draw maps, diagrams and tables. You may consult a book on geographical fieldwork methods to learn the techniques that are used to investigate the topic and then you can plan what aspects of the feature you will investigate. Or you may be guided by your teacher on which techniques are to be used. This will help you to collect only the information that is needed in order to answer your study question.

How will you collect the data?

- Always record your data clearly and on a data gathering form that can be easily understood. This form should include the date, the weather conditions (if relevant), the location and any other observations on the day. If you are writing in the field, it is good practice to use a pencil and to keep the forms and maps in a waterproof pouch.
- Be consistent when recording data. Always use the same measurement units; for example, do not mix centimetres and inches when measuring features.
- Ask the teacher or a classmate to read and check the data collection form before you

begin collecting data. If you are collecting data with a group of classmates you should have a practice session in which you complete a sample form so that everyone knows exactly how it should be filled in. It is better to complete a few extra forms if there is time available.

- Always leave the site in as good a condition as you found it. Do not leave litter. Try to avoid disturbing the site. Do not remove plants or muddy the water in a stream.
- Do not go alone to some locations. Always think of safety first.

How will you present your data? In order to avoid collecting unnecessary data, consider what your study is about. What question are you trying to answer? What techniques will you use to present the data?

It should be possible to divide your study into four or five sections. For example, a study about how a geographic feature affects the people in a community might follow this pattern:

1 A description of the study location and some of the features of the problem.

2 The causes of the problem.

3 The effects of the problem on the people who live there.

4 The solutions adopted to treat the problem.

Dividing the main question into separate sections allows you to think about how the data will be collected – see Table 1. Choose at least two different types of illustration for your data, one type for each section. These illustrations include: sketch maps, charts, photographs, circle (pie) charts, line graphs, tables, or special illustrations related to the topic.

If you are including a bar graph or circle chart (pie chart), make sure that the questions you ask on your questionnaire can be illustrated by the graph. For example, the questions below could be asked but only answers to Questions A and B can be presented as a bar graph or pie chart. This cannot be done as easily with Question C because people may give many different answers.

A How does pollution from the factory affect people in the neighbourhood?

Coughing
Red eyes
Skin rashes
Other

B Does pollution from the factory affect your family?

Yes
No
Not sure

C What is done to reduce the effect of pollution from the factory?

What resources are available to you to do the fieldwork? Do you need copies of your questionnaire, photographs of the area, a detailed map of the area, permission to visit certain companies?

Who will accompany you in the field? It is best to work with at least one helper.

When will you collect the information? Will you work at weekends or after school? If you are interviewing farmers it may be best to visit in the afternoon.

Table 1 Example of a planning outline for data collection

Section of the study	Data to collect
Description of the problem	What is the size, location?
Causes of the problem	What are possible causes?
People affected	How many people are affected, when, why?
Solutions adopted	What is done to reduce the problem?

If you are conducting a town study, it is best to do some of the work during the week. It may be wise to plan your fieldwork during the school vacation so that you can work during the week.

What problems can occur while you are collecting primary data? The rain could fall on that day – do you have a raincoat and umbrella, or do you return on another day?

Do you need special equipment for collecting data? Try to get hold of any special equipment earlier than you need it. Take some time to learn how to use this equipment and how to take care of it in the field.

Is a letter of permission required? A company may require a letter from the school or advance notice of your visit before an interview is granted, or permission to use their library resources. Ask your teacher for assistance in requesting permission for a visit and interview. Send the letter as early as possible. Always be polite when speaking with the public and with private companies.

Presenting the SBA

Title page

Write your name, candidate number, title of study and name of school and year on the outside of an A4 size folder. Write the same information on the first inside page of the report.

Strategy Sheet

You will fill in the Strategy Sheet at the start of the study and submit it to your teacher for approval. Place it as the second page in your study.

Table of contents

This page lists the sections in your study. Write in the page numbers for the start of each section.

Introduction

A short statement giving an overview of and justification for the topic, and narrowing it to the location.

Aim of study

This is the question that your study will be based on. It states the specific geographic feature that is being studied and the name of the town or village in which the study is located. This is not required in the Introduction.

Location of study

Every geographic study is located somewhere. You should include a map to show how your study area is related to the major features in your country (Table 2). Trace a map of your country or territory from an atlas and put in the general features. Depending on the nature of the study, you may include some other important

Table 2 Features to include on a general location map

Topic of study	Special features to include
River in village	Main rivers, mountains, village
Transport	Main roads, mountains, plains, settlements
Settlement	Main towns, mountains, industries, rivers
Special vegetation	Other special vegetation areas
Industries	Ports, roads, towns, settlements, location of resources
Rainfall	Mountains
Agriculture	Markets, towns, roads, rivers, settlements

features on this map. All general location maps must include a title, location (at least one latitude and longitude line), direction (arrow showing North), relative size (approximate scale) and a legend or key to the symbols used.

As well as the general location map, you may present another map of the region – a large-scale sketch showing the exact sites where you collected the primary data for the study area. Include all relevant and important features at the site.

Data collection

Record how, when and where you collected the primary data for the study.

How?

State the methods used to collect the data. You may have used one method or a combination of methods to collect data. If you used an interview sheet or questionnaire, this can be attached at the end of the study as Appendix 1.

You may have used special equipment. Describe the equipment and the recording sheet used.

When?

State the days on which you collected data. You may also state the times and the weather conditions if this caused you to change how you did the study. Did you choose the rainy season or the dry season to collect the data? State why.

Where?

State the exact location of your study. You may state the street name, village, parish or county and country. Include in this section a statement on what makes the study important. Is it the wettest part of the country or the driest part? Is it a major agricultural district or is it not considered to be an agricultural district? Is it a major town or a minor town? Include any information that would help to explain why this study is being done in this area.

Data presentation and analysis

This is the main section of the study. The maps, illustrations and written account must all be presented as neatly as possible. Always check and re-check your work for grammatical errors or spelling mistakes.

Table 3 Suggested planning outline for data presentation and analysis of how a meander changes in a section of a river

Data gathering	Data analysis
Primary data The size, shape of river banks, particles in river bed	Description of a meander in the river
Primary data Measure river flow, discharge, volume, locating the fast current in the river	How the meander changes
Secondary data Geology map, land use map	Why the river features change
Primary data Interview residents about the river	Predicted changes

The illustrations must be presented so that the data can be easily understood. Place the illustration close to where you first mention it in the report. Have someone proofread this section for you.

Choose at least two different types of illustration to present your data, one type for each section. Table 3 gives an example showing how to organise your work.

Arrange the data to present well-developed points using information from the primary and secondary data that you have collected. These points must be organised into a logical sequence of ideas.

Conclusion

Your study is not complete until you have answered the study question or aim of the study. Make a statement to answer the question written as the aim of the study. You may include a short summary of the data collected.

Bibliography

It is polite to state the sources of your secondary information in the section called Bibliography. You may have used a textbook to find a definition, an atlas to trace a base map, or you may have read a newspaper report or visited a website while searching for secondary information. These sources must be listed alphabetically and include the author, year the book was published and the name of the book or article. Also include the references for the relevant internet materials used. The style that is appropriate is the MLA technique for presenting a bibliography.

Examples:

Rocke, J. & Ross, S. Essential Mapwork Skills for the Caribbean, Nelson Thornes, 2014.

Jamaica Government Survey Department, Kingston (map), 1:50,000, Jamaica, Sheet #18, Series 1, Metric Edition, 1- JSD/OSD, 1984.

The Discovery Channel Online. 2007. Volcanic Eruptions. Discovery Channel. 28 June 2007 ‹http://dsc.discovery.com›.

Waugh, D. & Bushell, T., Nelson Key Skills Geography for GCSE, Nelson Thornes, 2014.

Weigand, P. Oxford Caribbean Student's Atlas, Oxford Schools Publishers, 2010.

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Geography for CSEC®
2nd Edition

Geography for CSEC® 2nd Edition has been tailored to the requirements of the latest CSEC syllabus.

Written by a team of experienced Geography authors, this title focuses on areas relevant to Caribbean students with up-to-date information and detailed case studies. It provides key issues facing the Caribbean region and the wider world such as climate change, environmental degradation and disaster management.

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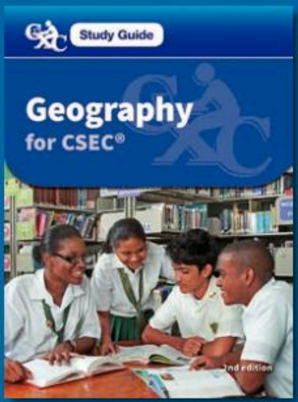

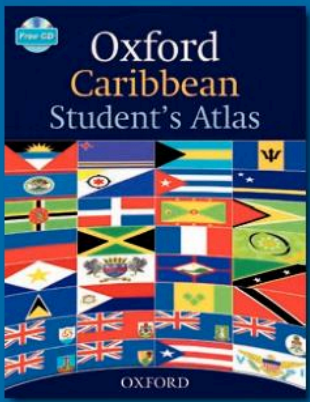

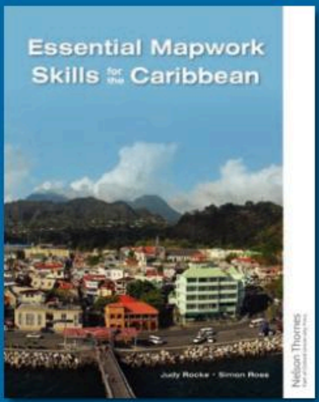

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