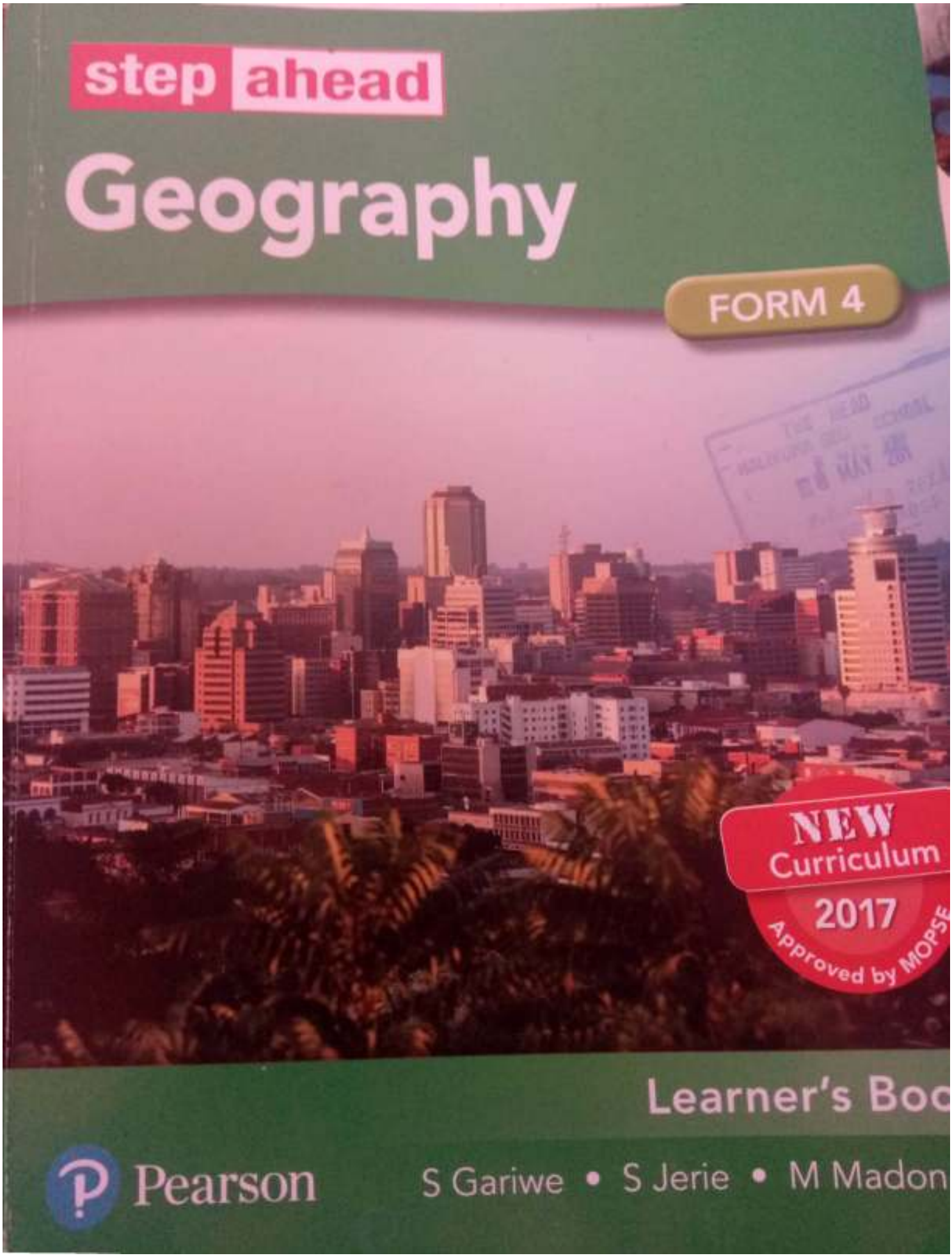

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Topic 1 Weather and climate

Objectives

By the end of this topic, you should be able to:

- describe the factors influencing the development and distribution of temperate depressions
- describe weather associated with different types of fronts
- discuss the distribution and development of tropical cyclones
- explain weather hazards associated with tropical cyclones
- identify human activities influencing climate
- describe the nature, causes and effects of climate change in Zimbabwe and the world at large
- identify ways of adaptation and mitigation against climate change.

Temperate depressions (temperate cyclones)

In Form 3 you learnt about air masses. An air mass is a body of air which is distinct from a neighbouring body of air, usually in terms of temperature or moisture differences. We will now look at that happens when different air masses come into contact with one another.

A temperate **depression**, also known as a temperate **cyclone**, is an area of atmospheric low pressure in the temperate regions. These depressions are associated with the collision of polar air masses and tropical air masses in the mid-latitudes. The mid-latitudes are found between the 40° and 60° lines of latitude, both north and south of the equator. This is where temperate depressions and their associated **fronts** form. Due to the rotation of the earth, air moves in a general clockwise direction in the southern hemisphere and in an anti-clockwise direction in the northern hemisphere around the depressions.

Depressions are characterised by warm and cold fronts, and they have a big impact on the weather conditions in the temperate regions. Depressions have varied weather conditions. To understand these, we will look at the formation of depressions and the fronts that form part of these depressions.

Formation of a depression

Depressions form as a result of friction between the cold polar air masses and the warm tropical air masses, where they meet in the mid-latitudes. This development is illustrated in Figure 1.1 showing the creation of a depression in the southern hemisphere.

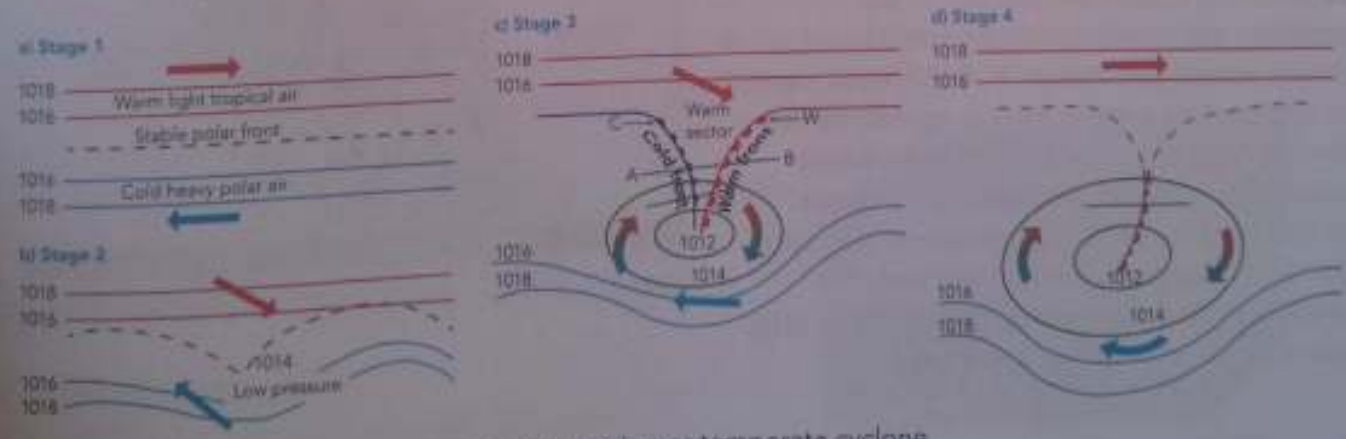


Figure 1.1 Stages in the formation of a depression or temperate cyclone

In Stage 1, there is a state of balance and so we have an undisturbed polar front.

With time, a disturbance along the front may create a bulge or wave as shown in Stage 2, and air pressure drops at the tip of the wave.

The low pressure so formed is characterised by a closed system of **isobars**, and since the system shown in Figure 1.1 is found in the southern hemisphere, a clockwise circulation of winds blowing around the centre of the system is created as shown in Stage 3. Once matured, the whole system begins to move from west to east. At this stage, separate fronts are created. As the tropical air moves, it rises over the cold polar air, creating a warm front marked W. At the rear of this front there is a section or wedge of tropical warm air masses called a warm sector (S). As the cold air pushes the warm air in the warm sector, it forces itself underneath the warm air, creating a cold front, marked C in Figure 1.2.

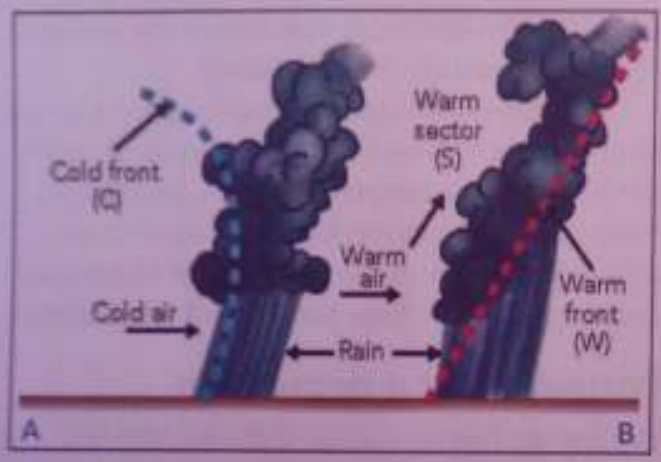


Figure 1.2 Cross-section of a depression or temperate cyclone at Stage 3

In Figure 1.2, three main features of the depression are shown, marked C (cold front), S (warm sector) and feature W is the warm front. The approach of a warm front is marked by the arrival of high cirrus clouds, which gradually thicken to become nimbostratus as the front part touching the ground approaches. This area experiences warm air that is rising and then moisture condensing to form light rains of long duration and generally dull weather.

Feature S, the warm sector, is associated with clear skies and warm, fine weather conditions. Feature C is the cold front. In this front, cold air undercuts and forces warm air up to form clouds of great vertical extent, such as cumulonimbus clouds that are associated with short-lived thunderstorms. As the cold front passes, there is very cold and overcast weather. As the depression moves from west to east, the cold front is moving faster than the warm front (think of the hands of a watch), and the cold front catches up with the warm front, forming an occlusion.

The distance between A and B in Figure 1.2 can range from a few kilometres to more than 1 000 km, and the warm sector can be as wide as 80 km.

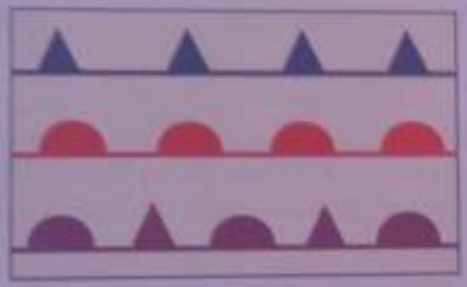
Figure 1.3 shows the occluded front of Stage 4. The occluded front occurs when the cold front catches up with the warm front and cold, dense air forces the warm air upwards. The warm air sector is no longer in contact with the ground. The occluded front is associated with overcast conditions, which brings cold weather and continuous rainfall due to the combination of cumulonimbus and nimbostratus clouds.

Figure 1.3 Cross-section of an occluded front (Stage 4)

Activity 1

1. What is a front?
2. Give the diagram below labels that explain the atmospheric features, as well as the climatic conditions. Give the diagram a heading.

3. Explain what the following symbols mean, and where you might find them.



4. Say if each of the following is true or false. If false, then give the correct answer.
   a) In the southern hemisphere, air circulates clockwise, just like the hands of a clock.
   b) A temperate depression is an area of high atmospheric pressure.
   c) Cold air is heavier and denser than warm air.
   d) Occluded fronts are linked to fine, sunny weather.
   e) Cirrus is a type of high cloud, and cumulus clouds often bring thunder and rain.
5. Use the diagram above to help you to describe the weather conditions experienced when a cold front passes over a place.

Frontal systems

An air mass is a large body of air with distinctive characteristics of temperature and **humidity**. The characteristics of air masses are determined by the source region. Those originating from land masses are referred to as **continental** and tend to be dry. Those from water surfaces are referred to as maritime and are generally moist. It is fairly uniform or homogeneous horizontally and covers large areas. As air masses move, they can sometimes collide. If air masses with different characteristics collide they do not mix freely with each other, but form a sloping boundary surface between them. We know that this is called a front.

Warm fronts

When a warm air mass advances on a colder air mass, the warm air will be forced to rise, because the cold air is denser. Rain will occur along the front, because the warm air often holds moisture and, as it cools, condensation occurs. This rain may occur across an area as wide as 360 kilometres as the front advances.

Warm front

Cold fronts

Cold fronts are more severe than warm fronts. Here, the cold air mass advances and pushes under a warm air mass, forcing it rapidly upwards. Cooling and condensation occurs, with heavy rain and even thunderstorms along the front. Typically, an area of up to 80 kilometres wide will experience heavy rain as the front moves over, with a sharp drop in temperature.

Cold front

In both hemispheres, frontal systems or depressions do not stand still. They move from west to east. The driving force is the global westerly wind system in each hemisphere. In the case of southern Africa, frontal systems pass over the subcontinent during the winter months (Figure 1.4). They bring sharp drops in temperature to South Africa, Lesotho, Swaziland and, if the system is very well developed, to Zimbabwe as well. Over the southern parts of South Africa and Lesotho, rain and snow on the mountains come from the passing of cold fronts.

Figure 1.4 A well developed cold front passes over southern Africa, leading to a drop in temperatures over Zimbabwe

Activity 2

1. Define an air mass.
2. Explain why different air masses do not mix freely.
3. Why do frontal systems move, rather than standing still over one place?
4. Name four southern African countries that are influenced by frontal systems during the winter.
5. Look again at Figure 1.4. Besides very cold weather, what else might Lesotho have experienced as the cold front passed over?
6. Keep a diary of weather conditions where you live for one week. For each day, record a one- or two-line description using the following table. You don't need weather instruments for this, you can just write a short description. At the end of the week, decide (yes or no) whether you think a frontal system might have passed over a) South Africa and b) Zimbabwe.

Date	Observation or description				
	Temperature	Cloud cover	Rainfall	Wind direction	Wind speed
Day 1					
Day 2					

Tropical cyclones

Tropical cyclones or tropical depressions are extreme low-pressure systems that form in tropical latitudes between 10° and 25° north and south of the equator. They form over oceans with sea surface temperatures of 27 °C or higher. The tropical cyclones are known by various local names. On the east coast of North America they are known as **hurricanes**, in the seas off China and Japan as **typhoons**, in the Indian ocean and east coast of Africa as cyclones and in the north of Australia as **Willy-Willies**.

Tropical cyclones are associated with strong winds that spiral towards the centre in an anti-clockwise direction in the northern hemisphere and clockwise in the southern hemisphere. During the cyclone season (summer) **meteorologists** give tropical cyclones names. Traditionally, these were always female names, with the first tropical

cyclone of the season having a name starting with A, the second with B and so on.

Figure 1.5 shows a cross-sectional view of a tropical cyclone, which can be used to describe the characteristic features of tropical cyclones. The winds spiral upwards in an area called a vortex, which surrounds the centre or the eye of the cyclone. The towering cumulonimbus clouds are associated with heavy rains and thunder. The high wind speeds and heavy rain associated with a tropical cyclone may cause serious damage to property, and even loss of life.

Figure 1.5 Cross-section of a tropical cyclone

Cyclones vary in diameter from 50 km to about 750 km. The size of the eye at the cyclone's centre varies between 15 km and 30 km across. The wind speeds around the eye can reach 200 km per hour and more.

The approach of a cyclone is usually accompanied at first by calm conditions, high air temperatures and high humidity. As the vortex approaches, dark clouds and gusty winds are experienced. The arrival of the vortex is accompanied by violent winds of great speed and torrential rains. When the eye of the cyclone passes over a place, calm conditions are experienced. The arrival of the rear of the vortex is characterised by violent winds, but the winds will be blowing in the opposite direction to that at the front of the vortex.

Figure 1.6 shows the typical tracks or paths of tropical cyclones, and the regions where tropical cyclones occur.

Cyclones generally move in a westerly direction, driven by tropical easterly winds. Note that moving air (wind) is named after the direction *from which it comes*. An easterly wind is therefore moving air in a westerly direction. A continued supply of moisture keeps the rising air around the vortices unstable, causing it to rise to great heights. Tropical cyclones start dying out as they reach the land (Figure 1.6) because the supply of warm moist air from above the ocean is lost, and there is greater friction between the moving air and the rough land surface. The area covered by the cyclone expands, but the wind drops, and rain becomes less.

Figure 1.6 Tropical cyclone tracks (red arrows) over southern Africa

Figure 1.7 Areas where tropical cyclones occur and the directions they follow

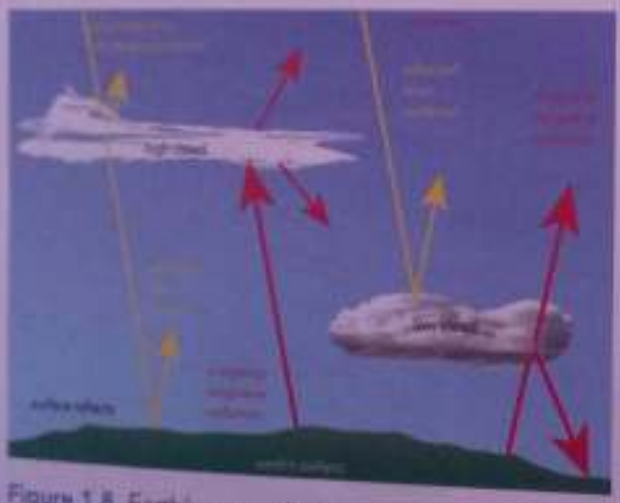


Figure 1.8 Earth's energy balance

Activity 3

1. How are tropical cyclones traditionally named?
2. In 1994 tropical cyclone Domoina brought flooding, destruction, and the loss of 242 lives to southern Africa. What number cyclone was Domoina in the 1984 tropical cyclone season?
3. Do some research and write some notes on the effects of tropical cyclones on people's lives. Look at cases that have occurred since 2000 in southern Africa, with one case outside southern Africa.
4. With the help of a diagram, describe and explain the nature of a tropical cyclone.
5. Look at Figure 1.7. Explain why the tracks of two of the tropical cyclones shown stop just short of Zimbabwe. Why does the third track stop south of Madagascar?

Human influence on climate

We have seen that weather and climate is very important to people. Humans may try to change the weather for their own benefit. More often, humans bring about change in the weather and climate unintentionally. Look at the following and think about possible reasons:

- Even though detailed climate records have only been kept for the past 400 years, twentieth century Earth surface temperatures were probably the warmest of any century in the past 1 000 years.

- The rate and duration of warming in the twentieth century was likely greater than in any of the previous nine centuries.
- The 1990s were the warmest decade on record.
- 2015 appears to have been the warmest year on record.
- The 11 warmest years of the past 140 have occurred since 1983.
- Average global surface temperatures have increased 0.4 to 0.8 degrees Celsius over the past 140 years.

Human activities contribute to climate change by causing changes to the Earth's atmosphere. The increase in so-called greenhouse gases, aerosols (small particles), and cloudiness all impact on atmospheric processes. The biggest contribution comes from the burning of fossil fuels such as coal and oil-based fuels. This in turn releases carbon dioxide gas to the atmosphere.

Greenhouse gases and aerosols affect climate by altering incoming solar **radiation** or insolation. Outgoing infrared (thermal) radiation is also affected. The Earth has an energy balance, where incoming and outgoing energy are equal (Figure 1.8). This is why atmospheric temperatures remain more or less constant. Changing the atmospheric abundance or properties of its gases and particles can lead to a warming or cooling of the climate system. At present, our concern is global warming, rather than cooling. We will look at this in more detail below.

Since the start of the **industrial era** (about 1750), the overall effect of human activities on climate has been a warming influence. Besides the increase in greenhouse gases, note also the important terms – afforestation (the planting of trees), deforestation (the clearing or destruction of natural forests) and **desertification**.

The human impact on climate during this era greatly exceeds that due to known changes in natural processes, such as solar changes and volcanic eruptions.

Here are some common direct and indirect impacts and the changes that they bring about:

Direct changes

- Farmers use heat from gas stoves or electrical heaters to prevent the occurrence of frost which might damage crops.
- Aviation workers use heaters to disperse fog and mist for better visibility as planes land and take off.
- People use cloud seeding to trigger rain by spraying **condensation** nuclei into clouds.
- People use cloud dispersants, such as silver iodide, to reduce the intensity of rain storms and to prevent the formation of hail stones.

Indirect changes

- Concrete and glass buildings absorb and trap heat, causing an increase in temperature, especially in urban areas.
- Smoke and gases produced by industry cause a **greenhouse effect** as they trap outgoing long-wave radiation, thereby leading to high temperatures in the troposphere.
- Motor vehicles also generate air pollution in terms of, mainly, carbon dioxide.
- Heat is released by machinery and power stations in urban centres, and by domestic use and central heating systems.
- Pollutants are released into the air from dust during farming and from industries, which then act as condensation nuclei to increase the chances of rain and fog.
- The use of **chlorofluorocarbons (CFCs)**, damages the atmosphere's **ozone layer**, which results in increased ultraviolet rays and general increased temperatures.
- The removal of vegetation creates bare surfaces with a high albedo (reflection), which impacts on local temperatures.
- Vegetated areas increase atmospheric humidity through evapotranspiration from the leaves of plants.
- Water bodies, like lakes, induce localised land and sea breezes, and frequent fog and rain in the surrounding areas. The building of large dams has the same effect. Lake Kariba is a southern African example.
- The process of desertification, often via overgrazing, leads to greater sand and soil movement by the wind. The moderating effect of vegetation on temperature is also lost.
- In developing countries, people rely on firewood and charcoal for fuel (Figure 1.9) which leads to vegetation loss and even desertification.

Figure 1.9 Firewood being sold for charcoal making. This leads to environmental degradation as more and more trees are cut down.

- Wind velocity may be reduced due to the construction of buildings, which act as wind breaks. However, air moving through narrow gaps between buildings will speed up, causing very high local wind speeds.
- Tall buildings can induce **orographic** uplift, which results in rain.

Activity 4

1. Explain the difference between direct and indirect changes impacting on the Earth's atmosphere.
2. Explain the difference between natural and human-induced changes impacting on the Earth's atmosphere.
3. Look at Figure 1.10. Identify the direct and indirect impacts shown in the figure under two headings (direct/natural impacts, and indirect/human-induced impacts).

Climate change

Changes to the Earth's atmosphere, either intentional or unintentional, give rise to climate change.

Nature, causes and effects of climate change

Climates have always changed over time but, over the past 100 years or so, human activities have accelerated climate change. The biggest driver of climate change is global warming. This means that the average temperature of the Earth's atmosphere and oceans is rising. A change in average temperature of just one or two degrees Celsius

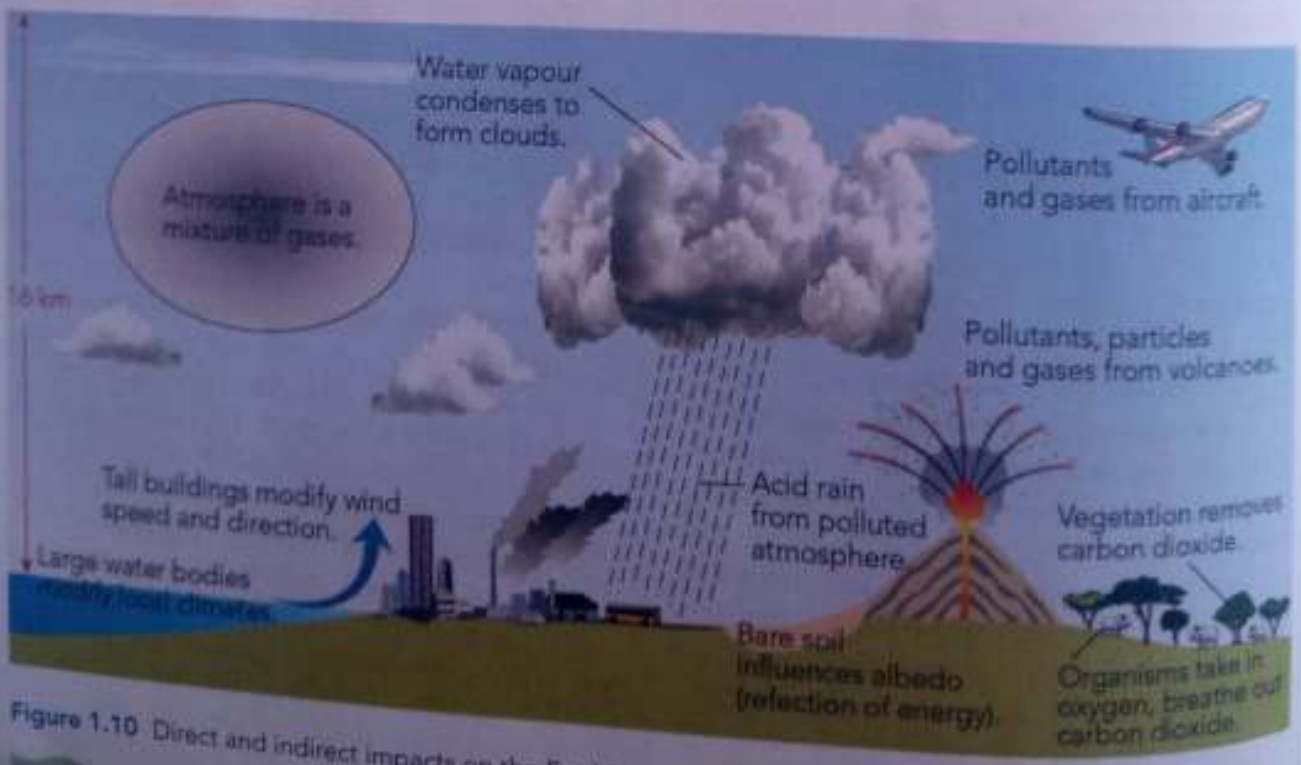


Figure 1.10 Direct and indirect impacts on the Earth's weather and climate

could have far-reaching impacts in the future. These would include rising sea levels, and changes to the Earth's weather and climate.

Causes

Natural causes of climate change have to do mainly with the Earth's orbital cycle around the Sun. Natural climate change follows a cycle ranging between very cold periods (ice ages) and warm periods, such as the one we are living in now. We will not discuss this in detail here. What we need to be concerned about is accelerated, human-driven climate change. We have looked at some of the ways in which humans influence climate above.

The main cause of human driven climate change is an increase in atmospheric carbon dioxide (CO_2) (Figure 1.11) from the burning of fossil fuels (coal and petroleum products). As the world's population has increased, and the demand for energy has increased, more and more carbon dioxide has been pumped into the atmosphere from factories, power stations and motor vehicles. More pollution in the atmosphere, and in particular more carbon dioxide (Figure 1.11), increases the greenhouse effect (Figure 1.8). We looked at this in detail under Human influence on climate on page 6. Other important greenhouse gases are methane and nitrous oxide. Instead of escaping into space, heat energy radiated by the Earth's surface is trapped in the atmosphere by greenhouse gases. This raises the temperature of the atmosphere and causes global warming.

Figure 1.11 Rising carbon dioxide levels and rising temperatures in the atmosphere

Vegetation acts as a natural sink for carbon dioxide. Plants, especially trees, take up carbon dioxide and give off oxygen (Figure 1.12). However, deforestation (see above) has damaged the Earth's rain forests.

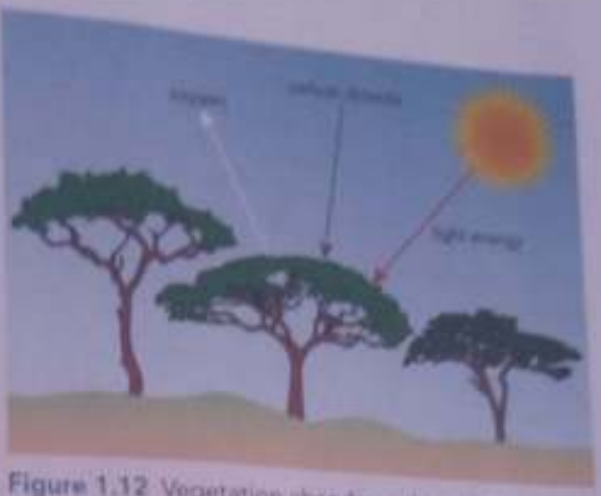


Figure 1.12 Vegetation absorbs carbon dioxide and releases oxygen

Effects of climate change

The most important effect of climate change is through global warming which impacts on climate and weather patterns. The impacts and effects of climate change are global; the whole Earth feels the impact of rising temperatures. The main effects include:

- rising sea levels as the sea water in warmed oceans expands, and ice at the poles melts
- melting glaciers which then retreat, or become smaller, and no longer feed rivers on which people rely
- drying up of some rivers, lakes and wetlands which are important to both people and nature
- habitat change for endangered or threatened wildlife, including tigers, elephants and penguins
- deforestation (loss of forests) and desertification (the spread of arid conditions)
- stress on agriculture and crop production in traditional food producing areas.

Adaptation to climatic change

Adaptation is the main way to deal with the impacts of changing climates. It involves taking practical actions to manage risks from climate impacts. This includes protecting people and their livelihoods.

Adaptation to climate change is very difficult. People may need to change the way they think about the use of resources and energy. In both developing and developed countries, people may not be happy about changes to the way they live and what they consume. Ways we can adapt include:

- making do with less, so that there are enough food and energy resources for a growing world population without having to follow practices which lead to increased global warming
- using alternative sources of energy, such as solar energy and wind energy, rather than burning wood and fossil fuels
- designing and building energy-efficient buildings and motor vehicles
- moving people from areas that might be threatened by, for example, rising sea levels.

Mitigation against climate change

Adaption and mitigation are closely linked. Mitigation means dealing with the causes of climate change. It involves efforts to make the impacts of climate change less severe. To mitigate climate change, we need to slow down global warming. To do this, we need to reduce carbon dioxide emissions into the atmosphere. The following can help in mitigating climate change:

- laws and international agreements regarding carbon dioxide emissions
- setting standards for vehicle exhaust emissions through more efficient petrol and diesel engines
- designing more efficient aircraft and jet engines
- carbon trading where nations who do not produce lots of carbon dioxide 'trade' with nations that do produce a lot of carbon dioxide.

Activity 5

1. Explain in your own words how the following things or activities contribute to climate change:
   - clearing forests for grazing of cattle
   - charcoal burning
   - increasing vehicle numbers in countries such as China and India.
2. What does mitigation mean? Explain why mitigation is necessary to try and control climate change, as well as some of the mitigation practices that can be put in place.
3. Identify the two alternative sources of energy that can help to lower carbon dioxide emissions:
   - coal
   - charcoal
   - wind
   - solar power
   - oil
   - wood burning.
4. Choose the correct word to complete each of the following statements:
   a) The number one greenhouse gas is _____. (nitrogen; oxygen; carbon dioxide)
   b) Small polluting particles are found in _____. (gas; soot; water vapour)
   c) An example of a fossil fuel is _____. (wind; coal; sunlight)
   d) A method of coping with climate change is _____. (adaption; degradation; combustion)
   e) Climate change is a _____. (rise in temperature; drop in temperature; rise or drop in temperature)

Summary

- Temperate depressions or temperate cyclones, as they are often called, are weather features associated with southern African weather.
- These features are driven by the westerly winds and move from west to east, either south of southern Africa (summer) or over southern Africa during the winter months.
- Temperate cyclones have a circular isobar pattern, with a low pressure in the centre.
- Air rotates (as do the associated fronts) in a clockwise direction around the central low pressure.
- Warm and cold fronts are associated with temperate cyclones. Cold fronts frequently pass over South Africa and Lesotho during the winter and even over Zimbabwe if the front is well developed.

- An occluded front occurs when a cold front catches up with the warm front which precedes it. In this way, the warm air sector is cut off, or occluded from the Earth's surface.
- The weather associated with temperate cyclones, and in particular the cold front phase, is a sharp drop in temperature as the cold air mass passes over, and cloudy, rainy conditions caused by the uplift of the warm moist air ahead of the cold front.
- Tropical cyclones are also low-pressure systems, with air rotating around the low-pressure centre in a clockwise direction in the southern hemisphere.
- In different parts of the world, they have different names, such as typhoon or hurricane.
- However, they move from east to west, driven by the easterly winds of the tropics.
- Tropical cyclones are accompanied by more severe weather than temperate cyclones. Very powerful winds and torrential rain cause hazardous conditions for both property and life. Over southern Africa, severe flooding in Mozambique and South Africa is not uncommon.
- Human activities are now recognised as having an influence and impact on climate, such that we speak of climate change, and global warming as temperatures rise.
- The burning of fossil fuels (coal and oil) is increasing the amount of carbon dioxide in the atmosphere.
- This in turn impacts on the Earth's energy balance, such that heat is trapped in the atmosphere (instead of escaping into space) and warming the atmosphere.
- Clearing of forests and trees makes things worse, as vegetation helps to absorb the greenhouse gas carbon dioxide.
- Adaptation to climate change, and mitigating against climate change (reducing its impacts) are important at both a local (Zimbabwean) and global scale.

Glossary

chlorofluorocarbons (CFCs) – a group of compounds which contain elements chlorine, fluorine and carbon usually produced by aerosol sprays, refrigeration, air conditioning systems and some solvents

condensation – process by which a substance changes from a vapour to a liquid state through cooling

continental – influenced by the land

cyclone – low-pressure system or air mass where pressure decrease is intense

depression – low-pressure system such as that associated with fronts in the temperate regions

desertification – the spread of desert-like conditions of aridity and sparse vegetation

fluvial – to do with running water and rivers

front – a boundary between two air masses of different temperature

greenhouse effect – the heating effect on the atmosphere caused by outgoing long-wave radiation, which is blocked more easily than incoming short-wave radiation

humidity – moisture content of the air

hurricane – another name for tropical cyclones, used in America

industrial era or revolution – the time, starting in Europe about 250 years ago, when human activity shifted dramatically from farming to industry

isobar – line on a map joining places of equal atmospheric pressure

isotherm – line on a map joining places of equal temperature

meteorologist – person who studies and forecasts weather

orographic – the forced ascent of air due to relief resulting in rainfall

ozone layer – a layer in the upper atmosphere where ozone is found in higher concentration; ozone gas absorbs most of the ultraviolet radiation from the sun

radiation – heat energy given out by the Sun or sent back by the Earth

typhoon – see hurricane or cyclone

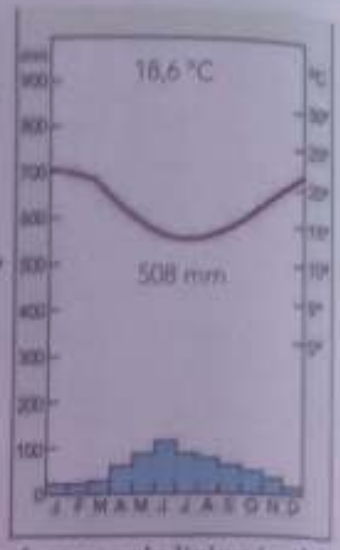
Willy-Willies - another name for tropical cyclones used in Australia

Topic test 1

1. The description of a climatic feature is given as an intense low-pressure area, which develops on the eastern parts of continents accompanied by thunder, lighting and highly destructive winds. Which of the following best describes this feature?
   A temperate depression
   B tornado
   C tropical cyclone
   D whirlwind.
2. The following are associated with the formation of temperate fronts, except:
   A friction of cold and warm air masses
   B formation of a low pressure system
   C intense rising of warm air
   D formation of a warm sector.
3. The following are names of tropical cyclones, except:
   A typhoons
   B hurricanes
   C Willy-Willies
   D tornadoes.
4. Which of the following gases helps to reduce global warming?
   A aerosols
   B ozone
   C carbon dioxide
   D volcanic dust.
5. The diagram below shows a depression in the northern hemisphere.

   a) What is a front?
   b) Name the fronts marked X and Y.
   c) Describe the weather conditions associated with the warm sector and the front marked X.
   d) With the aid of a diagram, describe any two rainfall types you have studied.
   e) Suggest possible actions one can take to reduce the effects of flooding in an area prone to floods.

6. The graph shows temperature and rainfall patterns for a place in Africa.



   a) What name is given to the above diagram?
   b) Describe the climatic characteristics of the place shown by the graph.
   c) What challenges face people living in this climatic type?
7. a) Describe the characteristic features of a tropical cyclone.
   b) Suggest measures that could be taken by a government to reduce the effects of a cyclone.
8. Describe giving examples how human activities bring about an increase in the green house effect.
9. a) What is climate change?
   b) Describe how human activities have contributed to climate change.
   c) Suggest four ways to deal with the negative causes of climate change.
10. Look at the following diagrams, A and B, and answer the questions that follow.

    a. What is pictured in diagram A?
    b. What useful function would have been performed by the vegetation in A?
    c. What has happened in diagram B and why might this have happened?
    d. How might the atmosphere respond as a result of the human activity that resulted in B?
    e. Could this happen in Zimbabwe? Explain your answer.

Topic 2

Landforms and landscape processes

Objectives

By the end of this topic, you should be able to:

- describe the nature of seasonal water flow in rivers
- explain river processes in shaping the landscape
- describe landforms resulting from river processes
- describe the characteristics of arid and semi-arid regions
- explain the distribution of arid and semi-arid regions
- explain the processes of wind action
- describe the landforms resulting from wind action
- describe the hazards associated with landform development
- identify methods of disaster risk management of volcanoes, earthquake flooding and mass wasting.

Landforms resulting from water action and river processes

Much of the rain that falls on the land ends up in rivers. As rivers flow, they use some of their energy to change the landscape through which they flow. Rivers erode, transport and deposit sediment and soil. In so doing, different landforms are created. These landforms make up the physical landscape that you see around you. Running water is the most important agent of erosion in Africa. We will look at how rivers erode, transport and deposit their loads to create landforms.

Seasonal flow of rivers

Almost all of southern Africa, including Zimbabwe, receives its rain during the summer months. Large rivers, or rivers which get their water from distant sources with all year round rain, may flow all year round. However, many

Figure 2.1 Seasonal changes in water volume in the middle course of the Zambezi River

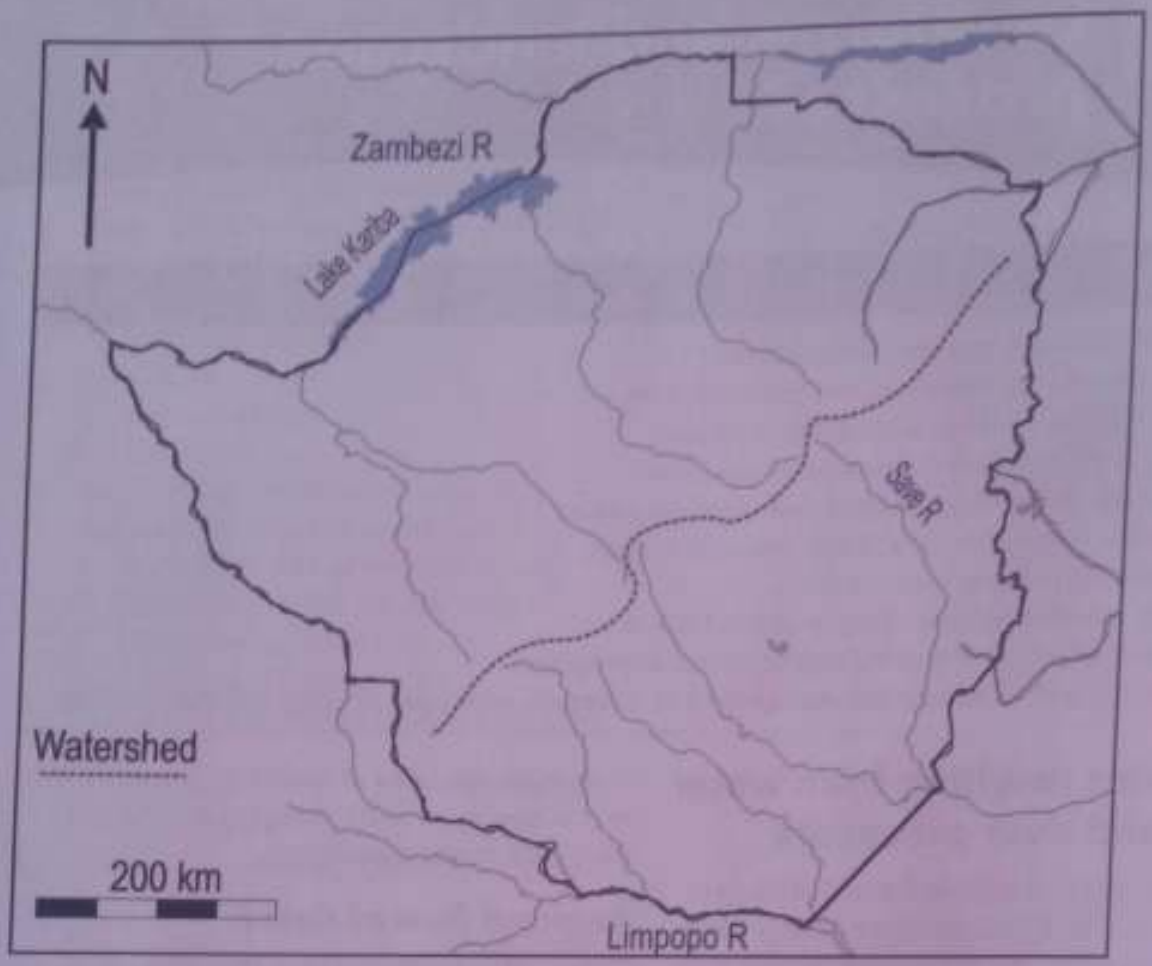


Figure 2.2 Main rivers of Zimbabwe. Note the directions in which these river flow.

of southern Africa's rivers carry little or no water during the dry season. Look at Figure 2.1 which shows how the volume of water in the middle course of the Zambezi changes with the seasons. All Zimbabwe's rivers carry more water in the summer months than in the winter.

Zimbabwe's main rivers, as shown in Figure 2.2, are:

- The Zambezi, which forms a natural border between Zimbabwe and Zambia to the north. Zimbabwean rivers draining into the Zambezi have a general northward flow. The Zambezi is Africa's fourth largest river and flows all year round. There is much more water in the river during the rainy season, between November and March/April.
- The Limpopo in the south, which forms a natural border with South Africa. Zimbabwean rivers draining into the Limpopo have a generally southward flow. The upper parts of the Limpopo are seasonal, and rainfall is unreliable. In dry years, the upper parts of the river may flow for only 40 or so days in the year. The further downstream, the more water there is. During very wet periods, flooding can occur in the Limpopo basin, for example, the severe floods of 2000.
- The Save River which rises in the middle of Zimbabwe and flows in a south-easterly direction into Mozambique.

Now that you have been introduced to Zimbabwe's main rivers, we will look at the characteristics of river basins, the processes which operate when running water is present, and the landforms which result from **fluvial** processes.

The features of river basins

Look at Figure 2.3 which shows the main features of river basins.

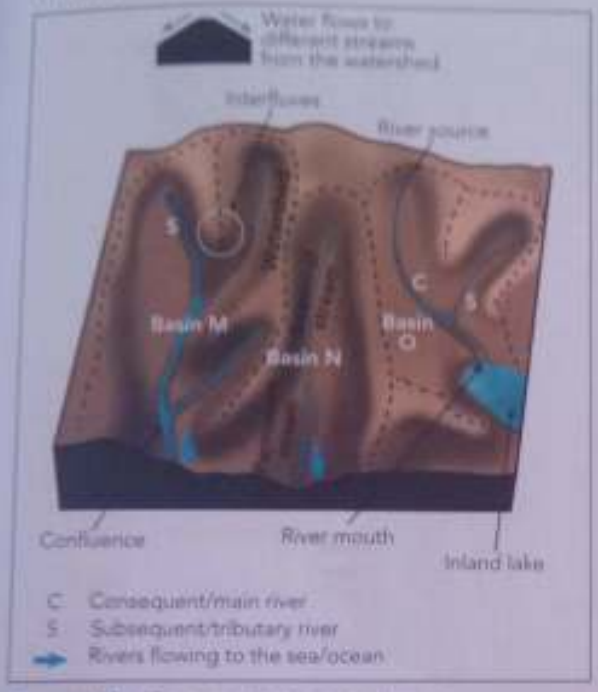


Figure 2.3 Features of drainage basins

A river basin is the area drained by a network of streams. It is also called a drainage basin or catchment area. In Figure 2.3 there are three drainage basins labelled M, N and O. Each drainage basin is separated from the one next to it by an imaginary line called a **watershed** or water divide. In each basin, there is a main river, which is the **consequent stream** since it forms because of water flowing over the original slope of the land. The consequent (C) is joined by **subsequents** or tributary streams (S). Obsequent streams flow in the opposite direction to the dip of rocks. The point at which a tributary joins the main river is the **confluence**.

Each **stream** has a starting point called the source. The **river source** can be a **spring**, from which water comes out of the ground and flows as a stream. It may be melting ice or a glacier. The source can also be water flowing from a lake or a swampy area. The point where the river ends or discharges its water is the **river mouth**. The route followed by a river from source to mouth is its course. Figure 2.3 shows two types of basins. Basin O drains into an inland lake and is therefore called an inland or endorheic drainage

Figure 2.4 Major catchment areas in Zimbabwe

basin. Basins M and N are external basins, since the rivers flow to the sea. The river in basin N flows for part of the year as a seasonal or intermittent stream in the upper part of the basin. In the lower part, it flows throughout the year as a permanent or perennial stream.

Interfluves are highlands separating river valleys and define the watersheds.

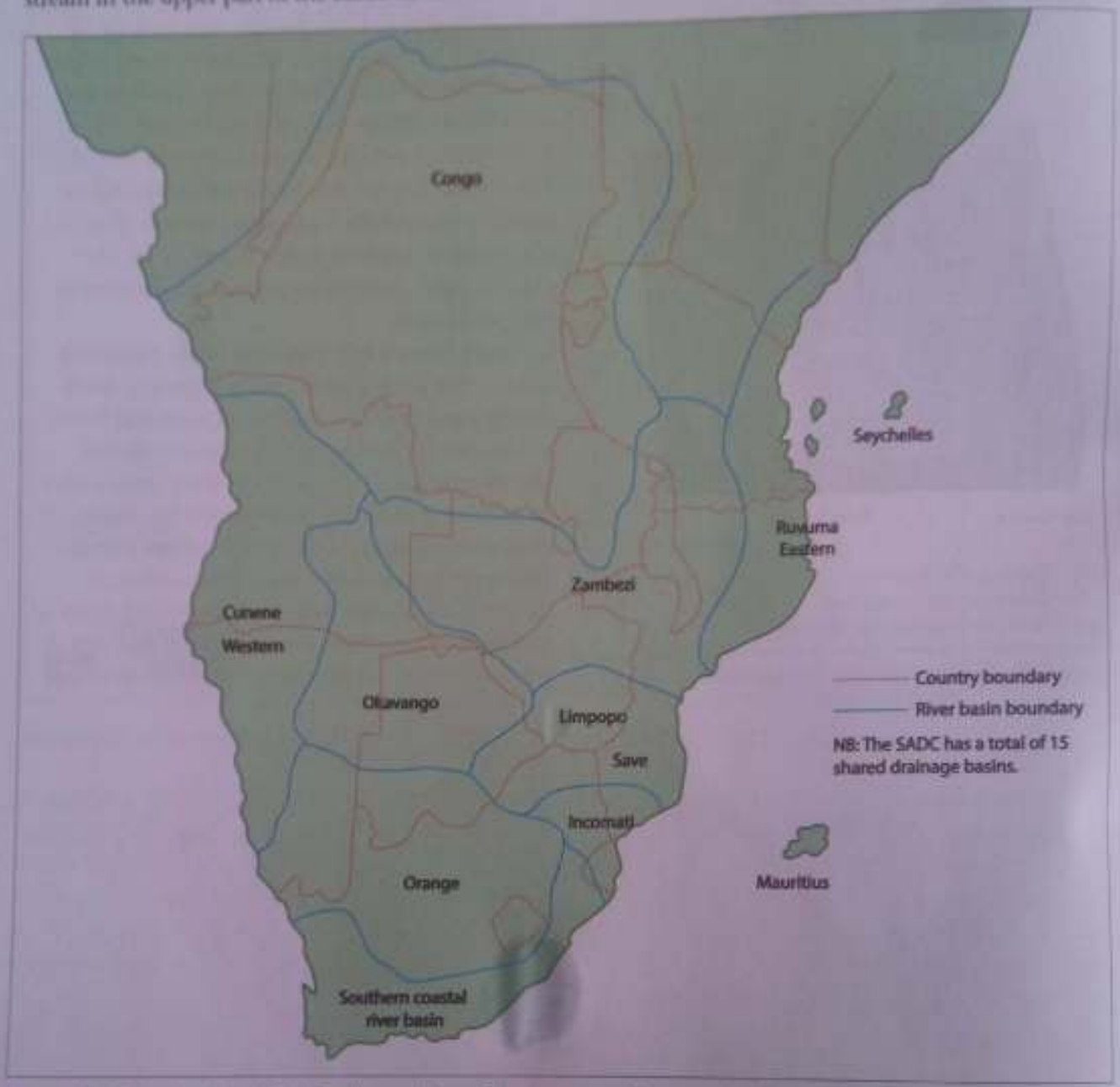


Figure 2.5 River basins of the Southern African Development Community (SADC) countries

Figure 2.6 Major river basins in Africa

Activity 1

This activity will help you to develop your ability to extract information from maps, and draw relevant diagrams and interpret them. Use the information provided in Figures 2.4, 2.5 and 2.6 as well as any other information you can find. Refer also to your atlas.

1. Complete the following by filling in the missing information:

From the central watershed in Zimbabwe (Figure 2.4), rivers generally flow northward to the ___ Basin and ___ to the Limpopo-Save Basin as shown in Figure 2.5. The ___ River in western Zimbabwe flows in the Mkagadikgadi Lake in Botswana as part of the ___ Basin, which is an inland drainage basin similar to the Chad Basin shown in Figure 2.6. River basins may cover many countries. For example, the Nile shown in Figure 2.6 is one of the world's longest rivers (6 115 km) and crosses nine countries, which are Egypt, ___, ___, ___, ___, ___, ___, ___ and Sudan. (Refer to your atlas.)

2. Use Figure 2.5 to draw up a table to show the nine major river basins and the riparian states they cover. A riparian state is one that covers part of a river basin, usually sharing it with other countries. Provinces, districts and wards can be riparian. The table should look like the one shown alongside, which uses the example of the Orange River Basin.

Basin name	Riparian states	Total number
1 The Orange River Basin	Botswana, South Africa, Namibia, Lesotho	4
2		
3		
4		
5		
6		
7		
8		
9		

3. a) Draw an outline map of Zimbabwe, similar to Figure 2.4, but with catchment boundaries only. Draw a bar graph to show the mean annual runoff within each named catchment.

   b) Using the map provided, and using the key on Figure 2.4, draw a pie chart to show total mean annual runoff for Zimbabwe. Provide a suitable title and key.

4. Briefly comment on the relationship between rainfall and the surface drainage system in Africa shown in Figure 2.6.

Drainage patterns

Rivers within a basin or part of a basin form a network of streams. The term used to describe this network of streams is drainage pattern. The drainage pattern shows the influence of the underlying rock and the slope of the land. Common drainage patterns include dendritic, radial, centripetal, trellis and parallel.

Dendritic drainage

The term 'dendritic' comes from the Greek word *dendron* (a tree). The various streams branch or join one another like the branches of a tree (Figure 2.7).

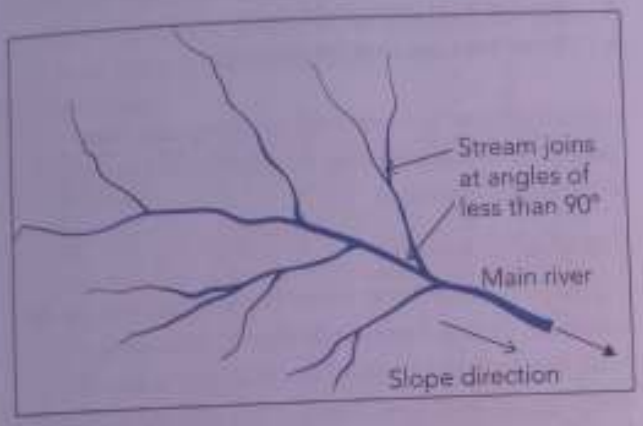


Figure 2.7 Dendritic drainage pattern

Dendritic drainage is a common pattern that can be identified on most topographical maps of Zimbabwe. The conditions necessary for its development include gently sloping ground and areas of the same rock type (homogenous geology) or with rocks of uniform resistance to erosion.

Radial drainage

This drainage pattern is formed where streams drain from a central highland in all directions. It is also termed centrifugal or divergent drainage. A radial drainage pattern is common on conical hills and domes (Figure 2.8).

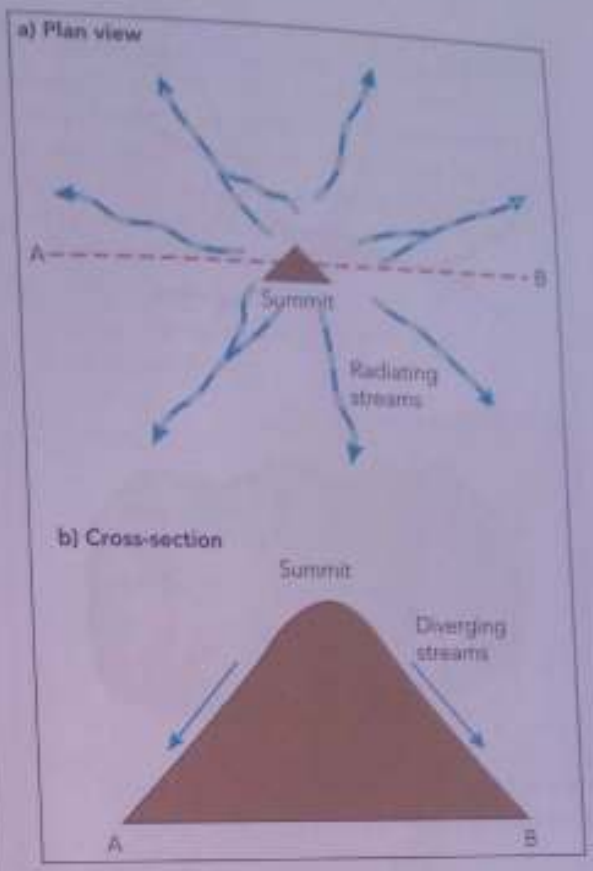


Figure 2.8 Radial drainage pattern

Radial drainage tends to be localised to features like volcanic cones and other features with a conical shape, and therefore the watershed is at the summit. Streams radiating from the summit can end up forming another pattern such as dendritic. The major condition for the development of radial drainage is a dome-shaped hill or mountain. In Zimbabwe, radial drainage is common in areas with granitic domes that are still covered by soil.

Centripetal or convergent drainage pattern

In this type of drainage, rivers drain towards the centre of a lake, a **swamp** or depression. It is the opposite of radial drainage. Centripetal drainage is essentially an inland drainage system. It is common on inland depressions such as faulted **intermontane** basins and calderas, as well as in arid and semi-arid areas.

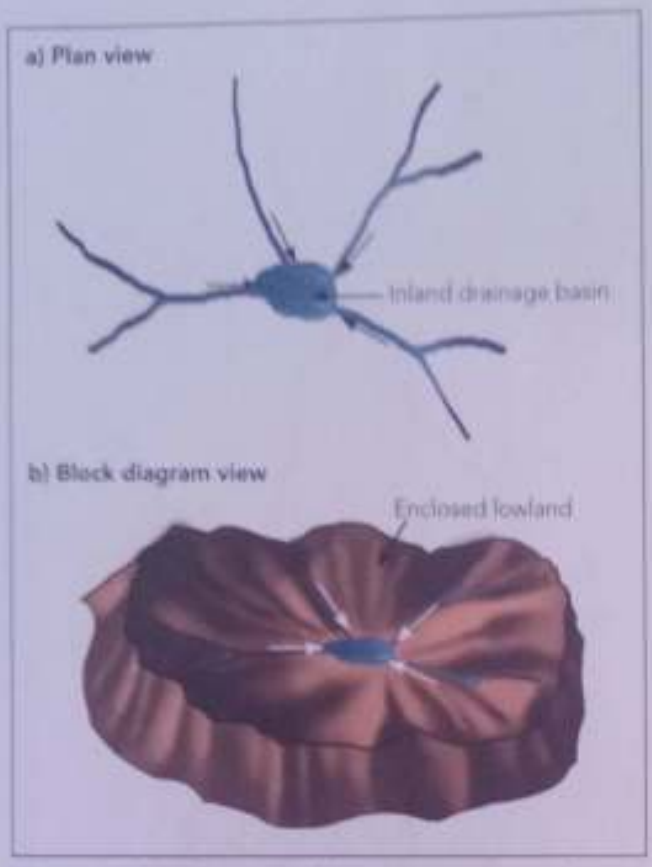
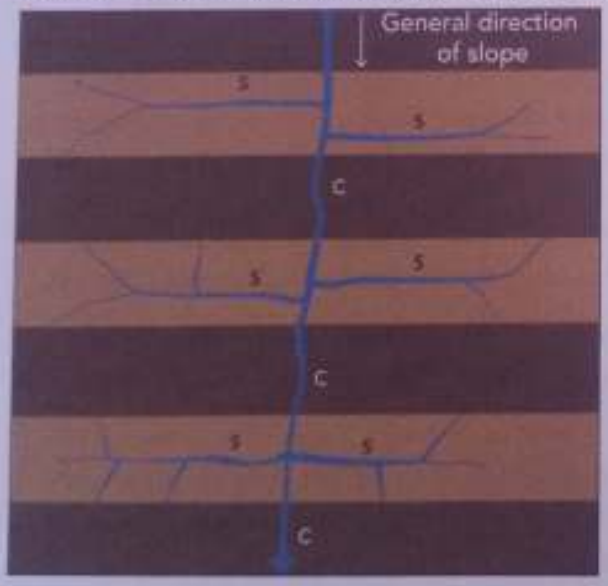


Figure 2.9 a) Centripetal drainage pattern and b) centripetal drainage on a caldera

Trellis or trellised drainage

Trellis drainage forms where streams join one another at right angles, as shown in Figure 2.10.



Consequent/main stream
Subsequent/tributary
Hard rock
Soft rock

Figure 2.10 Trellis drainage pattern

Trellis drainage develops in areas of alternate hard and soft rock. The main stream or consequent, as shown in Figure 2.10, follows the initial direction of the slope. The subsequents or tributaries then develop along the soft rock to join the main stream at right angles. The tributaries are in turn joined by other tributaries, also at more or less right angles. Streams that flow against the general dip of rock strata are termed obsequent streams. Trellis drainage is found in the Chimanimani mountains, where it has been governed by alternate bands of softer schists and hard quartzite. Other conditions for the development of trellis drainage are:

- fault lines or rectangular joints
- eroded fold mountain areas
- headward erosion by streams.

It is important to note that faulting can cause nearly all streams to join at right angles leading to rectangular drainage.

Parallel drainage

Figure 2.11 shows the south bank tributaries of the Zambezi, in the Zambezi National Park area, that flow more or less parallel to each other. Parallel drainage, in this case, has been encouraged by the gentle slope leading to the Zambezi River.

Figure 2.11 Parallel drainage, Zambezi National Park

The flow of water in streams

Rivers always flow down the slope (downstream) due to gravity. The volume and speed of flowing water changes from time to time and from place to place.

Stream velocity and stream discharge

The speed at which water flows along the stream **channel** is called the **stream velocity**. It is measured as the distance travelled by flowing water in a given time, for example, 10 m/s or 0,5 km/h. The amount, given as volume of water passing across a given section of the channel, is termed **stream discharge**. It is measured in cubic metres per second. Stream discharge, and therefore stream velocity, are measured at gauging stations that have been built on the major rivers in Zimbabwe.

Project

As a class project, carry out fieldwork to measure flow velocity and discharge around or near your school.

1. Where to go?
   Choose a section of a small stream channel or an open concrete storm drainage way, as illustrated below (Figure 2.12).

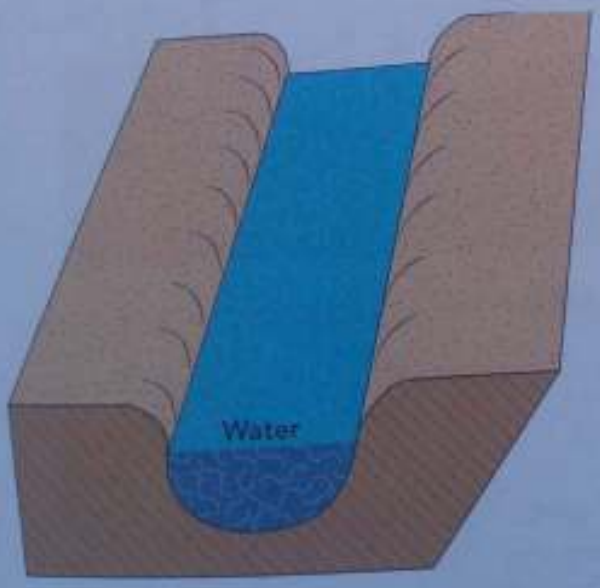


Figure 2.12 Straight stretch of channel (5–20 m)

It must be shallow, less than 1,5 m to avoid drowning and to enable crossing. Choose a solid smooth bed with little or no vegetation for easy movement of people and floater. The bed should not be swampy or have polluted sections, which are a hazard.

2. When to go?
   After the rainy season, but when there is still flowing water.

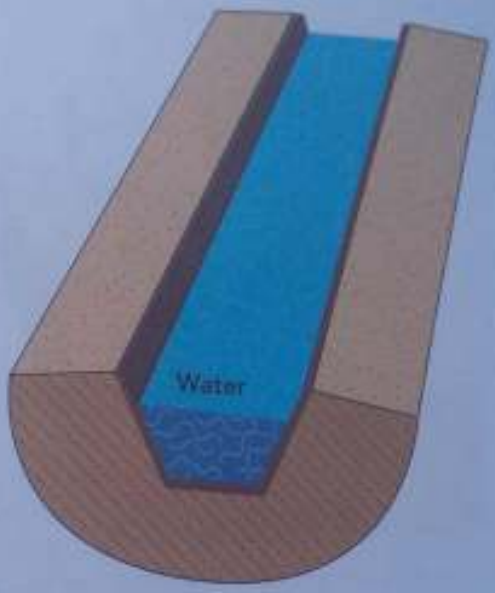


Figure 2.13 Straight open concrete drainage (5–20 m)

Choose any sizeable drainage way, and go just after heavy rains or storm (preparation and timing are important).

3. Equipment required
   - stopwatch to record the time taken by the floater to move along the channel section being studied
   - floater, for example, orange peel or empty match box
   - metre ruler, ranging poles/straight rods of up to 3 m long, measuring tape and/or strong rope to measure length, width and depth

- appropriate outdoor clothing, for example, gumboots
- first aid kit, field notebooks and pencils/pens.

4. How to measure what?
Figure 2.14 below illustrates the different elements to be measured on a channel. The procedures should be even easier on the drainage way.

A. Length, width and velocity

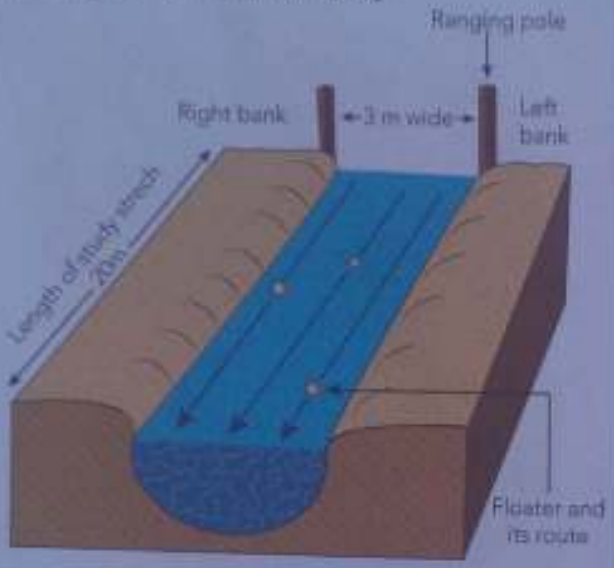


Figure 2.14 Measurement of different river elements

Channel width is measured by stretching the measuring tape tight over the water surface from one bank to another, for example, 3 m (300 cm).

Channel length is measured along the channel with tape as shown, for example, 20 m (2 000 cm).

Velocity is measured by recording the time taken by the floater to move down the length of the channel being studied. Repeat the float runs a few times (up to four) making sure the starting positions are near the banks and in the middle of the channel, as indicated in the diagram. The floater thrower (upstream) and time-keeper (downstream) should be within shouting and seeing distance of each other.

Velocity is calculated by dividing the distance with average time taken by the floater.

$(v = \frac{\text{distance}}{\text{time}} = \text{m/s})$

Let us use the following information to show how the average velocity is calculated.

Average time = $\frac{60}{6}$ s = 10 s

Velocity = $\frac{20}{10}$ s = 2 m/s or 200 cm/s

This means the water travels a distance of 2 m in 1 s. It should be noted that since the surface water flows faster than the water beneath, it is more accurate to divide the average time taken by 0,85. This gives a more accurate velocity reading across the whole section. The method described here gives a rough estimate of the time taken and hence the velocity and discharge.

B. Depth, wetted perimeter and cross-sectional area

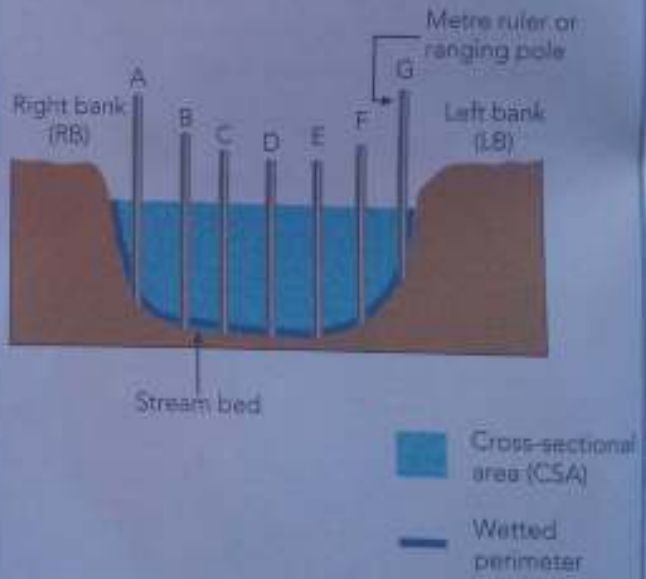


Figure 2.15 Measurement of different river elements

The channel depths are measured at regular positions (A to G in the diagram) across the channel at the downstream end of the section being studied. Note that this necessitates wading across the channel and the average depth of the channel is measured from the various depths. In the diagram above, the measurements may be as follows:

Average depth = $\frac{970}{7}$ = 140 cm

The wetted perimeter is the length of the channel bottom that is under water, that is, from point RB down to the channel bed and to point LB in the diagram below. The perimeter can be found by laying a strong and heavy rope or chain down along the channel from one bank to the other. The cross-section of the channel that is bounded by the wetted perimeter and the water surface is called the cross-sectional area (CSA). Though there are other methods of calculating the CSA, a simple approach is:

CSA = w × d

In our example, CSA = 300 cm × 140 cm
= 420 000 cm

(Remember, we are using the width of 300 cm as an example.)

C. Calculating stream discharge

Once we have the velocity and cross-sectional area of the channel, we can easily determine how much water passes through this section at any given time. This is the discharge or volume of the stream. Discharge is calculated as = CSA × v.

In the example we are working with:

Discharge = 420 000 cm^2 × 200 cm/s
(CSA) (velocity)
= 8 400 000 cm^3/s (in m^3 ÷ 1 000 000)
= 8,4 m^3/s

This example would be a fast-flowing stream.

Annual discharge pattern/river regime

Figure 2.16 shows the annual discharge for major African rivers. The graphs that show change in discharge over time are termed hydrographs. The term river regime is also used for the changes in discharge shown on the hydrograph, especially over one year.

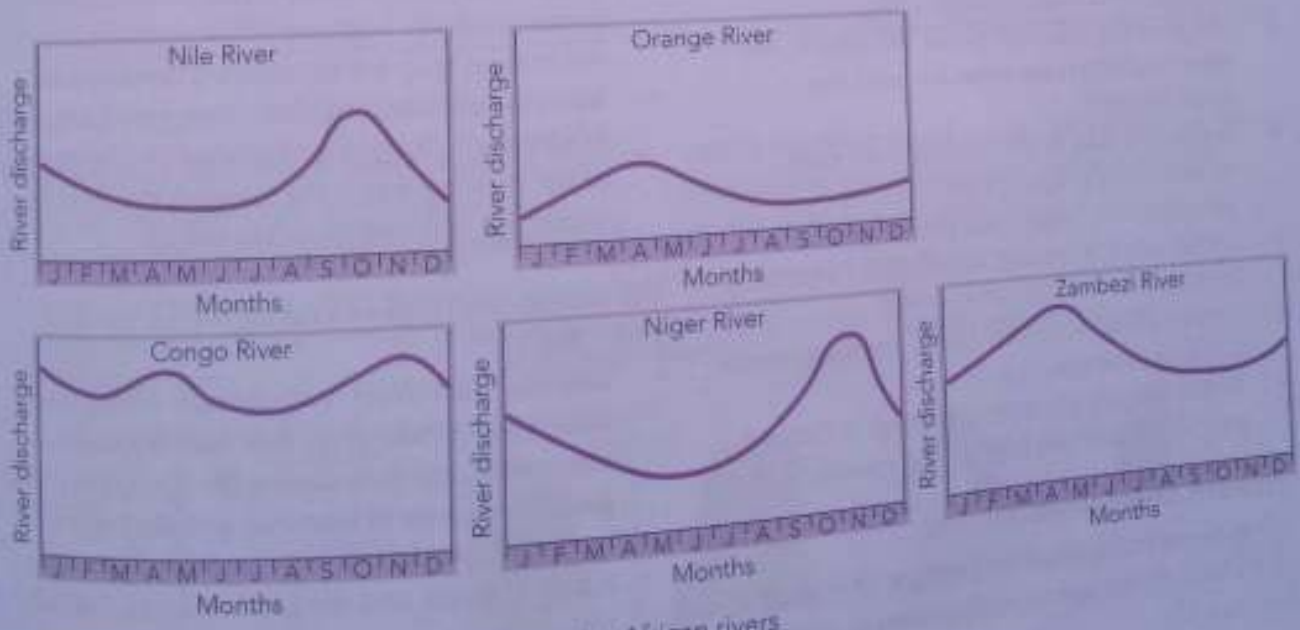


Figure 2.16 Annual discharge patterns for major African rivers

Activity 2

1. Compare and explain the discharge pattern of the major African rivers shown in Figure 2.16.
2. Add any other factors you can think of to the factors affecting river discharge given below.

Identify similar and different flow patterns	Describe how they compare	Give reasons for the flow patterns
1. Niger and Nile (similar)	Peak: Sept–Oct Low: Apr–Jun	Just after summer rains in NH Low rainfall/dry season
2. Zambezi and Orange (similar)	Peak: Mar–Apr Low: Jun–Sep	After summer rains in SH Dry season/low rainfall
3. Niger–Nile pattern vs. Zambezi–Orange pattern (different)	Peak: when the other has low discharge	Different wet and dry seasons in NH vs. SH.
4. Congo River (different)	Double peak in Mar–Apr and Sep–Oct Slight decrease Jan and Jul Has the largest discharge	High rainfall when sun is overhead Slight decrease in rainfall. Equatorial climate/rain throughout the year

Why the volume of water in rivers changes from time to time and from place to place

The volume of water changes for the following reasons:

- Climate: dry or wet or snow-melt periods, or wet throughout the year
- Size of drainage basin: contributions of tributaries and perennial streams are due to changes in rainfall
- Shape of the drainage basin: this affects the time it takes stream water to enter the main channel
- Seepage or loss: rivers flowing over areas of porous rock (absorption), **deserts** (evaporation), vegetation (interception)
- Urban areas: increased runoff into rivers from hard surfaces
- Other human activities: dams, farming, exotic forest plantations
- Position along the river: discharge is limited near the source but high at the mouth.

Stream transport

The material transported by a stream or river makes up its load. Rivers transport their load in four ways (Figure 2.17):

- solution (solution/dissolved load): salts and certain chemicals from rocks such as shale are dissolved in the river water. This load cannot be seen, but if the water evaporates, this load will be precipitated, usually as a fine white deposit.
- suspension (suspended load): fine sand, silt and clay are suspended in the water, giving the river a muddy colour if there is sufficient fine material in suspension.
- saltation (saltation load): small pebbles and very coarse sand will hop and bounce off the bed of the river as they are transported downstream.
- traction (traction/bed load): heavy pebbles and boulders are dragged and pushed by the power of the moving water; the stronger the flow, the bigger the bed load boulders will be.

The amount and type of load carried by the river varies due to:

- seasons: most rivers flow strongly during the rainy season (whenever that may be) with reduced (or no) flow during the dry season. The greatest amount of material, and the biggest material (boulders) will be carried when there is lots of water, and the greatest energy in the river.
- type of rock: some rock types do not erode easily, and contribute little to the river's load.

while easily erodible rock such as shale will contribute lots of material.

- condition of the surface in terms of vegetation: vegetated surfaces yield less in terms of eroded material than do bare surfaces, which are more vulnerable to erosion.
- human impacts: careful land management practices protect vulnerable surfaces, while irresponsible land use, be it agriculture, mining, building or any other practice, can contribute to erosion and the material which ends up in streams and rivers

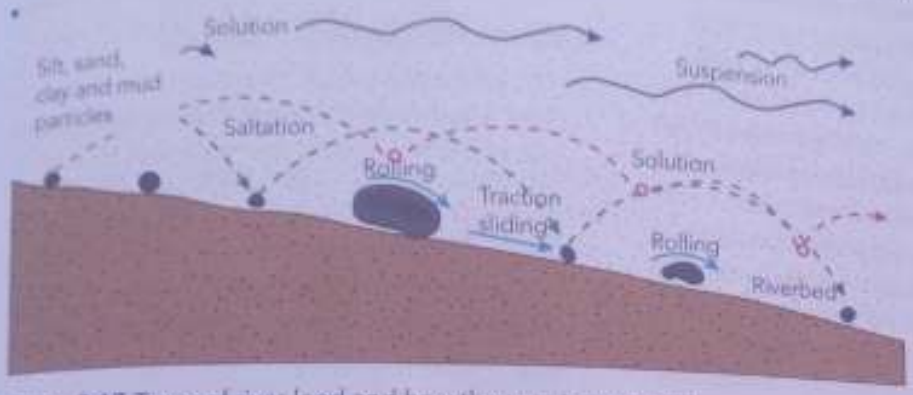


Figure 2.17 Types of river load and how they are transported

Activity 3

Fill in the missing words using information from Figure 2.17.

1. When water dissolves rock, it carries the material in _____, which makes up the dissolved load. The undissolved material carried within the body of moving water is the _____ load. Small stones and pebbles are carried along in a series of hops and jumps by a process termed _____. Larger materials, such as rocks, small boulders and logs, which are too heavy to carry in suspension, constitute the _____ or _____ load. These materials are either turned along over and over in a process called _____, or dragged along through the process of _____ or _____.

River erosion

The removal of material by rivers becomes possible when the water has overcome friction and is flowing. In other words, erosion is possible due to excess energy over and above that used to overcome friction and carry the stream load. The erosion occurs in three directions (Figure 2.18)

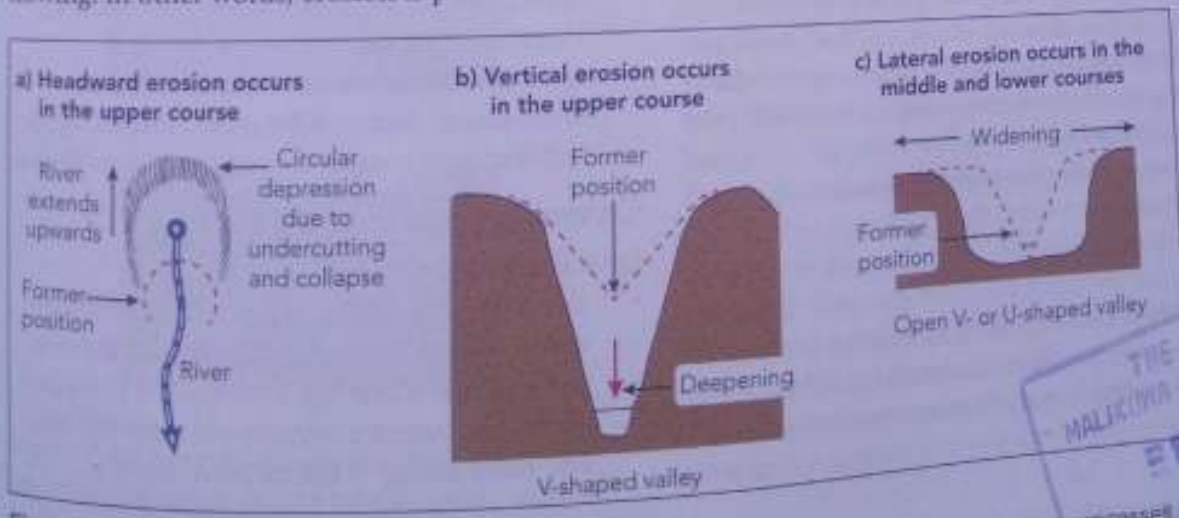


Figure 2.18 Directions of river erosion

The appearance of a river valley, whether as a steep-sided V-shape or open U-shape, is the result of the balance between vertical and lateral erosion. Where vertical erosion is greater than lateral erosion, valleys tend to be steep-sided. The reverse is also true. For a river to extend its channel length (headward erosion), or to extend its channel's depth (vertical erosion), or to extend its width (lateral erosion), it has to erode the rocks making up the bed or banks. This is done through the following processes:

- *Hydraulic action*: The sheer force of the moving water detaches and plucks loose and solid rock particles from the channel bed and banks.
- *Abrasion or corrasion*: This process occurs when channel bed and bank materials are scraped off, ground away and scoured by solid material carried by the river.
- *Potholing*: Erosion caused by abrasion results in potholes. Potholes are round holes drilled into solid bedrock by pebbles and stones due to the swirling or circular movement of water associated with turbulent flow (Figure 2.18).
- *Corrosion or solution*: River water dissolves rock particles through chemical weathering processes such as solution and hydrolysis.
- *Attrition*: Solid materials carried by the river hit against each other and break into smaller particles. The particles cause further erosion when they hit against the banks and bed, thereby scouring more materials while breaking up even further.

River deposition

A decrease in flow velocity reduces the ability of a river to transport its load. As a result, the river starts to drop or deposit the sediment it is carrying. Fluvial deposits of any size and shape are called **alluvium**. Deposition occurs in any of the following places along the course of the river:

- the channel bed
- the river valley floor during floods
- the banks
- the mouth.

As velocity decreases, coarse materials are deposited first, and finer materials last. This process is called sorting. Sorting also occurs when the river selectively picks up and transports material according to its velocity.

Factors influencing the river's ability to erode, transport and deposit its load

The factors influencing the river's ability to erode, transport and deposit its load are discussed below.

Gradient of channel

- The gradient through which the river waters flow determines the amount of energy a river has available to erode and transport its load.
- The upper course of the river has a steeper gradient; therefore the fast-flowing waters possess more energy.
- The middle and lower courses of the river have a gentler gradient; therefore the slow-moving waters have less energy.
- As far as gradient of channel is concerned, the upper courses of rivers have more energy to erode and transport compared to the middle and lower courses.

Volume/discharge

- Holding gradient constant, the greater the volume of water, the more energy there is for the river to use.
- Upper-course rivers have smaller volumes because their only source of water is overland flow, generated in the immediate vicinity, and channel precipitation. Therefore, they have less energy.
- Middle- and lower-course rivers/sections, on the other hand, have higher volumes due to the fact that they obtain their waters from upstream tributaries, overland flow generated in the immediate vicinity and channel precipitation. Therefore, they have more energy.
- As far as volume is concerned, middle- and lower-course streams have more energy to erode and transport compared to upper-course streams.

Channel shape in cross-section

Look at Figure 2.19 below.

- The channel (a) has a larger 'wetted perimeter', which is the cross-sectional length of the river bed and banks that the river water is in contact with. This means it experiences more friction, and more energy is lost to overcome this.

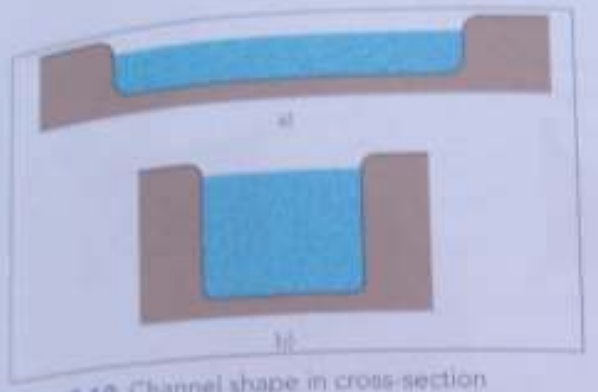


Figure 2.19 Channel shape in cross-section

- Channel (a) has less energy than channel (b). The latter has a small, wetted perimeter/cross-sectional length. This means it experiences less friction and less energy is lost in overcoming this. Therefore, as far as channel shape is concerned, channel (b) has more energy compared to channel (a).
- The narrow and deep channels represented by channel (b) are typical of upper-course streams, and the wide and shallow channels represented by channel (a) are typical of middle- and lower-course streams.
- As far as channel shape in cross-section is concerned, upper-course streams have more energy to erode banks and bed, and transport their load, compared to the middle and lower courses.

Channel roughness

Look at Figure 2.20 below.

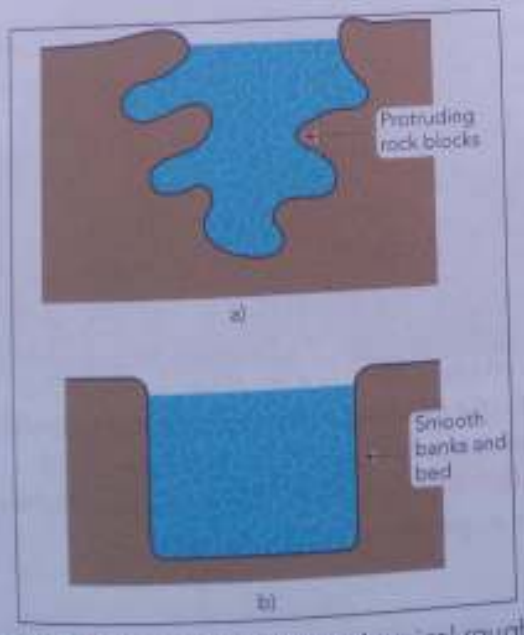


Figure 2.20 Channel roughness: a) typical rough upper-course stream and b) typical middle- and lower-course streams

a) Upper-course streams encounter more friction due to the very rough channels caused by protruding boulders and rocky outlines. This means such channels have less energy to erode and transport.

b) Middle- and lower-course streams encounter less friction because the banks and bed are smooth. This means such channels have more energy to erode and transport.

When all four factors interplay, as occurs in nature, the middle and lower courses have more energy to erode and transport. The approach used above assumes the factors work independently, which is not the case in nature. The conclusion that the upper course of a river has less energy explains why most of the fluvial or river features found in this part of a river show the dominance of vertical erosion. The middle and the lower courses of a river show the dominance of lateral erosion, because they have more energy.

Characteristics of river valleys

River valleys can be studied from two perspectives. First, the **long profile**, which is the cross-section along the length of the river from the source to the mouth. Second, the **short profile**, which is the cross-section across the river valley from crest line through the channel to crest line. This is commonly called the river valley. Refer to Figure 2.21, which shows the relationship between the short profile and the channel. The channel is within the river valley. While there is only one long profile of the river, the short profiles are infinite since they represent cross-sections across any point of the river valley. Figure 2.21 shows the general changes in the long and short profile of rivers.

Short profiles tend to change from V-shaped valleys to open-wide valleys with increasing distance from the source or headwaters to the mouth. The long profile shows a concave slope that is steeper in the headwater area, becoming gentler towards the mouth. The **base level** is the lowest point to which a river can erode its channel. The sea level is the usual base level, although dams, natural lakes and the existence of hard rock can create a local base level. Rivers cannot erode below their base level.

Table 2.1 summarises the features common in the three major sections of a river as shown in Figure 2.21.

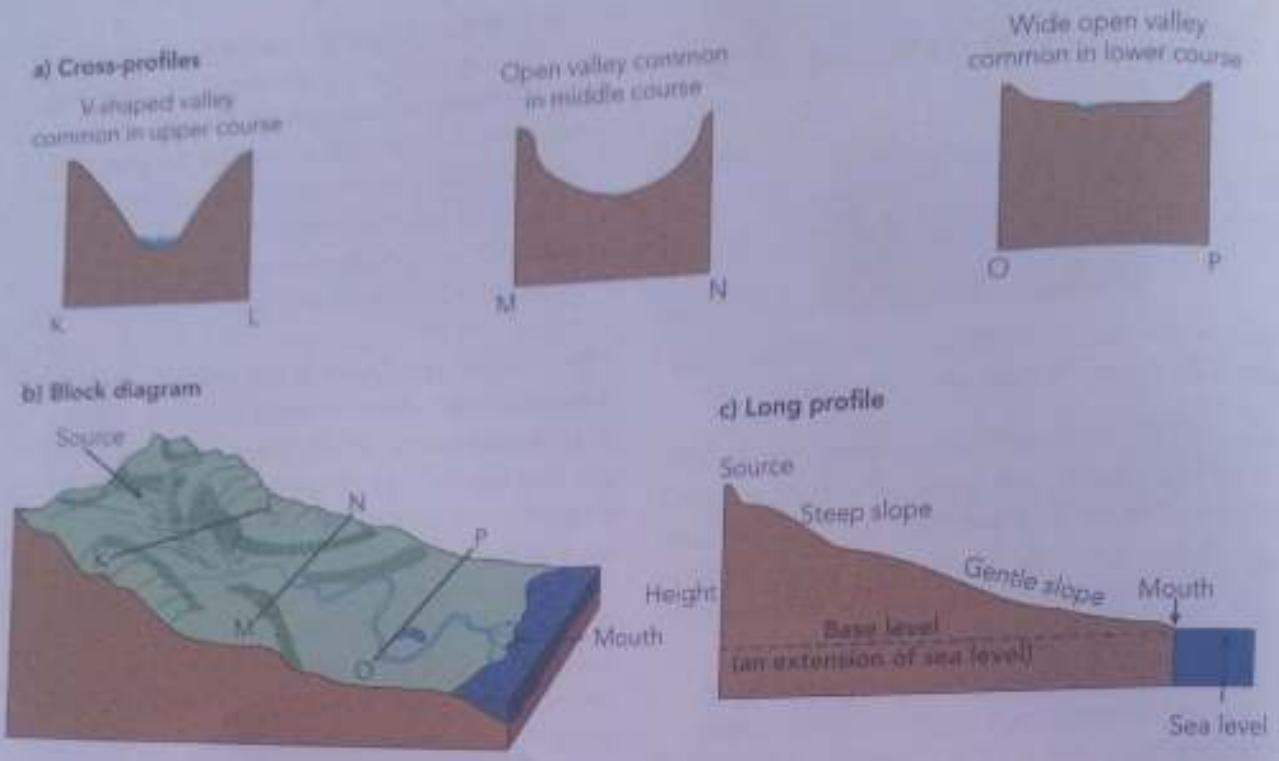


Figure 2.21 Variations in long and short profiles of a river

Table 2.1 Features common in major sections/reaches of rivers

Course	Common features
Upper course/or headwater reaches	V-shaped valleys, potholes, interlocking spurs, gorges, rapids, waterfalls; due mostly to vertical erosion
Middle course/reaches	Open V-shaped valleys, truncated spurs, meanders; mostly due to lateral erosion
Lower course/reaches	Flood-plain features, for example, bluffs, natural levees, raised beds, alluvial fans, deferred junctions, braiding, swamps, deltas; mostly due to deposition

Note that although specific features are given as occurring in specific sections or reaches of the river (Table 2.1), these features can occur in any part of the river course as long as the conditions necessary for their formation are met.

Features common in the upper course

Rivers flowing in mountainous and hilly areas erode vertically and may have little energy to perform lateral (sideways) erosion.

Potholes

These are circular holes scoured into solid bedrock by pebbles and stones carried by the river. The rough bed encourages turbulent flow where stones are caught up in swirling currents and scour holes in the channel bed. The conditions for the formation of potholes include turbulent flow (due to the steep, rough bed) and a solid bedrock **river load** comprising stones and pebbles.

Turbulent flow is a situation where water moves as a series of vertical and horizontal eddies, as illustrated in Figure 2.22. The opposite of turbulent flow is laminar flow, in which the water moves in parallel straight currents.

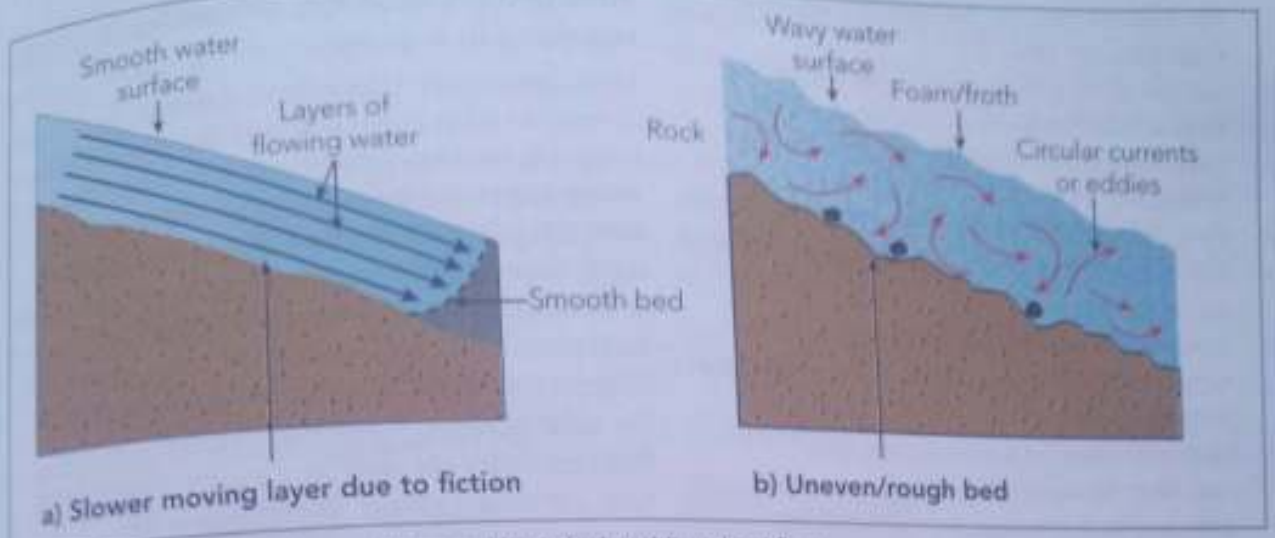


Figure 2.22 a) Laminar/layered flow and b) turbulent/disturbed flow

Interlocking spurs

Since the discharge in the upper reaches is small, streams avoid obstacles and follow areas of softer rock with the least resistance. The course of the river will twist and turn resulting in interlocking spurs as shown in Figure 2.23.

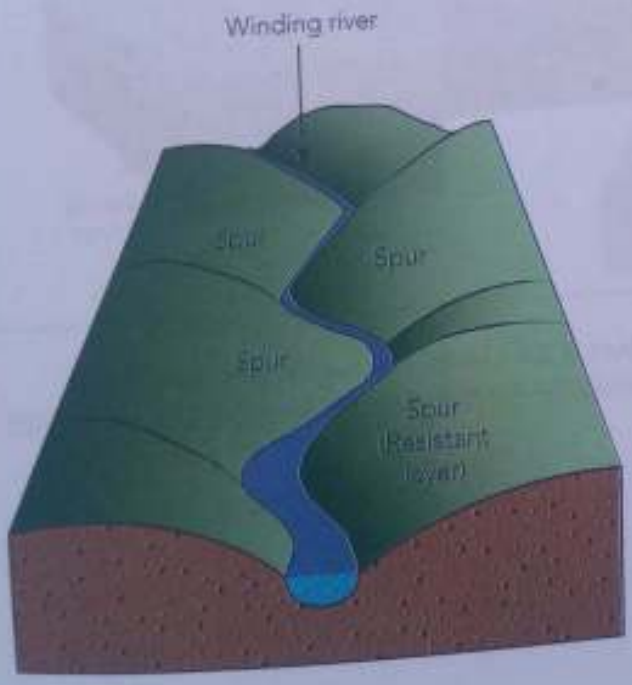


Figure 2.23 Interlocking spurs

The conditions for the formation of interlocking spurs include:

- fast-flowing water
- limited discharge off slopes
- occurrence of weak and resistant areas of rock (different rock types).

Narrow steep-sided valleys

Water flowing in small volumes in steep-sided areas erodes vertically. In their upper course, such rivers often carry coarse bed loads. As a result, the river valley is steep sided and V-shaped as shown in Figure 2.24.

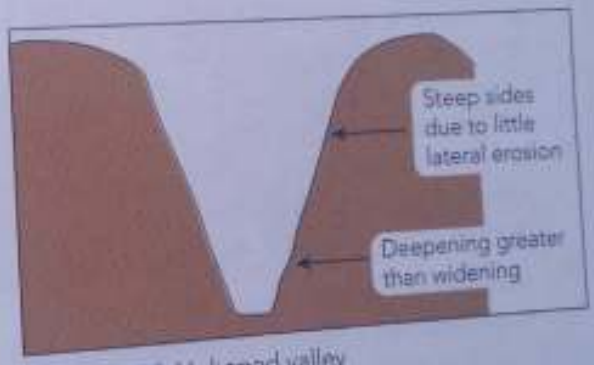


Figure 2.24 V-shaped valley

Gorges

Gorges are river valleys bounded by more or less vertically upstanding rock walls due to severe down-cutting, with little lateral erosion. In the upper course, gorges form where the rock is too resistant to allow any opening up of the valley. Only vertical down-cutting is possible. Gorges form as a result of the following conditions:

- vertical erosion in resistant rock, for example, the Lupata Gorges cut in resistant rhyolite rock in the lower Zambezi
- fault lines present zones of weakness that can easily be eroded. The gorges downstream of

the Victoria Falls on the Zambezi are good examples. See Table 2.2.

- vertical erosion in areas of uplift where the land surface has been moved upwards by crustal forces, for example, the Dande Gorge in Figure 2.25
- upstream retreat of a waterfall
- collapse of underground caverns in limestone areas
- down-cutting or incision of the predator or victor stream in river capture, for example, the Pungwe Gorge
- vertical erosion on a once-buried hard rock layer by an existing stream through superimposed drainage, for example, the Mutorashanga River in Figure 2.26
- vertical erosion as a river passes through a desert or semi-arid area where there is little mass movement to open up the valley.

Activity 4

1. For each of the conditions leading to the formation of gorges given below:
   a) research how the gorge forms
   b) illustrate the process of formation using diagrams and an example from Zimbabwe and elsewhere.
2. Return to the conditions promoting the formation of gorges and describe and illustrate how gorges are formed.

The examples of the erosion of once-buried rock (superimposed rock) and up-faulted areas (antecedence) are given below as guidance on how to present your findings.

Antecedent drainage caused by faulting resulting in a gorge

Rivers such as the Dande River (Figure 2.25) formed on a landscape before (ante) it was lifted following faulting. Antecedent drainage forms where a river continues to flow along its course even if it is passing through an area undergoing uplift through faulting or folding. Normal faulting occurred with the formation of the Zambezi Escarpment, but the Dande River maintained its original course and was able to erode deeply into the uplifted block. Rivers that descend into the Zambezi Valley through the Zambezi Escarpment have cut similar gorges. These include the Hunyani, Sanyati and Chizarira Gorges.

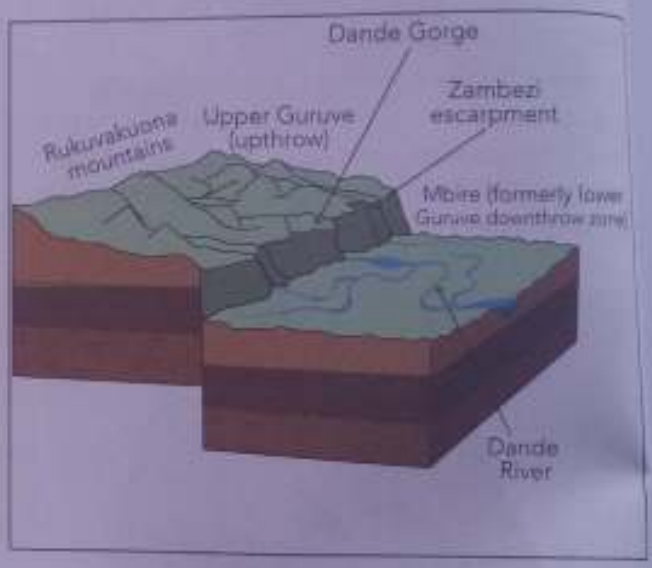


Figure 2.25 Gorge associated with faulting (Antecedence: The Dande Gorge) as a block diagram

Superimposition resulting in a gorge-like valley: Example the Mutorashanga Pass

Rivers that continue to erode through underlying hard rock, even well after the removal of overlying rock on which they initially flowed, are superimposed on the new layer. The process of superimposition and how it results in gorge-like valleys is shown in Figure 2.26. In both the Dande and Mutorashanga Gorges, headward erosion assisted the process.

Rapids and waterfalls

Rapids and waterfalls occur where there is a sudden drop in the elevation of a river or channel. Waterfalls reflect a steeper gradient than rapids. Cataracts are a series of rapids occurring in a given stretch of a river. The appearance and process of formation of rapids and waterfalls are summarised in Table 2.2.

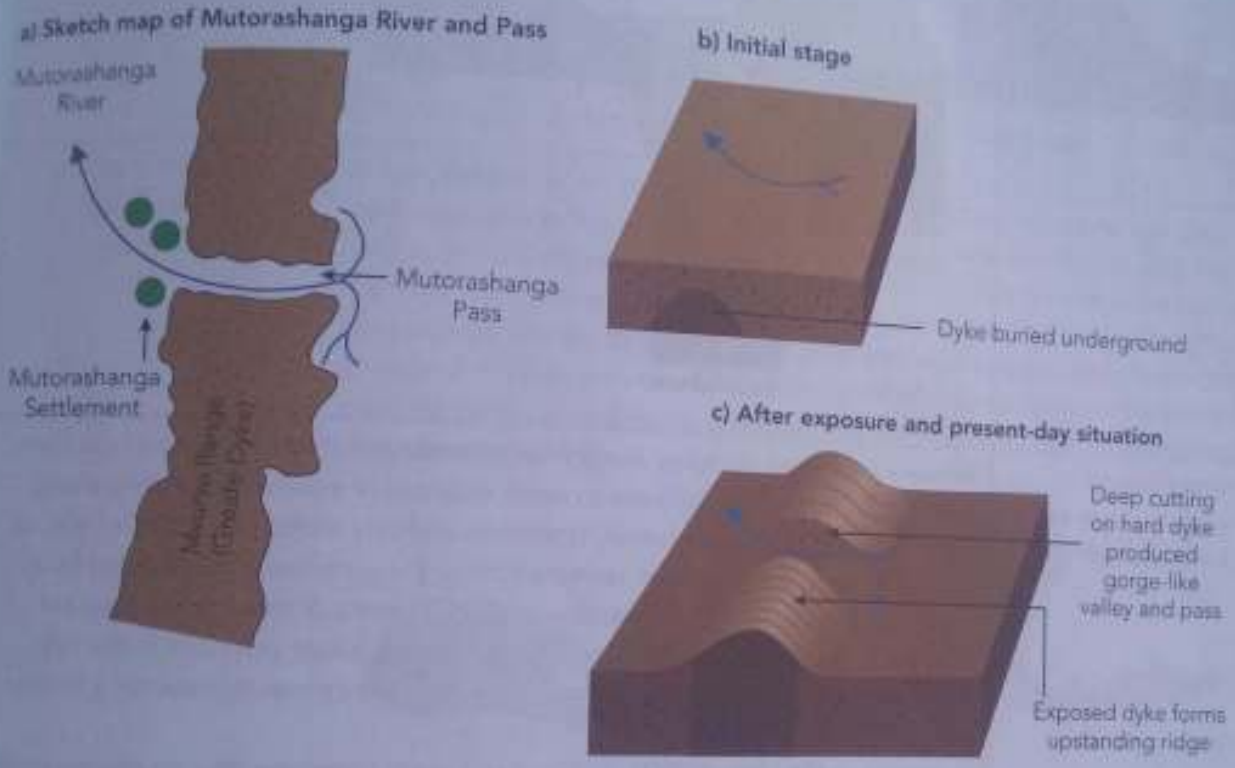
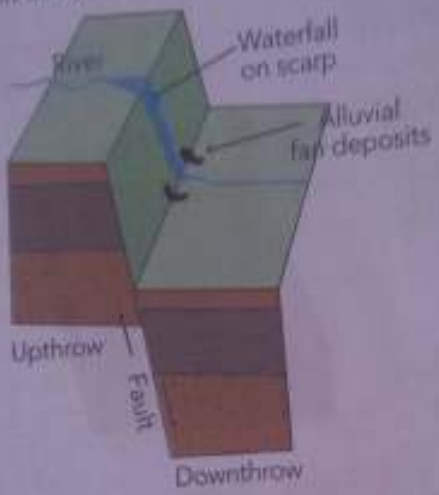
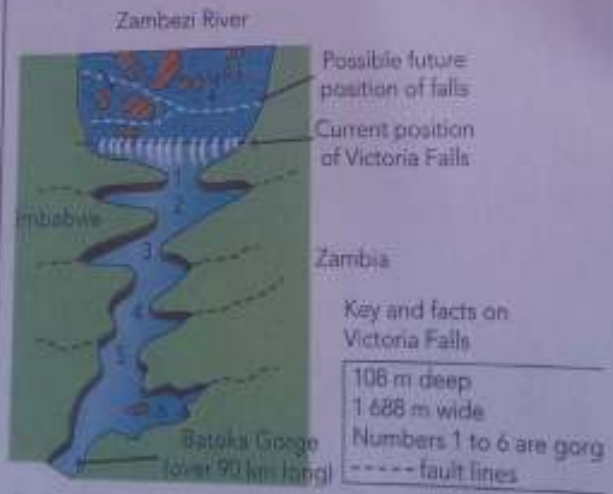


Figure 2.26 Superimposed drainage producing gorge-like valley

Table 2.2 Formation processes of rapids and waterfalls

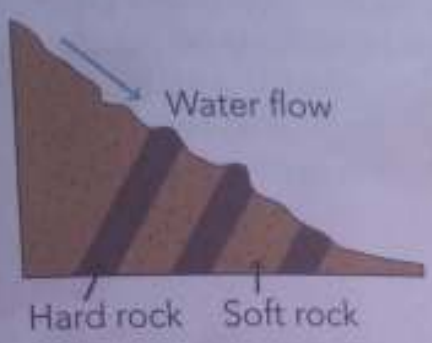
Appearance and reason	Formation processes and examples
1. Faulting	As a river descends the scarp in areas of faulting, it forms a waterfall. Most Zimbabwean rivers descend the Zambezi Escarpment through a series of falls. This type of waterfall is a knickpoint, which is a break in the long profile due to uplift or rejuvenation. 
2. Along lines of weakness such as joints and faults	Where a river flows across or along lines of weakness, it erodes vertically to form a waterfall. The Victoria Falls are a classic example of a waterfall forming along joints and fault lines in the basalt, limestone and clay rocks. The Victoria Falls, as can be seen on the map, have retreated through headward erosion along fault lines for a distance of 18 km over the last 50 000 years. Shown on the map are fault lines upstream of the falls, indicating possible future positions in the falls. Downstream, a series of gorges show a zig-zag river course representing former positions of the Victoria Falls. Therefore, as the Victoria Falls continue to retreat upstream, this tourist attraction will one day cease to become a Zimbabwean feature! This would be a big blow to the tourism industry of Zimbabwe. 

3. Band of resistant rock across the channel

a) Rapids over a series of resistant bands

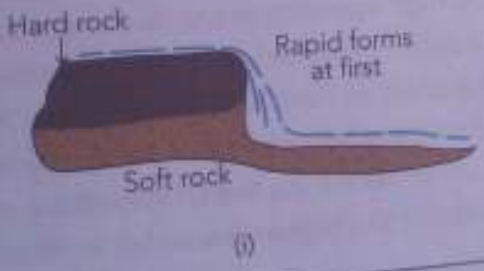
b) Rapids over wide rock band

The occurrence of a resistant band or rock across the channel means that the area downstream of the band can be deepened, thereby forming a waterfall or rapid. The rock bands can be of various widths and alignment relative to the stream. The possible rock positions and their influence are as shown in the diagrams (a) to (e) below.



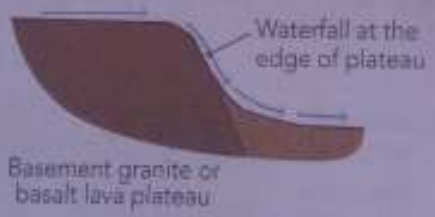
c) Horizontal rock band (sill-like structures)

At first, the horizontal band leads to a rapid (diagram c(i)). However, with time, continued deepening over the soft rock leads to a waterfall (diagram c(ii)). Plunge pool action is the deepening induced by the force of falling water at the base of the waterfall. Cutting underneath may lead to the collapse of the overhanging hard rock so that the process may begin all over again starting with the formation of a rapid. In time, the waterfall recedes upstream through headward erosion. The resistant band can eventually disappear and the river flows with no interruptions of rapids or waterfalls.



(i)

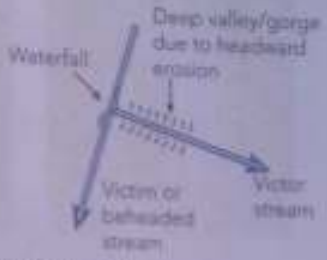
(ii)

d) Vertical rock band	A process similar to the one described for the horizontal rock band occurs. The difference is that the vertical band of hard rock may lead to a higher waterfall. With time, the base of the hard rock is undercut by plunge pool action. Eventually, the rock collapses thereby removing the waterfall. When the stream erodes its upstream area to the level of the collapsed rock, the process of waterfall formation can begin anew. 
e) Inclined rock band	Processes similar to those described above apply to waterfall formation when the hard rock is inclined. Can you describe what happens? Use the descriptions used for horizontal and vertical rock bands above as guides. 
4. Where rivers descend from plateau areas	Rivers draining from high-standing areas, such as plateaus, usually reach the lowlands through a series of waterfalls. In Africa, most rivers have waterfalls within 400 km of the coast as they descend from the African plateau, such as the Ethiopian and Drakensberg lava plateaus. An example of this type of waterfall is the Tugela Falls, which descends the Drakensberg mountains in South Africa through 948 m, making it the highest waterfall in Africa. 

5 River capture and its occurrence	River capture or river piracy occurs when one stream erodes deeper and backwards to undercut and divert the water of a neighbouring stream. The diagram illustrates this process. The point of capture is marked by a waterfall, since the capturing stream was at a lower level than the victim or captured stream. An example of such a waterfall is the Pungwe Falls, which marks the point where the Pungwe River captured the Nyakupinga River, a tributary of the Odzi River.

(i) Plan view before capture

(ii) Section along M and N



(iii) After capture

Activity 5

1. On a map of Zimbabwe, locate the waterfalls shown in photos A to C (Figure 2.28) and the river on which they are located.
2. a) Use a labelled sketch to show the main features of the waterfall in photo C.
   b) Explain how this scene may change with time.
   a) Describe the scene in photograph A.
   b) Explain how such a waterfall may have been formed.

Figure 2.28 Waterfalls in Zimbabwe (A) Nyangani Falls, (B) Mutarazi Falls and (C) Victoria Falls

3. Redraw the map below showing the major waterfalls in southern Africa. Indicate, by labelling, rivers and locations where they occur.

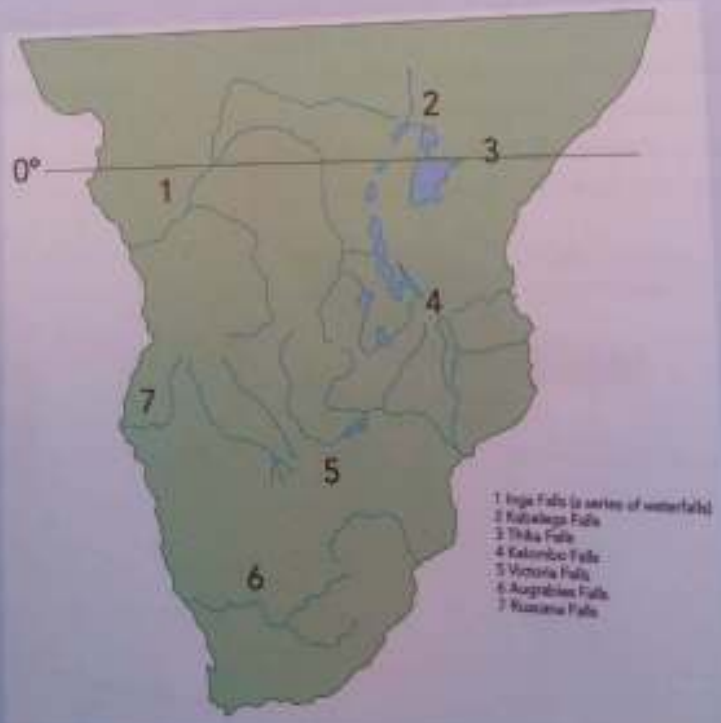


Figure 2.29 Major waterfalls in southern Africa

Features common in the middle course of the river

In the middle course, the volume of water in the river increases through the contribution made by tributaries. The load also increases, although the size of individual pebbles and grains is reduced through the process of attrition. The main work of the river is lateral erosion, which widens the valley sides to create open valleys. These are associated with the formation of truncated spurs and **meanders**. Valley widening is not the work of the river alone. It is also due to mass wasting processes acting on the valley slopes under the force of gravity.

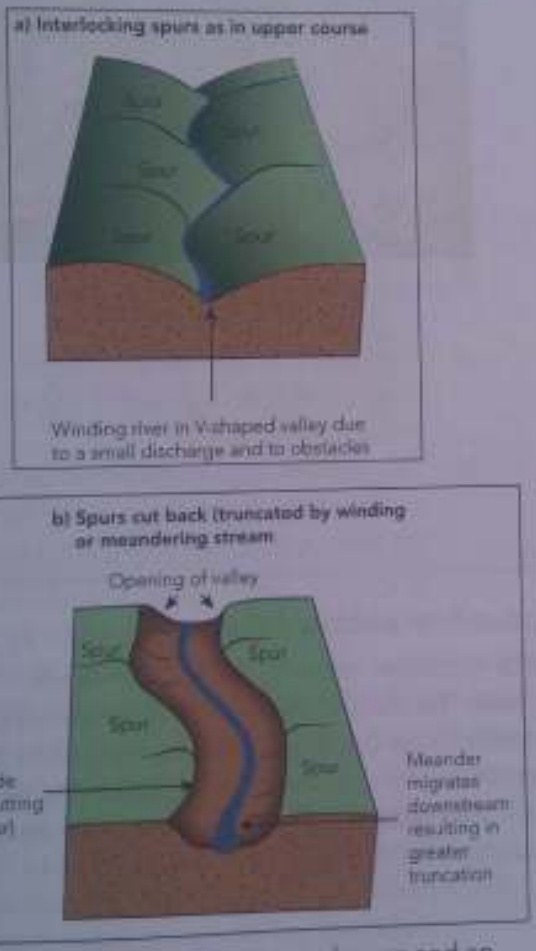


Figure 2.30 Formation of truncated spurs and an open valley

Truncated (shortened by cutting off) spurs and valley widening

The formation of truncated spurs and open valleys is shown in Figure 2.30. As the interlocking spurs are cut back through lateral erosion, their finger-like projections became blunted. These features are called truncated spurs.

Features associated with the lower course of the river

Although the features of the lower course are mainly due to deposition in the flood plain and at the mouth, flood plains are initially formed by erosion as shown in Figure 2.31.

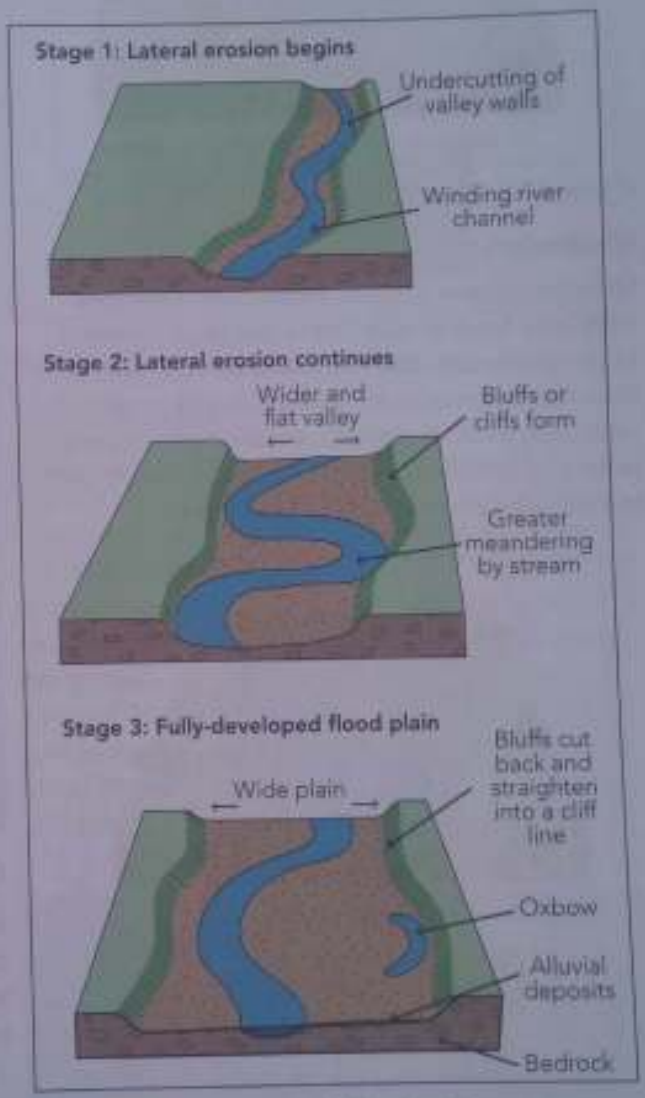


Figure 2.31 Formation of a flood plain

Bluffs or river cliffs, meanders, cutoffs and oxbow lakes, braided channels, natural levees, deferred tributary junctions, swamps and alluvial fans are all flood-plain features. A **delta** is the final flood-plain feature at the mouth of the river.

Figure 2.32 Flood-plain features

Meanders

Meanders (Figure 2.33) are formed when the river twists and turns in wide bends. Although common in the flood plain, they can develop in any part of the river. The reasons for their development are not well understood. However, meandering is a common behaviour of flowing fluids that avoid a straight path in preference for one that twists and turns.

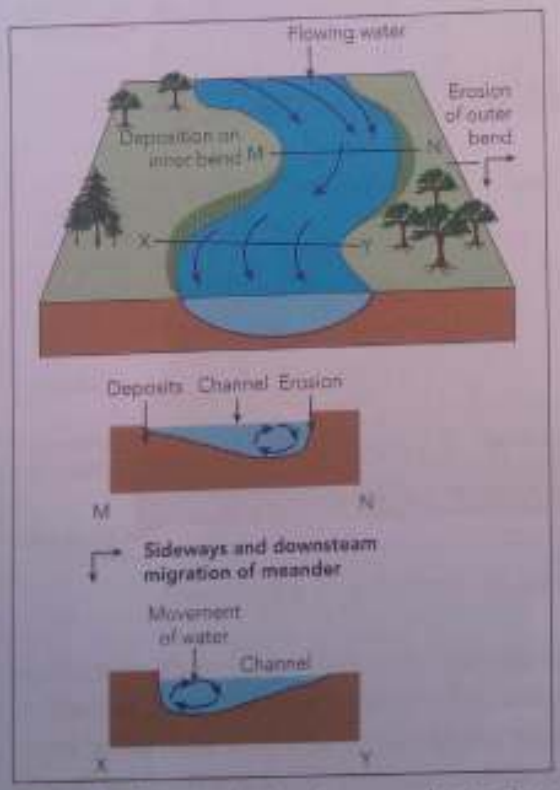


Figure 2.33 Characteristics of a meandering channel

The speed of moving water within a meandering channel is faster on the outer bend than on the inner bend. The outer bend is therefore eroded, while on the inner bend there is deposition since the water velocity is lower. The outer bend forms a concave slope with a river cliff, while the inner bend forms a slip-off convex slope. As a result of erosion on the outer bend and deposition on the inner bend, the stream shifts sideways and downstream.

Activity 6

1. Refer to Figure 2.34 for location.

Figure 2.34 Part of the Luangwa River

a) Draw a sketch of the river course shown and label the main features of a meandering stream.
b) Describe the landscape shown and suggest how it may have promoted the formation of meanders.

Cut-off or oxbow lake

Since erosion is marked on the outer bends, in time, the distance separating neighbouring meanders is reduced and may finally lead to the formation of an oxbow or cut-off lake (Figure 2.35). The **oxbow lake** is shaped like the horns of an ox or a horse shoe.

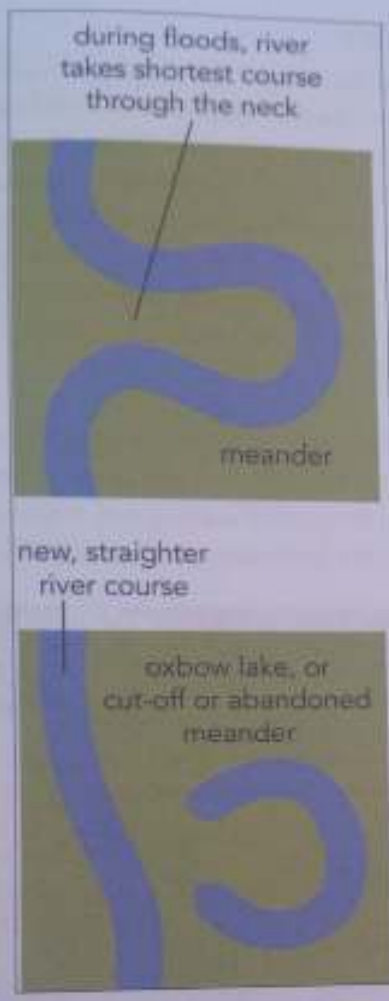


Figure 2.35 Formation of cut-off or oxbow lake

Braided channel

A braided channel forms when the river is unable to carry all of its sediment load and therefore starts to deposit it. In order to continue flowing, the river subdivides into smaller channels that continuously join and separate as shown in Figure 2.36. Braiding is not confined to the flood plain but can occur on any part of the river. For example, **siltation** and gold panning can lead to braiding if the river becomes choked with sediment. Low discharge in winter leads to braiding in some rivers in southern Africa.

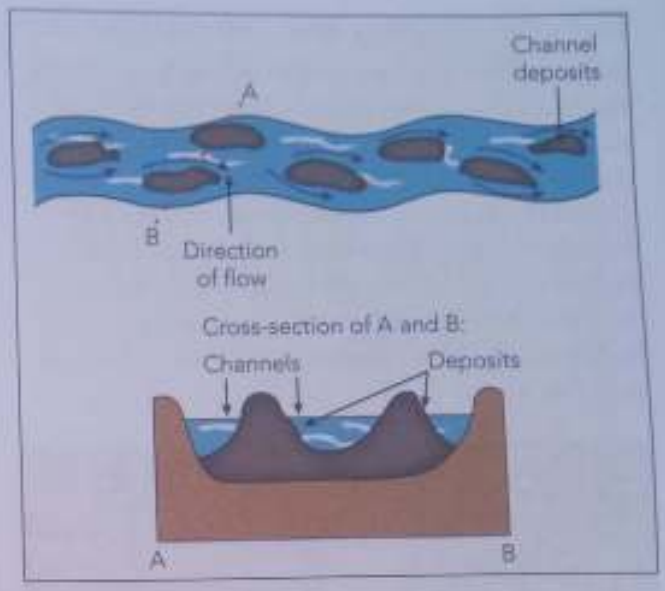


Figure 2.36 Formation of a braided channel

Natural levees

During floods, water spills over the channel banks onto the flood plain where some of the load is deposited. Most of the deposits are along the channel side, since the velocity of the water spilling onto the plain is lower than that in the channel. This leads to ridges, called **natural levees**, being built up along the banks of the channel. A series of floods will build the levees so that their level is slightly higher than the surrounding flood plain. The river now flows on a raised bed (Figure 2.37) due to deposition on the river bed.

Figure 2.37 Raised bed

Deferred tributary and deferred junction

With the development of the natural levees along the main river, tributaries are forced to abandon their initial confluence to flow parallel to the main river within the flood plain. These tributaries are termed **deferred tributaries** in that they do not join the main river where they used to, but have to run parallel to the main river and can only join if there is a break in the natural levees. Such a confluence is termed a deferred or delayed junction (Figure 2.38).

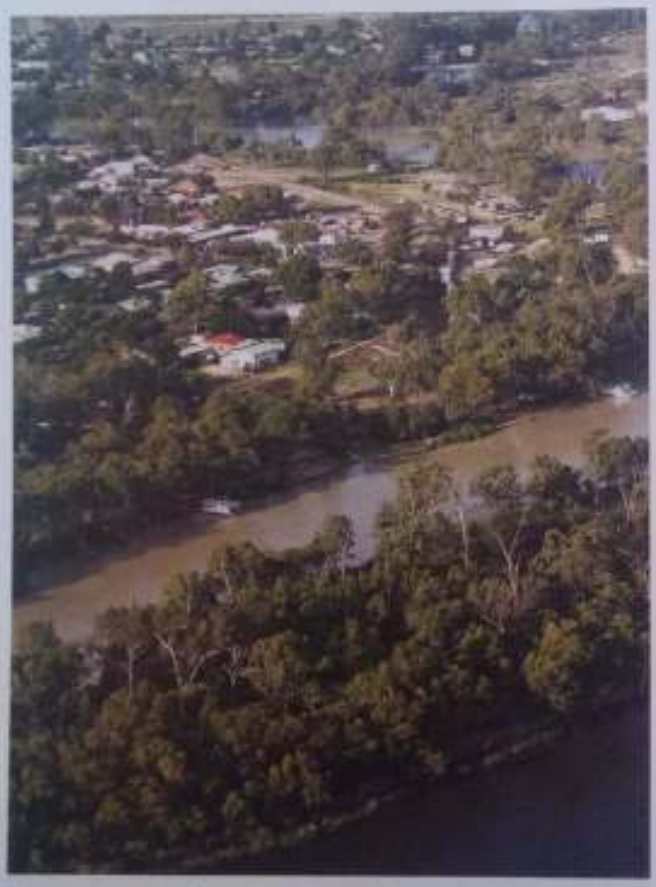


Figure 2.38 Deferred or delayed junction

Alluvial fan

An **alluvial fan** is the fan-shaped feature formed by the deposition of alluvium as a tributary descends the bluffs onto the flood plain. The deposition occurs at a point where the steep bluff changes into the flat plain, and is therefore the result of the reduction in velocity. Alluvial fans can form when the river descends onto a flat area like a rift valley or can form below an escarpment.

Swamps

Swamps are areas of stagnant or standing water with **wetland** vegetation. They develop in the flood plain due to frequent flooding and where tributaries fail to enter the main stream (Figure 2.39).

Figure 2.39 Swamp

Activity 7

1. Study the map below and answer the questions that follow.
   a) Represent the area shown with a fully labelled block (three-dimensional) diagram.
   b) Describe how any two named features on the map may have been formed.
   c) If you were a development planner, where would you settle people?

The river mouth

A river eventually reaches the sea or a lake. This is the end of its journey. A river cannot transport or erode below its base level. The base level is the level of the lake, or sea. At base level, the river velocity is reduced to zero. The river is forced to deposit its load. The type of land forms resulting from river deposition at the mouth differ depending on how much of the deposited material the ocean currents are able to remove and how quickly.

Deltas and river mouths

Most rivers enter the sea through several channels called **distributaries**, where the overall shape of the feature is triangular. The Greek letter **delta** is a triangular shape: Δ. Some rivers enter the sea through one channel, since the sea currents remove all the materials deposited by the river. Such river mouths are called estuaries. An estuary forms where the coast has been drowned by the sea. This happens when either a) sea level rises or b) the land subsides. Figure 2.40 shows the shape of an estuary.

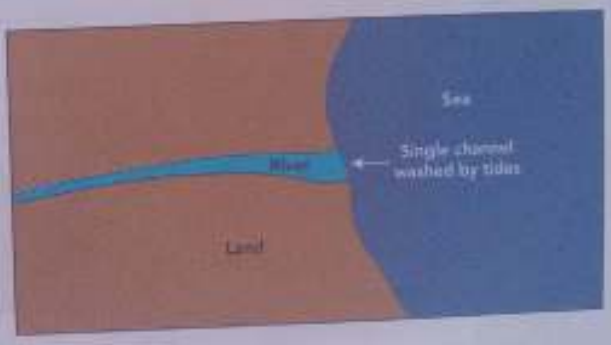


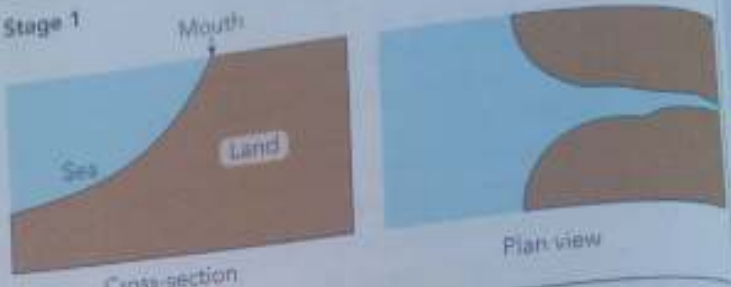
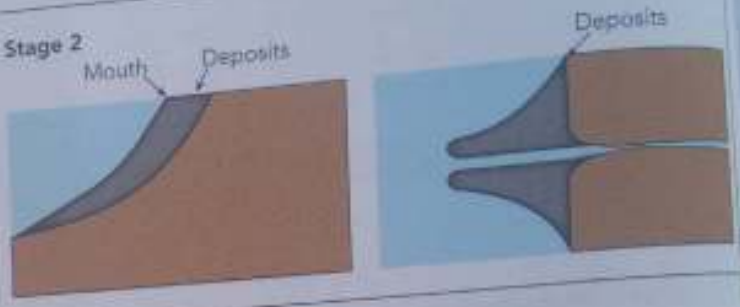
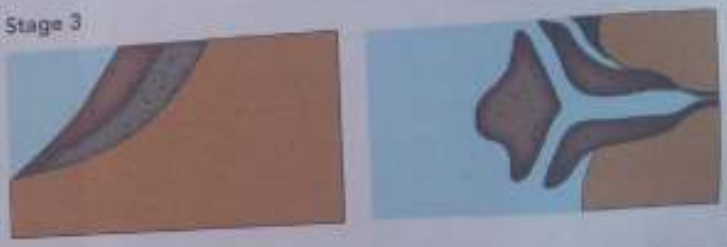
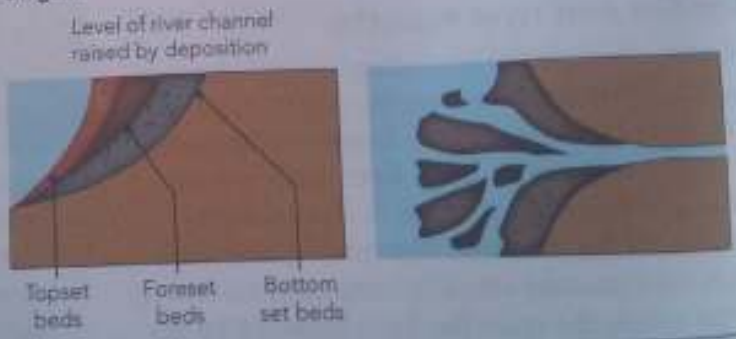
Figure 2.40 Estuary

Delta formation

The following main conditions determine the formation of a delta:

- The sea currents cannot remove all the deposited materials because of weak tidal action.
- The tides occur after lengthy intervals of deposition and are unable to remove the deposited sediments.
- The river carries a large load, which it deposits at its mouth.
- Clay particles carried in suspension may bind together when they react with seawater, and then settle on the bed. This process is termed flocculation.

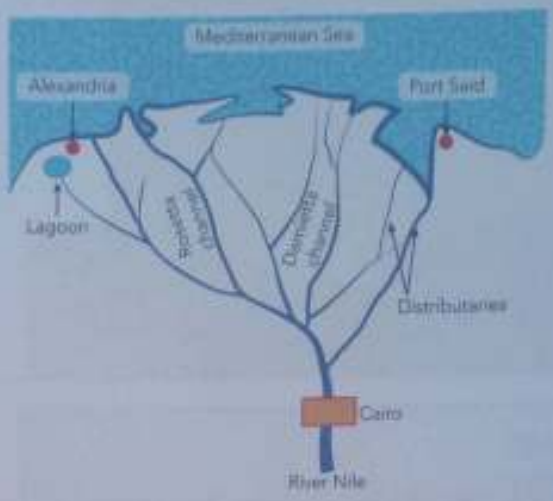
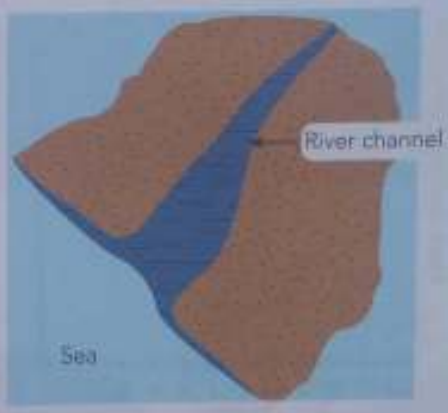
Table 2.3 The development of a delta

Stage 1	• Still waters • Large load • Slow river flow	Stage 1 
Stage 2	• Due to deposits, river mouth extends seawards • River still able to use one channel to empty its water into the sea	Stage 2 
Stage 3	• More deposits and continued extension of mouth seaward • Distributaries form as river is unable to move the materials • Distributaries are characteristically small, shorter channels to the sea	Stage 3 
Stage 4	• Seaward extension of mouth • More distributaries, delta deposits form layers called beds	Stage 4 

The deposition of sediment at the mouth follows the normal sequence of dropping the heaviest and largest particles first and the smallest further into the sea. Traction or bedload is the first to be deposited followed by gravel, sand, silt and then clay. It is important to note that the solution load, which is part of the water, is emptied into the sea where it contributes to the salty or saline nature of seawater.

Types of deltas

These are the major types of deltas, their characteristics and some examples.

1. Arcuate delta: Triangular-shaped delta with an arc-shaped shoreline. The Nile Delta (illustrated) and the Niger Delta are examples. Useful for arable land, pasture and settlement, but pests, diseases and marshes pose problems to people.	
2. Estuarine delta: Single channel with braids (deposits common on route down to coast). Example: the Zambezi River Delta situated 200 km north of Beira.	
3. Bird's foot delta: Formed where there are weak tidal currents, which allow distributaries to extend seawards. Example: the Mississippi River Delta.	

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4. **Cuspate delta:** Limited distributary development in coast with moderate currents. Example: Medjerda River Delta in Tunisia

Project

Study the graph below showing the seasonal variation in discharge for a typical African river.

1. a) In which climatic region and hemisphere is such a discharge pattern common and why?
   b) Explain how the type and amount of load transported by such a river varies according to seasonal changes in velocity and volume.
   c) Account for when and where the load is deposited.

Landforms resulting from wind action

Wind, like running water, is an important agent of erosion, transportation and deposition of sediment and soil. Air, like water, behaves as a fluid. However, air is not as dense as water. Wind cannot therefore pick up and transport particles larger than sand grains and tiny pebbles. Wind processes are also known as **aeolian** processes. These processes are especially important in two regions of the world:

- Arid regions are very dry regions. They include the hot and cold deserts of the world. Africa is home to two of the world's great hot, dry deserts, the Sahara in north Africa, and the Namib-Kalahari in southern Africa. Arid regions receive very little rain; typically less than 125 mm per year. They support little or no vegetation, which means exposed surfaces of bare rock, or mobile sand. Both are vulnerable to wind action.
- Semi-arid means half dry. These areas are transition zones between arid regions, and wetter regions. They are found on desert margins. They typically receive between 125 and 250 mm of rain per year, and support some vegetation. This is usually in the form of hardy shrubs and bushes. Grass is only found after rainy periods. Semi-arid regions are also subject to wind action.

Wind transportation processes

Transportation by wind is achieved through the processes of **suspension**, **saltation** and **surface creep**.

Suspension

Suspension is the process by which small particles, for example, fine clay and silt are carried by wind and then deposited elsewhere. Particles can be carried

over thousands of kilometres at great heights. Dust from the Sahara, for example, can reach America.

Saltation

This process involves sand particles with a diameter of up to 2 mm. These particles move along the ground in a series of hops (Figure 2.41).

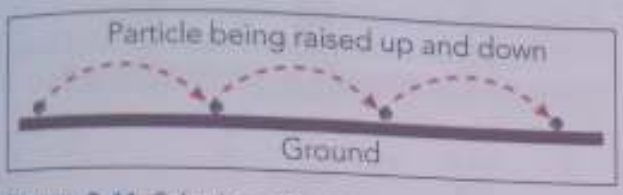


Figure 2.41 Saltation process

Surface creep or traction

The particles that are larger than 2 mm in diameter are dragged along, rolled along or pushed by strong winds (Figure 2.42).

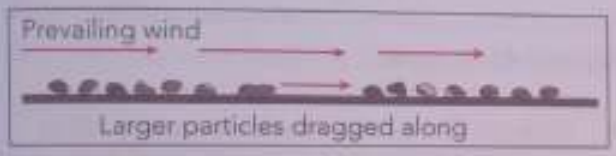


Figure 2.42 Surface creep

Wind erosion

Two processes are responsible for wind erosion, namely **deflation** and **abrasion**.

Deflation

Wind removes loose soil and sediment. The stronger the wind, the bigger the particles that can be removed by the wind. Wind deflation results in lowering the ground surface, forming deflation hollows. These depressions are very common in the Sahara, for example, the Quattara Depression in Egypt, which is 134 m deep.

The formation of a deflation hollow

- *Stage 1*: Initial stage of development in non-resistant rock.
- *Stage 2*: Hollow deepens as unconsolidated rock is blown away.
- *Stage 3*: Hollow is now very deep, with the water table above the bed. These become sites for oases in the Sahara.

In southern Africa, deflation hollows such as those in the Kalahari, at Etosha and in the Hwange National Park are called pans.

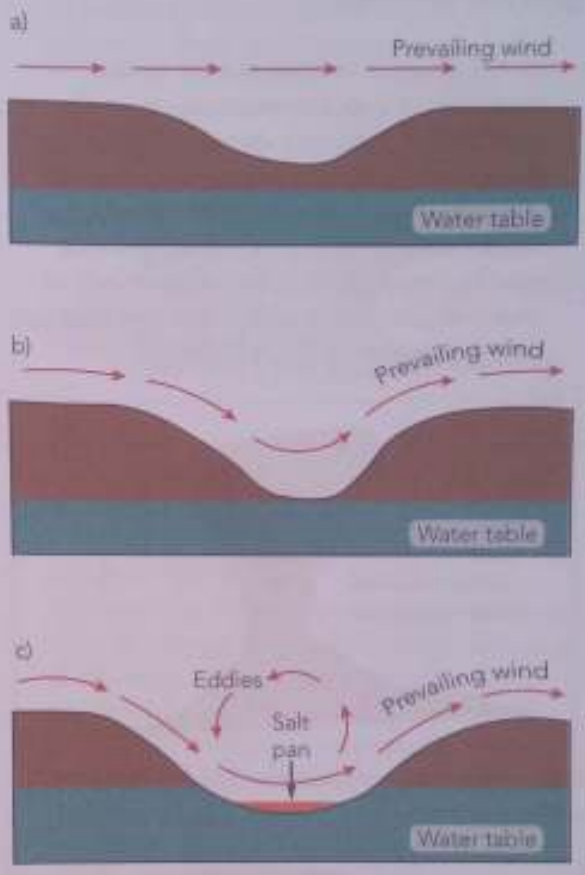


Figure 2.43 Formation of a deflation hollow

Abrasion

The sand blasting action of moving sand on rocks is called abrasion or corrasion. It is concentrated up to 1 m above ground level. Abrasion produces unique landforms such as:

- *Ventifacts/faceted pebbles*: These are products of wind abrasion that comprise a faceted and polished surface. The most common **ventifacts** are dreikanters (Figure 2.44) and are found in hot deserts such as the Sahara.

Figure 2.44 Dreikanter

- *Rock pedestals or mushroom rocks*: In the formation of a rock pedestal, the base of a rock is eroded through abrasion. The foot of the rock suffers the most from the effects of abrasion, resulting in the mushroom-shaped feature (mushroom rock). A **rock pedestal** may be formed from either uniform rock or rock comprising alternating layers of hard and soft rock (Figures 2.45 and 2.46).

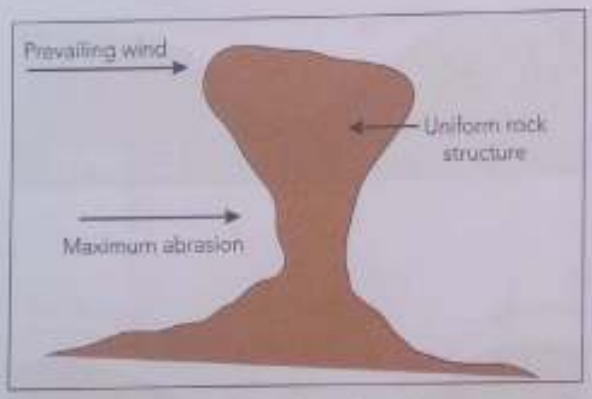


Figure 2.45 Rock pedestal resulting from erosion of uniform rock type

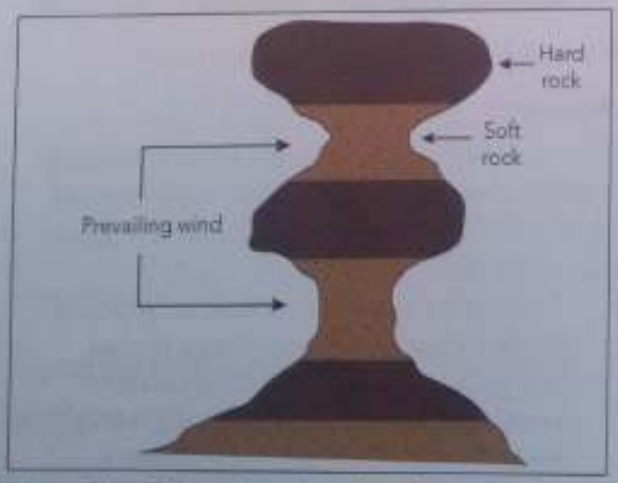


Figure 2.46 Rock pedestal resulting from erosion of alternating hard and soft rock

- *Zeugens*: Layers of alternating hard and soft sedimentary rocks may lie horizontally and wind may attack the weaker rock through lines of weakness such as faults. These are deepened as the wind abrasion continues to create elongated troughs. Usually, the ridges are flat-topped and steep-sided. These *zeugens* also occur in series or in sequence (Figure 2.47). In time, continued erosion by wind may undercut the features and the ridges collapse.

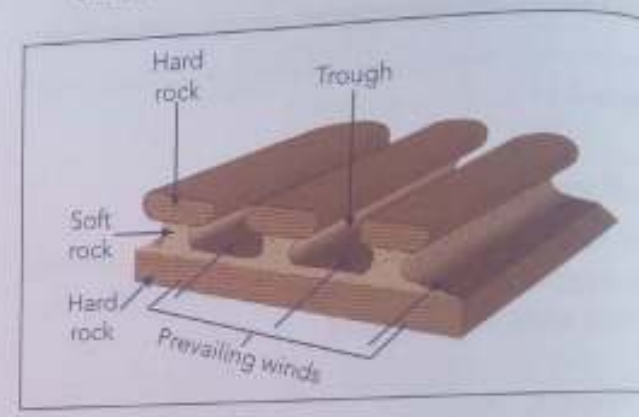


Figure 2.47 Zeugens

- *Yardangs*: These form where alternating bands or strata of hard and soft rock lie vertically. This is in contrast to zeugens, where the bands of rock lie horizontally. Weathering weakens the softer rock and this prepares the rock to be attacked and eroded by abrasion. The results of **denudation** are seen in the formation of ridges (upstanding masses) and furrows (trenches), as shown in Figure 2.48. *Yardangs* are common in the Sahara, the Namib and the Arabian deserts.

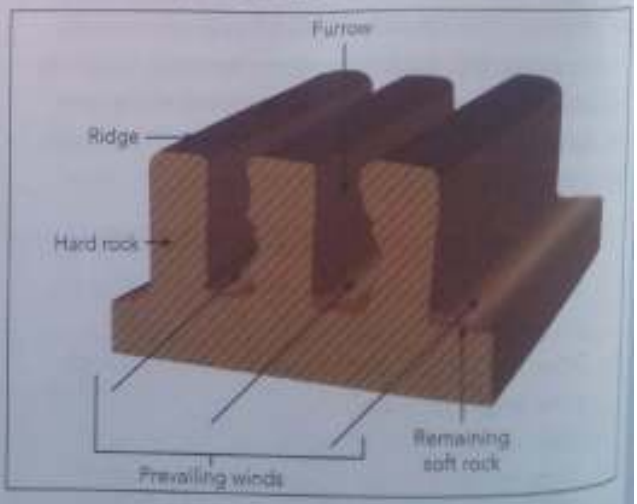


Figure 2.48 Yardangs

When wind erosion continues, the furrows are widened and this makes the ridges narrower, as illustrated in Figure 2.49.

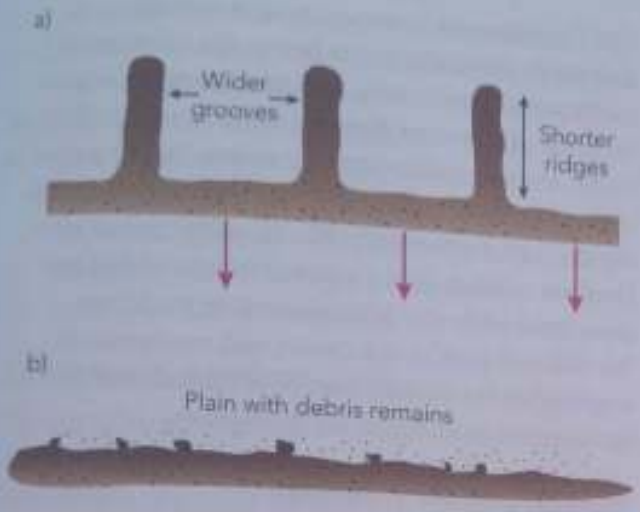


Figure 2.49 Completely worn-down landscape

Wind deposition

Deposition of sand results in loess or sand dunes.

Loess

The sand particles carried in suspension or transported by saltation may be deposited several hundred or even thousands of kilometres from the place of origin. This occurs as the wind velocity is reduced and therefore the wind cannot transport any larger particles. Deposition of sand occurs in the form of **loess**, which is fine-grained and yellowish in colour. Loess forms fertile soils, such as those of north-western China.

Sand dunes

There are two main types of sand dunes namely **barchans** and **seif dunes**, as well as three other types called parabolic dunes, star dunes and transverse dunes.

- *Barchans*: Barchans are formed where winds blow consistently from a particular direction, and such winds are termed prevailing winds. An obstruction, such as vegetation, may cause the sand to accumulate, marking the first phase in the formation of the barchan. More sand accumulates on the central part of the feature, but less accumulates on the sides, which project out as the horns. Horns are created because on the sides, where there is no obstruction, sand is easily moved forward by the wind (Figure 2.50). Barchans have the following characteristics: crescent-shaped, two horns pointing downward, steep concave leeward slopes due to eddies, gentle convex slopes due to prevailing winds, and an asymmetrical shape because of the gentle windward slope and steep leeward slope.

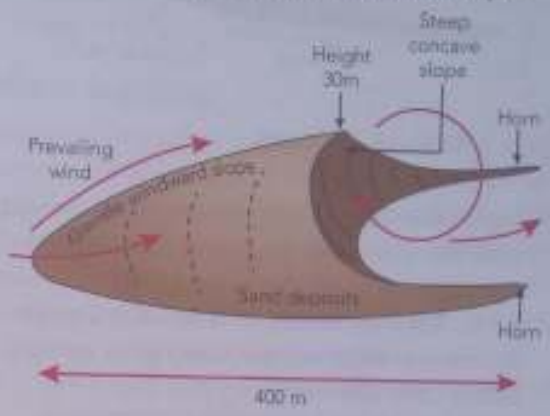


Figure 2.50 Barchan dunes

- *Seif dunes*: Seif dunes are formed when barchans combine. They are longitudinal in form and lie parallel to the general direction of the wind (Figure 2.51). The seif dunes can be up to 100 m high and over 120 km in length. The steepness of the slopes is about 20°. Wind eddies help in clearing the corridors of any sand. Dunes of this nature occur in the Sahara (in Libya and Algeria), the Namib and the Kalahari desert.

Figure 2.51 Seif dunes

- *Parabolic dunes*: These are U-shaped mounds of sand with convex noses trailed by elongated arms. Unlike barchans, their arms point upward (Figure 2.52). Parabolic dunes

depend on vegetation (grasses, shrubs and trees), which help anchor the trailing arms, as the nose migrates downwind. They are formed when sand is eroded from a blowout and deposited in the immediate vicinity.

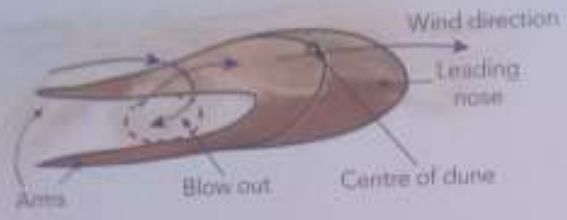


Figure 2.52 Parabolic dunes

- *Star dunes*: These are pyramidal sand mounds with three or more arms that radiate from the high centre of the mound (Figure 2.53). They are found in areas with a multi-directional wind regime. They grow upward rather than sideways.

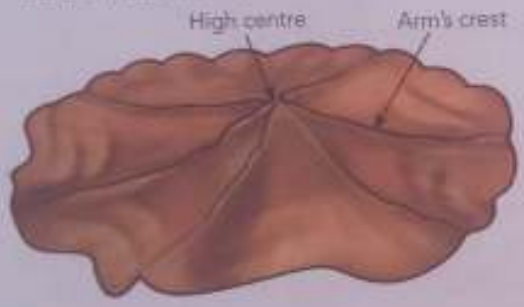


Figure 2.53 Star dunes

- *Transverse dunes:* These dunes are perpendicular to the prevailing wind. One side of the crest a) is eroded by the eddy effect of the wind, and the eroded material is deposited on the next side b) (Figure 2.54).

Figure 2.54 Transverse dunes

Hazards associated with landform development

The Earth's outer layer, or crust, is dynamic, not static. Powerful forces below the crust cause earthquakes, volcanoes, and movement of whole sections of the crust through faulting and folding of rocks. On the surface, gravity causes rock material to slide and fall. Usually, the movements in the crust are slow, and not noticeable. However, sometimes they are sudden, and violent. We refer to hazards associated with the development of landforms. We will not look at the causes and mechanisms responsible for natural hazards in detail, but will focus on what happens on the surface.

Volcanoes as hazards

Volcanoes erupt when molten material from the Earth's second layer, the mantle, reaches the surface. Volcanic eruptions do not simply occur at random. Scientists have mapped the areas of the Earth where they are most likely to occur. In Africa, these areas include the eastern DRC and Cameroon. Zimbabwe is not volcanically active. The following are examples of volcanic action that are hazardous:

- Molten lava can flow like a river, destroying vegetation and human-made features such as roads, bridges and houses.
- Volcanic eruptions can trigger heavy rains by providing water vapour and condensation nuclei. The heavy rains and falling ash produce mud flows (lahars), which can reach speeds of 90 km/h and these can wipe out villages and towns.
- Red-hot rock material, stones and dust can be ejected or thrown from the volcano as high as one kilometre into the atmosphere and destroy vegetation, kill people or bury settlements.
- Dangerous gases, such as carbon dioxide, carbon monoxide, hydrogen sulfide and sulfur dioxide, can be released into the atmosphere and this can seriously affect the health of people and animals, and even destroy vegetation. A good example is Lake Nyos in Cameroon in 1986.
- Volcanic eruptions can produce huge clouds

of very hot gases with temperatures of up to 1 000 °C, mixed with volcanic dust, which move down slopes at speeds of 100 km/h and destroy everything in the way.
- Landslides can be triggered by volcanic activity, resulting in the destruction of human life and physical features.
- Volcanic activity can trigger tsunamis, as in the case of the eruption of Krakatoa in south-east Asia in 1883, when 30 000 people drowned. Tsunamis are large waves that can be as high as 20 m or more, and move with speeds of nearly 800 km/h.

Effects of earthquakes

Earthquakes are sudden, violent movements on the surface of the Earth triggered by shockwaves from the release of energy deep below the surface. The effects of earthquakes include the following:
- They cause vertical or lateral displacements of the crust.
- They can cause the opening and closing of deep cracks on the Earth's surface, resulting in loss of life, and severe damage to property.
- Parts of the ocean floor may be suddenly raised, or lowered, by an earthquake.
- They cause the formation of tsunamis. An example is the deadly south-east Asian tsunami of December 2004. The effects were felt in far-off places such as the east African and South African coasts, Australia, India and areas bordering the Indian Ocean.

The impact of an earthquake varies greatly. However, the effects are felt more in developing countries than in developed countries, and more in poor, rural areas than in urban areas, for the following reasons:
- Many villages are built in precarious physical locations like on mountain slopes.
- There are rarely contingency plans for dealing with the immediate effects of earthquakes.
- The provision of water and sanitation is usually poor and easily affected, resulting in a high risk of post-event disease and infection.
- Local medical and welfare facilities are usually poor and they are unable to respond to any emergency.
- Houses are often built of poor materials, which easily disintegrate during earthquakes.
- The location of buildings and settlements are not planned and they are easily affected by floods from burst dams.
- Rescue, relief and aid are often slow in reaching the affected areas because of their remoteness and poor communication. This results in even more deaths and suffering.

Mass wasting

Mass wasting refers to the slow, or rapid movement of loose rock material down a slope under the influence of gravity. Hazardous rapid mass movements include rock falls, mudslides and debris flows.
- Rapid mass movements bury, crush or sweep away whatever is in their path.
- The result may be loss of life and damage to property and infrastructure such as roads, railways and power lines.
- Unlike volcanoes and earthquakes, mass movements can occur anywhere there are steep slopes. Mountainous areas, with heavy rainfall to trigger the movement, are most vulnerable.

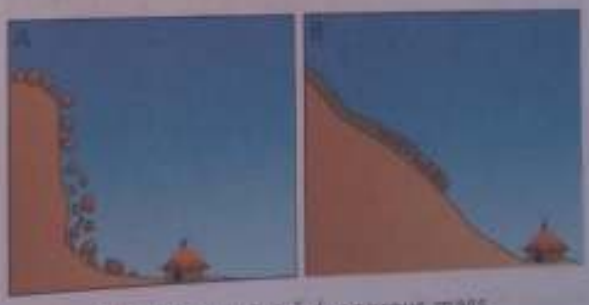


Figure 2.55 Two types of dangerous mass movement: rock fall (A) and earth flow (B), which is a sliding movement

Flooding

We have already looked at flow regimes and hydrographs. To understand flooding, look at the hydrograph in Figure 2.56.

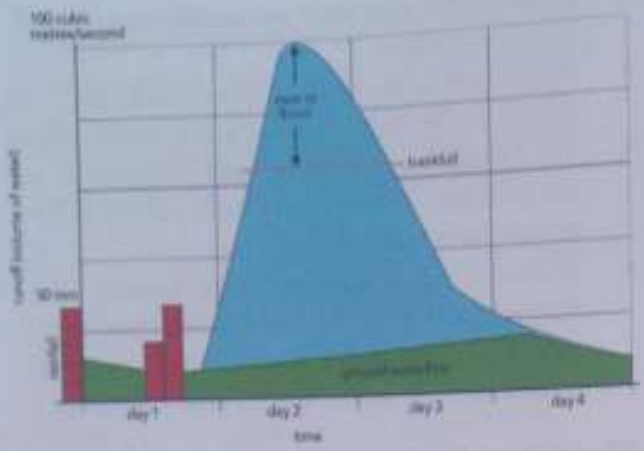


Figure 2.56 Hydrograph showing flooding when water volume is greater than bankfull

Heavy rain in the catchment on Day 1 causes the river to rise on Day 2. When bankfull is reached, there is more water in the river than it can carry between its banks. Flooding occurs on Days 3 and 4 as the river overflows its banks. Late on Day 3 the water volume falls below bankfull, so flooding stops. By Day 4, things are back to normal, but of course the floodwaters on the surrounding floodplain have caused damage to property and crops, and even loss of life.

Figure 2.57 Buffalo drinking from a river that is well below bankfull. The river bank is behind the animals.

Disaster risk management of volcanoes, earthquakes, flooding, mass wasting

The Earth's environment is full of potential hazards. These range from weather hazards such as lightning or flooding, to geological hazards such as those looked at above. Such hazards present risks, which have to be managed to protect the environment, property and, most importantly, lives. Before we look more closely at disaster risk management, note the following terms:

- *Disaster*: a natural or human-caused occurrence that results in damage to the environment, or property, and often to loss of life.
- *Risk*: the chance which a person or a community or a society is prepared to take in order to benefit from some specific reward.
- *Hazard*: a natural or human-made phenomenon or thing which has the potential to cause anything from a minor problem to a major disaster.
- *Manage*: to control a situation, ideally for a best possible outcome.
- *Disaster risk management*: the concept and practice of reducing disaster risks through systematic efforts to analyse and manage the causal factors of disasters.

Strategies for disaster risk management include:

- reduced exposure to hazards
- preparing people and property so that they are less vulnerable
- effective management of the environment and areas at risk
- improved preparedness for adverse events.

Let us look at some practical examples of preparing for, and coping with, the hazards discussed above.

What to do in areas at risk of volcanoes

Volcanic soil is very fertile, which is why people choose to live and farm on the slopes of volcanoes. The prediction of volcanic eruptions is generally accurate and reliable. The only action to take is to leave the area at risk, and return when told that it is safe to do so. A properly managed evacuation procedure should be in place.

What to do in areas at risk of earthquakes

Earthquakes are unpredictable. Scientists know which areas are at risk, but they cannot forecast earthquakes

in the way that they can a volcanic eruption:

- Make sure you have a fire extinguisher, a first aid kit, a battery-powered radio, a torch and extra batteries at home.
- Learn first aid.
- Know how to turn off gas, water and electricity supplies into the home.
- Make a plan for where to meet your family if an earthquake takes place.
- Do not leave heavy objects on shelves as they will fall during an earthquake.
- Anchor heavy furniture, cupboards and appliances to the walls or floor.
- Learn the earthquake plan at your school or workplace.

What to do during an earthquake

Follow these guidelines if an earthquake happens:

- Stay calm. If you are inside, stay inside. If you are outside, stay outside.
- If you are inside a building, stand against a wall near the centre of the building, stand in a doorway, or crawl under heavy furniture (a desk or table). Stay away from windows and outside doors.
- If you are outside, stay in the open away from power lines or anything that might fall. Stay away from buildings (things might fall off the building or the building could collapse onto you).
- Do not use matches, candles or any type of flame. There might be broken gas lines or flammable liquids might have spilled from pipelines or storage tanks.

What to do after an earthquake

Follow these guidelines for what to do after an earthquake:

- Check yourself and others for injuries. Provide first aid to anyone who needs it.
- Check water, gas and electricity lines for damage. If any are damaged, shut off the valves.
- Check for the smell of gas. If you smell it, open all the windows and doors, leave immediately, and report it.
- Turn on the radio and only use the phone in an emergency.
- Stay out of damaged buildings.
- Be careful around broken glass and debris. Wear boots or sturdy shoes to keep from cutting your feet.

What to do in areas at risk of flooding

Flooding almost always occurs in low-lying areas called flood plains, which lie on either side of a river. People choose to live in these areas because of the fertile soil, which is deposited on the floodplain from time to time. Today, floods are almost always predictable. Flash floods, however, hold great risk. In the event of a flood prediction:

- Move people, livestock and valuable possessions to high ground away from the river and its floodplain when the first warning is given.
- It may be possible to barricade houses with sandbags or to divert some floodwater by digging drainage ditches, but this will only help if it is localised flooding.
- If flood water rises rapidly, get onto the roof of any tall, strong building, or even climb a tree. Do not try to save your possessions; your life is more important than they are.

What to do in areas at risk of mass movement

Rockfalls, landslides and mudslides generally occur in mountainous areas, usually after heavy rain triggers the mass movement. The following can assist in preventing mass movement, lowering the risk, and coping with mass movement:

- Look for previous signs of mass movement, such as old rock falls, and scars on mountain and hill sides where slides have taken place in the past.
- Be especially aware and alert after heavy rain.
- Look for signs of movement, which were not there previously, on slopes.
- If necessary, leave the danger area until the rain has passed and things have dried out.
- Keep away from steep slopes with loose rock, which might fall.
- Don't use machinery or vehicles that cause vibration, which might trigger a fall or slide.

Figure 2.58 Rockfall near the South Africa-Lesotho border. Note the sheer cliffs, and the big boulders resting on the slope.

Summary

- Most rivers in Africa are seasonal by nature. This means that the rivers flow more strongly in the rainy season than the dry season. Zimbabwe's rivers experience their strongest flow in the summer months.
- River (fluvial) processes, namely erosion, transportation and deposition by running water, are the most important processes shaping the landscape around us.
- A variety of different landforms result from river processes. Some landforms are landforms of erosion, and some are landforms of deposition.
- In general, southern Africa is dry. Very dry areas (deserts such as the Sahara and Namib) are known as arid regions.
- Much of the rest of southern Africa, including Botswana, south-western Zimbabwe and the vast Karoo region of South Africa are semi-arid.
- The processes of wind (aeolian) action, which include erosion, transportation and deposition of sediment and soil, are particularly important in arid and semi-arid regions.
- Landforms resulting from wind action may also be erosional (think of the sandblasting effect of sand carried by the wind) or depositional in the form of sand dunes and other features.
- There are various hazards (dangers) associated with both running water and wind action. Flooding is a constant risk in low-lying areas along rivers, while moving sand can bury buildings and wind can carry away fertile topsoil.
- Disaster risk management involves being prepared for natural disasters caused by volcanoes, earthquakes, flooding, heavy rains, lighting and high winds, ice storms, torpedoes, desert storms or mass wasting (mass movement).
- Risk, hazard and disaster are not the same thing. See the glossary below for definitions.
- Proper preparation and risk management can help prevent in particular natural forces such as earthquakes, volcanoes or flooding turning into major disasters.
- Having a proper coping strategy for any threat to life or property is part of good disaster risk management.

Glossary

abrasion – erosion caused by sand-blasting action, the scraping off, grinding away and scouring of channel bed and bank by solid material carried by the river

aeolian – to do with wind; wind processes

alluvial fan – deposition of sediments by streams at the base of an inland basin

alluvium – fluvial deposits of any size and shape

barchans – a crescent- or horn-shaped wind depositional feature

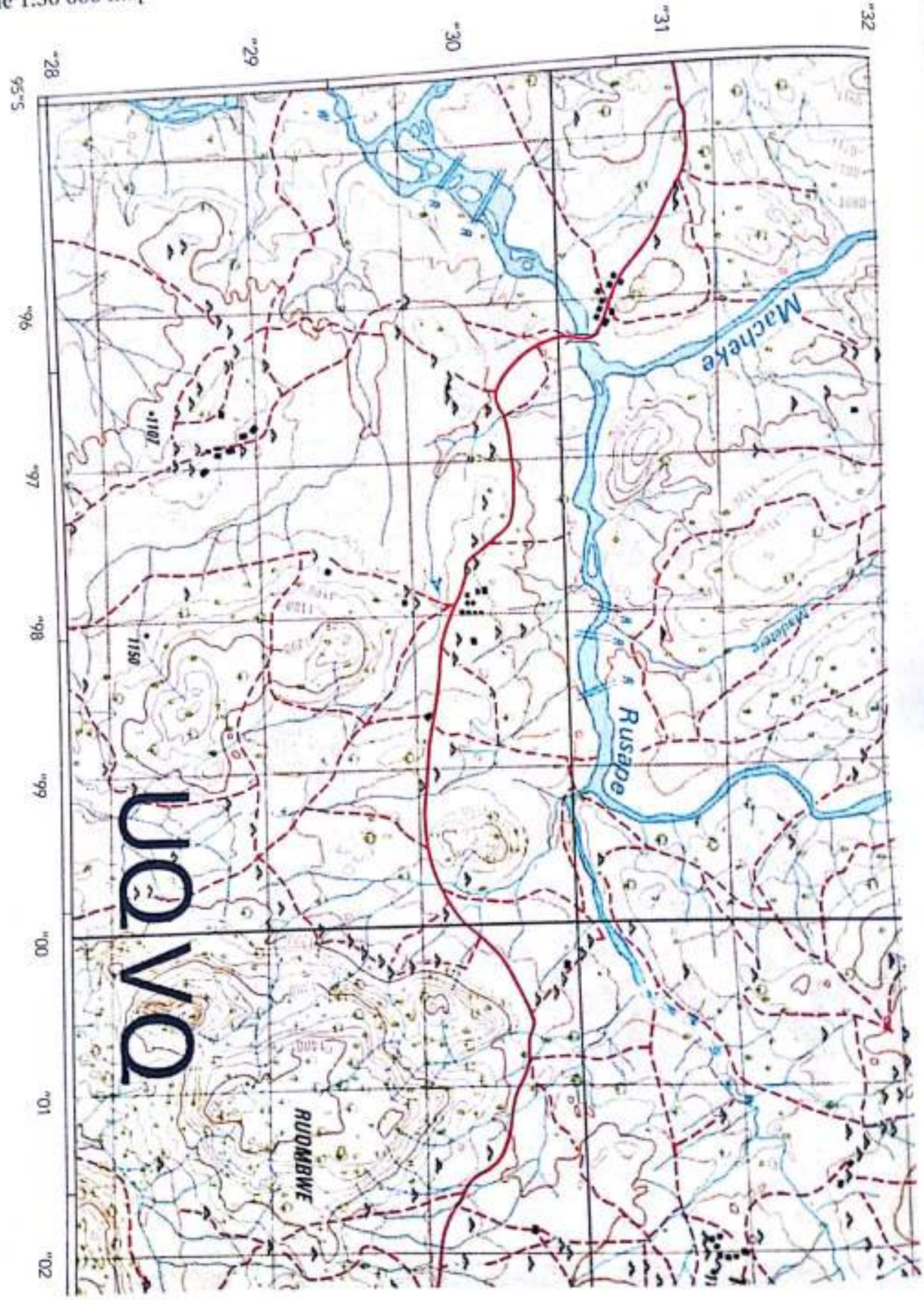
base level – level of the river mouth, such as the sea level or lake, below which the river cannot erode

bluff – steep-sided edge of the flood plain formed by erosion of meandering stream; also termed river cliff

channel – the course or furrow in which a river flows
confluence – a point at which two or more rivers join
consequent stream – the main river in a basin flowing in the direction of the original slope
deferred tributary – a flood plain tributary that runs parallel to the main river due to failure to break through the levees; it eventually joins the main river through a deferred junction
deflation – wind erosion by blowing away loose material
delta – a triangular-shaped deposition feature at the mouth of a river consisting of sediment deposits and short distributaries
denudation – the process of laying bare the surface through weathering, mass wasting, erosion and transportation
desert – an arid, sparsely vegetated and low-productivity area
disaster – a natural or human-made event which results in the loss of life and/or property
distributaries – small straight channels through which a river flows into the sea as it avoids deposited material
hazard – a potential disaster; living on the slopes of a volcano is hazardous
interfluve – the high highland area between two rivers, which can be a spur
intermontane – in between mountains
loess – fine-grained yellowish deposition of sand several kilometres from place of origin
long profile – the cross-section of the river course from the source to the mouth
meander – a bend in the channel of a river
natural levees – ridges that elongate on both sides of a channel in the flood plain and are due to deposition
oxbow lake – a water body in the meander bend that has been cut off from the main channel
pollution – poisoning of the environment through gases, solid waste and liquid waste
risk – the chance a person or community is prepared to take in the face of a hazard, given that there are also potential benefits
river load – material carried by the river as solid sediments and in solution
river mouth – location where the river ends, usually as a delta or an estuary
river source – where the river begins – either from a glacier, a lake, a swamp or a spring
river – water flowing in a well-formed channel under the force of gravity
rock pedestal – a mushroom-shaped feature caused by wind abrasion
saltation – transportation by wind of particles with a 2 mm diameter
seif dunes – wind depositional features of sand, which are longitudinal and parallel
short profile – the cross-section across the river from the crest on one bank to the crest on the opposite bank; commonly called the river valley
siltation – filling up of river channels, dams and other water courses with deposited silt
spring – the point at which water comes out of the ground
stream discharge – the volume of water passing a cross-section of the channel in a given time
stream velocity – the speed at which water flows in a channel; given as distance per unit of time
stream – the same as a river, but usually used to describe smaller tributaries to the main river
subsequent streams – tributary rivers that drain into the main stream
surface creep – transportation by wind by dragging and rolling particles with a diameter greater than 2 mm
suspension – transportation by wind of particles less than 2 mm diameter high up in the atmosphere where fine particles move above the ground
swamp – a wetland where the water table is at the surface
ventifact – a faceted and polished rock pebble formed by wind erosion
wetland – marshy areas with a high water table, for example, dambos and vleis
watershed – an imaginary line that separates one river catchment area or basin from another; the terms 'water divide' or 'water chain' also refer to this line
windward – the side of a mountain range facing the wind
yardang – a ridge and furrow feature comprising alternating vertical layers of hard and soft rock
zeugen – a ridge and furrow feature comprising alternating horizontal layers of hard and soft rock

Topic test 2

Refer to the 1:50 000 map extract of Chiduku as you answer the following questions.

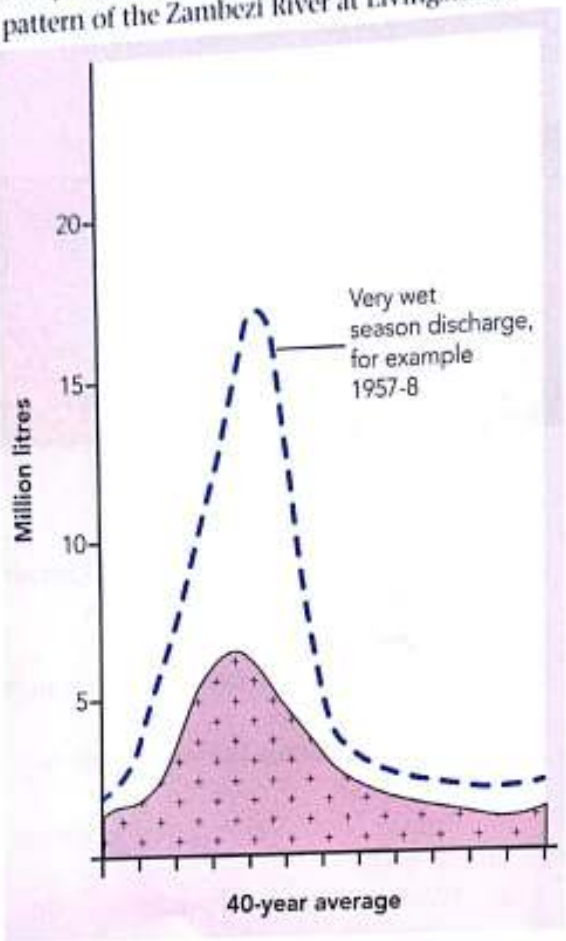


1. The drainage pattern in the area is:
   A dendritic
   B parallel
   C trellis
   D radial.
2. The course of the Rusape River suggests that it flows:
   A over a folded area
   B along fault lines
   C on a domed area
   D on hard rock.
3. In which one of the following grid squares is there a braided channel?
   A 9532
   B 9531
   C 9530
   D 9529
4. The water table appears at the surface in grid square:
   A 0028
   B 0029
   C 0030
   D 0031
5. The map shows an area of the Chiduku map showing a footpath. The footpath follows a:
   A gorge
   B dry valley
   C levee
   D watershed.

6. Study the photograph below.

   a) Name the feature shown in the photograph.
   b) Draw a labelled sketch to show the main elements of the feature shown in the photograph.
   c) Describe and explain how such a feature has been formed.
   d) How is the feature likely to change in the future?
7. The diagram shows the long profile of three African rivers.
   a) What differences and similarities exist between the three long profiles?
   b) With the aid of diagrams, describe three possible ways in which waterfalls are formed.
   c) Discuss the effect of human activities on river processes.

8. Study the diagram below showing the discharge pattern of the Zambezi River at Livingstone.

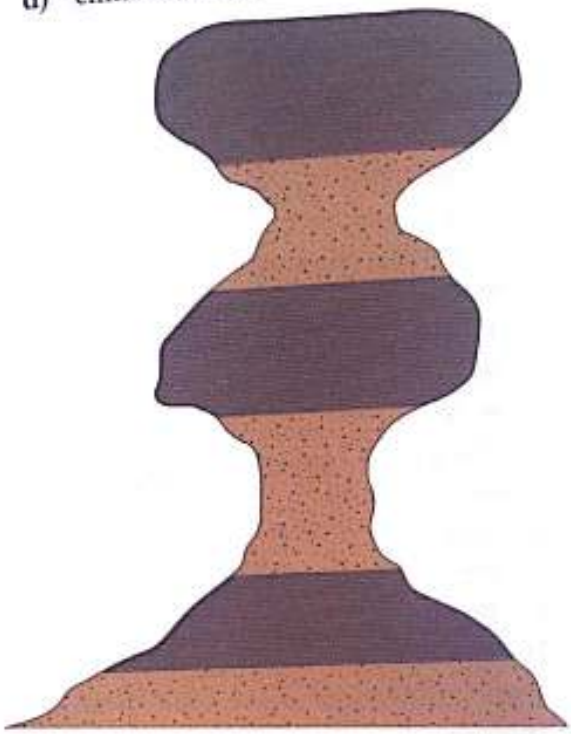


a) Describe and explain the pattern of discharge shown.

b) What are the effects of a very high seasonal discharge, such as the one shown in the diagram above, on:
   i) fluvial processes
   ii) human activities?

9. Which of the following pairs of features is the result of wind erosion?
   a) Barchan and yardang
   b) Zeugen and ventifact
   c) Seif dune and deflation hollow
   d) Wadi and erg.

10. The feature shown in the figure below results from:
   a) water action
   b) wind deposition
   c) wind erosion
   d) climate change



11. a) With reference to two named features, explain why the action of water is regarded as important in hot deserts?

   b) Describe and explain, using diagrams, two landforms resulting from each of the following:
   i) wind erosion
   ii) wind deposition.

12. Match the word or term in column B with the word or term in column A:

Column A	Column B
aeolian	natural feature formed by Earth surface process
fluvial	altitude below which a river cannot erode
mass movement	to do with moving air
flooding	natural and human-made surroundings
landform	to do with running water
landscape	downslope shift of rock and soil under force of gravity
base level	a number of landforms will make up this
environment	happens when river exceeds bankfull

13. Explain the differences between the following terms in your own words:
    a) disaster
    b) risk
    c) hazard.
14. What is the difference between a natural, and a human-made disaster? Give an example of each.
15. What is meant by the term management when it comes to hazards, risks and disasters?

Topic 3 Ecosystems – soils

Objectives

By the end of this topic, you should be able to:

- identify components of soil
- explain soil processes and in particular the processes of leaching, gleization and cheluviation
- name type of soils formed through soil forming processes in the tropics
- explain the soil profile
- identify soil properties
- describe the horizons in the soil profile.

Soil components

Soils are a very important part of any ecosystem. Soils support plant life which, in turn, sustains and supports animal life. Humans rely on soil to grow crops, and to provide fodder for their animals. Without soil, there would be no life on Earth.

Defining soil

Soil is the upper layer of the Earth where plants grow and animals live. It is at the interface of the solid Earth, and the atmosphere. It varies in depth or thickness from a few centimetres to several metres. Soils are mainly a product of the weathering of rocks and they are very important to the survival of plants and animals on the Earth's surface. Soil comprises mineral matter, organic matter, air and water.

Soil components

Soil is a mixture of rock particles and decaying remains of plants and animals. Soil also contains water and air in the spaces between the particles. Soils also contain living organisms such as worms, termites, ants and many other insects and bacteria. Bacteria play a crucial role in the decomposition or decay of plant and animal remains.

Table 3.1 Composition of soils

5%	25%	25%	45%
organic matter	water	air	mineral matter

Activity 1

Visit the school garden and dig up a sample of soil with a hoe or a shovel in an area with grass or weeds.

1. With a partner, break down the soil sample by rubbing it between your thumb and forefinger and catching the soil in your other hand. Make a list of anything you can specifically identify in the soil.

- Does there appear to be any mineral matter?
- Is the sample completely dry or are there signs of moisture?
- Is there any organic matter present?
- Are there any living creatures (ants, worms, beetles) visible to the naked eye?

2. From what you have identified, discuss with your partner the components of the soil.

Soil forming processes in the tropics and soil types

Soil needs time to form. However, soil can be removed or damaged by soil erosion in a very short period of time. We need to understand how soil forms if we are to manage and use it correctly.

Factors influencing soil formation

A number of factors influence the formation of different types of soils. There are five major soil-forming factors:

- parent rock material
- climate
- organisms or **biotic** factors
- relief or slope
- time.

Parent material and time are passive soil forming factors while climate, biotic factors and slope are active soil forming factors. This means that climate and biotic factors act on parent material over time to produce soil.

So, soils are formed by the action of climate and living organisms operating on the rocks of the Earth over a long period of time. Mature soils take hundreds, or even thousands of years to form, depending on local conditions.

The major process operating in soil formation is weathering. Both chemical and physical weathering play important roles in the formation of soil. The rock that is weathered to produce the soil is referred to as the parent material. The parent material determines the minerals found in the soil, that is, the soil's chemical composition, as well as the soil's colour. The interacting factors that contribute towards the formation of soils are shown in Figure 3.1.

Parent material

Soil is formed mainly from the weathering of parent rocks. The parent rocks from which soils are derived include igneous, sedimentary and metamorphic rocks. Do you still remember these types of rocks from Form 2 and the chapter on weathering and rocks?

A soil usually takes on the characteristics of the underlying rock. This then influences the texture or particle size of the soil, as well as its colour and depth. Rocks rich in quartz result in sands and silts. These soils are coarse-grained in texture. Feldspar-rich rocks result in clays with a higher moisture-holding capacity. These soils are fine-grained.

Climate

The rate of rock weathering is influenced by climate. Rates of weathering are high in parts of the world where temperatures and rainfall are high. These are usually the tropical rainforest areas and some sub-tropical areas such as the **savannah**. The large amounts of humus in these areas assist in the formation of organic acids, which promote high rates of decay. Deep layers of soils usually form in these areas.

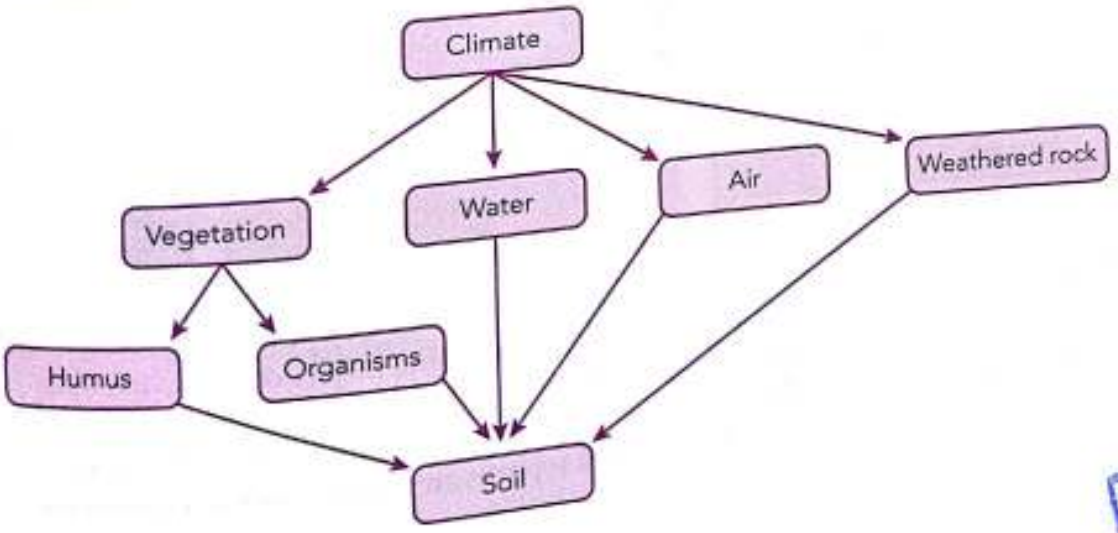


Figure 3.1 Factors in soil formation

Relief

Steep slopes are usually associated with shallow soils because the rates of soil removal, or soil erosion are higher. Low-angle, low-lying slopes develop **waterlogged** soils because of the poor drainage. Water accumulates down slope, because it receives water from the upper slopes, as well as minerals and organic matter. Deep, mature soils are more likely to develop on valley floors than on hill slopes.

Organisms

The nutrient cycle, which is the continuous movement of nutrients between living and non-living components of an ecosystem, is vital for the well-being of soils. Bacteria and fungi break down dead vegetation through decay and decomposition. Earthworms and termites also help to mix mineral and organic matter. Larger burrowing animals such as moles may also aerate the soil.

Time

Soil formation is an extremely slow process. Recently formed soils are closely related to the parent rock in terms of their characteristics. Examples of recent or young soils include loess, alluvial and recent volcanic lava deposits. Mature soils are usually deep and show an adaptation to the prevailing **environment**, which reflects the prolonged effect of all the soil-forming factors.

Activity 2

1. Copy and complete the following table about where soil comes from.

Rock type	How it is formed	Examples
Igneous		
Sedimentary		
Metamorphic		

2. Explain the difference between active and passive soil forming factors.
3. Explain what you understand by the term *weathering*.
4. Choose any one factor in soil formation. Use the information in this book, and any other sources you can find, to write a paragraph explaining how this factor contributes to soil formation.

Important tropical soil processes

Tropical regions tend to have a high rainfall, and high temperatures. The hot, wet climate produces some important soil processes. Three important soil processes can be highlighted. All of them depend on soil water and all occur in tropical regions.

Figure 3.2 A very deep, red tropical soil

Leaching

Leaching is the movement of chemical compounds downward, under the influence of gravity, from one soil horizon to another. See below for an explanation of a soil profile and soil horizons. Leached topsoils are infertile, because nutrients

have been removed through the leaching process. Plants that grow on leached soils must take their nutrients from very close to the surface, so they have shallow root systems.

Gleization

Gleization is the development of a gley horizon in the lower part of the soil profile above the parent material due to poor drainage conditions. This leads to waterlogging, and a lack of oxygen in the soil. Like leaching, gleization leads to a reduction in soil fertility. Plants will struggle to grow in gley soils, because their roots will become waterlogged.

Cheluviation

Cheluviation is the downward movement of materials in the soil and is similar to leaching. However, it is plant acids rather than water which facilitate the movement of metallic (iron and aluminium) compounds in the soil.

Laterites and lateritic soils develop in tropical regions where there is very heavy rainfall. The term laterite comes from a word meaning brick. It refers to a cemented horizon in certain soils which, when dried, become as hard as bricks. This happens when iron and aluminium compounds build up in the soil, while silica is removed. Lateritic soils are soils where the laterization process leads to lots of iron and aluminium, making the soils red in colour, and generally infertile.

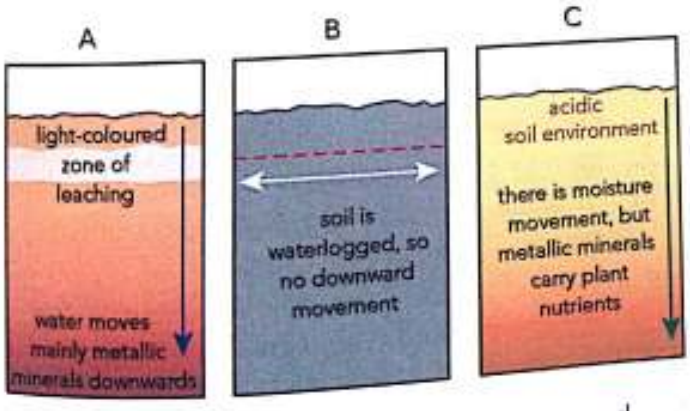
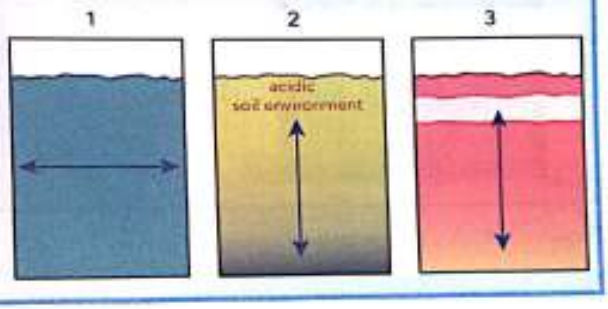


Figure 3.3 Comparative movement of water and soil material under (A) leaching, (B) gleization, and (C) cheluviation

Activity 3

1. Why do soils in tropical rainforests have small amounts of humus-derived nutrients remaining in them at any time? Hint: Think about the fast rate of leaf decay and nutrient uptake in these areas.
2. Look at the following diagrams. The arrows represent the main direction of water movement. For each diagram:
   - identify the active soil process
   - explain briefly what is happening
   - decide whether the soil will be fertile or infertile.



Soil properties

There are different kinds of soil all with their own properties.

Soil profile

If a pit is dug into the soil until bedrock is reached, different layers will be observed. The different layers are called horizons. They can also be seen on road or railway cuttings. The different horizons from the top to the bottom are known as the **soil profile**. Generally, four horizons can be identified on a soil profile and these carry the codes A, B, C and D Horizons (Figure 3.4).

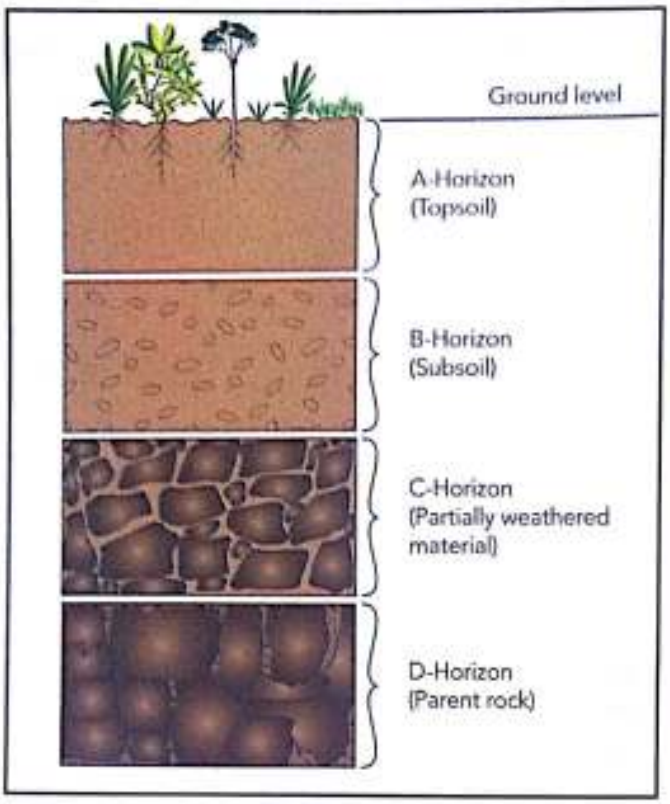


Figure 3.4 A-, B-, C- and D-Horizons

- The A-Horizon is the topsoil and it is usually dark in colour because it contains humus. This part of the soil profile contains most of the nutrients and the roots of the plants. The humus is derived from the decomposition of dead plants and animals. In this layer, under conditions of high rainfall, leaching takes place. Leaching is the downward movement of soluble minerals. Horizon A is therefore also referred to as the zone of eluviation.
- B-Horizon is known as the subsoil and it is lighter in colour with fewer plant roots and humus. This layer can also be referred to as the zone of accumulation or illuviation. Materials from zone A accumulate in this zone. It is therefore referred to as the zone of illuviation.
- C-Horizon is made up partly of weathered or broken up rock. It is very compact with very few pore spaces.
- D-Horizon is the unweathered parent rock, also known as the bedrock.

Activity 4

With the assistance of your teacher, dig a soil pit and study the soil horizons, colours, thickness and materials contained in the horizon. Use the following outline to draw the soil profile that you have observed

	A-Horizon (Topsoil)
	B-Horizon (Subsoil)
	B-Horizon (Partially weathered material)
	D-Horizon (Parent rock)

Soils are very important to plants, animals and people. Human beings and animals survive on plants. Soils provide the place for plant seeds to germinate, they support their growth, keep moisture for the plants and also provide most of the food which the plants require.

Project

1. Visit a nearby area that has some deep gullies, with the side layers exposed. If there is no such area near you, dig down into some soil up to the bedrock, with guidance from your teacher.
2. Identify the soil horizons exposed.
3. Measure each of the soil horizons using a tape measure.
4. Using diagrams, describe the nature of the soil profiles in the area you were studying.

Soil characteristics

Soils vary greatly in nature, and the variation is a result of such factors as the parent rock, climate, vegetation and relief. The main characteristics of soil can be identified as texture, structure, colour, chemical composition or acidity, drainage and soil depth.

Soil texture

Soil texture refers to the size of soil particles. Most soils are a mixture of different soil grain sizes. The soil texture can be felt by pressing the soil sample between two fingers. The soil grain sizes can be grouped into gravel, sand, silt and clay. Clay is made up of the smallest particles and the grains would increase in size in silt, then sand, and finally gravel which is made up of small rock pieces. We will look at soil types in more detail below. The grain sizes for the different types of soil are as follows:

- clay – less than 0,002 mm in diameter
- silt – 0,02 mm to 0,002 mm in diameter
- sand – 2 mm to 0,02 mm in diameter
- gravel – more than 2 mm in diameter.

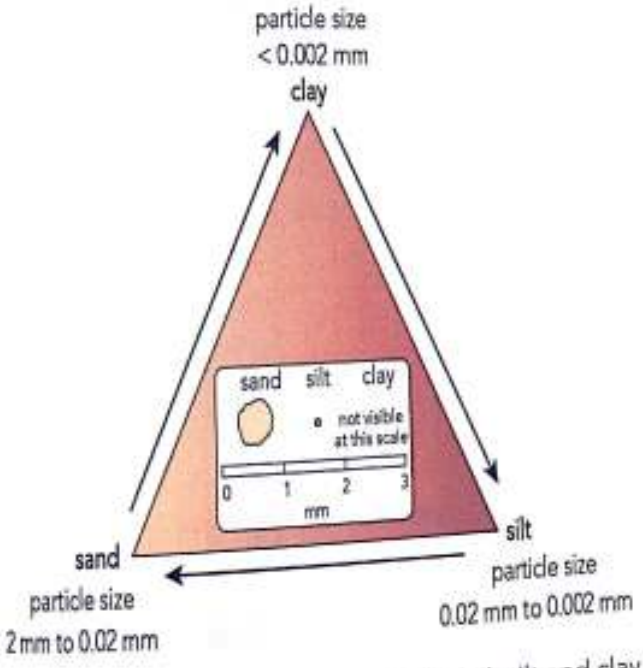


Figure 3.5 Soil texture in terms of sand, silt and clay

Soils comprise a mixture of sand, silt and clay. Texture greatly affects the rate of water movement in a soil. Water moves more rapidly in sand and more slowly in clay and silt. This is because the pore spaces (between the soil particles) are bigger in sandy soils.

Soil structure

The grains that make up the soil and the other components of the soil stick together as soil peds. The soil peds that form during ploughing or digging, form particular kinds of soil structures namely:

- crumby (crumbs)
- granular (grains)
- platey (plates)
- blocky (blocks)
- prismatic (prisms)
- columnar (columns).

This is shown in Figure 3.6.

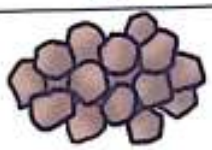
Type of structure	Shape
crumb	
granular	
platey	
blocky	
prismatic	
columnar	

Figure 3.6 Different soil structures

Soil structure helps to determine:

- the rate at which soils absorb water
- how vulnerable the soil might be to soil erosion
- the volume of air and water which the soil can hold
- the ease with which the soil can be worked or ploughed.

Activity 5

1. With the help of your teacher, collect samples of sandy soils, clay and silt soils, for display in your class.
2. Discuss the advantages and disadvantages of these types of soil texture for farmers, who are trying to grow crops.

Soil colour

Soil colour gives clues regarding the soil composition and origin. Figure 3.7 shows a range of typical soil colours. Soils can be red, brown, yellow, black, or even grey to green. Dark soils (E) usually have high **humus** content from organic matter and light soils have less humus. The chemical composition of the soil also affects its colour. Red soils (A) are usually rich in iron oxides and whitish soils (G) are rich in calcium. The colour also depends on the parent rock. Most soils are brownish (B and C) in colour. Brown is a mixture of red and yellow. Wind-blown sand is often yellow in colour (D). Waterlogged soils are most often grey-green in colour (F).

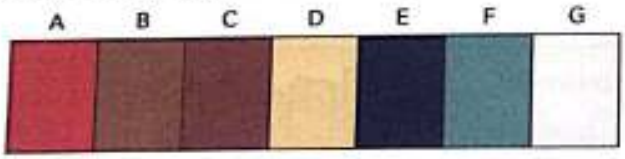


Figure 3.7 Typical soil colours range through red, yellow, black, brown and even, in some environments, grey-green

Soil chemical composition

Soils are made up of minerals and chemical compounds. **Soil pH** is a measure of how acid or basic a soil is. Soils can be referred to as acidic, neutral or alkaline. High acidity in a soil is caused by low lime or low calcium content and high alkalinity is a result of high lime content. The acidity or alkalinity of a soil is measured using what is known as the pH value, which is a measurement of the concentration of hydrogen ions in the soil water. The pH scale runs from 1 to 14. The neutral point is around 7. Values below 7 indicate an increase in acidity and values above 7 show increasing alkalinity. Most soil organisms and plants prefer neutral soils.

Figure 3.8 Soil acidity and alkalinity (pH)

Table 3.2: pH scale

Description	Value
strongly alkaline	>7,5
alkaline	6,5–7,5
neutral	6,0–6,5
slightly acidic	5,5–6,0
medium acidic	5,0–5,5
strongly acidic	4,5–5,0
very strong acidic	<4,5

The best soils for farming have a pH value of between 6,0 and 6,5. When soils are too acidic, bacterial activity is inhibited and such soils are poisonous or toxic. Lime is added to these soils to neutralise them so that bacterial activity is promoted.

Soil depth

Soil depth is very important to plants and farmers. Thin soils are not good for plants or farming purposes, whereas deep soils support a lot of vegetation and are good for farming purposes. Look again at Figure 3.1. There is a strong relationship between soil depth and slopes. Steep slopes usually have thin soils and gentle slopes have deep soils.

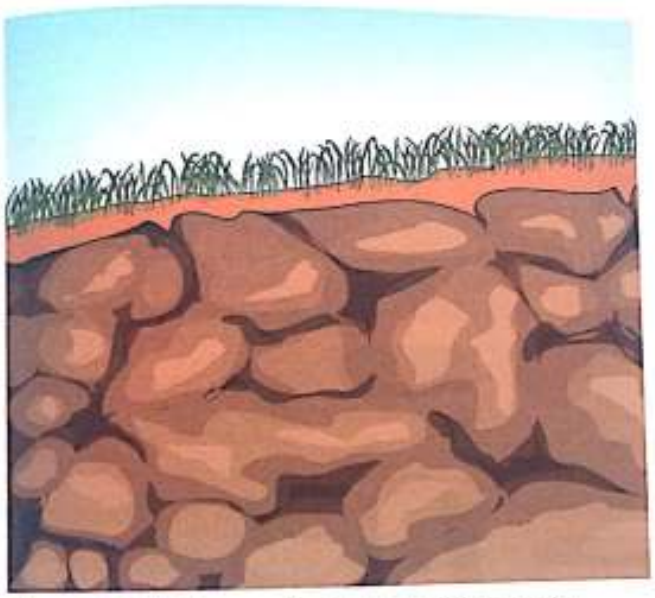


Figure 3.9 Thin layer of soil that has formed on weathered bedrock on a slope

Soil types

As seen from the study of soil texture, soil grains vary in size. The size of the soil particles varies from gravel (2 mm and more in diameter), sand (2 mm to 0,02 mm), silt (0,02 to 0,002 mm) and then to clay (less than 0,002 mm diameter).

The main soil types are primarily identified using soil texture and these are sandy soils, clay soils and loam soils:

- *Sandy soils*: These have large grain particles, hold very little water and drain quickly. It is easy to cultivate sandy soils but plants suffer from a lack of water in dry weather. There are some crops that favour sandy soils, for example, tobacco.
- *Clay soils*: These soils are made up of microscopic clay particles. These are very small particles that can hold water molecules on their surfaces, or in the pore spaces between the particles, but they do not allow water to pass through easily. It is difficult to cultivate crops in clay because they are hard when dry and sticky when wet. Plants grown in clay soils may suffer from having too much water around their roots.

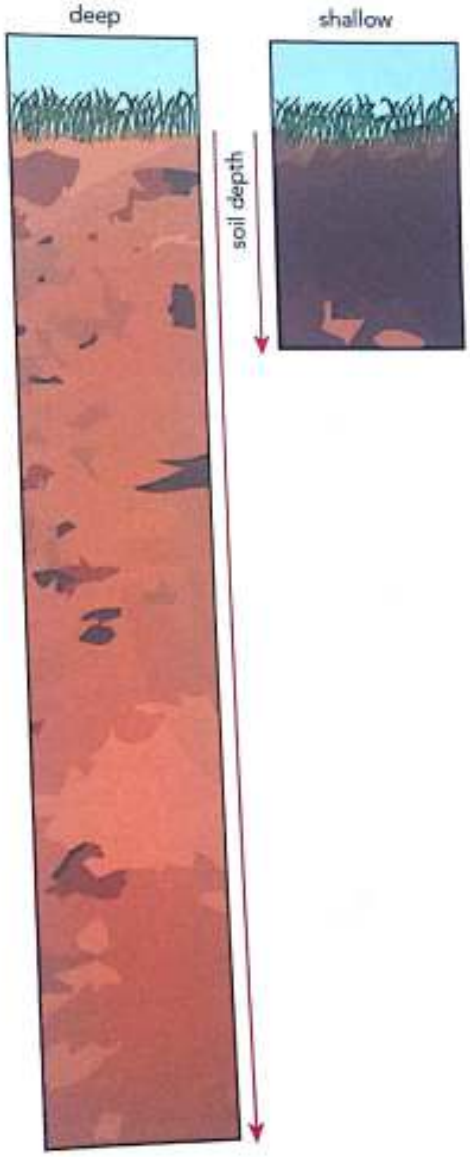


Figure 3.10 A very deep, and a very thin or shallow soil profile compared

- *Loam soils*: They are a result of the mixture of sand, silt and clay particles. The soils hold water well and have good drainage. They are suitable for cultivation and plant growth.
- *Alluvial soils*: These are formed when rivers in flood deposit soil eroded from upstream. They are usually fertile and it is easy to cultivate them. They have a high content of humus from the decomposition of organic material carried by the rivers.
- *Aeolian soils*: These are wind-blown soils and are often very fertile too. The loess soils of China and Europe are a good example.

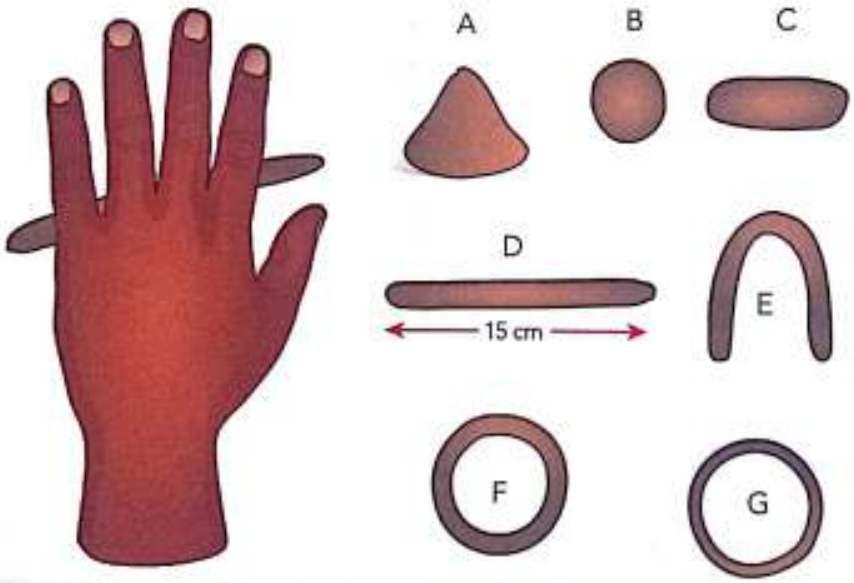
Some soils are identified by their colour and are referred to as red, brown or black soils. Parent material can also be used to identify some soils, for example, limestone soils. A dominant climatic type can be used to label a soil type, for example, desert soils.

Activity 6

With the help of your teacher try and identify different types of soils in terms of their texture. Bring some samples from where you live and some from around your school grounds.

After recording the different samples, do the following:

1. Drip water onto about one tablespoon of fine soil held in your hand.
2. Squeeze and roll the soil until it starts to stick to the palm of your hand.
3. Look at the following figure. The extent to which each soil sample can then be shaped gives an idea of its texture class (sand, silt, clay, loam).



A *Sand*. Soil remains loose and single-grained and can be heaped, but not formed.

B *Sand loam*. Can be shaped into a ball that easily falls apart.

C *Silt loam*. With more silt it can be rolled into a short thick cylinder and is called a silt loam.

D *Loam*. About equal sand, silt and clay and can be rolled into a thick thread about 15 cm long that breaks when bent.

E *Clay loam*. Soil can be rolled as above but can also be bent carefully to a U-shape without breaking.

F *Light clay*. Soil feels smooth and can be bent into a circle with some cracks.

G *Clay*. Handles like thick dough and can be bent into a circle without cracks.

Summary

- There are different soil components that make up soil. These are mineral material (from weathered rock material), an organic component, air and water. Without all of these, we have sediment, not soil.
- Soil forms through various processes acting on rock material to break it down into smaller particles.
- Soil processes continue to impact on soil even after it has formed.
- Leaching is a process whereby water in a soil profile moves soluble elements and soil nutrients from the topsoil downwards, leaving concentrations of metallic minerals in the topsoil.
- Gleization happens in waterlogged, marshy environment where little oxygen is present. These are called reducing environments, and organic material is preserved.
- Cheluviation is the downward movement or mobility of materials in the soil and is similar to leaching. However, it is plant acids rather than water which facilitate the movement of metallic (iron and aluminium) compounds in the soil.
- Lateritic soils and laterites tend to form in tropical regions under heavy rainfall.
- A soil profile is a vertical selection of succession of soil horizons, from top to bottom, each with its own identifiable properties and colour.
- Soil properties include soil particle size, organic content, moisture content, pH, colour; the make up or composition of the soil.
- The main soil horizons, from top to bottom, in a soil profile are: O (not always present) A, E, B, C and R.
- Soil types are often classified in terms of the relative amounts of sand, silt and clay in the soil.

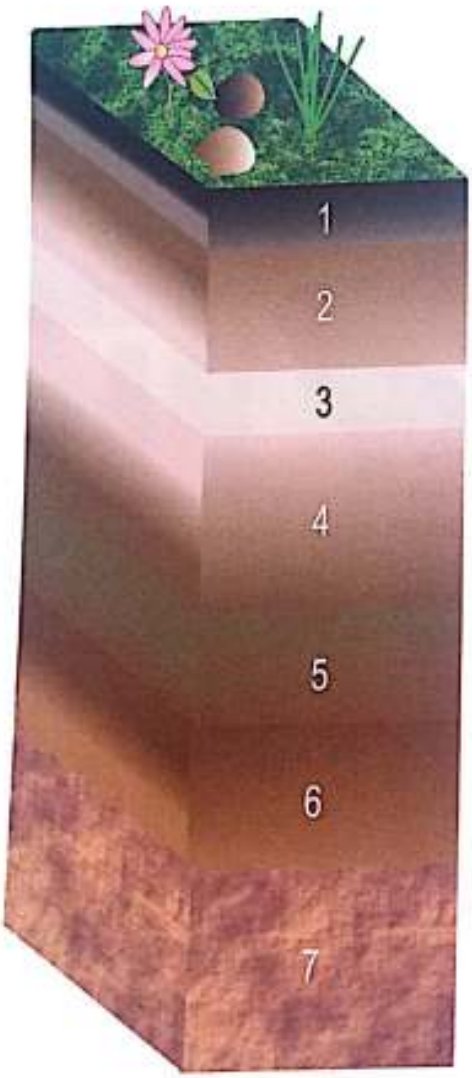
Glossary

alluvial – to do with running water or rivers
biosphere – the world of plants
biotic – living organisms, for example, plants and animals
environment – all that surrounds us; our surroundings
food chains – hierarchical (ranked from low to high) feeding relationships in an ecosystem
ped – the basic form or shape of a soil structure, for example, a crumb, a plate or a column
savannah – tropical vegetation dominated by grass and trees
soil pH – degree of acidity or alkalinity of a soil
soil profile – horizontal layering through a soil
tropics – areas between the Tropics of Capricorn and Cancer
waterlogged – saturated, filled with water

Topic test 3

Look at the diagram below and answer the following questions:

1. Give the diagram a name.
2. Give labels for 1, 2, 3 and 4.
3. What is represented by 7?
4. Explain the link or connection between 6 and 7.
5. Where are you likely to find:
   a) the most organic material and
   b) the least organic material?
6. How do sandy, silt and clay soils behave if you add water to a sample of each?
7. Explain these terms in your own words:
   - soil chemical composition
   - soil colour
   - soil structure.



Unit 4

Mapwork and Geographical Information Systems

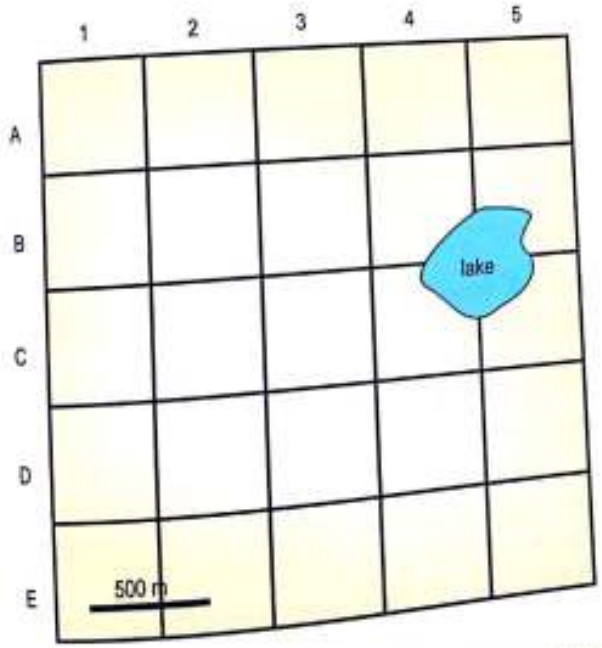
Objectives

By the end of this topic, you should be able to:

- describe the basic functions of Boolean logic
- apply Boolean logic in solving simple spatial problems
- describe the concept of overlay analysis
- apply relational and conditional statements in overlay analysis.

Introduction

In Forms 1 and 2 you were introduced to mapwork. Because Geography is a spatial subject, maps are the geographer's most important tool. With the introduction of computers, mapwork too has become computerised. You were introduced to this in Form 3 with the concept of global positioning systems (GPS) and the electromagnetic spectrum. **Geographical Information Systems (GIS)** are computer-based systems which allow spatial **data** (information regarding the position of an object or objects, usually by means of coordinates on a map) to be stored in a computer, and utilised by GIS **software** programs to produce a variety of useful **maps**. Non-spatial data are attribute data. These data tell us more about the attributes or characteristics of the object or objects.



chemical	ppm
NaCl	1000
H_2S	500
Mg	600
$CaCO_3$	600
FeO	300

Figure 4.1 Spatial and non-spatial (attribute) data in a geographic example. We can express the position of the lake in terms of simple coordinates (1 to 5, and A to E) while the table tells us about the attributes of the lake water in terms of its chemistry.

Logic

If you are told to put your hand into a fire, you are unlikely to do so. Simple **logic** tells you that, if you follow the instruction, you will burn your hand! So, what is logic? Logic is reasoning conducted or assessed according to strict principles of validity. You reason or think, correctly, that you will burn your hand, but you can also validate this by putting, say, a piece of paper into the flame. If you do this 100 times, the result will be the same; the paper will burn. You have established a strict principle. This is logic!

In the computer world (remember, a GIS is a computer-based mapping system) logic refers to a system or set of principles underlying the arrangements of elements in the computer so as to perform a specific task. This just means that the computer deals with information in a logical way, to produce outputs which are useful to the end user. If you ask a computer to add 2 + 2 + 2 and divide by 2, it will always produce the answer 3, as the arrangement of elements in the computer is logically set up to carry out or execute arithmetic functions correctly.

Figure 4.2 A GIS system with its different components

In the case of a Geographical Information System (GIS) the computer (or, to be more accurate, the GIS software program in the computer) is working, logically, with spatial data, on different planes or layers. This is shown in the form of a diagram in Figure 4.3. Of course, if you open up the computer, you are not going to see anything like Figure 4.3.

All the data and processing is stored and processed electronically, at incredibly fast speeds, by the computer using the GIS software installed. In the example shown in Figure 4.3, we are using information on:

- population distribution
- average household income
- % employment
- average ages
- education.

We use this information to come up with a summary layer in the form of a map for a particular area. In our example, such a map might be used to assist planners to decide where to build, for example, a new school, or a clinic. The important thing to remember is that computers are simply machines, which operate in a logical way, to produce useful results, provided we provide accurate information for the computer to work with.

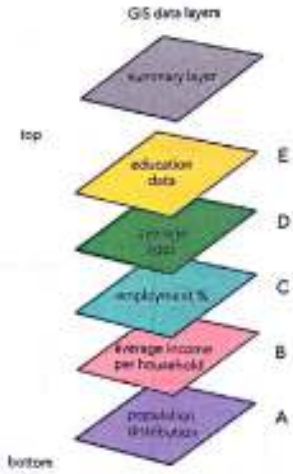


Figure 4.3 How GIS data layers are dealt with by a computer

Boolean logic

We need to understand more about logic if we are to understand how computers, and GIS work. Boolean logic is named after the mathematician George Boole, who lived two centuries ago. **Boolean logic** is a form of algebra (where letters and symbols are used to represent numbers and values in equations) in which all values are reduced to either TRUE or FALSE. Boolean logic is very important in computer science and

GIS because it fits with the **binary** numbering system. Binary means two numbers. Each bit of information in a computer has a value of either 1 or 0. Put differently, following Boolean logic, a bit has a value of either TRUE or FALSE.

Follow this example to understand the idea of Boolean logic:

- We start off with a statement, which we will call P, which is either TRUE or FALSE. It cannot be anything in between. This is called the law of the excluded middle. The statement is true, or it is false. For example, a person is either alive, or they are dead, there is no state in-between!
- We then form other statements, which are TRUE or FALSE, by combining our original statement with other statements using AND, OR and NOT.
- For example, if P is true then NOT(P) is false. So, if 'this is Zimbabwe' is TRUE then 'NOT(this is Zimbabwe)' is false. We often translate the logical expression into English as 'this is not Zimbabwe' and this makes it easier to see that it is FALSE, as our country is indeed Zimbabwe.

The nice thing about Boolean logic is that we can write down arguments clearly in symbolic form in what are known as **truth tables**. The rules for combining expressions are usually written down as tables listing all of the possible outcomes. For the three fundamental operators (AND, OR and NOT) these are:

P	Q	P AND Q
F	F	F
F	T	F
T	F	F
T	T	T

P	Q	P OR Q
F	F	F
F	T	T
T	F	T
T	T	T

P	NOT P
F	T
T	F

Notice that while the Boolean AND is the same as the English use of the term, the Boolean OR is a bit different. If someone asks you if you would like 'water OR juice' you will not say yes to both.

In the Boolean case however 'OR' includes both. When P is true and Q is true the combined expression (P OR Q) is also true. There is a Boolean operator that matches the English use of the term 'OR' and it is called the 'EXCLUSIVE OR' written as EOR or XOR. Its truth table is:

P	Q	P XOR Q
F	F	F
F	T	T
T	F	T
T	T	F

This would stop you having both the water and the juice because the last line is True (XOR True = False).

If we want to design machines that have to respond to the outside world in a complex way, Boolean logic is a great help. For example, we have an alarm, which we set to only work at night and will go off if a window is forced open. We start with a light sensor, which sends a signal to the alarm's control box, indicating the truth of the statement:

- P = It is daytime.
- NOT(P) is true when it is night-time. This is a practical application of Boolean logic.

We need something that works out the truth of the statement:
R = Burglary in progress from: P = it is daytime and Q = Window open
Logic provides the solution that:
R = NOT(P) AND Q

That is the truth of a break-in is taking place and is given by the following truth table:

P	Q	NOT(P)	NOT(P)AND Q
F	F	T	F
F	T	T	T
T	F	F	F
T	T	F	F

From this you can see that the alarm will only go off when: it is night-time, and a window is opened.

Activity 1

1. Give definitions or explanations for the following:
   - Geographical Information System (GIS)
   - logic
   - algebra
   - statement
   - binary.
2. What exactly is Boolean logic?
3. Say whether each of the following statements is TRUE or FALSE:
   a) P = 1 Q = 1 P and Q = 3
   b) P = daytime NOT(P) = night-time
   c) The outlaw is wanted dead or alive
   d) The outlaw is wanted dead and alive
   e) Question: Do you want tea or coffee? Answer: Yes please.

Boolean logic and Venn diagrams

A **Venn diagram** shows the relationships between and among sets. These are groups of objects that share something in common. Venn diagrams are used to show set intersections. The symbol used is ∩. Venn diagrams are used in scientific work, including computer applications. Venn diagrams normally comprise overlapping circles (Figure 4.4). The interior of the circle symbolically represents the elements of the set, while the exterior represents elements that are not members of the set. For example, in a two-set Venn diagram, one circle may represent the set of all pasture land. The second circle may represent the set of all cattle. The overlapping region or *intersection* would then represent the set of all pasture land used to graze cattle. Shapes other than circles can be employed as shown in Figure 4.5.

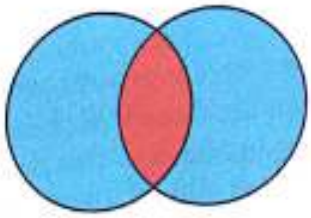


Figure 4.4 The diagram shows the intersection of two sets, represented by blue circles. The intersection is shown in orange.

Venn diagrams and GIS

The concept of Venn diagrams in Geography and GIS should now be easier to follow. Look at Figure 4.5. It shows the relationship among three overlapping sets X, Y, and Z. The intersection relation is defined by the logic AND (look for the sign). An element is a member of the intersection of two sets if that element is a member of both sets. Venn diagrams are generally drawn within a large rectangle that denotes the universe. The universe is simply the set of all elements that we are dealing with.

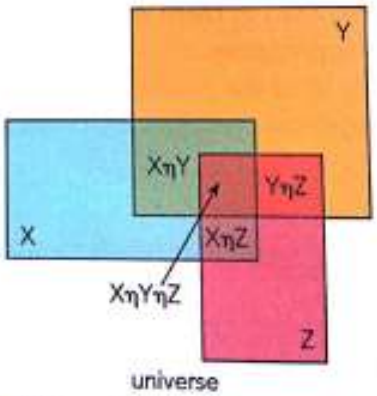


Figure 4.5 A Venn diagram, showing three sets, X, Y and Z

In this example, points that belong to none of the sets X, Y, or Z are part of the universe shown in pink. Points belonging only to set X, or set Y or set Z are shown in different colours. Points belonging to X and Y but not to Z are indicated in a different

colour, as are points belonging to Y and Z but not to X, and points belonging to X and Z but not to Y. Points contained in all three sets are dark black in colour.

Boolean logic in solving simple spatial problems

Look back the explanation of Boolean logic in terms of truth tables. We can express the same logic by using Venn diagrams, instead of tables (Figure 4.6).

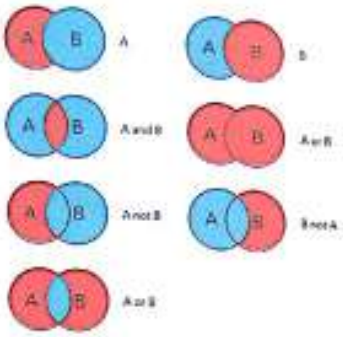


Figure 4.6 Boolean logic truths in terms of a Venn diagram

Now, look at the following spatial problem which we will solve using Boolean logic in the form of **overlays**. These overlays are discussed in more detail below. The problem facing an African country is that of setting aside land as a reserve for endangered mountain gorillas in a certain part of the country. Input data are land use and slope. Figure 4.7 shows, in simple form, how this might appear on a GIS screen on a computer. The steps are:

- First, we choose the land use and slope categories we wish to overlay (see the checkboxes in the legend window).
- Second, choose the Boolean operator. In this case, it is AND.
- This is because the mountain gorillas need, in their sanctuary area, forest, AND moderate to steep slopes. This is the habitat the animals need.
- We choose forest and two slope categories, namely slope steepness 10% to 30%, and slopes greater than 30%.

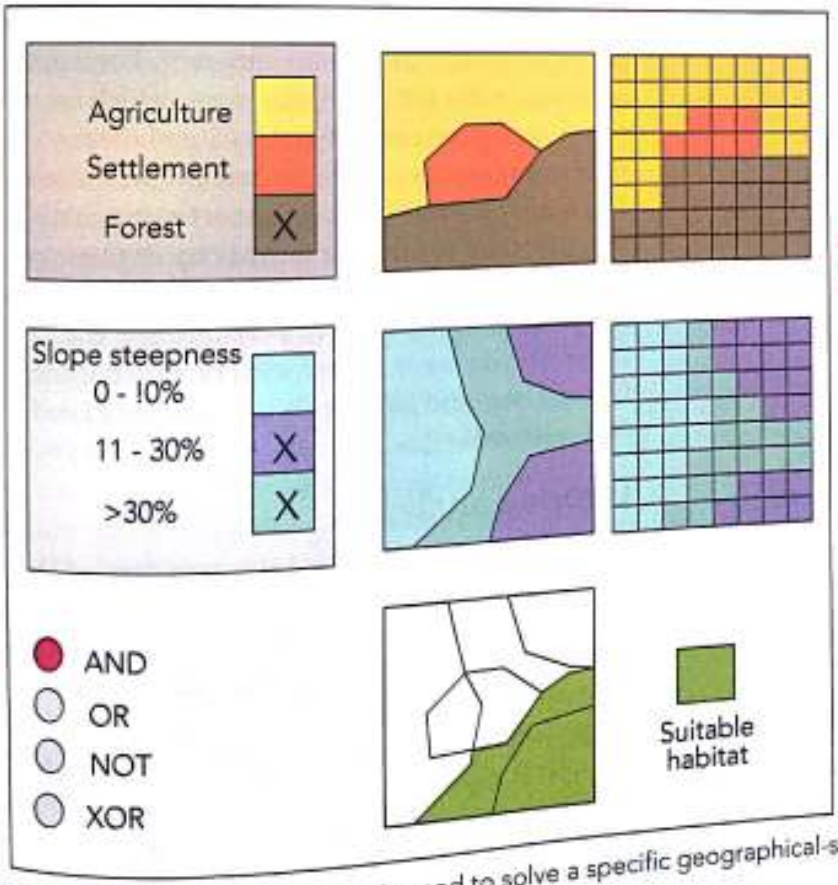


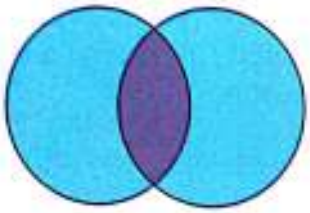
Figure 4.7 GIS and Boolean logic used to solve a specific geographical-spatial problem

- Both are hard criteria and must be met by the intersection, AND.
- Having done this, we instruct the computer (GIS program) to calculate the Boolean overlay for the habitat required. This is shown in Figure 4.7.

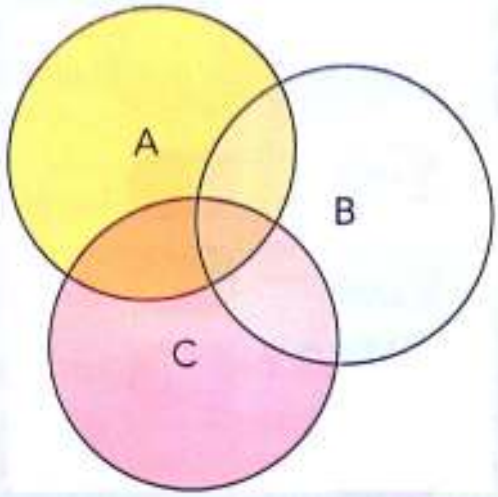
The decision makers can now go about setting aside land in the area shown in green on the map as suitable habitat.

Activity 2

1. What is a Venn diagram?
2. Venn diagrams are always circular in shape. True or false?
3. Explain what is represented by this diagram, by giving the diagram a caption or title:



4. Define these terms as applied to a GIS, using Boolean logic and Venn diagrams to solve real-world spatial problems:
   a) spatial problem
   b) universe
   c) Boolean operator
   d) hard criteria
   e) overlay
   f) end user or decision maker.
5. In which of the following would a GIS be of little or no use:
   a) Planning for the siting of a new clinic, based on population distribution in an area
   b) Preserving wildlife habitat for an endangered species
   c) Deciding on the date for an important football match
   d) Locating a new road through an environmentally sensitive area.
6. What does ∩ represent or symbolise?
7. Redraw this diagram in your exercise book and shade or mark the following intersections:
   a) A ∩ B
   b) A ∩ C
   a) A ∩ B ∩ C



Vector and raster data

Note the maps (layers) in Figure 4.7. The two overlays on the left, and those on the right are both GIS layers, but they are different. The maps or layers on the left are vector maps, which use points, lines (arcs) or **polygons** (closed shapes, such as the outline of the settlement on the map). The maps or layers on the right are raster maps. In a GIS, they contain data made up of pixels or, in this case, blocks called cells. Each pixel or block has an associated value. You cannot 'see' the value (all you see is a layer with blocks) but the GIS can 'see' and work with the data associated with each cell.

Overlay analysis

What have we done above? We have applied the principles that we looked at previously to a real geographical (spatial) issue. Remember, geography is a spatial subject, dealing with space, place and time as well as the attributes or characteristics of objects or sets in space, place and time. Overlay analysis is a group of methodologies commonly used by geographers when we are trying to

find, say, the ideal place to site a new clinic or school. It is also used to **model** and decide if, for example, a site is suitable for a particular purpose. GIS software helps us to apply a common scale of values to different inputs to come up with or create an integrated analysis. Look again at Figures 4.3, 4.5 and 4.7 in this regard. What a GIS does is overlay analysis, to come up with answers, suggestions or guidelines with regarding to geographical (spatial) issues.

Here are some real-world geographical examples of the use of overlay analysis and suitability models:

- Where to site a new housing development.
- Which areas of Zimbabwe should be flagged for wildlife preservation.
- Where economic growth is most likely to occur.
- Where the locations are that are most susceptible to flooding in the rainy season.

Overlay analysis often requires the analysis of many different factors. For instance, choosing the site for a new housing development means assessing such things as land cost, proximity to existing services, slope, and flood frequency. This attribute information exists in different forms with different value scales (dollars, distances, degrees, millimetres and so on). Also, the factors in your analysis may not be equally important. It may be that the risk of flooding is more important in choosing a site than the low cost of the land. How much more important is for the geographer to decide.

Here are the general steps when performing an overlay analysis. Remember, you will be working with a computer loaded with or connected to GIS software. You will have to provide the information needed by the program to assist you deal with your particular question or problem.

The steps are:

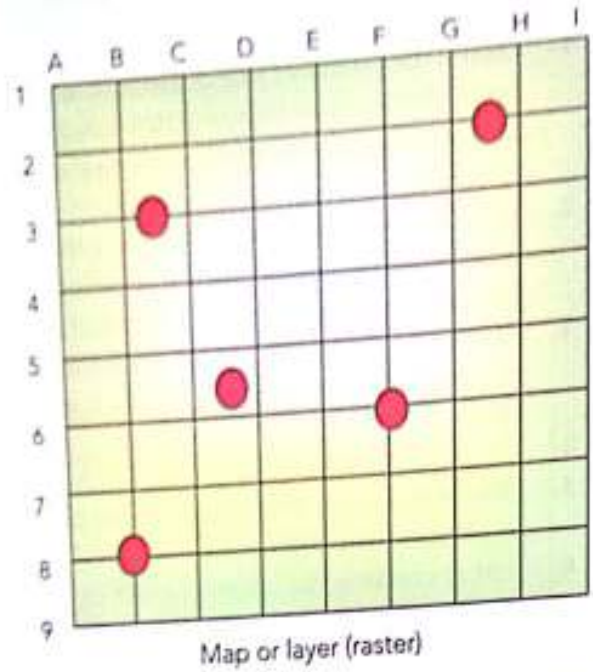
1. Define the problem; this is a logical starting point. If you don't have a defined problem or question, you will not be able to start the analysis.
2. Break the problem into sub-models; this just means breaking up the issue or problem into smaller, easier to work with section.
3. Determine the significant layers that are relevant to your problem (look again at Figure 4.3).
4. Reclassify or transform the data within a layer.
5. Weight the input layers; some layers are more important than others.
6. Add or combine the layers (the GIS does this for you).
7. Analyse (the GIS does this for you).
8. Use the results to make decisions with regard to your original problem.

Relational and conditional statements in overlay analysis

In overlay operations new spatial elements are created on the basis of multiple input maps. **Raster** data is suitable for such operations, since all maps used in the analysis have the same **georeference**. In Figure 4.8, the GIS map stores information regarding each point or pixel. For example, in this case, information on altitude, slope, soil type, vegetation and land use. We could even input information for the settlement, for example, how many people (on average) live in each dwelling.

Relational statements in a GIS tell us whether one expression is larger than, smaller than, or equal to another expression.

Conditional statements in a GIS tell the program to execute or carry out one option if the statement is true, and another if it is false. The if-then-else statement is probably the best-known and most widely used example of a conditional statement.



Map or layer (raster)

The real landscape

Figure 4.8 Georeference; the features in the real landscape correspond accurately with the coordinates on the map

Syntax	Operation	Used to
= eq Equal to	a = b	test the equivalence of two values
< lt Less than	a < b	test the negated equivalence of two values
< = le Less than or equal to	a < = b	test if the value of the left value is greater than that on the right
> gt Greater than	a > b	test if the value of the left expression is less than that on the right
> = ge Greater than or equal to	a > = b	test if the value of the left expression is greater than or equal to that of the right
<> ne Not equal to	a <> b	test if the value of the left expression is less than or equal to that of the right

Activity 3

1. Explain the difference between vector and raster maps in a GIS.
2. Explain the difference between a relational and a conditional statement in a GIS.
3. What does it mean when we georeference something in a GIS?
4. Complete this matrix by filling in the blank spaces:

Syntax	Operation	Used to
= eq Equal to		test the equivalence of two values
	a < b	test the negated equivalence of two values
< = le Less than or equal to	a < = b	
	a > b	test if the value of the left expression is less than that on the right
> = ge Greater than or equal to	a > = b	
<> ne Not equal to		test if the value of the left expression is less than or equal to that of the right

5. Imagine you are a GIS expert. You need to convince a local district council that buying a GIS program (software) to run on the computer in their office would be a good investment to help them plan for and run their local district more efficiently. How would you go about explaining the benefits of GIS to such a group?

Summary

- Geography is a spatial subject, and maps are a geographer's most useful tool.
- A Geographical Information System (GIS) is a computer-based mapping device which is far more flexible than paper maps.
- GIS uses a system of overlays or layers, which are made up of vectors (lines, points, arcs, shapes or polygons) which represent some feature or features on the Earth's surface.
- Raster data is information about a certain point, line or shape, which is 'hidden' in the computer.
- GIS software lets the operator work with the spatial vectors and the attribute data to come up with solutions to practical problems.
- Boolean logic is essential to GIS problem solving in that TRUE or FALSE statements inform the computer program as to what to do next.
- While Boolean logic can be represented in terms of truth tables, we can express the same logic by using Venn diagrams, instead of tables. These diagrams usually comprise overlapping circles or rectangles.
- Tens, or hundreds of thousands of binary (true – false, if – then) calculations are performed in a split second in order to come up with useful solutions or answers to a problem.
- Georeferencing refers to making sure that all our GIS overlays and data correspond with one another, and with the 'real' situation on the ground.

- Relational statements in a GIS tell us whether one expression is larger than, smaller than, or equal to another expression.
- Conditional statements in a GIS tell the program to execute or carry out one option if the statement is true, and another if it is false. The if-then-else statement is probably the best-known and most widely used example of a conditional statement.
- The big advantage of GIS over paper maps, is that it is compact, efficient and fast, and, using Boolean logic, can compare spatial and attribute data in milliseconds to provide answers to the questions we pose.

Glossary

binary – two values, such as 0 and 1

Boolean logic – a form of algebra (where letters and symbols are used to represent numbers and values in equations) in which all values are reduced to either TRUE or FALSE

conditional statement – in a GIS tells the program to execute or carry out one option if the statement is true, and another if it is false

data – information, usually stored on a computer's hard drive and then processed by the computer to give some sort of useful result

Geographical Information System (GIS) – computer system (program) used to store and process spatial data in vector and raster format to solve problems related to positions on the Earth's surface; a GIS can show many different kinds of data on one map, usually by means of overlays

georeference – accurate correlation between points or places on the map or GIS screen and the real world

hardware – computer itself and its peripherals such as the monitor, screen and mouse; software runs on hardware

logic – reasoning conducted or assessed according to strict principles of validity

map – a reduced two-dimensional representation of reality

model – a reduced representation of reality, which usually represents more than two dimensions, and may be in electronic form on computer

overlay – a layer on a map or on a GIS; overlays are superimposed on one another

polygon – a closed shape

raster data – or information stored in a GIS and relating to a particular point, line or polygon

relational statement – in a GIS, such a statement tells us whether one expression is larger than, smaller than, or equal to another expression

software – computer program written to perform a specific task, such as word processing, or graphic design

truth table – a table with rows and columns showing how the truth or falsity of a proposition varies with that of its components

vector – a point, line or polygon in a GIS

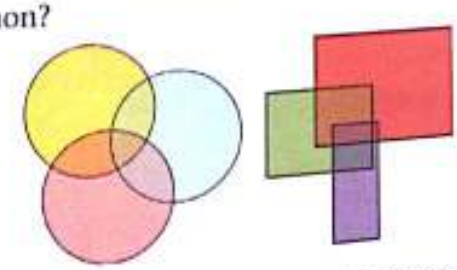
Venn diagram – a diagram representing mathematical or logical sets as circles, closed curves or other polygons within an enclosing rectangle (the universal set); common elements of the sets are represented by intersections (overlaps) of the circles or other shapes

Topic test 4

1. Explain, in your own words, what a GIS is.
2. Match the definition in Column B with the word or term Column A:

Column A Word or term	Column B Definition
attribute data	a way of reasoning to provide a rational or sensible answer
hardware	a map or GIS layer that can be stacked on another one
logic	point, line or polygon on a GIS
map	to do with space and place
overlay	the way in which attribute data is stored in a GIS
raster	an assertion or putting forward of a fact, opinion or idea
software	computer, screen, mouse and keyboard
spatial	data that belongs to a certain point or place on a GIS
statement	computer program, written to solve a problem
vector	a reduced two-dimensional representation of the real world or part thereof

3. What do the following diagrams have in common?



4. Name three practical examples of where a GIS might be used.
5. Boolean logic:
   - A uses truth tables
   - B does not use truth tables
   - C is named after a famous chemist
   - D is a very accurate but slow method of calculating distances.
6. A relational statement:
   - A is used to describe members of your family
   - B tells us whether one expression is larger than, smaller than, or equal to another expression
   - C is used to relate a story, or idea
   - D is the opposite of an accurate statement.
7. A conditional statement:
   - A is never used in GIS
   - B depends on the computer program being used
   - C tells the GIS program to execute or carry out one option if the statement is true, and another if it is false
   - D is never more than 50% accurate.
8. Georeferencing:
   - A is not really important in GIS
   - B makes sure that all the GIS overlays and data correspond with one another, and the situation in reality
   - C is used by geologists to arrange or reference their rock samples
   - D is part of the training of all librarians.
9. A binary statement or binary expression:
   - A is used to bind computer hardware and software
   - B proves that Geography is a spatial subject
   - C went out of fashion once computers were invented
   - D uses two simple values such as true false, or 0: 1 or yes no.
10. Explain the general steps followed when performing an overlay analysis on a computer which is running a GIS program. Use a simple example of a problem or issue that might be addressed using overlay analysis. You can use this diagram to assist you.

Topic 5 Minerals and mining

Objectives

By the end of this topic, you should be able to:

- explain sustainable use of mineral resources
- describe environmental impact assessment
- describe the importance of environmental impact assessment in mining
- explain the cost-benefit analysis concept
- describe the importance of the cost-benefit analysis in mining.

Sustainable use of mineral resources

The activities that use the elements of the physical **environment** need to continue supporting human life, not only for the present generation but for future ones too. Such careful and continued use of natural resources is called sustainable use, which leads to sustainable development. To develop sustainably, the environment in which people live has to be safe, clean and properly managed.

Exploitation is the use of something else (be it a person, a resource, a country or a situation) with no regard for the consequences or **impacts** for that person, resource, country or situation). If we exploit mineral resources, we are using those resources in an unsustainable way.

Reuse and recycling

Resources such as soil and even water are renewable resources. This means they can be used over and over again. This is of course provided they are not exploited. Unfortunately, minerals are not a renewable resource. Once mined and used, we cannot replace them. However, with **reuse** and **recycling** (note that they are not exactly the same), we can make the world's and Zimbabwe's mineral resources go further, and last longer.

Activity 1

1. Define the following:
   a) resource
   b) exploitation
   c) recycle
   d) reuse.
2. Which of the following could be reused, which could be recycled, and which could be reused or recycled?
   a) steel
   b) glass bottles and jars
   c) old car tyres
   d) plastic containers.
3. Find out what the symbol on the left stands for, and explain why and how the object on the right can be reused or recycled.

Environmental Impact Assessment (EIA) in mining

Mining is an extractive industry. This means that mineral ore is dug, quarried or blasted out of the ground. Mining is very intrusive. This means that it leaves its mark on the landscape. The use of heavy machinery, noise and dust are part of almost all mining operations. Mining has an impact on:

- the physical environment, which is dug up or blasted and permanently altered
- the **biosphere** in that vegetation may be destroyed and animal life disturbed
- water resources, which are part of most mining operations, and which may be overexploited, or become polluted
- the human environment, in that peoples' livelihoods may be impacted in different ways.

In order to protect both the physical and human environment, an **Environmental Impact Assessment (EIA)** should be carried out before mining to mitigate against negative impacts. Mitigation means reducing, or making less, the impact of the proposed mining activity. Note that both the physical impacts, and the impact on people or socio-economic impacts must be considered. For example, mining in an area may create new jobs and bring in more money, but there may be negative social impacts such as overcrowding, rising crime rates, and abuse of alcohol.

Figure 5.1 Mining activities always impact on the environment in some way

What is an Environmental Impact Assessment (EIA)?

An Environmental Impact Assessment (EIA) is the term used for assessing, considering or evaluating the environmental consequences or impacts, both positive and negative of a plan, policy, programme, or proposed project before starting with that project.

EIAs are compulsory by law in all developed countries, and more and more developing countries. An EIA is usually a formal procedure, governed by rules and regulations in a step-by-step way. Independent, neutral specialist companies usually carry out the EIA on behalf of their client, for example, a large mining company wanting to start a new mine. Public participation is important. This means that the concerns and objections of ordinary people must be considered.

The purpose of the EIA is to make sure that decision makers, who may be politicians, or a local authority, or a business or mining company, consider the environmental impacts and then decide whether or not to carry out the project.

EIAs do not lead to or follow a predetermined environmental outcome. Rather, the decision makers must account for environmental values in their decisions. Their decisions must be justified in terms of detailed environmental studies and public comments on the likely environmental impact.

An EIA follows a procedure, outlined below.

1. Screening

The EIA process starts at the beginning of a project. The important questions are: *'What will the effects of the project be on the environment?'* and *'Are those effects significant?'* If the answer to the second question is yes, an EIA should be undertaken. This first step in an EIA is called **screening**.

2. Scoping

Where a decision is made to conduct an EIA, the issues that need to be addressed must be identified. This provides the scope of the EIA, and is known as **scoping**.

3. Baseline study

Following on from scoping, all the necessary information on the present state of the environment is collected. This is called a baseline

study because it provides a baseline against which possible impacts and change as a result of the project can be measured.

4. Impact prediction

Once the baseline study has been completed, impact prediction can begin. Impact prediction involves predicting the likely changes to the environment as a result of the project.

5. Impact assessment

The next phase involves the assessment of the identified impacts. This requires careful, expert interpretation and understanding of the impacts. The findings will influence decision makers as to whether or not to let the project go ahead.

6. Mitigation

The assessment of impacts often brings up issues, such as potential damage to the environment. Mitigation involves taking measures to reduce or remove environmental impacts.

7. Producing the Environmental Impact Statement

The outcome of an EIA is usually a formal document, known as an Environmental Impact Statement (EIS), which sets out factual information relating to the development, the information gathered during screening, scoping, the baseline study, impact prediction and assessment, mitigation, and monitoring measures.

8. EIS review

Once the EIA is complete, the EIS is submitted to the relevant decision makers (often a government department or local authority). This is the body with the power and authority to allow, or refuse the project application.

9. Follow up

Follow up relates to the post-approval phase of EIA and includes monitoring of impacts, the ongoing environmental management of the project, and noting any impacts. Follow up provides an opportunity to control environmental impacts, effects and to learn from the whole EIA process.

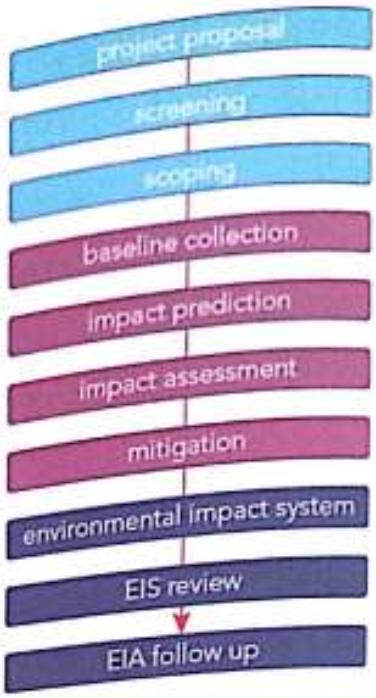


Figure 5.2 Steps in the EIA process

The importance of environmental impact assessments in mining

Because, as we have noted, mining often has very severe impacts on the environment, EIAs are especially important in mining. There are hundreds of examples from the last two centuries of impacts and damage to the environment, in Europe, America and Africa, which have left permanent damage to the environment. Mining is one area of economic activity where an EIA for each new project, for example a new mine, or expansion of a mine, needs to be considered.

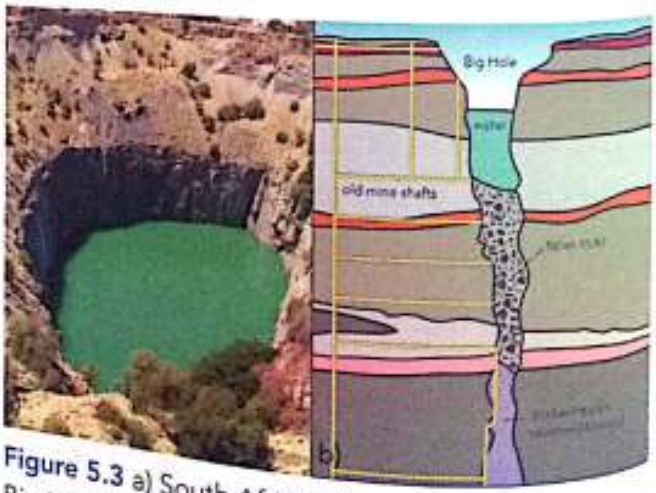


Figure 5.3 a) South Africa's famous Kimberley Big Hole (left) and b) what lies below the surface (right). The impact on the environment is far greater than it seems from the surface. This impact on the environment is permanent.

Activity 2

1. Which of these are likely to be negative impacts in an EIA to establish a new coal mine?
   a) employment opportunities
   b) new shops and facilities for workers
   c) demands on limited water supply
   d) dust pollution
   e) increased tax revenue for the state.
2. Look at the series of photos labelled A to D and answer the following questions:
   a) What does each of the photos, A, B, C and D, appear to represent?
   b) Which photo shows the most pristine (untouched) landscape, and which one shows the most degraded landscape?
   c) What activity appears to be taking place here? Explain your answer.
   d) What is rehabilitation? Do you think this landscape could be rehabilitated?
   e) If your answer to d) was no, explain why not. If your answer to d) was yes, what might be the major issue for the various role-players?
   f) Do you think an EIA was carried out before this project began? Explain your answer.

A

B

C

Cost-benefit analysis (CBA)

Would you walk 10 kilometres for five cents? You would probably not. Would you walk 10 kilometres for $100? You probably would. You have done a quick **cost-benefit analysis (CBA)** in your head. The risk (exhaustion and blisters) is the same in both cases, but the benefit in the second case is far greater than the risk. Put differently, the **benefit** from walking 10 kilometres for five cents is not sufficient to make the **cost** or effort worthwhile. However, $100 for walking the same distance is worth it.

So, a cost-benefit analysis is a process by which decisions (usually business decisions) are analysed. The benefits of a given situation or action are added up, and then the costs associated with taking that action are subtracted.

Figure 5.4 Weighing up benefits against cost. If the scale tips one way, it is worth it. If the scale tips the other way, it is not worth it. This is the basis of almost all business decisions.

Here is a simple example. A company wants to establish a new mine. After all the calculations are done, they find that to produce a ton of coal will cost $50. At the same time, the price the company can get for their coal is $48. In spite of all the job opportunities it would create, and the development of a new town for the workers, along with a school and a hospital, the costs outweigh the benefits. The company therefore decides not to go ahead.

The cost-benefit analysis process

Here are the steps that are followed in a cost-benefit analysis:

- First, make up a complete list of all the costs and all the benefits associated with the new project. Costs must include direct and indirect costs, unseen costs and the cost of possible risks. Benefits must include all direct and indirect income, and unseen benefits, for example, increased production from improved worker safety and morale.
- Second, a unit of monetary measurement (US$ are most often used) must be applied to all the things on the list. This is straightforward for direct costs and benefits, but more difficult to do for unseen costs and benefits and may need expert help. Do not underestimate costs or overestimate benefits.
- The third step is to compare the results of the total costs and total benefits to see if the benefits outweigh the costs (Figure 5.4).
- Finally, a decision is made to go ahead with the project or not. In some cases (where the gap between costs and benefits is small) the cost-benefit analysis might be reviewed to see if costs can be reduced, or benefits increased. If not, the project may be put on hold, or even scrapped.

Note that as a general rule, the smaller and simpler the project, the easier it is to apply cost-benefit analysis. On very big projects, especially those which will run on into the long term (decades or more) cost-benefit analysis is more difficult to apply accurately. This is because:

- the bigger the project, the more complex the cost-benefit analysis
- over long periods of time, there may be unforeseen aspects, such as drop in demand for a particular mineral, or an increase in production costs
- interest and borrowing rates may change
- new technologies or methods of production may make the existing project obsolete.

The importance of the cost-benefit analysis in mining

Cost-benefit analysis in the mining industry is particularly important because of the points listed directly above. Other important points are:

- Supply and demand of minerals on a world-wide scale is very unpredictable. A mine that is profitable today, might not be in a few years' time, and the other way around.
- It is very expensive to set up and start the operation of a new mine.
- Mining can have huge environmental impacts, some of which might be unforeseen, and which might add to future costs.
- For the sake of the country and the environment, it would be irresponsible not to perform a proper cost-benefit analysis on any new, or expanded, mining operation.

Activity 3

Calculating cost-benefit for a mining project in Zimbabwe

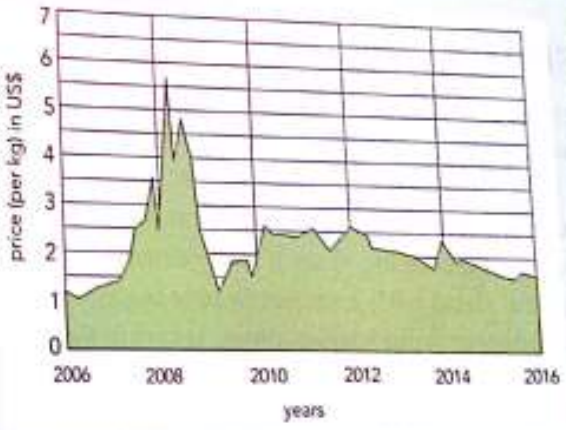
This is a theoretical CBA exercise based on an imaginary new mine planned for Zimbabwe. Use the sheet below for your CBA.

Chichidza Mining wants to start up a new chrome ore mine in the KweKwe area. Before they do this, they hire you to undertake a CBA. The mine will produce 5 000 tons of ferrochrome (a chrome-iron ore, with about 50% chrome content) per month. The present price per kg (there are 1 000 kg in a ton) is US$2.

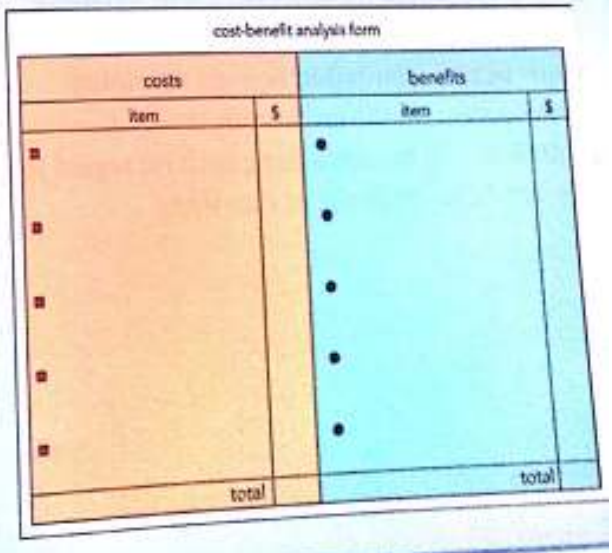
Here are the monthly costs for now and for five years from now:

Item	Cost now US$	Cost in five years' time US$	Cost in ten years' time US$
1. Wages	2 000 000	3 000 000	8 000 000
2. Running costs	2 000 000	2 500 000	5 000 000
3. Water	500 000	1 000 000	2 000 000
4. Environmental rehabilitation	500 000	500 000	2 000 000
5. Tax	1 000 000	1 500 000	3 000 000
Monthly total:			

1. Using the information above, perform a cost benefit-analysis for the new mine looking at:
   a) now
   b) five years' time when the price of ferrochrome is US$4 per kilogram
   c) ten years' time when the price of ferrochrome is US$8 per kilogram but production has declined to 4 000 tons per month.



2. Suggest ways to either:
   a) save costs in the future
   b) increase benefits in the future.



Summary

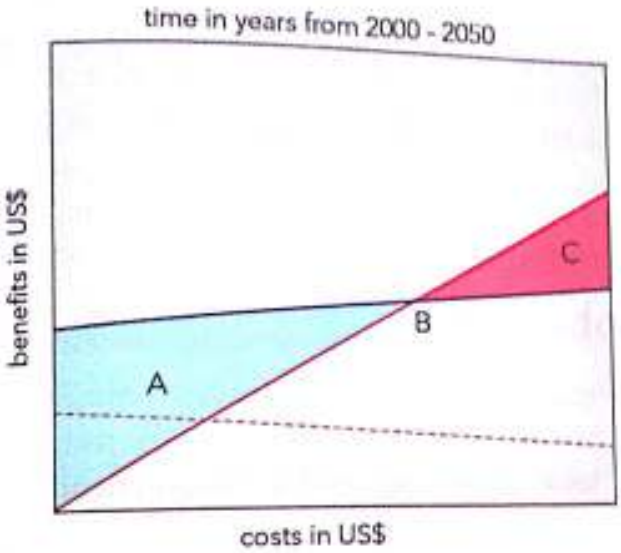
- The sustainable use of mineral resources is important. We have a responsibility towards future generations in terms of ensuring the long-term future for Zimbabwe's mineral wealth.
- Reuse and recycle are important concepts in the sustainable use of minerals. They do not mean exactly the same thing.
- Environment refers to our surroundings, both natural, or human-made (such as an urban environment).
- An environmental impact assessment (EIA) is a procedure which is followed to look at the possible impacts on the environment from a development or project, such as a new mine, or a new factory.
- Because mining tends to have severe environmental impacts, EIAs should almost always be carried out before a new mining operation starts.
- Cost-benefit analysis is a procedure carried out before a new mine or other project is started. It looks at both the costs (negative) and the benefits (positive) of a new operation in money terms.
- A cost-benefit analysis provides a basis for a decision as to whether or not a new business will be profitable, or whether it will lose money.
- Because mining is a long-term commitment, cost-benefit analyses are very important in the mining industry.

Glossary

benefit – to gain
cost – what must be put in, often in money, in order to get something out or buy something
cost-benefit analysis – a comparison between costs and benefits to see if it is worthwhile going ahead with a project or new business
environment – our surroundings, whether natural, or built
Environmental Impact Assessment (EIA) – a formal procedure for addressing and weighing up the possible impact or influence of a new mine, factory, plantation or even a housing development on the environment
exploitation – to use something with no regard for the well-being or future of that thing
impact – effect on something, whether good or bad
mining – removing, usually by digging, quarrying or blasting, minerals from on or beneath the surface of the Earth for human use
recyle – to return something such as glass, or cold drink cans so that they can be processed to provide the raw material for, for example, new bottles or cans
reuse – to use something more than once
scoping – identifying the issues (the scope) which must be addressed in an EIA
screening – the first step in an EIA is to ask: *'What will the effects of the project be on the environment?'* and *'Are those effects significant?'*

Topic test 5

1. Define the following, in your own words where possible:
   a) Environmental Impact Assessment
   b) cost-benefit analysis
   c) exploitation.
2. Are an EIA and a CBA the same thing? Explain your answer in not more than four lines.
3. Look at the following graph and answer the questions that follow:



   a) What does the graph represent?
   b) What is shown by the blue shaded area marked A?
   c) What is shown by the red shaded area marked C?
   d) What happens at B?
   e) Is this project or business likely to keep running after about 2040? Explain why or why not.
   f) In what way would things be different for this business if the costs followed the dotted red line?
4. Explain how and why either an Environmental Impact Assessment (EIA) or cost-benefit analysis might be carried out for a new Zimbabwean mining project.

Topic 6

Environmental management

Objectives

By the end of this topic, you should be able to:

- explain what is meant by environmental management
- identify international treaties and protocols
- discuss the advantages and disadvantages of domesticating international treaties and protocols
- describe land use planning
- explain land use planning as a strategy for sustainable environmental management
- identify challenges in land use planning
- suggest mitigation measures.

Environmental management at a global level

The environment is what we see, experience and interact with around us each day. In other words, it is the world around us. Environment can be defined on the basis of scale:

- the Earth in our planetary environment
- environments at a continental or regional sca
- local environments (the environment in whic we live).

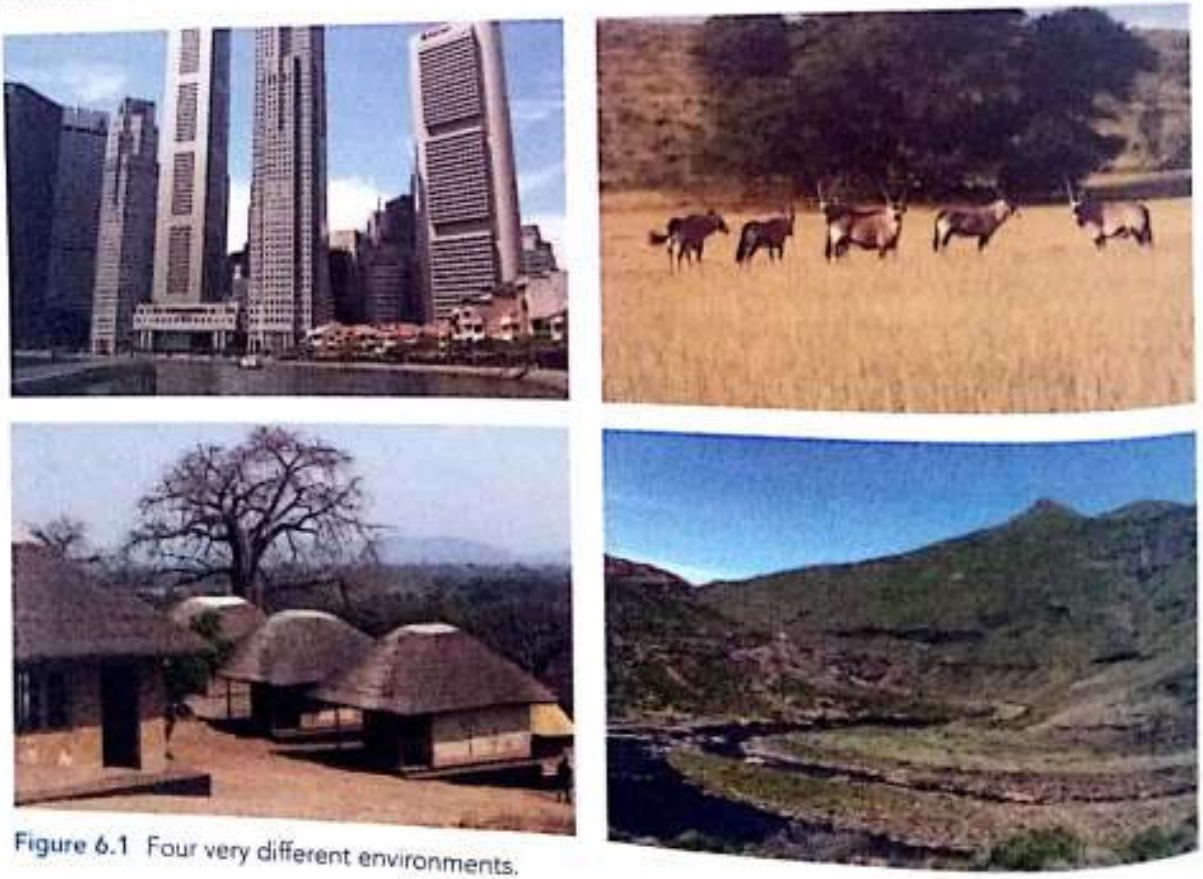
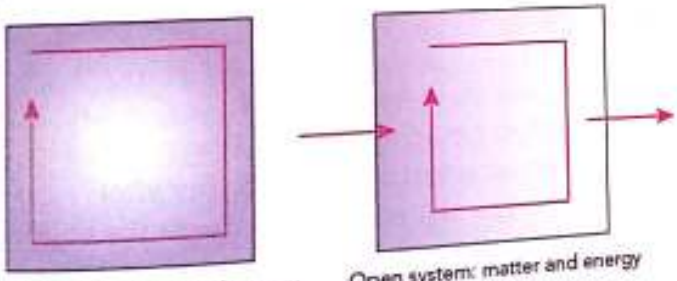


Figure 6.1 Four very different environments.

Environments are not limited to biophysical environments, such as savannah, or coastal environments. Much of the world's population lives in urban environments. It is just as important therefore to consider environments at the level at which people experience them on a day-to-day basis.

For Form 4, however, we will consider global environments. We are looking therefore at environments, and environmental management, on the global scale. Typically, we would consider different biomes or regions of the Earth. Environmental management at a global level has to do with managing, conserving and using and managing resources at an international level. Because the Earth is (with the exception of solar radiation and meteorites) a **closed system**, what happens in China in terms of, for example, air pollution, will have an impact or effect on the whole Earth. In the same way, if a single country such as the USA uses the Earth's resources at an unsustainable rate, the impact will be felt on a global scale. Remember that an **open system** is one where energy and matter can move into, or out of, the system like a lake, for example. A closed system is one where neither energy nor matter can enter or leave.



Closed system: matter and energy circulate within the system but cannot enter or leave the system.

Open system: matter and energy can enter and exit the system.

Figure 6.2 Open and closed systems

Figure 6.3 The Earth as seen from space; the Earth is, effectively, a closed system

Humans appear to have finally recognised that we all rely on the same planet and its resources to survive. If one nation breaks the rules with respect to global environmental management, all nations may suffer the consequences. For this reason, a number of initiatives, protocols and treaties have been put in place so as to properly manage **environmental issues** at a global level. Before we look at these, you need to be reminded of the main environmental issues facing the Earth.

Rising sea levels

Climate change leads to rising sea levels. Average sea levels are rising around the world and this has an impact on people living in coastal environments especially small island states (SISs).

Melting Polar ice and glaciers

Climate change impacts within the next 100 years could mean the world's glaciers will have disappeared, as will the Polar ice cap, and the huge Antarctic ice shelf, Greenland, may be green again.

Tropical cyclones, hurricanes and typhoons

These will increase in strength, and flooding will become more common under more extreme climatic conditions.

Heatwaves and droughts

Despite heavier rain in some places, droughts and long heatwaves may become more common as temperatures rise due to global warming.

Changing fisheries

As sea temperatures change, so global fishing grounds may may be reduced or extended as fish breeding conditions change.

Changes to agriculture

Farmers in temperate zones are finding drier conditions difficult for crops, such as maize and wheat, and once prime growing areas, such as Zimbabwe, may be threatened. Warming may affect deciduous fruit production, where trees need a cold winter to rest.

Shift in forest types

Areas under forest may change, and the types of trees may also gradually change as forest tree species adapt to climate change.

Reduced food security

This is critical for a growing world population. Different crops grow best at quite specific temperatures and when those temperatures change, their productivity changes significantly.

Pests and disease

Rising temperatures may favour agricultural pests, diseases and disease vectors. For example, much of Zimbabwe and South Africa are malaria-free, but this may well change in the future.

Ocean acidification

Rising temperature and rising CO_2 levels are making the world's oceans more acidic. More acidic seawater affects the ability of sea creatures to make shells. Shelled species, small and large, are the base of the ocean food chain. Their loss may impact on the food-producing potential of the world's oceans.

Activity 1

1. Name three different levels at which environmental management can be applied. What is the top level?
2. Explain in two or three lines what you understand by the term *global climate change*.
3. Two of the following are *not* predicted outcomes of global climate change. Identify them:
   a) global warming
   b) sea levels dropping
   c) ocean acidification
   d) shift in forest type
   e) decrease in strength of tropical storms
4. Explain the difference between each of the following:
   a) sustainable versus unsustainable development
   b) global warming versus global cooling
   c) open systems versus closed systems
   d) rural versus urban environment
   e) advantage versus disadvantage

International protocols and treaties

What are protocols and treaties?

A protocol is an agreement that negotiators from different countries put together after discussion. The signed protocol forms the basis for a final **treaty** or **convention**.

A treaty is an agreement where the parties negotiate to reach common ground and avoid further conflict or disagreement. It must normally be approved by the government whose representative has signed it.

A convention begins as an **international** meeting of representatives from many nations. When this results in general agreement about procedures or actions they will take on specific topics, we speak of a convention. Environmental conventions include agreements on wetlands, endangered species, desertification, climate change and similar issues.

UN Framework Convention on Climate Change

The United Nations Framework Convention on Climate Change (UNFCCC) was put into place in 1992 at the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro. This conference is known as the Earth Summit where 154 nations signed the UNFCCC. This committed them to reduce atmospheric concentrations of greenhouse gases. The goal was *to prevent dangerous anthropogenic (human) interference with Earth's climate system.* This would require large reductions in greenhouse gas emissions such as CO_2. Developed countries undertook to take the lead.

Kyoto Protocol

After the signing of the UNFCCC treaty, parties to the UNFCCC have met at various conferences (COPs or conferences of the parties) to discuss how to achieve the aims of the Rio Earth Summit. At the first COP, parties decided that to stabilise their greenhouse gas emissions at 1990 levels by the year 2000 was not good enough, and further discussions at later conferences led to the Kyoto Protocol. The Kyoto Protocol sets emissions targets for developed countries that are binding under international law.

The Kyoto Protocol has had two commitment periods, the first from 2008 to 2012, and the second, from 2013 to 2020. It is important to note that the USA did not ratify (agree to) the Kyoto Protocol, while Canada rejected it in 2012.

Not all nations are agreed on the second-round Kyoto targets, which could be seen as a worrying sign in terms of efforts to control climate change.

Montreal Protocol

The Montreal Protocol addressed substances that deplete the **ozone** layer (a protocol to the Vienna Convention for the Protection of the Ozone Layer). It is an international treaty designed to protect the ozone layer by phasing out the production of substances that are responsible for ozone depletion. It was agreed on in August 1987. Since then, it has undergone eight revisions. As a result of the international agreement, *the ozone hole in Antarctica is slowly recovering.*

The Bamako Convention

The Bamako Convention (in full: Bamako Convention on the ban on the Import into Africa and the Control of Transboundary Movement and Management of Hazardous Wastes within Africa) is a treaty of African nations prohibiting the import of any hazardous (including radioactive) waste. The Convention was negotiated by twelve nations of the Organisation of African Unity at Bamako, Mali in January, 1991, and came into force in 1998. The aim is to stop rich, developed countries from exploiting poorer, developing countries in Africa by dumping toxic waste in these African countries, even with the approval of the accepting country.

Basel Convention

The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal, usually known as the Basel Convention of 1989, is an international treaty that was designed to reduce the movements of hazardous waste between nations. It specifically aimed to prevent the transfer of hazardous waste from developed to less developed countries. It does not, however, address the movement of radioactive waste, which the Bamako Convention does. The Basel Convention came into force in 1992.

Zambezi River Basin Action Plan

The Zambezi River System Action Plan (ZACPLAN) is a multinational plan under the United Nations Environment Program (UNEP). The aim is to incorporate effective use and management of the Zambezi River system. Eight countries (Angola, Botswana, Malawi, Mozambique, Namibia, Tanzania, Zambia, and Zimbabwe) are directly involved. The Zambezi River Basin is used by all these southern African countries. Refer to Figure 6.4 for these riparian countries. The plan aims to manage resources collectively amongst, and between SADC nations to reasonably meet national, and international goals for water resources. The Zambezi River System Plan is the

culmination of a UN commission focusing on the projection that the demand for the basin's water resources will increase as populations increased, and the economies of these southern African countries developed.

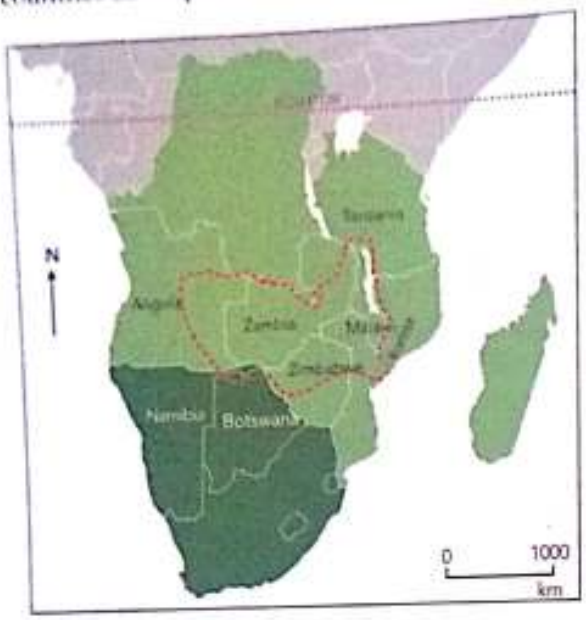


Figure 6.4 Zambezi River catchment (outlined in red) showing the countries (labelled) that contribute to this catchment

The advantages and disadvantages of domesticating international treaties and protocols

The world is sometimes referred to today as a global village. This means that all countries and nations are part of a single environment. We are all, in a sense, neighbours living in one community. Modern communication (particularly the internet) and the way global markets (trade and finance) work, means that it is difficult for any one country to *go it alone*. Possibly the only country in the world with a policy of complete isolation is North Korea.

Being part of the global community has both advantages (pros) and disadvantages (cons) for any country. This applies to Zimbabwe as much as any other nation when it comes to accommodating international treaties, agreements and **protocols** within our country's domestic policies and structures.

Here are some of the advantages and disadvantages of being party to international, or even just African organisations with regard to climate and the environment.

Advantages

- Recognition as part of the wider international community's efforts to control climate change.
- Access to international expertise on environmental issues.
- In some cases, possible access to funding to promote sound environmental initiatives.
- Collaboration and co-operation with regard to preserving the environment. Examples might include trade and smuggling of endangered species, and illegal trade in ivory.

Disadvantages

- Zimbabwe's own needs or policies might have to take second place to what the global community feels is necessary.
- Once a nation is part of a protocol, or has signed an environmental agreement or treaty, it is binding.
- Developing countries often feel that the developed nations push their own agendas at the expense of, say, African nations. This needs to be guarded against.

Activity 2

1. Explain the difference between a treaty, a protocol and a convention.
2. Identify the treaty, protocol or convention from the following short description:
   a) deals specifically with water resources in southern Africa
   b) designed to protect the atmosphere's ozone layer
   c) aims to stop exploitation of African countries by developed nations dumping their toxic waste
   d) international treaty that was designed to reduce the movements of hazardous waste between nations
   e) aims to prevent dangerous human interference with Earth's climate system.

3. Hold a class debate on the advantages (pros) and disadvantages (cons) of domesticating international treaties and protocols (in other words, for Zimbabwe to be party to international treaties and protocols, and adapt domestic policy around environmental issues accordingly). You may need some guidance from your teacher on this one, or to do some research regarding Zimbabwe's position on some of the treaties and protocols discussed above.

Land use planning as a strategy for sustainable environmental management

As with all countries, Zimbabwe has a number of plans for development and for sustainable environmental management. Without **planning**, land use and development can become ad-hoc. This simply means on a bit-by-bit basis, with no clear goal, strategy or framework. The results could be problematic, for example, a school built next to a storage depot for dangerous substances, or a mine right next door to a fragile ecosystem. Proper planning is necessary for both urban and rural areas.

Land use planning as a strategy for sustainable environmental management

(This section draws from an article by Innocent Chirisa and Smart Dumba published in the *Journal of African Studies and Development* in 2012. The article was titled: *Spatial planning, legislation and the historical and contemporary challenges in Zimbabwe: A conjectural approach.*)

Sustainable environmental management involves planning for today (the short term) and for the future (the long term). The very word sustainable implies that the plan for an area or region must be workable in the longer term. Environmental planning that is not sustainable may either collapse or, at worst, cause harm or damage to the particular environment on which it is focused.

Spatial or land use planning is more complex than simple land use regulation. It must take into account the conflicts among sectoral policies. For example, economic development policies might clash with policies for environmental management. Do we conserve a piece of land, or do we use it for development? The key role of spatial planning is to promote a more rational arrangement of activities and to reconcile competing policy goals (Chirisa and Dumba, 2012).

Zimbabwe's Regional Town and Country Planning Act of 1998 is the main Act dealing with the physical environment of the country. It is:

'An Act to provide for the planning of regions, districts and local areas with the object of conserving and improving the physical environment and in particular promoting health, safety, order, amenity, convenience and general welfare, as well as efficiency and economy in the process of development and the improvement of communications; to authorize the making of regional plans, master plans and local plans, whether urban or rural; to provide for the protection of urban and rural amenities and the preservation of buildings and trees and generally to regulate the appearance of the townscape and landscape; to provide for the acquisition of land; to provide for the control over development, including use, of land and buildings; to regulate the subdivision and the consolidation of pieces of land; and to provide for matters incidental to or connected with the foregoing.'

The Act deals with land use planning at a regional level. The Act comprises 75 Sections and one Schedule. The sections are divided into 11 Parts:

- Preliminary
- Regional Planning
- Local Planning Authorities
- Master and Local Plans
- Control of Development
- Subdivision and Consolidations
- Acquisition and Disposal of Land
- Compensation
- Roads
- Functions of Administrative Court Under This Act
- General T.

The Act provides for the making of Regional, Local and Master Plans for the control of development through a permit system and Development, Enforcement, and Prohibition Orders, and for the expropriation or otherwise acquisition of land covered by a Local Plan or a Master Plan.

Challenges in land use planning

The scope of land use planning differs from one country to another. Zimbabwe's priorities are not necessarily the same as those of, for example, a European country. However, most spatial plans have a number of things in common. Land use planning generally faces these challenges:

- it must identify long- or medium-term objectives and strategies for the country in terms of land
- it must consider land use and physical development as one of government's many activities
- it must bring together and co-ordinate sectoral policies such as transport, agriculture and the environment.

There are different levels of looking at land use planning or spatial planning:

- the micro-level; for example, village, district and ward
- meso-level; for example, province and region
- macro-level; supra-region (an example might be southern Africa such as the ZACPLAN that we previously looked at) and the globe.

As things happen at these different levels, they present challenges which often repeat themselves. Strategic planning and management is a tool, or method, or strategy for meeting these challenges. Government **policy** and laws must be continually assessed, evaluated and revised so as to address the challenges effectively. Here is a simple environmental example. It is no good having a really good conservation policy in place to preserve a national park if the animals in the park have all been hunted and killed for food. Similarly, it is no good having a wonderful **tourist attraction** in the form of a national park full of animals if the local people are starving because they do not have access to land and food.

Mitigation measures: risk-informed land use planning, related policies and legislation

From the point of view of the environment, land use planning and the policies and laws linked to such planning must be risk informed. This means that such planning must take into account things like:

- the risk of climate change
- population pressure on land
- the need to balance economic development with good environmental management practices
- financial implications of land use planning.

In Zimbabwe, as in almost all African countries, planning practices were shaped by the colonial-post colonial legacy. This means that, despite the change in government at independence, the old order still exists (to a degree) in terms of planning. This can be referred to as a colonial spatial planning challenge. Even the *Regional Town and Country Planning Act of 1998* did not resolve the colonial spatial planning challenge. Zimbabwe must continue to address, from an African perspective, issues around land use and spatial planning with regard to the Zimbabwean environment. This must be done in such a way as to benefit the country, its people and the environment.

Activity 3

Write an essay or report in which you consider an environmental plan for the area in which you live. It could be urban, or rural. Your teacher will assist and guide you, and will point you towards any available resources.

Your plan needs to take into account:

- the realities of the area (is it densely or sparsely populated, what are the resources like, is it a rural or an urban area, is it poor, average or relatively wealthy)
- which aspects of the environment need to be considered (urban and rural environments are very different)
- whether there are any unique environmental aspects (this means things, good or bad, that are found in your local environment and not elsewhere)
- the medium- and long-term goals of the environmental plan.

You can structure your report, which will probably be about four pages long, as follows:

- Heading (give the report a title which tells readers what the report or plan is about)
- Introduction (where you state the aims of the report)
- Physical and socio-economic background
- Map (spatial representation of the area)
- Challenges
- How challenges will be overcome
- Future projection (how will the environment respond, or what will it look like in the future)
- Conclusion (what you have finally decided, and why, in terms of your proposed plan)
- References or source material (acknowledge where you got material.)

Summary

- The environment is simply that which surrounds us in terms of where we live, work and play.
- Environments are broadly grouped as rural (away from the city or town) and urban (towns and cities, with higher population densities).
- Environmental management involves drawing up or formulating sound policies to either preserve certain environments, or to improve or change certain environments so that they are fit for the purpose for which they are intended.
- This brings in the notion of planning. It is important to decide what a particular environment should look like, and how it can best be used.
- On a global level, climate change and over-exploitation of global resources by a rapidly growing world population are the greatest threats to the Earth's environment.
- The result has been concern for the global environment, and a number of international protocols, treaties and conventions intended to manage the Earth's biophysical environments and resources in a sustainable way.
- For Zimbabwe, as with other nations, there are positive and negative aspects to being party to international agreements.
- As a developing country, Zimbabwe has to match land use and the challenges around land distribution and planning, with environmental issues and sound environmental management.
- Acts such as the *Regional, Town and Country Planning Act* are designed to do just this, though they are not without their challenges.

Glossary

closed system – system where neither energy nor matter can enter or leave

convention – an international meeting of representatives from many nations with the aim of reaching general agreement about procedures or actions they will take on specific topics such as global warming

environmental issue – anything to do with the environment, typically where there is a problem which must be resolved

fauna – animal life

flora – plant life

international – all the nations or countries of the world, or between one or more countries

land use – the purpose for which a particular portion of land is used

legislation – policies or laws to protect the environment

open system – a system where energy and matter can move into, or out of, the system

ozone – a form of oxygen (O) which protects the Earth's atmosphere from harmful radiation from the Sun

planning (strategic) – the act of decision making regarding how a particular situation, or resource, or portion of land is to be utilised and managed

policy – the formal statement with regard to an issue, or a plan or resource; policy is usually formulated by government by way of a law or an act of parliament

protocol – an agreement that negotiators from different countries put together after discussion and which forms the basis for a treaty

tourist attraction – a feature or area that people want to see or visit

treaty – an agreement where the parties (usually independent countries) negotiate to reach common ground on a certain issue and avoid further conflict or disagreement

Topic test 6

1. The environment refers to:
   A towns and cities
   B farmland and countryside
   C any defined area on the Earth's surface
   D the polar regions.
2. An open system:
   A allows matter to enter
   B allows energy to leave
   C allows both matter and energy to enter and leave
   D allows matter and energy to enter but not leave.
3. A closed system:
   A is the opposite of an open system
   B cannot ever function properly
   C is better than an open system
   D is always balanced out by an open system.
4. An international treaty would be signed by:
   A just one country
   B countries of southern Africa only
   C countries of Asia only
   D a number of different nations.
5. Mitigation means:
   A increasing the risk or impact
   B replacing the risk or impact
   C decreasing the risk or impact
   D monitoring the risk or impact.
6. At what levels can land use planning operate, and what are some of the challenges involved? Use Zimbabwean examples in your answer.
7. What is the difference between a plan and a policy when it comes to environmental management?
8. Explain why it is necessary for a country, particularly a developing country such as Zimbabwe, to have a development plan in place that also takes the environment into account.

Topic 7 Agriculture and land reform

Objectives

By the end of this topic, you should be able to:

- explain the effects of climate change on agriculture and suggest mitigation and adaption measures
- identify agricultural pests and diseases, and describe their effects on agriculture
- suggest manual, biological and chemical control measures for pests and diseases
- evaluate the advantages and disadvantages of urban agriculture
- identify problems of urban agriculture and suggest solutions to the problems
- list types of agribusiness in Zimbabwe
- identify sources of funding for small-scale agribusiness
- evaluate the importance of agribusiness to the individual and the economy.

Climate change and agriculture

Climate change is the term given to changing weather conditions around the world. These include changes to temperature and rainfall. World climates have never been static. This means that there has always been change. What we are concerned about is accelerated climate change driven largely by human activities over the past two hundred years. During this time, the world has come to rely on burning fossil fuels (coal and oil) thus increasing levels of carbon dioxide (CO_2) in the atmosphere. Refer back to Topic 1 for more detail on climate change.

Figure 7.1 Maize is an important Zimbabwean agricultural crop; climate change may impact on where and when maize can be grown in Zimbabwe in the future

The structure of Zimbabwean agriculture

Before we look at the effects of climate change on agriculture, it is important to consider the place of agriculture in the economy of Zimbabwe. Zimbabwe has an agricultural-based economy. Agriculture contributes about 15% to Zimbabwe's **gross domestic product (GDP)**. It provides about 60% of the total employment and supplies raw materials to industry. The agricultural sector is made up of:

- large-scale commercial farms
- small-scale commercial farms
- communal agriculture
- resettlement areas.

The structure of agriculture in Zimbabwe has changed with **land reform** in Zimbabwe and 99% of farmers are smallholder farmers. Zimbabwe is divided into six natural regions on the basis of soil type, rainfall, temperature and other climatic factors (Figure 7.2). These regions also represent the agricultural potential for the production of crops and livestock. It is these regions, and what they can produce, which are threatened by climate change.

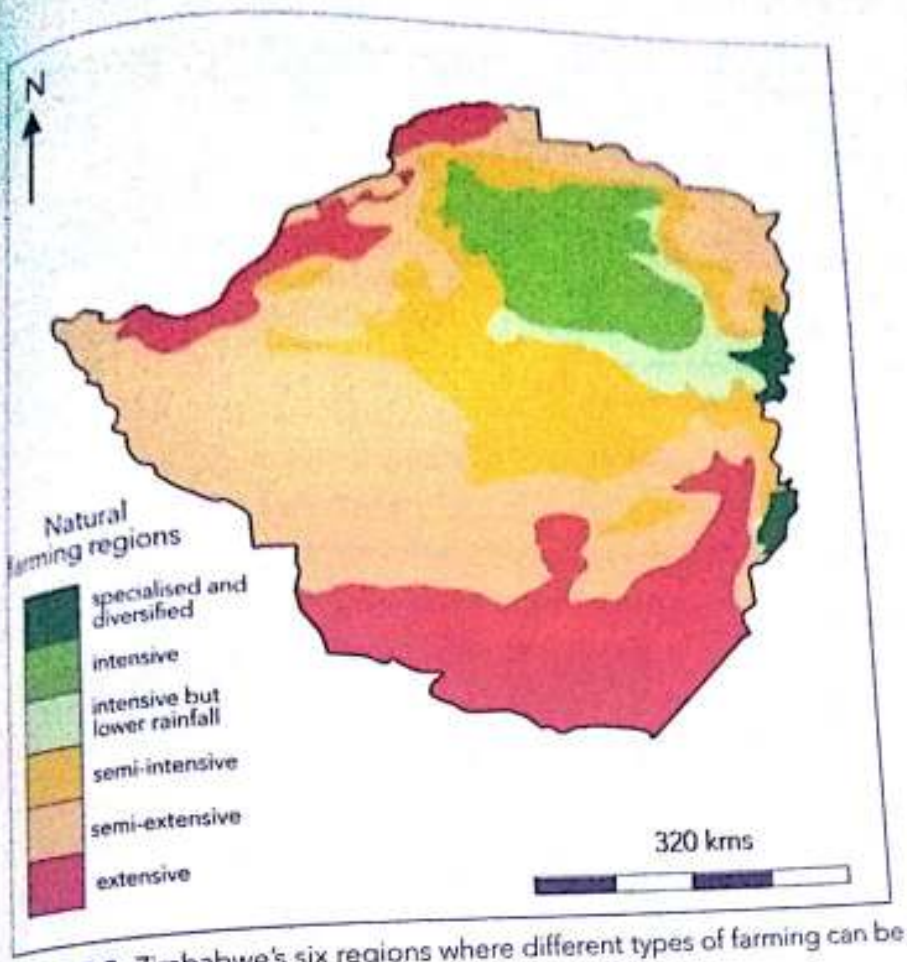


Figure 7.2 Zimbabwe's six regions where different types of farming can be practised

Activity 1

1. Give a definition of agriculture.
2. Think back to what you learnt about agriculture in Forms 1 to 3, and name four different agricultural crops grown in Zimbabwe.
3. Look at Figure 7.2 and briefly explain why you think that intensified agriculture is possible in some parts of Zimbabwe (for example, the north east) but not in others (for example, the south east).
4. What is meant by agricultural sectors with respect to Zimbabwe?

Effects of climate change on agriculture

The impact of climate change on agriculture occurs in three main ways:

- changes in precipitation, which effectively means more, or less rain
- changes in temperature, which means higher, or lower average temperatures, or more extremes of temperature (higher maximum, and lower minimum temperatures)
- changes to **growing seasons** for different crop types (longer or shorter growing seasons).

The regions in green (Figure 7.2) have the highest rainfall, and those in red are the driest. Table 7.1 gives a summary of past and future climate trends for Zimbabwe. From this, we can see that climate change impacts should be a concern.

Table 7.1 A summary of past and future climate trends in Zimbabwe

Climate feature	Key message	Source
• past climate variability	• high variability, frequent drought years and occasional flood events	• historical rainfall records
• past climate trends	• increasing temperatures (~ 1°C per year)	• historical temperature and rainfall records
• future climate trends	• increasing temperatures of around 2.5°C by 2050 • possible decrease in rainfall particularly during the rainy season onset (September to November)	• World Climate Research Progam's Coupled Model Inter comparison Project Phase 3 (CMIP3) • Global Climate Model Multi-model Projections • Climate Systems Analysis Group (CSAG) University of Cape Town fine scale projections

Source: Adapted from the Department for International Development, UK, Support for the Strategic Programme Review for Climate Change, Zimbabwe.

Changes in precipitation and drought

In Zimbabwe, precipitation deviations from a long-term mean have increased over the last century. This simply means that rainfall is more unreliable than in the past. Lower than average rainfall means lower than average crop yields, and less grazing for animals. In extreme years, drought occurs. The impact of drought on farming is an issue, particularly in southern African countries. If average annual rainfall is, for example, 1 500 mm per year, and there is a drop of 100 mm, that is 6,7%. However, if the annual average is 500 mm (the absolute minimum needed to grow maize) and there is a drop of 100 mm, that is 20%, and the consequences will be disastrous.

Figure 7.3 The impact of drought; a) parched surfaces, and b) animals may die

Temperature changes

Climate change predictions often focus on **global warming**. Look at Table 7.1. Hotter temperatures mean more stress on vegetation as plants lose more water through their leaves, and soil temperatures rise. Higher temperatures therefore mean greater evapotranspiration. The diurnal temperature range may also be decreasing. This means the difference between day and night temperatures is less than previously recorded. More hot days and fewer cold days over time may also be the new norm. In general, climate change implies disruption of the water cycle (Figure 7.4). In dry areas there is moisture deficiency, whereas in wet areas there may be too much moisture.

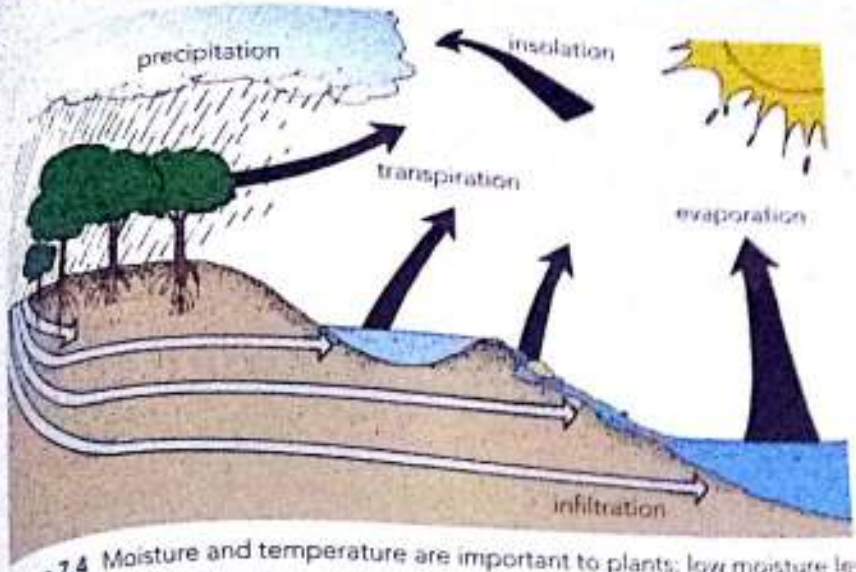


Figure 7.4 Moisture and temperature are important to plants; low moisture levels and high temperatures will stress a plant, which will wilt, and may die

Changes to growing seasons

Specific crop types have specific climatic needs or requirements.

Maize, for example needs:

- day-time temperatures between 18 °C and 27 °C and around 14 °C during the night as well as 140 frost-free days. The crop is very susceptible to frost; therefore, its cultivation in temperate latitudes is limited.
- an annual rainfall between 600 mm to 1 110 mm. It can be grown in areas having just 400 mm of rain.

Tobacco needs:

- a semi-tropical climate with temperatures between 21 °C and 31 °C during the growing period
- an annual rainfall between 500 mm and 1 250 mm
- no strong winds and storms during the growth period
- frost as the crop matures.

Some deciduous fruit trees, on the other hand, need winter temperatures close to or below freezing so that the dormant plants can rest before the next growing season. If any of the critical climatic factors are not met for a particular crop, the growing season may be shortened. This results in a lower crop yield, or even crop failure. As climate changes, growing seasons change. This must be taken into account for future planning.

Mitigation

Mitigation means to lessen, or to reduce the impact of something. Lessening the impact of climate change on crop production may involve the following:

- determining likely future scenarios for Zimbabwe and planning accordingly (see future climate trends in Table 7.1)
- introducing and growing different crops from what are currently grown; this can be effective in terms of export cash crops, such as tobacco
- introducing **genetically modified** maize (for example) which can cope with less rain and/or a shorter growing season
- educating and training farmers to enable them to adapt to climate change
- irrigating crops (if water is available) or planting crops at higher altitudes (if land is available) where temperatures are cooler
- introducing bovine (cattle) types which are, for example, more adaptable to drier conditions
- using indigenous farming knowledge by introducing indigenous drought-resistant crop varieties.

Research and planning ahead are the best ways to prepare for what may lie ahead, and to implement what are known as coping strategies so that Zimbabwean agriculture can flourish.

Activity 2

1. Discuss the impact of climate change on crop growing and crop production, as well as livestock farming world-wide. Use the headings below to guide you. It may be necessary to do some research to complete this task. You can use this information (parts are adapted from the US Environmental Protection Agency) to help you.

Agriculture and climate change

Agriculture is the most important sector of the world's economy. The crops and livestock that the world's farmers produce keep humans alive. Without agricultural production, there would be wide-spread famine. Agriculture is highly dependent on the climate. Increases in temperature and carbon dioxide (CO_2) can increase some crop yields in some places. But to realise these benefits, nutrient levels, soil moisture, water availability, and other conditions must also be met. Changes in the frequency and severity of droughts and floods could pose challenges for farmers and livestock herders and threaten food safety. Overall, climate change could make it more difficult to grow crops, raise animals, and catch fish in the same ways and same places as we have done in the past. The effects of climate change also need to be considered along with other evolving factors that affect agricultural production, such as changes in farming practices and technology.

Impacts on crops

Crops grown in the world's bread baskets (the USA, Canada, parts of Europe) are critical for the world food supply. Wheat, maize and rice are all traded on world markets. Changes in temperature, atmospheric carbon dioxide (CO_2), and the frequency and intensity of extreme weather could have significant impacts on crop yields. For any particular crop, the effect of increased temperature will depend on the crop's optimal temperature for growth and reproduction. In some areas, warming may benefit the types of crops that are typically planted there, or allow farmers to shift to crops that are currently grown in warmer areas. Conversely, if the higher temperature exceeds a crop's optimum temperature it will have a negative effect.

Higher CO_2 levels can affect crop yields. Some experiments suggest that higher CO_2 levels can increase plant growth. However, other factors, such as changing temperatures, ozone, and water and nutrient constraints, may counteract these potential increases in yield. For example, if temperature exceeds a crop's optimal level, and if sufficient water and nutrients are not available, yield increases may be reduced or reversed. More CO_2 has been associated with reduced protein and nitrogen content in alfalfa and soybean plants, resulting in a loss of quality. Reduced grain and forage quality can reduce the ability of pasture and rangeland to support grazing livestock.

More extreme temperature and precipitation can prevent crops from growing. Extreme events, especially floods and droughts, can harm crops and reduce yields. For example, in 2010 and 2012, high night-time temperatures affected maize yields across the USA's Corn Belt.

Dealing with drought could become a challenge in areas where rising summer temperatures cause soils to become drier. Although increased irrigation might be possible in some places, in other places water supplies may also be reduced, leaving less water available for irrigation when more is needed.

Many weeds, pests, and fungi thrive under warmer temperatures, wetter climates, and increased CO_2 levels. Weeds compete with crops for light, water, and nutrients. The ranges and distribution of weeds and pests are likely to increase with climate change. This could cause new problems for farmers' crops previously unexposed to these species.

Though rising CO_2 can stimulate plant growth, it also reduces the nutritional value of most food crops. Rising levels of atmospheric carbon dioxide reduce the concentrations of protein and essential minerals in most plant species, including wheat, soybeans, and rice. This direct effect of rising CO_2 on the nutritional value of crops represents a potential threat to human health. Human health is also threatened by increased pesticide use due to increased pest pressures and reductions in the impact of pesticides.

Impacts on livestock

Changes in climate could affect animals both directly and indirectly. Heat waves may increase under climate change, and this could directly threaten livestock. Over time, heat stress can increase vulnerability to disease, reduce fertility, and reduce milk production.

Drought may threaten pasture and feed supplies. Drought reduces the amount of quality forage available to grazing livestock. Some areas could experience longer, more intense droughts, resulting from higher summer temperatures and reduced precipitation. For animals that rely on grain, changes in crop production due to drought could also become a problem.

Climate change may increase the occurrence of parasites and diseases that affect livestock. The earlier onset of spring and warmer winters could allow some parasites and pathogens to survive more easily. In areas with increased rainfall, moisture-reliant pathogens could thrive. Potential changes in veterinary practices, including an increase in the use of parasiticides and other animal health treatments, are likely to be adopted to maintain livestock health in response to climate-induced changes in pests, parasites, and microbes. This could increase the risk of pesticides entering the food chain or lead to evolution of pesticide resistance, with subsequent implications for the safety, distribution, and consumption of livestock and aquaculture products.

Increases in CO_2 may increase the productivity of pastures, but may also decrease their quality. Increases in atmospheric CO_2 can increase the productivity of plants on which livestock feed. However, the quality of some of the forage found in pasturelands decreases with higher CO_2. As a result, cattle would need to eat more to get the same nutritional benefits.

Crops:

a) temperature increase
b) extreme weather events and flooding
c) weeds, pests and diseases
d) water availability and irrigation.

Livestock:

a) temperature increases
b) grazing
c) feed quality
d) diseases.

2. Southern Africa, including Zimbabwe, is within or close to the tropics. In general, southern Africa is hot, and dry conditions are common. What unique or special challenges does the geographical position of southern Africa present for agriculture in the region under climate change conditions? Use this outline map to assist you.

Agricultural pests and diseases, and solutions

The occurrence and outbreak of pests and diseases are a major limitation to agricultural activity. Pests and diseases attack or infect plants and animals and can lead to the destruction of crops, and animal illnesses and deaths.

Frequent outbreaks of crop and animal pests and diseases are experienced in Zimbabwe, the SADC region and elsewhere in Africa. These outbreaks lead to reduced agricultural yields, threatening food security, increasing poverty and even contributing to starvation. Common pests and diseases in Zimbabwe include:

- army worm
- red locusts
- quelea birds
- foot and mouth disease.

During the period 1995 to 2007, major outbreaks in Zimbabwe included:

- *Army worm outbreaks in the 1994 to 1995 season.* These caused extensive crop and pasture damage. The greatest damage, as is the case for most pest or disease outbreaks, was among communal farmers. Communal farmers often lack the resources and knowledge to combat these outbreaks. In the 2005 to 2006 and 2006 to 2007 growing seasons, army worm outbreaks were reported in some parts of Zimbabwe. The solution is spraying with chemicals such as Carbaryl, Malathion and Trichloforfon in the affected area. Pheromone traps, which use a synthetic female hormone to attract male worms can be used to forecast and detect outbreaks since a count of 25 males indicates an imminent outbreak.
- *The red locust outbreak of 1995 to 1996.* This destroyed crops and pastures. Locusts eat flowers, leaves and fruit, and can even break plants due to their combined weight. Half a million locusts eat what 10 elephants or 2 500 people eat in a day. Each locust eats its own weight in food every day. This gives us an idea of the great damage which locusts can have on farming. The solution is spraying with chemicals as in the case of the army worm.
- *A quelea bird invasion in August 2005.* This destroyed 50% of Zimbabwe's winter wheat harvest, estimated at 280 000 tons, owing to a lack of effective and timely control. These migratory birds move in flocks of up to 1 200 000 birds. Quelea birds can wipe out entire wheat fields in a matter of days. The birds are not only a problem to Zimbabwe. Farmers in countries such as Nigeria stay awake all night in their fields beating drums to scare away the quelea birds. One suggested solution is that the birds can be trapped and eaten. However, the more effective method is to use aircraft to spray chemicals where they roost for the night. In 2006, the Department of Agriculture and Extension Services (AREX) needed some 8 000 litres of Queletox to destroy the birds which threatened the winter wheat crop.
- *An invasion of tsetse fly in 2005.* Although the tsetse fly had been eliminated in Zimbabwe by the end of the 1980s, there was a re-invasion in areas such as Mbire and Muzarabani, bordering Mozambique. This was due to wildlife movements. The tsetse fly carries nagana, or sleeping sickness, which affects wild and domestic animals.

Figure 7.5 Army worm (A), red locusts (B), quelea bird (C), tsetse fly (D)

Diseases caused by bacteria and fungi can also affect crops or animals. Farmers need to control pests and diseases to ensure a higher yield. This is usually done in one or more of three ways:

- Manual or direct control means, for example, trapping, catching or killing rats, mice and jackal, or even removing ticks from animals by hand. In the case of invasive plants, this would involve cutting down or hacking out the plants.
- **Biological controls** include using a known enemy of the particular pest or disease to either kill it, eradicate it (wipe it out) or prevent it spreading or developing.
- Chemical control includes **pesticides**, which farmers use to control pests, while weeds are controlled using **herbicides**, and fungus diseases are controlled with **fungicides**.

Growing different crops and plants in one field is a form of biological farming called intercropping. It may help to control pests and diseases because one plant may repel a pest or disease that attacks other plants in the field.

There is a need for an efficient disease and pest monitoring and control system in farming areas. This involves controlled movement of livestock between areas. It also involves the use of foot-baths for motorists and people entering controlled zones, fencing off or creating buffer zones to check the movement of livestock and preventing the movement of affected stock. Restricting stock movement by keeping animals in a specific area is known as quarantining them.

Table 7.2 Pests and their control measures

Pest/disease/animal name and its nature	Effects on crops or animals	Measures to control
1. Tsetse fly spread trypanosomiasis through biting people and animals	• Nagana disease in animals, which results in deaths • Sleeping sickness in human beings, which limits their potential to work and can eventually lead to death • Limits the areas where cattle can be reared	• Ground or aerial chemical spraying • Use of scented net traps • Treatment of affected person/animal and international co-operation
2. Anthrax is an infection caused by the bacterium *Bacillus anthracis*	• Can result in pneumonia, blood infection, and death in cattle, sheep, horses, pigs as well as in humans	• Vaccination • Culling of diseased animals • Antibiotics • Decontamination and disinfecting of anthrax carcasses and infected material
3. Foot and mouth disease	• See the detailed case study below	• See the detailed case study below
4. Insects such as the maize stalk-borer, American bollworm in cotton	• Stalk borer larvae at various stages of development burrow into and eat different parts of the plant • Boll worms are larvae of a moth which eat leaves, and the bolls, of cotton plants	• Burning or ploughing in crop residue to get rid of any remaining insects • Biological control and intercropping show some success • Chemical control (stalk borer and bollworm)
5. Rodents and fungi in the harvest and post-harvest period	• Damage or destroy harvest that have been stored • Rodents contaminate harvested grain with their droppings	• Store harvested grain in proper storage facilities • Exterminate rodents by controlled trapping or poisoned bait
6. Marauding animals such as elephants, baboons, wild pigs and lions	• Damage or completely destroy crops or, in the case of predators, kill livestock	• Fencing • Ensuring wild animals are limited to Parks and Reserves • Capturing and relocating problem animals • Working with conservationists to find solutions

Activity 3

1. Explain what is meant by biological control for combating agricultural pests and diseases.
2. Why is international co-operation between the countries of southern and central Africa so important in combating, in particular, animal diseases? Look again at the map of southern Africa in Activity 2 to help you.

3. Which of the following affects crops, and which affects animals:
   a) foot and mouth disease
   b) Anthrax
   c) Stalk borer
   d) insect larvae such as boll worm
   e) fungal diseases
   f) tick-borne diseases
   g) rats and mice.

Case study: Foot and mouth disease (FMD)

FMD is a contagious disease caused by a virus that affects cloven-hooved animals such as cattle, pigs, sheep and goats. The affected animal develops blisters in the mouth, on the feet or hooves and teats. FMD is a notifiable disease, meaning that it is a legal requirement to report any outbreak of the disease to veterinary officials or the police.

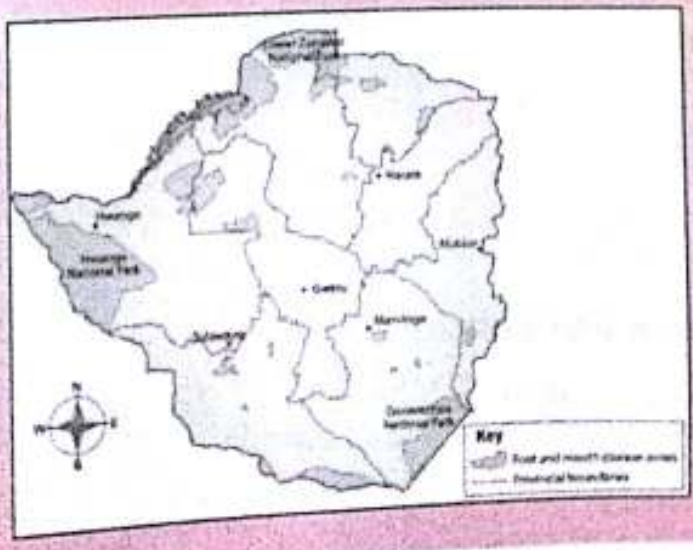
Effects

An outbreak of FMD has the following effects:

- poor animal health which may lead to animal deaths
- low animal productivity in terms of meat, milk and draught power
- stoppage of trade in animals and animal products
- bans on imports of animal products from affected countries
- the control of the disease demands resources in the form of vehicles, labour, vaccines, equipment, materials and the erection and maintenance of cordon or separating fences; it is therefore very expensive.

Control measures

- The Department of Veterinary Services (DVS) is responsible for controlling any FMD outbreak. Veterinary authorities use the following strategies to control, stop and eliminate FMD:
  - The zoning of the country into game areas, buffer zones, surveillance zones, foot-and-mouth-free zones and export zones.



- The safari and national parks are separated from the rest of the country by means of a game fence. This is meant to prevent contact between the African buffalo, which is the main reservoir of FMD, and domestic livestock.
- Buffer zones, between 20 and 30 km wide, surround the parks. No cattle are allowed in these areas. Next are the surveillance zones in which cattle and other cloven-hooved animals have to be vaccinated. Cattle fences separate surveillance zones from FMD-free zones. In the south, the fence runs south of Mt Selinda to Birchenough Bridge, following the border between the communal and commercial ranching areas in Chiredzi, to Rutenga, Makado, West Nicholson and Fort Tuli on the Botswana border. In the north, the cattle fence runs from Nyamandlovu to Victoria Falls' main road, through Gwayi to Lake Kariba on the Zambezi. The interior parts are FMD-free zones, with some areas around Marondera and Chinhoyi producing cattle for export. Thus, the distribution of cattle is affected by the occurrence of FMD.
- Restrictions on livestock movement involve the following quarantine or seclusion measures:
  - Use of permits to move both domestic and wild animals and their products, tracing systems to identify the origin and movement of animals, vehicle sanitation, stock registers, cattle cleansing and import and export regulations.
  - Regular livestock inspections on farms, at dip tanks, cattle sales, agricultural shows and slaughter points.
  - Vaccination against the disease and laboratory diagnosis to determine the virus types and sub-types. The diagnoses are carried out at the Central Veterinary Laboratory in Harare, Botswana Vaccine Institute and Onderstepoort Veterinary Laboratory in South Africa. It should be noted that vaccination can never fully protect animals since FMD is endemic.
  - Other measures involve the destruction of affected animals.

Activity 4

Imagine that you are a veterinary officer in Zimbabwe and there has been an outbreak of foot and mouth disease in the district under your control. Describe:

- the measures you would take to control the disease
- the problems you are likely to encounter in your efforts
- how you would overcome these problems.

Urban agriculture

Urban agriculture is the growing of crops on vacant land within and on the outskirts of cities and towns. It is mostly a seasonal activity. Urban residents use this as a survival strategy to supplement food supplies in the wake of rising food prices. This ensures urban food security. Surplus produce is sold, thereby increasing household income. It has been estimated that in a good rainy season, 60% of Harare's food supply comes from urban agriculture.

Urban agriculture is characterised by the following:

- Poor households are the leading users of urban land for agriculture. Such household plots are worked on mostly by women and children.
- Lodgers have a low rate of participation since municipal officials allocate land to houseowners. Lodgers thus usually cultivate on unallocated land.
- Common crops grown are maize, sweet potatoes, beans and seasonal vegetables.
- Cultivation is concentrated along wetlands and stream banks. This can result in siltation and destruction of fragile riverine ecosystems.
- Urban agriculture can utilise organic waste and waste water on edible crops and pastures. On peri-urban Harare Municipality farms such as Corrow-borough, situated on the western side, partially treated waste water is used to irrigate pastures.

On some larger low-density peri-urban plots, market gardening in greenhouses (see Figure 7.6) has become important in major urban areas like Harare.

Advantages of urban agriculture

- It provides food security to the poor households in the wake of high retail food prices.
- It is a source of varied food crops and animals, such as chickens and rabbits. This encourages balanced diets.
- It utilises vacant urban spaces.
- It is a source of livelihood in that it employs the jobless through part-time paid work and as a source of income as surplus is sold.
- If well planned, for example using greenhouses, it can provide quality and timely goods in demand for the agricultural produce market.

Disadvantages of urban agriculture

- It can lead to environment degradation through erosion and siltation of stream courses. Can increase the danger of hazards such as flooding, landslides etc.
- It destroys fragile habitats for endangered species, such as water fowls.
- It is an eyesore to the beauty of the townscape. It is alien to urban areas and represents a 'ruralisation' of towns.
- Maize fields become hideouts for criminals, hence increase in muggings and rape cases, among other crimes.
- Standing fields cannot be cut and so become breeding grounds for mosquitoes.
- Very poor families may not have easy access to this livelihood activity. So it entrenches existing inequalities in access to resources.

Possible ways to mitigate these challenges

- Introduce a planned, controlled, no permanent user utilisation of urban spaces for agriculture policy.
- Use a plot allocation process that is pro-poor residents, such as lodgers, the homeless and the unemployed.
- Enforce applicable environmental management regulations, for example on avoiding streambank cultivation.

Fig 7.6 A vegetable crop in a greenhouse

Activity 5

As a class, debate the topic: Urban agriculture should be banned, or at least regulated. Your teacher will explain the procedure for a formal debate including the terms:

- proposer
- seconder
- speaker against
- seconder against
- discussion
- voting.

Agribusiness

Agribusiness is the business of agricultural production. It includes all aspects of farming, and everything to do with farming, which is seen as a business. It includes animal breeding, crop production, farm machinery, processing, and seed supply, and marketing and sales. The United Nation's Food and Agriculture Organization (FAO) operates a section devoted to Agribusiness Development that aims to promote food industry growth in developing nations.

In Zimbabwe, the communal farming sector occupies about 20 million hectares of land. The small-scale commercial farming sector is made up of around 50 000 units on what were large-scale commercial farms. What remains of the large-scale commercial farming industry comprises about 5 million hectares and another 4 million hectares held by large agribusiness concerns. Dairy, tobacco and fruit are farmed as part of agribusiness production. Agriculture used to employ a third of the national labour force and made up about a quarter of Zimbabwe's **Gross National Product (GNP)** and half its exports. Crop yields were above regional averages for southern Africa. Commercial farmers were able to borrow in order to cover production costs and ensure outputs. Communal farmers dominated the markets for **agricultural commodities** such as maize (60%) cotton (80%), small grains, ground nuts and beans.

The drought years of 2015 and 2016 had a severe impact on agribusiness in Zimbabwe. Food crops have been hardest hit, as have other crops that rely on rain. **Irrigation** helps to maintain some agricultural output, and tobacco has generally been a success story. However, all of southern Africa, including Zimbabwe, now has to import food, and the whole region is vulnerable to food shortages and hunger.

As commercial agriculture contracts, so do the businesses associated with it. These include:

- businesses dealing in farm equipment, such as tractors and machinery
- businesses supplying farming infrastructure, such as fencing, gates, wind mills, water pumps and irrigation equipment
- businesses supplying fertilisers, pesticides and herbicides
- agricultural cooperatives
- land surveyors, property administrators, lawyers and agricultural finance personnel
- auctioneers and the transportation business.

The agribusiness sectors in Zimbabwe have many players in the network, for example input supply, production, processing, distribution, marketing, wholesale, retail and consumption. This creates a value chain relationship where business entities, groups and/or individuals (also called players or actors) and their activities specialise or work or focus on a product at various stages or phases in the agriculture industry. Aspiring business people or companies can identify an area or niche where they want to do business. Remember that such players or entrepreneurs are all in the same broad business of agriculture though, and depending on what improvements have been invested, the value or cost of the product varies. Operation in a sector needs to be supported by an enabling or conducive environment at a national and international level and with ready markets for whatever products are produced. The types of agribusiness in Zimbabwe include input suppliers, producers, processors, distributors (such as wholesalers and retailers) who all should be able to access financial backing from commercial banks, micro-finance institutions, government loans and programme donors and non-governmental organisations.

Conditions and advantages for agribusiness

- There is well-developed infrastructure that serves the main farming areas of the country including communal lands. Some of the roads are in need of repair though.
- The agricultural potential of the country is diverse with possibilities for producing maize, tobacco, cotton, wool, beef, dairy products, poultry and honey products, fish (aquaculture is very popular), among the many possible lines of business.
- There is a high irrigation potential, which can be developed to counter the problems of frequent droughts.
- Agribusinesses, especially small- to medium-scale ventures, are a source of employment and livelihood for the many unemployed out-of-school youths in Zimbabwe.
- The high literacy rate means that the majority of people in Zimbabwe are able to run their own agricultural related ventures.
- It is a source of government revenue from taxes.

Prohibitive conditions and disadvantages of agribusiness

- Small-scale and individual players face stiff competition from established large-scale actors.
- For prospective large player entrants, the legislative issues to do with the Indigenisation Act and future agricultural land rights are still uncertain and unclear.
- There is generally a lack of finance and, if available, it is very costly, for example high interest rates. Small venture individuals need some start-up capital, money and facilities for initial basic training or induction.
- The domestic markets are weak, especially the producer prices coupled with a low buying potential among a population many of whom are unemployed and live on a hand-to-mouth basis.
- An underperforming economy with a shrinking industrial base limits the potential market for agro-products.
- Climate change induced droughts and erratic rainfall are constant problems in the agricultural sector.

Activity 6

1. Give a definition of agribusiness in your own words.
2. Name four branches of agribusiness in Zimbabwe.
3. Explain why agribusiness is important to the economy of Zimbabwe.
4. Two of the following would not be part of agribusiness. Identify the two activities:
   - crop spraying
   - irrigation farming
   - hunting
   - veterinary services
   - fishing.
5. In a class group, think about and discuss an agribusiness that could be started in your particular region of Zimbabwe. Think about:
   - the type of business
   - how the local community might benefit
   - how the business might be funded (bank loan, donor funding)
   - how environmentally sustainable the business would be.

Summary

- Climate change is the change, over a number of years, to aspects of the weather such as temperature and rainfall. It appears to be having an impact on farming all over the world. Agriculture in Zimbabwe and elsewhere needs to adapt to changing climatic conditions. This might include growing different crop types, or expanding agriculture into new areas.
- Agricultural pests and diseases are sicknesses, viruses or bacteria which infect or attack plants (crops) or animals. Insects, or animals that eat or attack plants or domestic animals are also classified as pests.
- Pests and diseases can be controlled manually (for example, trapping or killing rats or locusts) biologically (by introducing a plant or animal which attacks and kills the pest or disease) and chemically, with herbicides, pesticides, fungicides or animal drugs such as antibiotics.
- Urban agriculture is agriculture (farming) in urban (built-up) areas. People often grow food, or keep chickens and domestic animals, in settlement areas so as to provide an extra food source, or even to sell for some income. Urban agriculture has advantages, but also some disadvantages or problems.
- Agribusiness includes everything associated with farming as a business. What is produced by commercial farmers, small-scale farmers, or on estates, is thought of in cash terms. Agribusiness therefore includes growing crops or raising animals, but also the whole infrastructure around farming. This includes everything from agricultural machinery, to financing of agricultural products, to marketing.
- Sources of funding for small-scale agribusiness include commercial banks, government funding, donor funding or private funding.
- Because agriculture is so important to Zimbabwe, agribusiness remains vital to the country's economy. Many individuals earn a living from some aspect of agribusiness, and the economy benefits from taxes and the products such as tobacco produced for export.

Glossary

agribusiness – everything to do with the business of agricultural production

biological control – the use of natural controls such as insects, plants or animals to control a plant or animal disease or to combat the unwanted plant or animal species

climate change – changes in weather patterns over a long period (number of years, not just a season or two) including temperature and rainfall changes in amount and distribution

commodity – a product or something whose output can be measured

genetically modified – any organism, plant or animal, containing genetic material that has been artificially changed so as to produce a desired characteristic

global warming – rising atmospheric temperatures on an ongoing basis

gross national product (GNP) – the value of all goods and services from human activities in a country for one year

gross domestic product (GNP) – the value of all goods and services from human activities in a country for one year plus income from overseas assets

growing season – the period of time during which plants will increase their biomass (in other words, grow bigger, or bear fruit and seed)

herbicide, pesticide, fungicide – chemicals, produced in a laboratory or factory, which target weeds, insects or types of fungus respectively; they are used to control plant and animal pests and diseases

irrigation – the introduction of water other than natural rainfall by spraying, flooding or dripping, to get a harvest, or to improve the harvest

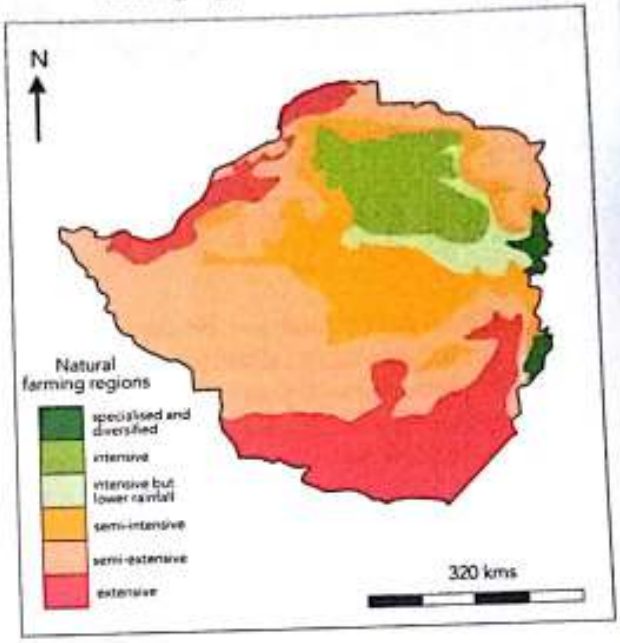
land reform – changes to the distribution of land, or ownership of land, usually undertaken to gain equality amongst those who previously did not have access to land

urban agriculture – farming undertaken in built-up areas such as settlements, towns and cities

veterinarian – animal doctor

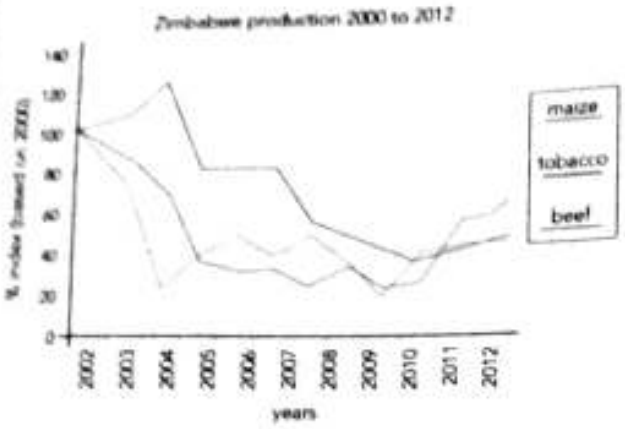
Topic test 7

1. Climate change is likely to result in:
   - A global temperatures falling
   - B global temperatures rising
   - C snow over Zimbabwe
   - D the Zambezi drying up completely.
2. International co-operation between southern African countries on agricultural matters is important because:
   - A animal diseases can easily spread across international borders
   - B animal diseases cannot easily spread across international borders
   - C each country is completely isolated and on its own
   - D people can visit other countries on holiday.
3. Biological control of pests and diseases in agriculture involves:
   - A using lots of chemicals
   - B using lots of people to catch quelea birds
   - C using the natural biological enemies of diseases and pests to control them
   - D waiting for a plant disease to die out over time.
4. Land reform in Zimbabwe is aimed at:
   - A a more equal (equitable) distribution of land
   - B getting more tourists to visit Zimbabwe
   - C establishing more game reserves and national parks
   - D none of the above.
5. Urban agriculture in Zimbabwe:
   - A is practised in rural areas
   - B only takes place in forested areas
   - C needs very big pieces of land
   - D takes place in or close to human settlements.
6. Look at the simplified map of farming regions of Zimbabwe below:
   a) Identify the four different regions.
   b) Explain why there are different types of farming region in Zimbabwe.



7. Do you think urban agriculture is a good or a bad thing? Explain your opinion. There is no right or wrong answer, but you must be able to support what you think about urban agriculture with good reasons.

8. Study the graph of agricultural production in Zimbabwe between 2000 and 2012 and answer the questions which follow the graph



a) Which agricultural commodity is one of Zimbabwe's most important export?

b) Which commodity do most Zimbabweans rely on as a main food source?

c) Describe and explain the general trend in output for all these commodities.

d) Explain, giving possible reasons, why outputs have changed (up and down) over the years.

e) Which commodity seems to have made the best recovery since 2012?

f) Data is only available up until 2012 but, given the severe droughts of 2015 and 2016, and the high rains in 2017, what is likely to have happened to the graph where it stops on the right?

9. What is agribusiness? List five types of agribusiness, and explain why agribusiness is important to a developing country like Zimbabwe.

Topic 8

Industry

Objectives

By the end of this topic, you should be able to:

- describe service industry
- define tourism
- describe tourism in Zimbabwe
- describe problems associated with tourism in Zimbabwe
- suggest solutions to problems faced by tourism in Zimbabwe
- describe quaternary industry in Zimbabwe
- explain problems associated with service industries in Zimbabwe.

Introduction

Industries are human economic activities. Farming (agriculture) and mining are regarded as primary industries, and manufacturing (factories) as secondary industries. **Tertiary industries** are dealt with under this topic, they include the service industries.

Service industries

Service industries are those whose products are not tangible. This means you can't touch them. Examples of service industry workers and professionals include:

- teachers (education)
- accountants (finance)
- shop assistants and informal traders (retail trade)
- cleaners
- health workers (medical sector staff)
- transport
- police, judges, magistrates (law enforcement)
- city, town council and district workers (municipal services)
- secretarial workers (offices).

These service industries occur in most human settlements at different levels. The more advanced settlements have more service industries than the less developed settlements. This means that the more developed countries in the northern hemisphere such as the USA, Canada and most European countries, as well as those in the southern hemisphere, such as Australia, New Zealand and South Africa, have more service industries than developing countries in Africa, South America and most of Asia. We will look at Zimbabwe's most common service industry – tourism.

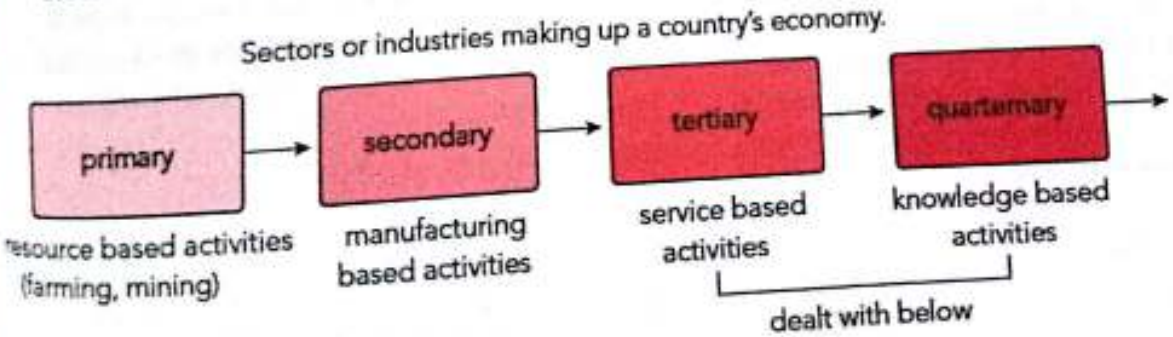


Figure 8.1 Sectors or industries making up a country's economy

Tourism and its importance in Zimbabwe

Tourism means moving to places of interest for pleasure. A tourist is someone who visits places to enjoy the views and experiences in new and different places. The time taken varies from a day's journey to holidays lasting for weeks. The distance also varies greatly and is related to affordability. Tourism is governed by people with the time and money to spend on visiting and exploring different places of interest.

Activity 1

1. Name the tourist attractions that you have visited in Zimbabwe. Explain:
   - how you got there
   - why you visited
   - what you think could be done to attract more visitors to that particular place.
2. Without reading ahead, make a list of four or five advantages, as well as four or five disadvantages of tourism for a country like Zimbabwe.

Tourism as a service industry

Tourism is basically a **service** industry. In this section, the general aspects of tourism are discussed, namely the factors that influence the development of tourism as well as the benefits and costs of tourism. Some important definitions related to tourism are given below.

Definitions

- *Tourism*: The World Tourism Organisation defines tourism as the temporary or interim movement of people from places of their usual residence or work for such purposes as leisure, education, business and health for a period of less than a year.
- *Tourist or excursionist*: A tourist is a visitor who spends at least one night in the destination visited. Excursionists spend less than one night in their destination. Tourism depends on the existence of natural and geographic features. Humankind has chosen to utilise the natural environment for social and economic benefits.

Factors influencing tourism

The development of tourism in general depends on the following factors.

Climate

Some areas in the northern hemisphere experience unpleasant climatic conditions such as very cold temperatures for most of the year. The people from these areas therefore visit places within the tropics or southern hemisphere where the weather is sunny and pleasant for their holidays. Tourists from Canada, the USA, western European countries and Scandinavian countries take time off to visit the tropical countries in Africa and Asia to experience the pleasant sunny conditions.

Attractive scenery

High mountains such as the Eastern Border Highlands in Zimbabwe or Table Mountain in South Africa provide an attractive sight for tourists from within or outside the country. The same can be said of lakes such as Lake Kariba in Zimbabwe, where tourists can enjoy boating and fishing as forms of recreation. Some tourists would prefer to relax on coasts with pleasant beaches. The other attractions for tourists include wildlife areas such as Hwange National Park in Zimbabwe or forests such as those in the Congo Basin in the DRC or the Amazon Basin in South America.

Figure 8.2 Victoria Falls is one of the seven natural wonders of the world

Historical or cultural attractions

Some places are important for cultural reasons. Of cultural importance are national monuments such as the Great Zimbabwe ruins and Khami ruins in Zimbabwe, some palaces, temples or mosques in the Middle East and other parts of the world. Cities such as Jerusalem and Mecca are destinations for religious tourists or pilgrims. The pyramids of Egypt provide a big attraction for tourists worldwide. Some entertainment facilities also fall within this category. These include world-famous theatres and places where dance and music groups perform for an audience.

Accommodation

Visitors need good accommodation to make their stay comfortable. Most countries that have **tourist attractions** make an effort to have well-developed accommodation facilities for their visitors. Accommodation comes in the form of camping sites, hotels, motels, chalets, lodges, flats, houses and caravan sites.

Transport accessibility

Most tourists need to get to various attractions, so a reliable means of transport is essential for the tourist attractions to be accessible. This means a good road network, affordable modes of transport and reliable air transportation systems need to be developed. In Zimbabwe, special coaches, air and road links and car-hire services have been developed to link up various tourist destinations. Package tours are a common feature of tourist travel.

Foreign currency

Foreign currency is needed to import special foods and provide good facilities for visitors. In developed countries this is easily available, but in developing countries a shortage of foreign currency is a hindrance to the development of tourism.

Advertising

The attractions of a country need to be promoted to the host country (for domestic tourists) and to the outside world (international tourists) in various ways that include the electronic media (radio, television or internet) and the print media (newspapers and magazines). Travel agents are also a helpful means of advertising.

Political stability

Tourists visit areas where there is peace, safety and security. Wars have a negative impact on tourism.

Services

Tourists need various services such as those for shopping, banking, entertainment and eating (restaurants and delicatessens). These services would provide the visitors with their daily requirements and make their stay in an area as comfortable as possible.

Figure 8.3 Great Zimbabwe National Monument is a UNESCO world heritage site

The advantages of tourism

Employment

Many people are employed in the tourism industry. The various jobs include those of drivers, cooks, waiters, porters, clerks, cleaners, tourist guides and shopkeepers. In Zimbabwe, 426 000 people are employed directly or indirectly in the tourism sector, according to the World Travel and Tourism Council. In Kenya, the sector employs 543 000 people while in France, a **developed country**, almost 2 714 000 people are employed in the tourism industry.

Foreign currency earnings

During the past 30 years, tourism has grown to become one of the world's fastest-growing service sectors. It is the world's third-largest export product after oil and motor vehicles. Africa contributes two per cent of the world's share of international earnings from tourists. Tourists are regarded as 'invisible exports' if they bring in foreign exchange into a country.

Infrastructure development

Tourism leads to the construction of hotels, other forms of accommodation and various information offices. Air and ground transportation facilities need to be built and these include airports and roads as well as their operations, especially in remote areas.

Stimulus for economic growth

The food processing and other agricultural industries are developed. This is because hotels and restaurants in an area need food for their guests. These sectors also employ people and these people need services, so they stimulate the growth of the country's service sector as well.

Wildlife conservation

Wildlife resources are conserved as tourists want to see, in particular, the **flora** and **fauna** of Africa. Tourism authorities are actively involved in wildlife **conservation** programmes in Zimbabwe.

Figure 8.4 Hwange National Park has over 100 mammal species and is known for its large elephant population

Social benefits

The tourists mix with and appreciate people of other cultures. Cultures of a varied nature come

into contact in a casual manner and there can be cultural exchange for the benefit of both parties. In Zimbabwe, cultural cohesion can be promoted through **domestic** tourism as people of different tribal origins mix casually. National pride is also promoted as domestic travellers increase their knowledge of their country.

The disadvantages of tourism

It is costly to promote, establish and maintain tourist attractions. To add to this, salaries and wages need to be paid to the staff employed in the industry. Many tourism jobs are not well paid.

There may be environmental degradation due to pressure exerted upon the environment by human utilisation. Tourists may also disturb wildlife habitats as they constantly enter the wildlife areas.

Income from tourism may be unreliable because the numbers of tourists visiting an area may fluctuate. This may be due to the seasonal nature of tourism. This could also be due to bad publicity in the local and international media, or economic or political instability in an area.

Tourism can result in cultural erosion and foreign cultures may overtake local cultures. It is because of this that as early as 1980 the government of Zimbabwe issued a memorandum of policy that tourism should not be allowed to degrade local cultures.

Diseases can be spread through contact between different people in the tourist resorts. Such diseases as HIV/AIDS and other sexually transmitted diseases can be spread through contact.

Top managerial jobs are often taken by foreigners. Most tourist attractions in developing nations are in the hands of or are controlled by foreigners, who repatriate profits back home.

Activity 2

Having read about the general advantages and disadvantages of tourism, look at your answer to Activity 1 Question 2 and share your ideas in a class discussion on the advantages and disadvantages of tourism.

The tourism industry in Zimbabwe

Tourism is seen as a vital source of foreign exchange by the government. This is because of the earnings made from payments by the tourists in the food, accommodation, transport and entertainment industries. Most of the tourists to Zimbabwe are drawn from South Africa, North America, France, Zambia, Botswana, Germany, Japan and Australia. Figure 8.5 shows tourist numbers who visited Zimbabwe between 1996 and 2014.

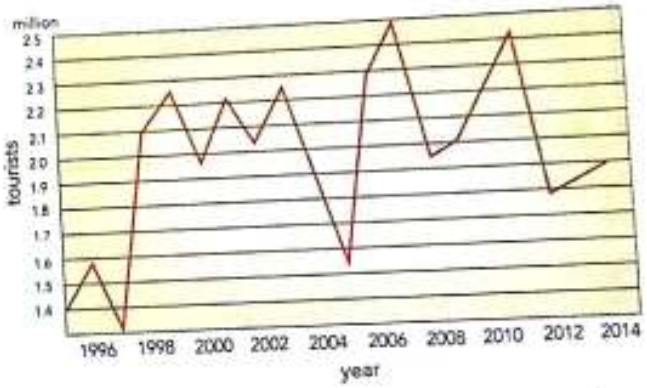


Figure 8.5 Zimbabwe tourism, showing the number of visitors each year between 1996 and 2014

Tourist attractions

Tourism in Zimbabwe is based mainly on the Parks and Wildlife Estates that are found chiefly in the peripheral areas of the country. These are mainly sparsely populated areas. Figure 8.6 shows the location of these Parks and Wildlife Estates.

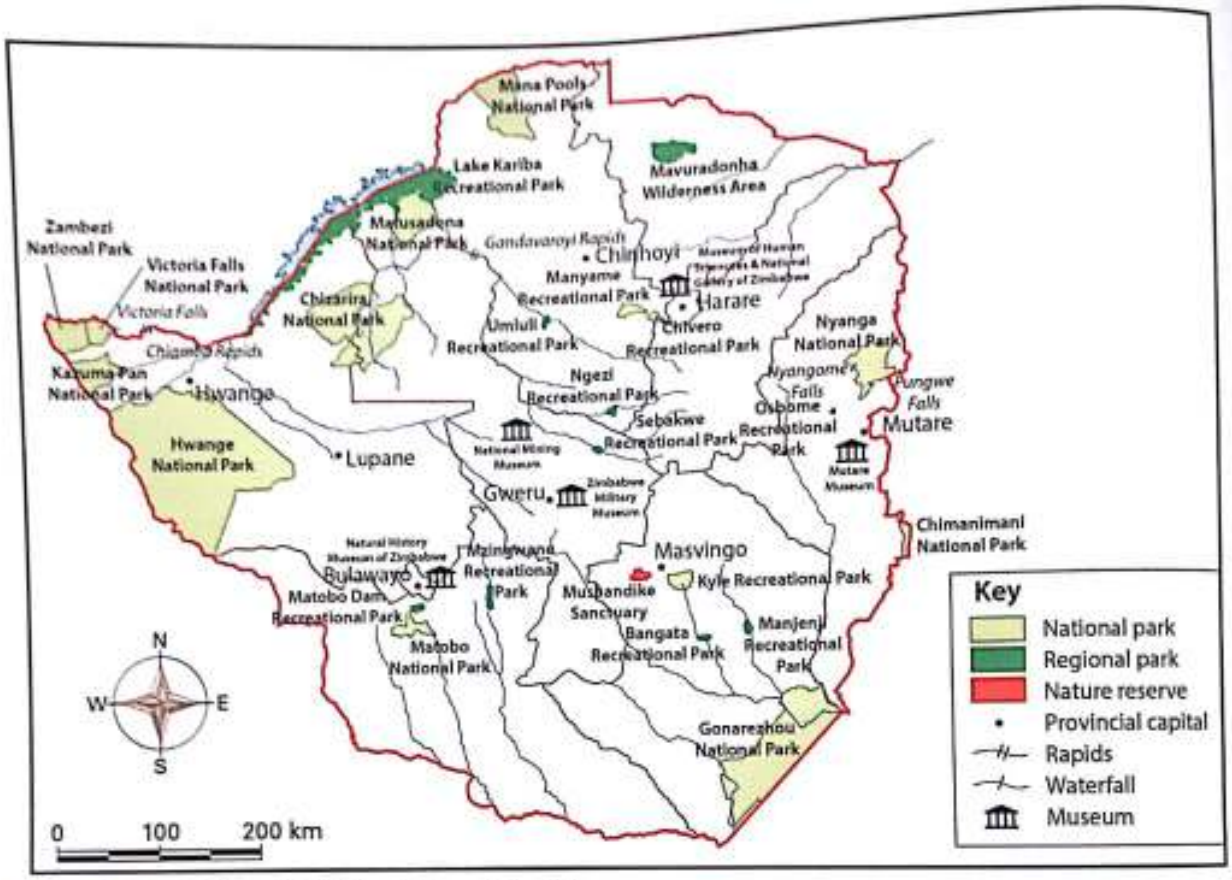


Figure 8.6 The Parks and Wildlife Estates of Zimbabwe

The Parks and Wildlife Estates cover almost 5 million hectares, which is almost 12,7% of the country. There are six categories of land use that can be identified. These are national parks, botanical reserves, botanical gardens, sanctuaries, safari areas and recreational parks. Let us look at the characteristics of these areas and their importance in tourism development in Zimbabwe.

National parks

There are 11 national parks in Zimbabwe, which cover 2 703 900 ha (6,8% of the country). These areas are noted for their wild animals, scenic views, spectacular relief and historical significance. Table 8.1 summarises the main characteristics of Zimbabwe's national parks.

Table 8.1 The characteristics of Zimbabwe's national parks

Name of park	Area (ha)	Main attributes	Main visitor activities or attraction
Chimanimani	17 110	mountains, scenery, important river catchments	walking, climbing
Chizarira	191 000	mountains, spectacular views, important river catchments, wildlife	game viewing, walking, climbing
Gonarezhou	505 000	scenery, major rivers, wildlife; now part of the Great Limpopo Transfrontier Park (GLTFP)	game viewing, walking, climbing, angling
Kazuma Pan	31 300	wildlife	game viewing
Mana Pools	219 600	mountains, scenery, major rivers, wildlife	walking, climbing, game viewing, angling
Matopos	42 400	scenery, important river catchments, wildlife, historical significance (Rhodes' grave)	game viewing, walking, angling
Matusadona	140 700	mountains, scenery, major rivers, wildlife	game viewing, walking, climbing, angling
Nyanga	33 000	mountains, scenery, waterfalls, important catchments, historical significance	walking, climbing, angling
Victoria Falls A	1 904	major rivers, historical significance	wild areas, walking, climbing
Victoria Falls B	436	waterfall	scenery
Hwange	1 465 100	spectacular wildlife	game viewing, walking
Zambezi	56 010	scenery, major rivers, wildlife	game viewing, walking, climbing, angling

Figure 8.7 Mana Pools is a UNESCO Natural World Heritage Site famous for game viewing from the water

Botanical reserves, botanical gardens and sanctuaries

Botanical reserves are important for the protection of individual species of animals and plants. Botanical gardens are managed especially for the preservation of indigenous species. Examples include Bunga Reserve for mountain forest (Chimanimani Forest), Chisekera for the mangrove fern, and Sebakwe I, II, III for Acacia Karoo, Great Dyke flora and Mountain Acacia respectively.

Sanctuaries are areas where animals are especially protected. These include Chimanimani Eland that has 1 800 ha set aside for the protection of eland. Mbadze Pan has an area of 40 ha and is a bird sanctuary on an oxbow lake of the Shangani River. Nyamanetsi Sanctuary is 2 480 ha and is characterised by Great Dyke flora, and Tshabalala Sanctuary is 1 100 ha in size and is used for game viewing and educational purposes.

Safari areas

These areas are set aside for recreational hunting and the cropping of wild populations. Examples include Zhete (hunting, crocodile research and university research), Dande (hunting and outdoor recreation), Doma (hunting), Malipati (limited safari hunting), Sapi (individual hunting, canoe safaris) and Tuli (individual hunting, botanical reserves).

Recreational parks

These are found where natural features have been preserved and protected to maintain biological diversity. They develop close to dams for the purposes of recreation. Examples of recreational parks include Chinhoyi Caves where the main features are dolomite caves, Lake Kariba for angling, game viewing, water sports and commercial fishing, Lake Chivero for outdoor recreation, commercial fishing and fisheries and Sebakwe for commercial fishing, some angling and yachting.

Other attractions in Zimbabwe

A number of historical sites or cultural sites provide tourist attractions in different parts of the country. These include the amazing Great Zimbabwe ruins, believed to be the most spectacular in Africa, south of the Sahara. The Khami ruins and Dhlodhlo ruins, in Matebeleland, are also interesting to visit. Museums in Gweru (for military purposes), Bulawayo and Harare as well as other parts of the country are places of interest to tourists.

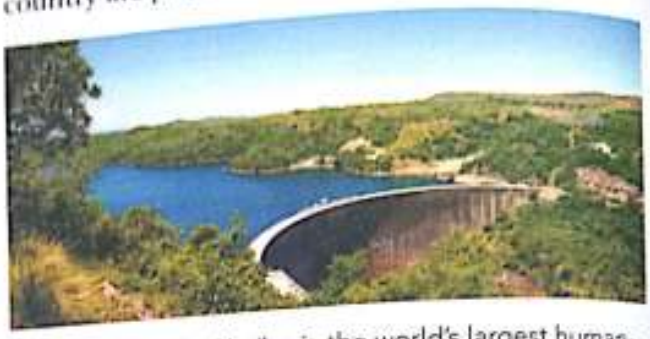


Figure 8.8 Lake Kariba is the world's largest human-made lake

Communication

Zimbabwe has an established internal network of roads and this is still increasing in size. The railway system with its headquarters in Bulawayo is reasonably efficient and connected to the main areas. The railway transportation system is also cheap to the ordinary traveller. Air transport serves both domestic and international routes.

- *Domestic routes*: Tourists may want to get to their destinations quickly and so they use air transport. Air transport serves Harare, Bulawayo, Victoria Falls, Gweru, Kariba, Hwange and Buffalo Range. Other areas, such as Bumi Hills and Nyanga, are served by small carriers and charters.
- *International routes*: These connect Zimbabwe to Johannesburg, Durban, Botswana, Gabarone, Nairobi, Lusaka, Lilongwe, Dar-es-Salaam and other African centres; Australia (Melbourne); London; India (Calcutta); and other cities of the world. Harare has a modern international airport, appealing to the international traveller.

The potential for increasing tourism

Zimbabwe has a vast potential for increased tourist revenue because:

- There are many wonderful scenic attractions including the world-famous Victoria Falls and other natural landscapes including the Chinhoyi Caves, the Zambezi River, and the Eastern Highlands with mountains such as Nyanga, Chimanimani and the Vumba.

- Wildlife areas in Zimbabwe include Hwange National Park, Mana Pools, Lake Mutirikwe area and Gonarezhou. Lake Mutirikwe, Lake Chivero, Lake Kariba and many small dams provide for sport (fishing) and recreation.
- Transport infrastructure is well developed in the form of roads, railways and air networks to help link up the tourist attractions. Accommodation is available in the form of high-quality hotels and lodges in the resorts and the major centres.
- Domestic tourism is gaining momentum because more local people are visiting tourist resorts within the country. More and more efforts in promoting domestic tourism are being made through the Zimbabwe Tourist Development Corporation (ZTDC).
- Zimbabwe's warm, sunny climate favours tourism. This type of climate is favoured by tourists from cold countries in the northern hemisphere such as Canada, the USA and Western Europe.

Activity 3

How do you think local tourism can be encouraged in Zimbabwe?

Quaternary industries

Quaternary industries provide services to all the other industries, basing their activities on research and expertise to improve manufacturing techniques, agricultural techniques, disease control and information technology. The above-mentioned types of industry are interrelated and form linkages among themselves as shown in Figure 8.9. Quaternary industries often have medium- to long-term goals. This means that they use, rather than generate funds (money) for the future benefit of the country.

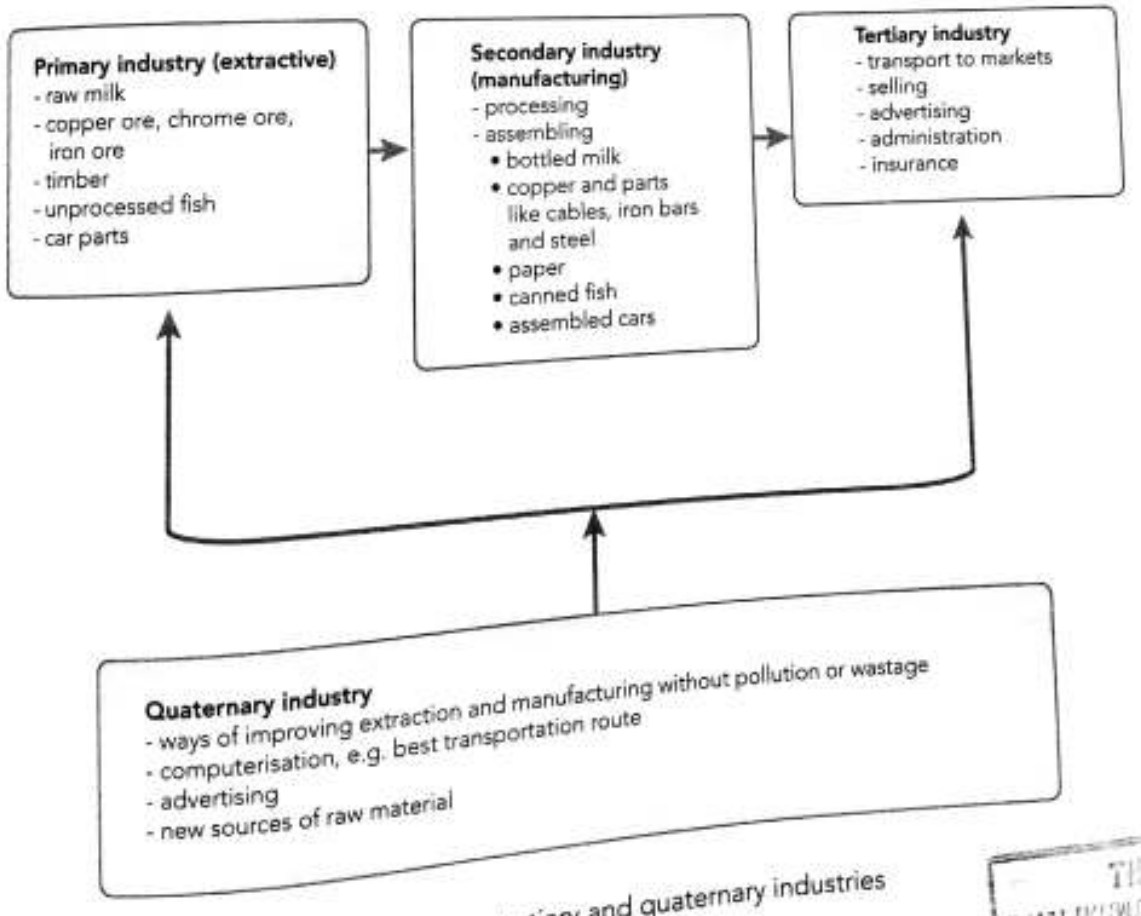


Figure 8.9 Links between primary, secondary, tertiary and quaternary industries

Quaternary industries include:

- research by universities and state laboratories or private companies
- IT (information technology) support
- research and development of alternative energy sources.

Problems associated with quaternary industry in Zimbabwe

Quaternary industries are found mainly in highly developed countries, with plenty of money to invest in research and development. In developing countries, including Zimbabwe, quaternary industries are hampered by a lack of expertise and capital (money). Zimbabwe's economy focuses on primary and, to an extent, secondary industries. These were discussed in Form 3. Tertiary industry supports primary and secondary industry but, as with most developing countries, Zimbabwe relies on knowledge and expertise from developed counties in terms of quaternary industry. Developing countries have urgent needs such as education and health. There is little or no money left for the government to fund quaternary industry.

Summary

- Service industries provide services, as in commerce, trade, transportation, banking, insurance and tourism, these are tertiary industries.
- Quaternary industries provide services such as research development and the development of specialist expertise in, for example, information technology.
- Service industries provide services such as tourism and recreation, teaching, insurance, transport and secretarial services.
- Tourism is a service industry that brings in foreign currency to countries such as Zimbabwe, South Africa and Kenya.
- Zimbabwe is well placed to take advantage of the global growth in tourism.
- The development of tourism in a country depends on the existence of attractions, the climate, transport, accessibility of attractions, accommodation, level of advertising, political stability, economic stability, foreign currency availability and land availability.

Glossary

conservation – to look after, or preserve or keep for the benefit of all

developed country – generally wealthy countries of Europe and North America with highly developed economies and infrastructure

domestic – local, not foreign

quaternary industry – quaternary means four, so these are fourth (high) level service industries such as the development of computer technology, or agricultural or medical research

service – something other than goods, for example, finance, education, health, tourism

tertiary industry – meaning third level, or tier (after farming and mining, and manufacturing); tertiary industries are service industries

tourism – visiting a country, place or area for relaxation and to experience that country, place or area for oneself

Topic test 8

Choose the answer that does *not* fit in.

1. Well-known Zimbabwean wildlife area:
   A Gonarezhou
   B Hwange
   C Kruger Park
   D Mana Pools.
2. Well-known tourist attractions in Zimbabwe:
   A Niagara Falls
   B Victoria Falls
   C Great Zimbabwe
   D Matopos.
3. Lake Kariba is very popular for:
   A fishing
   B boating
   C viewing game from the water
   D surfing.
4. Which one of the following is a primary industry:
   A tourism
   B farming
   C education
   D health.
5. Which of the following are typical of quarternary industry?
   A forestry and fishing
   B looking at alternative energy sources
   C mining and farming
   D health and education.
6. What are the advantages of tourism for a country such as Zimbabwe? Give five exampes.
7. List six types of employment associated with the tourism industry.
8. Suggest four ways in which Zimbabwe can grow its tourism industry.
9. Hunting of big game is becoming a controversial issue. State your opinion on hunting (for or against) and support your opinion as to why you think hunting is a good, or a bad thing.
10. Explain why quaternary industries are not a major part of the economy of African countries, including Zimbabwe.
11. a) What is domestic tourism?
    b) Describe five ways domestic tourism can be promoted in Zimbabwe.

Topic 9 Settlement and population

Objectives

By the end of this topic, you should be able to:

- identify and explain factors that influence population growth
- describe and explain causes and effects of migration
- outline different categories of migration
- explain the rationale for having population policies
- explain the effects of population policies for developed and developing countries
- describe and explain diseases associated with developed and developing countries
- explain the social and economic effects of diseases
- describe the features of the various stages of the demographic transition model (DTM)
- identify countries with high/low population growth rates
- explain the effects of population growth (negative or positive).

Population growth patterns

Look at Figure 9.1 It shows how the world's **population** has grown over the last 400 years. In this chapter, we will look in more detail at the reasons for this growth, as well as where and why people live where they do.

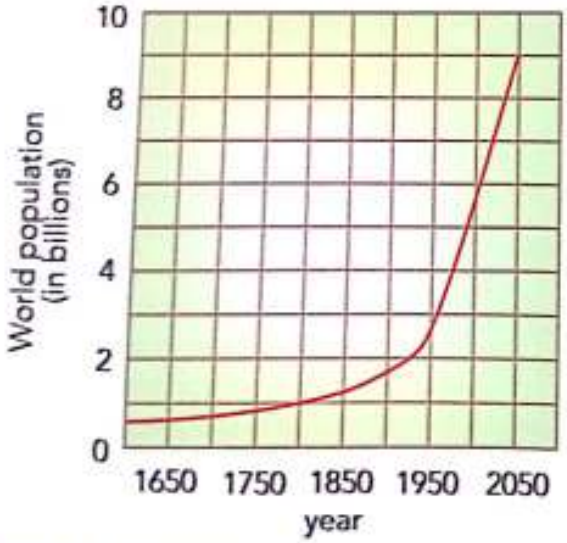


Figure 9.1 World population growth

Population sizes do not stay the same. The things that lead to changes in the size of a population are its fertility, mortality and net **migration**. The growth of population is a function of the **fertility rate**. The fertility rate is the number of children born per woman of child-bearing age (between 15 and 49 years). Population growth is also a function of death rates versus birth rates whereby more births will give us a positive growth, known as a natural increase, and more deaths will give us a negative growth rate, known as a natural decrease. Migration change refers to the increase or decrease of the population of an area due to the balance between the outgoing (emigration) and incoming (immigration) population.

The world-wide trend is a decline in birth rates leading eventually to reduced population growth. A zero growth rate is predicted or has been reached as follows:

- in Europe by 2015
- in North America by 2030
- in China by 2070
- in South East Asia and Latin America by 2090
- in Africa by 2100.

Table 9.1 World and regional population data

Area	Total population in millions 2011	Population in millions 2011		Population growth rate % 2010–2015	Total fertility per woman aged 15–49 2010–2015
		Male	Female		
World total	6 974,0	3 517,2	3 456,8	1,1	2,5
More developed regions	1 240,4	603,1	637,3	0,4	1,7
Less developed regions	5 733,7	2 914,2	2 819,5	1,3	2,6
Least developed regions	851,1	245,4	425,7	2,2	4,2
Arab states	360,7	185,0	175,7	2,0	3,1
Asia and the Pacific	3 924,2	2 008,0	1 916,2	0,9	2,1
Eastern Europe and Central Asia	473,7	226,6	247,0	0,3	1,8
Latin America and the Caribbean	591,4	292,1	299,3	1,1	2,2
Sub-Saharan Africa	821,3	410,5	410,8	2,4	4,8

Table 9.1 shows the world and regional population trend from 2011 to 2015.

Besides a general decrease in population growth rate, the world population is still growing and we need to know why the population is growing and why it varies from place to place.

Factors affecting birth rates

Fertility is the ability of a population to produce babies. Two measures of fertility are the **crude birth rate (CBR)** and the **total fertility rate (TFR)**.

The crude birth rate is the number of babies born in a year per 1 000 people in the population.

$$\text{CBR} = \frac{\text{number of births}}{\text{total population}} \times 1\,000$$

Mortality is the number of deaths in a population in a year. It can be measured in several ways, including the **crude death rate (CDR)** and the **infant mortality rate (IMR)**.

The crude death rate is the number of babies born in a year per 1 000 people in the population. You can calculate the crude death rate in the same way as the crude birth date, using the formula:

$$\text{CBR} = \frac{\text{number of deaths}}{\text{total population}} \times 1\,000$$

The following factors affect birth rates:

Level of economic development

Improvements in living standards result in a drop in the birth rate, while the birth rate remains high if there is no economic development. Children provide a form of security to parents in old age.

Subsistence farming economies

Children in poor farming communities are seen as a source of cheap labour. The more children a farmer has, the more labour is available.

Demographic structure

A country with a high population of young adults tends to have higher birth rates.

A country or region with a high percentage of children and old people will tend to have lower birth rates.

Education levels

Generally, the more advanced the level of education of the parents, the lower the birth rate. This is the case because with more education comes the knowledge of birth control, social awareness and a greater choice. Education tends to delay or postpone the marrying age for women and so reduces birth rates.

Social class

People who are less educated are also generally less well-off materially, less ambitious, and have more children. The middle-income group has the lowest birth rate. The middle-income group is more focused on building up material wealth and having too many children may prevent this.

Religion

Most of the world's religions encourage family development. Some are opposed to birth control and most condemn abortion. Strongly religious communities tend to have high birth rates, for example, the Muslim and Roman Catholic communities. High birth rate areas due to religious beliefs include South America and parts of the Middle East. In Zimbabwe, for example, the Johanne Marange Apostolic sect in Manicaland advocates larger families.

Marrying age of woman

Some cultures promote the marrying of girls at an early age. In farming communities and rural areas, 16 years of age is often the marrying age. If a woman has her first child by the age of 18, she has more years in which to produce children, which affects the birth rate.

The importance of a male child

Many cultural groups believe in the importance of a male child with the result that a large family may be produced before this is achieved. Even if a boy is born after three or four girls, two or three may be added in order to ensure the survival of at least one boy (Figure 9.2).

Figure 9.2 In some communities, male children are valued more than female children

Social status

Some communities determine social status by the number of wives and children a man has. In trying to achieve higher social standing, large families are created.

Political influence

Some governments make an effort to encourage a higher population by offering incentives to people with larger families. Again, this tends to increase the birth rate.

Activity 1

1. In groups discuss the topic: '*There are more advantages than disadvantages in having a large family*'.
2. With the help of your teacher, carry out a census in your class on the number and age of children in pupils' families. After gathering this information, show it in table form, and calculate the average family size.
3. Conduct a second census, namely the families of the parents (uncles and aunts) of children in your class. After getting the average family size, compare and then discuss the results.
4. Draw age-sex pyramids (see the example in Activity 2) using this data.
5. As a community worker, what arguments would you advance to convince parents that '*a girl child is as important as a boy child*' so that there is no need to prefer male children to female children?

Factors affecting mortality rates

There has been a general decrease in mortality (also known as death) rates in the world as a result of the following factors:

Improved medical technology

Medical knowledge has resulted in the eradication of the child killing diseases such as polio, whooping cough, measles, diphtheria and tetanus. This has greatly reduced infant mortality rate.

Advances in agriculture and industry

The agricultural developments that have taken place lead to greater food availability and therefore reduced deaths due to malnutrition. The advances in agriculture have also resulted in better diets, plentiful food supplies and therefore better health and higher life expectancy.

Improved health and hygiene

Industrial development brought along the use of soap and other chemicals to improve hygiene of the people and therefore reduce deaths due to poor hygiene.

Educational level

Educated parents are aware of the importance of a balanced diet, immunisation of children, and improved health and hygiene for their children.

Improved working conditions

As a country becomes more advanced technologically, working conditions in factories, mines and on farms improve. These better, healthier work environments lead to a general drop in mortality rates among workers.

Other factors affecting population growth or decline

Immigration and emigration also impact on total populations. People may leave an area, or country, by emigrating. The destination area or country receives them as **immigrants**. We will learn more about this shortly. Mass emigration leads to a decline in population. Massive population declines have resulted in the past from:

- ethnic cleansing and genocide
- famines which have caused people to leave an area
- forced population movements which have been socially engineered by governments.

Population growth in Zimbabwe

The factors affecting population growth have had an effect on population growth in Zimbabwe. After independence, Zimbabwe was one of the world's countries with the highest population growth rates.

Fertility rates in Zimbabwe were close to eight children per woman in the 1960s and this dropped to seven by the 1980s and started falling fast to 5,4 by the early 1990s and to 3,6 by the year 2002. Soon after independence there was greater access to education for girls, effective primary health care was introduced and the status of women improved. The more educated a woman is, the more likely she is to have a smaller family. Women who had no education had on average six children, those with primary education had a fertility rate of four or more children, whereas those with secondary education had a rate of around three children.

Population censuses in Zimbabwe from 1962 to 2012 can shed light on the situation in Zimbabwe (see Table 9.2). The average household size has remained stable between 2002 and 2012 at 4,2 persons per household.

The census results from 2002 and 2012 show a fall in the birth rate and a stable growth rate of 1,1% per annum. This can be attributed to:

- the availability of family planning
- increased education and literacy
- better health facilities
- more employment opportunities for women
- later marriages
- urbanisation
- more income and rising living standards
- increased access to mass media campaigns against large families, for example, Oliver Mtukudzi wrote an anti-natalist (birth) song *'Baba mwana rongai mhuri'*.

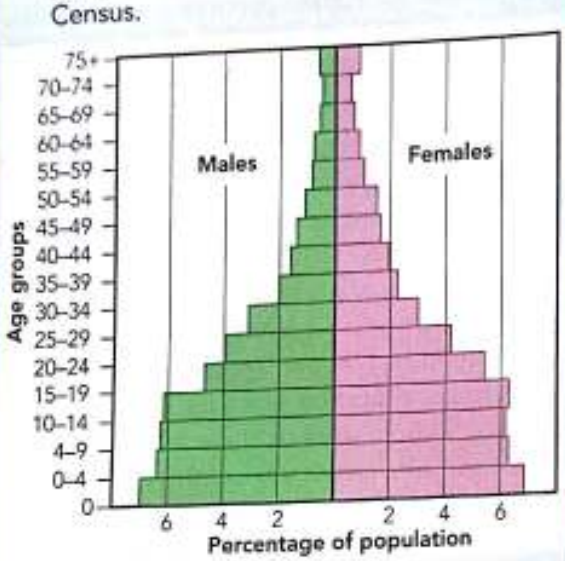
However, the death rate rose from 11 to 17 deaths per 1 000 people from the mid-1990s mainly due to the HIV pandemic.

Table 9.2 Population censuses in Zimbabwe from 1962 to 2002

Year	1962	1969	1982	1992	2002	2012
Population	3 875 470	5 099 340	7 546 071	10 412 548	11 631 657	12 973 808

Activity 2

1. The figure below shows the population pyramid for Zimbabwe from the 2002 Census.



a) Why is this type of graph called a population pyramid?
b) Can you see any pattern with regard to the shape or structure of Zimbabwe's population pyramid?
c) Explain why the population pyramid has this particular shape.
d) This pyramid structure is common for African countries. What issues is Zimbabwe likely to face in the future as a result of its **population structure**?

Causes and effects of migration

We have already seen that migration is the movement of people from one area to another or from one country to another. A person who migrates is known as a migrant. A person who arrives in a country is called an immigrant and a person who leaves a country for another country is called an **emigrant**. The process of people moving into a country is immigration and moving out is emigration. Migration is an important cause of population change (increase or decrease).

Causes of migration

There are two main types of migration: voluntary and forced migration.

Voluntary migrations

These are free movements, which involve choice. The reasons for the movements could be politically, socially or economically motivated. Under voluntary migrations, people could be moving for better jobs, education, better housing or improved health care.

Forced migrations

Forced migrations are the movements of people due to negative factors. People are forced or driven to move so as to survive. The causes include:

- wars
- political conflicts
- natural disasters such as floods, earthquakes, volcanic eruptions and drought
- forced resettlement such as in Apartheid South Africa
- redevelopment processes by governments, for example, Operation restore order in 2005 in Zimbabwe
- slavery.

Activity 3

1. Forced migration is always a sensitive issue. Sometimes, mass killings or persecution, or even genocide go hand in hand with forced migration.
   With the help of your teacher, list and discuss forced migration in post-colonial Africa. This might need some research on your part. The following countries could feature in such a discussion:
   - Rwanda
   - Democratic Republic of the Congo (DRC)
   - Sudan
   - Nigeria.

2. Say whether each of the following examples is voluntary or forced migration:
   a) nomads moving around with their goats and sheep
   b) farmers leaving an area because of drought
   c) Zimbabweans entering South Africa to work
   d) people moving from Syria to Europe because of war
   e) people moving to a different area or country in search of better education (schools) for their children.

Factors affecting population migration

Population migration is driven by **push** and **pull** factors. Push factors drive migration from a place. Pull factors attract migration towards a place.

Push factors

- shortage of employment opportunities
- low wages and salaries
- highly oppressive governments
- poor living conditions
- poor educational facilities
- lack of development in the economy of a country
- natural disasters, such as drought
- war
- racial, tribal or religious discrimination
- high taxes
- poor soils or a shortage of farming land.

Pull factors

- high living standards
- availability of employment or better job prospects
- higher wages and salaries
- good educational health and other social facilities
- favourable climate and, for farmers, more fertile soil
- presence of friends and relatives
- spirit of adventure
- lower taxes
- retirement close to family, or better medical facilities
- marriage.

Figure 9.3 Some push and pull factors which affect population migration

Activity 4

1. Fill in this table about population migration. The headings will guide you.

Main reason for the migration	Push or pull factors involved	Voluntary or forced

2. Why does Figure 9.3 seem to show the distance in light, bright colours, and the foreground in dark colours?
3. Why do we not see the peoples' faces in Figure 9.3?
4. Explain why a number of people are carrying their belongings with them.

Effects of population migration

The effects of migration tend to be similar in spite of the type of migration. The difference is more in the details of the negative or positive effects on both the sending and receiving region.

Effects on the source or sending region

Positive effects are:

- reduced unemployment rates
- reduced pressure on farming land and grazing land
- reduced pressure on educational, health and other social facilities
- reduced birth rate because it is often younger people of reproductive age that migrate
- money sent back to the sending region helps raise living standards
- migrants may return and bring back new skills to help develop the sending area.

Negative effects are:

- loss of able and active young people
- reduced labour force and loss of skilled people
- family breakup and stress if the split up is for lengthy periods
- the elderly, the weak and small children remain behind, which impacts on death rates
- lack of investment in the area, so development slows down or stops
- rural centre and infrastructure decline due to low demand and utilisation
- schools and shops may actually close down.

Effects on the receiving region

Positive effects are:

- gains in young, energetic and skilled labourers
- highly skilled professionals, for example, doctors, are attracted
- availability of willing workforce to train
- a country or area experiences increasing development
- immigrants are a source of demand for services and goods; hence development of ancillary services (multiplier effects) and more investments.

Negative effects are:

- money is sent out of the country or the region
- immigrants may not integrate, resulting in cultural conflicts (for example, the xenophobia experienced in South Africa); tensions may build up with the local people as the migrants might be taking their jobs
- social, cultural and language issues as immigrants may not adapt easily
- immigrants may strain the tax base because they also need services such as health and education
- a strain on resources such as housing, health and educational facilities.

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Activity 5

1. This question is about migration. Link the statement in Column B with the words or statement in Column A. Where more than one answer appears to be correct, choose what you think is the most relevant answer.

Column A	Column B
Xenophobia	many people are attracted by economic opportunities
Genocide	people are forced to emigrate, though they don't really want to leave
Skilled workers leave a country	this happened in countries like the old USSR and China
Country prospers and the economy grows	economically active people have emigrated
Social engineering as the government directs mass migrations within its borders	people are forced to flee or be killed
Less and less tax available to the government	the primary (main) controls acting on emigration and immigration
Famine or drought	people are isolated, or even attacked, because they are foreigners
Push and pull factors	results in a shortage of doctors, engineers and other professional people

2. *'Migration can be both a good, and a bad thing at the same time'*. Discuss this statement.

Further classification of migration

Migrations can be classified as forced or voluntary, or on the basis of push and pull factors. Here are some more ways of classifying migration.

Timeframes for migration

- *Seasonal movements*. For example, people going to pick cotton or seasonal fruits in farming areas. These seasonal movements could also be tourists visiting particular areas during particular seasons.
- *Temporary movements*. As a result of people escaping wars or drought or for political reasons and later returning to their home. Political migrants are also referred to as asylum seekers.
- *Long-term movements*. When people move to other areas or countries to work for more than a year but later return to their country of origin. These migrants could be contract workers.
- *Permanent movements*. Where people move with their families to settle in another area or country forever. Resettlement movement falls into this category.

Distance and direction

- *International migration*. Migration takes many forms and occurs at every level from the local to the world scale. The development of air travel has made international migration easier.
- *Internal migration*. Internal movements can be classified into five groups:
  - *Rural to rural*. In this type of migration, people could move from one rural area to another temporarily or permanently. Temporarily could be people going to pick cotton. People may settle permanently in another area because there are better soils or more land. This also includes the resettlement process.

- *Rural to urban*. This is the most common movement in **developing countries**. In this type of migration people move away from rural areas to cities. Again, it could be short-term, long-term or permanent. Generally, people move away from rural areas because of the poor life quality compared to urban areas where the living standards are thought to be better.
- *Urban to rural*. This type of migration is common in developed countries where people move away from the pollution of the cities to the fresh air and greater space of rural areas. In developing countries like Zimbabwe it is mainly the elderly people who go back home to retire.
- *Urban to urban*. This migration type is also known as inter-urban, whereby people move from one town or city to another for various reasons and for varying durations.
- *Intra-urban*. In intra-urban migration people move from one area to another within the same city or town, for example, from high-density suburbs to low-density residential areas.

Activity 6

1. List one or two examples, including place names, for the following migrations in Zimbabwe:
   a) rural to rural
   b) rural to urban
   c) urban to rural
   d) inter-urban (urban to urban)
   e) intra-urban.
2. Match the statement in Column B with the word or statement in Column A.

Column A	Column B
international migration	temporary migration
picking fruit during harvesting	educational opportunity so temporary migration
offered a job in another area for two years	migration to a city
flooding of an area	seasonal migration
go to South Africa to complete a higher degree	contract worker
work on farms is very scarce	probably emigrating permanently

Population policy

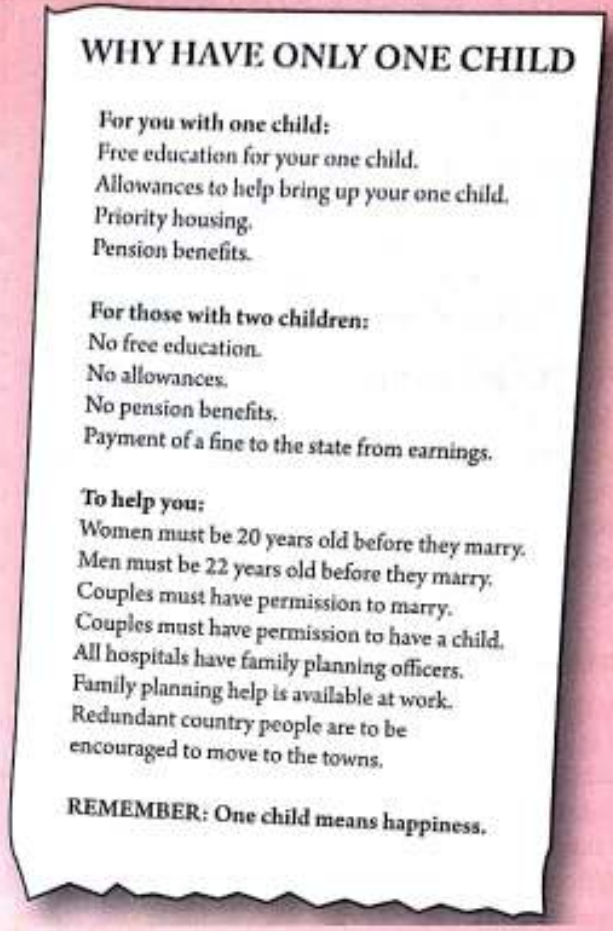
Population policy has to do with the government's attitude towards, and controls on population. Economic considerations are important. If a government is concerned about **overpopulation**, it will try to control population increases (family planning, curbs on immigration). There have been cases where governments have been concerned about underpopulation. Here, efforts to raise the birth rate, and to encourage immigration may be put in place. We will look at this in more detail below.

Case study: Family planning in China

The population of China was 300 million in 1962 and by 1969 it had grown to 800 million people. By 1979 the population had grown to about 970 million, putting a strain on the economy as more services were needed for the people. The average family had three children, resulting in very rapid population growth. The state, or government, decided to act. It did this in two ways:

- it raised the status of women in society by encouraging education and employment rather than staying at home and bearing children
- it introduced the one-child policy (see Figure 9.4).

By 1995, the birth rate in China had declined from 33 per thousand to 17 per thousand, and the natural growth rate from 26 per thousand to 11 per thousand.



WHY HAVE ONLY ONE CHILD

For you with one child:
Free education for your one child.
Allowances to help bring up your one child.
Priority housing.
Pension benefits.

For those with two children:
No free education.
No allowances.
No pension benefits.
Payment of a fine to the state from earnings.

To help you:
Women must be 20 years old before they marry.
Men must be 22 years old before they marry.
Couples must have permission to marry.
Couples must have permission to have a child.
All hospitals have family planning officers.
Family planning help is available at work.
Redundant country people are to be encouraged to move to the towns.

REMEMBER: One child means happiness.

Figure 9.4 China's measures for family planning (newspaper articles)

Population policies in developing and developed countries; limiting or promoting population growth

One of the basic concepts when dealing with human needs is supply and demand. People rely on the Earth's resources to survive. While the world's population increases, resources remain the same. The result is population pressure. This relates population size and density to available natural resources. The resources include soils, climate, mineral deposits, farmland, and water and energy supplies.

Many governments have population policies in place to try and balance supply and demand. If a population continues to grow while resources remain the same, the standard of living will drop. This simply means the population will become poorer.

Developing and developed countries experience different problems around population growth. While developing countries are trying to curb or control population growth because of limited resources, some developed countries are worried about declining or negative growth. This is because there will be a shortage of workers entering the labour market in the future. Also, declining populations mean reduced buying power in developed economies, resulting in an economy that does not grow.

Overpopulation

Overpopulation occurs when there are more people than the developed or potential resources. Overpopulation may result from an increase in population or a decline in resources. There is no

simple measure of overpopulation but it is usually identified by such things as low per capita income, low and declining living standard, high levels of unemployment, famine, malnutrition and diseases. It also shows itself through overgrazing, shortage of land and deforestation, among many environmental symptoms. Examples of overpopulation often given, though these are not permanent situations, would include Ethiopia, India, Somalia and Bangladesh.

Underpopulation

Underpopulation exists in an area where the population is too small to fully utilise the available resources. It could also be a situation where the resources could support a larger population with no reduction in the living standard. Canada is an example.

Optimum population

This is the ideal situation whereby the population can exploit the resources and provide the highest standard of living and quality of life. If the population decreases or increases from this level, the standard of living will fall. This population is difficult to measure and so no country can be offered as an example.

Population and diseases

In the past, disease played a major role in limiting population growth. A few hundred years ago, the two big killers were famine, and epidemics. Advances in medicine, and in particular vaccination, have almost rid the world of many killer diseases. These include smallpox and polio.

Population and health

Demographers are also concerned with people as a resource. If people are well and healthy they can contribute to the economy, and the development of the area in which they live and work.

Health problems

Most people, especially in the tropical developing countries, are at risk from a variety of diseases, in addition to hunger. Ill people cannot work on the land or in factories, so there is little development. It has been noted that a third of the world's population is ill and that the majority of these are in developing countries and a large proportion are children, who are the future workers. Most national budgets are taken up by the provision of health care to sick people and this does not bring about development. The major diseases affecting the developing world, including Zimbabwe are:

- malaria
- cholera
- HIV and AIDS.

Kwashiokor is a condition of malnourishment, rather than a disease. Other tropical diseases include bilharzia and sleeping sickness. Let us look at them in more detail:

- *Malaria*. It is caused by the female anopheles mosquito that transmits parasites from infected persons to healthy ones. Malaria kills both children and adults and makes adults weak and unable to work.
- *Kwashiorkor (Pellagra)*. It is caused by poor nutrition and affects mainly infants and young children in poor and undeveloped tropical and subtropical regions. A large number of children are dying from this disease and it is one disease that has maintained a high infant mortality rate in Africa. The disease can be controlled by feeding affected children with milk and high-protein food.
- *Sleeping sickness*. This is caused by the tsetse fly that carries a parasite called a *trypanosome*. The disease results in people becoming weak and unproductive. Since the parasite also attacks animals, people cannot keep cattle, so there is no draught power for ploughing, leading to hunger and other diseases.
- *Bilharzia*. This is caused by water snails that carry *bilharzia schistosoma*. The disease attacks the kidneys, eyes and brain. A lot of people die from this disease and people suffering from it cannot work. It is common among poor farmers and fishermen who have to work frequently in polluted water. The disease can be tackled through education by

informing people about the importance of sanitary conditions.

- *Cholera*. It is a highly infectious disease that can spread rapidly, especially in conditions where sanitation and water supplies are very poor. If untreated it kills through severe dehydration. Nearly 60% of its victims die within two to six days. The disease is common in South East Asia, Africa and some parts of the tropical world.

HIV/AIDS pandemic and its effects

The Human Immunodeficiency Virus (HIV) that causes Acquired Immunodeficiency Syndrome (AIDS) has played havoc on people, especially in Africa, which has the highest rate of infection. The results of the HIV or AIDS pandemic include:

Demographic effects

The active age group that is between 15 and 65 has been the most affected. Within this group girls and women have high rates of infection. The overall life expectancy has declined to below 40 in most SADC countries. Unborn and newborn babies can be infected through mother to child transmission and breastfeeding, respectively.

Social effects

These include frequent bereavements, increase in orphans as both parents die of HIV/AIDS and increased numbers of households headed by children and the elderly.

Economic effects

More money is spent on the provision of treatment and care of HIV-infected people and on funerals. A lot of time is lost due to absenteeism caused by illness or due to having to care for the infected, with the result that productive work is slowed down. Since the active age group is most affected, it has meant that some families have lost breadwinners. All sectors of the economy have felt the negative effects of HIV/AIDS.

Diseases of developed countries

Apart from HIV/AIDS, most developed countries have to deal with illnesses and diseases related to unhealthy lifestyles and what is called excessive consumption. These include:

- various cancers (the link between smoking and lung cancer has been medically proven)
- diabetes
- obesity (being very overweight)
- heart disease and circulatory diseases.

With the free movement of people between many parts of the world, disease control is important. This is why many countries, especially developed countries, insist on vaccination against various diseases for travellers arriving from developing countries.

How countries are responding to health problems

Many diseases affect mostly the poor who depend on agriculture, cannot afford medical care and who are often located in very remote parts of the world. Many diseases, such as those caused by malnourishment, or by parasites such as bilharzia and malaria are debilitating. The diseases weaken the people, resulting in, for example, low agricultural production. This in turn can lead to famine and starvation, further exposing the people to more attacks by other diseases in a vicious cycle that repeats itself. The poor thus remain poor.

Many diseases are caused by poor sanitary conditions. The major victims are children, hence the need for governments to promote primary health care. Governments should offer people safe water supplies, educate them on basic sanitation, ways of preventing and controlling common diseases and immunisation of children against the major child killer diseases.

The Zimbabwean government has made great strides in promoting primary health care with the introduction of village health workers, health service centres, district hospitals and the national referral centres in the major cities. The system has worked very well despite the challenges that have faced Zimbabwe.

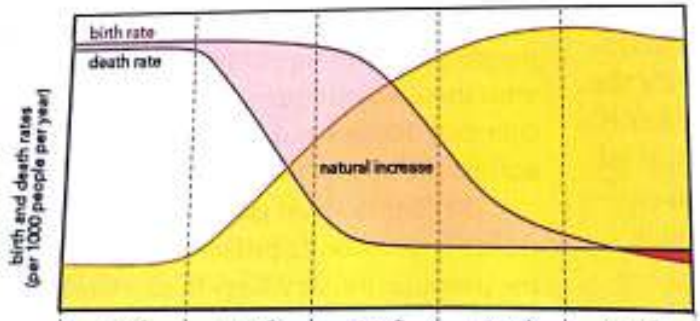
Activity 7

1. Name three killer diseases that are no longer a threat to the world's population.
2. Explain why these diseases are no longer feared.
3. What is meant by the HIV/AIDS pandemic?
4. What are some of the effects or results of this pandemic for countries such as Zimbabwe, South Africa, Botswana and Swaziland?
5. Explain why the diseases that affect people in developing countries are different from those affecting people in developed countries.
6. Look at the following diseases and tick the box that best *describes* the disease.

Disease	No longer a global threat	Disease of developing countries	Disease of the wealthy	Disease of rich and poor	Result of poor sanitation
bilharzia					
smallpox					
malaria					
cholera					
tuberculosis (TB)					
HIV/AIDS					
obesity					
diabetes					
kwashiorkor					

The demographic transition model (DTM)

Interesting trends have been identified from studies of birth and death rates over time in developed countries. There seems to be a pattern in the population change, also known as demographic change. It shows relationships between population growth and economic development. A model was then created, based on the situation in Europe, to illustrate these population changes, termed the demographic transition graph or cycle. The demographic transition graph has five stages (Figure 9.5).



	stage 1	stage 2	stage 3	stage 4	stage 5
birth rate	high	high	falling	low	very low
death rate	high	falls rapidly	falls more slowly	low	low
natural increase	stable or slow	very rapid	slows down	stable or slow	stable or a slow decrease

Figure 9.5 The demographic transition model (DTM)

The **demographic transition model (DTM)** shows the relationship between births, deaths and general population growth as governed by the stage of economic development of a country. The graph can be used to determine where a country is and the possible future changes to its population. Not all countries will go through all five stages:

- Few countries are in Stage 1, where population growth is very low due to high birth and death rates. This represents a poor population, with a subsistence economy in which famine and natural disasters occur often.
- Most developing countries, including most African countries, are in Stage 2. The countries are experiencing a drop in death rate due to improved food and health facilities. Birth rates are still high due to social, cultural and economic factors explained above. The 2002 census results show that Zimbabwe could be moving out of Stage 2 towards Stage 3.
- Many recently developed countries are in Stage 3. In this stage the birth rate begins to fall fast due to improved standards of living.
- Stage 4 is represented by the developed countries of Europe and North America. The birth rate, as well as the death rate, is low.
- There are very few countries in Stage 5. Here, the population is actually decreasing. Japan, where both birth and death rates are very low, is an example.

Activity 8

1. In Stage 3 of the DTM graph, there is a sharp drop in birth rate. Suggest six reasons for this sharp drop.
2. Do some research and find out in which stage of the DTM is each of the countries listed below:
   a) The United States of America
   b) Russia
   c) Democratic Republic of the Congo
   e) South Africa
   f) Lesotho
   g) New Zealand
   h) Thailand
   i) China
   j) Japan.
3. Think about where you live in Zimbabwe. Which stage of the DTM applies to your town, area or district? As you are unlikely to have data on birth and death rates available, you can only really discuss the question in class, and try to reach agreement on a possible answer.
4. If you apply the DTM model to a city, and to a rural area, which is likely to be in a higher stage? Explain your answer.
5. Does migration play a role in the DTM (yes or no)? Now, explain your answer, bearing in mind what the DTM is designed to show.

Effects of population growth/ decline

Depending on which stage of the DTM a country is in, it could experience population growth or decline.

Population growth

The world's population has been growing rapidly. In January 1982 the population of the world was 4,5 billion people and in July 1987 the world population stood at 5 billion people. By the year 2000, the world population was about 6,1 billion people.

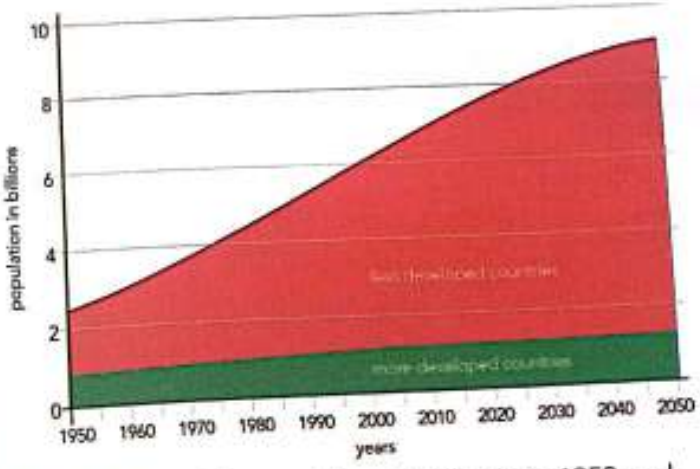


Figure 9.6 World population growth since 1950 and projected to 2050

More people means more food, accommodation, jobs, education, health facilities, transport, water and other resources for their well-being. As the world's population grows, accessing resources and basic services, especially in poor countries, becomes more and more difficult. The world's population was 5 million in 10 000 BC while today it is 7 billion. This rate of population growth is a cause for concern. Population growth impacts on available resources and the environment comes under pressure. When the population exceeds the available resources, overpopulation is the result. In Zimbabwe, population growth has accelerated. Since the census of 1962, the population in the country has been increasing rapidly (Table 9.2).

In southern Africa, the population growth rate has averaged three per cent per year. This growth rate creates problems when the population exceeds the country's ability to meet people's basic needs. Table 9.3 shows the populations of countries in southern Africa for 2011 and projected for 2025.

Table 9.3 Population growth in southern Africa

Country	Population (millions) 2011	Population (millions) 2025
Angola	19,6	24,7
Botswana	2,0	3,4
Lesotho	2,2	4,4
Malawi	15,4	24,7
Mozambique	23,9	35,4
Namibia	2,3	4,7
South Africa	50,5	65,7
Swaziland	1,2	2,2
Tanzania	46,2	84,9
Zambia	13,5	26,3
Zimbabwe	12,8	22,6
Total	189,6	298,7

Population decline

Declining populations are a feature of late Stage 4 and Stage 5 countries in the DTM. Populations may decline through emigration, and war or famine, but we are looking here at population decline as a result of a very low birth rate. Examples include Ukraine, Russia, Belarus, Hungary and Greece. All these countries are in Europe. The other notable example is Japan. In an overpopulated world, population decline might seem like a good thing, but it is not. Here are the results:

- *Labour shortage*. As populations decline in a region, there are fewer and fewer people in the workforce. The working-age population in Japan has been steadily decreasing since 1995. Japan's economy has been contracting ever since. If industries can't recruit workers, they will be unable to meet levels of output necessary to stay in business.
- *Well-being of the population*. Economic downturns caused by population decline can affect the general well-being of the population. Economic recession means more depression and even psychological problems, such as feelings of helplessness and hopelessness.
- *Competition*. When a country suffers from depopulation, it loses its advantage over other states and regions with regard to competing for export markets.
- *Rural-urban imbalance*. A declining population can lead to imbalances between urban and rural populations. Whether it is the cities, or the rural areas that lose people, the resulting imbalance is not a good thing.
- *Disproportionate ageing*. This is a very big issue. Populations become older (the average age increases) when there is a decline in population. This puts all sorts of pressures on society. Instead of investing in a younger generation, who will be economically active, the government must spend resources on old people. Investing in old-age care rather than schools is not a good thing for the economy of a country.

Activity 9

1. In groups, discuss the following scenario. Suppose there are 40 students per class in your school this term and 20 students are added to each class next term.
   List the problems that would result from this increase in the numbers of students, in relation to the following:
   a) space in the classrooms
   b) exercise books
   c) textbooks
   d) books to be marked by the teachers
   e) space in the school grounds
   f) library space
   g) sports equipment
   h) other problems.
2. Now, take each of the above, and think of an analogy in terms of population growth in the world. For example, space in the classroom = shortage of houses. You can ask your teacher to guide you with this task.

What can be done to reduce population growth?

The population growth rate can be reduced. This requires a reduction in the birth rate, which can be done in many ways:

- *Family planning*. Birth control can be effective in reducing the birth rate. This is done through educating people (both married and unmarried) about the advantages of smaller families. A small family means enough food for all the family members. Women can also concentrate on their careers when they do not spend so much time bearing children. Fewer children also means fewer health problems for women. In Zimbabwe, the Zimbabwe National Family Planning Council is the organisation that promotes family planning. China is one country that has used family planning to control population growth.
- *Educating people*. More schools and other education schemes should be introduced to promote literacy. This will enable people to read and understand information about population control. The Ministry of Education, Sports, Arts and Culture and the Ministry of Health and Child Welfare in Zimbabwe have been involved in education campaigns about population control in rural areas. In general, access to and ownership of resources such as land, forests, water, minerals and wildlife can help to reduce population growth. As people's income and well-being improve, they reduce the need for children as helpers.
- *Develop rural centres*. In Zimbabwe, industries have been introduced at growth points and rural electrification has been undertaken. This is so that more people use radios and televisions through which they get information to improve themselves and also to learn more about birth control.

Activity 10

1. Which of these will lead to a reduction in the population growth rate, and which will probably not?
   a) improved standards of education and literacy
   b) improved communication via radio and TV
   c) free housing
   d) family planning.
2. Debate the following: '*Poverty reduction is directly related to population control*'. Divide into teams to argue for and against this topic. Your teacher will assist you with the formal rules of a debate.

Summary

- The factors which influence population growth have been studied by geographers, statisticians and planners, and are generally well understood.
- These factors include changes to birth and death rates. In general, birth rates have risen, while death rates have dropped.
- Migration is the movement of people from one area or region to another, or from the rural areas to the urban areas, or even from one country to another.
- Emigrants leave an area or place, immigrants arrive at a place or area.
- Migration may be forced or voluntary, and is driven by many different factors.
- Economic migration (seeking a better future) is a powerful driver of migration.
- Many states or governments have population policies in place to control both population growth as well as migration.
- Disease has a big influence on population distributions, birth and death rates, and even on migration.
- The diseases that affect developing countries and poorer nations are not always the same as those which affect developed countries and richer nations.
- The demographic transition model (DTM) is a useful way of looking at and explaining population changes as a country develops.
- Each country moves through a number of stages, From Stage 1 to (in time) Stage 5. Birth and death rates change as a country moves through the stages.
- Populations grow and decline, and both these bring about positive, as well as negative changes for the country as a whole.

Glossary

crude birth rate (CBR) – is the number of babies born in a year per 1 000 people in the population

demographic transition model (DMT) – a model for explaining population change (growth and decline) over time

emigrant – person who leaves an area or country

fertility rate – ability of a population to produce babies

immigrant – person who moves into an area or a country

infant mortality rate (IMR) – death rate amongst young children

migration – a movement that involves a change of home and crossing of some administrative boundaries on a temporary or more permanent basis

mortality rate or crude death rate (CDR) – is the number of deaths in a population in a year; can be measured in several ways, including the crude death rate (CDR) and the infant mortality rate (IMR).

overpopulation – an excess of population over resources

population – the total number of people living in a place

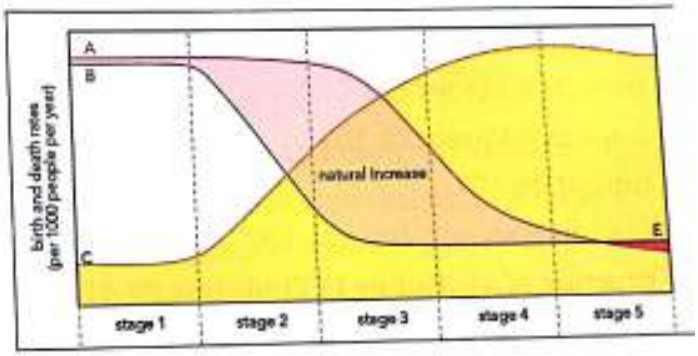
population structure – the age-sex distribution usually shown by means of an population or age-sex pyramid

pull factor – a factor that attracts people

push factor – a factor that causes people to leave an area

Topic test 9

1. Natural population increase is:
   A the birth rate minus the death rate
   B the death rate minus the birth rate
   C the fertility rate minus the growth rate
   D the life expectancy minus the death rate.
2. The birth rate of a country such as Zimbabwe can be reduced through:
   A encouraging early marriages
   B family planning programmes
   C allowing men to marry more than one wife
   D giving people more wages or salaries.
3. a) Explain the following terms:
      i) birth rate
      ii) death rate
      iii) life expectancy
      iv) age-sex pyramid
      v) internal migration
      vi) international/external migration
      vii) overpopulation.
   b) What are the problems that result from a rapid growth of population?
   c) Suppose you are a population planning officer. What reasons would you give to people in rural and urban areas of Zimbabwe for the need to plan their families?
4. Give the correct term for the following:
   a) Migration that people choose to do, without being forced to migrate.
   b) People who leave their country to move to another.
   c) People who are forced to leave their homes for fear of some kind of harm.
   d) Migration from one part of the country to another part of the same country.
5. Give three negative impacts of a rapid rise in population in a developing country.
6. Which of these are diseases of developed countries, and which are disease of developing countries:
   a) malaria
   b) obesity
   c) chronic heart disease
   d) kwashiorkor
   e) cholera
   f) bilharzia.
7. Explain why HIV/AIDS can be regarded a disease of both developed and developing nations.
8. Look at the diagram, and answer the questions that follow:



   a) Give the diagram a heading.
   b) Label A, B, C, D and E.
   c) Explain what the Stages represent.
   d) Explain what is happening to population over time in terms of this model.