
BILL DODD | MICK LAW | IAIN MEYER | PHIL O'BRIEN
JACARANDA
SENIOR GEOGRAPHY 2
FOR QUEENSLAND
UNITS 3 & 4 | FOURTH EDITION
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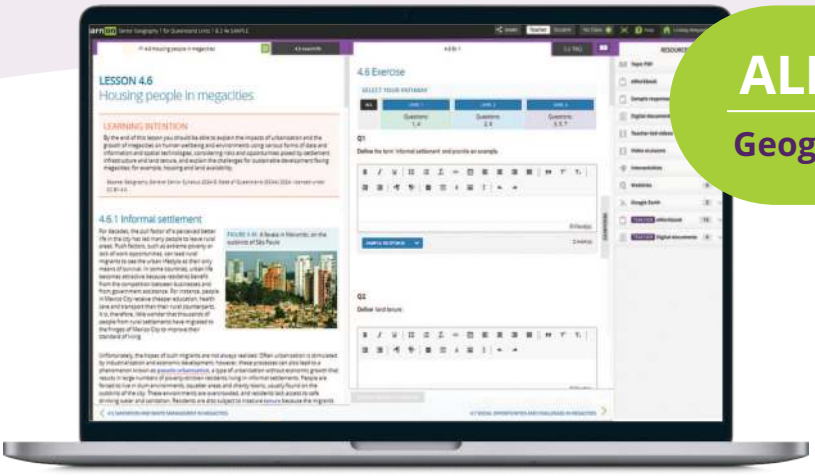
It is strongly recommended that teachers examine resources on topics related to Aboriginal and/or Torres Strait Islander Cultures and Peoples to assess their suitability for their own specific class and school context. It is also recommended that teachers know and follow the guidelines laid down by the relevant educational authorities and local Elders or community advisors regarding content about all First Nations Peoples.

All activities in this resource have been written with the safety of both teacher and student in mind. Some, however, involve physical activity or the use of equipment or tools. **All due care should be taken when performing such activities.** To the maximum extent permitted by law, the author and publisher disclaim all responsibility and liability for any injury or loss that may be sustained when completing activities described in this resource.

The publisher acknowledges ongoing discussions related to gender-based population data. At the time of publishing, there was insufficient data available to allow for the meaningful analysis of trends and patterns to broaden our discussion of demographics beyond male and female gender identification.

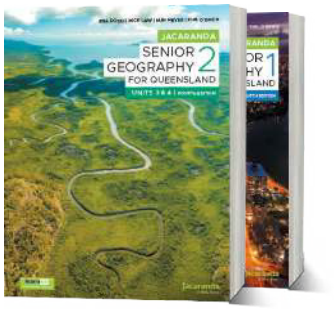
Contents

About this resource



ALIGNED TO THE QCAA

Geography Senior Syllabus 2025 v1.0



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FOR QUEENSLAND | UNITS 3 & 4 FOURTH EDITION

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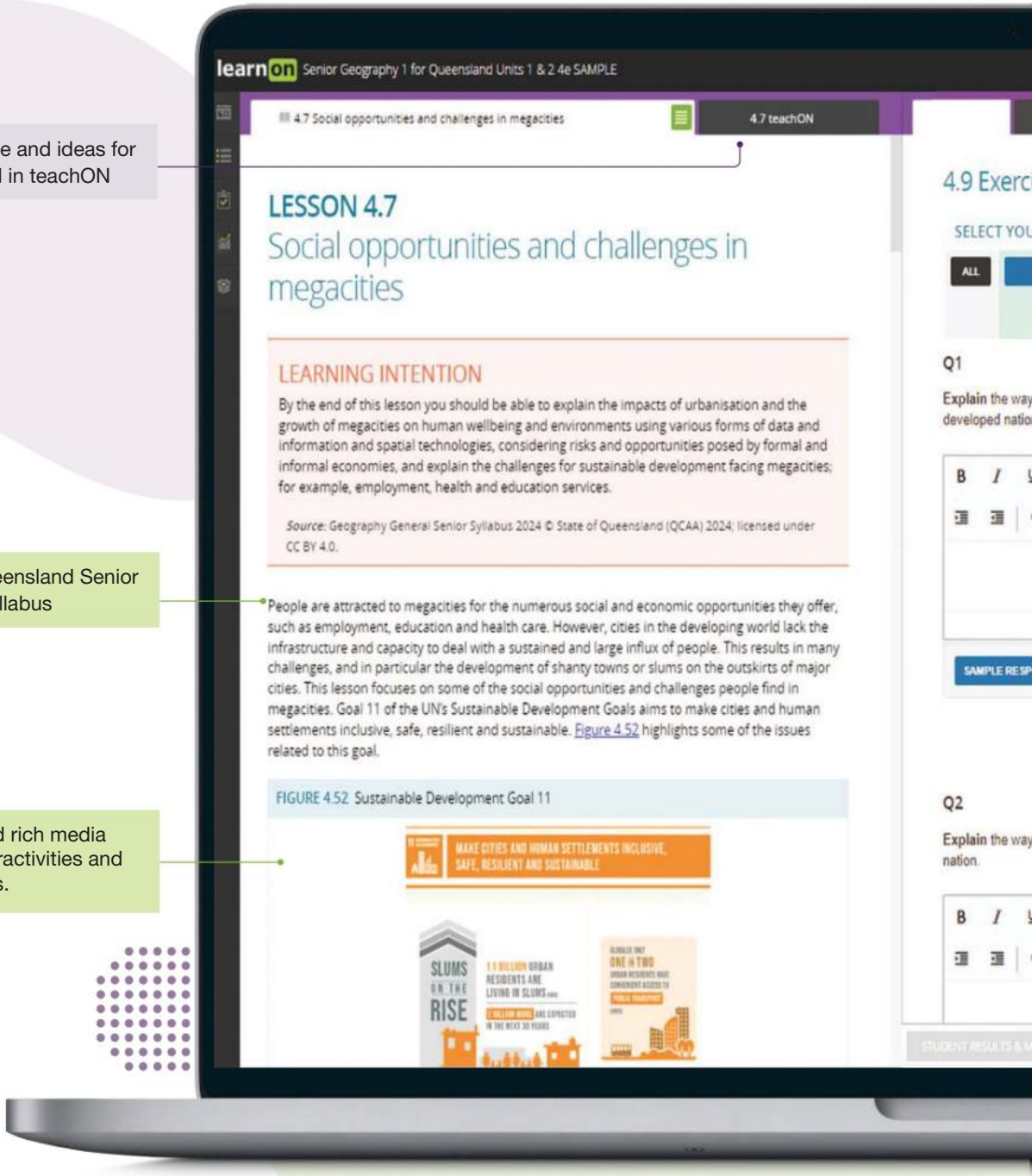
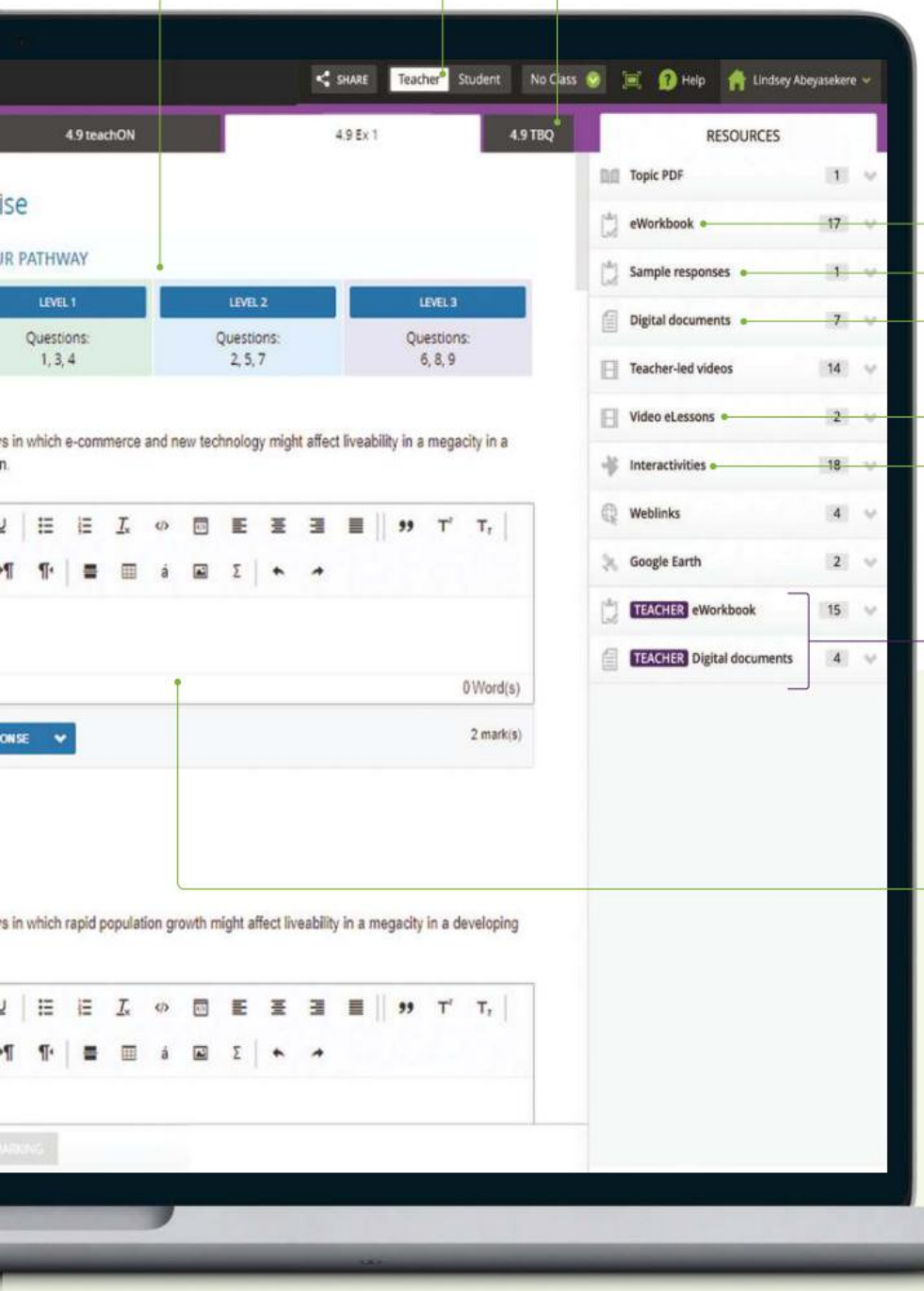


powerful learning tool, learnON



Differentiated question sets

Teacher and student views

Textbook questions

eWorkbook

Answers and sample responses

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Interactivities

Enhanced teaching support resources

Interactive questions with immediate feedback

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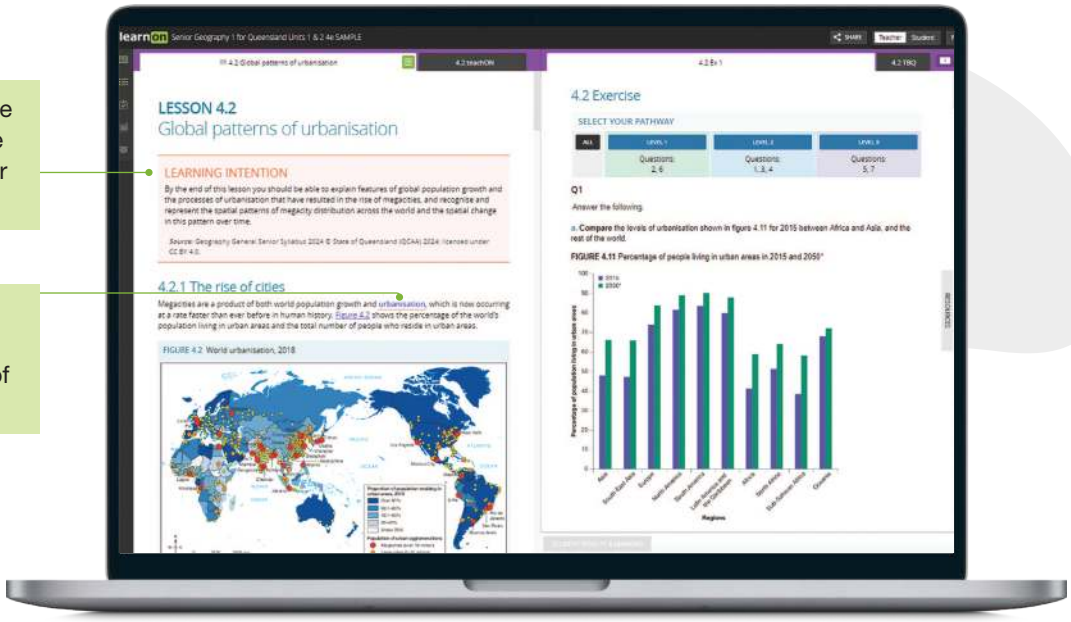
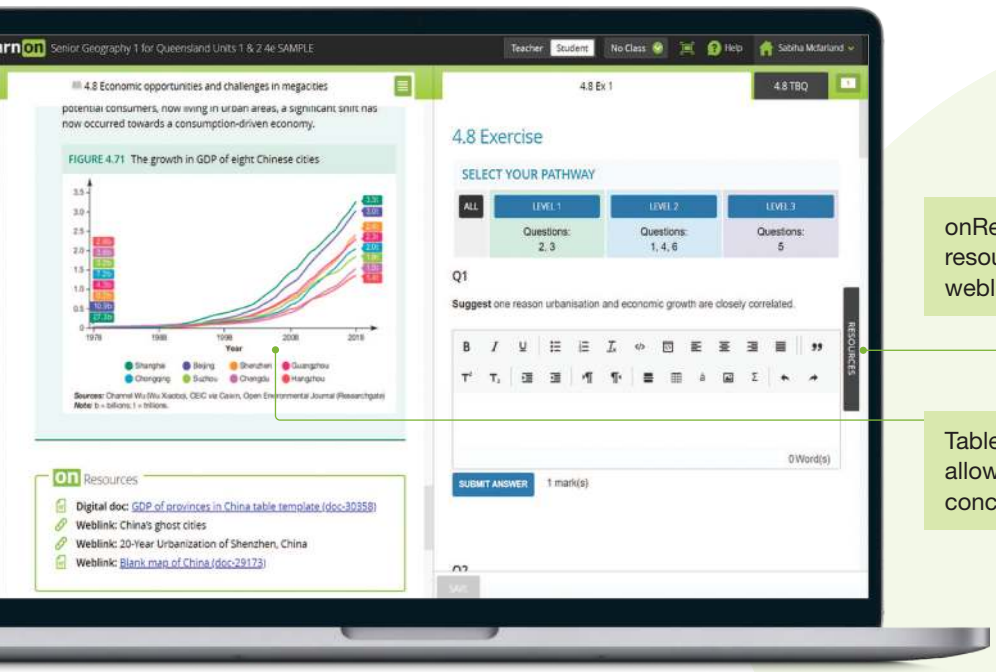
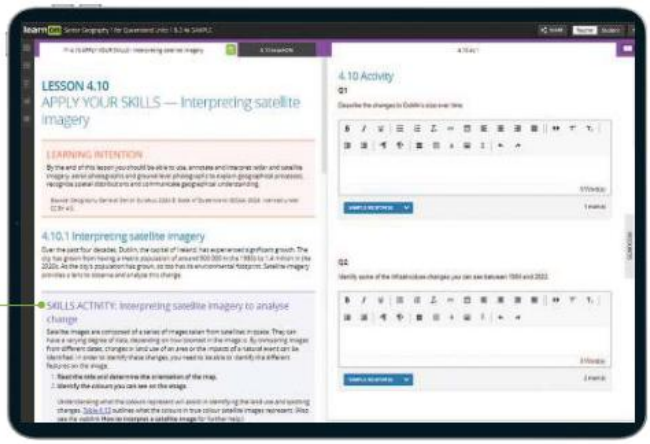


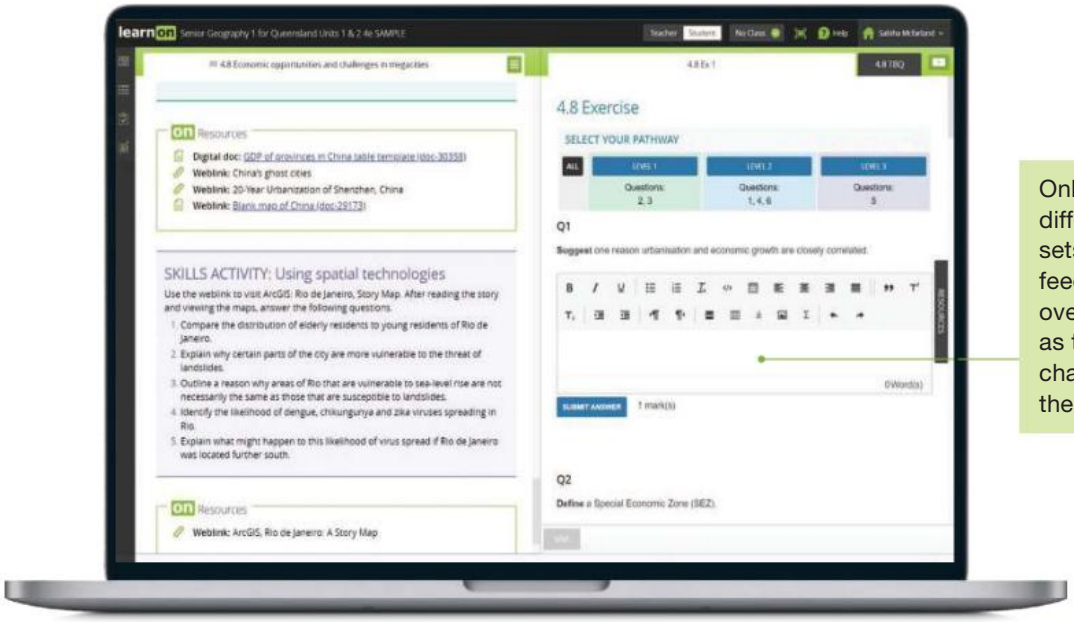


onResources link to targeted digital resources including video eLessons and weblinks.

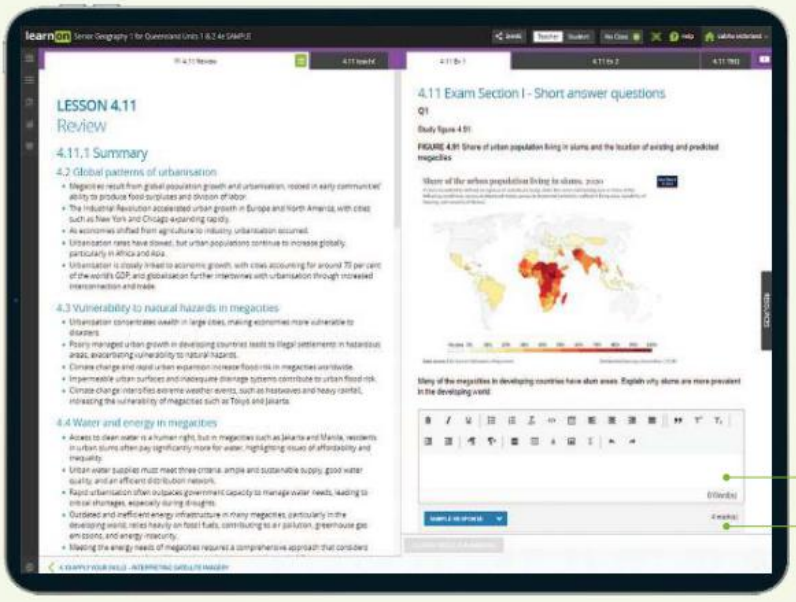
Tables and images break down content, allowing students to understand complex concepts.



Skills activity lessons to develop geographical skills and understanding



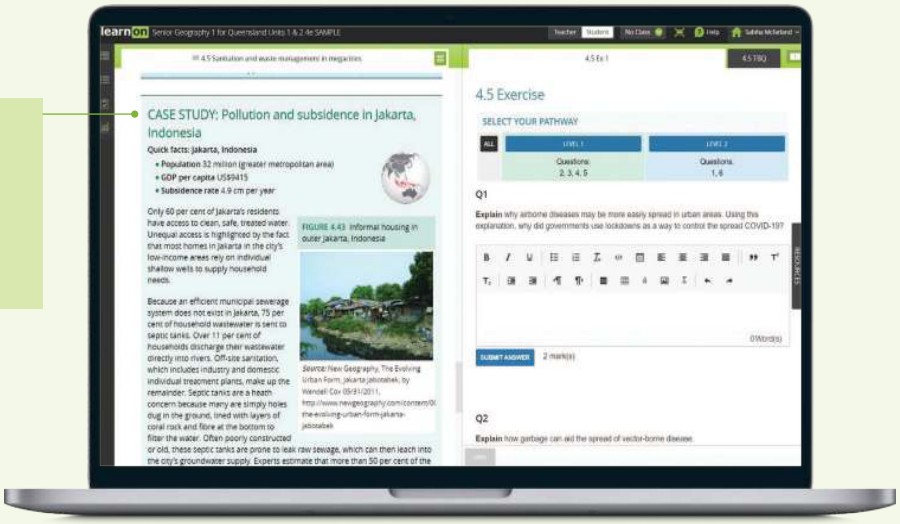
Online and offline differentiated question sets, with immediate feedback, help students to overcome misconceptions as they occur and to challenge themselves at their own level.



Online and offline exam questions with immediate feedback are available in each subtopic.

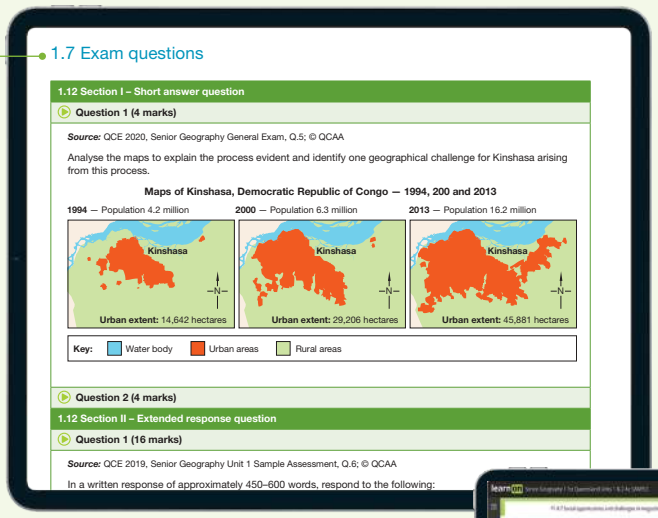
Case studies

Case studies to develop students' understanding of geographical processes and concepts.

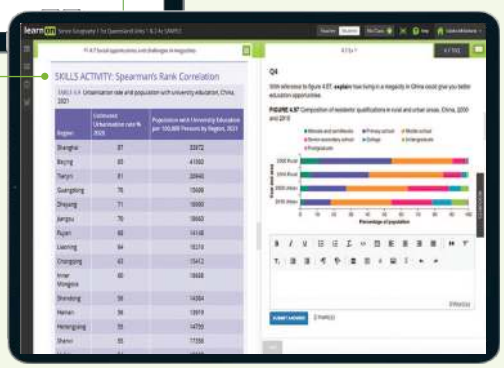


Skill development

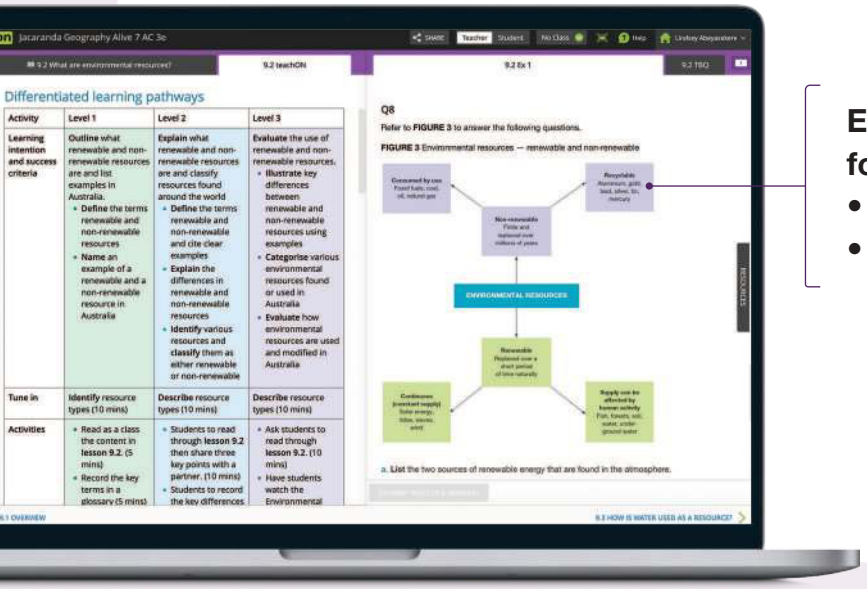
Topic-level differentiated question sets and exam questions, with digital sample responses for immediate feedback



Skills activities to develop specific geographical skills and understanding



A wealth of teacher resources



Enhanced teaching-support resources for every lesson, including:

- work programs and curriculum grids
- practical teaching advice

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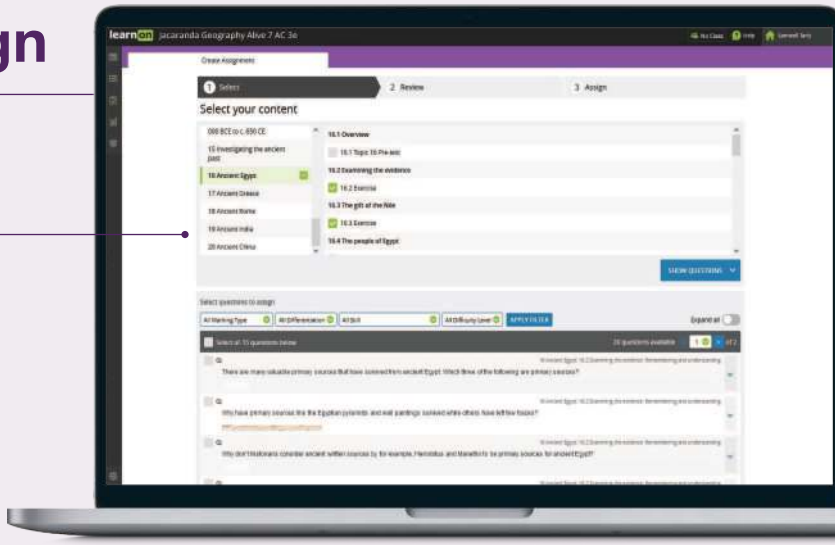
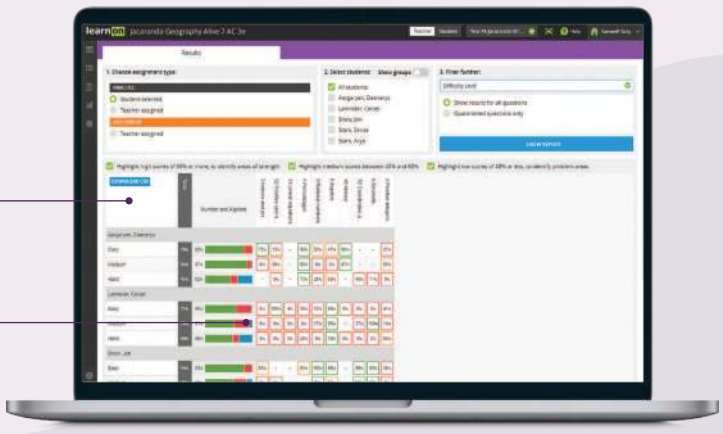
An inbuilt testmaker enables you to create custom assignments and tests from the complete bank of thousands of questions for immediate, spaced and mixed practice.



Reports and results

Data analytics and instant reports provide data-driven insights into progress and performance within each lesson and across the entire course.

Show students (and their parents or carers) their own assessment data in fine detail. You can filter their results to identify areas of strength and weakness.



Meet our author team

Bill Dodd

Bill Dodd is a highly experienced and enthusiastic geography teacher with an extensive background in text writing and field studies. Although having been a HOD and former state panelist, his prime passion is delivering engaging lessons in the classroom and providing stimulating outdoor experiences to inspire future custodians of our beautiful planet. He believes there has never been a more urgent time for students to have a knowledge and appreciation of their world and its geography.

Dr Philip O'Brien

Dr Philip O'Brien is an experienced Secondary school teacher who has taught Geography at all levels in the United Kingdom and Queensland including Brisbane Boys' College. Philip has Masters' degrees from University of Queensland and Griffith University and a PhD from Griffith University. He has been involved in writing all editions of Jacaranda's Senior Geography textbooks and has written textbooks for Western Australian and Victorian Geography syllabuses. He has also written a number of articles for 'Geography Review', a magazine designed for A-level students in the United Kingdom.

Mick Law

Mick Law is a dedicated geographer and educator with over 15 years of experience in geospatial education in schools. He has developed school programs, led ESRI Australia's GIS in-schools initiative, and founded Contour Education, a geospatial consultancy. Mick has worked with Queensland's Department of Natural Resources, Mines and Energy to promote geospatial technologies in education. He is active in the industry, formerly on the GTAQ Executive and journal editor, and now chairs the Destination Spatial Queensland Executive.

Iain Meyer

Iain Meyer is a veteran geography educator with over 40 years of experience in the UK and Australia, including as Head of Geography at Melbourne Grammar School. A London University graduate, he has co-authored senior geography textbooks and contributed regularly to Geography Review. Iain has been Chief Examiner for the Oxford and Cambridge Board, a QCAA panel member, and was awarded a BP Education Fellowship at Oxford. He remains passionate about geography and is currently focused on applying visible thinking strategies inspired by Harvard's Project Zero.

Lessa Gore-Brown

Lessa Gore-Brown is an experienced educator with a background in field studies and a passion for Geography. She has taught across UK, Australian, and IB exam boards, covering a wide variety of Geography topics and syllabi. For the past seven years, she has been teaching in Queensland schools. Lessa is keen on using innovative methods such as GIS and drones in teaching and fieldwork. She has held curriculum leadership roles, developed educational resources, and has experience in script marking and assessment moderation. She has most recently been involved in updating the Senior Geography resources in line with the revised QCAA syllabus.

Nicole Gray

Nicole is a dedicated Deputy Principal and passionate advocate for human-centred education. With decades of diverse experience as a teacher and curriculum leader, she brings deep insight and empathy to her work. A valued Jacaranda author across multiple Geography titles, Nicole is committed to developing inclusive solutions where every voice is heard and respected.

Acknowledgements

The authors and publisher would like to thank the following copyright holders, organisations and individuals for their assistance and for permission to reproduce copyright material in this book.

The full list of acknowledgements can be found here:

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1 Land cover transformations and climate change

UNIT 1 TOPIC 1

SUBJECT MATTER

In chapter 1, students:

- **recognise** the spatial distribution of the different types of land cover, including global, regional and local forests, wetlands, ice, croplands, rangelands and urban land use
- **explain** the interconnection between the Earth's physical systems and how changes in land use, such as deforestation, land drainage, land reclamation, resource extraction, intensification of agriculture and pastoralism, coastal modification, and soil and water degradation can interrupt these systems and result in land cover transformation at global, regional and local scales
- **recognise** the spatial patterns of land cover change at a variety of scales, using remotely sensed images and aerial photographs
- **explain** how selected factors, such as world population growth, growing affluence and advances in technology, have had an impact on the rate and extent of land cover change at a variety of scales
- **explain** the concept of anthropogenic biomes
- **explain**, using conceptual models, the key processes and relationships associated with global climatic systems
- **explain**, using evidence, how anthropogenic activity (such as changes in land use) may be influencing climate change
- **explain** the interconnections between land cover change and climate change
- **analyse** data to interpret indicators of climate change and generalise about the current and future implications for people and environments.

Students must conduct a case study to:

- investigate the effects of climate change on a specific type of land cover (e.g. vegetation, ice sheets and glaciers, coral reefs) at a regional or local scale of study.

LESSON SEQUENCE

Fully worked solutions for this chapter are available in the Resources section at www.jacplus.com.au.

LESSON
1.1 Overview

Hey students! Bring these pages to life online


Watch videos


Engage with interactivities


Answer questions and check results

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1.1.1 Introduction

As the Earth's population continues to grow, there has never been a more demanding time for governments and communities to provide food, water and shelter for so many. With a global population now exceeding 8 billion and increasing by 80 million per year, demand for living space and basic **resources** has probably reached an optimum level. However, the pressure to provide these essential needs, as well as supply industrial and technological goods, and energy and infrastructure comes with a price tag. This cost is an escalation in the level and intensity of exploitation of the Earth's existing land, water and mineral resources, but these resources are finite.

resources sources from which some benefit is produced (e.g. wood, minerals, water)

Over-exploitation of resources, regional conflicts and pandemics have severely disrupted global trade as well as goods and food supply chains. At the same time, many areas are confronted with the threat of climate change, now seen as responsible for destructive weather events, heat waves, catastrophic wildfires, record glacial melts, and inundation of coastal wetlands and low-lying islands.

The challenge for present and future generations is to create an acceptable balance between demand and sustainable supply.

However, the following situation prevails:

- habitable land cover for growing food, living space and resource extraction is regarded as finite, and the extensive use of land for agriculture has a major impact on the Earth's wilderness and biodiversity
- scientists estimate around 30 per cent of land cover has been altered in the last 50 years, and up to 17 per cent changed more than once. Some experts have used satellite evidence to confirm areas where land use change has been up to four times greater than previously thought.

FIGURE 1.1 Climate change makes extreme weather events such as floods more likely.

This topic explains some of the physical and human geographical processes that have resulted in changes to surface land areas, and the subsequent spatial and temporal patterns evident today. It will also examine how these changes may be linked to climate change, and the implications for present and future generations.

1.1.2 Syllabus links

Syllabus links	Lesson
Recognise the spatial distribution of the different types of land cover, including global, regional and local forests, wetlands, ice, croplands, rangelands and urban land use.	**1.2**
Explain the interconnection between the Earth's physical systems and how changes in land use, such as deforestation, land drainage, land reclamation, resource extraction, intensification of agriculture and pastoralism, coastal modification, and soil and water degradation can interrupt these systems and result in land cover transformation at global, regional and local scales.	**1.3**
Recognise the spatial patterns of land cover change at a variety of scales, using remotely sensed images and aerial photographs.	**1.2**
Explain how selected factors, such as world population growth, growing affluence and advances in technology, have had an impact on the rate and extent of land cover change at a variety of scales.	**1.5**
Explain the concept of anthropogenic biomes.	**1.5**
Explain, using conceptual models, the key processes and relationships associated with global climatic systems.	**1.4**
Explain, using evidence, how anthropogenic activity (such as changes in land use) may be influencing climate change.	**1.4** **1.6** **1.7**
Explain the interconnections between land cover change and climate change.	**1.4**
Analyse data to interpret indicators of climate change and generalise about the current and future implications for people and environments.	**1.4**
Conduct a case study to investigate the effects of climate change on a specific type of land cover (e.g. vegetation, ice sheets and glaciers, coral reefs) at a regional or local scale of study.	**1.4**

KEY QUESTIONS

- What is land cover and its distribution?
- What processes connect the Earth's physical systems and affect land cover?
- What are the different types of land cover (vegetation biomes, biogeographic areas, anthropogenic biomes)?
- How does population growth, an increase in affluence and technology impact land cover?
- How do human activities such as settlements, croplands, rangelands and forestry transform land cover surfaces?
- How do these transformations impact the Earth's systems?
- What are global climatic systems?
- What is climate change? How does it impact land cover types?
- What are the implications of climate change on people and the environment, and how might people best respond to them?

LESSON
1.2 What is land cover and its distribution?

LEARNING INTENTION

By the end of this lesson you should be able to recognise the spatial distribution of the different types of land cover, including global, regional and local forests, wetlands, ice, croplands, rangelands and urban land use.

1.2.1 Continents and oceans

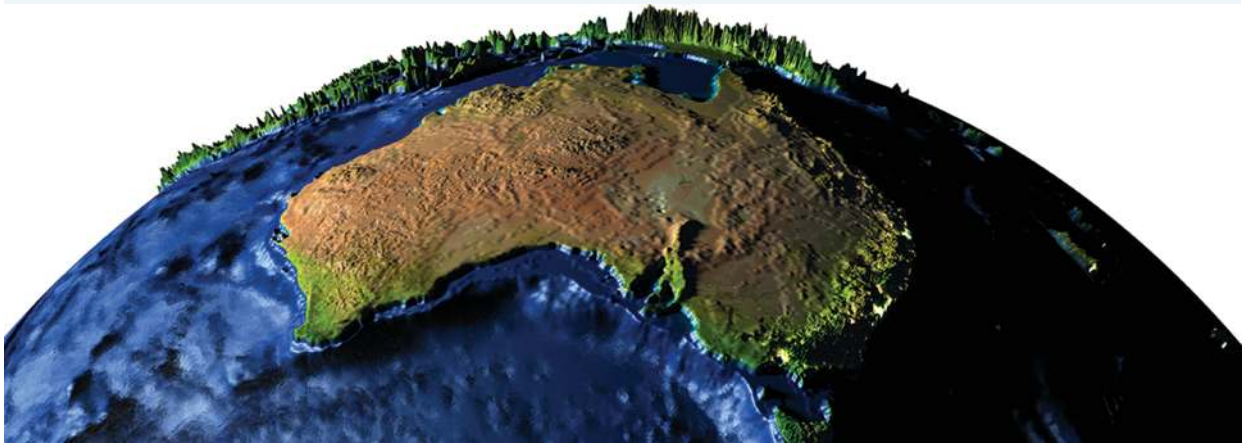
The Earth is covered by land and water. Land covers about 30 per cent of the surface and is made up of seven large landmasses called **continents**, as well as many large and small islands (see figure 1.2). The continents are Africa, Asia, Europe, North America, South America, Australia and Antarctica. Examples of large islands are Sri Lanka, Borneo, New Guinea, Madagascar and New Zealand, while inhabited small islands and **archipelagos** include Indonesia, Japan and the United Kingdom. Although a continent, Australia is often linked to Oceania, a region that includes the South Pacific Islands. Asia has the largest land area and population, and Africa is the second largest.

continents the largest landmasses on Earth: Africa, Antarctica, Asia, Australia, Europe, North America and South America

archipelago an island group or chain of islands, such as Indonesia

oceans the largest bodies of water on the Earth, holding more than 96 per cent of all water; ocean water is approximately 3.5 per cent salt

FIGURE 1.2 Only 30 per cent of the Earth is covered by land.



Between the continents are very large basins of water called **oceans**, which contain an estimated volume of about 1.35 billion cubic kilometres of water. This huge expanse covers 70 per cent of the surface and is divided into four major oceans — the Pacific, Atlantic, Indian, Arctic and Southern oceans.

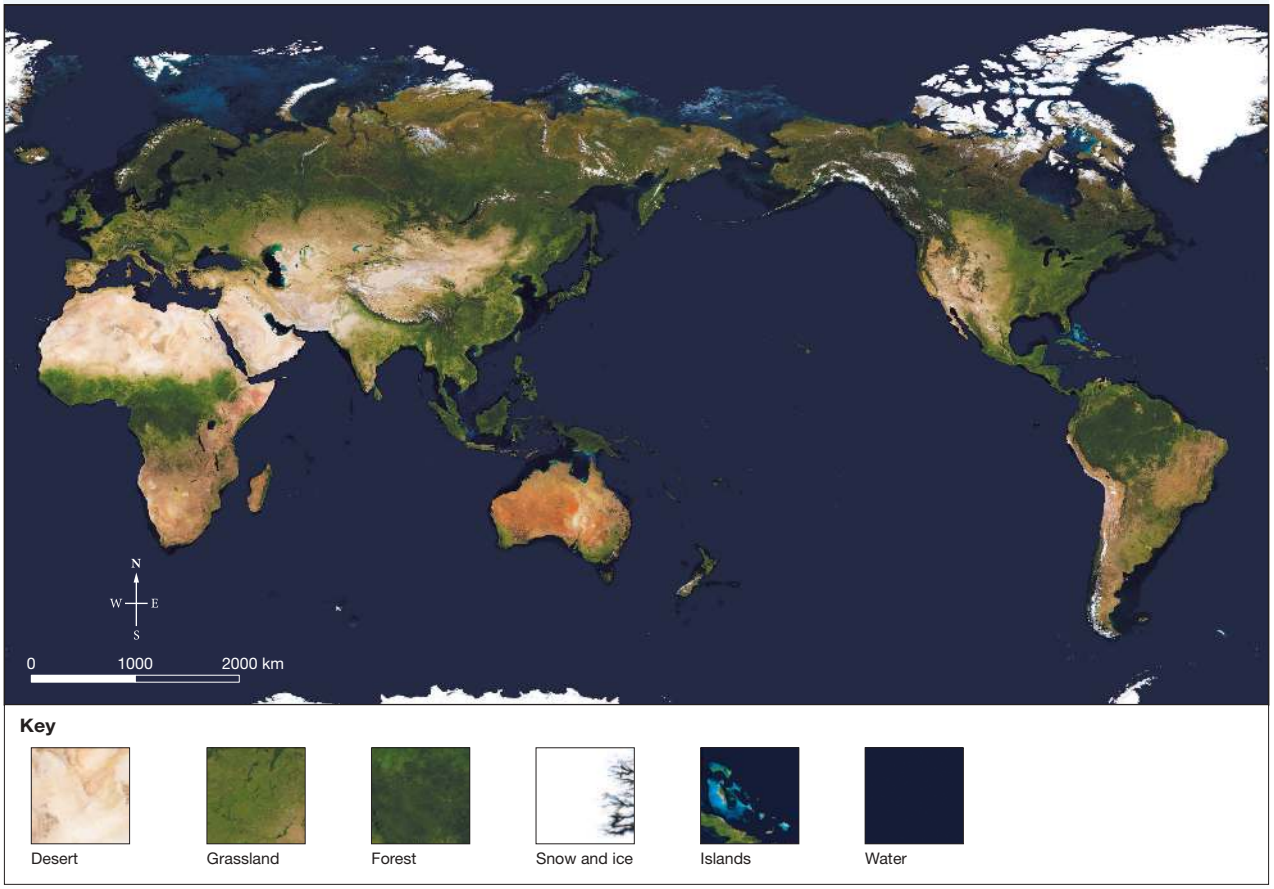
Oceans also contain smaller sections called seas (for example, the Mediterranean Sea and Caribbean Sea), as well as large gulfs (e.g. the Persian Gulf and Gulf of Mexico) and bays (e.g. Hudson Bay and Bay of Bengal).

Because of their vast area, the combined oceans absorb a huge amount of the Sun's heat. Ocean water takes longer to heat than continental land, but once heated it retains warmth longer and moderates air temperatures at the surface. Oceans are able to transfer some of this heat into the atmosphere and other parts of the world by powerful convectional currents. All oceans are connected and water circulates around the entire planet, playing a key role in the exchange of heat and moisture between other physical systems — the atmosphere and lithosphere.

Despite their size, oceans have become fragile environments through exposure to human progress. Technological advances, population growth and growing affluence have made oceans vulnerable to the effects of human activities such as fishing, shipping, coastal land clearing, marine construction and pollution. In the past, the sheer size of oceans enabled them to absorb the effects of human-induced change. However, today, the intensity and speed of human change has given marine **ecosystems** little time to adjust, placing them at risk of overload and eventual collapse.

ecosystems communities of biotic (living organisms) and abiotic (non-living things like water and soil) that are linked through nutrient cycles and energy flows. An ecosystem may be large like a barrier reef or small like a garden.

FIGURE 1.3 The distribution of landmasses and oceans



Source: Reto Stöckli, NASA Earth Observatory

SKILLS ACTIVITY: Geographic inquiry

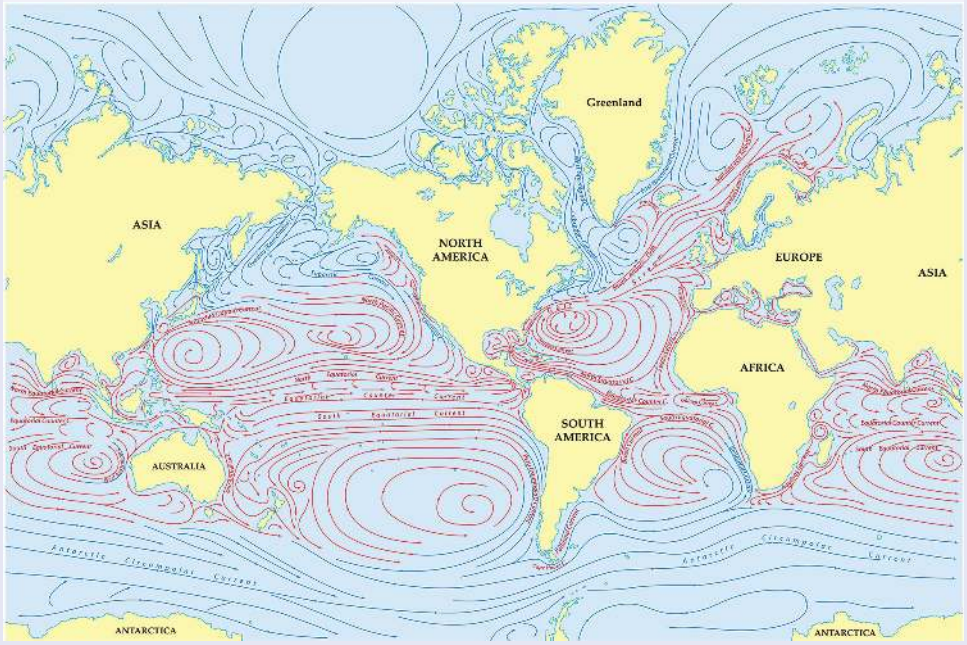
1. Complete your own research to find the size of each of the continents and oceans. Create two tables similar to the ones shown to record your answers.

Continents	Estimated area (km^2)
Asia	
Africa	
North America	
South America	
Antarctica	
Europe	
Australia	

Oceans	Estimated area (km^2)
Pacific	
Atlantic	
Indian	
Southern	
Arctic	

2. Use this information to design a circle (pie) graph comparing their sizes.
3. Identify how many countries are in each of the following continents:
   Europe, Australia, Antarctica
4. Figure 1.4 shows world ocean currents, and corresponding temperatures with blue being cold and red being warm.
   - **A.** There is a spatial association between latitude and water temperature.
   - **B.** The Western Australian Coast has a confluence of warm and cold ocean currents.
   - **C.** Warm water extends far into the northern hemisphere off the coast of Europe.
   - **D.** The Humboldt current (off the west coast of South America) brings warm water to the Chilean coast.
   - **E.** The continents have limited impact on the direction of oceanic currents.

FIGURE 1.4 Ocean currents and ocean temperatures



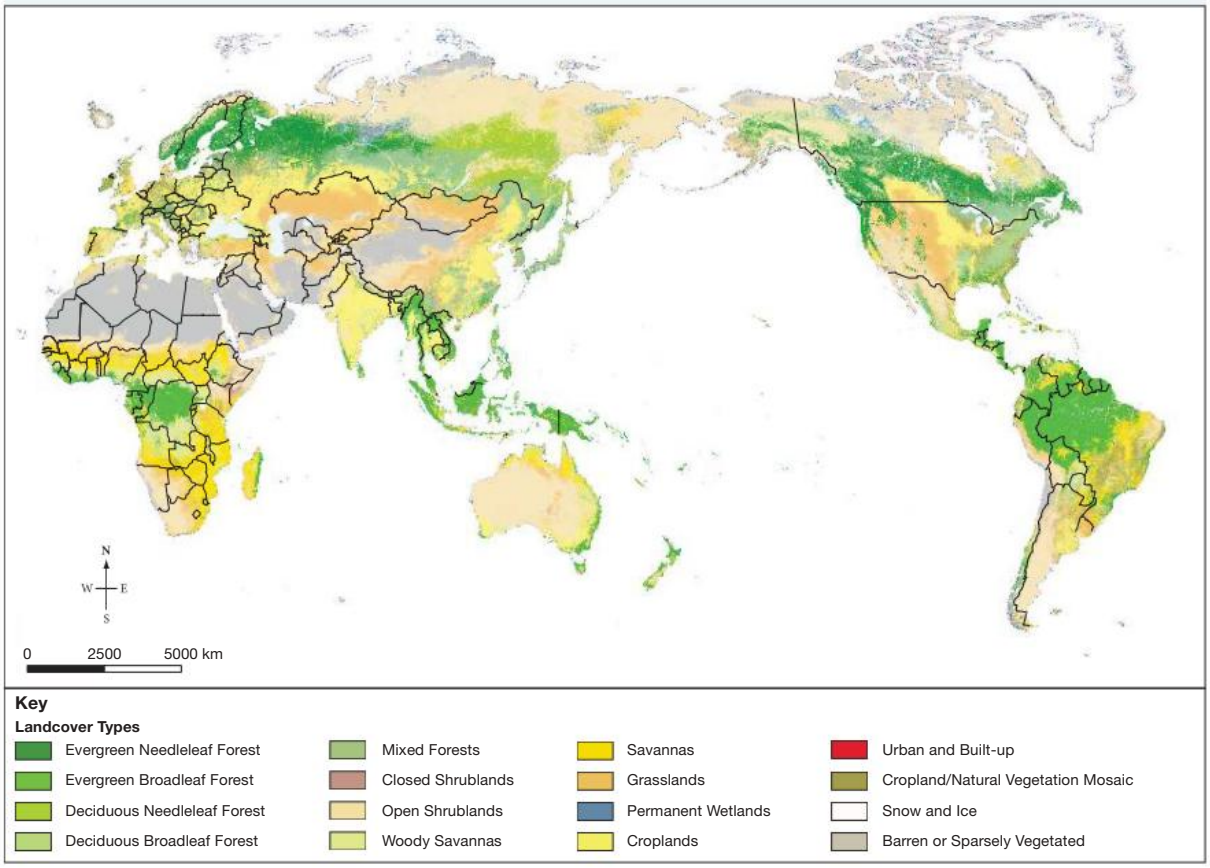
1.2.2 Patterns of land cover

The term **land cover** is used by geographers to identify the different materials that cover the surface of the Earth (see figure 1.5). It refers to forest, grass, farmland, roads, buildings, exposed ground, lakes and water, and was first used by the plant ecologist Frederick Clements in the 1800s. Land cover is different from **land use**, which is a term used to describe how people use an area for economic, social or cultural purposes, such as farming, golf courses or cemeteries.

land cover what is covering the land (e.g. vegetation, human infrastructure or development, agriculture or bare earth)

land use how people use an area for economic, social or cultural purposes

FIGURE 1.5 Different types of land cover



Source: Boston University and NASA GSFC

Scientists can collect accurate details of the extent of land cover using satellites. The European Space Agency (ESA) collects land cover data in 36 different classifications, including human settlements, agriculture (cultivation, grazing lands), vegetation (forests, grasslands, shrublands), ice sheets, areas of water and artificial surfaces.

Due to the extensive areas of land cover, they are usually mapped using remote sensing (satellite) techniques. Field survey work is also still important and may be required if samples need to be gathered or tested.

FIGURE 1.6 Land cover information from DEA Land Cover C3 (Landsat)

Vegetation level

Bare surface

Unvegetated — Sparse

Vegetation cover %

Herbaceous cultivated terrestrial vegetation

1–4% — > 65%

Woody cultivated terrestrial vegetation

1–4% — > 65%

Herbaceous natural terrestrial vegetation

1–4% — > 65%

Woody natural terrestrial vegetation

1–4% — > 65%

Aquatic vegetation

1–4% — > 65%

Wet months

Water persistence

1–3 — > 9

Categorical classes

Tidal region

Artificial surface

Source: DAFF (https://www.agriculture.gov.au/abares/aclump/land-cover)

1.2 Exercise

1.2 Exercise

Learning pathways

LEVEL 1	LEVEL 2	LEVEL 3
1, 4, 7	2, 6, 8	3, 7, 9

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

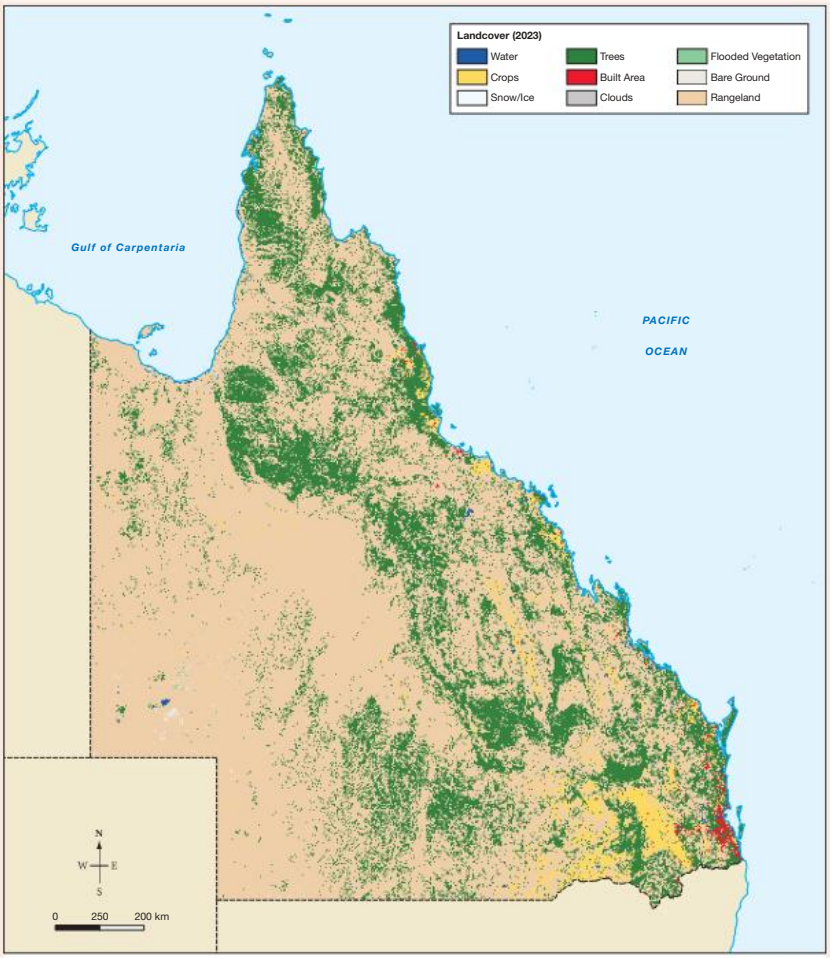
Find all this and MORE in jacPLUS

Explain and comprehend

Refer to figure 1.6 to answer the following.

1. a. **Identify** where the most closed forest is located.
   b. **Identify** the state which has the least area of forest.
   c. **Identify** the state which has largest area of salt lakes.
   d. **Identify** which two states appear to have the most tussock grasses.
   e. **Describe** the dominant vegetation type in Tasmania.
2. Use the map in figure 1.7 to answer the questions.

FIGURE 1.7 Land cover of Queensland in 2023 according to Environmental Systems Research Institute (ESRI)



Source: K. Karra, C. Kontgis, Z. Statman-Weil, J. C. Mazzariello, M. Mathis and S. P. Brumby "Global land use/land cover with Sentinel-2 and deep learning." IGARSS 2021-2021 IEEE International Geoscience and Remote Sensing Symposium. IEEE, 2021. Map drawn by Spatial Vision.

a. **Explain** briefly what the map in figure 1.7 is showing.
b. **Identify** the dominant land cover.
c. **Estimate** the percentage of land cover that is the following.
   i. Forestry
   ii. Grassland
   iii. Inland water bodies
   iv. Herbaceous crops (grains)

3. **Match** the land cover type in list A with a correct example in list B in the following table.

List A	List B
Forestry (closed)	New York metropolitan area
Desert (barren land)	Eucalypt forests of south-east Queensland
Forestry (open)	Boondall Wetlands, near Brisbane
Grassland	Serengeti National Park, Africa
Woody crops	Wheat belt of Canada
Artificial/urban	Grape vines in Barossa Valley
Herbaceous crops	Greenland ice sheet
Snow and glaciers	Amazon Rainforest
Mangroves	Sahara Desert

Analyse and apply

4. Study the images provided. **Identify** which land cover (from list A in the previous question) best describes each image.



5. **Decide** if the following statements are true or false.
   a. Approximately 35 per cent of land is covered by some form of tree or forest cover.
   b. Approximately 15 per cent is regarded as barren land (mountains, deserts).
   c. Urban and artificial areas account for about 2 per cent of land cover.
6. If global air and sea temperatures continue to increase, **identify** and **explain** which land cover is most at risk of decreasing.

Propose and communicate

7. As population increases and demand for both human and stock food increases, **propose** which land covers are likely to increase, and which ones may decrease.
   Discuss this statement, using examples.
8. The Earth's surface is made up of a mix of land and ocean. **Discuss** how the spatial distribution of land and sea cover might influence human activity and settlement patterns?
9. Urban expansion often encroaches on natural land covers like forests and wetlands.
   Propose a local planning strategy to protect forests or wetlands from further urban development? Present your ideas using a spatial representation and written justification

Samples responses for this chapter are available online.

LESSON
1.3 The Earth's physical systems

LEARNING INTENTION

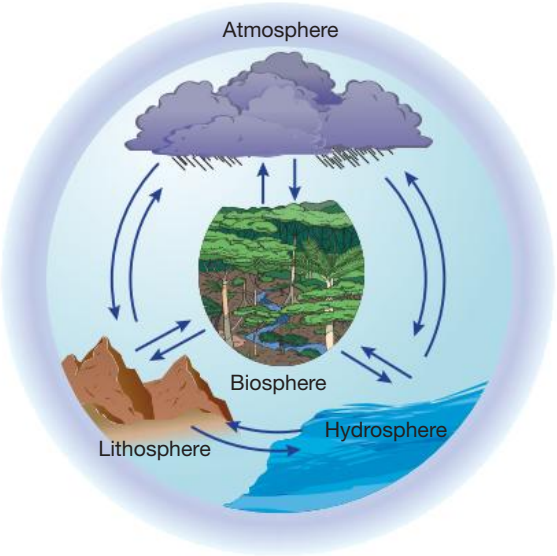
By the end of this lesson you should be able to explain the interconnection between the Earth's physical systems.

The Earth comprises four geographic systems — the atmosphere, the lithosphere, the hydrosphere and the biosphere. Three of these are non-living systems:

- the lithosphere (the Earth's crust and landmasses)
- the atmosphere (the mix of gases surrounding the Earth)
- the hydrosphere (water such as oceans, rivers, lakes and glaciers).

Together, the non-living systems form another system that supports life — the biosphere or ecosphere (see figure 1.8). These four systems can be divided further into smaller zones. The hydrosphere contains oceans and seas, the terrestrial parts of the lithosphere contain **biomes**, and the atmosphere is divided into layers such as the **troposphere** and stratosphere. The biosphere can be broken down into classifications such as **biogeographic areas**, ecosystems and communities.

FIGURE 1.8 The Earth's systems



Over time, all four systems have been largely shaped by geophysical factors such as climate, soils, vegetation and geomorphology. However, with increased levels of human activity in recent times, advances in technology have shown that people now have more impact on these systems than previously thought. These human-induced changes are called **anthropogenic**. Because a system is a dynamic network consisting of inputs, processes and outputs, a change in one part of the system will affect other parts of the system.

For example, increasing carbon emissions into the atmosphere increases the amount of CO_2, which allows the atmosphere to hold more water vapour, so storms have the potential to be more violent and destructive. Another compounding effect is created when people build too many dams or extract too much water from rivers or aquifers. In doing so, they reduce essential water run-off into estuarine ecosystems and wetlands, which results in the death of plants and animals.

biomes very large regions of the Earth where area-specific plants and animals have adapted to the climate, soil and relief of that environment; deserts and rainforests are biomes

troposphere the lower 10–12 km of atmosphere where most weather activity takes place

biogeographic areas smaller regions where the distribution of plants, animals and geology reveals many shared or common features, such as Wallum country of southern Queensland

anthropogenic created by human interaction with the biosphere

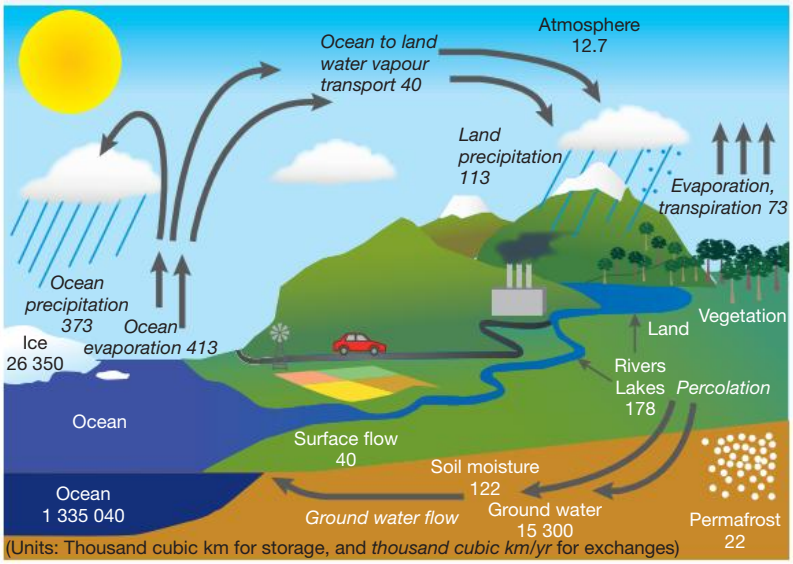
1.3.1 Connections between the Earth's physical systems

The Earth's physical systems are connected by a complex network of pathways and loops (cycles), which allows these systems to exchange, transfer and recycle essential energy and chemicals. The most important cycles are the hydrological (water) cycle, the carbon cycle and the nitrogen cycle. Certain human activities in one of these systems can cause disruption to the operation of other cycles. For example, fertilisers may improve crop growth on land but if the chemicals enter a river, they cause pollution and the growth of algal blooms, which are both effects of drainage degradation.

The hydrological cycle

Water exists in three main forms: liquid (ocean, rivers and lakes), solid (snow, glaciers and ice sheets) and gas (vapour or clouds in the atmosphere). The **hydrological cycle** continuously circulates these various forms of water between the oceans (hydrosphere), land (lithosphere) and atmosphere through a series of processes such as evaporation, condensation, transpiration, **precipitation**, infiltration and run-off.

FIGURE 1.9 The hydrological cycle

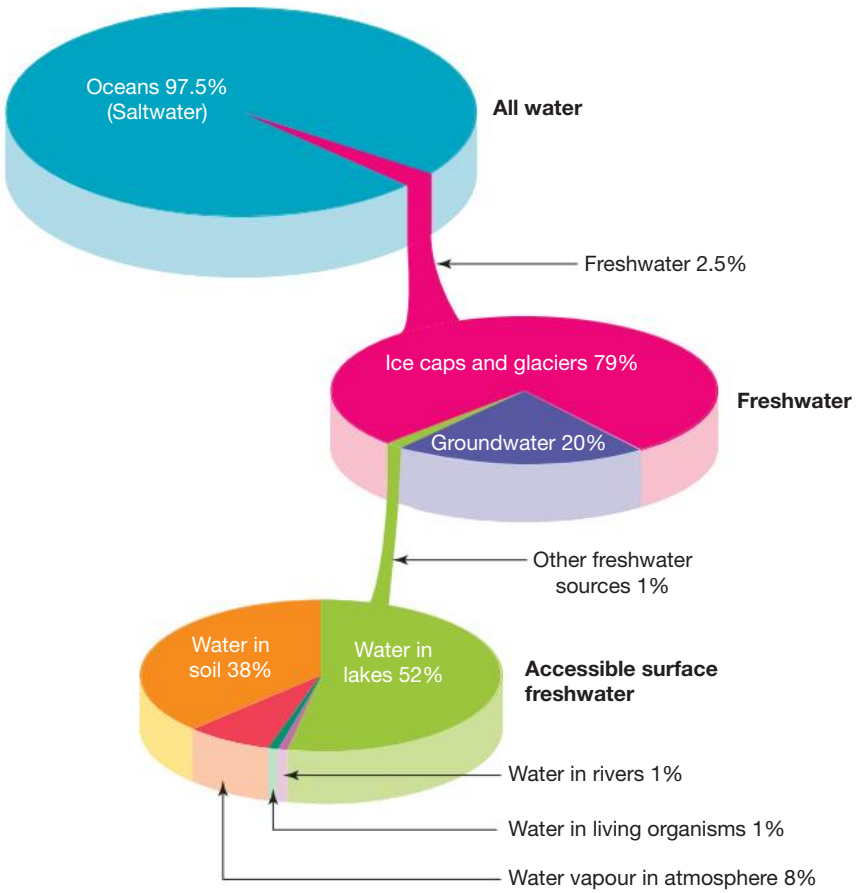


Water covers most of the Earth's surface, with 97.2 per cent found in the oceans, 2.15 per cent locked up in ice sheets and glaciers, and 0.31 per cent held in sub-surface systems. The remainder is found on the surface as inland seas, lakes, rivers, dams and in the atmosphere. This tiny remaining percentage is probably the most life-sustaining part of the cycle. Figure 1.10 breaks down this water distribution in more detail.

hydrological cycle the process of exchanging water between the air, land and sea through evaporation, condensation and precipitation

precipitation rainfall

FIGURE 1.10 A visual breakdown of the distribution of water on Earth, by location and type



DID YOU KNOW?

The water we drink today was possibly once stored in the polar ice caps (as a solid), the Pacific Ocean (liquid) or in the atmosphere (gas). It can take thousands of years for water to pass through the stages of the water cycle.

The carbon cycle

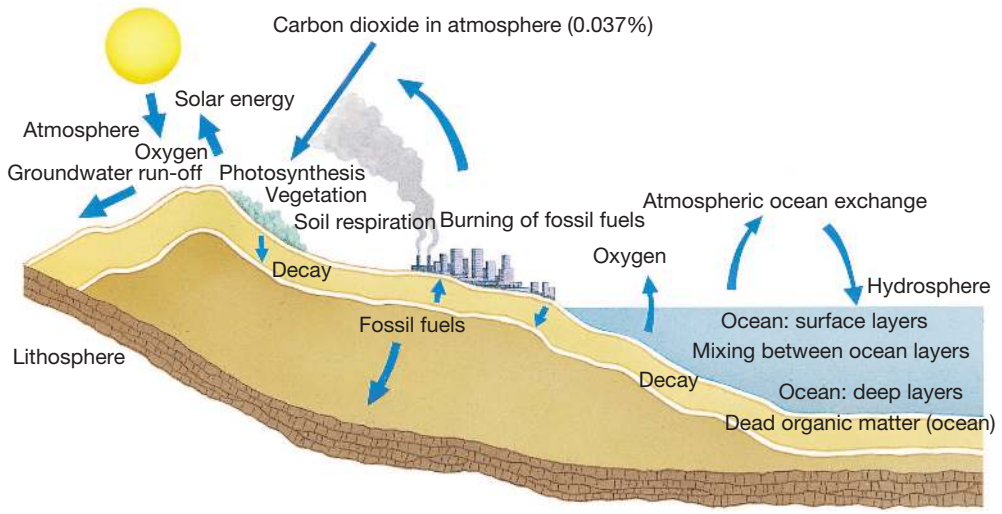
The **carbon cycle** is the process of transferring, storing and exchanging some of these chemicals between the physical and living systems (see figure 1.11). For example, plants take in CO_2 from the atmosphere and store it as glucose so they can grow. An animal may eat the plant and store CO_2 in its body or exhale it back into the atmosphere. When the animal dies, it decays, and carbon is returned to the earth as organic matter.

carbon cycle the chain of biogeochemical processes that exchange or move carbon between the biosphere, the atmosphere, hydrosphere and lithosphere

nitrogen cycle the biogeochemical loops where nitrogen in its various forms is circulated between the atmosphere, hydrosphere, lithosphere and biosphere

Forests and soils are also important carbon sinks. Trees capture CO_2 from the atmosphere and when they die or are removed, return any stored CO_2 to the atmosphere. CO_2 is also stored in a stable form below ground as coal, oil and gas. When humans burn these fossil fuels, more carbon is released into the atmosphere. Although it took millions of years to lock up this carbon, it takes only seconds to put it back in the air. Readings of CO_2 concentration of around 345 ppm are now common in some parts of the world. (Prior to the Industrial Revolution, CO_2 concentration was under 300 ppm.)

FIGURE 1.11 The carbon cycle

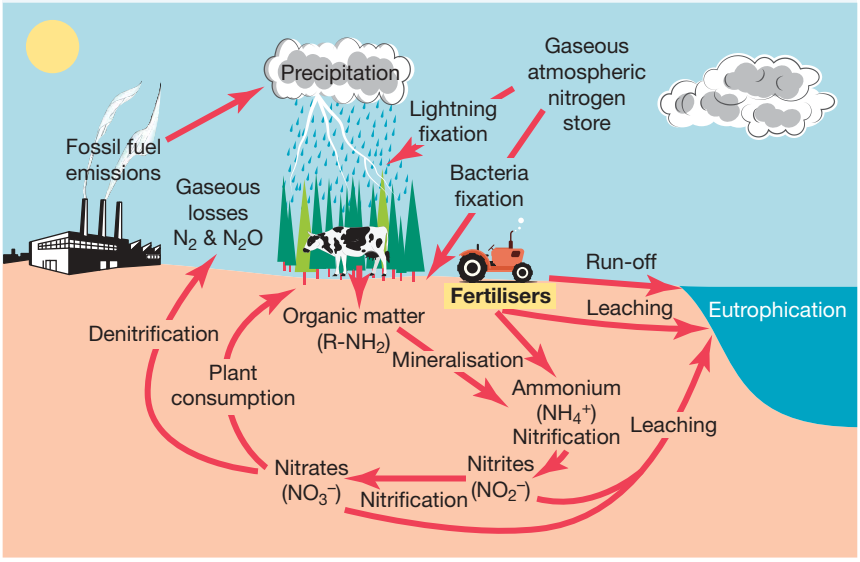


The nitrogen cycle

Nitrogen is an essential element for life because it is a key component of amino acids, proteins, DNA and other biological molecules. The **nitrogen cycle** is important for transferring this abundant gas between and within the physical systems (see figure 1.12). Occupying about 78 per cent of the Earth's atmosphere by volume, nitrogen is also found in decaying organic matter, inorganic soil matter and marine sediment. The nitrogen cycle maintains a balance between levels in the atmosphere, the land and marine systems.

Despite its abundance, most plants are unable to obtain nitrogen in its gaseous form. The only exceptions are some types of blue-green algae. Plants need to absorb nitrogen through their root systems in the form of nitrates (NO_3) and ammonium salts (NH_4) when these are dissolved in water. The biological process that takes microbes in the soil to break down nitrogen and then release it is what we call **mineralisation**. This process turns the organic form of nitrogen into a mineral form that the plants can then take up.

FIGURE 1.12 The nitrogen cycle maintains a balance of nitrogen levels in the atmosphere, the land and marine systems. However, excessive usage of nitrogen-based fertilisers can change this balance, resulting in eutrophication and algal blooms in waterways.



mineralisation the process by which chemicals present in organic matter are broken down into easily available forms to plants

DID YOU KNOW?

Grass often looks healthier after an electrical storm. This is because each bolt of lightning carries sufficient energy to split the nitrogen atoms (N_2) in the air. They then fuse with oxygen to form nitrates and fall to the ground as a form of fertiliser.

1.3 Exercise

1.3 Exercise

Learning pathways

LEVEL 1	LEVEL 2	LEVEL 3
1, 4, 7	2, 5, 6, 8	3, 9, 10

Explain and comprehend

1. **Select** the correct terms from the text box to complete the sentence.

biosphere	hydrosphere	lithosphere	deforestation	erosion
ecosystems	atmosphere	troposphere	weather	systems

The Earth consists of four geographic _____. The _____ is made up of rock and soil in the crust and supports the land masses. Wind and water move soil about by a process called _____. The _____ is the mix of gases surrounding the Earth. The lowest level of this system is known as the _____. Here the air may move, get hot or cool and even wet. This process of atmospheric change is commonly known as the _____. The physical system consisting of water bodies such as rivers, lakes and seas is known as the _____. Collectively, these three systems provide habitats and resources for living things. This fourth system is called the _____. Within this system are smaller _____ such as forests or wetlands. In some countries, vegetation is removed for farming and urban activities in a process called _____.

2. **Identify** which of the geographic systems could be affected by the following events.
   a. A deep ocean earthquake followed by a destructive tsunami
   b. A tropical cyclone or hurricane that batters the coast and brings deluges of rain and flooding
   c. A prolonged drought that results in severe wildfires which destroy forests, wildlife habitats and farms
3. Read through the key features of the hydrological (water) cycle, the carbon cycle and the nitrogen cycle. **Compare** the three cycles to **identify** similarities and differences.
4. **Decide** if the following statements are true or false about the hydrological, carbon and nitrogen cycles.
   a. All three cycles are biogeochemical (i.e. they involve both living things and physical components of the Earth).
   b. All three cycles are continuous (with no beginning or end).
   c. All three cycles have a gaseous state at some point in time.
   d. All three cycles are interconnected processes that release essential elements into different ecosystems.
   e. All three cycles require photosynthesis as a form of energy.
5. Re-arrange the following processes of the hydrological cycle into the correct order.
   Precipitation, condensation, evaporation, run-off, precipitation, interception

Analyse and apply

6. **Explain** four ways that carbon may be released into the atmosphere.
7. **Explain** how deforestation upsets the carbon balance between the biosphere and the atmosphere.
8. **Explain** how the ocean acts as a major sink for carbon dioxide.

Propose and communicate

9. **Propose** how acidification of the oceans may have an impact on some marine species such as those with shells or corals.
10. **Explain** why farmers rely on organic fertilisers when so much nitrogen s in the air.

Sample responses for this chapter are available online.

LESSON
1.4 Global climate systems

LEARNING INTENTION

By the end of this lesson you should be able to explain the interconnection between the Earth's physical systems.

Climate is best described as the average state of weather conditions over a long period of time, such as a month, whereas **weather** refers to the conditions in a much shorter space of time, such as a day or week. The global climate is created by the interaction between several systems, including wind patterns, precipitation, ocean currents and the transfer of heat from the Sun.

climate the average state of weather conditions over a long period of time

weather conditions in the air above the Earth over a short period of time

1.4.1 Wind patterns

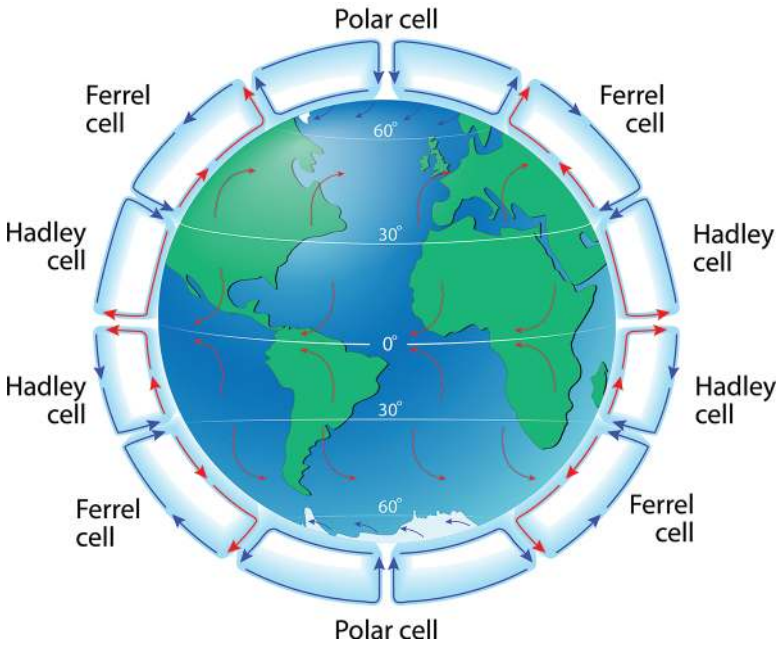
The Earth is not heated evenly by the Sun because it is round. These variations in heat create large zones where air pressure is different. In places where air is cool, it is denser and falls to the surface of the Earth, creating an area of high pressure. If air is warm, it expands and rises, forming an area of low pressure. Air moves from a high pressure area to an area of low pressure to even out. These pressure differences on a large scale create a global wind system (see figure 1.13); however, it is the rotation of the Earth that causes the cells of air to move from west to east.

coriolis effect a force like inertia that deflects objects moving across the surface (air, ocean currents, etc) to the left in the southern hemisphere and to the right in the northern hemisphere. It is caused by the rotation of the Earth.

trade winds the easterly prevailing winds (north-east and south-east) blowing from sub-tropical areas towards the tropics

Intertropical Convergence Zone (ITCZ) the large region of low pressure close to the equator where the trade winds of both the northern and southern hemispheres meet. Due to high temperatures, warm ocean water and trade wind convergence, the region has unstable air that rises, forming thunderstorms. It moves either side of the equator according to the summers and often appears on weather maps as a monsoon trough.

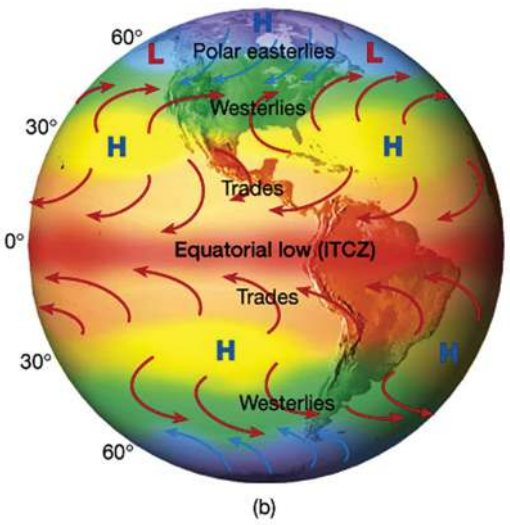
FIGURE 1.13 The global wind system



Winds are also affected by the **Coriolis effect** because the Earth is rotating. This means that in the southern hemisphere winds are deflected to the left, and in the northern hemisphere they are deflected to the right. Each hemisphere has three major wind belts (systems) — polar easterlies (from about 60–90 degree latitudes), prevailing westerlies (30–60 degrees) and **trade winds** (0–30 degrees). Around the equator, the zone between these wind belts is commonly known as the **Intertropical Convergence Zone (ITCZ)**. (Figure 1.14 shows these wind patterns.) The subtropical convergence zones about 30 degrees north or south are called 'horse latitudes'.

The ITCZ is not a stationary phenomenon, and nor are its movements symmetrical above and below the equator. Many factors, including seasons and land masses, influence its overall movement.

FIGURE 1.14 Actual wind patterns due to the Coriolis effect

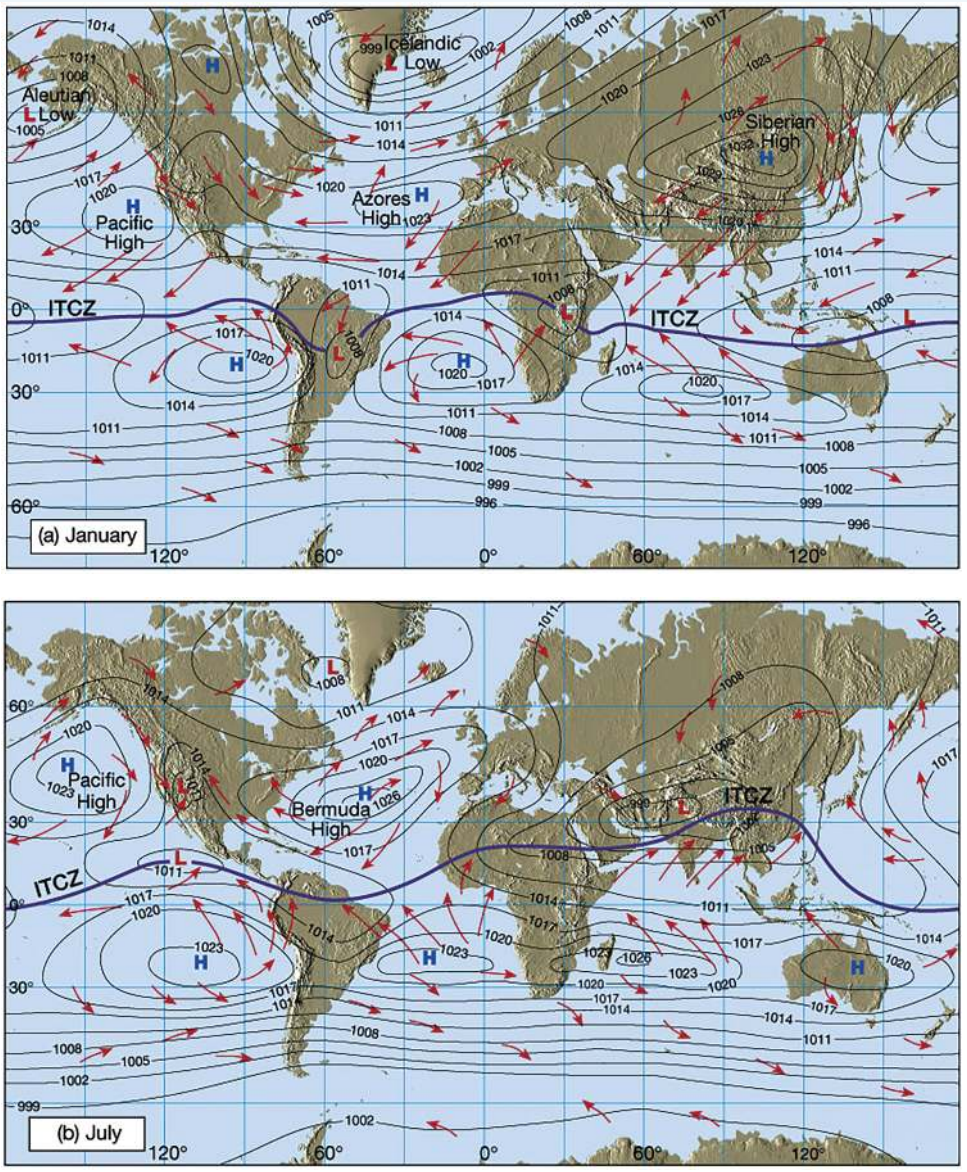


(b)

1.4.2 Precipitation patterns

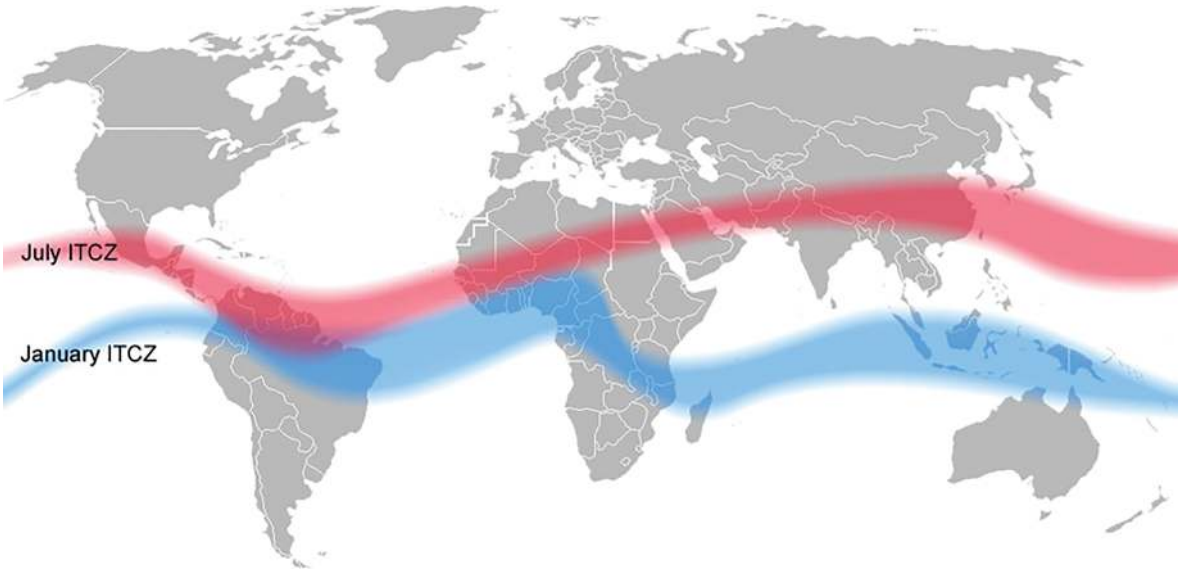
Due to the uneven distribution of landmasses and ocean, as well as an uneven surface of the Earth, availability of moisture and subsequent rainfall varies considerably from place to place. As a rule, rainfall is heaviest in the tropics due to the instability of warm air masses and the ITCZ. Global patterns of precipitation are closely aligned to wind patterns and heat transfer in the atmosphere. The atmospheric circulation shown in figure 1.13 and the movement of air cells in figure 1.14 help explain the global patterns of precipitation shown in figure 1.16.

FIGURE 1.15 (a) Southern shift of ITCZ in January. (b) Northern shift of ITCZ in July.



Warm moist air in the low-pressure cells near the equator expands and rises. The moist air then condenses, forming storm cells that release heavy rainfall. As the air moves away from the equator, it begins to cool and sink towards the surface. This dry air (high-pressure cell) produces little or no rain. This is why the major deserts are found around 20 to 30 degrees latitude.

FIGURE 1.16 Annual precipitation

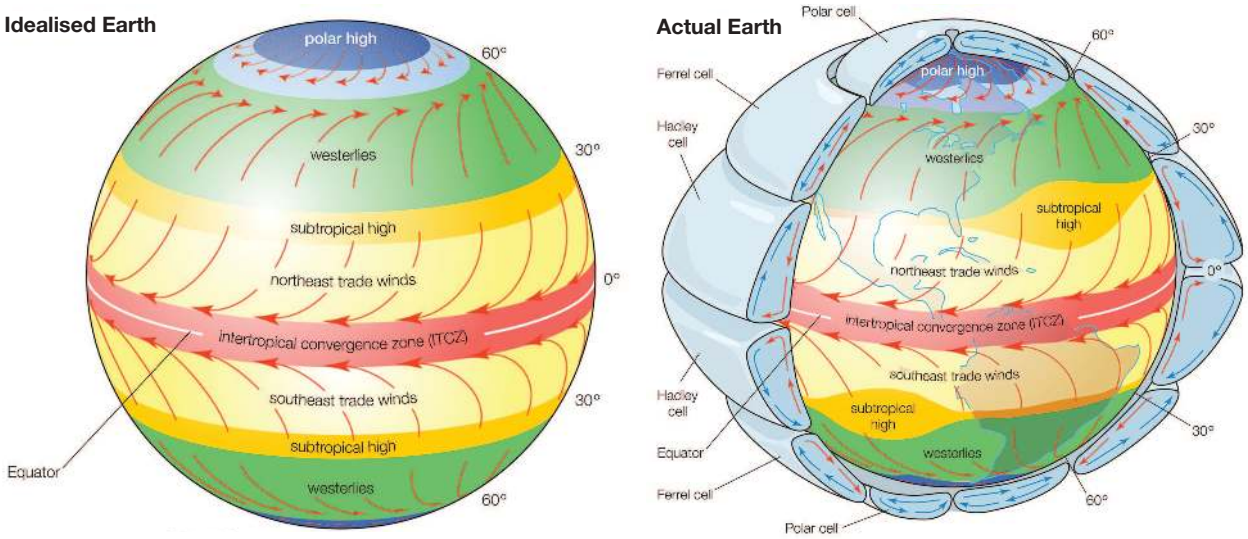


Source: https://geoforcxc.com/natural-systems/weather-and-climate/inter-tropical-convergence-zone/

1.4.3 Heat transfers in the atmosphere

The tilt of the Earth causes physical differences between air and ocean temperatures. The Earth is tilted at an angle of 23.5 degrees, which adds to the different levels of heat absorption both on land and in the oceans, as shown in figure 1.17. As well as providing a 24-hour day–night cycle, the angle of the tilt also determines our four seasons: spring, summer, autumn and winter.

FIGURE 1.17 The angle of the Earth affects how the heat from the Sun is absorbed.

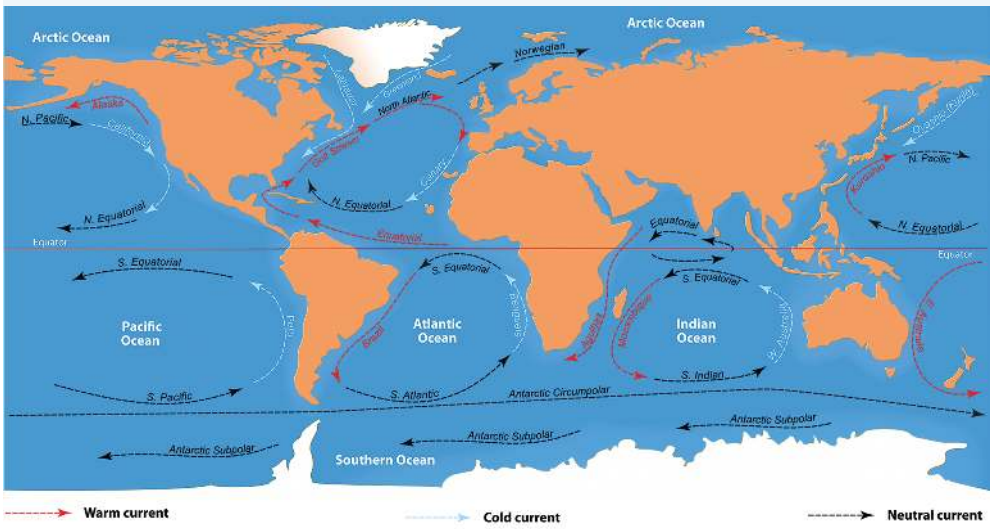


The levels of solar radiation reaching the Earth are much different between summer and winter. During summer, regions directly facing the Sun have large amounts of incoming solar radiation and, therefore, get quite hot. In winter, levels of solar radiation are much lower, so the land and air remain cool. Amounts of heat absorption are also affected by the angle of incidence of incoming rays. That is why temperatures are so low near the poles.

1.4.4 Ocean circulation and heat transfer

Heat energy is transferred between the equator and the poles by very large ocean currents (see figures 1.18 and 1.19). Ocean currents are large masses of water that circulate water flow around the oceans, either in a clockwise or anticlockwise direction. Currents are formed by the Coriolis effect and influenced by winds, water density, tides and the shape of the ocean floor. Moving like large gyres, ocean currents help regulate climate by distributing uneven amounts of heat from the Sun. These gyres are important controllers of climate, particularly in regions adjacent to the ocean, and their effects can be felt over large distances. For example, the warm Gulf Stream flows up the east coast of North America but also affects the climate of places in northern Europe.

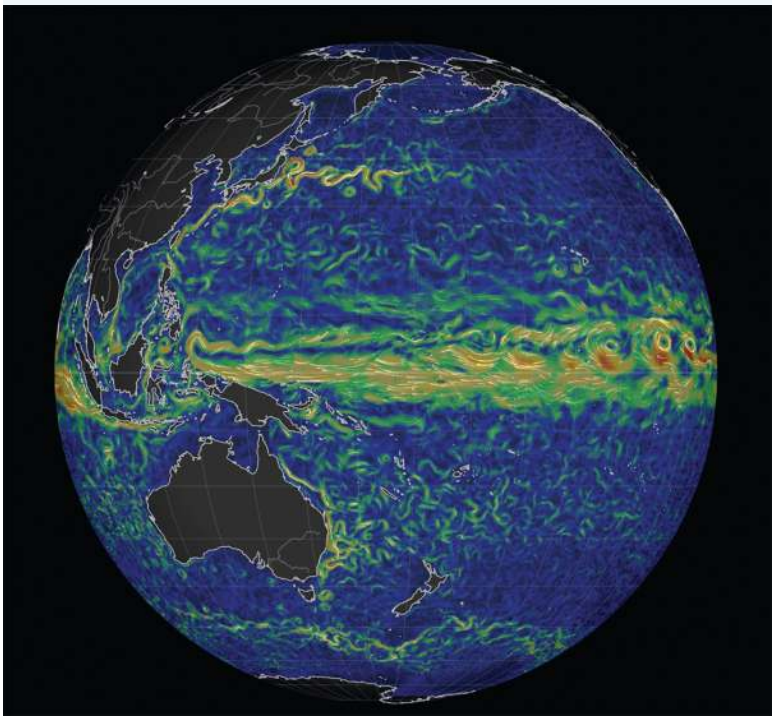
FIGURE 1.18 The circulation of warm, cold and neutral ocean currents



Thermohaline currents, driven by water density and temperature differences, flow below the surface and along the sea floor. These currents form in polar regions when cold waters sink and move towards the equator, in a process called downwelling. If ocean temperatures become more uniform, these currents may weaken or become less effective.

The Gulf Stream/North Atlantic drift is an important ocean current that regulates temperatures along the east coast of North America and northern Europe. It takes warm water from the Gulf of Mexico north along the east coast of North America, crosses the Atlantic and flows towards the English and Scandinavian coasts, keeping northern ports along these coasts ice-free most of the year. As the melting ice in the Arctic Ocean cools the water and decreases the salinity, the current sinks and then returns southward along the ocean floor. This also helps to trap CO_2 deep in the ocean. However, this current has recently shown signs of slowing down, possibly due to ocean warming. The last time this occurred was approximately 1 million years ago, during the Pleistocene Ice Age. Today, the concern is that as the oceans warm, the differences between temperatures and salinity will no longer be sufficient for downwelling to continue. This is unknown territory.

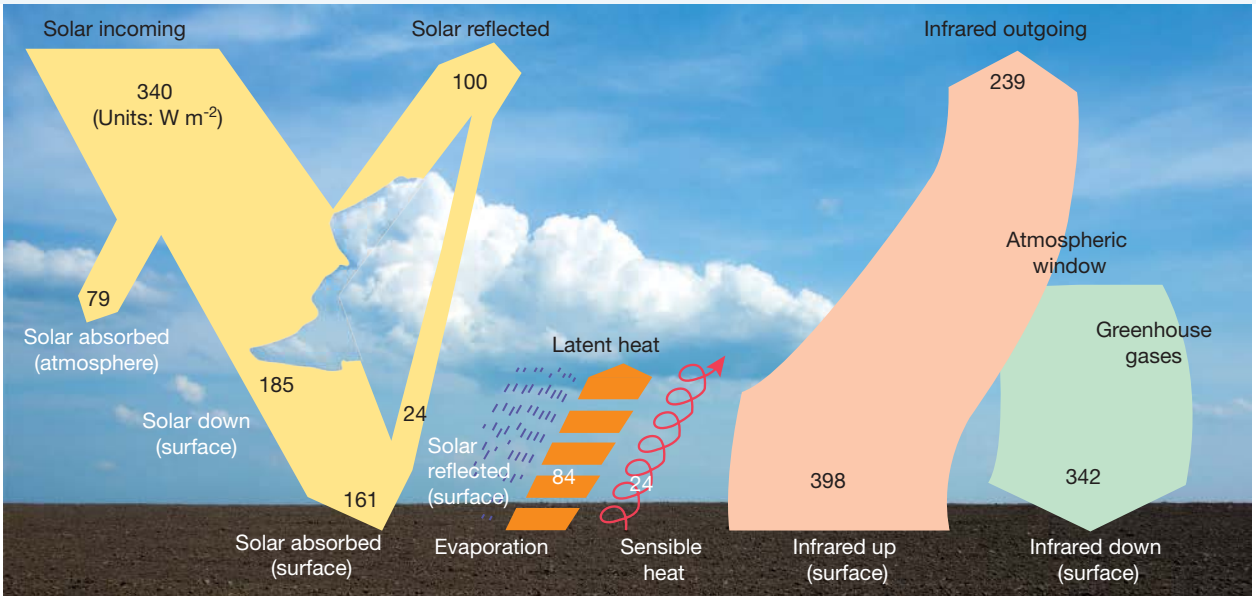
FIGURE 1.19 The ocean currents are shown in green, yellow and red.



1.4.5 The Earth's energy budget

Energy from the Sun enters the Earth's system during the day by radiation and warms the Earth's surface. Most of this energy is absorbed by the Earth but some is transferred back into the atmosphere by infrared radiation, conduction and evaporation of water (latent heat released later when water condenses). Energy also leaves the Earth during the night by infrared radiation from the atmosphere. If the atmosphere contains more CO_2, it must increase in temperature for energy balance to occur. The arrows in figure 1.20 show global average energy transfer rates in units of watts per square metre (W/m^2).

FIGURE 1.20 The Earth's energy budget



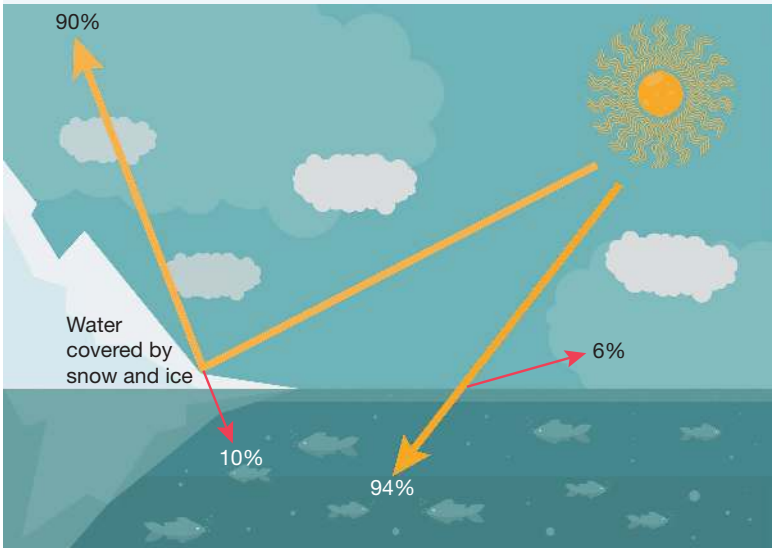
1.4.6 Surface reflectivity and albedo

Incoming solar energy is either absorbed as heat energy or reflected into space without heating the Earth. When the sun's rays strike the Earth, light-coloured surfaces such as snow or ice reflect up to 95 per cent of solar energy. On the other hand, dark areas such as rainforest, cultivated soil or ocean water absorb most of the heat and reflect only small quantities.

The measure (%) of how much solar energy is reflected away is called **albedo**. Snowfields and ice sheets have a high albedo, but oceans, rainforests and ploughed fields have a low albedo (see figure 1.21). Human activities such as land clearing, construction and road building (bitumen) can alter the albedo significantly.

albedo a measure of the ability of surfaces to reflect sunlight (heat from the sun). Light surfaces return much of the heat back to the atmosphere and dark surfaces absorb heat from the sun.

FIGURE 1.21 Measurement of surface albedo



Global warming is also altering the land surface, by affecting the rate of ice melt in many glaciers in the Arctic and on the Antarctic ice shelf. This results in more land being exposed to sunlight, so more heat is absorbed by the Earth. Seas in the far north of the world, such as the Barents Sea, north of Russia, are now ice-free most of the year. This has enormous geopolitical implications for people and animals in these areas.

EXAMPLE: The El Niño/La Niña phenomenon

El Niño and La Niña are weather events marked by unusual sea surface temperatures. El Niño, named by Peruvian fishers in the seventeenth century, describes warmer coastal waters occurring every five to nine years. Normally, the eastern Pacific Ocean remains cool due to the Humboldt Current and upwelling, which attracts marine nutrients and fish. During El Niño, waters warm, leading to failed fish harvests, increased rainfall and flooding in South America's west coast, droughts in southeast Asia and eastern Australia, and cold winters in North America.

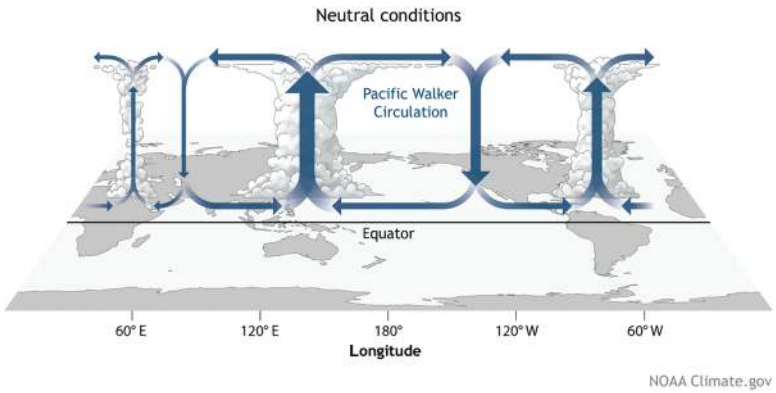
During La Niña years, warm moist air rises over Indonesia, leading to cloud and rain formation. The air cools and dries as it moves eastward in the upper troposphere, descending near South America above the cold Humboldt Current, keeping the region dry.

DID YOU KNOW?

'El Niño' is Spanish for 'little boy' or 'Christ child'. The Peruvians used this term because they first experienced the event around Christmas.

Scientists first thought El Niño was an occasional event that produced high rainfall over Peru and Ecuador, but data has since revealed it is part of a global event involving both the atmosphere and ocean waters. They realised there was a link with the **Walker Circulation** (Walker Cell), which is a model of air flow in the tropics in the troposphere (see figure 1.22).

FIGURE 1.22 The Walker Circulation



Source: NOAA Climate.gov

walker Circulation a model of air flow in the lower atmosphere across the oceans, consistent with differences in air temperature between continents and oceans. It is used as a measure for determining the onset of an El Niño event.

thermocline the cool layer of ocean water below the surface; it is still warmer than the very cold layer on the ocean floor

southern Oscillation Index (SOI) a measure of the development and intensity of El Niño or La Niña events in the Pacific Ocean. It is based on the pressure differences between Tahiti and Darwin.

greenhouse gases gases such as water vapour, carbon dioxide, methane, nitrous oxide and ozone found in the atmosphere; because they absorb radiant energy and trap heat, they help warm the Earth and cause the greenhouse effect

The Walker Circulation consists of easterly winds in the lower troposphere, moist air rising over the western Pacific, westerly winds in the upper troposphere, and descending dry air over the eastern Pacific. This pattern varies annually, causing extreme weather events globally.

During La Niña years, trade winds push warm, moist air towards Indonesia and Australia's east coast, driving ocean circulation and contributing to monsoon systems and Hadley Cells (low-pressure cells). Strong south-easterly winds in the Australian region raise the ocean level about 40 centimetres higher than near South America.

From observation and data, it has been established that El Niño begins when subtle changes occur to the oceanic–atmospheric circulation. Such changes include:

- the intertropical convergence of south-east and north-east winds shifting further south than usual (often shown as a monsoon trough on weather charts)
- surface air pressures over northern Australia rising steadily
- wind intensity from the Pacific to Australia weaking due to warming sea surface temperatures.

These changes are subtle, but their effects are enormous. Once trade winds decrease, the current that draws water from the South American coast weakens, and the bulge of water in the western Pacific (along the Australian coast) flows back towards the east. This flattens out the **thermocline** and warmer water smothers the effect of the cold upwelling along the South American coast.

The best indicator of an imminent El Niño is the strength of the **Southern Oscillation Index (SOI)**, a measure of pressure difference between the central Pacific (Tahiti) and northern Australia (Darwin). Referred to as ENSO (El Niño Southern Oscillation), the difference in surface air pressure is calculated daily and converted to an average figure, or index.

1.4.7 What is the greenhouse effect?

Greenhouse gases are a collection of naturally occurring gases in the troposphere that allow the sun's rays through to the Earth and trap some of the heat. Scientists estimate that without protective greenhouse gases, including CO_2, the Earth's surface temperatures would be approximately –20°C, making the planet uninhabitable. Of the total incoming radiation from the Sun, approximately 31 per cent is reflected by cloud, other air-borne particles and the Earth's surface. The remaining 69 per cent is absorbed by ozone in the stratosphere, water vapour, clouds, pollutant gases in the troposphere and the Earth's surface.

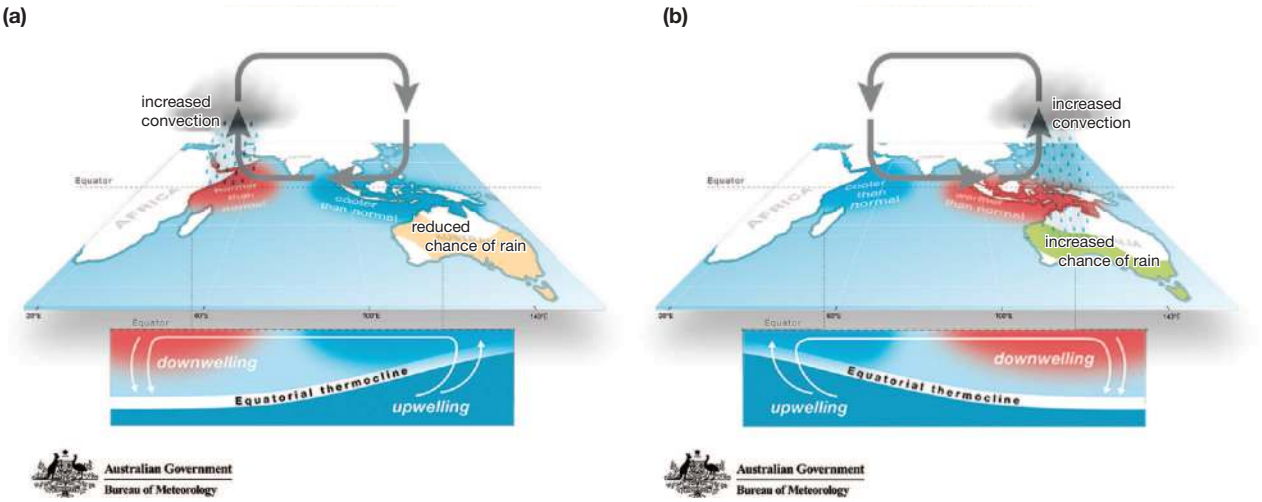
To maintain an energy balance, the Earth releases long-wave radiation equivalent to the amount of incoming short-wave radiation (69 per cent). Since most of this energy comes from the surface and may be trapped by greenhouse gases in the air, surface air temperatures increase until the correct amount of energy is released. Scientists agree that because the Earth is retaining too much heat, an enhancement of the greenhouse effect that controls temperature will upset this balance and affect aspects of climate in many areas.

1.4.8 The Indian Ocean Dipole

The Indian Ocean Dipole (IOD) is a measure of sea surface temperatures between two places, hence the title *dipole*. A meteorologist can measure sea surface fluctuations using a western pole in the Arabian Sea (western Indian Ocean) and an eastern pole in the Indian Ocean, south of Indonesia. Alternating warm and cool ocean temperatures affect the rising and falling of atmospheric moisture, and give a clearer indication of when dry or wet spells may occur over the western mainland.

The IOD experiences both negative and positive phases (see figure 1.23). Meteorologists have concluded that when the IOD is in a negative phase, winds drive moisture towards the Australian coast and rain occurs over the north-west mainland. If the phase is positive, moisture moves away from the mainland and dry spells become frequent over Western Australia. These phases may align with El Niño periods in the Pacific. According to the Bureau of Meteorology (BOM), from 1960, when reliable records of the IOD began, to 2016, 11 negative IOD and 10 positive IOD events have occurred, while others are neutral.

FIGURE 1.23 The Indian Ocean Dipole in (a) positive phase and (b) negative phase



Source: © Commonwealth of Australia, Bureau of Meteorology

1.4.9 The Arctic Oscillation and polar vortex

The far north of the Earth experiences significant seasonal climatic differences due to vast expanses of ice and snow. Two key phenomena affecting climate patterns are the Arctic Oscillation (AO) and the polar vortex.

The AO is part of the climate pattern affecting the Northern Hemisphere, with counterclockwise winds circulating around the Arctic at about 55°N latitude. The North Atlantic Oscillation (NAO) is similar, controlling westerly winds and storm paths.

Changes in the AO and NAO behaviour are measured using an index. During the positive AO phase, the flow around the North Pole is strong, limiting cold air outflow. During a negative phase, weaker winds allow cold air and storms to move south into populated areas (see figure 1.24). Surface pressure cells and land masses (Europe,

Asia, North America) also influence this. The AO and NAO work with the polar vortex, creating undulating wave motions and jet streams that carry icy air to mid-latitudes (causing freezing weather at these latitudes) and bring warm air north (causing ice melt and **permafrost** thawing).

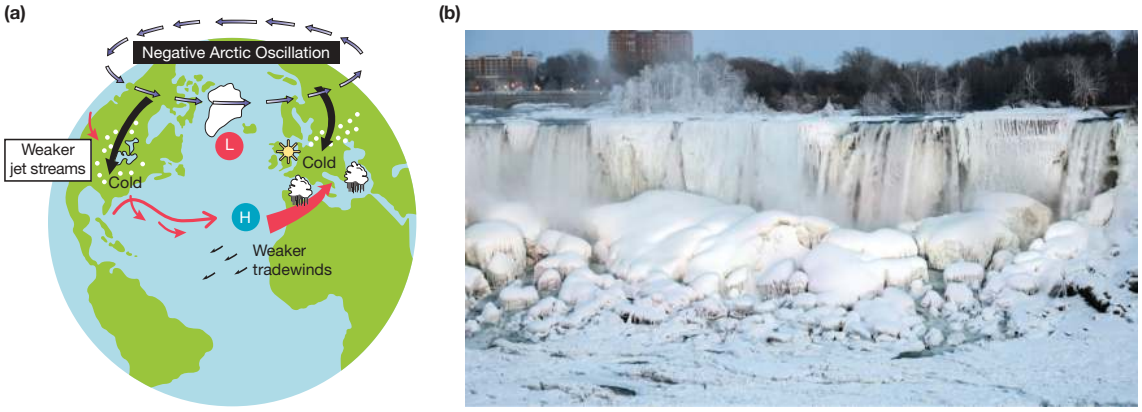
permafrost any ground (rock, soil, sediment) that is frozen or remains 0 °C or colder for a period of two years. It is most common in regions in the high latitudes, such as the tundra. Global warming is threatening to thaw out large areas of permafrost.

Polar vortex

Weather in the far north of the Earth is also influenced by the polar vortex, a large area of swirling cold air at low pressure near the North Pole. The South Pole has a similar vortex, but it has limited effect on human populations since Antarctica is largely uninhabited. While the polar vortex is permanent, it has unique features affecting weather in high latitude regions in northern Europe, northern Asia and North America. These features include the following:

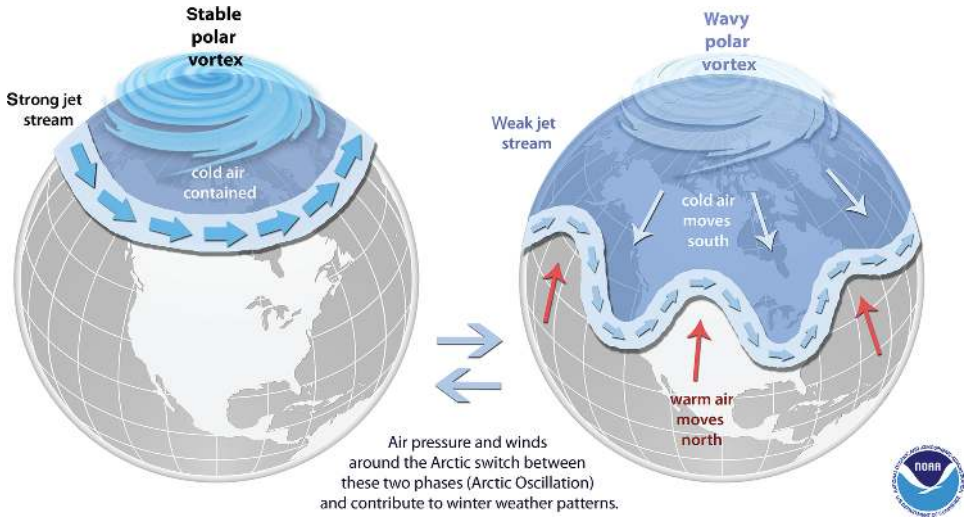
- The polar vortex forms due to significant temperature differences between polar regions and mid-latitudes.
- It builds up during northern autumn and strengthens in winter when there is no direct sunlight. The vortex then weakens but remains stable in summer when sunlight reaches the North Pole.
- It is situated high in the troposphere, meaning cold air can be carried away by jet streams to areas not used to such cold snaps. This disruption can last four to eight weeks, causing freezing conditions in Europe, Russia, Canada and the United States (see figure 1.25), disrupting communities and infrastructure.

FIGURE 1.24 (a) The Arctic Oscillation and (b) its chilling effects



Source: Campos, Camila & Horn, Myriel. 2018. Figure 3, The Physical System of the Arctic Ocean and Subarctic Seas in a Changing Climate: Proceedings of the 2017 conference for YOUng MARine RESearchers in Kiel, Germany. 10.1007/978-3-319-93284-2_3

FIGURE 1.25 The polar vortex can cause abnormally cold temperatures in northern regions during winter.



Source: National Oceanic and Atmospheric Administration

SKILLS ACTIVITY: Analyse geographic data and information

Refer to table 1.1 to complete the following.

1. Construct a vertical bar graph to compare Albedo levels of reflectivity. Use different colours for each of the three categories: low (from 0 to 25), medium (25 to 40) and high (40 and above).
2. Consider why variations exist in albedo between surfaces such as types of soil, snow and grasslands.
3. Describe the interconnections between land cover loss and albedo. Use generalisation to suggest the impact on climate change.

TABLE 1.1 Albedo levels for common surfaces (percentage of solar energy reflected)

Surface	Albedo level
Sea water/lakes	6–7
Bitumen road	5–10
Dark soil	5–15
Grey soil	10–20
Rainforest	5–15
Crops	15–25
Desert	25–30
Savanna grasslands (dry)	25–30
Snow (days old)	40–70
Cumulus cloud	70–90
Snow (fresh)	75–95

1.4 Exercise

1.4 Exercise

Learning pathways

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 5	3, 4, 6, 8	7, 9, 10

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Explain and comprehend

1. **Define** El Niño, La Niña and the Indian Dipole.
2. **Identify** what each has in common, and how each is different.
3. **Describe** briefly how an El Niño affects weather in mainland Australia.
4. **Outline** how meteorologists know if an El Niño period is approaching.
5. **Identify** how often each of these events might happen.
6. **Explain** how the polar vortex differs from the Arctic Oscillation.

Analyse and apply

7. **Explain** how a La Niña period may affect farmers (such as banana and cane growers, and dairy farmers) in eastern Australia.
8. **Explain** briefly how the Indian Ocean Dipole affects the northern regions of Western Australia.
9. **Explain** why the polar vortex over Antarctica seldom creates severe weather events.

Propose and communicate

10. Consider why the polar vortex of late 2013, 2014 and 2015 caused the Niagara Falls to partially freeze (see figure 1.25).

Sample responses for this chapter are available online.

LESSON
1.5 Changes to land cover

LEARNING INTENTION

By the end of this lesson you should be able to explain how changes in land use, such as deforestation, land drainage, land reclamation, resource extraction, intensification of agriculture and pastoralism, coastal modification, and soil and water degradation can interrupt global climate systems and result in land cover transformation at global, regional and local scales.

Natural land cover, or vegetation biomes, exist as a result of the climatic environments that have been created through the interactions between global climatic systems such as precipitation patterns, ocean circulation, heat transfer and global winds. Without any human interruptions, these biomes would continue. An examination of changes to land cover looks at the processes that have transformed natural land cover, such as changes to land drainage, **deforestation**, intensification of agriculture, soil degradation and water degradation. These processes continue to alter natural land cover, which results in the destruction of any remaining truly 'natural' environments. This ever-changing human modification of environments has led to the development of the **anthropogenic biome**.

deforestation the intentional clearing or removal of forests to make way for some other purpose such as farming, housing, constructing a dam, and so on. Deforestation is regarded as a permanent loss of forest and is most common in countries with large areas of rainforest such as Brazil and Indonesia.

anthropogenic biome the human biome, created by human interaction with the biosphere

tundra the very cold, flat and almost treeless biome below the northern Arctic. Because of the permafrost and snow cover for much of the year, there is only a short growing season for some mosses, lichens and grasses.

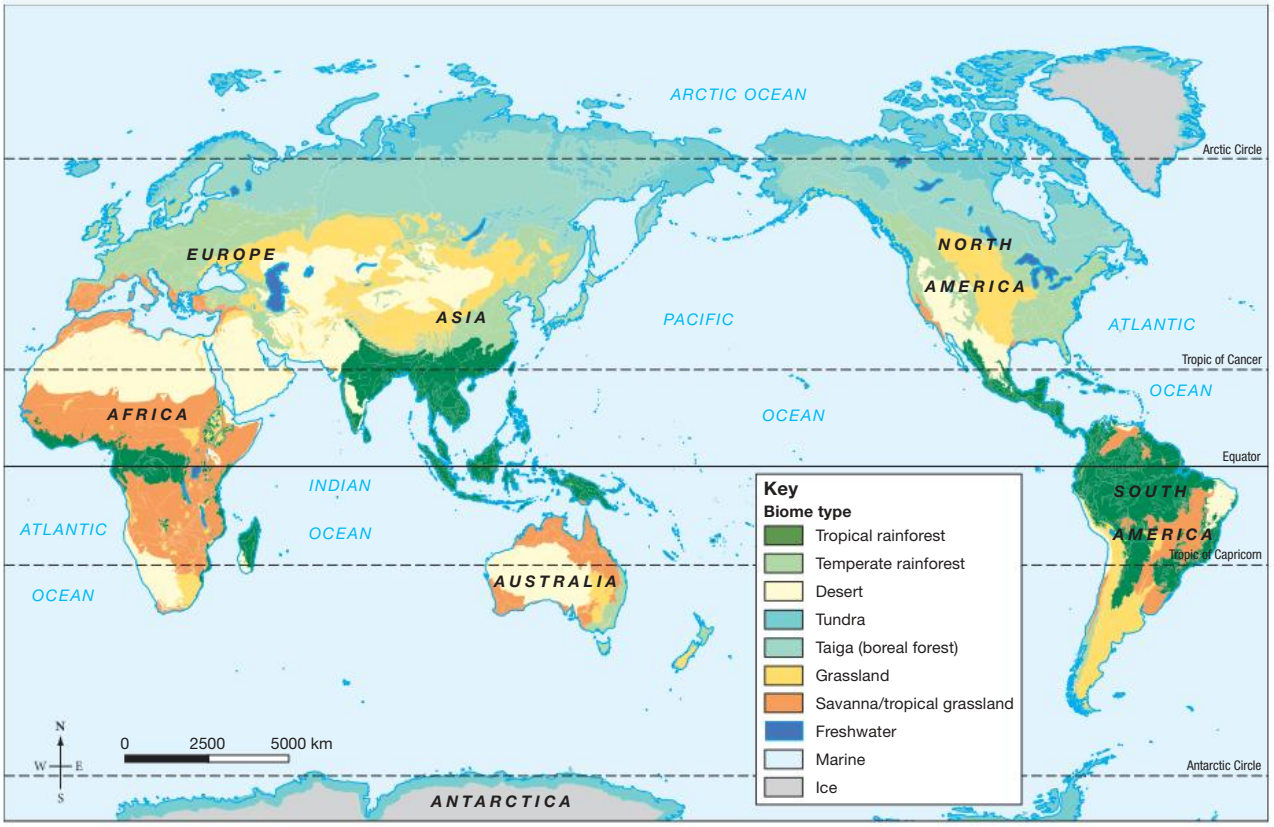
1.5.1 Distribution of land cover — biomes and biogeographical areas

Most terrestrial regions contain large natural landscapes where climatic conditions have been constant for thousands of years. They differ from each other by supporting diverse communities of plants (trees, shrubs and grasses) that have specifically adapted to the climates and soils of those regions. Known as biomes, they are named after their most common vegetation land cover — rainforests, dry forests, deserts, grasslands, woodlands, **tundra**, boreal (taiga) forests, mountain regions and polar regions (see figure 1.26). Biomes are also home to many animal species adapted to their vegetation. For example, a tropical grassland biome supports herbivorous (plant-eating) animals such as giraffes and elephants.

Biomes have their own unique landscapes and landforms, generally because of variations in climate. Each of these variations affect temperature, humidity and rainfall. The main climatic factors are:

- latitude (distance from the equator)
- distance to the sea
- elevation above sea level
- proximity to ocean currents.

FIGURE 1.26 The distribution of the Earth's major biomes



Source: Redrawn by Spatial Vision based on the information from the Nature Conservancy and GIS Data

Biomes also contain smaller biogeographic areas that support specific communities of plants and animals according to precise environmental conditions such as climate, soils and vegetation. Australia, for example, has 89 distinct biogeographic regions, including the wet tropics of North Queensland, the Nullarbor Plain in South Australia and Western Australia, and the Australian Alps in New South Wales and Victoria. Local ecosystems, such as mangrove wetlands, fall into this category based on climate and soils.

Many biomes are favourable places for people to live because they have an abundance of natural resources such as fertile soil, water, timber and animals once hunted by humans. When human populations were small and global systems such as the atmosphere and oceans perceived to be large, people often thought that nature could take care of itself, meaning that these systems were so large they were immune from human misuse and natural catastrophe, and were capable of 'self-healing'. We know now that this is not true.

1.5.2 Factors influencing changes in land use

Increased population growth and demand for food, water and other resources have increased the pressure on the land and fertile soils. Although unoccupied grasslands and forests once existed, and a vast source of arable land lay waiting to be cultivated, people now realise this is no longer the case. Fertile arable land in particular is limited in supply due to urban expansion and human-related degradation over the past century.

Poor catchment management practices involving water removal and irrigation, dam construction, deforestation, waste disposal, overgrazing, overcultivation and chemical pollution have contributed to the degradation of land and water resources. Land cover is further degraded by occurrences such as salinity, soil acidification, soil erosion, desertification, water pollution, loss of wildlife as well as exposing land to the effects of flooding and bushfires. Many projects to sustain economic development, food security and employment have resulted in long-term changes to the Earth's biophysical systems.

SKILLS ACTIVITY: Acquire and represent geographic data and information

Recognising spatial patterns of land cover

Refer to figure 1.27 to answer the following questions.

FIGURE 1.27 Longji rice terraces, Guangxi province, China

Explain the land cover patterns

1. List some of the obvious land cover transformations.
2. What might the hills and slopes have looked like before being used for rice cultivation?
3. Explain why the slopes are terraced.
4. How do you think water is distributed between these terraced paddy fields?
5. What do you think are the main interruptions to some of the Earth's physical systems? Explain.
6. Would you consider these areas 'degraded'? Explain.

SKILL ACTIVITY: Geographic inquiry

Impacts of affluence and technology on land transformation

Refer to table 1.2 to answer the following questions.

TABLE 1.2 Causes and effects of common land cover transformations and interruptions

Image	Land use shown in image	Explain how the land has been 'transformed'
a) image of a dam 	Dam for water storage, irrigation and electricity generation	Originally there was a river or creek valley; dam wall built at planned location; river valley flooded
b) image of a planted bean field 		
c) image of cattle grazing land in Idaho, USA 		
d) image of a solar farm 		

(continued)

TABLE 1.2 Causes and effects of common land cover transformations and interruptions *(continued)*

e) image of a traffic interchange 		
f) image of a rock quarry 		

1. **a.** Identify the different types of land transformation by completing the table.
   b. Explain how the land cover in each has been transformed due to either technology or affluence (wealth).
   c. Consider an example of a location where each of these transformations has occurred.
   d. What impact has each of these alterations possibly had on the original land?
2. What strategies may have been introduced in each case to reduce the impact on people and the environment of the alteration?

1.5 Exercise

1.5 Exercise

Learning pathways

LEVEL 1	LEVEL 2	LEVEL 3
1, 4, 7	2, 6, 8	3, 5, 9

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Explain and comprehend

1. **Identify** the main climatic factors that affect the distribution of biomes.
2. **Name** three types of human activities that contribute to land degradation.
3. **Explain** how latitude affects the climate of a biome.
4. **Describe** two ways in which human modification has altered natural environments.

Analyse and apply

5. **Explain** how an increase in population growth might affect the demand for natural resources.
6. Apply your knowledge of land degradation to **explain** how poor catchment management can impact soil quality.
7. **Compare** and **contrast** the characteristics of a tropical grassland biome and a boreal forest biome.
8. **Analyse** the impact of urban expansion on fertile arable land.

Propose and communicate

9. **Evaluate** the long-term consequences of deforestation on the Earth's biophysical systems.

Sample responses for this chapter are available online.

LESSON
1.6 Anthropogenic activity and how it has transformed land cover

LEARNING INTENTION

By the end of this lesson you should be able to explain, using evidence, how anthropogenic activity (such as changes in land use) may be influencing climate change.

1.6.1 Anthropogenic biomes

As the Earth's population grows, and more people need shelter, food, water and other resources, the number of unexplored or uninhabited places remaining in the world lessens. To satisfy these human demands, people are transforming much of the terrestrial surface. The global population is continuing to grow, but by how much and how quickly? How long can the Earth sustain population growth? How many people can the Earth support? What happens if there are too many people?

Studies have revealed that more than three-quarters of the Earth's ground surface has now been directly affected by human activities and that 24 per cent of the Earth's surface area is most likely to experience a decline in ecosystem function and productivity. At the same time, ocean and atmospheric studies show that the effects of pollutants are universal (see figure 1.28).

FIGURE 1.28 Some effects of population growth and demand for space and resources

Areas that have experienced sustained human interaction are called anthropogenic biomes.

The physical spread of people around the world has been studied multiple times. German botanist-climatologist Wladimir Köppen mapped the original climatic zones in the early 1900s. These maps showed significant sections of the land surface to be unoccupied or pristine wilderness. However, a study by Erle Ellis and Navin Ramankutty in 2008 revealed that up to 77 per cent of the terrestrial surface is now human-dominated. They have re-mapped these human-altered landscapes into a mosaic of anthropogenic biomes, and their research has also shown that with technological advantage, people can live almost anywhere, apart from the most extreme environments. The only remaining wilderness areas are in very isolated mountains, forests, hot deserts or ice caps.

People use land resources for a range of activities, including agriculture, urban development, manufacturing, transport, water supply, forestry, coastal and port functions, energy and mining. Using three criteria — **population density**, land use type and common vegetation — Ellis and Ramankutty identified six major anthropogenic biomes. These are:

- dense settlements
- villages
- croplands
- **rangelands**
- forests
- wildlands.

1.6.2 Land cover change and climate change — is there a connection?

The effects of landscape change have become more noticeable as populations have increased and people have moved into what were once considered isolated or inhospitable environments. Over the past 200 years, the Earth's cover has been subjected to a great deal of alteration. Most changes have occurred in the land cover biomes. These changes include:

- forest and scrubland clearing for farming cultivation, cattle grazing, plantation **crops**, industrial development and urban expansion
- overgrazing and vegetation removal in arid areas resulting in desertification
- dam construction and diversion of waterways
- pollution of the atmosphere and waterways
- loss of wildlife habitats and depletion, and extinction of many wildlife species
- storage and careless dumping of solid and liquid toxic wastes
- extraction of natural resources such as **minerals**, timber and marine creatures.

population density a measurement of the number of people located in a given area, usually the number of people per square kilometre

rangelands a broad term describing remote country used for grazing domestic livestock or wild animals. They include tallgrass and shortgrass prairies, semi-desert grasslands, shrublands, woodlands, savannas, chaparrals and steppes. Much of Australia's inland could be classed as rangeland.

crops plant or animal products that can be grown and harvested for consumption and/or profit

minerals naturally occurring solid chemical compounds (e.g. salt, quartz)

evapotranspiration the process of water transferring from the land to the atmosphere via evaporation and transpiration

Activities and events such as deforestation, desertification, land drainage, land reclamation, resource extraction, intensification of agriculture and pastoralism, coastal modification, and soil and water degradation can interrupt natural processes and systems. In recent times, land clearing and deforestation have been linked to desertification and an increase in surface albedo (refer to section 1.4.6). This results in a cooling effect, particularly in mid–high latitudes, and eventually lower rainfall. Deforestation also lowers **evapotranspiration**, again contributing to lower rainfall because less moisture is released into the air. These events may be contributing to global warming, climate change, extreme weather events, sea level rise, glacial and ice cap melting, and coral reef deterioration.

Forests are very important in regulating climate change. Like oceans, forests act as a carbon sink that absorbs carbon dioxide and other greenhouse gases that would otherwise remain free in the atmosphere. When large areas of forest are destroyed, this vital role as a sink is lost. Scientists estimate that approximately 15 per cent of all greenhouse gas emissions are the result of deforestation. As well, trees protect the topsoil with their roots and overhead canopy by reducing the impact of heavy rain. When trees are removed, so too is the protection for soils, which are easily weathered and washed into rivers. As nutrient-rich soils are washed away, people think they need to clear more land to grow crops. Land activities such as farming requires ploughing of soil, grazing and timber extraction, and these activities result in soil loss, and mining and quarrying require digging and movement of soil (see figure 1.29). All of these contribute to soil erosion. It is easy to forget that this same soil is essential for future generations.

FIGURE 1.29 Prime farming land can be destroyed by mining.

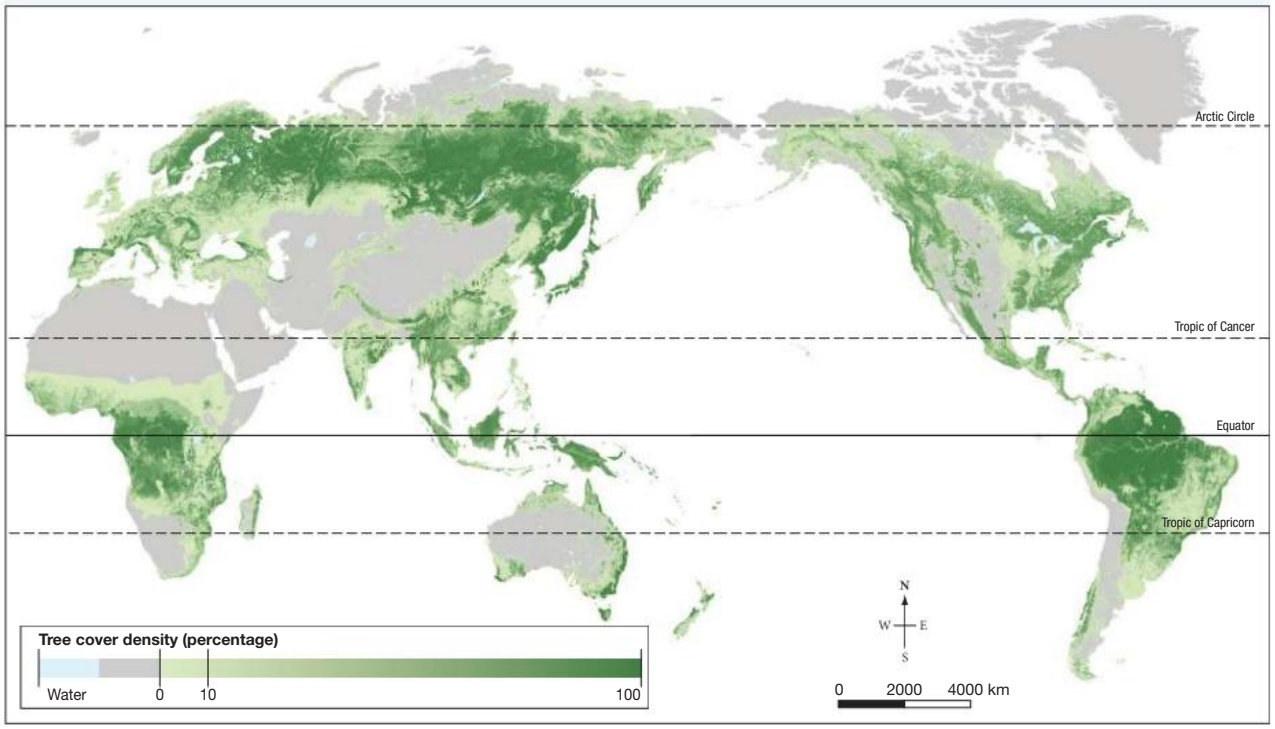
Australia's diverse climate zones, topography and soils support a wide range of land covers and uses. However, land cover change in Australia is different from many other industrialised countries where land usage patterns have become relatively stable. In Australia, land use patterns are still undergoing significant change, with approvals still being given to the farming and forestry sectors to 'open up' more land and retrieve timber. At a time when coal-fired power stations are being phased out in many countries, governments in Australia are still considering maintaining existing coal mines.

1.6.3 Forests — the dominant land cover

Forests are the largest and most widespread of all biomes (see figure 1.30). Dominated by trees, forests cover approximately 31 per cent of the land surface, support the most terrestrial **biodiversity** and contain up to 80 per cent of the total plant biomass.

biodiversity biological diversity; describes the variation of living plant and animal species that occupy an area or ecosystem

FIGURE 1.30 Location of the world's forests



Source: Food and Agriculture Organization of the United Nations, 2010, FAO Data, http://foris.fao.org/static/data/fra2010/forest2010mapwithleg.jpg. Reproduced with permission.

Forests are the most complex land biome. Depending on the climate, soil, aspect and elevation, they support more than 60 000 different species of trees. They also provide habitats for wildlife, timber for building and may be used as national parks.

The trees in forests have many uses. Scientists estimate that approximately 1.6 billion people rely on forests for food, freshwater, timber, clothing and traditional medicine. However, a forest's greatest asset is probably its ability to store carbon in its wood. A healthy growing tree can absorb about 20 kilograms of CO_2 each year. A tree that has lived for 40 years will have stored at least a tonne of CO_2.

Forests can be classified in many ways. Tropical and sub-tropical rainforests are found in the warmest regions, temperate forests in the mid-latitudes, and boreal coniferous forests in the colder climates. Geographers group them by biome (e.g. rainforest or open forest) and biogeographic area (e.g. mangroves or mulga). Others, such as botanists, may group them according to leaf type (e.g. evergreen, deciduous, coniferous or eucalyptus — see figure 1.31). Human interference is reducing the amount of forest land cover all over the world.

FIGURE 1.31 Eucalyptus forest; flooded gum is the dominant species.

Source: Bill Dodd

Around 100 years ago, the world supported about 50 million square kilometres of forest, but today that has declined to about 40 million square kilometres. Evidence also reveals that people are cutting down forests at an alarming rate. According to the Food and Agricultural Organization (FAO), approximately 7.3 million hectares are destroyed each year. These are mostly rainforests in Indonesia, Brazil, Thailand and the Democratic Republic of Congo.

1.6.4 Tropical rainforests

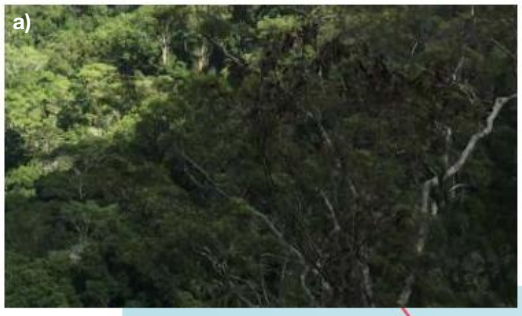
Rainforests are thriving communities of plants that have adapted to very high levels of rainfall and humidity and have attained a state of ecological climax. They feature a closed canopy and high tree density that prevents sunlight from reaching the understory and ground layers. This creates a shady and damp environment and luxuriant vegetation.

Tropical rainforests (once called jungle) grow in hot, equatorial countries such as Brazil, Indonesia, India, Malaysia, Papua and New Guinea, Zaire, and northern Australia (see figure 1.32).

Temperate rainforests also flourish in wet, cooler places such as southern Queensland and New South Wales, and colder areas such as Tasmania or New Zealand.

FIGURE 1.32 Aspects of tropical rainforests: (a) Rainforest canopy East Africa, (b) Orangutans are found in the rainforests of Borneo and Sumatra, (c) Australia has rainforests including the Daintree, (d) Toucans populate the rainforests of Mexico, Venezuela and Colombia

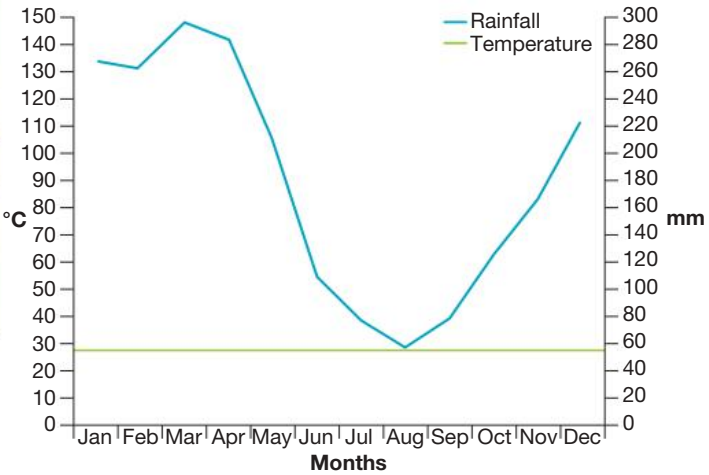
Tropical rainforests are found in the warmest and wettest countries of the world such as Brazil, Indonesia, India, Malaysia, Papua and New Guinea, Zaire, Peru, Gabon and northern Australia. Rainfall totals may vary from as little as 250 mm /year to as mush as > 3000 mm /year. Rainfall is generally constant while humidity remains high. Temperatures rarely drop below 20°C.



Source: **Bill Dodd**

***Source*:** Bill Dodd

A typical precipitation and temperature model for a rainforest area



***Source*:** © Climate-Data.org / AM OP / OpenStreetMap contributors

Rainforest features

Location

Rainforests cover 6 per cent of the Earth's land and produce up to 40 per cent of its oxygen. Tropical rainforests are near the equator, mainly in South America, South-East Asia, Africa and Australia. Temperate rainforests grow in cooler coastal areas of North America, Chile, southern Australia and New Zealand.

Appearance and species

Tropical forests are ancient and support diverse species, especially birds, reptiles and insects.

Common features

The common features of rainforests include the following:

- identifiable layers. The canopy has dense vegetation that limits sunlight to the understorey. It contains tree crowns, vines, strangler figs, epiphytes and orchids.
- old and developed, such as the Amazon rainforest, which is about 55 million years old.
- diverse plant and animal species, with rainforests housing over half of known animal species and two-thirds of known plant species. Each square kilometre can have up to 100 different tree species.
- a decomposing layer of leaves and twigs that maintains nutrient recycling. Fungi and bacteria help decompose tonnes of leaf litter daily, enriching the soil.
- unique plants adapted to wet conditions, such as buttress roots for support in shallow soils and cauliflory on tree trunks
- humid and shady conditions creating a microclimate.

Weather and climate

Rainforests thrive in hot/warm and wet weather conditions, where temperatures seldom fall below 18 °C and humidity is generally high (>75 per cent).

Vegetation

Vegetation in rainforests is highly dependent on moisture and shade. Rainforests feature very large, tall trees that provide food and many other resources. Due to the wet soil, the large trees need buttress roots to support them. The tallest trees provide a canopy that blocks up to 95 per cent of sunlight from the forest floor, and an understorey that contains palms, ferns, lianas, strangler fig, epiphytes and orchids. Approximately 3000 edible fruits grow in rainforests, many with medicinal capabilities. Several trees provide everyday goods, such as coffee, rubber, bananas, mangoes and figs, while others, including the cedar, maple, teak and mahogany varieties, provide valuable timber.

Wildlife

Due to their wide range of locations, rainforests support many different species of mammals, birds, insects, reptiles, amphibians, fish and worms. Some of these include the gorilla in Africa, the jaguar in South America and the orangutan in South-East Asia. Scientists estimate that half of the 10 million known species of animals, insects and plants live in rainforests. The majority of these are insects, such as butterflies, beetles and mosquitoes. Many smaller animals such as monkeys, sloths and possums live in the trees to avoid predators, and some rarely descend to the forest floor.

Human activities

Some countries have indigenous communities that live in the rainforest, and these people see the forest as their home, which provides shelter and food. In developed countries, remaining rainforests are protected as national parks or wildlife reserves, where people visit for camping, hiking and other forms of recreation. Many scientists study rainforests because they are places of medical and biological learning. However, many rainforests are destroyed by human activities, such as either legal or illegal logging, mining, clearing for growing commercial crops such as palm oil and cocoa.

FIGURE 1.33 A rainforest has a canopy that protects understorey and ground-layer plants from direct sunlight.

DID YOU KNOW?

Rainforests play an essential role in regulating the balance between O_2 and CO_2 in the atmosphere. Often called the 'lungs of the Earth', rainforests can absorb (store) about 260 gigatons of carbon each year.

1.6.5 Using forests for recreation and national parks

National parks protect areas of significant biodiversity or unique landforms under law. They often form part of community projects to preserve nature for future generations. Rainforests, now rare in many countries, are frequently designated national parks or heritage sites with limited access to safeguard them and their wildlife. These parks provide opportunities for public education and enjoyment, emphasising the importance of conserving ecosystems.

Queensland's notable forest national parks include Lamington, Eungella, Daintree and Springbrook. The Gondwana Rainforests, covering about 366 500 hectares between south-east Queensland and Newcastle in New South Wales, attract up to 2 million visitors annually.

Clearing of rainforests

Deforestation, the intentional clearing of forests for agriculture, ranching, logging, mining and development, has significantly transformed rainforest areas over the past 200 years. This process disrupts the carbon cycle, enhancing the greenhouse effect. Forest-clearing methods include burning, clear-felling and logging, leading to immediate and long-term environmental degradation such as loss of soil fertility and wildlife, and moisture transpiration affecting global precipitation patterns.

Large-scale deforestation in Brazil and Indonesia for activities such as cattle ranching, palm oil plantations and mining has increased in recent years. According to the Food and Agriculture Organization, around 8 million hectares of forest are cleared each year, equivalent to 27 football fields per minute.

The value placed on pasture and plantation land drives widespread deforestation in places such as Brazil and Indonesia. Deforestation often occurs to make way for animal grazing, agriculture and mining (Brazil), plantations for palm oil (Indonesia and Borneo), and mining (Brazil). For example, in Brazil, pasture land

has more value than forested land, so clearing is the preferred option for both farmers and land speculators. Approximately 70 per cent of forest clearing in Brazil is for cattle grazing. Deforestation is widespread in Indonesia to allow companies to grow palm oil for biofuel and food additives. Nearly 40 per cent of the world's certified palm oil comes from these areas, impacting global certified palm oil production.

SKILLS ACTIVITY: Analyse geographic data and information

Explaining the motives and effects of large-scale deforestation

FIGURE 1.34 The effects of deforestation

Healthy ecosystem

- Trees intercept rainfall to protect forest floor
- Leaves fall to ground to supply nutrients to soil
- Bacteria and fungi convert litter to humus
- Sunlight activates photosynthesis and food taken in by roots
- Leaves absorb CO_2 and release oxygen into the air
- Carbon sequestered by wood
- Very little soil erosion
- Habitat for many animals and birds

After deforestation

- No trees to reduce impact of rainfall; significant soil erosion
- No leaves to nourish soil
- No humus replacement
- Carbon released when forest burnt; no oxygen produced
- Increased loss of nutrients by leaching
- No longer habitat for wildlife
- No evapotranspiration and therefore less moisture for precipitation

1. Referring to figure 1.34, compare the differences between a healthy rainforest ecosystem and one where trees have been removed and the ecosystem eliminated.
2. Write two extended paragraphs to explain these differences by using the key points listed in your sentences.
3. In a third paragraph, attempt to generalise how these changes might impact on the future of local anthropogenic biomes, such as a forest park.
4. The clearing of rainforest occurs for reasons including cattle ranching and palm oil planting. Choose one reason for the clearing of rainforests in Brazil or Indonesia. **Investigate** the reasons further including the economic, social and environmental effects of the clearing. **Organise** your information in a table format.

Criteria	Advantages	Disadvantages
Economic (local and national)		
Social (local communities)		
Environmental (plants, soils, wildlife)		

5. **Research** and **discuss** alternative land-use strategies that could reduce rainforest clearing while still supporting local communities and the economy.

1.6.6 Tropical grasslands (savanna) and rangelands

The term **savanna** refers to a biome classification first used by the people in Central America when referring to flat treeless areas where they lived. Today, it is used to describe similar grassy and scattered tree plains anywhere in the world (see table 1.3), but particularly the tropical grasslands of eastern Africa and northern Australia. Many savanna areas have been converted into rangelands, a general term that also includes shrublands, woodlands and semi-desert areas used for grazing domestic livestock or wild animals. Rangelands is also used to describe both tallgrass and shortgrass **prairies**, **steppes**, **chaparrals** and some tundras if used for animal grazing.

savanna the region of tropical grasslands intermixed with woodlands. Trees are widely spaced and there is no distinct canopy

prairies vast stretches of temperate grassland with few trees. They are fertile due to the thousands of years of decaying grasses. Because soils are highly compacted with few air spaces, it is difficult for trees to grow.

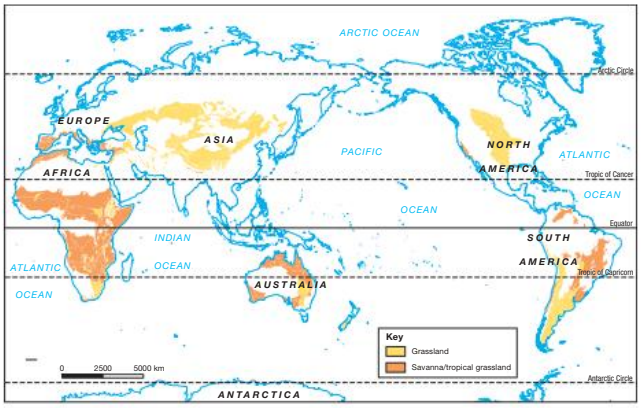
steppes flat grassland with no trees

chaparrals the hot, dry shrublands and heath country in the US and South Africa

Savanna lands form a transition zone between forest regions and hot deserts. Because biomes are controlled by climate, they don't have definite boundaries. Instead, they gradually merge into different landscapes, sometimes having features of both biomes. Savanna regions have some trees but also dry grassy features.

Some of the important land features and uses of tropical grasslands are outlined in table 1.3.

TABLE 1.3 Features of tropical grasslands

Category	Details
Location  *Source:* MAPgraphics Pty Ltd, Brisbane	Africa, central Asia, South America, Australia; between tropics of Cancer and Capricorn
Appearance and features 	Extensive plains, tall grasses up to 4 m, hills, mountains, deciduous trees (e.g. Umbrella Thorn Acacia, Boab tree)

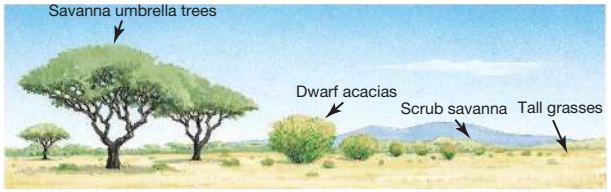
Weather and climate 	Tropical, temperatures 20–32 °C, wet summers, dry winters, annual rainfall 1000–1500 mm
Vegetation 	Coarse, low grasses, drought-tolerant, fire-resistant, thorny plants, sporadic deciduous trees (e.g. Boab tree)
Wildlife 	Giraffe, elephants, zebra, wildebeest, buffalo, lions, cheetahs, hyenas, jackals, hippopotamus, crocodiles
Human activities 	Nomadic herding, grazing, harvesting wood, fruit, seeds, national parks, safari tourism; prone to land degradation

FIGURE 1.35 (a) Farmers' huts in Zimbabwe and (b) a baobab tree in the grasslands of Zimbabwe

DID YOU KNOW?

Hunters and poachers kill about 20 000 elephants each year in Africa, often for a single body part that is sold illegally on the 'black market'.

CASE STUDY: Namibia and Zimbabwe to cull elephants because of drought

Quick facts: Namibia and Zimbabwe

- **Population Namibia** 3 million
- **Population Zimbabwe** 16 million
- **Total estimated elephant numbers in Africa** 415 000

In 2024, authorities in Namibia announced plans to cull (kill) over 700 wild animals in areas they believed numbers exceeded the available grazing and water supply. The planned cull included 83 elephants, 30 hippopotamuses, 60 buffalo, 50 impala, 100 wildebeest and 300 zebras. The government then planned to distribute meat from the animals to people unable to grow food due to the prolonged drought.

Zimbabwe was also planning to kill 200 elephants and distribute meat to its people. A lack of food security due to climate change and difficulty obtaining grain because of war is affecting many southern African countries. At the time of the cull, authorities argued that if they did not take this action, human–wildlife conflicts would inevitably increase.

SKILLS ACTIVITY: Act on geographic knowledge

Exploring the impact of changing land use of the savanna into farmland

Read the information on the transformation of savanna grasslands in various African countries and complete the questions.

The African Development Bank (AfDB) is leading initiatives to transform Africa's savannas into productive agricultural zones, enhancing food security and economic growth. The Technologies for African Agricultural Transformation for the Savannahs (TAAT-S) program aims to convert 16 million hectares to farmland for crops such as maize, soybean and rice using modern techniques.

Country-specific initiatives include the following:

- Ghana: The Savannah Agriculture Value Chain Development Project (SADP) (2023–2027) will boost maize, rice and soybean production across 8000 hectares.
- Tanzania: A US$129.7 million youth agribusiness initiative will empower 11 000 young 'agripreneurs'.
- Ethiopia and Sudan: Projects focusing on wheat self-sufficiency, with Ethiopia aiming for export potential and Sudan increasing production by 645 000 metric tonnes.

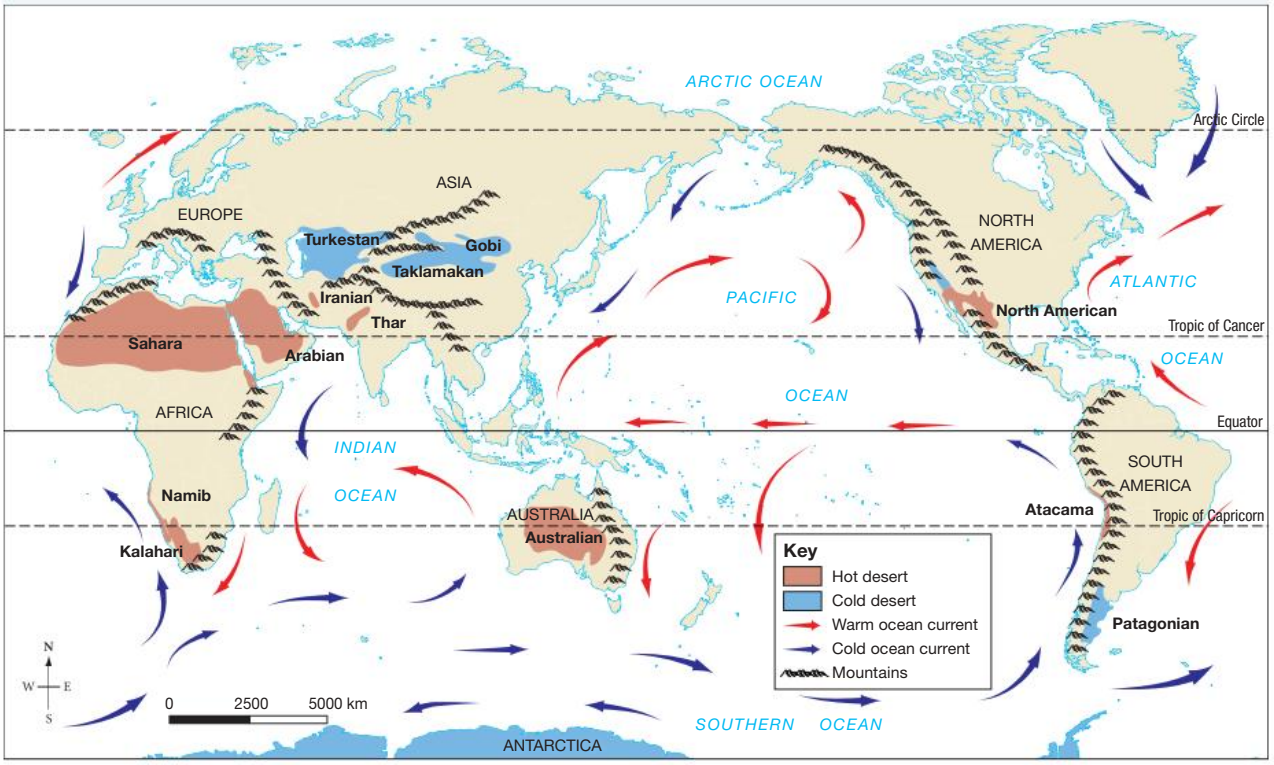
These initiatives highlight AfDB's commitment to sustainable agriculture, climate resilience and reducing reliance on food imports.

1. Conduct a SWOT analysis (strengths, weaknesses, opportunities and threats) for the TAAT-S program. Focus on its potential impact on food security, economic growth and environmental sustainability.
2. Evaluate the possible social, economic and environmental impacts of converting savanna grasslands into farmland. Consider both the positive and negative consequences for local communities and the ecosystem.
3. Compare the agricultural transformation initiatives in Ghana and Tanzania. What are the key similarities and differences in their approaches, and how do these relate to the specific needs of each country?

1.6.7 Deserts

The Earth contains large areas of hot, dry land known as desert. Deserts are areas that receive less than 250 millimetres of rain in a year and where land has less than 50 per cent of the ground surface covered by vegetation. Scientists estimate that deserts (hot and cold) cover approximately 20 per cent of the terrestrial surface. Hot deserts experience extreme sun and heat due to their proximity to the equator; cold deserts are generally found in mountainous areas between the polar regions and the tropics, which means they receive less Sun and tend to be colder during winter. (Figure 1.36 shows the locations of deserts around the world.) Despite their often harsh conditions, deserts can be used by people for mining, extensive cattle grazing, scientific observations, remote weapons testing and military bases.

FIGURE 1.36 Locations of major desert biomes



Source: MAPgraphics Pty Ltd, Brisbane

Some of the important land features and uses of deserts are outlined in table 1.4.

TABLE 1.4 Features of deserts

Category	Details
Location	Deserts are found on every continent except for Europe. Hot deserts are found between latitudes 15 and 30 degrees north or south of the equator, on the western side or middle of a continent, and in regions adjacent to large mountains where there is a rain shadow.
Reasons for formation	High pressure cells prevent clouds forming; cold ocean currents prevent moisture; high mountains create rain shadows.
Appearance	Deserts are rocky and often classified by rock type: erg (sandy; see figure 1.38), reg (stony), hamada (rocky). Some have large salt pans.
Weather and climate	Extreme temperatures: hot days, cold nights. Summer temperatures can exceed 45 °C and drop below 0 °C. Low rainfall (less than 250 mm annually), high run-off and erosion, humidity less than 20%.
Vegetation	Plants are drought escapers (e.g. saltbush, ephemerals) or drought resisters (e.g. cactus, spinifex, mulga, coolabahs, ghost gums, river red gums).
Wildlife	Active at night (e.g. camels, foxes, bilbies, snakes, lizards, scorpions, beetles).
Human activities	Tourism (e.g. Uluru, Kata Tjuta, Wave Rock, Kings Canyon, Standley Chasm, Grand Canyon and Nevada Desert) and mining (e.g. gold, iron ore and opals).

FIGURE 1.37 Erg deserts are dominated by large, sandy dunes that are shaped by the wind.

DID YOU KNOW?

Large waterholes and oases still exist in the Sahara Desert, thousands of kilometres inland. Figure 1.38 shows Oum al-Maa Lake, an oasis in the middle of the Ubari Sand Sea in south-western Libya.

These natural oases have long supported small-scale agriculture and trade routes. However, anthropogenic activities—such as over-extraction of groundwater, modern irrigation, and desert tourism—are increasingly altering the delicate balance of these ecosystems.

FIGURE 1.38 Oum al-Maa Lake in the Sahara Desert

1.6.8 Desertification

Desertification turns fertile land into unproductive arid areas due to human activities such as overgrazing or natural causes such as drought (see figure 1.39). This process increases albedo (refer to section 1.4.6), reflecting more heat back into the atmosphere and raising global temperatures, which in turn accelerates desertification by altering precipitation patterns.

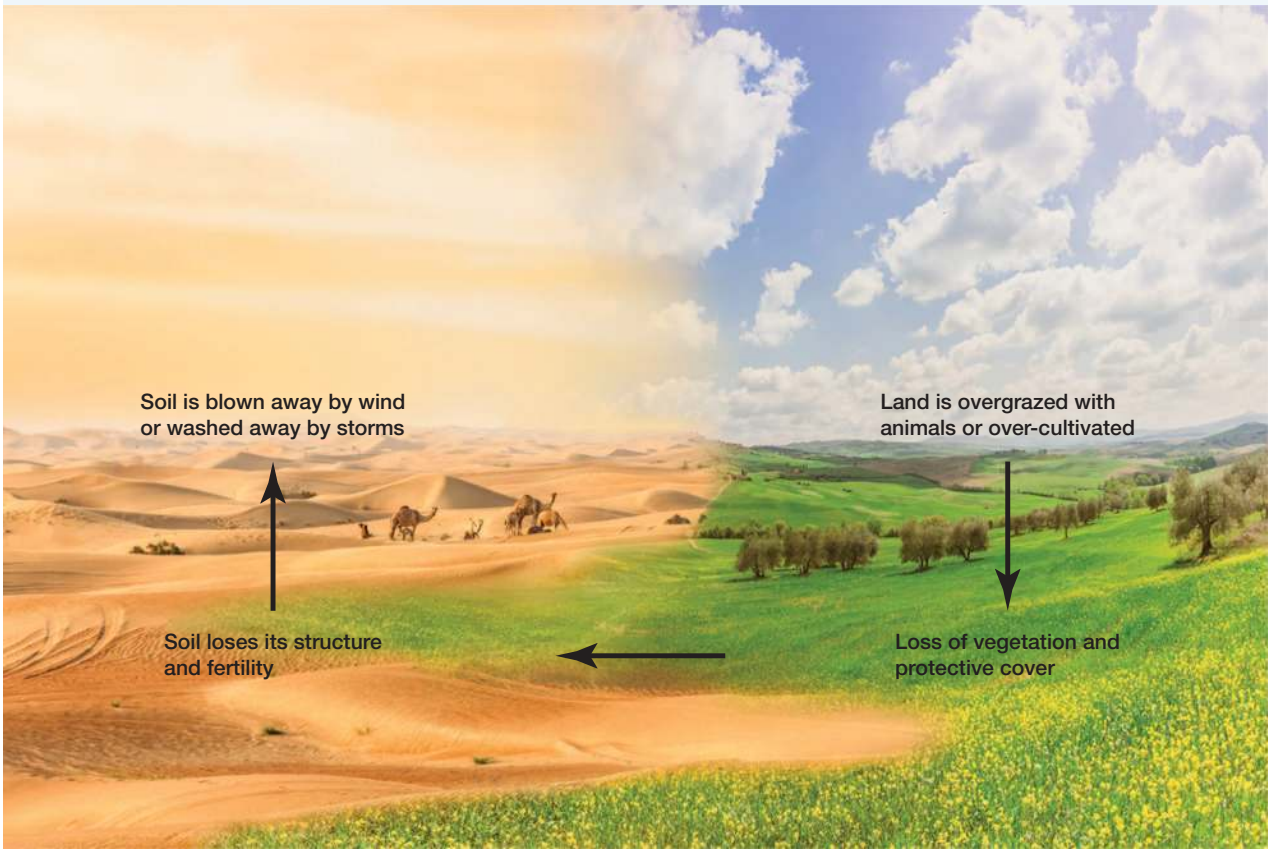
Poor traditional farming methods have contributed to large-scale desertification, but reversing it requires more than stopping these practices. It involves changing societal attitudes and developing innovative farming techniques. Efforts such as the UN's Millennium Development Goals aimed to address this, but poverty, war, corruption and climate change have hindered progress. With many of the world's poor living in drylands, they lack the resources and skills to combat desertification, necessitating a global approach. This approach includes:

- eradicating extreme poverty and hunger
- assisting developing countries in developing sustainable land management programs
- encouraging international research, development and cooperation where all countries can benefit from new technologies and farming practices.

At a local or regional level, governments may:

- integrate soil conservation, and land and water management programs with strategies to protect soils from erosion, salinisation and other forms of degradation
- implement programs of desert greening, where strategies are developed for the reclamation of deserts for agriculture, forestry or biodiversity. Desert greening also has the potential to solve water, energy and food shortages.

FIGURE 1.39 Causes of desertification



CASE STUDY: Desertification in Africa

Quick facts: Africa and desertification

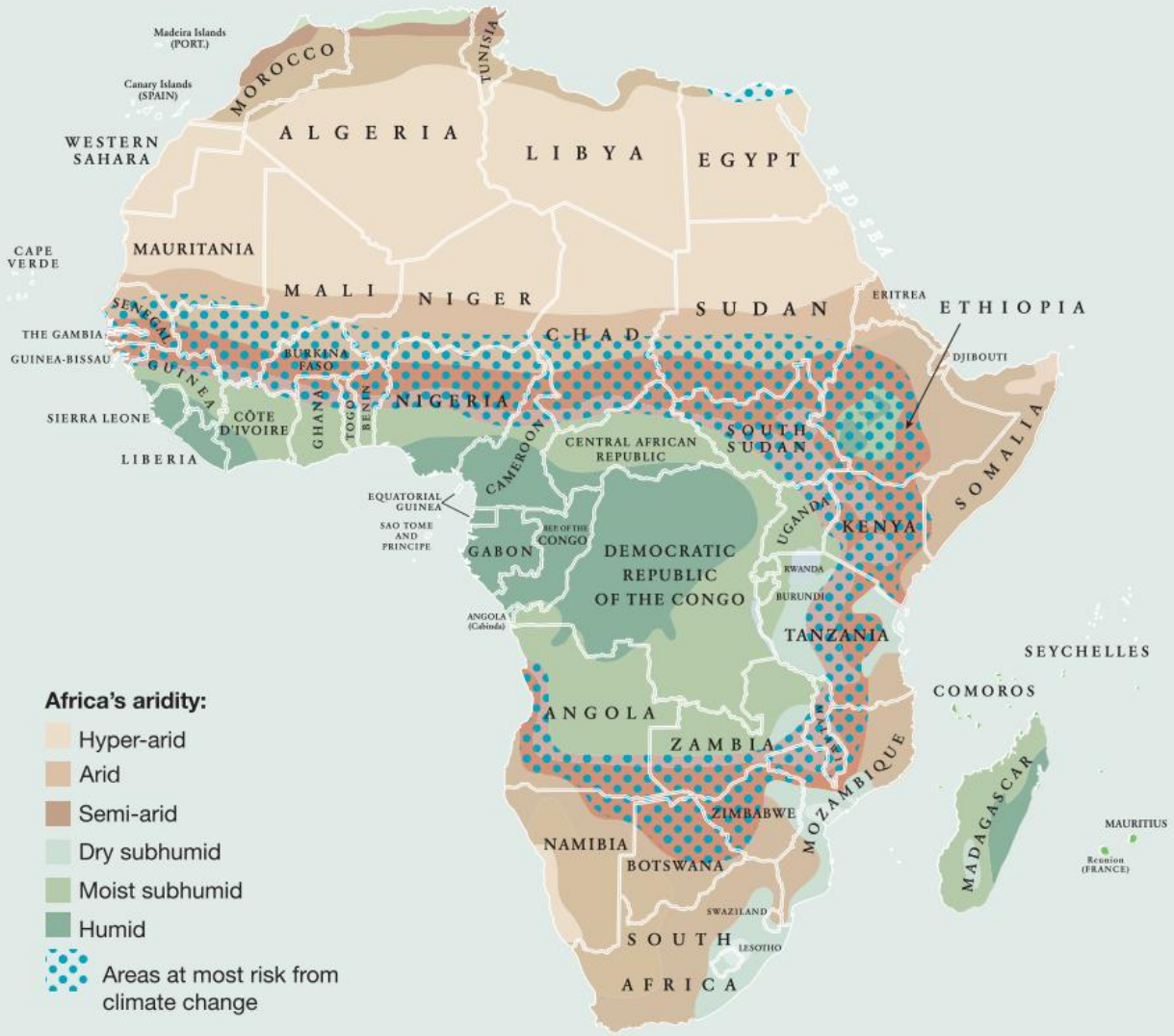
- **Total population of Africa** 1.5 billion
- **Average GDP per capita** US$2955
- **Sahara Desert total area** 9.2 million square kilometres

Located on the southern edge of the Sahara Desert in Africa, the Sahel is a semi-arid grassland/savanna biome that stretches from the Atlantic Ocean on the west coast to the Red Sea on the east coast. The Sahel includes parts of Sudan, Chad, Niger, Mali and southern Mauritania, and forms a buffer zone between the hot Sahara Desert and the humid savanna grasslands further south.

FIGURE 1.40 Herders still graze their livestock in the Sahel, but available vegetation is decreasing.

The Sahel has been used for grazing and farming, but over-grazing and over-farming in the twentieth century, combined with droughts, led to severe degradation. Vegetation loss and erosion turned much of the area into a wasteland, resulting in a famine during the 1970s that killed approximately 100 000 people and most livestock. Chad, centrally located in the Sahel, experiences significant impacts from variable wet seasons, affecting pastureland and food security. The Sahel faces increased desertification and climate change, posing future risks of further desertification and food insecurity unless efforts to mitigate these issues are implemented.

FIGURE 1.41 Areas most at risk from climate change in Africa



Source: CNN, data from Grid-Arendal, Columbia University

1.6.9 Coastal biogeographic areas — mangroves and wetlands

The term **wetlands** is used to describe low-lying areas containing salt marshes, swamps, bogs, peatlands and mangroves. A wetland is a discrete ecosystem that is regularly inundated by water, and so has its own unique plants and wildlife, particularly birds. Even though wetlands may be found in most countries, local variations exist, depending on climate, topography, soil type, water quality and type, and even human activities.

wetlands low-lying areas containing salt marshes, swamps, bogs, peatlands and mangroves; regularly inundated by water

Wetlands are usually classified into two groups:

- coastal tidal wetlands (mangroves, salt marshes)
- inland or non-tidal wetlands (lakes, streams, lagoons, swamps, billabongs).

Coastal wetlands

Coastal wetlands are the low-lying areas adjacent to coastlines and may include mangrove forests, aquatic subtidal beds with seagrass and kelps, as well as coastal marshes and swamps. The Australian coastline contains extensive areas of wetland, particularly in far northern waters around the Gulf of Carpentaria and the top end of the Northern Territory. Many other smaller pockets exist around stream estuaries, bays, inlets, sheltered islands and secluded backwaters not affected by **littoral drift**.

littoral drift the movement of sedimentary materials into the littoral zone (shoreline) under the influence of waves and tides

Coastal wetlands have several key ecological functions. These include:

- providing an energy buffer between marine and land systems to reduce the effects of wave erosion and river flooding
- being a safe haven and nursery for juvenile fish and crustacea (mud crabs, prawns and shrimp)
- being a source of food and nutrients for many marine food chains
- providing a habitat for many species of migrating and coastal birds, and dugong
- acting as an outside laboratory where marine research can be conducted.

Coastal wetlands contain water of varying salinities where only salt-tolerant plants (halophytes) can grow. Fluctuating water levels and moving soil due to tides ensure most shallow coastal mud flats or sand bar flats are without vegetation.

Seagrasses and kelp (a brown seaweed) grow in shallow coastal waters where sunlight can reach the sea floor. Seagrasses are angiosperms, a higher order plant that produces flowers, but like terrestrial grasses, need sand or mud to secure their root systems. More than 50 species of seagrass are found globally, with 25 found in Australia. They provide food and protection for small marine creatures but are sometimes considered a nuisance by boaters because they wrap around boat propellers.

The dominant coastal wetland plant is the mangrove, a tree with aerial root systems capable of growing in saline water and compressed sand that is low in oxygen (anaerobic) (see figure 1.42). When undisturbed, mangroves become dense and form forests. The thick network of intertwined roots is covered by saltwater at high tide and exposed at low tide. Mangrove root systems act like baffles, slowing water movement between tides and trapping silt. This sediment mixes with detritus from the sea floor and algae, providing nutrients for mangrove plants and small crustacea and fish seeking protection from larger predators. Mangrove forests are among the most carbon-rich forests, storing carbon dioxide and other greenhouse gases in their flooded soils for millennia.

FIGURE 1.42 Mangrove at Nudgee Beach, near Brisbane

Source: Bill Dodd

Despite the ecosystem services they provide, mangroves are being destroyed at a high rate. Coastal development and aquaculture reduce the spread of mangroves, and scientists estimate that between 1980 and 2000, 35 per cent of global mangrove forest was lost. Consequently, due to changes in climate creating an increase in extreme weather events such as coastal low-pressure systems, significant coastal erosion had occurred because the mangrove forests no longer buffer the wave energy. This has created a negative feedback loop.

Inland wetlands

Inland or non-tidal wetlands are shallow, freshwater areas not affected by tidal action and include lakes, streams, lagoons, marshes, swamps, billabongs and bogs. They are constantly inundated because the water table is either at or close to the surface. Inland wetlands are generally high in nutrients because little is removed from them. As a result, they support a variety of aquatic plants such as reeds, grasses, rushes, sedges, waterlilies and wildflowers.

Some basic differences exist between the wetland types. Marshes tend to support smaller plants such as sedges, reeds and grasses, while swamps are more nutrient-enriched and can support trees. A bog is a wetland where dead plant matter and moss accumulate to form peat, a high-carbon compound once dug up and cut, dried and burned as fuel, particularly in Ireland, Scotland and parts of England.

Inland wetlands also perform several key ecological functions, including:

- providing important fish and bird habitat
- helping to mitigate and control erosion
- assisting with flood control and storm run-off
- use as recreational sites for people to enjoy
- use as nature reserves where biological studies are performed
- acting as carbon sinks.

Much like mangrove forests, wetlands are ecosystems that are at risk to anthropogenic activities, which threaten their resilience to changes in climate despite their ability to sequester carbon. Wetland vegetation absorbs carbon dioxide through photosynthesis but, because they are water logged, any decaying organic matter releases methane. As such, increased rates of methane in the atmosphere will increase temperatures, thus increasing the rate of decaying matter; again, a feedback loop is created. Additionally, changes to global precipitation and temperature patterns will either increase or decrease the spatial distribution of wetlands globally, depending on their localised climatic changes.

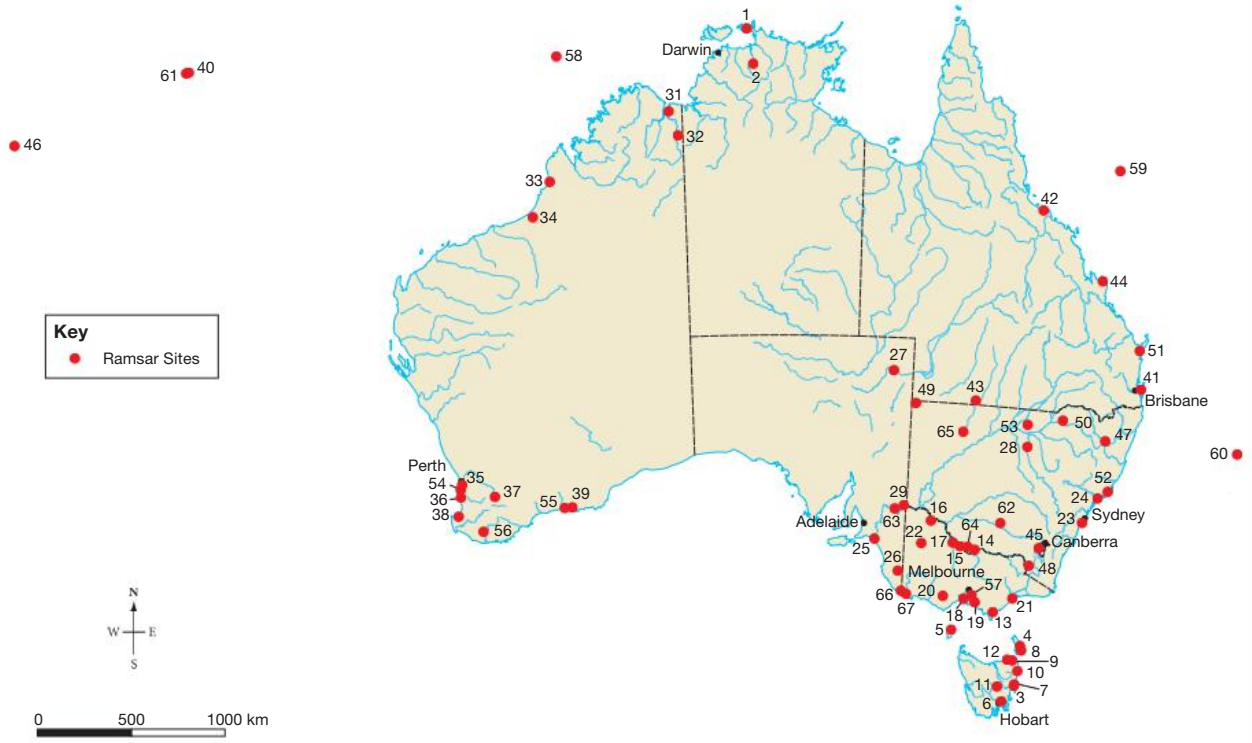
Ramsar sites

In 1971, UNESCO drew up an inter-governmental convention to encourage countries to protect and manage their unique wetlands to protect wildlife and migrating birds. Because the first treaty was signed at Ramsar in Iran, it is now commonly called the Ramsar Convention. Globally, 2331 Ramsar locations are in place, covering more than 2 million square kilometres. The United Kingdom has the most individual sites while Bolivia has the largest area of wetlands listed. Australia has 65 Ramsar sites, covering an area of about 8.3 million hectares (see figure 1.43).

Sites with Ramsar status benefit from:

- Conservation of biodiversity, including endangered species and migratory birds
- Improved water quality and natural flood regulation
- Preservation of important ecosystem services like carbon storage and groundwater recharge
- Support for sustainable local activities such as fishing, farming, and ecotourism
- Recognition under international environmental agreements, encouraging long-term conservation

FIGURE 1.43 Ramsar wetlands of Australia



Ramsar Sites

1. Cobourg Peninsula
2. Kakadu National Park
3. Moulting Lagoon
4. Logan Lagoon
5. Lavinia
6. Pitt Water-Orielton Lagoon
7. Apsley Marshes
8. East Coast Cape Barren Island Lagoons
9. Flood Plain Lower Ringarooma River
10. Jocks Lagoon
11. Interlaken (Lake Crescent)
12. Little Waterhouse Lake
13. Corner Inlet
14. Barmah Forest
15. Gunbower Forest
16. Hattah-Kulkyne Lakes
17. Kerang Wetlands
18. Port Phillip Bay (Western Shoreline) and Bellarine Peninsula
19. Western Port
20. Western District Lakes
21. Gippsland Lakes
22. Lake Albacutya
23. Towra Point Nature Reserve
24. Hunter Estuary Wetlands
25. The Coorong, and Lakes Alexandrina and Albert Wetland
26. Bool and Hacks Lagoons
27. Coongie Lakes
28. The Macquarie Marshes
29. Riverland
31. Ord River Floodplain
32. Lakes Argyle and Kununurra
33. Roebuck Bay
34. Eighty-mile Beach
35. Forrestdale and Thomsons Lakes
36. Peel-Yalgorup System
37. Toolibin Lake (also known as Lake Toolibin)
38. Vasse-Wonnerup System
39. Lake Warden System
40. Hosnies Spring
41. Moreton Bay
42. Bowling Green Bay
43. Currawinya Lakes (Currawinya National Park)
44. Shoalwater and Corio Bays Area (Shoalwater Bay Training Area, in part - Corio Bay)
45. Ginini Flats Wetland Complex
46. Pulu Keeling National Park
47. Little Llangothlin Nature Reserve
48. Blue Lake
49. Lake Pinaroo (Fort Grey Basin)
50. Gwydir Wetlands: Gingham and Lower Gwydir (Big Leather) Watercourses
51. Great Sandy Strait (including Great Sandy Strait, Tin Can Bay and Tin Can Inlet)
52. Myall Lakes
53. Narran Lake Nature Reserve
54. Becher Point Wetlands
55. Lake Gore
56. Muir-Byenup System
57. Edithvale-Seaford Wetlands
58. Ashmore Reef National Nature Reserve
59. Coral Sea Reserves (Coringa-Herald and Lihou Reefs and Cays)
60. Elizabeth and Middleton Reefs Marine National Nature Reserve
61. The Dales
62. Fivebough and Tuckerbil Swamps
63. Banrock Station Wetland Complex
64. NSW Central Murray State Forests
65. Paroo River Wetlands
66. Piccaninnie Ponds Karst Wetlands
67. Glenelg Estuary and Discovery Bay Wetlands

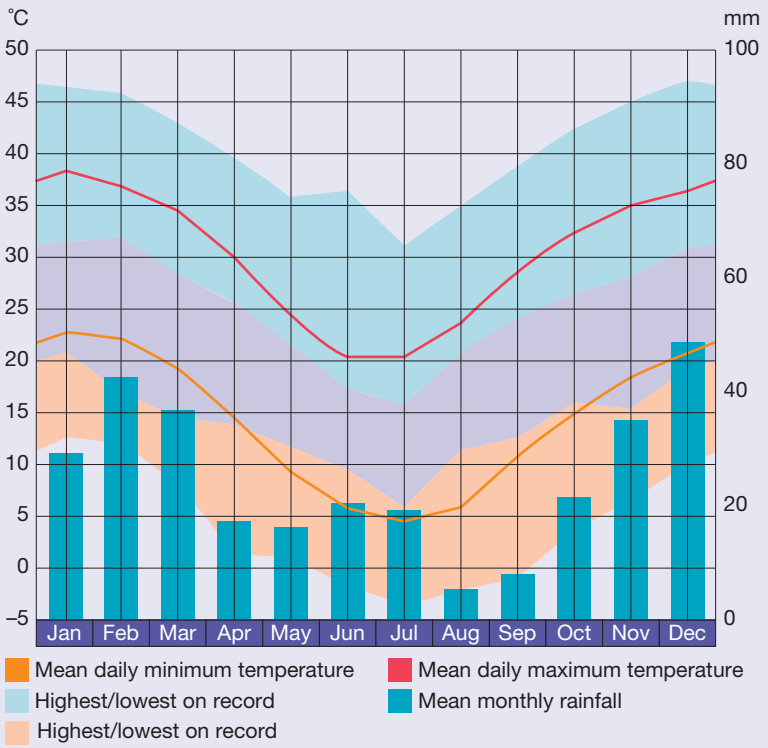
Source: © Commonwealth of Australia 2019

SKILLS ACTIVITY: Analyse geographic data and information

Uluru weather data

Refer to figure 1.44 and table 1.5 to answer the following questions.

FIGURE 1.44 Climate chart for Uluru



Source: © Weatherzone

TABLE 1.5 Average monthly maximum temperatures and rainfall for Uluru (NT)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
°C	37	36	35	30	25	20	20	24	28	32	35	36
mm												

1. What weather information is shown by the red line? Does it match with the information in table 1.5 (rounded off)?
2. What does the orange line show?
3. What information does the light blue zone show?
4. What data is shown by the blue bars?
5. Estimate the mean monthly rainfalls and complete table 1.5.
6. What is the mean annual total in millimetres?
7. Does Uluru have a 'wet' season and 'dry' season?
8. Calculate the average annual total rainfall. Is Uluru desert or semi-desert?

1.6 Exercise

1.6 Exercise

Learning pathways

LEVEL 1	LEVEL 2	LEVEL 3
1, 4, 7	2, 3, 6, 8	5, 9

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Explain and comprehend

1. Based on your knowledge, **identify** the percentage of the Earth's land surface covered by forests.
2. **Identify** two key ecological functions of coastal wetlands.
3. **Identify** the biome that is dominated by large, sandy dunes shaped by the wind.

Analyse and apply

4. **Describe** how deforestation can impact the climate and contribute to global warming.
5. **Explain** the significance of Ramsar sites in wetland conservation.
6. **Identify** the three main human activities that lead to desertification.
7. **Analyse** the impact of deforestation on the carbon cycle and its long-term consequences for the Earth's biophysical systems.

Propose and communicate

8. **Compare** and **contrast** the characteristics of a tropical grassland biome and a boreal forest biome.
9. **Evaluate** the effects of land degradation on soil quality and propose sustainable management practices to mitigate these effects.

Sample responses for this chapter are available online.

LESSON
1.7 Anthropogenic biomes

LEARNING INTENTION

By the end of this lesson you should be able to explain, using evidence, how anthropogenic activity (such as changes in land use) may be influencing climate change.

1.7.1 How do humans transform natural biomes into anthropogenic biomes?

Ever since humans walked on the Earth, they have made changes and modified their environment. At first, some changes were small and, at times, not noticeable. These changes included hunting other species, growing food (agriculture), building settlements and domesticating animals. However, as people travelled further and explored new lands, their ability to log forests and exploit resources as well as build larger settlements (urbanisation) increased. Mechanical inventions and the use of new fossil fuels soon gave people a huge advantage in being able to control and change large areas of land. Today, our impact on the natural environment is so significant, very few places in Earth could be called 'pristine'.

The most common areas of anthropogenic transformation are as follows:

- urbanisation, including road and dam building
- industrialisation, including pollution and waste disposal
- deforestation and food production
- global warming and climate change.

SKILLS ACTIVITY: Ask geographic questions

Airports require extensive tracts of flat land. As a result, many are constructed beside the coast, resulting in the removal of wetlands and forests.

FIGURE 1.45 Sydney Airport, looking south-west over the Domestic and International Terminals towards Botany Bay

1. Identify some of the transformations that may occur when airports are constructed or extended and how they have impacted on the natural environment.

Human transformation	Impact on natural environment

1.7.2 Effects of global warming

Evidence shows that global warming is affecting environmental elements such as oceans and climate. The most significant effects are outlined in this section.

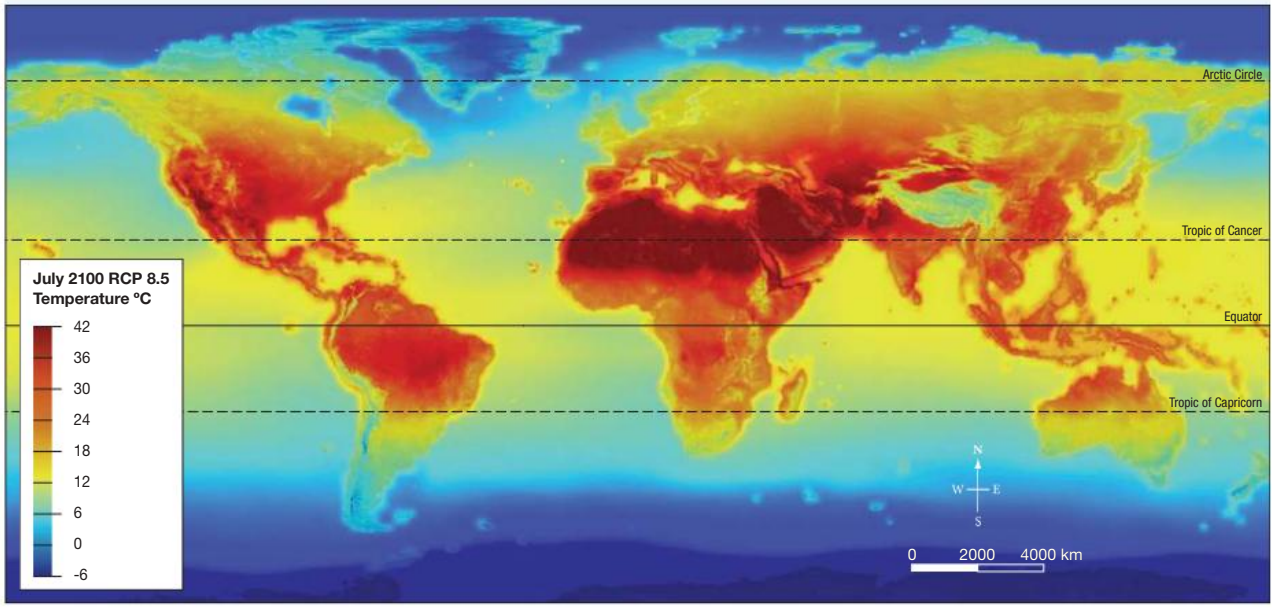
Water expands when warmed, leading to thermal expansion of ocean water, which scientists estimate will raise sea levels by 20 centimetres by 2030. Low-lying coastlines such as those in Bangladesh will be vulnerable to cyclones and storm surges, increasing the number of refugees. Islands such as Tuvalu, Kiribati, Vanuatu and the Maldives are at risk of inundation and saltwater intrusion into their groundwater. Mangroves may either drown or move inland.

Warmer oceans also increase water vapour in the air, amplifying global warming. Melting ice around Antarctica adds atmospheric moisture, potentially causing more snowfall in cold areas. Warmer water also melts ice sheets from beneath.

Glaciers in temperate regions will melt faster, reducing snow cover and affecting local flora and fauna.

Changes in air and ocean temperatures will alter circulation patterns, impacting weather and climate. If greenhouse gas emissions continue at current rates, average global temperatures could rise between 0.3 and 1.4 °C by 2030, and an additional 0.6 to 3.8 °C by 2070. This may lead to more storms and cyclones in coastal areas and hotter, drier conditions inland, with increased frequency of extreme weather events like El Niño. Figure 1.46 shows predicted changes in temperature due to global warming.

FIGURE 1.46 Global warming predictions



Source: *NASA*. Map redrawn by Spatial Vision.

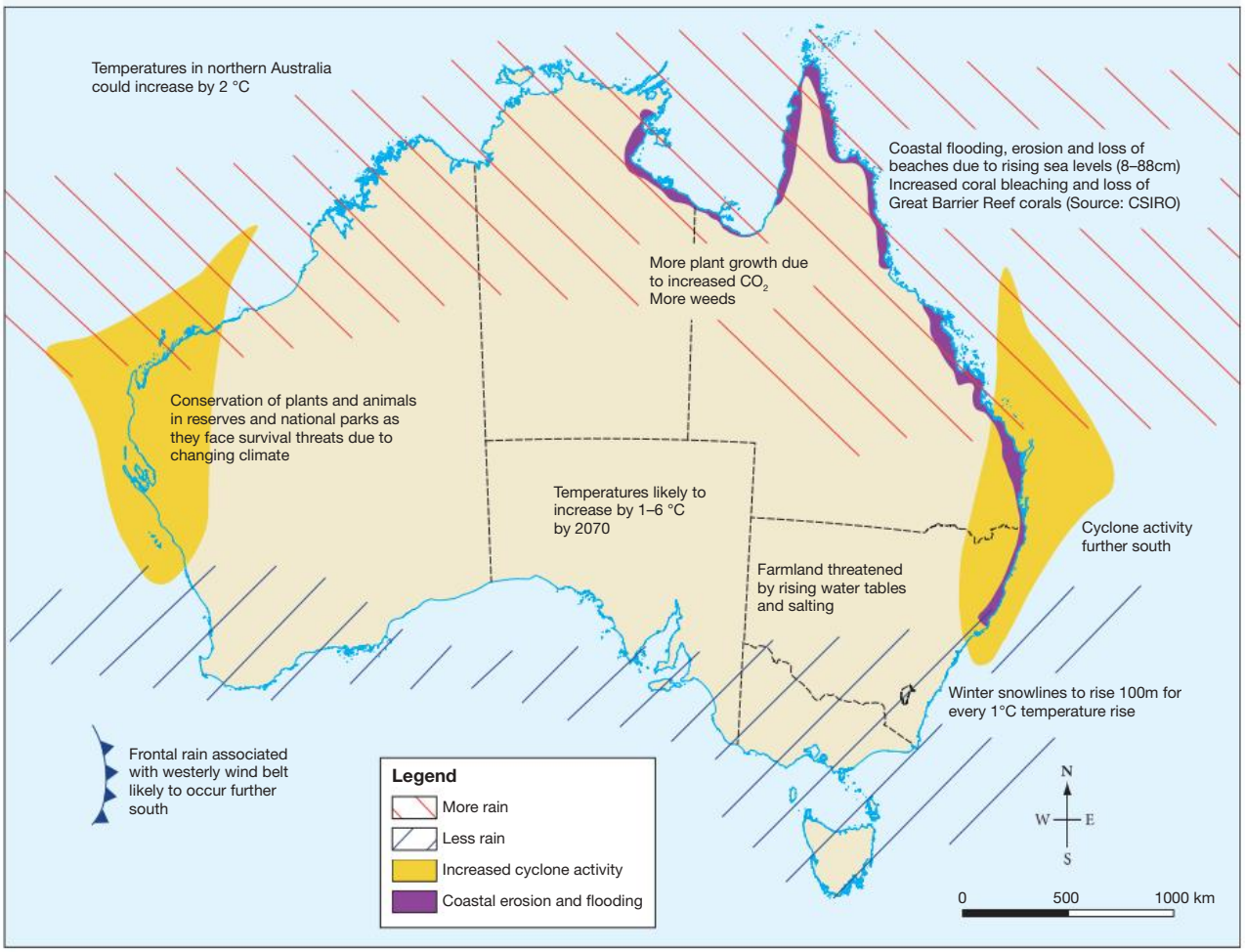
The potential impacts of global warming in Australia are shown in table 1.6.

TABLE 1.6 Potential effects of global warming in Australia

Effect of global warming	Details
Temperature increase	0.5 to 2.0 °C warmer within 200 km of the coast; 0.5 to 2.5 °C warmer inland
Evaporation increase	2 to 4% increase for each degree of temperature increase
Rainfall changes	10 to 20% increase during wet periods; 10% decrease during drier months
Storm intensity changes	More intense and violent storms; heavier falls of rain in shorter periods
Wildlife risk	Species unable to adjust to warmer temperatures or loss of food supply; example of species at risk include mountain pygmy possum, green ringtail possum and coral communities in the Great Barrier Reef
Extreme events	Drought, fires, flooding contributing to reduction of small animals and birds

Global warming also affects food production and farmlands, forests (through stress and bushfires), wildlife, and the health of inland river systems (through low flow rates and toxic algal blooms). Hot periods in Australia have become hotter and dry periods have become drier. Drought will affect grain and fruit crops, reducing yield quality or making these products much more expensive. Cattle and sheep raising will be limited due to high temperatures and lack of water. Longer dry spells and more intense periods of rainfall may increase soil erosion, whereas higher levels of CO_2 would increase plant growth. Figure 1.47 provides more detail on the predicted effects of climate change.

FIGURE 1.47 The predicted effects of climate change



Source: Map drawn by Spatial Vision.

1.7.3 Climate change and its indicators

Climate change is a substantial variation from regular or expected climate patterns on a regional or global scale. The term is often attributed to increased amounts of water vapour, CO_2 and methane in the atmosphere due to changes caused by human factors, as opposed to those resulting from the Earth's natural processes.

Although some people continue to debate climate change, adequate evidence exists to show many features of the world's physical systems are warming. Many international scientists argue the Earth is now at a 'tipping point' and only drastic responses will succeed. The changes in the atmosphere and oceans are the most noticeable, but changes in the land and soils are also noticeable to some extent, as shown in figure 1.48.

The Earth has passed through cooling and heating phases in the past, initiated by events such as changes in orbital position, ice ages or smaller random events such as the eruption of Krakatoa or meteorite collisions. However, the atmospheric and ocean trends of the past 50 years are conspicuous. While each one of these trends is not specifically 'climate change', collectively they are pointing to adjustments that affect climate in ways we have not seen before. According to the Australian Government's Department of the Environment and Energy, the most significant changes attributed to climate change are:

- record high surface air temperatures
- increased average number of hot days per year
- decreased average number of cold days per year
- increasing intensity and frequency of extreme events (e.g. fires and floods)

- changing rainfall patterns
- increasing sea surface temperatures
- rising sea levels and possible salt inundation of coastal areas
- increasing ocean heat content
- increasing ocean acidification
- changing Southern Ocean currents
- melting ice caps and glaciers
- decreasing Arctic sea ice.

FIGURE 1.48 Climate change is causing significant changes to our environment.

EXAMPLE: 2024 — the world's hottest year?

In 2024, the Copernicus Climate Change Service (C3S) reported that global temperatures averaged 1.6 °C above pre-industrial levels, marking the first calendar year to exceed the 1.5-degree threshold of the COP Paris 2015 climate agreement.

Extreme heat in 2024 caused more fatalities than floods, bushfires, storms and cyclones combined. Heatwaves particularly affect the elderly, sick and vulnerable populations, while also intensifying droughts, wildfires and severe storms.

Several countries experienced unprecedented temperatures. Japan recorded its hottest summer, and Australia reported its second-warmest year on record, with national mean temperatures 1.46 °C above the 1961–90 average. An El Niño event contributed to higher temperatures and altered rainfall patterns throughout the year.

According to the Bureau of Meteorology, Australia's climate has warmed by 1.51 ±0.23 °C since national records began in 1910. Every decade since 1950 has been warmer than the last, with both daytime and night-time temperatures increasing. In 2024, Australia experienced its warmest spring on record, with national average temperatures 2.10 °C above the 1961–90 average. Scientists warn that continued fossil fuel emissions are exacerbating global warming, posing significant threats to human health and ecosystems worldwide.

DID YOU KNOW?

While we may use the terms interchangeably, weather and climate mean different things. Weather is the day-to-day condition of the atmosphere, such as temperature, winds, humidity and rainfall. Storms, windy, humid and hot days are examples of weather.

Climate, on the other hand, is the pattern of weather over a long period of time. An area may have a hot, wet climate based on measurements taken over decades or longer. Due to the pattern of weather types, climate has been predictable in the past.

Effects on the polar regions

The Earth's polar regions, once isolated from human influence, have been exposed to changes due to recent exploration and technology. NASA's GRACE satellite data shows that since 2002, both Arctic and Antarctic ice sheets have been losing mass. This is significant because these regions store over two-thirds of the planet's freshwater. Meltwater from these ice sheets has contributed to rising ocean levels since the 1990s. Despite similarities in ice coverage and climate, the polar regions differ in location, size, governance and ecosystems.

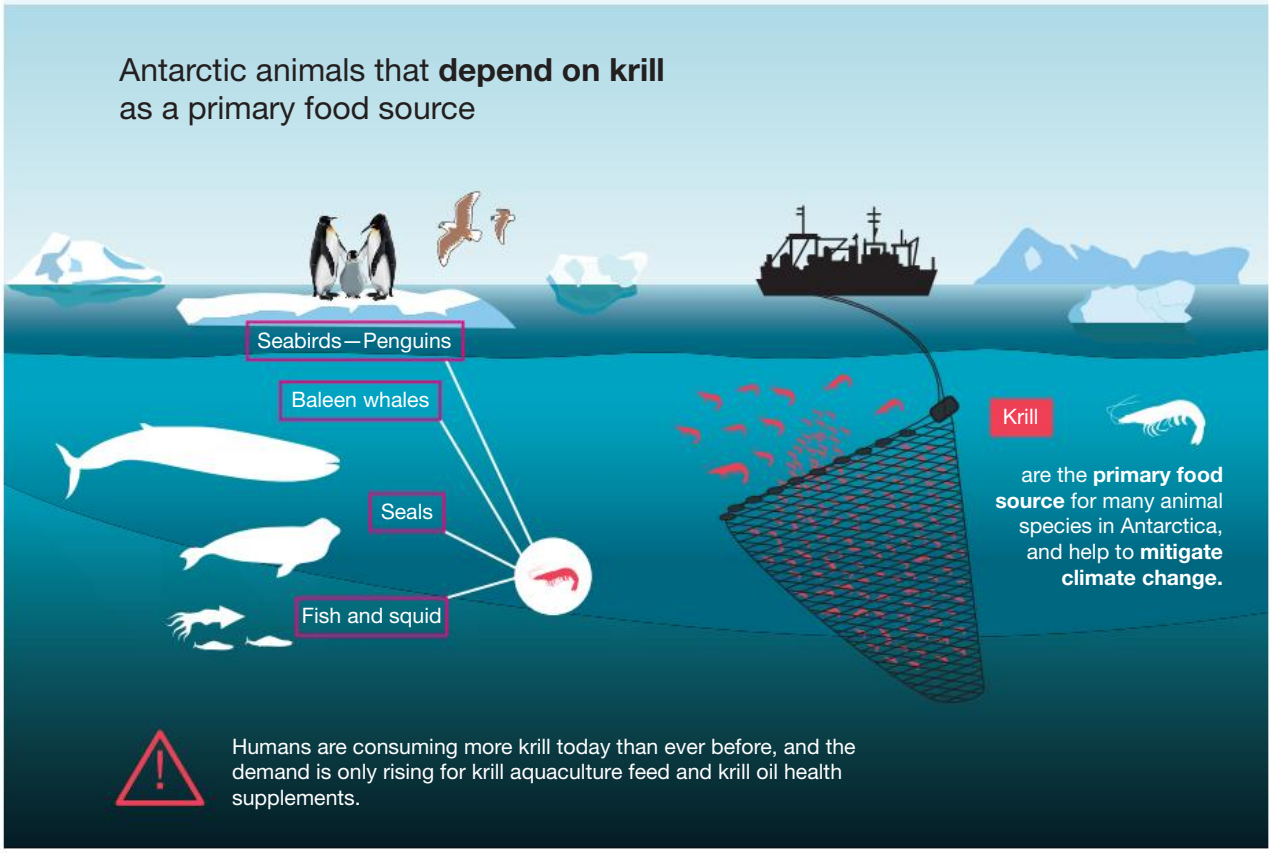
Antarctica

Antarctica has the following features:

- It is a large land continent, approximately 1.5 times larger than Australia, covered by ice.
- The continent contains about 90 per cent of the planet's freshwater.
- Antarctic ice sheets have an average thickness of over 2 kilometres, with the deepest section exceeding 4 kilometres.
- It is the coldest, windiest and driest continent on Earth, with the coldest air temperature ever recorded being –89.6 °C in 1983 at Vostok. Coastal temperatures range from summer maximums of around 9.0 °C to winter minimums around –40 °C.
- Cyclonic gale-force winds are generated by deep low-pressure systems from southern oceans.
- Scientists indicate that the polar regions are warming faster than any other part of Earth.
- Antarctica hosts a unique ecosystem including seals, whales, penguins, fish and krill (see figure 1.49).

The continent has no ownership or permanent population; it accommodates only scientists and staff working for research purposes under the 1959 Antarctic Treaty.

FIGURE 1.49 Krill supports a vast food web in Antarctica.



DID YOU KNOW?

Recent satellite images show Antarctic sea ice has now reached its lowest extent of below 2.0 million square kilometres three years in a row (2022, 2023 and 2024), over the 46-year measurement period (see figure 1.50 and table 1.7). Does this indicate warmer air and sea temperatures may be past a tipping point?

FIGURE 1.50 Antarctic annual minimum sea ice extent, 1979–2024

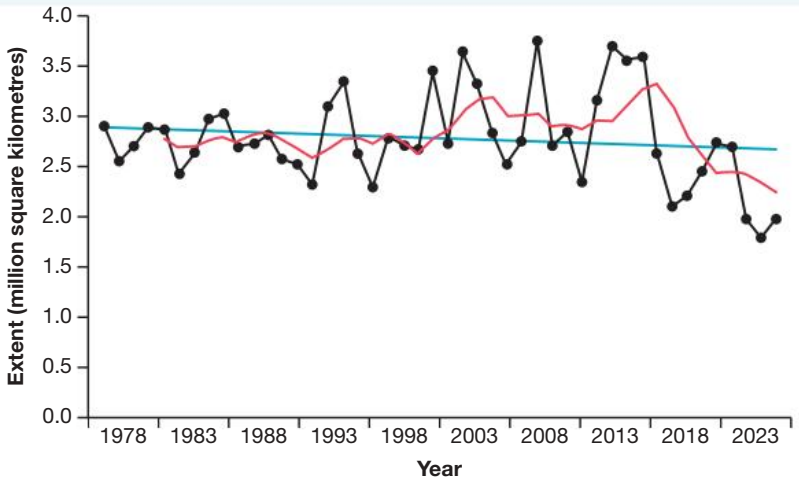


TABLE 1.7 Lowest measurements of minimum Antarctic ice extent

Rank	Year	Minimum ice extent (millions of km^2)	Minimum ice extent (miles^2)	Date recorded
1	2023	1.79	691 000	Feb 21
2	2022	1.98	764 000	Feb 25
	2024	1.99	768 000	Feb 20
3	2017	2.11	815 000	March 23
4	2018	2.22	857 000	Feb 21

CASE STUDY: The Arctic Ocean

Quick facts: Arctic Ocean

- **Total area** 14 million square kilometres
- **Ocean depth at North Pole** about 4 kilometres
- **Ice thickness at North Pole** about 2 to 3 metres

The Arctic is a large ice sheet that sits over the Arctic Ocean, with the North Pole sitting in the middle. The territorial seas and Economic Exclusion Zones in the area are under the authority of adjacent coastal states — including Canada, the United States, Iceland, Norway, Denmark, Finland, Sweden and Russia.

In the Arctic, changes are different, but somewhat similar to those seen in the Antarctic. According to most scientists, the release of greenhouse gases is the biggest threat to the polar north. Sea ice cover in winter is less and thinner than last century, and in summer, it is melting faster, causing an estimated 13 per cent per decade reduction. Some scientists predict the entire ice cap may be gone by the 2030 decade. The effects of ice loss include:

- Melting ice adds freshwater to the Arctic Ocean and North Atlantic. This has a diluting effect on sea water, making it less dense and causing currents to slow.
- Polar animals such as narwhals, polar bears and walruses that depend on seasonal ice melt for hunting are at risk of starvation.
- Less ice reduces the albedo effect, accelerating heat absorption and warming.
- Warming temperatures result in less sea ice and rising sea levels throughout the world. It is also causing permafrost (frozen ground) to thaw and release more methane from decayed plants (see figure 1.51).
- A reduction in sea ice will make the region more accessible to shipping and possible exploitation of northern resources. Considering the number of countries that border the Arctic Sea, the geopolitical implications will be challenging.

FIGURE 1.51 Methane bubbles up from the thawed permafrost at the bottom of the thermokarst lake through the ice at its surface.

SKILLS ACTIVITY: Interpret and use data from different types of maps

Interpreting satellite images and line graphs

Use figures 1.52 and 1.53 and work in pairs to provide solutions to the following questions.

FIGURE 1.52 Arctic sea ice concentration, compared to 1981–2010 median

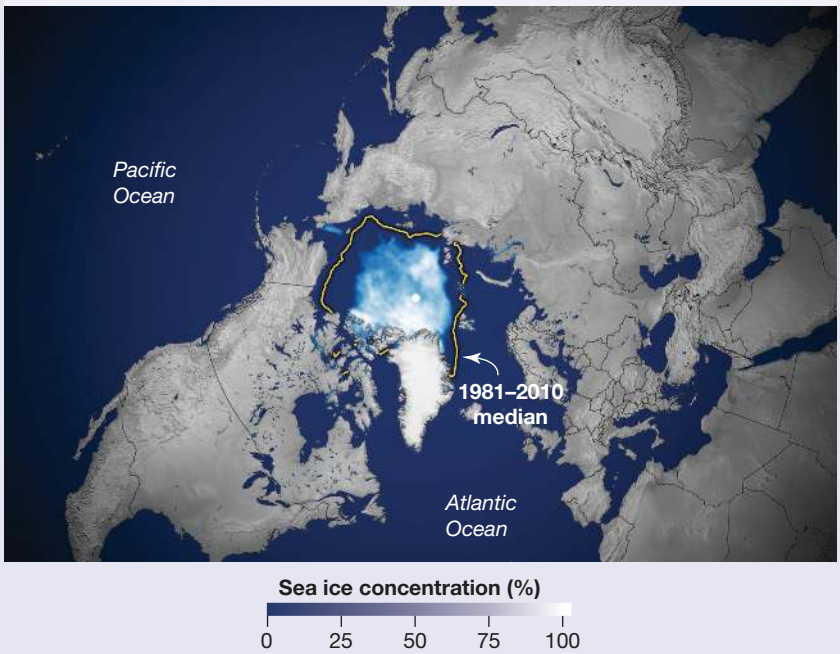
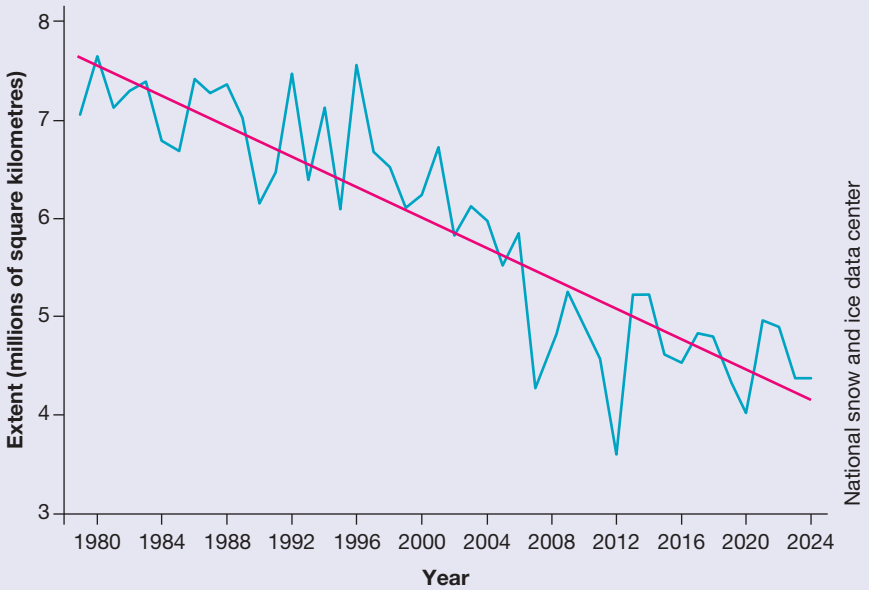


FIGURE 1.53 The monthly September ice extent for 1979 to 2024 shows a decline of 12.1 per cent per decade.



Source: National Snow and Ice Data Center (University of Colorado Boulder)

1. **a.** Explain the purpose of both the pink line and blue line in figure 1.52.
   b. Explain why the blue line is irregular.
   c. Describe the extent of Arctic ice cover before 1996.
   d. Describe the variations in ice cover. What is quite noticeable about the ice cover after 2002?
   e. In what year was the ice cover the lowest?
   f. Estimate the area of ice cover decline over the 45-year period.
   g. Consider what has led to the depletion in ice cover during this period.

1.7.4 What can be done to mitigate climate change?

If weather can be forecast accurately a few days beforehand, is it possible to forecast climate change years in advance? Unfortunately, forecasting weather and climate changes are totally different challenges. Because weather is about short-term (daily) changes to the atmosphere, its immediate alterations are calculated on impending variables that can be measured, observed and displayed on a **synoptic chart**. It is like being able to predict traffic congestion at peak hour or following a road incident.

synoptic chart a weather chart that shows a summary of weather detail over a large area; for example, the daily weather map of Australia shows a summary of air pressure, rainfall, winds and temperature

Predicting climate change is like estimating the flow of the whole road network over a decade, which would include many unknown variables, such as improvements to public transport, future road budgets, introduction of driverless cars, and fuel and ticketing costs. Forecasting climate change requires consideration of many long-term factors, such as rainfall reliability, drought, atmospheric and ocean warming, planetary wind circulation patterns, levels of CO_2 and methane emissions, methods of electricity generation and energy consumption, and many more. However, once human behaviours become established as a consistent pattern, it is possible to extrapolate data and predict conceivable scenarios and effects of climate change.

What are the future implications for people and the environment?

With the prospect of further climate change likely, storms, cyclones, droughts and bushfires are expected to become more severe across the Australian landscape. As more forests (carbon sinks) are lost to land clearing and fire, the atmosphere will inevitably increase its levels of CO_2.

At a global level, countries must do whatever is possible to reduce global warming. The most obvious strategies are to reduce further deforestation and rehabilitate damaged areas by planting trees, as well as re-think energy production dependent on carbon fuels. Because these strategies have huge capital costs, governments need to take the lead and invest money into such changes.

At a community level, we need to:

- investigate ways of removing carbon dioxide from factories and cars, and either storing it underground or in the oceans
- encourage landowners to plant more trees or develop agroforestry on unproductive land
- provide incentives such as taxation relief to industries making genuine progress at lowering carbon emissions
- reduce land clearing and plant more trees — research has shown that planting saltbush in semi-arid regions, for example, will absorb up to 20 tonnes of carbon per hectare after only three years.

By relying on fossil fuels as our major energy source, Australia is missing out on opportunities for developing alternative energy solutions. We are also at risk of being left behind when industrial and business reform occurs in order to meet the new energy technologies. Australia's energy and greenhouse policies need to be separated from political decision-making, a process which sometimes only looks as far ahead as the next election.

At a personal level, it is important that individuals see issues such as global warming and climate change from a global point of view and appreciate that we are all part of the Earth's physical systems. Strategies for individuals to help save the planet from climate change include:

- making genuine efforts to save energy around the home or school and reducing demands on power stations — for example, turning off or using fewer lights, air conditioners and appliances
- purchasing appliances with a high energy rating
- using more renewable forms of energy such as wind, solar and water power to lower coal and oil consumption
- walking, cycling, using public transport or participating in car pools rather than using the family car for all travel
- recycling and reducing demand for landfill.

While large amounts of money are needed to repair many of our old environmental problems, there is also a need to improve future planning and prevent mistakes happening. Successful proactive planning for the future can only occur by understanding today's environmental issues, appreciating why they exist and confronting them with intelligent solutions. Tomorrow's decision-makers and practitioners will need to make wise choices and have the resolve to succeed.

For more information and resources about climate change, refer to the weblinks in the Resources tab.

Treaties, protocols and global conferences

Greenhouse gas emissions have been a concern for well over 40 years. In 1987, countries signed the Montreal Protocol to phase out greenhouse gases. Initially, only developed nations were blamed, but developing countries soon joined in using fossil fuels, necessitating a broader agreement. At the 1992 Earth Summit, 154 countries aimed to cut emissions below 1990 levels by 2000, but only Germany and Great Britain succeeded.

Since 1995, UN Climate Change Conferences (UNFCCC) have addressed global warming. The 1997 Kyoto Protocol pledged to reduce emissions by 5.2 per cent below 1990 levels by 2012, yet many countries struggled due to financial crises and political issues. Notable figures such as David Attenborough and Al Gore raised awareness, with limited success. Some countries, including Australia and Norway, were permitted to increase emissions under specific conditions.

Several climate conferences ended without significant progress as leaders prioritised domestic politics. The 2009 Copenhagen summit yielded vague promises. The 2015 Paris Agreement aimed to limit temperature rise below 2 °C this century, striving for 1.5 °C, but some countries later withdrew, including the United States.

The 2018 United Nations Climate Change Conference (more commonly referred to as the Katowice Climate Change Conference or COP24) highlighted divisions, with the UN warning the Paris goals were at risk. Activist Greta Thunberg criticised leaders for inaction at both the 2018 and 2019 conferences. In 2021, Thunberg spoke at the Youth4Climate summit in Milan and participated in COP26 in Glasgow, criticising leaders for 'empty words'. COP27 and COP28 took place in 2022 and 2023 respectively. The COP28 conference was notable for its unprecedented acknowledgment of fossil fuels as the primary driver of climate change.

FIGURE 1.54 Greta Thunberg urges action among world leaders.

1.7 Exercise

1.7 Exercise

Learning pathways

LEVEL 1	LEVEL 2	LEVEL 3
1, 2	3, 4, 5, 6	7, 8, 9

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Explain and comprehend

1. **Define** the term 'anthropogenic biomes'.
2. **Identify** three common uses of land resources by humans.

Analyse and apply

3. **Explain** how urbanisation contributes to the transformation of natural biomes.
4. **Discuss** the impact of global warming on sea levels by 2030.
5. **Identify** the six major anthropogenic biomes according to Ellis and Ramankutty.
6. **Analyse** the effects of global warming on the Great Barrier Reef and propose potential mitigation strategies.

Propose and communicate

7. **Evaluate** the significance of the 2015 Paris Agreement in combating climate change. What challenges have arisen since its inception?
8. **Explain** how changes in land use, such as deforestation or intensive agriculture, contribute to increased greenhouse gas emissions. Use evidence to support your explanation.
9. **Propose** sustainable management practices to mitigate the effects of land degradation on soil quality, using evidence from online research.

Sample responses for this chapter are available online.

LESSON
1.8 Review

1.8.1 Summary

This chapter has covered some key points about climate change and the transformation of global land cover.

What is land cover and its distribution?

- Land cover is the different materials that cover the earth. It refers to forest, grass, farmland, roads, building, exposed ground, lakes and water.

The Earth's physical systems

- The Earth has four physical systems: the atmosphere, the lithosphere, the hydrosphere and the biosphere.
- These physical systems are connected by three energy cycles: the water cycle, the carbon cycle and the nitrogen cycle.

Global climate systems

- Our global climate systems are affected by wind patterns, heat transfer in the atmosphere and ocean currents.
- Global patterns of precipitation are closely aligned to wind patterns and heat transfer in the atmosphere.
- Heat energy is transferred between the equator and the poles by very large ocean currents, which are large masses of water that circulate water flow around the oceans.
- El Niño and La Niña are global events involving both the atmosphere and ocean waters, and affect weather and climate in Australia.
- The Earth's energy balance is the process of energy from the Sun entering the Earth's system during daylight hours by radiation and warming the surface. The energy then leaves during the night hours by infrared radiation from the atmosphere.
- 'Albedo' is a term that means the proportion of light reflected by a surface. Light-coloured surfaces such as snow or ice reflect up to 95 per cent of solar energy so they have a high albedo. Dark areas such as rainforest, ploughed soil or ocean water absorb most of the heat and reflect only small quantities away.
- Loss of landcover is affecting the ability of the surface to reflect or absorb heat, due to changes in the surface albedo.
- Greenhouse gases are a collection of naturally occurring gases in the troposphere that allow the Sun's rays through and trap some of the heat. This prevents the Earth becoming too cold to be habitable. However, too much greenhouse gas raises the temperature of the Earth.
- The Indian Ocean Dipole is a measure of sea surface temperatures, in which alternating warm and cool ocean temperatures affect the rising and falling of atmospheric moisture. These give an indication of when dry or wet spells may occur over the western half of Australia.
- The Arctic Oscillation and the polar vortex are two phenomena that play key roles in climatic patterns and the distribution of air.

Changes to land cover

- Biomes are very large regions of the Earth where area-specific plants and animals have adapted to the climatic conditions, soil and relief of that environment; for example, deserts and rainforests are biomes.
- Anthropogenic biomes are areas that have experienced sustained human interaction that has transformed land cover.
- Increased population growth and demand for food, water and other resources have increased the pressure on the land and fertile soils.

Anthropogenic activity and how it has transformed land cover

- Many human projects, in order to secure economic development, food security and employment, have resulted in long-term changes to the Earth's biophysical systems.
- Technology and increasing affluence have influenced the transformation of land cover.
- Forests cover about 31 per cent of the land surface, contain the highest levels of terrestrial biodiversity and up to 80 per cent of the total plant biomass. However, the amount of forested areas are dramatically declining.
- Deforestation refers to the intentional clearing of forests for other purposes such as farming, cattle grazing, logging, mining, and urban and industrial development, causing transformation of land cover.
- 'Rangelands' is a term used to describe grasslands, shrublands, woodlands, wetlands and deserts that are grazed by domestic livestock or wild animals. The term refers to the use of land for a particular human activity, whereas grasslands or savanna are terms that describe the climate and vegetation.
- The Earth contains large areas of hot, dry land known as desert. These are areas that receive less than 250 millimetres of rain in a year and where less than 50 per cent of the ground surface is covered by vegetation.
- Desertification is a form of land degradation where land that was once fertile and arable has been transformed into unproductive arid land, often due to human causes (overgrazing, vegetation removal) or natural causes (drought).
- Wetlands and mangrove forests are ecosystems that are at risk to anthropogenic activities, which threaten their resilience to changes in climate despite their ability to sequester carbon.

Anthropogenic biomes

- Forests act as a carbon sink that absorb carbon dioxide and other greenhouse gases that would otherwise remain free in the atmosphere. When large areas of forest are destroyed, this vital role as a sink is lost.
- Greenhouse gases have been linked directly to global warming and probable climate change.
- Adequate evidence shows many features of the world's physical systems are warming. These include trends in changes in rainfall, temperature, sea surface temperatures, ocean currents and melting ice caps.
- As well as urban car use and factory emissions, land clearing for grazing and farming have contributed towards Australia's dry spells and droughts, and have probably been a significant cause of increased CO_2 levels in the atmosphere and climate change.
- Various global conferences and treaties have attempted to combat climate change. However, despite the evidence and pledges, many countries have found it difficult to meet their carbon reduction targets.
- Actions can be taken at a community level to help combat climate change.

1.8.2 Key terms

albedo a measure of the ability of surfaces to reflect sunlight (heat from the sun). Light surfaces return much of the heat back to the atmosphere and dark surfaces absorb heat from the sun.
anthropogenic created by human interaction with the biosphere
anthropogenic biome the human biome, created by human interaction with the biosphere
archipelago an island group or chain of islands, such as Indonesia
biodiversity biological diversity; describes the variation of living plant and animal species that occupy an area or ecosystem
biogeographic areas smaller regions where the distribution of plants, animals and geology reveals many shared or common features, such as Wallum country of southern Queensland
biomes very large regions of the Earth where area-specific plants and animals have adapted to the climate, soil and relief of that environment; deserts and rainforests are biomes
carbon cycle the chain of biogeochemical processes that exchange or move carbon between the biosphere, the atmosphere, hydrosphere and lithosphere
chaparrals the hot, dry shrublands and heath country in the US and South Africa
climate the average state of weather conditions over a long period of time
continents the largest landmasses on Earth: Africa, Antarctica, Asia, Australia, Europe, North America and South America

coriolis effect a force like inertia that deflects objects moving across the surface (air, ocean currents, etc) to the left in the southern hemisphere and to the right in the northern hemisphere. It is caused by the rotation of the Earth.
crops plant or animal products that can be grown and harvested for consumption and/or profit
deforestation the intentional clearing or removal of forests to make way for some other purpose such as farming, housing, constructing a dam, and so on. Deforestation is regarded as a permanent loss of forest and is most common in countries with large areas of rainforest such as Brazil and Indonesia.
ecosystems communities of biotic (living organisms) and abiotic (non-living things like water and soil) that are linked through nutrient cycles and energy flows. An ecosystem may be large like a barrier reef or small like a garden.
evapotranspiration the process of water transferring from the land to the atmosphere via evaporation and transpiration
greenhouse gases gases such as water vapour, carbon dioxide, methane, nitrous oxide and ozone found in the atmosphere; because they absorb radiant energy and trap heat, they help warm the Earth and cause the greenhouse effect
hydrological cycle the process of exchanging water between the air, land and sea through evaporation, condensation and precipitation
Intertropical Convergence Zone (ITCZ) the large region of low pressure close to the equator where the trade winds of both the northern and southern hemispheres meet. Due to high temperatures, warm ocean water and trade wind convergence, the region has unstable air that rises, forming thunderstorms. It moves either side of the equator according to the summers and often appears on weather maps as a monsoon trough.
land cover what is covering the land (e.g. vegetation, human infrastructure or development, agriculture or bare earth)
land use how people use an area for economic, social or cultural purposes
littoral drift the movement of sedimentary materials into the littoral zone (shoreline) under the influence of waves and tides
mineralisation the process by which chemicals present in organic matter are broken down into easily available forms to plants
minerals naturally occurring solid chemical compounds (e.g. salt, quartz)
nitrogen cycle the biogeochemical loops where nitrogen in its various forms is circulated between the atmosphere, hydrosphere, lithosphere and biosphere
oceans the largest bodies of water on the Earth, holding more than 96 per cent of all water; ocean water is approximately 3.5 per cent salt
permafrost any ground (rock, soil, sediment) that is frozen or remains 0 °C or colder for a period of two years. It is most common in regions in the high latitudes, such as the tundra. Global warming is threatening to thaw out large areas of permafrost.
population density a measurement of the number of people located in a given area, usually the number of people per square kilometre
prairies vast stretches of temperate grassland with few trees. They are fertile due to the thousands of years of decaying grasses. Because soils are highly compacted with few air spaces, it is difficult for trees to grow.
precipitation rainfall
rangelands a broad term describing remote country used for grazing domestic livestock or wild animals. They include tallgrass and shortgrass prairies, semi-desert grasslands, shrublands, woodlands, savannas, chaparrals and steppes. Much of Australia's inland could be classed as rangeland.
resources sources from which some benefit is produced (e.g. wood, minerals, water)
savanna the region of tropical grasslands intermixed with woodlands. Trees are widely spaced and there is no distinct canopy
southern Oscillation Index (SOI) a measure of the development and intensity of El Niño or La Niña events in the Pacific Ocean. It is based on the pressure differences between Tahiti and Darwin.
steppes flat grassland with no trees
synoptic chart a weather chart that shows a summary of weather detail over a large area; for example, the daily weather map of Australia shows a summary of air pressure, rainfall, winds and temperature
thermocline the cool layer of ocean water below the surface; it is still warmer than the very cold layer on the ocean floor
trade winds the easterly prevailing winds (north-east and south-east) blowing from sub-tropical areas towards the tropics
troposphere the lower 10–12 km of atmosphere where most weather activity takes place

tundra the very cold, flat and almost treeless biome below the northern Arctic. Because of the permafrost and snow cover for much of the year, there is only a short growing season for some mosses, lichens and grasses.
walker Circulation a model of air flow in the lower atmosphere across the oceans, consistent with differences in air temperature between continents and oceans. It is used as a measure for determining the onset of an El Niño event.
weather conditions in the air above the Earth over a short period of time
wetlands low-lying areas containing salt marshes, swamps, bogs, peatlands and mangroves; regularly inundated by water

KEY QUESTIONS REVISITED

You should now be able to answer the following questions.

- What is land cover and its distribution?
- What processes connect the Earth's physical systems and affect land cover?
- What are the different types of land cover? (vegetation biomes, biogeographic areas, anthropogenic biomes)
- How does population growth, an increase in affluence and technology impact upon land cover?
- How do human activities like settlements, croplands, rangelands and forestry transform land cover surfaces?
- How do these transformations impact upon the Earth's systems?
- What are global climatic systems?
- What is climate change? How does it impact on land cover types?
- What are the implications of climate change on people and the environment and how might people best respond to them?

1.8.3 Exam questions

1.8 Section I — Short answer question

Question 1 (3 Marks)

Identify the land cover change in figure 1.55, and explain the challenges that this creates.

FIGURE 1.55 Aerial view of Lake Taupo and the Waikato River, New Zealand

Question 2 (5 Marks)

Explain how changes in land use can interrupt Earth's physical systems.

Question 3 (10 marks)

a. Explain a global climatic system using a conceptual model.
b. Explain how anthropogenic activity has altered or influenced this system?
c. Identify the implications of the altered system for people and places.

Question 4 (10 marks)

Use figures 1.56 and 1.57 when responding to this question.

FIGURE 1.56 World vegetation

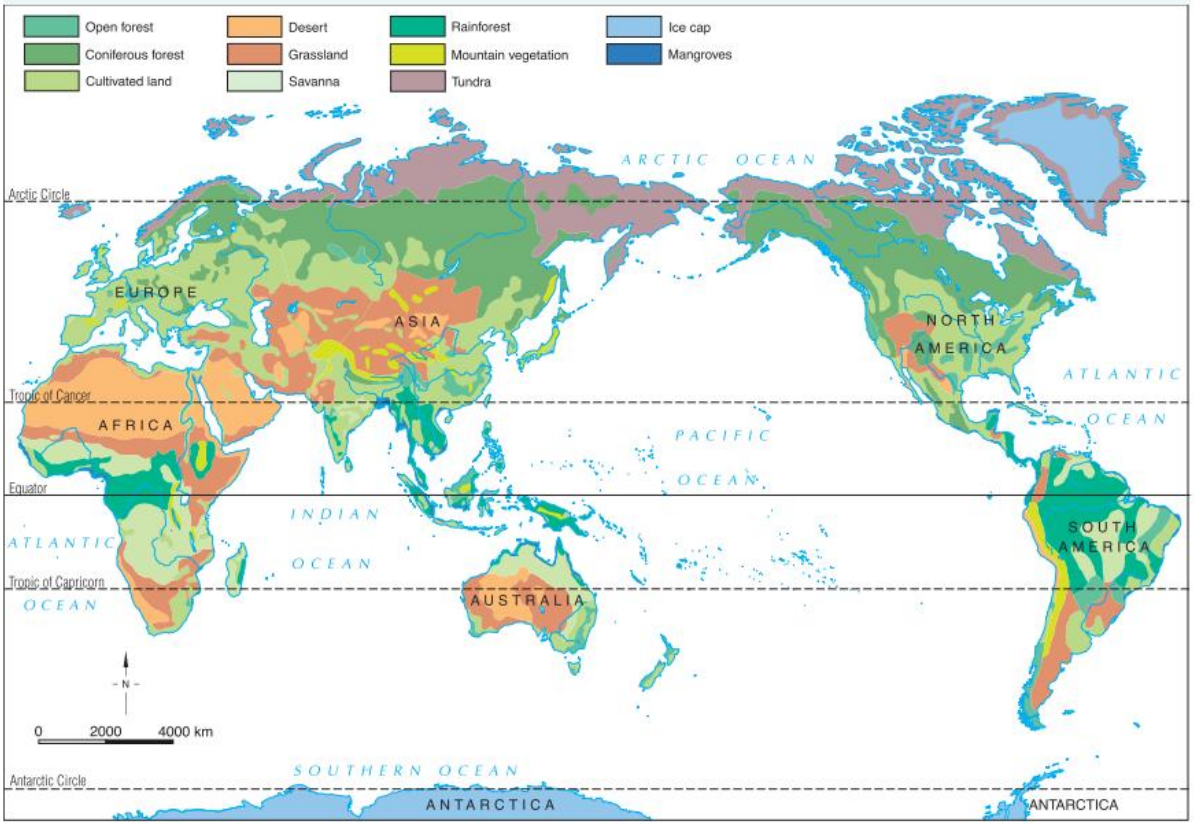
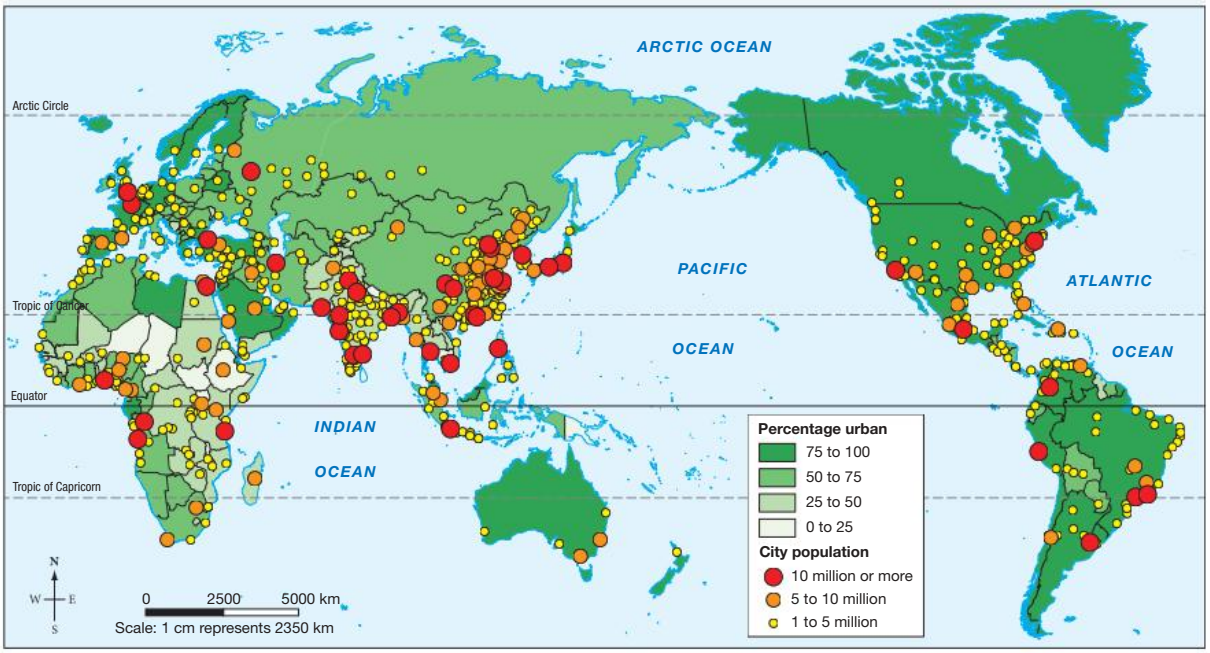


FIGURE 1.57 World urbanisation, 2017



Source: United Nations, Department of Economic and Social Affairs, Population Division 2018. World Urbanization Prospects: The 2018 Revision

a. Identify the spatial pattern of urban growth.
b. Explain how this anthropogenic activity has impacted global vegetation.
c. Identify the implications of this anthropogenic activity for people and places.

Question 5 (5 marks)

Using the data from table 1.8, create a graph representing the forest cover for the world regions between 2010 and 2020.

TABLE 1.8 World forest cover, 2010 and 2020 and projected for 2030.

Region	2010 (Mha)	2020 (Mha)	Projected 2030 (Mha)	Trend (2010–2020)
Africa	624	624	585	Net loss of ~3.9 Mha/year
Asia	593	593	605	Net gain of ~1.2 Mha/year
Europe	1020	1020	1023	Net gain of ~0.3 Mha/year
North & Central America	751	751	751	Relatively stable forest area
Oceania	191	191	195	Net gain of ~0.4 Mha/year
South America	842	842	816	Net loss of ~2.6 Mha/year
World Total	4060	4060	4180	Target: +3% (~+120 Mha by 2030)

Question 6 (10 marks)

a. Referring to the graph you created for question 5, describe the trends in world forest cover.
b. Using figure 1.57 and your graph from question 5, describe the relationships that exist between forest cover and urbanisation.
c. Identify the implications of this relationship for people and places.

Section II — Extended response

Question 7 (15 marks)

Using data and information from the stimulus material provided in section I, write an extended response (approximately 500 words) to the following.

- Analyse the data and information to make inferences about the patterns, trends and relationships that have resulted in a specific geographical challenge.
- From your analysis, make generalisations about the biophysical and anthropogenic impacts of the identified challenge for a specific region or place in the world.

Sample responses for this chapter are available online.

2 Responding to local land cover transformations

UNIT 3 TOPIC 2

SUBJECT MATTER

In chapter 2, students:

- **explain** geographical processes and biophysical and anthropogenic interactions that result in land cover change
- **comprehend** geographic patterns by recognising spatial patterns of land cover change and identifying relationships and implications for people and places
- **analyse** climate and land cover data and information to infer how patterns, trends and relationships represent geographical challenge/s
- **apply** geographic understanding from the analysis to generalise about the impact of geographical challenge/s on biophysical and anthropogenic environments
- **propose** action/s in response to the generalisations to create or improve the sustainability at a fieldwork location
- **communicate** understanding using appropriate forms of geographical communication.

LESSON SEQUENCE

Fully worked solutions for this chapter are available in the Resources section at www.jacplus.com.au.

LESSON
2.1 Overview

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2.1.1 Introduction

The world around us is in a constant state of change: night changes into day, summer into autumn, forests become housing estates, roads carve their way across the land, seeds grow into giant trees and a dry stream bed can become a raging torrent after rain. All of these changes are felt most strongly at the local scale, in the places closest to us that we see, feel, hear and interact with. Some of the prominent types of land cover in Queensland include deserts, coasts, rivers, and forests and grasslands. These are all different land covers, and so are shaped by different processes.

Land cover changes are visible and prominent, and they are driven by either **biophysical** (of or relating to the physical environment, which includes the living organisms that inhabit it) or **anthropogenic** (caused by human beings) processes. Natural causes of land cover change include erosion, deposition and natural hazards, while human causes include residential developments, removal of native vegetation for farming, laying of roads, building infrastructure such as airports, creating dumps for landfill, growing plantation forests and mining for ore.

Understanding and managing land cover changes helps to ensure the balance of **development** and **sustainability**, and the retention of the features of local places that make them special — for example, the natural land cover shown in figure 2.1.

In this chapter, you will investigate land cover change and its implications on people, places and environments. You will also explore options for your fieldwork activity.

land cover what is covering the land (e.g. vegetation, human infrastructure or development, agriculture or bare earth)

biophysical of or relating to the physical environment, which includes the living organisms that inhabit it

anthropogenic caused by human beings

development the process of changing the purpose of a piece of land by constructing or removing something

sustainability a process of maintaining balance in an environment while retaining the ability of current and future inhabitants to use that environment

FIGURE 2.1 Natural land cover in the Daintree National Park, Queensland

2.1.2 Syllabus links

Syllabus links	Lessons
Explain the geographical processes that result in particular physical features (e.g. dune systems, river systems, deserts, forests, grasslands) that shape the identity of places at a local scale.	**2.2, 2.3, 2.4, 2.5**
Explain the importance of Aboriginal and Torres Strait Islander peoples' connection to Country/Place, and their understanding of natural features and elements of the local ecosystem/s (e.g. dune systems, river systems, deserts, forests, grasslands).	**2.2, 2.3, 2.4, 2.5**
Interpret land use maps to identify where changing land cover (e.g. deforestation, land reclamation, agricultural practices, urbanisation, land drainage, pastoralism, mining) has had an impact on the biophysical environment in a local area.	**2.2, 2.4, 2.5**
Explain Aboriginal and Torres Strait Islander peoples' care for land (as applicable to their local area, where relevant) and the impacts of these practices on land cover over time.	**2.2, 2.3, 2.4, 2.5**
Explain geographical processes that have contributed to land cover change in a local area, including: • anthropogenic processes (e.g. urbanisation, agriculture and resource exploitation) • natural processes (e.g. weather, natural hazards).	**2.2, 2.3, 2.4, 2.5**
Recognise the spatial changes to land cover at a local scale and represent these on maps using spatial technologies.	**2.4, 2.5**
Explain the implications for environments and people of the changing land cover, including on spiritual and cultural features of value for Aboriginal and Torres Strait Islander peoples, where appropriate.	**2.2, 2.3, 2.4, 2.5**
Explain a local land or water management challenge using a conceptual model; for example, threats to biodiversity, reduced water quality or availability, diminished riparian health, salinity, loss of coastal protection through diminished mangroves or dune systems, waste management (e.g. landfill), coral reef loss or destruction.	**2.4, 2.5**
Conduct a field study (for assessment purposes) to collect primary data for investigating a land management or water management challenge as a result of land cover change on a local scale. As part of this field study, students must • use geographic inquiry to carry out fieldwork for investigating a local land management or water management challenge • identify data required and appropriate methods for data collection • analyse data gathered in the field to explain the nature, location and extent of the challenge • apply geographical understanding from their analysis to generalise about the impacts on people, including Aboriginal and Torres Strait Islander peoples, where appropriate, and the sustainability of the environment for the place being investigated • propose action/s in response to the generalisations to address the land management or water management challenge to create or improve the sustainability at the fieldwork location • transform primary data collected in the field using cartographic, graphic and mathematical skills, spatial and information, and communication technologies to communicate findings in a fieldwork report.	**2.6**

KEY QUESTIONS

- What is land cover change?
- How is land cover important to us environmentally, socially and culturally?
- What processes are involved in local land cover changes?
- What are the impacts of local land cover changes?
- How can we manage local land cover changes to maximise sustainability?

LESSON
2.2 Coastal land cover transformations

LEARNING INTENTION

By the end of this lesson you should be able to explain the geographical processes that result in coastal land cover change and the coastline's connection to identity, cultural heritage and values. Through the analysis of spatial patterns, you should be able to identify the implications of these land cover changes.

2.2.1 Our transforming coastlines

The coast is an important place for many Australians, and is considered a place of recreation and beauty. It is also a popular place to live near, with approximately 87 per cent of the Australian population living within 50 kilometres of the coastline. The coast's popularity is due to factors such as improved climate, and access to water resources, agricultural industries, transport and recreation. Our coasts are delicate ecosystems that need to be in balance, and changes to our coastline can adversely affect those ecosystems.

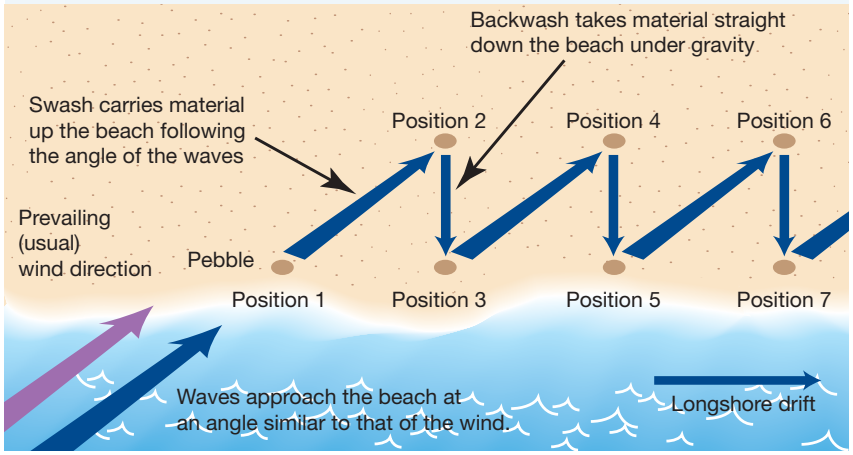
Biophysical changes

The most significant biophysical changes to coastal landforms are caused by the processes of **erosion** and **deposition**. Erosion and deposition are natural processes that can be exacerbated by anthropogenic changes. Dune systems develop through the deposition of sediment from the ocean, driven by onshore winds. Through the process of longshore drift (see figure 2.2), sediment is removed and deposited along coastlines.

erosion the wearing down of rocks and soils on the Earth's surface by the action of water, ice, wind, waves, glaciers and other processes

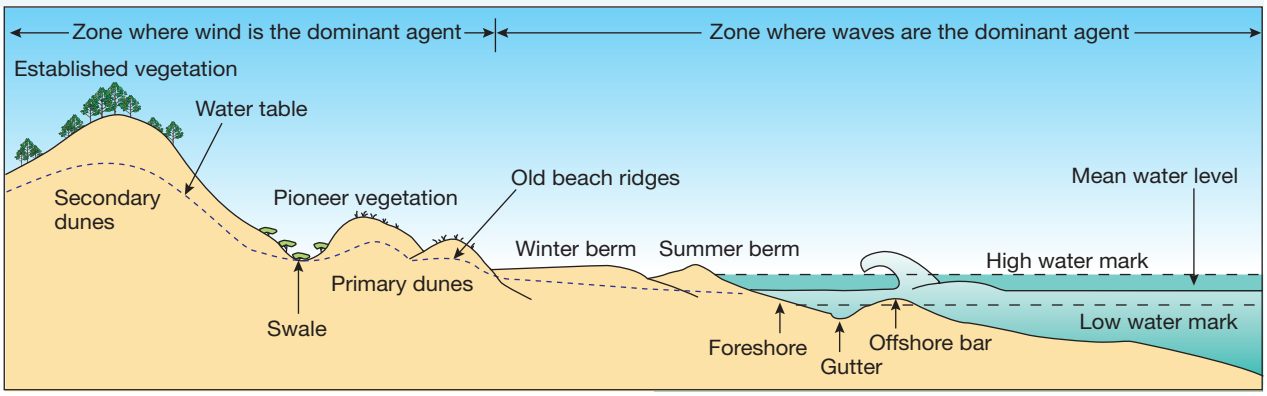
deposition when seas, rivers or the wind drop the material they have been carrying, creating or changing landforms

FIGURE 2.2 Longshore drift



As sediment builds up along the coastline, wind transports the sediment up the beach, forming dune systems (see figure 2.3). Additional dunes can develop behind the primary dunes, and they are known as secondary and tertiary dunes (also shown in figure 2.3). As the dune systems grow, vegetation forms, stabilising the dune system from wind erosion. Dunes act as a reserve for the beach to replenish itself in times of erosion events.

FIGURE 2.3 Typical dune structure



Development along the coastline removes vegetation and habitat, and can damage or wipe out dune systems and mangrove environments (refer to lesson 1.6.9). Coastal vegetation is important but vulnerable, and acts as a stabiliser. This means its removal can lead to erosion. Dunes are components of the sediment budget on low-energy coasts and their removal can have widespread impacts in other areas of the ecosystem.

Coastal erosion occurs due to wind and wave action. Along the east coast of Australia, the most destructive coastal erosion events come from east coast lows. East coast lows are low pressure systems that are slow moving and often cause strong winds, heavy rain and rough swells. In January 2022, rough swells led to the erosion of the northern tip of Bribie Island, splitting it into two (see figure 2.4). Due to the connection between atmospheric conditions and erosion events, climate change is predicted to increase the frequency and intensity of east coast lows.

FIGURE 2.4 Aerial view of Bribie Island divided in two by tide in combination with ex tropical cyclone Seth

Modifying coastlines through anthropogenic changes

Wind, wave and current action are responsible for moving sand on and off a beach and along a coastline, but anthropogenic changes can interrupt these biophysical processes and create long-term problems. Significant changes to our coastlines can interrupt natural geographic processes, including longshore drift.

CASE STUDY: Tweed River

Quick facts: Tweed Heads

- **Population** 63 721 (Tweed Heads urban centre)
- **Average number of boats that pass through Tweed River entrance per year post sand dredging** 22 246 (up from 11 760 pre-project)
- **Estimated economic value of a navigable Tweed River entrance and improved beach amenity** $228 million

The training walls or breakwaters at the mouth of the Tweed River in New South Wales were built to keep the mouth of the river clear and so protect the commercial shipping operations that used the river (see figure 2.5). Unfortunately, the development of the training walls meant the process of longshore drift was artificially interrupted. This led to a significant reduction of sediment along the beaches of the southern end of the Gold Coast.

The lack of sediment being moved onto the Gold Coast beaches led to the removal of huge amounts of sand, the destruction of many kilometres of dunes and the exposure of roads and houses that had been built close to the beaches.

Managing coastal development has its own unique challenges. One of the best examples of effective management of issues related to change along coasts is the Tweed River Sand Bypassing System (TRSBS). This system is considered innovative because of the way in which it solves a problem by replicating a natural process.

After a series of storms swept through the Gold Coast area in the early 1970s, massive erosion occurred on these exposed beaches, causing damage to the dunes, property and infrastructure. Giant boulders and car bodies were imported to the beach to try to reduce the sand loss. This widespread and shocking destruction of an iconic Australian beach highlighted the seriousness of the problem, and sparked the search for solutions. Nearly 30 years later, the TRSBS was installed and operational.

FIGURE 2.5 Tweed River training walls

Source: Skyepics

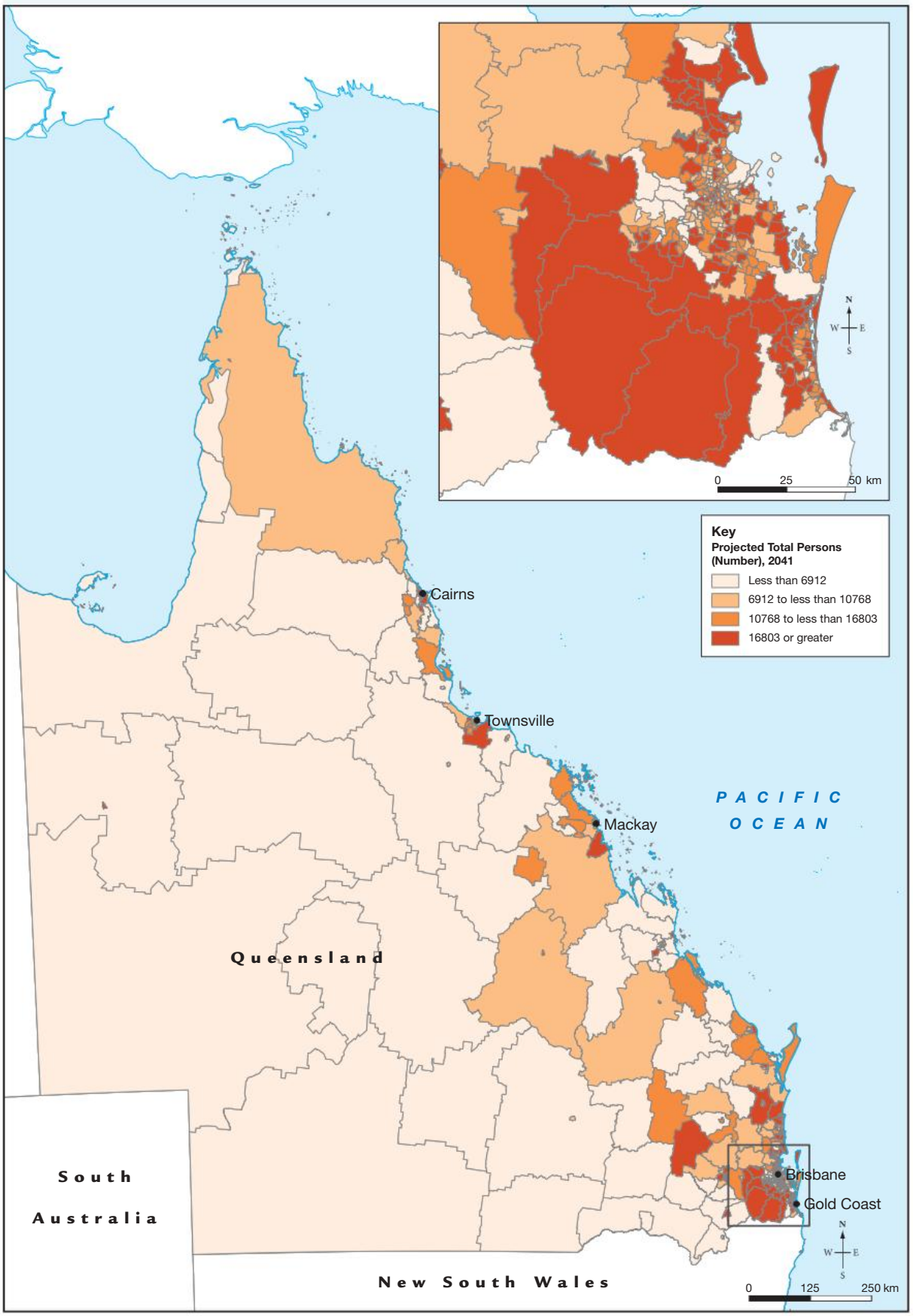
The TRSBS is a sand transport system that collects sand from the southern side of the river and then pumps the sand under the river to the north side. Once the sand is moved, the wind, waves and currents move sand naturally along the Gold Coast beaches. Almost immediately after installation, sand levels along the southern Gold Coast beaches were stabilised and sand budgets along these beaches returned to normal levels. The training walls are still in place, and fishing and boating vessels can enter the Tweed River unimpeded.

2.2.2 The pressure of urbanisation on coastal areas

Urbanisation is the movement of people into urban areas, often from rural and remote areas. It is the growth in proportion of a population living in urban environments. This phenomenon is occurring across the world, with more people and a greater proportion of the global population living in cities. By 2023, 57 per cent of people worldwide were living in an urban place, and this proportion has been steadily increasing over the last century. Projections from the United Nations (UN) indicate that rural populations have stopped growing and the population of urban areas can expect to increase by 2.5 billion by 2050.

A high proportion of the Australian population has always lived in cities and close to the coast. European settlements that began as towns grew, attracting more and more people. Some people moved into rural areas as the country was opened up to farming, but the trend over the past 100 years has clearly been one of increasing urbanisation. Figure 2.6 shows the components of population change in Queensland since 1981 and how this is projected to continue.

FIGURE 2.6 Population change in Queensland, projections to 2041



Source: © The State of Queensland Queensland Treasury 2019

DID YOU KNOW?

Queensland's population change comprises three components:

- natural increase (births minus deaths) net
- interstate migration (interstate arrivals minus interstate departures)
- net overseas migration (overseas arrivals minus overseas departures).

2.2.3 The spatial pattern of urbanisation

In Australia, the trend over the past 100 years has been one of increasing urbanisation. Australia has five urban areas with populations of more than one million: Sydney, Melbourne, Brisbane, Perth and Adelaide.

A local government area (LGA) is a portion of land, including all the people and buildings on it, that a local government is responsible for. Queensland's ten largest LGAs, and their projected populations in 2046, are shown in table 2.1. Of the top ten LGAs, seven are located in close proximity to the coastline and have the potential to place the existing landscapes under further pressure. The growth of these urban areas places strain on coastal ecosystems. Urbanisation is a major cause of coastal wetland habitat destruction and significantly alters the natural functioning of coastal ecosystems.

TABLE 2.1 Projected Queensland population in 2046, ten largest LGAs

LGA	2021 ERP*	Low	Medium	High
Brisbane	1 264 024	1 459 649	1 603 148	1 757 745
Gold Coast	633 764	849 262	983 004	1 129 670
Moreton Bay	484 428	668 313	796 515	934 678
Logan	350 740	463 532	539 874	621 735
Sunshine Coast	346 648	464 971	545 523	632 555
Ipswich	233 302	399 032	529 064	670 062
Townsville	195 515	225 752	264 899	306 053
Toowoomba	175 316	198 411	211 402	225 042
Cairns	169 312	205 285	231 164	259 743
Redland	161 730	173 098	183 649	194 908

Source: Queensland Government Population Projections Summary (2023 edition)
* Estimated resident population

Urbanisation occurs at the edges of cities and towns but can also occur inside these places. Urbanisation includes farmland, forests and grasslands being removed for housing developments on the urban fringe. These areas also see infrastructure development as roads, highways and rail lines are built to connect people to other places. Inside cities and towns, infill development occurs, where population densities are increased to accommodate more people in the same area. This is usually done by replacing single-dwelling houses with townhouses or apartments, or replacing existing apartments with even bigger ones.

Figure 2.7 shows the scale of urbanisation in south-east Queensland over ten years. In 1999, Brisbane, the Gold Coast and the Sunshine Coast were distinct urban entities, but by 2019 these cities had started to merge, particularly along the Pacific Motorway, as people and businesses took advantage of the convenience of a major transport route connecting all three urban areas.

FIGURE 2.7 Satellite images of south-east Queensland, (a) 1999 and (b) 2018

Source: © State of Queensland 2018

SKILLS ACTIVITY: Geographic inquiry

Locate a recent satellite map of south-east Queensland to compare changes from 2018 to the present.

1. Can you see more urbanisation? In which areas?
2. Discuss the impacts that can occur from changes in urbanisation along this coastline.

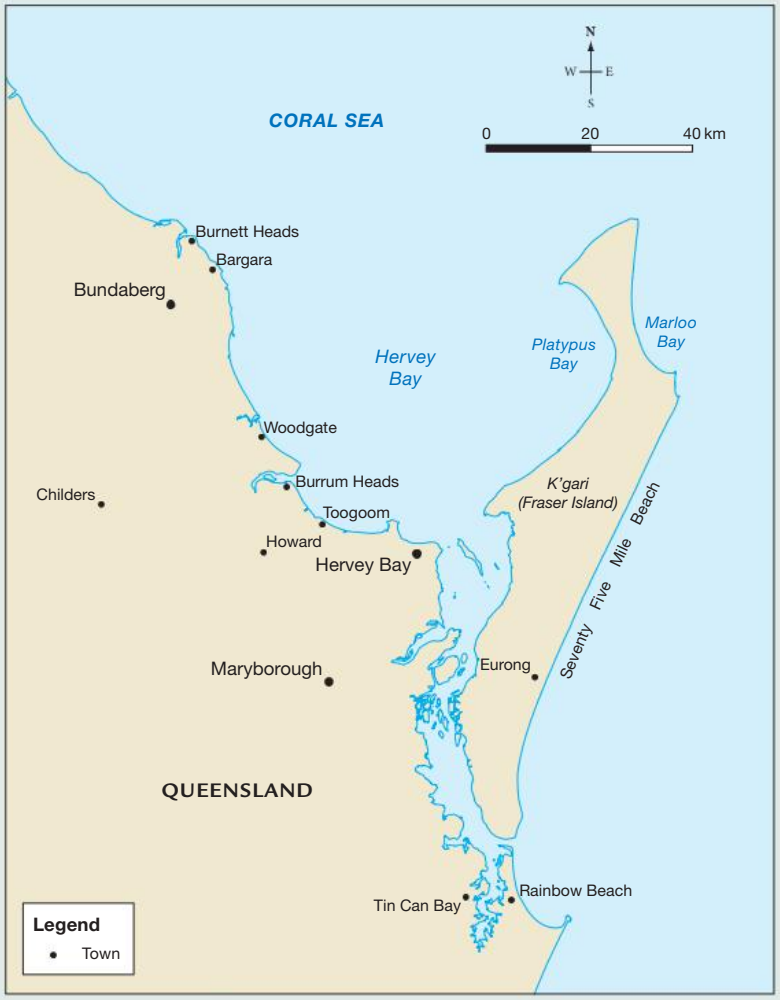
CASE STUDY: Protecting K'gari

Quick facts: K'gari

- **Population** 152
- **Median age** 52
- **Estimated number of annual visitors** 500 000

K'gari, located off the coast from Hervey Bay (see figure 2.8), is the largest sand island in the world and Queensland's largest island.

FIGURE 2.8 Map of K'gari



Source: Map drawn by Spatial Vision

K'gari was recognised as a World Heritage Area in 1992 for its outstanding universal value due to its biodiversity, cultural values and ongoing biological, hydrological and geomorphological processes. K'gari remains an important land for the traditional custodians, the Butchulla people.

Prior to European settlement, the Butchulla people used patch mosaic burning to sustainably manage the K'gari ecosystem. However, after colonisation, logging operations spanning the 130 years prior to 1991 and sand mining from 1950 to 1977 stopped this cultural practice.

An estimated 500 000 to 800 000 people visit K'gari each year, with tourism growing exponentially since the 1970s, driven by the aesthetic values that people attributed to the island. Camping and four-wheel driving became popular; however, they negatively impacted local water sources and dune systems. Water samples taken from camping areas, for example, indicate high levels of faecal-related nutrients, which have seeped into soil samples taken from the water table. Additionally, high numbers of four-wheel drive vehicles on the sand dunes have resulted in erosion. Most notably, in 2020 an illegal campfire spread out of control and burned 80 000 hectares, almost half the island of K'gari (see figure 2.9). The fires caused extensive loss of vegetation, and so exposed sand dunes to wind erosion. Additionally, over half of the island's ecosystems were impacted, reducing the food available for herbivorous species.

FIGURE 2.9 Impact of 2020 fire on K'gari

As part of the review into the 2020 fires, back burning for the purpose of hazard reduction has been replaced with patch mosaic burning as a way for the Butchulla people to manage their Country.

Aboriginal and Torres Strait Islander peoples have used fire in a variety of ways, including to enable access to parts of the environment, for hunting and for ceremonial purposes. It was also used as a land management tool — fires were deliberately started in cooler months to reduce fuel loads, stimulate habitat growth for some animal species and to allow fire-sensitive plant communities to thrive. Studies have shown that effective use of fire to undertake continuous but small-scale burning can actually increase biodiversity in an area. These methods create a mosaic of burnt and unburnt areas across the landscape, which is in contrast to one-off, large-scale burns that may be undertaken by non-Indigenous authorities. These fires wipe out large swathes of the land, tend to reduce biodiversity and increase stress on the environment.

SKILLS ACTIVITY: Geographic inquiry

Looking for erosion or deposition at school

1. Conduct a field trip around your school to find locations that show evidence of erosion or deposition, either natural or human-induced.
2. Select one location showing erosion or deposition that you observed and draw a figure to demonstrate how that erosion or deposition occurs. Ensure you use labels to fill out any information not indicated in the figure.
3. Investigate other types of erosion that you might expect in your local area. What are the different causes of that erosion?

2.2 Exercise

2.2 Exercise

Learning pathways

LEVEL 1	LEVEL 2	LEVEL 3
1, 7	2, 4, 5, 8	3, 6, 9

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Explain and comprehend

1. **Explain** the biophysical changes that transform coastlines.
2. **Explain** the anthropogenic changes that transform coastlines.
3. **Explain** the different ways that people use coastlines.
4. With reference to one land cover change, **construct** a flow chart to show the effects and implications for coastlines.
5. **Research** and **list** Aboriginal and Torres Strait Islander peoples' fire management strategies.

Analyse and apply

6. **Explain** how anthropogenic changes to coastlines impact biophysical processes.
7. **Outline** the impact increased rates of urbanisation have on the coastline.

Propose and communicate

8. **Propose** a future management plan for K'gari that maintains cultural, economic and environmental values.
9. **Evaluate** the effectiveness of embedding Aboriginal and Torres Strait Islander peoples' fire management strategies into local environments. Use evidence to support your claim.

Sample responses for this chapter are available online.

LESSON
2.3 Relationships with our rivers

LEARNING INTENTION

By the end of this lesson you should be able to explain the geographical processes that result in inland waterways land cover change, and various rivers' connection to identity, cultural heritage and values. Through the analysis of spatial patterns, you should be able to identify the implications of these land cover changes.

2.3.1 River landscapes

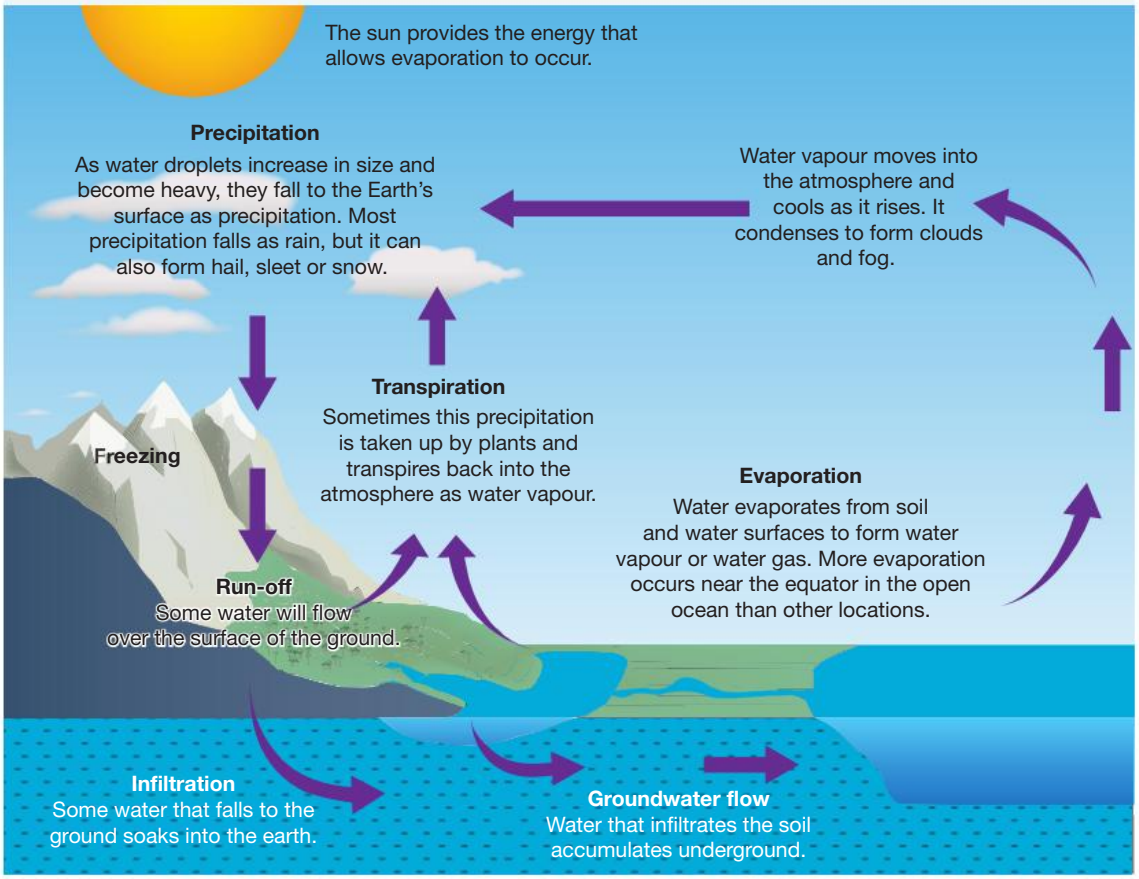
Rivers and waterways form an important part of the **water cycle** (see figure 2.10) because they drive through the landscape, taking water downstream from headlands at higher ground. When enough water collects in a catchment (the area that feeds a river system), gravity can turn it into a trickle by pulling it down towards sea level. As these trickles become tributaries and move downstream, more water collects into streams or rivers and, over time, all of this water can accumulate to create huge flows of water and the mighty river systems of the world, including the Nile, the Amazon, the Yangtze, and even the Murray or the Brisbane River.

water cycle a model that demonstrates the movement of water on, above and below our environment

Waterways play a vital role in moving water across the land, especially on dry **continents** such as Australia. Land cover changes can have profound impacts on our rivers and waterways, which can in turn impact agricultural and rural communities along the waterways.

continents the largest landmasses on Earth: Africa, Antarctica, Asia, Australia, Europe, North America and South America

FIGURE 2.10 The water cycle



2.3.2 Biophysical changes

Rivers and their catchments are constantly changing and evolving. The two most common biophysical changes to river systems are erosion and weathering.

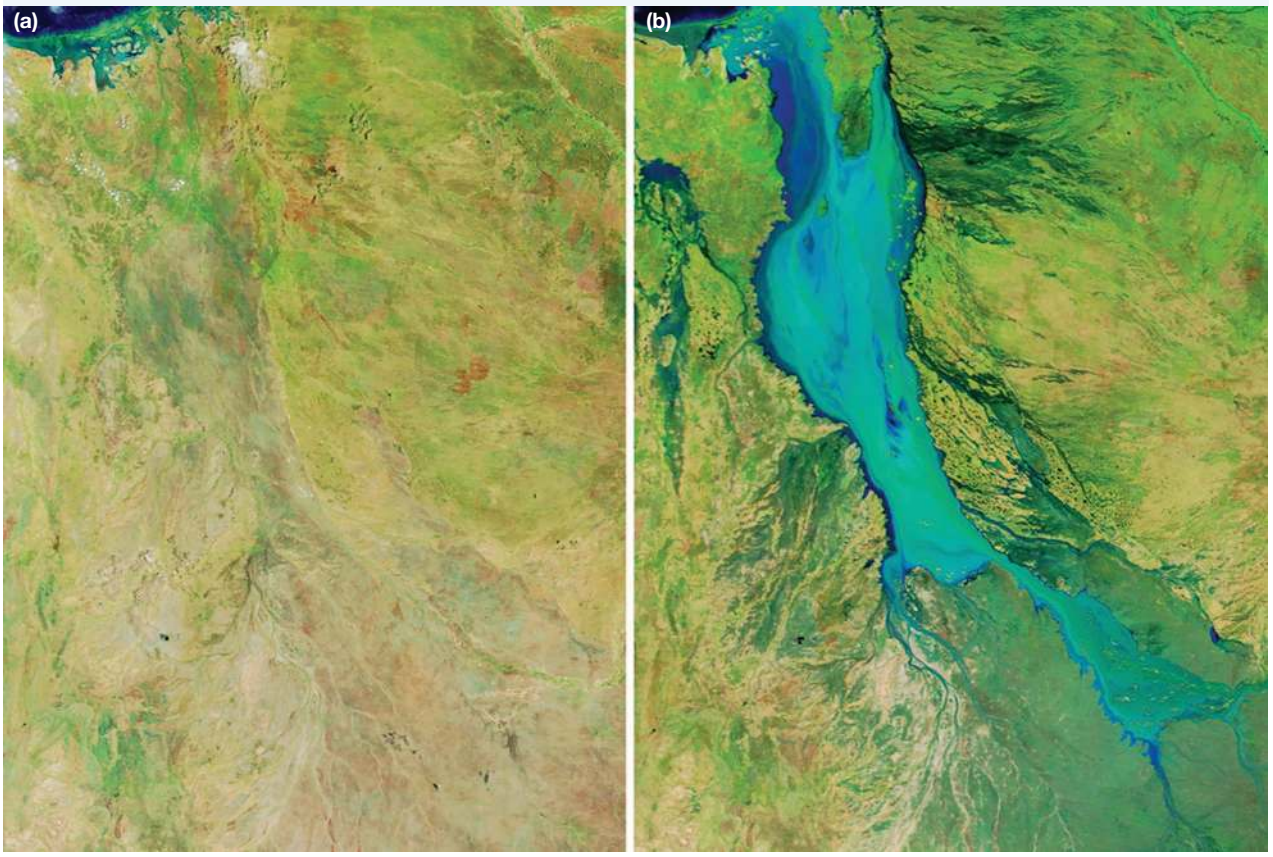
Erosion and deposition

Erosion of the Earth can be seen in all river systems as the movement of water has carved its way through stone and soil over many years. This erosion leads to unique river valley shapes, such as U- and V-shaped valleys in the upper reaches and meanders, oxbow lakes and deltas in the lower reaches of river systems.

Deposition of sediment occurs when eroded sediment is deposited due to energy loss. This usually occurs when the wind or water carrying the sediment slows down and drops the sediment. The inside bend of a river is an example of deposition of sediment. As the river moves around the bend, the water moves faster on the outside but slower on the inside. This is why sediment gets deposited at river bends.

The process of erosion and deposition within river systems can be exacerbated by flooding events. After the 2019 floods in north-west Queensland, for example, Flinders River experienced significant erosion, with 100 metres of riverbank being swallowed in the flood water, leaving behind 8-metre-high cliffs. Flinders River, which flows into the Gulf of Carpentaria, is typically hard to identify on a satellite image; however, the flooding rain in 2019 caused the river to swell to 60 kilometres in width (see figure 2.11).

FIGURE 2.11 Flinders River in 2019, (a) before and (b) after flooding



Source: NASA

As a result of this erosion, experts estimated that approximately 47 237 tonnes of fine sediment was deposited into the Gulf of Carpentaria. The Gulf is home to expansive seagrass meadows that hold value for local First Nations Australians and provide an important role in the marine ecosystem. Excess sedimentation through deposition of erosive materials can increase the turbidity of the water, reflecting sunlight required for the seagrass and causing it to starve. This has implications for the fisheries industry in this area.

Weathering within rivers

Weathering is the physical, chemical or biological breakdown of rocks and minerals into smaller parts (see figure 2.12). Physical weathering occurs when larger rocks are broken into smaller rocks. This is often seen in river systems where water pushes rocks down the river and they are broken up as they travel. Frozen water expanding in cracks and crevices of rocks can also cause physical weathering, as can wind and rain.

Chemical weathering occurs when rock is broken down due to chemical reactions. Carbon dioxide, oxygen and water often react with the atmosphere or minerals in the rock to cause this process.

FIGURE 2.12 Examples of physical, chemical and biological weathering

Biological weathering occurs when living things break down rocks or minerals into smaller pieces. This can occur when tree roots destabilise and break down rock or when microbes release chemicals that slowly disintegrate rock. Although physical and chemical in process, these examples are driven by biological entities and are thus categorised as biological weathering.

2.3.3 Anthropogenic changes

Agriculture has had the largest global impact on land cover change, particularly in proximity to river systems. Ever since humans embraced agriculture, we have required land and water to grow crops, for somewhere to live, to store supplies and produce, to transform the raw materials into something worth selling and to graze livestock. However, this can have drastic impacts on our river systems.

The spatial pattern of agriculture

Agriculture refers to the cultivation of plants and animals for use by humans. We use agricultural products every day. For instance, most of what we eat is sourced from crop production or by slaughtering domesticated animals, and most products, including leather, natural clothing fibres, medicines and oils, are created through agricultural production.

Modern, large-scale industrial farming businesses operate over huge areas of land and produce most of our food, crops and animal products, while having a significant impact on the natural environment and rural communities.

In Queensland's agricultural industry, what is grown now depends on geography and climate. Different crops grow in different areas and different animals are suitable for large-scale production in different areas.

Queensland is dominated by three main crops: wheat, sugar cane and sorghum. In 2023–24, 720 000, 328 300 and 415 000 hectares of land were devoted to each, respectively. As shown in table 2.2, the amount of land set aside to grow different crops can change over the years due to farmers adapting to different climatic conditions, fluctuations in prices for crops, resource availability (particularly water availability), changing consumer needs and desires, and changing technology.

TABLE 2.2 Area by agricultural crop, Queensland, 2013–14 to 2023–24

Crop		Financial year										
		2013–14	2014–15	2015–16	2016–17	2017–18	2018–19	2019–20	2020–21	2021–22	2022–23	2023–24
Sugar cane		359.1	360.1	361.5	385.7	35 709	362.4	350	340.6	329.1	317.8	328.3
Cereals for grain	Barley	105.8	125.5	137.7	149.0	105	99	80	227	207	136	150
	Sorghum	355.6	546.7	363.1	249.9	352.3	393.5	159	422.4	427.5	490	415
	Maize	26.2	30.7	30.1	35.3	25.7	28.2	16.9	16.6	24	20	20
	Oats	23.3	65.3	36.2	47.4	45	35.8	50.1	63.1	50.2	18	25
	Rice	n.a.	2.2	3.9	0.3	1.0	0.8	0.6	0.7	0.6	0.6	0.4
	Triticale	n.a.	2.2	3.9	0.3	0	0.3	0	9.1	1.8	0.5	0.4
	Wheat	758.0	633.5	611.1	622.2	639	419	441.4	966.1	9401.6	980	720
Legumes for grain	Chickpeas	216	165	251.6	550	507	164.9	1701.7	213.7	293.2	200	220
Oilseeds	Soybeans	4.9	6.6	7	5	7.5	4.2	3.6	8.7	8	6.2	6
	Sunflower	4.9	9.4	9.2	5	4.2	4	3.6	8.9	8.3	5	3
Cotton		140.0	73.2	93.8	203.1	175.1	128.9	14.7	104.6	214.1	218.9	122.1
Peanuts (in shell)		5.5	4.7	4.8	4.6	3.9	4.5	4.4	5.6	6.4	4.5	4.1

n.a. = not available

Source: © Australian Bureau of Statistics

Due to Queensland's climate and geography, the state is uniquely placed to grow sugar cane. In the 2023 season, Australia harvested 29.76 million tonnes of sugarcane from 3 41 084 hectares located between far north Queensland and northern New South Wales (see figure 2.13). Sugar cane is used in everything from raw sugar through to ethanol supplements for petrol; however, the industry is more focused on raw sugar production. While the sugarcane industry provides economic benefits to Queensland, these benefits come with a substantial environmental toll.

FIGURE 2.13 Harvesting of sugar cane near Innisfail

Sugar cane has the potential for widescale nutrient loss, caused by run-off increasing nutrient loads within the river systems, creating eutrophication. In far north Queensland, where rainfall is more frequent and higher, nutrient run-off from sugarcane farming has been identified as a significant threat to the Great Barrier Reef. Project Catalyst, a Grower Led Innovation Project for the sugarcane industry, was formed to reduce and mitigate the impacts of agriculture on the Great Barrier Reef. Project Catalyst works with farmers to reduce their environmental impacts while maintaining social and economic benefits.

2.3.4 The impact of agriculture on our rivers

CASE STUDY: The Murray–Darling Basin

Quick facts: Murray–Darling Basin

- **Total coverage of basin** 1 061 469 km^2
- **Total water flow** 24 000 gL per year, on average
- **States and territories covered** Queensland, New South Wales, the ACT, Victoria and South Australia

Of the five states or territories the Murray–Darling Basin covers (see figure 2.14), Queensland alone accounts for approximately one-quarter of its total area. The Basin drains into the Murray and Darling rivers. The Darling River has its headwaters in southern Queensland and northern New South Wales, and the Murray River begins in the New South Wales and Victorian Alps. The Murray and Darling rivers bring water from the Great Dividing Range west and then south, where the river system empties into the ocean in Goolwa, in south-eastern South Australia. While the total water flow in the Murray–Darling Basin has averaged 24 000 gL per year, this can fluctuate depending
on rainfall.

Humans have had the biggest impact on the Murray–Darling Basin in two main areas. One is the diversion and overuse of water for agricultural purposes, and the other is the removal of vegetation along the rivers' **riparian zone** and in the Basin itself.

The overuse of water for agricultural purposes removes water from the water cycle and from ecosystems along the waterway. This has led to many different impacts, including loss of water volume at different periods in the Basin's history and at different locations, **algal blooms** all along the system, increased pollution and lowering of water quality because the system cannot flush itself with the regularity it requires. Land cover change from inside the Murray–Darling Basin can lead to increased run-off, which can carry sediment, nutrients and chemicals such as pesticides into the water system.

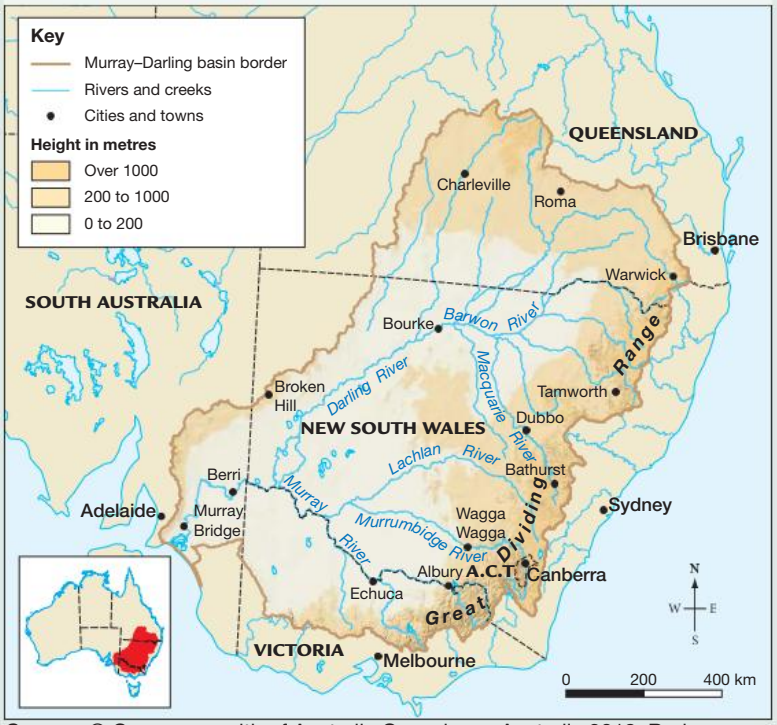
Riparian zones act as a buffer that can slow down run-off and keep some of the heavier materials, such as sediment or pesticides, out of the waterway. Removal of these zones removes the buffer and can increase the amount of damaging materials that flow into the water system.

riparian zone the interface between a waterway and the land that provides habitat, prevents erosion and blocks nutrients and sediments from entering the waterway

algal blooms rapid increases in the accumulation of algae in a water body due to some external pressure (e.g. rapid increase or decrease in temperature or increased nutrients)

In early 2019, millions of fish along stretches of the Murray–Darling system died and floated to the surface in multiple, spontaneous events (see figure 2.15). This demonstrates the connectivity between different elements of the river system.

FIGURE 2.14 The Murray–Darling Basin



Source: © Commonwealth of Australia Geoscience Australia 2018. Redrawn by Spatial Vision.

This event occurred because land clearing led to an increase in nutrients in the waterway and overuse of water reduced the total amount of water. The situation was exacerbated by an extended drought across south-eastern Australia, and then an algal bloom and rapid temperature change extracted all of the oxygen from the waterway, which led to the rapid death of millions of fish. Water extraction, drought and vegetation loss all played a part in the final outcome.

FIGURE 2.15 The Menindee fish deaths in early 2019

Source: Graeme McCrabb / AAP

Potential solutions to the changes

Since 1915, various arrangements have been in place that have outlined how the Murray–Darling's water resources will be used and managed. In the early 1990s, a shift towards a market-based approach allocated water resources to users and water use was then capped. As water quality and volume have continued to fall along the Murray–Darling, greater consideration has been given to the value of water flows for environmental uses in the Basin. These moves have likely been exacerbated by the continual closing and shifting of the mouth of the Murray–Darling. Other, more radical, solutions call for the reregulation of water allocations along the Murray–Darling, with greater consideration given to environmental flows and uses. Ultimately, strong evidence highlights that an appropriate balance has not yet been struck between the environment and economic users of the system's water.

Sustainable management of the Murray–Darling Basin also needs to reflect the cultural and spiritual value of water for Aboriginal peoples. Cultural flows, which are water entitlements that are owned by Aboriginal Nations for the purpose of improving spiritual, cultural, environmental, social and economic conditions of First Nations Australians, are an important aspect of management within the Murray–Darling Basin. Over 50 different Aboriginal Nations are connected to the Murray–Darling Basin, each with their own traditional ecosystem knowledge and unique connection to the river system. The implementation of the Cultural Flows for Cultural Economies program aims to support the ownership and autonomy of Aboriginal peoples and Torres Strait Islander peoples within the Murray–Darling Basin.

2.3.5 A sustainable future?

Management of river systems has been ineffective in the past when it failed to recognise the interconnectedness of ecosystems and the importance of management techniques in parts of catchments away from the waterway and its riparian zone. Greater emphasis on how farmers manage their lands in recent times has yielded significant improvements to water quality, although many improvements are still to be made, as demonstrated by the problems in the Murray–Darling Basin.

Rejuvenation of river ecosystems can happen through a range of methods. In general, rebuilding of the riparian zone and reinstating water flow, where possible, are the two most important actions to positively manage rivers.

Rethinking agriculture

Sustainable management of our rivers and water sources also needs to come from our greatest use of water: agriculture. Incorporating more sustainable practices that are adapted to Australia's climates and resources provides a way forward.

For more than 60 000 years, Aboriginal and Torres Strait Islander peoples have undertaken sophisticated and sustainable land management practices that have been based on an intimate and deep connection to the local area and the land beyond. Aboriginal and Torres Strait Islander peoples ploughed fields and harvested crops, mainly tubers such as yams, though not in the regimented way recognised by Europeans when they arrived in Australia. First Nations Australians also carefully selected and preserved foods and irrigated crops, with evidence even showing that they transported fish stocks and harvested aquatic animals such as eels with sophisticated aquaculture infrastructure, such as those found at Budj Bim in Victoria. Aboriginal and Torres Strait Islander peoples managed the land using age-old techniques that have been tested and retested under Australian conditions.

With regards to agriculture, these techniques include:

- harvesting and cultivating crops to use as a source of food and a commodity for trade. Vast tracts of what is commonly thought of as useless land were once covered in fields of Australian grains that are slowly being reintroduced to growers.
- damming of waterways strategically for water storage and agricultural purposes
- threshing, harvesting, drying and milling of grains for cooking (flour). This occurred in numerous locations around Australia, as evidenced by records from European explorers.
- transportation of seed stocks across the landmass in order to increase genetic diversity of plant species
- deliberate selection of seed stocks to create varieties that are tailored to their local environmental characteristics, soils, climate, rainfall and even topography
- storage of surplus grains for trade and use in non-seasonal periods
- capture and storage of fish, eels and other marine life through drainage manipulation and the construction of fish traps, widely regarded to be the oldest human-made structures in existence.

All of these innovative and ingenious methods of managing the land were not recognised by Australia's colonial settlers as they sought to make Australia as British as possible and used British agricultural methods instead. Although they did not realise it, these methods were entirely unsuitable for Australia's climate and soils.

However, people are now recognising the benefits of the traditional methods and they are starting to be used again.

EXAMPLE: Permaculture

Permaculture is a set of design principles that recognises the interconnectedness of ecosystems. It is a systems approach to agriculture that attempts to replicate natural systems in order to achieve sustainability. The concept has spread beyond agriculture to include culture more broadly. The principles of permaculture can be applied in fields such as agriculture, systems ecology, environmental design, town planning, urban design, and water and soil resource management.

FIGURE 2.16 Permaculture in action

Permaculture principles are being adopted widely these days. They are applicable at scales from the individual, to the local area, to the national. The 12 design principles of permaculture that allow users to considerably alter their impact on the environment are as follows:

1. Observe and interact: Understand nature's patterns in order to design appropriate solutions to problems.
2. Catch and store energy: Develop systems to capture and store energy in all parts of development.
3. Obtain a yield: Grow for a purpose.
4. Apply self-regulation and accept feedback: Improve your work and outputs.
5. Use and value renewable resources and services: Decrease dependence on non-renewable resources.
6. Produce no waste: Use resources efficiently to eradicate waste.
7. Design from patterns to details: Observe and replicate natural patterns where possible.
8. Integrate rather than segregate: By putting the right things in the right place, relationships develop between those things and they work together to support each other.
9. Use small and slow solutions: Smaller solutions encourage greater attention to detail in an area or project.
10. Use and value diversity: Diversity reduces vulnerability to threats and enhances the unique nature of the environment in which it resides.
11. Use edges and value the marginal: The interface between things is where the most interesting events take place. These can be the most productive elements in the system.
12. Creatively use and respond to change: Observation and understanding of local environmental patterns allow us to adapt to change quickly.

SKILLS ACTIVITY: Explain and synthesise data

Graphing Queensland's crops

Go to the website of the Queensland Government department responsible for agriculture to answer the following questions. (At time of print, this was the Department of Primary Industries.)

1. What percentage of Queensland is used to grow cereal crops?
2. What are the top three crops in terms of production in the most recent year or season you can find?
3. Create a line graph showing the yield of cotton in Queensland over a period of time. Ensure your graph adheres to common chart conventions.
4. Suggest reasons for the fluctuations in production in some crops over time.

2.3 Exercise

2.3 Exercise

Learning pathways

LEVEL 1	LEVEL 2	LEVEL 3
1, 4, 7	2, 5, 8	3, 6, 9

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Explain and comprehend

1. **Explain** how agriculture changes rivers.
2. **Explain** how erosion and deposition change rivers.
3. **Outline** the flow-on effects of too much sedimentation in the water.

Analyse and apply

4. **Explain** how erosion is a result of biophysical and anthropogenic changes in the river landscape.
5. **Identify** the changes to land cover that have occurred in the Murray–Darling Basin.
6. **Outline** the implications of these changes in the Murray–Darling Basin.

Propose and communicate

7. **Evaluate** the importance of First Nations Australians in the management of places.
8. **Evaluate** the effectiveness of permaculture as a sustainable agricultural process.
9. **Respond** to the following statement using evidence: 'Queensland should ban sugarcane farming across the state until more sustainable methods can be found.'

Sample responses for this chapter are available online.

LESSON
2.4 Transforming our deserts

LEARNING INTENTION

By the end of this lesson you should be able to explain the geographical processes that result in desert land cover change, and the desert's connection to identity, cultural heritage and values. Through the analysis of spatial patterns, you should be able to identify implications of these land cover changes.

2.4.1 Deserts

Deserts are areas that experience little precipitation and have little vegetation or ground cover. They are not completely barren and can occur in tropical, temperate and polar regions. Deserts make up almost 30 per cent of the Earth's land surface, with most of the world's deserts located 30 degrees north or south of the equator. No deserts are found on the equator itself, where you might expect them to exist due to the heat and abundant sunlight.

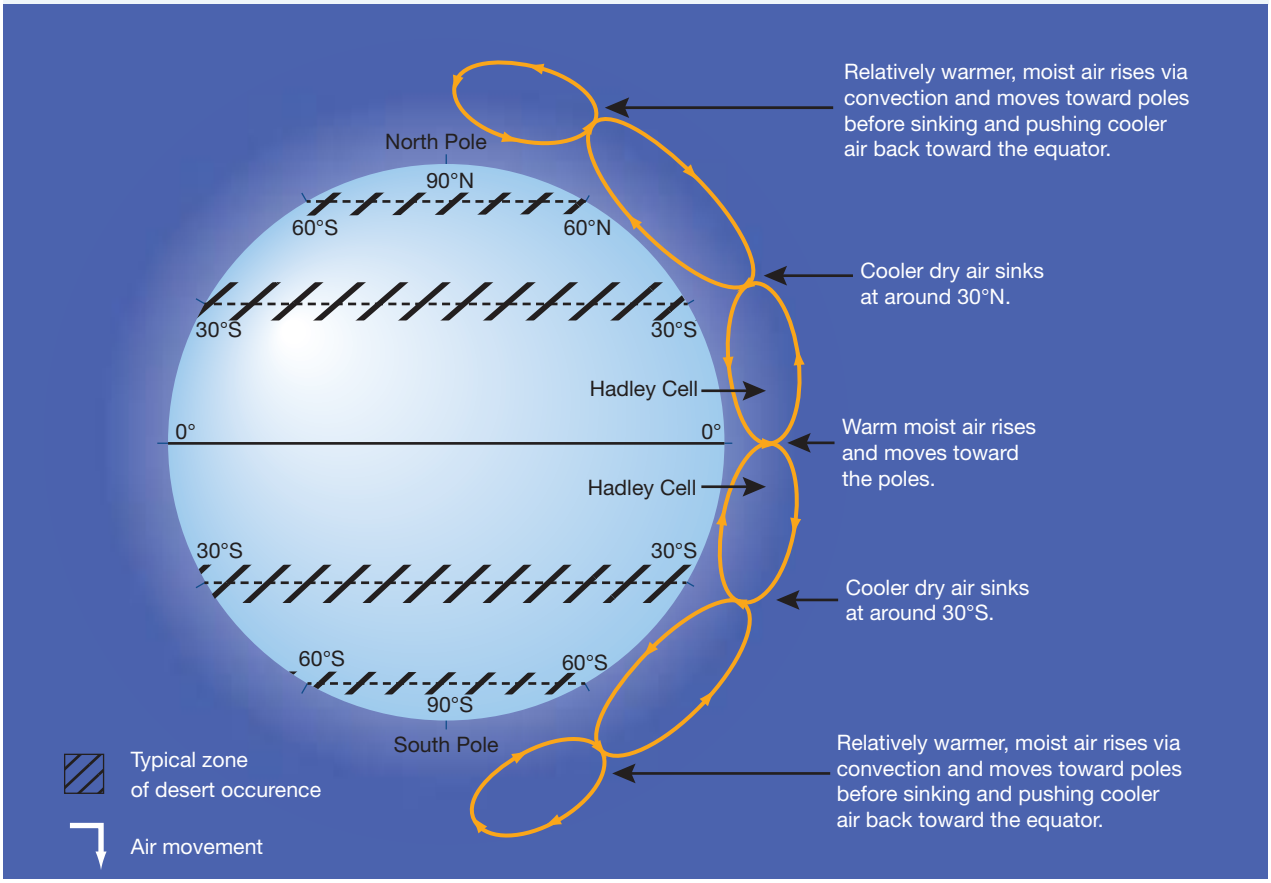
At the equator, the sun's energy warms up water, which causes it to evaporate and be carried into the air. Large, warm masses of moist air are driven towards the poles from the equator by the **Coriolis effect** (see figure 2.17). These cells slowly deposit their moisture in the form of rain and then start to cool and sink. This sinking tends to occur around 30 degrees north and south of the equator. On the ground, these areas

Coriolis effect a force like inertia that deflects objects moving across the surface (air, ocean currents, etc) to the left in the southern hemisphere and to the right in the northern hemisphere. It is caused by the rotation of the Earth.

experience relatively cool, dry sinking air, which leads to the formation of deserts as precipitation is greatly reduced at these areas. The poles both share similar environmental conditions that promote deserts, although they are significantly colder.

Deserts are the harshest environments on Earth and are noted for their unique and creative plant and animal adaptations. These adaptations allow these species to survive in a low-precipitation and low-vegetation environment.

FIGURE 2.17 Movement of air masses that influence the location of deserts

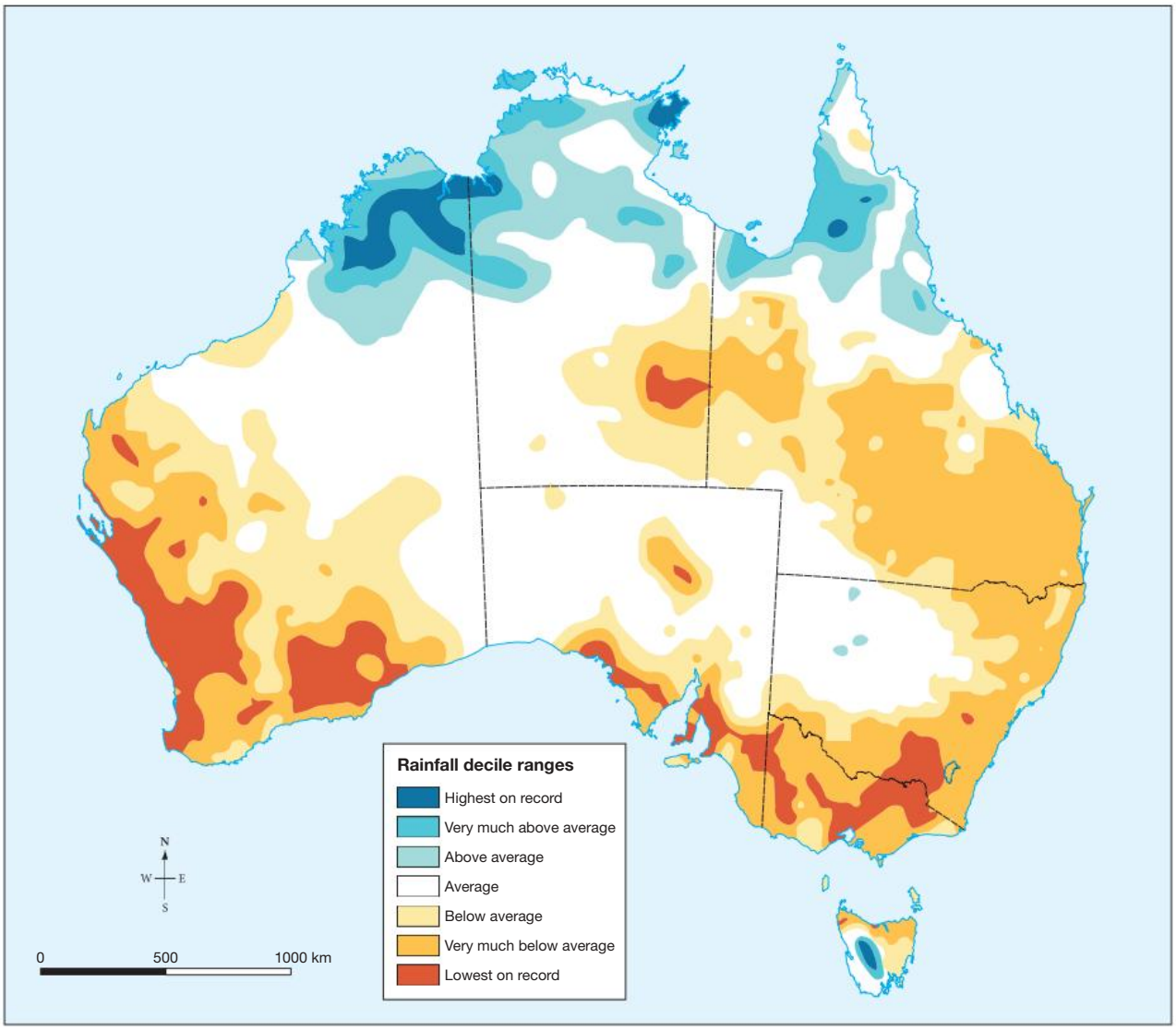


2.4.2 Changes within the desert landscape

Biophysical changes within the desert

Australia has one of the lowest average rainfall measures on Earth, so drought is a hazard that many Australians are familiar with. Drought is a hazard that can affect everywhere in Queensland, but particularly in inland regions where rainfall is less certain. The 24-month rainfall deficiency map in figure 2.18 shows that central southern Queensland and south-west Queensland have experienced some of the lowest rainfall totals in recorded history. This is also reflected across Australia more broadly. The south-west of Australia has seen a rainfall decline of approximately 16 per cent in the cool season since 1970. This means that drought is a hazard that will continue to influence Queensland (and Australia) and one to which we must adapt.

FIGURE 2.18 Rainfall decile map from 1994 to 2023



Source: © Commonwealth of Australia, 2024, Australian Bureau of Meteorology. Map redrawn by Spatial Vision

Note: this decile map shows where rainfall in Australia was above average, average or below average between 1993 and 2023. Areas across northern and central Australia that received less than 40 per cent of their annual rainfall from April to October are faded.

Drought events aren't as instantaneous as other hazard events and the processes that lead to them occur over long periods of time. Two main processes lead to drought: prolonged periods of reduced **precipitation** in an area and increased evaporation. Drought can dry up the soil, which prevents or inhibits plant growth. This land cover change is also felt by animals and people, because vegetation and crops are available for eating. The provision of water supply during periods of drought places pressure on groundwater supplies such as the Great Artesian Basin.

Groundwater is water held within water-bearing rocks, or aquifers, in the ground. These work like sponges by holding water in the tiny holes between the rock particles. An artesian aquifer occurs between impermeable rocks creating great pressure. This water is accessed through wells and drilling of bores which, through the pressure, brings water up to the surface (see figure 2.19). The Great Artesian Basin lies under 22 per cent of the Australian continent, with 70 per cent of this beneath Queensland. The Great Artesian Basin provides a source of fresh water to many inland towns, including Diamantina Shire in far western Queensland, where residents solely rely on the Basin for drinking water.

precipitation rainfall

FIGURE 2.19 An artesian bore at Cunnamulla, Queensland

2.4.3 Anthropogenic changes

Resource exploitation

Resource exploitation is one of the main anthropogenic changes occurring within the desert areas of Queensland. Our knowledge and understanding of how to use different **resources** is what has driven every technological advancement that has changed humanity, from the domestication of animals, to the development of metals, the invention of the printing press and the current digital revolution. The use of resources by humans has changed the world fundamentally.

Natural resources are features of the natural environment from which we derive benefits, such as sunlight, **nutrients**, water, plant and animal species, and **minerals**. Almost everything seen in nature can be used to benefit humans. All animal species, including humans, consume resources to survive, mainly in the form of other animals or plant species.

In a geographical context, natural resources are consumable, and humans use resources to create materials — either to sustain us or for our convenience, enjoyment and/or pleasure. Some broad examples of the use of resources include:

- **crops** and some domesticated animals for food and clothing
- minerals and **fossil fuels** to create plastics
- minerals and plants to create building materials such as cement, wood and plastics that are used to build homes, cities, towns and businesses
- minerals and fossil fuels for vehicles and fuel for transportation
- minerals and fossil fuels to create many modern electronics
- minerals and fossil fuels as a source of power for homes and businesses
- renewable energy (solar, wind, geothermal, wave and hydro) to power homes and businesses.

resources sources from which some benefit is produced (e.g. wood, minerals, water)

nutrients substances used by an organism to survive, grow and reproduce

minerals naturally occurring solid chemical compounds (e.g. salt, quartz)

crops plant or animal products that can be grown and harvested for consumption and/or profit

fossil fuels fuels formed by natural processes that contain energy originally captured during photosynthesis (e.g. decomposition of living matter into coal or oil)

The spatial pattern of mining

Mining is the removal of materials, sediments and ores from the ground in order to process them. It has long played a role in Queensland's history, from Aboriginal peoples' and Torres Strait Islander peoples' use of stone and other mineral resources, to modern, large-scale mining operations that cover many hectares and extract millions of tonnes of material from the ground. Mining is a key driver in Queensland's economy and shapes the identity of many locations across the state.

Cultural impacts of mining

Mining operations are active all over the state of Queensland, and the location of the mines depends on the resource being mined. Weipa in far north Queensland, for example, is one of the world's largest bauxite producers (see figure 2.20). Coal is found in abundance in central Queensland and the Darling Downs.

FIGURE 2.20 Bauxite mine at Weipa, Cape York

Approximately 60 per cent of mining projects are close to the communities of Aboriginal and Torres Strait Islander peoples, often resulting in the destruction of sacred sites and accessibility limitations. Mining can bring some benefits for communities when greater autonomy is provided, allowing cultural practices and care for Country to be maintained. This is the case for the 10 Deserts Project, which ran between 2018 and 2023 and was enabled by BHP. Despite efforts made by mining companies, in some cases these partnerships have not been genuine. This was particularly the case in the Ranger Uranium Mine, located in the Northern Territory, where uranium has the potential for ongoing accumulation of radioactive materials in bush foods and water.

Environmental impacts of mining

Habitat loss and degradation are among the most immediate direct impacts of mining.

CASE STUDY: Opal mining in Winton — industry versus environment

Quick facts: Winton

- **Population** 856
- **Median age** 45
- **Economic contribution of opal mining** $14 million

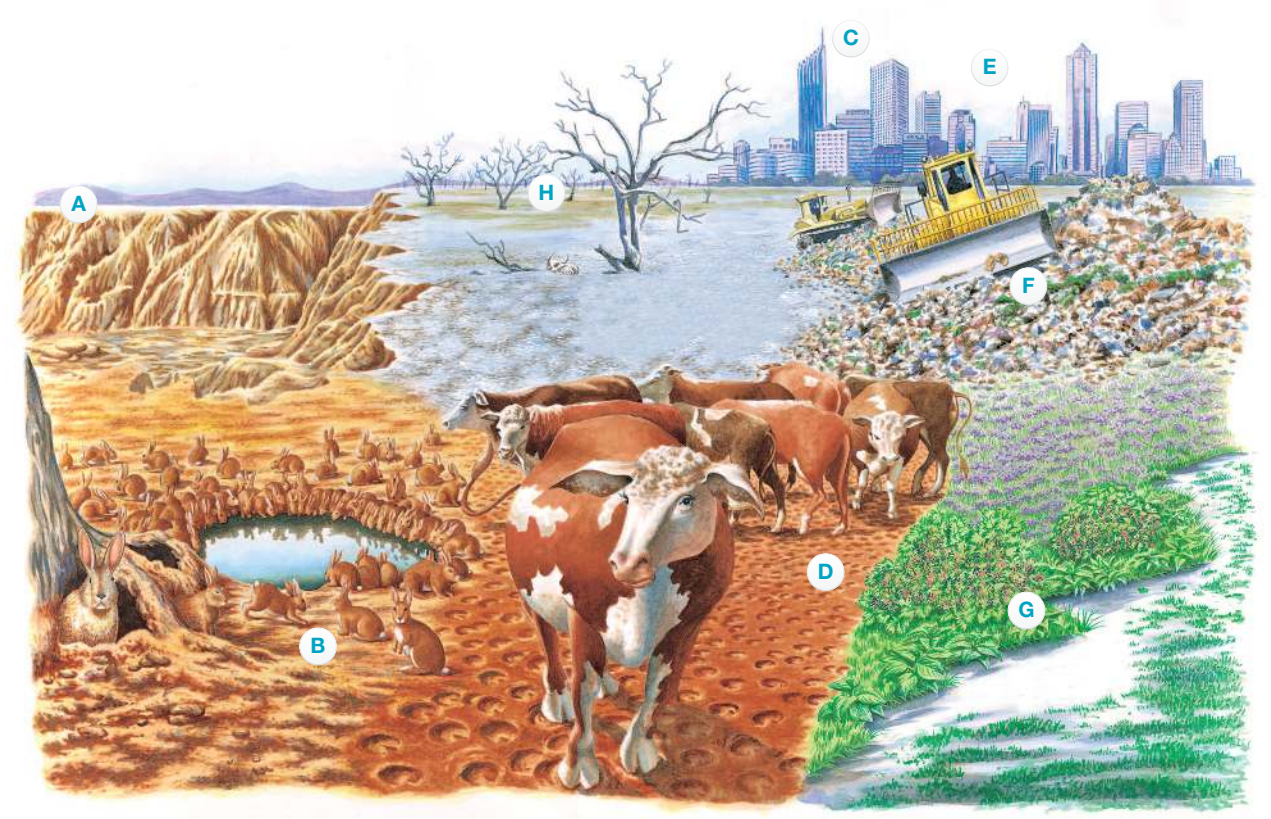
Winton (see figure 2.21), located in central west Queensland, was historically supported by the sheep and shearing industry but now relies on opal miners. As well as contributing $14 million per year to Winton, the opal industry employs 16.8 per cent of the town's population. The nearby properties of Vergemont, Tonkoro and Melrose, which were once cattle stations, now provide over 80 per cent of the opal for Winton's industry. In 2024, the Queensland Government purchased these properties to create a protected areas corridor of 1.5 million hectares. These stations are located at the headwaters of the Lake Eyre Basin, a key habitat for a number of endangered and vulnerable species, and containing 34 unique regional ecosystems. The land sits in Maiawali Country and has significant cultural heritage values. The transition of this area from opal mining to a national park places the local economy of Winton at risk.

FIGURE 2.21 Winton, Queensland

Land degradation within arid areas

Land degradation is a decline in the quality of land to the point where it is no longer productive. It refers to processes such as soil erosion, exotic species invasion, salinity and desertification. Natural processes such as prolonged drought can also lead to land degradation. Desertification is an extreme form of land degradation (refer to section 1.6.8 for more information) and can be closely linked to cattle grazing and soil salinity.

FIGURE 2.22 Land degradation



A When land is cleared or overgrazed, it becomes vulnerable to erosion by wind and water. The nutrient-rich soil is either washed or blown away, reducing the quality and quantity of crop yields. Dust storms result and sediment is transported to rivers, where it can smother marine species.

B Introduced species such as rabbits eat grass, shrubs and young trees (saplings) down to the soil, thus exposing it to erosion. Their burrows increase erosion as they destabilise the soil. Rabbits also compete with native animals for food and burrows.

C Tourism encourages the clearing of sand dunes for high-density housing, and mountain slopes for ski runs, leaving the surface exposed to erosion.

D Overgrazing leads to nutrient-rich soil being washed or blown away. Animals with hard hoofs such as sheep and cattle trample vegetation and compact the soil, making it increasingly difficult for native species to grow. This leads to increased run-off after heavy rain.

E Climate change will affect land degradation in the future. Higher sea levels will flood low-lying coastal areas. Expanding cities, removal of vegetation and use of concrete reduces the ability of the land to absorb moisture. This not only increases erosion, but can reduce the amount of rainfall in an area.

F Urban communities produce large quantities of waste, which is deposited in landfills. Much of the rubbish remains toxic or, in the case of plastic bags, takes hundreds of years to break down. Liquid and solid waste seeps into groundwater and runs off into rivers and eventually into the sea, killing marine species.

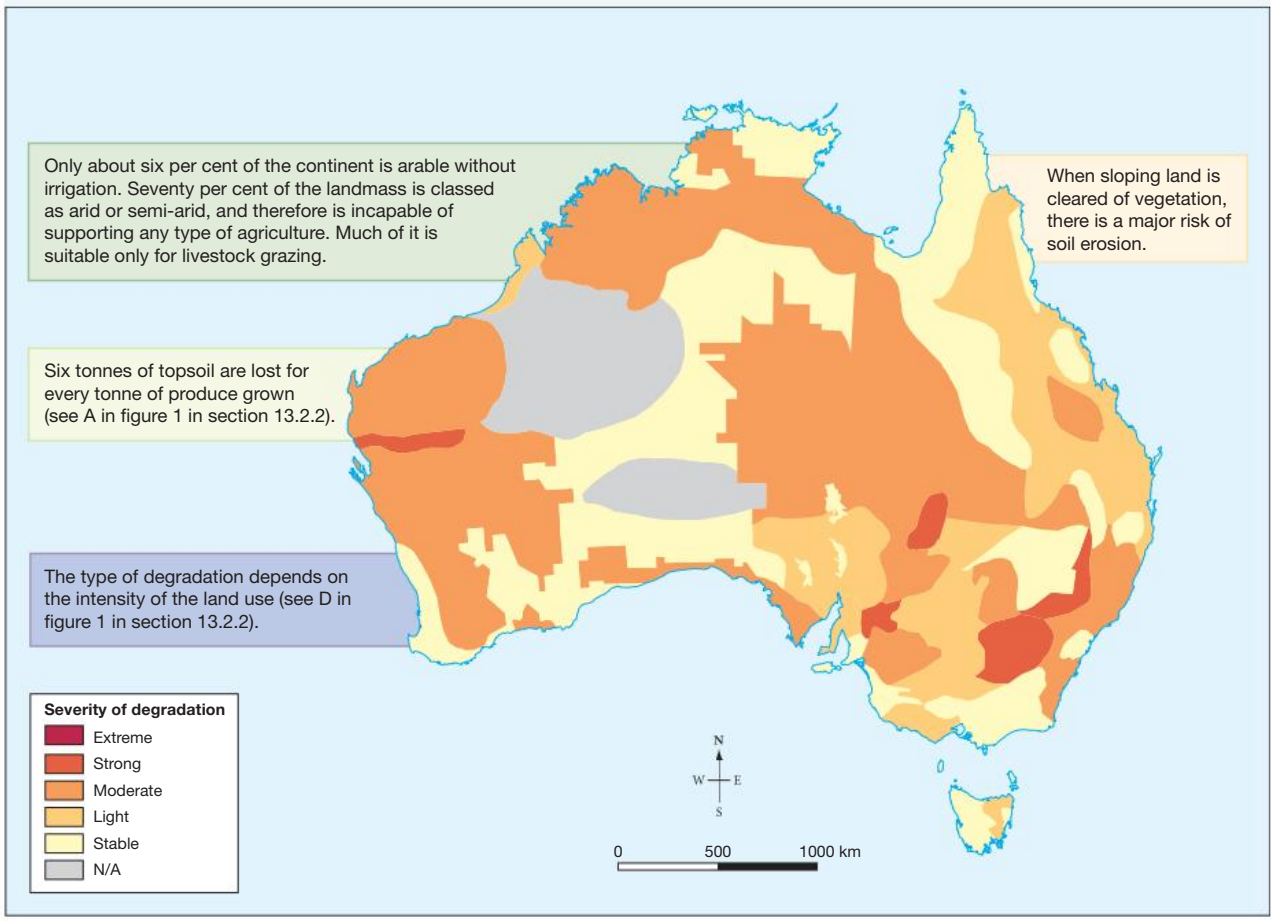
G Introduced plant species such as blackberries and Paterson's Curse (Salvation Jane) choke the landscape and compete with native vegetation. Their dense groundcover prevents light from reaching the soil.

H Salinity occurs naturally in areas where there is low rainfall and high evaporation and where the land was below sea level millions of years ago. Salinity is also caused by excess irrigation and clearing natural vegetation. In some cases the watertable rises, bringing salt to the surface.

Overgrazing by heaving, hard-hoofed animals such as sheep and cattle increases the rate of land degradation. Australia's semi-arid grazing lands have become severely degraded after more than 200 years of overgrazing by domestic herbivores such as cattle and sheep. As the soil compacts underneath the hoofs of the grazing animals, the vegetation's short root systems become damaged, which results in the vegetation dying off. This reduces infiltration of rainfall and increases the risk of topsoil being washed away and erosive events.

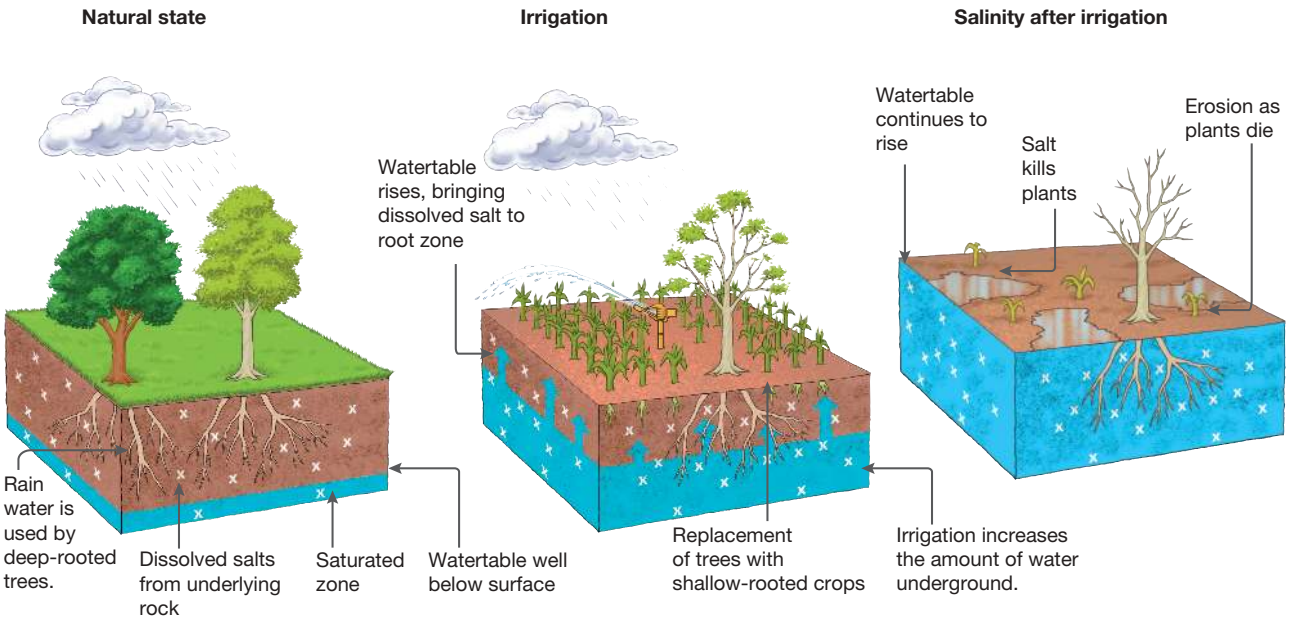
Within arid areas, water is often sourced from underground. The Great Artesian Basin is the main water source for a number of communities within Queensland. While accessing artesian water can increase the liveability of an area, it can also have adverse impacts on the soil, with the most common impact being soil salinity. As people tap into underground water sources through bores, the water table can rise surrounding the bore. This brings up the naturally occurring salts within the soil, creating a larger concentration of salt. As the land is typically cleared for agricultural purposes, the lack of deep-rooted vegetation also exacerbates the rising water table (see figure 2.22).

FIGURE 2.23 Severity of soil degradation in Australia



Source: ISRIC (1991)

FIGURE 2.24 The development of irrigation salinity



2.4.4 The cultural and spiritual value of desert areas

FIGURE 2.25 Simpson Desert landscape

Desert landscapes of Australia make up more than one-third of the continent and are home to 18.4 per cent of Aboriginal and Torres Strait Islander peoples. The Simpson Desert (see figure 2.25), located on Munga-Thirri Country across the borders of the Northern Territory, South Australia and Queensland, is home to the Wangkangurru Yarluyandi people. The Munga-Thirri landscape plays an important part in spiritual connection to The Dreaming and cultural customs for the Wangkangurru Yarluyandi people. Widespread habitat degradation and waves of species extinction can be linked to the removal of the traditional owners from their lands and the subsequent inability to continue culturally and environmentally sustainable practices. With the slow release of land back to traditional owners, desert areas such as Munga-Thirri are undergoing sustainable management transformations.

Desert areas are rich in biodiversity and face pressures such as climate change, tourism and invasive species. The 10 Deserts Project was led by the Indigenous Desert Alliance (IDA), a collaboration across Australia's desert Country aimed at increasing biodiversity through continued custodianship of the land by Aboriginal and Torres Strait Islander Peoples. By building the capacity of traditional owners to manage their land, the wellbeing of communities and landscapes is more likely to increase.

SKILL ACTIVITY: Analyse geographic data and information

Explain the impacts of cattle grazing on land cover

1. Research the impact that cattle grazing has on land in Queensland. Consider the economic value of the industry, its employment potential and the environmental impact of land clearing and the grazing itself.

Present and analyse the data

2. Use an online mapping tool from the Queensland Government such as QLUMP to create and examine where cattle grazing and cropping occurs in Queensland.
3. Describe where cattle grazing and cropping occur across Queensland using appropriate terminology. Represent some of your data using a chart, graph or map. Consider the best method of data representation for your needs.

2.4 Exercise

2.4 Exercise

Learning pathways

LEVEL 1	LEVEL 2	LEVEL 3
1, 4, 7	2, 5, 8	3, 6, 9

Explain and comprehend

1. **Explain** the biophysical processes that create deserts.
2. **Explain** how periods of drought affect deserts.
3. **Identify** the natural processes that are potentially interrupted by cattle grazing in Queensland.

Analyse and apply

4. **Explain** how land degradation occurs in desert areas.
5. **Identify** how the Great Artesian Basin helps people who live in arid areas.
6. **Explain** the benefits and challenges associated with mining. Consider the implications.
7. Using your analysis from question 6, **evaluate** whether or not mining is worthwhile.

Propose and communicate

8. **Outline** some recommendations to increase the sustainability of mining.
9. **Identify** what potential methods could be applied to reduce the negative impacts of cattle grazing in Queensland.

Sample responses for this chapter are available online.

LESSON
2.5 Forests and grasslands under threat

LEARNING INTENTION

By the end of this lesson you should be able to explain the geographical processes that result in forest and grassland land cover change, and their connection to identity, cultural heritage and values. Through the analysis of spatial patterns, you should be able to identify implications of these land cover changes.

2.5.1 Forests and grasslands

In any part of the Earth where vegetation covers the ground, the flow of energy from the Sun, water and nutrients drive growth. Forests and grasslands are filled with vegetation that converts solar energy through photosynthesis. Primary and secondary producers consume that energy and decomposers break down the producers when they die. All of these elements cycle energy through our ecosystems.

FIGURE 2.26 A typical Queensland forest

Forests cover around 31 per cent of Earth's landmass and they can be found where a moderate amount of precipitation falls (refer to lesson 1.6.3); that is, enough precipitation to support grasses and stabilisers, undergrowth, trees and a richer amount of plant life than grasslands or savanna. Forests can be classified as either tropical (see figure 2.26), temperate or boreal (polar), depending on the temperature at each location.

Grasslands, also known as **savanna**, **prairie**, **steppes** or **tundra**, are areas of the Earth that get enough rainfall to support grasses but not enough to support more advanced plant species. Grasslands are defined by their limited precipitation and by the dominance of grass species in the absence of larger plant species. Occasionally, fire can pass through grasslands, causing widespread land cover change but also renewal of some of the vegetation in these areas as the burnt grass is fed back into the soil, making it rich and fertile.

savanna the region of tropical grasslands intermixed with woodlands; trees are widely spaced and there is no distinct canopy

prairie vast stretch of temperate grassland with few trees. Prairies are fertile due to the thousands of years of decaying grasses. Because soils are highly compacted with few air spaces, it is difficult for trees to grow.

steppes flat grassland with no trees

tundra the very cold, flat and almost treeless biome below the northern Arctic. Because of the permafrost and snow cover for much of the year, there is only a short growing season for some mosses, lichens and grasses.

Biophysical impacts on forests and grasslands

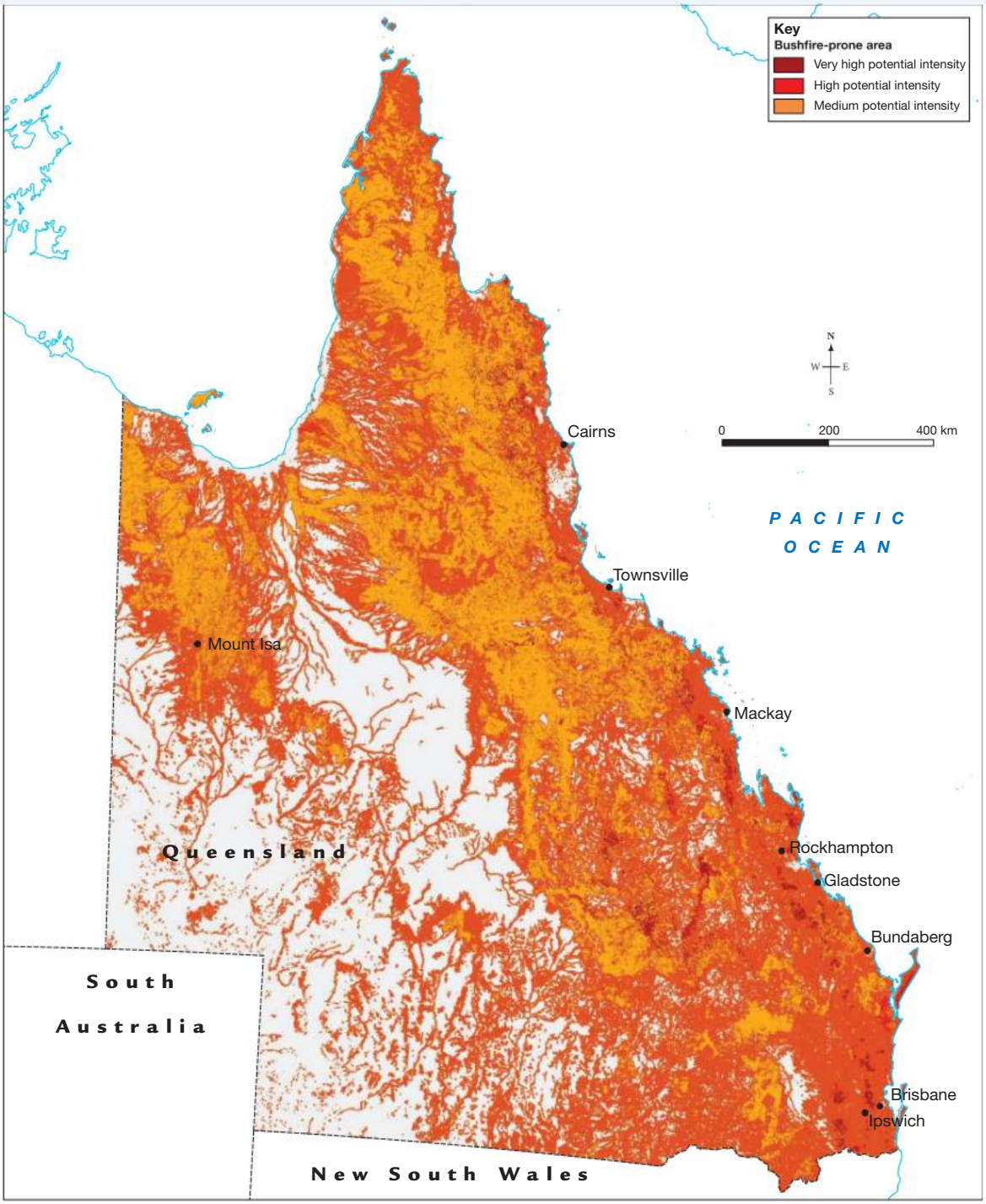
Natural hazards can have a devastating impact on the natural environment and on land cover in particular due to their large scale. In Queensland, the two hazards that have the greatest impact on forests and grasslands are bushfire and cyclone.

2.5.2 Bushfire

Bushfires are a hugely important part of Australia's ecosystems, with many species adapted to and relying on bushfires to stimulate growth. Some plant species in Australia, for example, have adapted to only release their seeds due to heat and will experience massive regeneration after bushfire events. Bushfires considerably alter large swathes of land cover in very short periods of time, which means their impact on land cover can be enormous.

Australians identify many bushfire events by name. Ash Wednesday (1987) and Black Saturday (2009) are two such examples. These events are named because they had a huge impact on the land and everything that inhabits it, including people. Their impact was felt everywhere on the continent. For Victoria and South Australia, summer and autumn are the high bushfire risk periods, while for New South Wales and Queensland, late spring and early summer are the most dangerous. The Northern Territory and northern Western Australia experience most of their fire events in winter and spring. Geoscience Australia notes that the largest fires occur in remote parts of the country, such as northern Western Australia, the Northern Territory and western Queensland, while the most damaging fires in terms of loss of life and economic impact occur on the edges of our cities and towns.

FIGURE 2.27 Queensland's bushfire-prone areas



Source: © Commonwealth Scientific and Industrial Research Organisation, 2015–17

CASE STUDY: Queensland's ancient Gondwana forests on fire

Quick facts: Gondwana World Heritage Area Rainforests

- **Total area of World Heritage site** 366 500 hectares
- **Estimated total area burned during 2019–20 bushfires** up to 53 per cent

The 2019–20 bushfires across Australia were devastating. Over 24 million hectares burned, with fire-sensitive ecosystems, such as rainforests, being severely impacted. In Queensland, more than 7.7 million hectares burned, including 1.6 million hectares of protected areas and 12 000 hectares of Ramsar wetlands. Included in this impacted area were the Gondwana World Heritage Area Rainforests (see figure 2.28). The Gondwana Rainforests represent outstanding examples of the major stages of Earth's history, ongoing geological and biological processes, and exceptional biological diversity. The rainforests have unique ecosystems that once existed 180 million years ago on the Gondwana supercontinent. These rainforests, which require specific climatic conditions, have not evolved to adapt to fire. As a result, the freshwater crayfish, Fleay's Frog and Albert's Lyrebird experienced significant habitat loss — 46 per cent, 12 per cent and 18 per cent respectively. Scientists are linking the extreme low levels of moisture in the rainforest to their fire sensitivity. They argue that with increasing global temperatures, more rainforests will be at risk of fire.

FIGURE 2.28 Effect of fires in the Gondwana Rainforests, 2019

Bushfire events are frequent in Queensland due to climatic conditions and the availability of fuel. Arid areas in the west of the state and grasslands covering the central areas are less prone to bushfire events, but areas of woody vegetation, particularly in the north, are more likely to experience bushfires (see figure 2.27). However, due to the major population centres being on the east coast, particularly in the south-east, these bushfire-prone areas in the north may not always face the highest risk in terms of damage and loss of life. The areas of rural–urban convergence, where the population increases, tend to see more death, injury and destruction of property.

2.5.3 Cyclone

Queensland's cyclone season (November to April) usually brings between four and five cyclones into the Brisbane Tropical Cyclone Warning Centre's area of responsibility, which stretches from far north Queensland to just north of Newcastle in New South Wales. Although not all of the cyclones that enter this zone will cross the coastline, Queenslanders in high-risk areas are taught to be well-prepared for these events, and local and state government initiatives have been designed to ensure people's safety. However, the natural world cannot prepare for these events and when a cyclone does cross the coast it usually has devastating impacts on the land.

Cyclones bring wind gusts of between 100 km/h and 280 km/h in extremely violent events. Winds moving at these speeds can cut through huge swathes of the land and destroy almost everything in their path. Human developments are often blown to pieces in strong cyclone events, and forests, crop lands and other vegetation can be stripped from their roots and sediment. Floods associated with cyclonic rainfall can destroy everything in their path, as seen in the Townsville and the Far North Queensland floods of early 2019.

Along with the high winds and huge amounts of rainfall, tropical cyclones can also bring storm surges and post-cyclone flooding. Most of these cyclones affect areas in far north Queensland, and it is rare for a cyclone to

have a direct impact on the southern part of the state, although it has happened in the past, most famously when Cyclone Wanda brought extensive flooding to south-east Queensland in 1974.

2.5.4 Anthropogenic changes

The impact of vegetation removal on forests and grasslands represents the main anthropogenic change to these areas. The removal of vegetation from forests and grasslands drastically alters the land cover in these areas and the way they interact with surrounding ecosystems.

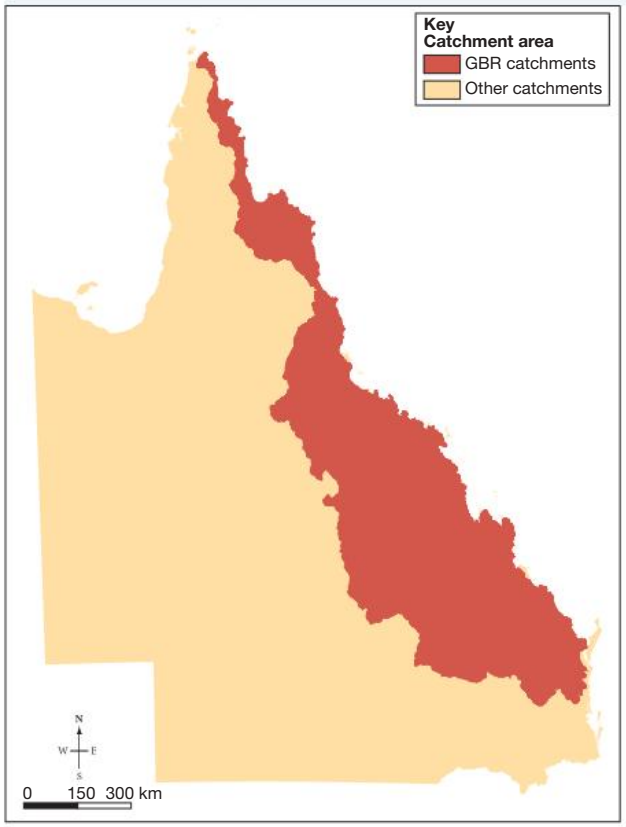
The spatial pattern of deforestation

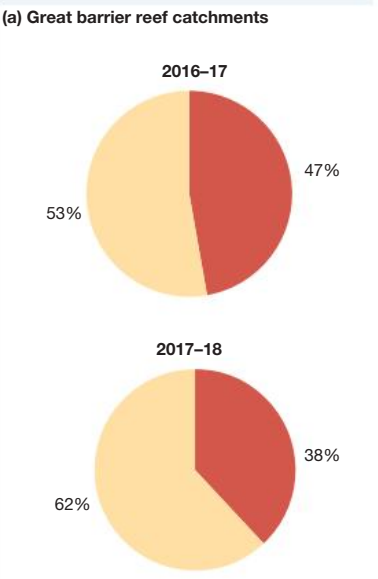
Deforestation occurs when forests are removed, most often for development or to use the wood as a resource. The creation of forests can take hundreds of years, but deforestation occurs over a relatively short period and is, therefore, semi-permanent. It is dramatically increasing in modern times because the global population has increased so rapidly in the past century. Australia is in the middle of a deforestation boom period, particularly in Queensland. During 2021–22, 323 676 hectares of land was impacted by clearing in Queensland. This is ten times more deforestation than what occurred in Indonesia for palm oil in the same year. Of this clearing, 88 per cent was for pasture and 44 per cent occurred in the Great Barrier Reef catchment.

Land clearing in Queensland predominantly occurs in the Brigalow Belt and the Mulga bioregions of central southern Queensland, representing three-quarters of all clearing. These regions contain most of the catchment area for Queensland's section of the Murray–Darling Basin and clearing in these areas can have significant impacts, not just in Queensland, but also further downstream in the catchment. Queensland is home is more biodiversity than any other Australian state, most of which is found in forests and grasslands.

deforestation the intentional clearing or removal of forests to make way for some other purpose such as farming, housing, constructing a dam, and so on. Deforestation is regarded as a permanent loss of forest and is most common in countries with large areas of rainforest such as Brazil and Indonesia.

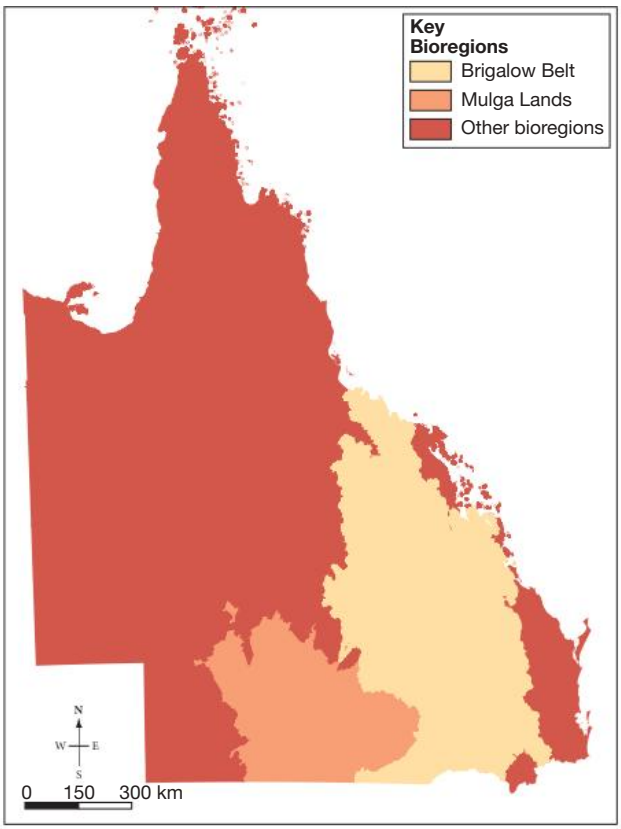
FIGURE 2.29 Clearing rates across (a) the Great Barrier Reef catchment area, (b) by bioregion and (c) by drainage division in Queensland, 2016–18





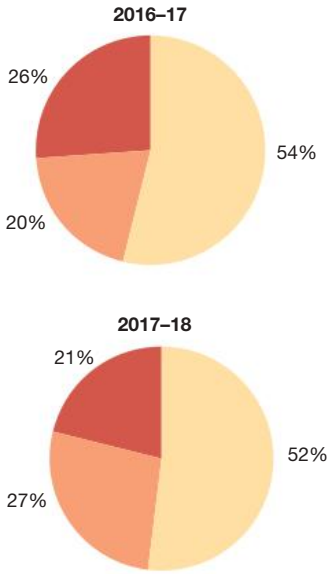
The woody vegetation clearing rate in the Great Barrier Reef catchments was 166 000 ha/year in 2016–17 and 148 000 ha/year in 2017–18. This represented 47 per cent and 38 per cent of the total statewide woody vegetation clearing rates in 2016–17 and 2017–18, respectively. The 2015–16 woody vegetation clearing rate was 158 000 ha/year.

Source: © State of Queensland, 2018

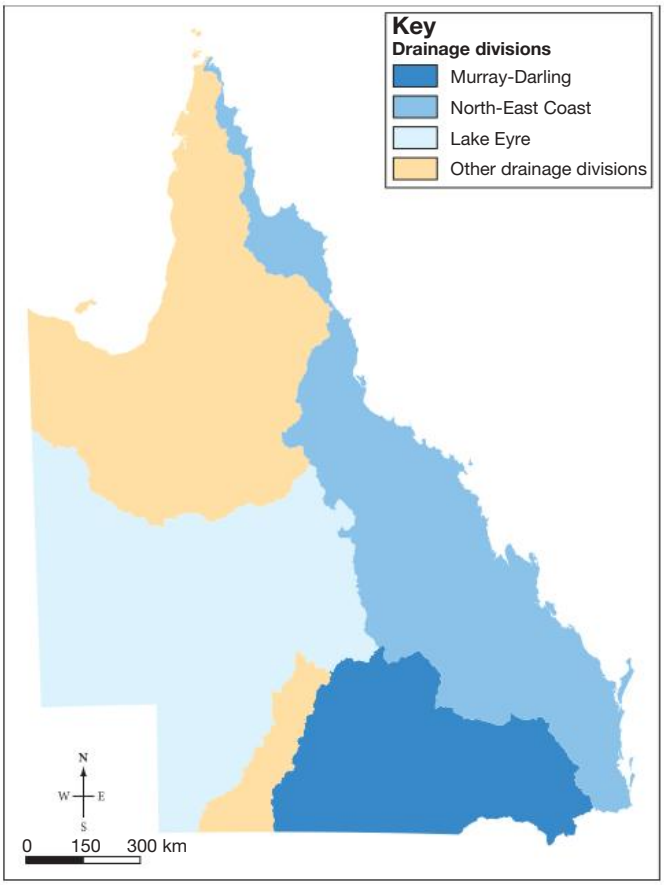


Source: © State of Queensland, 2018

(b) Bioregions

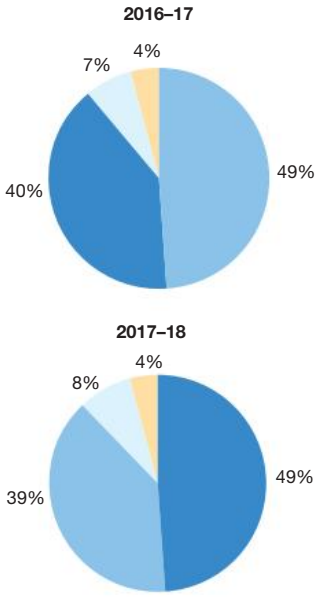


Of Queensland's 13 bioregions, the Brigalow Belt and Mulga Lands recorded the highest woody vegetation clearing rates in the 2016–17 and 2017–18 periods. The Brigalow Belt's clearing rate was 193 000 ha/year in 2016–17, and 204 000 ha/year in 2017–18. The Mulga Lands' clearing rate was 73 000 ha/year in 2016–17 and 106 000 ha/year in 2017–18.



Source: © State of Queensland, 2018

(c) Drainage divisions



The Murray–Darling and North-East Coast drainage divisions recorded the highest woody vegetation clearing rates in 2016–17 and 2017–18. The woody vegetation clearing rate in the Murray–Darling was 142 000 ha/year in 2016–17 and 192 000 ha/year in 2017–18. The North-East Coast division's clearing rate was 173 000 ha/year in 2016–17 and 154 000 ha/year in 2017–18.

Land cover loss in forests and areas of woody vegetation can have a variety of impacts. By removing vegetation, especially via **broadscale clearing**, which often uses two bulldozers joined by a chain to clear large areas of land (see figure 2.30), the most dramatic impact can be the loss of habitat for thousands of animal species. Wildlife corridors are valuable tracts of vegetated land that allow migration, colonisation and interbreeding of different plant and animal species. Loss of these tracts can impact **biodiversity** and species resilience.

FIGURE 2.30 Broadscale clearing chain, usually connected to two bulldozers

Source: © 2019 Green Collar Group

The most obvious impact of land cover change in forested areas is the associated flora and fauna species loss. Australia is a significant place in terms of species **diversity** on the planet. Of the world's vertebrate species, 12 per cent are found in Australia, of which four out of five are native, and we have experienced the known loss of at least 90 species extinctions since European colonisation. University studies have found that habitat loss affects 74 per cent of Australia's threatened species; land cover changes for agriculture and urbanisation constitute most of that loss. The loss of native species increases the opportunities for non-indigenous species to be introduced into an ecosystem, which can further damage the environment.

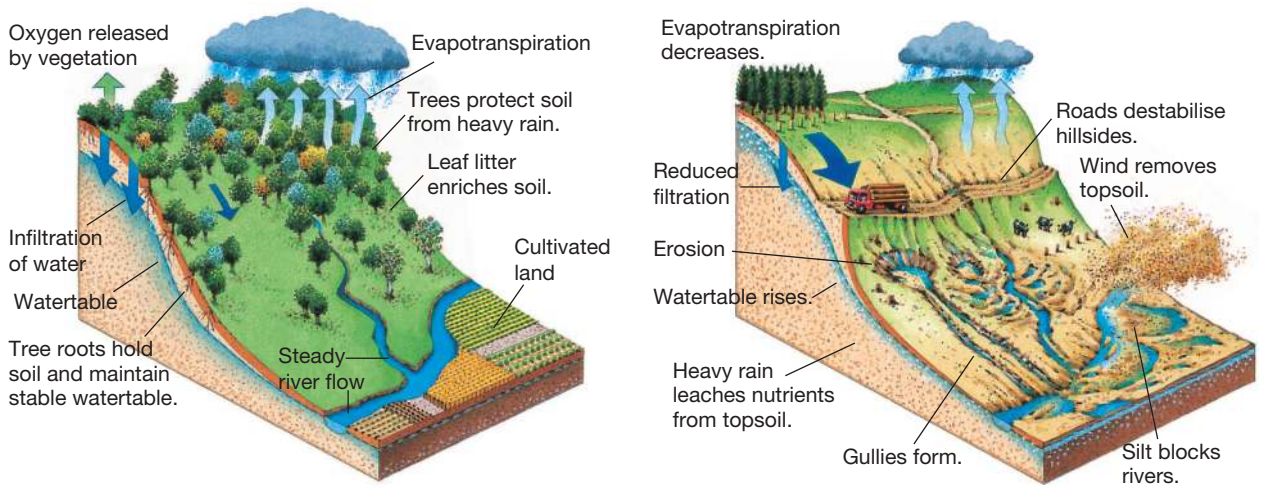
Removal of vegetation can lead to an increase in erosion (see figure 2.31). Vegetation stabilises loose soil, and its removal can leave that soil exposed. Exposed soil will be removed by wind or water, so erosion is almost guaranteed. Soil erosion is specifically the movement of soil, generally topsoil, from one part of the Earth to another driven by wind or water. Soil erosion can be natural or human-induced and can occur at small or large scales. Soil management is critical to the functioning of a society and entire civilisations have collapsed due to poor soil management practices.

broadscale clearing indiscriminate clearing of large tracts of land, usually to prepare that land for agricultural production. A heavy chain strung between two heavy bulldozers is the favoured method of broadscale clearing in Queensland.

biodiversity biological diversity; describes the variation of living plant and animal species that occupy an area or ecosystem

diversity a variety of different things or species

FIGURE 2.31 (a) and (b) land clearing and deforestation leave the land vulnerable to erosion



As water rolls across the land, it picks up everything in its path. Exposed soil is collected and moved by the water, and gravity, into a waterway that eventually feeds into a river system. This leads to increased sediment in the waterway, which reduces the waterway's ability to convert solar energy into oxygen via algae. This

increased run-off of soil usually brings with it any nutrients that may be used in the catchment area. Pesticides and herbicides add considerable nutrients and other chemicals to the waterway as they are collected by water and moved from the land into the waterways.

Streambank erosion is the wearing away of the banks of a waterway. This is a huge problem in Queensland, with the greatest impacts seen on the Great Barrier Reef. The Queensland Government is tackling the problem by using satellite imagery to identify problem streambanks and then implementing possible solutions. These mitigation measures could include:

- physical remediation (including piloting of different techniques)
- mulching, revegetation and fencing
- native grass seed production
- grazing land management improvements
- traditional owner engagement and training
- scientific research and monitoring to understand the nature of gullies
- communication with stakeholders
- encouraging employment and tourism opportunities.

2.5.5 Forests and vegetated areas

Managing the human impacts on vegetated areas has probably been one of our nation's greatest failings since European colonisation. With the rate of land development only increasing, it will be one of the hardest areas to manage. Prior to European colonisation, over 30 per cent of Australia's landmass was covered in forest. Today that figure lies at around 16 per cent. Most vegetation loss has been to accommodate grazing and crop lands. Although in recent years most Australian states have reduced tree clearing rates, Queensland's increase in tree clearing for pasture has overshadowed the improvements made in other states.

Activism can encourage action and awareness of issues related to land cover change in forested or vegetated areas. Because environmental outputs in supply chains (i.e. pollution) are not factored into the economics of a product, action at a corporate level on environmental issues can come with pressure from the public. Consumer-driven actions such as organised boycotts or awareness campaigns can force businesses to carefully consider their actions and those of their suppliers. This can eventually force changes in corporate behaviour. One example of this are the recent campaigns relating to palm oil. The production of palm oil requires the clearing of pristine rainforest vegetation across the globe to create palm oil plantations. Activists have generated awareness of these issues and this has allowed consumers to choose products without palm oil to take action against the environmental damage done by palm oil plantations. Many of the world's major manufacturers and food and beverage makers have reconsidered where they source the oils used in their products and this has reduced demand for palm oil. It is hoped this will lead to a slowing of the land clearing that was happening at alarming rates, particularly across South-East Asia.

2.5.6 Aboriginal and Torres Strait Islander peoples' connections to the land

The land is of great significance to Aboriginal and Torres Strait Islander peoples. It is a place of birth and death, it sustains, it teaches, it helps to explain the world and beyond, it defines spirituality, it is all ancestors, and it changes and grows as people do. People's relationship with the land is reciprocal — one both takes and gives back.

Aboriginal and Torres Strait Islander peoples' understanding of features and elements of their local areas grows from their connection to place. Aboriginal peoples have used the land as a central theme in The Dreaming, as a means of explaining and understanding how the world was created and why many geographic environments, processes and features exist.

activism efforts to affect societal change through grass roots action

This connection to the land can be physically expressed through:

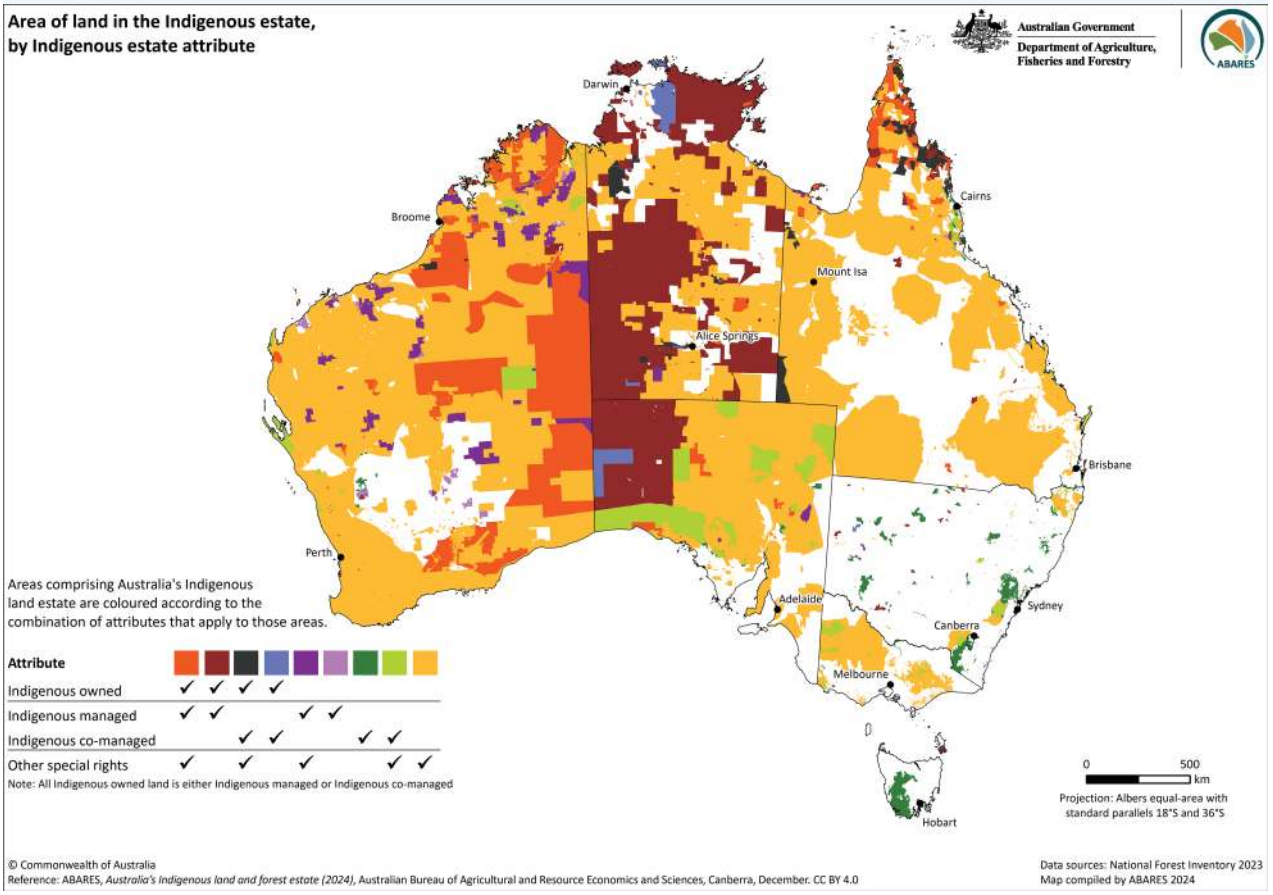
- the natural environment
- Dreaming sites
- sacred sites
- archaeological sites (for instance, quarries, middens and skeletal remains)
- ceremonial sites
- water holes
- burial grounds.

Observing a natural process over time, such as the life cycle of a dragonfly, and teaching about that aspect of the environment allowed Aboriginal and Torres Strait Islander peoples to learn about everything that naturally surrounded that process. These included the weather, geography, water and water flows, vegetation, flowering seasons, and other animals in the food chain that relied on or coexisted with the dragonfly. All of this knowledge originates from the land. Seasonal calendars are one way some of this knowledge can be represented visually. These calendars change across different parts of the country, but an example from far north Queensland is shown in figure 2.32.

FIGURE 2.32 Seasonal calendar for the Yirrganydji people of far north Queensland

Source: © Yirrganydji Community 2019, hosted by Bureau of Meteorology, http://www.bom.gov.au/iwk/calendars/yirrganydji.shtml

FIGURE 2.33 Areas across Australia comprising Indigenous land estate



EXAMPLE: The Lost Girl

The Aboriginal connection to place can be represented by the traditional story *The Lost Girl*. It tells the story of a girl who wanders away from her family and then falls asleep in the shade of a rock. When she wakes, she is alone and does not know how to get back to her camp. She calls for help but is not heard. The girl tries to find her way back, finding sustenance on her way. She takes water from the river when thirsty and berries when she is hungry. The sheltered rocks keep her warm and a crow flying in the night sky then guides her back to camp.

Her family rejoice on her return, and when asked if she had been scared, she responds

> *How could I be frightened? I was with my Mother. When I was thirsty, she gave me water; when I was hungry, she fed me; when I was cold, she warmed me. And when I was lost, she showed me the way home.*

Source: https://readingtime.com.au/lost-girl/

Much more can be done to increase the Aboriginal and Torres Strait Islander peoples' management of Queensland's forest and grassland areas. Figure 2.33 shows that very little of Queensland is managed by the traditional owners.

Traditional knowledges that protect and manage land and sea environments are being used more often in conjunction with conservation techniques that developed from European traditions and science. For example, the number of Indigenous Protected Areas (IPAs) across Australia is increasing, as is the number of Indigenous Ranger programs. An IPA is a sea or land area that is protected and conserved under the management of local Aboriginal and/or Torres Strait Islander peoples, which helps to maintain continuing cultural connection with Country and preservation of important sites with traditional land management technologies. Indigenous Ranger programs employ Aboriginal and Torres Strait Islander peoples in conservation programs to protect Country. The programs aim to combine contemporary and traditional land management knowledges to protect vulnerable sea and land environments and threatened species, and to reduce the impact of introduced species.

The diverse and exceptional knowledges that Aboriginal and Torres Strait Islander peoples have of Country, and how to care for it, have resulted in increasing respect today in relation to sustainably managing the land. Cultural practices that successfully maintained Country for tens of thousands of years are now being recognised for their dynamic ability to counteract the impact of exploited lands in today's world. Further, the value of native plants and their uses is being respected, with many Aboriginal and Torres Strait Islander peoples' businesses and communities at the forefront of introducing and advocating Australian native plants as both a source of food and healing. This is directly aligned with knowledge systems that hold a deep understanding and respect of Country and the environment.

SKILLS ACTIVITY: Geography skills

Create a map and explain natural hazard and land cover change

1. Using an online mapping tool such as the Queensland Globe, Google Maps or ScribbleMaps, create a simple thematic map showing the varying levels of risk for the different types of natural hazards referred to in lesson 2.5.
2. Add data for one more natural hazard that isn't listed in the lesson to your map.
3. Describe in a paragraph which areas of Queensland have the highest overall risk for land cover change due to natural hazard.
4. In another paragraph, describe which areas have the lowest risk for natural hazard induced land cover change.

2.5 Exercise

2.5 Exercise

Learning pathways

LEVEL 1	LEVEL 2	LEVEL 3
1, 4, 7	2, 5, 8	3, 6, 9

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Explain and comprehend

1. **Outline** the key biophysical changes to forests and grasslands.
2. **Explain** how people impact forests and grasslands.
3. **Outline** the flow-on effects of these changes.

Analyse and apply

4. **Explain** how the loss of topsoil impacts future vegetation growth.
5. If climate change increases the frequency of natural hazards, **predict** how this will affect forests and grasslands.
6. **Explain** the interconnection between urbanisation and the loss of forests and grasslands.

Propose and communicate

7. **Explain** how connection to land helps traditional owners manage environments.
8. **Propose** some strategies to minimise the anthropogenic changes to forests and grasslands.
9. **Propose** recommendations for the sustainable management of forest and grasslands areas. **Justify** your recommendations.

Sample responses for this chapter are available online.

LESSON
2.6 Fieldwork in the local area

LEARNING INTENTION

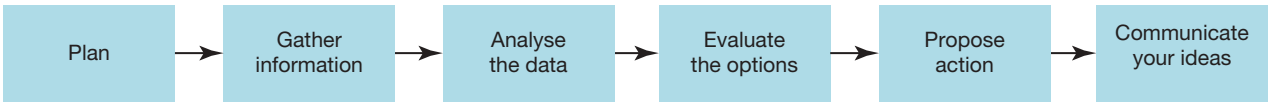
By the end of this lesson you should be able to plan and conduct a fieldwork inquiry.

2.6.1 Introduction to fieldwork

Fieldwork is an important part of Geography and offers the best of what the subject is about: getting out to experience and explore the real world. Fieldwork is always built around an investigation, and the data you collect in the field should give you a better understanding of the geographical issues at hand.

The geographic inquiry model (see figure 2.34) is a framework used by geographers to help structure an inquiry. It is a great way to help you organise your thinking as you plan an investigation, and it can be used to address issues from local to global scales.

FIGURE 2.34 Geographic inquiry approach



2.6.2 Plan

Selecting your study area

Every inquiry should start with a question or problem, so begin by considering some of the issues that you have been studying in class. Try to frame your question in such a way as to allow you scope to collect data, analyse it, make conclusions and respond with meaningful proposals. This might mean adjusting your geographic area or the scope of your problem.

The geographic area you select is important. If you select an area that is too large, you may give yourself too much to cover in your data collection and your analysis can also get unwieldy. Having too much to cover also means that you may not be able to complete your analysis and develop proposals within the word limit.

Planning and structure

Use the geographic inquiry model to structure your investigation. Develop key questions and start with as many focus questions that you can think of — these will expand and change as you start to collect data and research, and you get a better understanding of the issue in question.

Develop your key and focus questions to help you to organise your research and data collection. These key questions usually take the form of:

- *What* and *where* is the issue or problem at hand?
- *How* and *why* does it occur?
- *What* are the environmental, social and economic *impacts*?
- *What* are the proposals and *solutions*?

The key questions can then be narrowed down through the use of focus questions that concentrate your research into smaller areas. These focus questions can change and should be updated as you gather more information through your research and fieldwork.

The following example outlines how you might structure an inquiry into a new housing development in an area on the urban fringe. As you begin to research your focus questions, you will find more information and uncover more questions to ask, which means your investigation should be reviewed and will be constantly evolving.

Your initial focus questions could be as follows:

- What and where is the development?
- How and why is the development going to influence the local landscape?
- What are the impacts of the development on the local area, economy and society?
- What solutions can be put in place to ensure that the development has minimal impact on the local landscape?

Now is a good time to begin thinking about what sort of data you will need to collect and what sort of research you will do. Will your **primary data** answer all of your questions? What types of **secondary data** should you collect and where will you need to go to get it? Think about the organisations that might host this data.

primary data data collected by the author directly from the source

secondary data data collected by someone other than the author

SKILLS ACTIVITY

Planning your fieldwork

1. Decide on which type of land cover you will be working on in your fieldwork report.
2. Come up with an issue or problem that you want to address for your fieldwork study. Try to frame this issue or problem as a question (e.g. 'Should Brisbane have a second airport runway that removes mangroves?', or 'How can we address the spread of the cane toad in western Queensland?').
3. Create a rough outline of your investigation using the geographic inquiry model key questions.
4. Underneath each key question, generate some focus questions to get your investigation started. Write down where you might find the answer to each focus question. Is it primary data or secondary data?
5. What data collection methods will you have to employ to undertake your fieldwork?

Format options

You could present your report in many ways, and you should think about the method that will best communicate your information. The traditional, typed and printed hardcopy report will be the most common format, but if you have the skills, you might like to consider using an alternative format, such as the ones listed. It is important to remember that whatever format you use, you should always ensure that you fulfil the requirements of the report and that you are able to include all relevant information. For instance, a social media thread may not give you enough scope to include all relevant information but a website would allow you to elaborate and demonstrate your knowledge and skill.

Possible format options include:

- hardcopy report
- story map
- video
- game
- interactive web presentation
- Prezi or PowerPoint presentation.

2.6.3 Gather information

In undertaking fieldwork, you should endeavour to collect as much relevant data as possible to help your investigation. Primary data is collected firsthand. In research, primary data holds the most weight because it is data collected by the author to help them answer specific research questions — it is data collected for that purpose. Secondary data is collected by someone else and can include census data, government data and information, and research findings. Your analysis, and subsequently your decisions, solutions and proposals, will be evidence-based provided you have collected appropriate primary data and sourced reliable and relevant secondary data.

One of the hardest points in your fieldwork will be choosing what to measure so that you can give yourself the best opportunity to show off your analysis skills.

2.6.4 Fieldwork ideas for urban areas

Urban areas are areas of constant change that most people have some experience with. We see shops change hands, apartment blocks go up, parks become housing estates and roads get upgraded. Consider the following activities to collect useful primary data:

- urban transects
- land use maps
- survey of services (e.g. transport options or health services)
- survey of resident opinions on an issue or proposed solution
- field sketching

- analysis of satellite imagery over time
- gentrification and urban consolidation
- public space survey.

2.6.5 Fieldwork ideas for coastal areas

Coasts come in high- and low-energy versions. You may collect data in one or both depending on the issue being investigated. The following activities give you opportunities to collect meaningful data while on the coast.

Low-energy coasts:
- dune transects
- dune profile
- land use mapping
- field sketching
- wave analysis
- wind analysis
- sediment analysis
- investigating beach protection measures (e.g. groynes or sand-bypass).

High-energy coasts:
- field sketching
- wave analysis
- wind analysis.

A sample investigation Coastal Fieldwork Booklet is provided in the Resources tab.

2.6.6 Fieldwork ideas for rivers or other waterways

Waterways offer many opportunities to measure and collect useful field data. Everything from an intermittent stream to a raging river can give geographers great data. Try the following examples:
- flow analysis — velocity
- water quality
- land use mapping
- historical imagery comparison
- stream bed measurements or survey
- field sketching.

FIGURE 2.35 Water quality data collection

2.6.7 Fieldwork ideas for vegetated areas

Most schools have access to some sort of vegetated area and a properly remote patch of forest may not be too far away. The following fieldwork ideas should be achievable for most:
- canopy analysis
- quadrat analysis
- vegetation mapping
- infrastructure mapping
- field sketching
- soil sampling.

See the SkillBuilders in the Resources tab for practical guides on various geographic techniques.

SKILLS ACTIVITY

Collecting your data

1. Collect your field data.
2. You will need to represent your data visually. Think about what the most suitable method will be to represent your data. Consider what message you want to convey and how you can do that most efficiently without confusion.
3. Find some online tools to help you represent and analyse your data. Many simple online data tools are available to help your reader understand your issue.

2.6.8 Analyse the data

Once you have collected your data, you need to analyse it. You can use a number of methods to do this. Generally, you are looking for patterns in the data that are related to the topic at hand. Sometimes these patterns are self-evident (i.e. poor water quality near an industrial area) but sometimes additional data needs to be collected or analysed in conjunction with your data to draw out the message.

The primary data that you collect and secondary data that you select and interpret should be able to help you explain the geographic processes at play in your issue and why they have led to the source of any geographical challenges. Your analysis should also focus on the different impacts that could occur as a result of your challenge continuing. You should be able to extrapolate from your analysis to generalise about the impacts of your issue.

Think about different ways to visualise your data so that you can demonstrate your understanding of the processes involved in each issue and the analysis that you have undertaken to reach your findings. You can use traditional methods to present data, such as maps, tables, charts, field sketches or photographs, but you can also consider other methods, such as data visualisations or digitally generated maps using spatial technologies.

Spatial technologies

Spatial technologies are the tools of geographers. They help us answer 'where' questions and can help us illuminate some of the issues that geographers study. They are used in a range of geographical and non-geographical ways, including environmental management, species tracking, weather and climate analysis, oceanic and inland water monitoring, economics and history.

geospatial technologies tools that allow the user to collect, manipulate, distribute, analyse and communicate geospatial information, such as GPS receivers, GIS applications or UAV drones

Geospatial technologies help us to measure, analyse and represent spatial or geographic information, usually digitally.

In regards to your field study, you could use spatial tools to:

- examine land use and/or land cover from a satellite image
- investigate public transport and cycling infrastructure in the area around your place of study
- visualise census and other demographic data using Google Maps or the ABS online mapping tools
- visualise environmental data such as earthquakes or species extent using online digital tools
- map data you have collected in the field, such as water quality data or survey results.

FIGURE 2.36 Geospatial technologies in the field

Source: © State of Queensland 2018

2.6.9 Evaluate the options

Evaluating is the art of selecting or choosing between options. You should consider a range of proposals and then choose the best one. It is important that you have clear and measurable reasons as to why you have chosen the option you chose. This may come down to the data you have collected while in the field.

2.6.10 Propose action

The ultimate reason you are undertaking all of this fieldwork and collecting all of this data is to make recommendations in order to effect change around the issue you have selected. Consider developing a set of criteria that you can use to help you evaluate your proposals.

2.6.11 Communicate your ideas

The last task is to put all of your planning, research, data, analysis and decision-making into a coherent piece of writing that can be presented. You will be given specific guidelines on how to structure and present your findings, so make sure you understand what is required of you. A sample and scaffolded field report are provided in the Resources tab.

Before you submit your work, take time to review it or have someone read it to ensure it makes sense and flows logically. Having someone who hasn't seen it before can be advantageous because they will be looking at it from a neutral point of view, while you are very familiar with your work. Good luck!

SKILLS ACTIVITY

Writing your field report

Write your field report.

Two useful resources are provided in the Resources tab. These are:

- a scaffolded Field Report Booklet
- a sample Coastal Fieldwork Booklet.

LESSON
2.7 Review

2.7.1 Summary

This chapter has covered some key points about responding to local land cover transformations.

Coastal land cover transformations

- Natural processes impact land cover, and erosion and deposition of sediment are two long-term processes that shape the land around us.
- Coasts have a number of different physical processes at play that affect coastal landforms, such as erosion and deposition, dune systems, rivers and waterways, and longshore drift.
- Development on coasts removes vegetation and habitat, and causes erosion and damage to dunes.
- Australia has a high proportion of the population living in cities and close to the coast, and the trend over the past 100 years and into the future indicates increasing urbanisation, which affects land cover such as coastlines as they give way to houses, industry and commercial land use.

Relationships with our rivers

- Natural processes such as erosion, deposition and weathering impact river systems.
- Land cover changes can have profound impacts on our waterways and rivers, leading to impacts on agricultural and rural communities along waterways.
- Aboriginal and Torres Strait Islander peoples have an ancient history of agriculture, including harvesting and cultivating crops for food, and damming of waterways for water storage and agricultural use.
- The Murray–Darling Basin is an important water source for Australia's agriculture.

Transforming our deserts

- Desert areas are impacted by drought.
- Mining has long played a role in Queensland's history and still contributes to changes in land cover.
- The Great Artesian Basin is an important water source for arid areas of Queensland.
- Salinity and desertification are two major implications of anthropogenic changes to desert land cover.

Forests and grasslands under threat

- Deforestation occurs when forests are removed, most often for agricultural development, urbanisation or to use the wood as a resource.
- Queensland has an exceptionally high rate of land clearing, predominantly occurring in the Brigalow Belt and the Mulga regions of central-southern Queensland.
- Impacts of land cover change in forested areas include the associated flora and fauna species loss, and erosion.
- The land is of great significance to Aboriginal peoples and Torres Strait Islander peoples. Their understanding of features and elements of local areas grows from their connection to place.
- Aboriginal and Torres Strait Islander peoples have used fire for land management, to enable access to parts of the environment, for hunting and for ceremonial purposes.

Fieldwork in the local area

- Fieldwork is an important part of Geography and the geographic inquiry model can help provide a framework for investigation.

2.7.2 Key terms

activism efforts to affect societal change through grass roots action
algal blooms rapid increases in the accumulation of algae in a water body due to some external pressure (e.g. rapid increase or decrease in temperature or increased nutrients)
anthropogenic caused by human beings
biodiversity biological diversity; describes the variation of living plant and animal species that occupy an area or ecosystem
biophysical of or relating to the physical environment, which includes the living organisms that inhabit it
broadscale clearing indiscriminate clearing of large tracts of land, usually to prepare that land for agricultural production. A heavy chain strung between two heavy bulldozers is the favoured method of broadscale clearing in Queensland.
continents the largest landmasses on Earth: Africa, Antarctica, Asia, Australia, Europe, North America and South America
Coriolis effect a force like inertia that deflects objects moving across the surface (air, ocean currents, etc) to the left in the southern hemisphere and to the right in the northern hemisphere. It is caused by the rotation of the Earth.
crops plant or animal products that can be grown and harvested for consumption and/or profit
deforestation the intentional clearing or removal of forests to make way for some other purpose such as farming, housing, constructing a dam, and so on. Deforestation is regarded as a permanent loss of forest and is most common in countries with large areas of rainforest such as Brazil and Indonesia.
deposition when seas, rivers or the wind drop the material they have been carrying, creating or changing landforms
development the process of changing the purpose of a piece of land by constructing or removing something
diversity a variety of different things or species
erosion the wearing down of rocks and soils on the Earth's surface by the action of water, ice, wind, waves, glaciers and other processes
fossil fuels fuels formed by natural processes that contain energy originally captured during photosynthesis (e.g. decomposition of living matter into coal or oil)
geospatial technologies tools that allow the user to collect, manipulate, distribute, analyse and communicate geospatial information, such as GPS receivers, GIS applications or UAV drones
land cover what is covering the land (e.g. vegetation, human infrastructure or development, agriculture or bare earth)
minerals naturally occurring solid chemical compounds (e.g. salt, quartz)
nutrients substances used by an organism to survive, grow and reproduce
prairie vast stretch of temperate grassland with few trees. Prairies are fertile due to the thousands of years of decaying grasses. Because soils are highly compacted with few air spaces, it is difficult for trees to grow.
precipitation rainfall
primary data data collected by the author directly from the source
resources sources from which some benefit is produced (e.g. wood, minerals, water)
riparian zone the interface between a waterway and the land that provides habitat, prevents erosion and blocks nutrients and sediments from entering the waterway
savanna the region of tropical grasslands intermixed with woodlands; trees are widely spaced and there is no distinct canopy
secondary data data collected by someone other than the author
steppes flat grassland with no trees
sustainability a process of maintaining balance in an environment while retaining the ability of current and future inhabitants to use that environment
tundra the very cold, flat and almost treeless biome below the northern Arctic. Because of the permafrost and snow cover for much of the year, there is only a short growing season for some mosses, lichens and grasses.
water cycle a model that demonstrates the movement of water on, above and below our environment

KEY QUESTIONS REVISITED

You should now be able to answer the following questions.

1. What is land cover change?
2. How is land cover important to us environmentally, socially and culturally?
3. What processes are involved in local land cover changes?
4. What are the impacts of local land cover changes?
5. How can we manage local land cover changes to maximise sustainability?

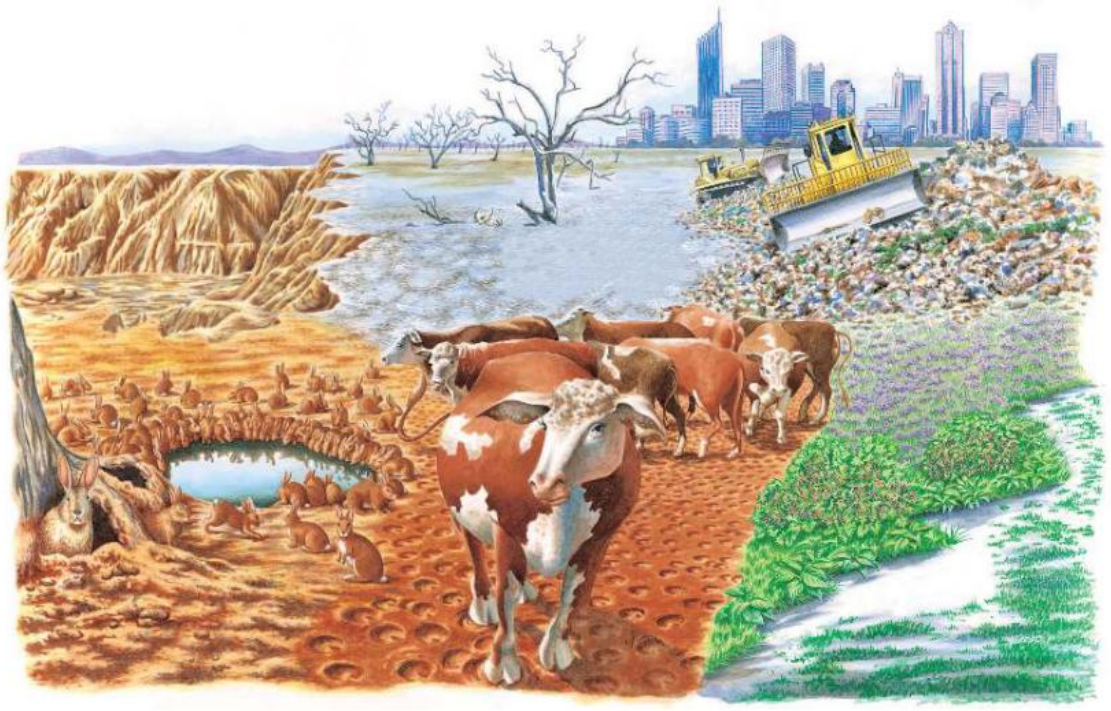
2.7.3 Exam questions

2.8 Section I — Short answer questions

Question 1

With reference to figure 2.38, explain the geographical processes that have contributed to land cover change.

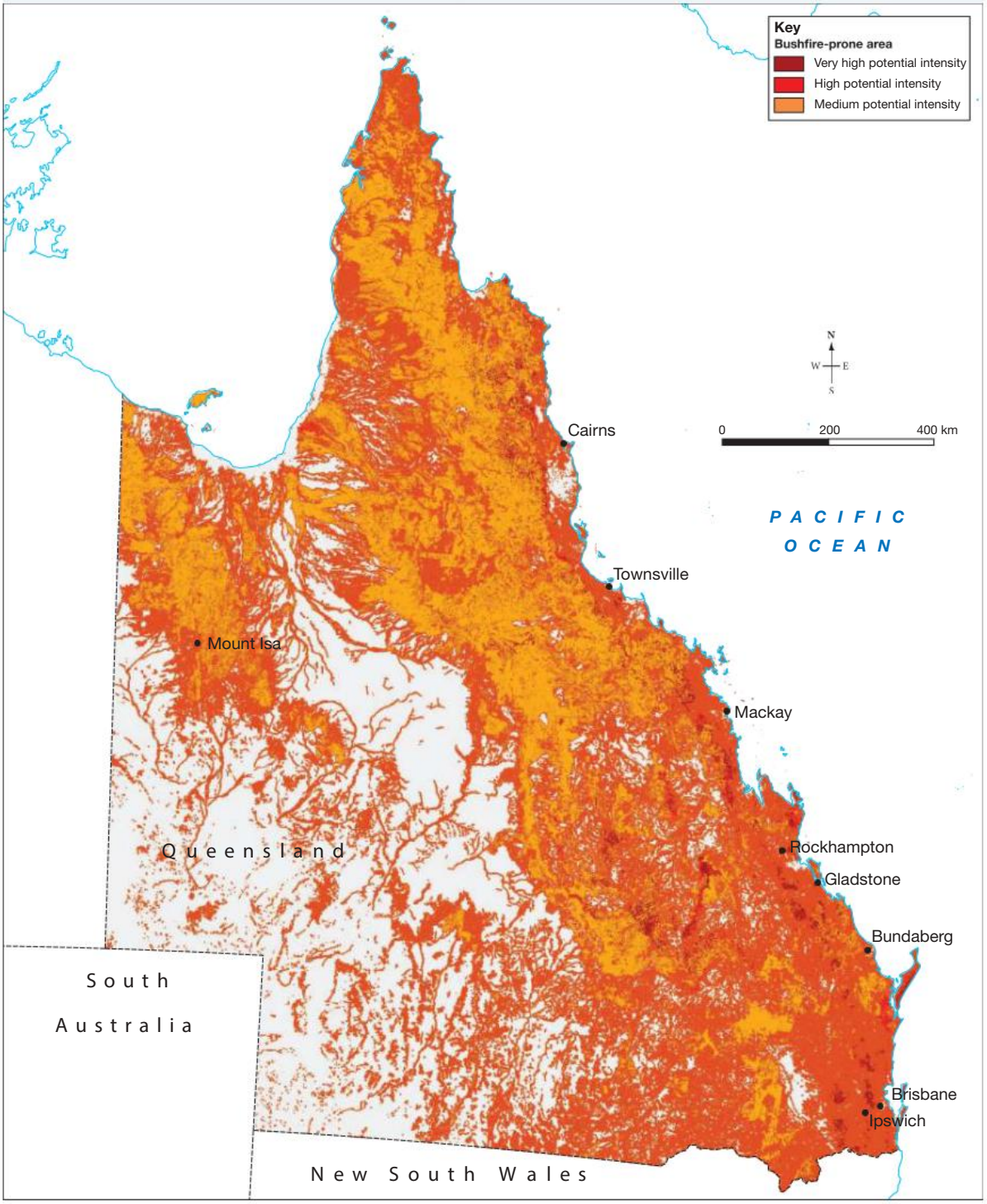
FIGURE 2.38 Land degradation



Question 2

Analyse spatial patterns of bushfire-prone areas in Queensland. Identify the various land covers that bushfires will impact and recommend sustainable management strategies.

FIGURE 2.39 Queensland's bushfire prone areas



Source: © Commonwealth Scientific and Industrial Research Organisation, 2015–2017

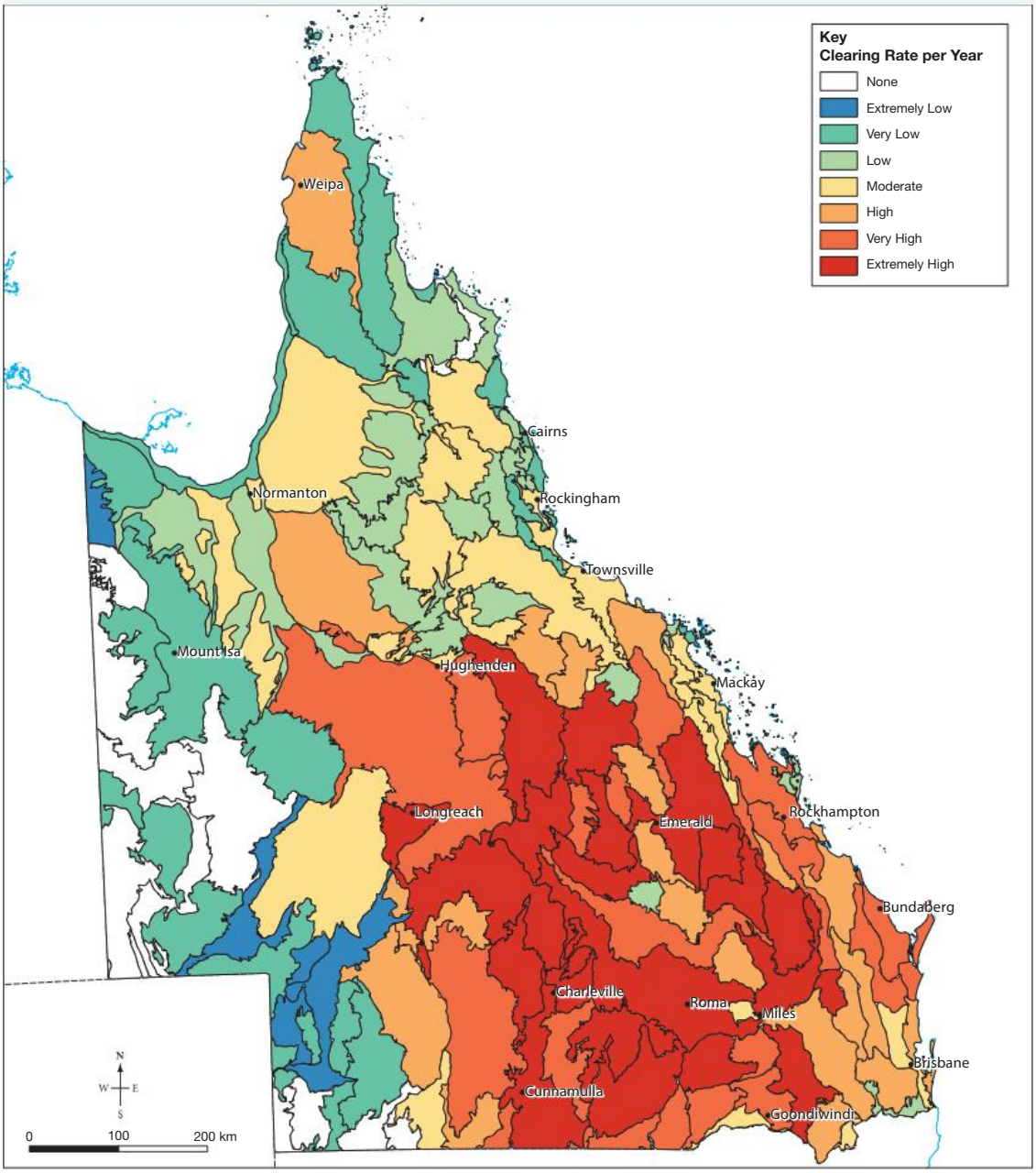
Section II — Extended response

Question 3

In a written response of approximately 450–600 words, respond to the following:

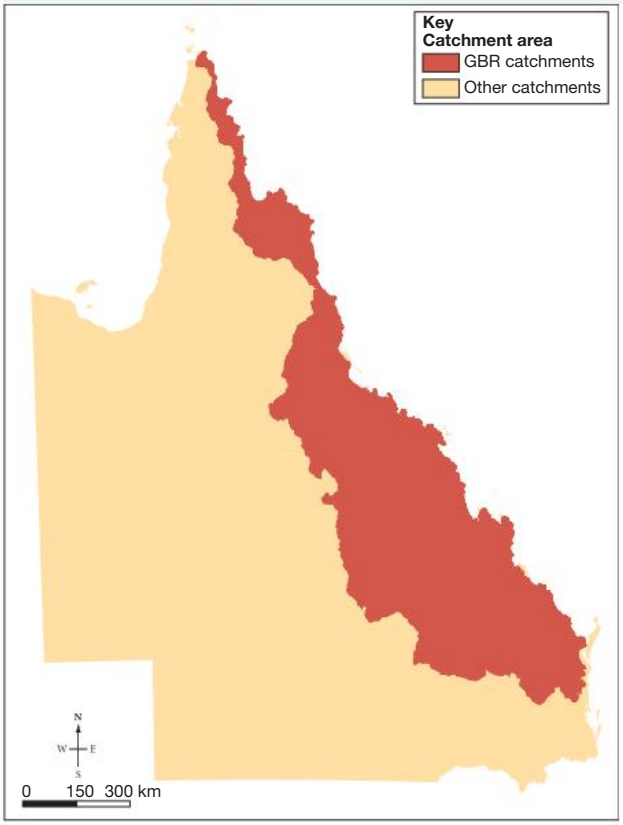
- Analyse and interpret the data presented in the stimulus material to identify the extent of land cover transformation during the given time periods. Explain the biophysical and anthropogenic processes contributing to this change.
- Apply your understanding to generalise the implications for the environment and people due to this changing land cover.
- To what extent do current patterns of land cover change (e.g. urban expansion, deforestation for agriculture, or renewable energy development) continue the trends shown in the stimulus material? Evaluate the implications of these ongoing changes for sustainability of the environment.

FIGURE 2.40 Spatial distribution of woody vegetation clearing in Queensland, 2017–18

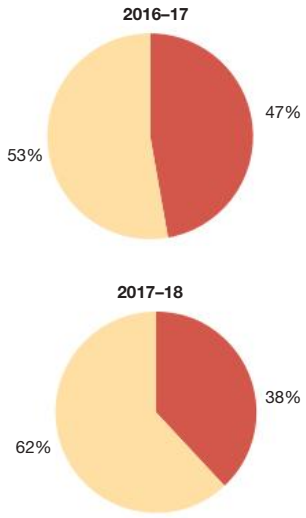


Source: © State of Queensland, 2018

FIGURE 2.41 Clearing rates across (a) the Great Barrier Reef catchment area, (b) by bioregion and (c) by drainage division in Queensland, 2016–18

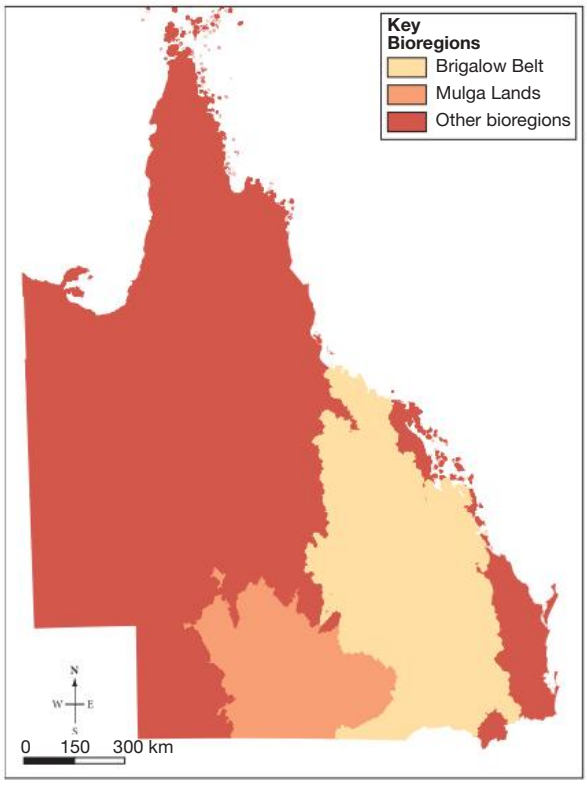


(a) Great barrier reef catchments

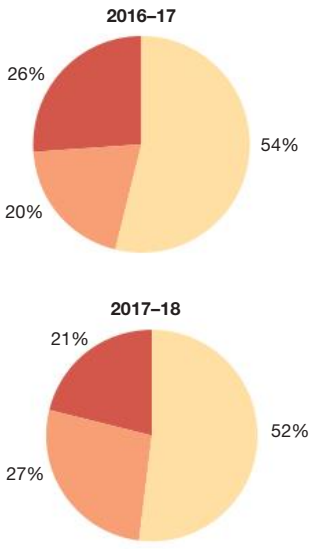


The woody vegetation clearing rate in the Great Barrier Reef catchments was 166 000 ha/year in 2016–17 and 148 000 ha/year in 2017–18. This represented 47 per cent and 38 per cent of the total statewide woody vegetation clearing rates in 2016–17 and 2017–18, respectively. The 2015–16 woody vegetation clearing rate was 158 000 ha/year.

Source: © State of Queensland, 2018

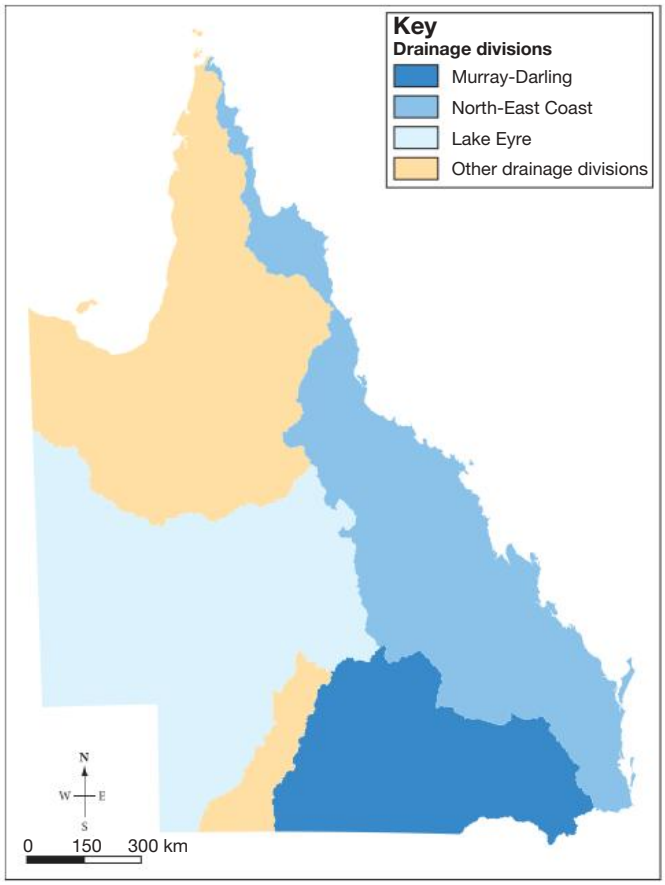


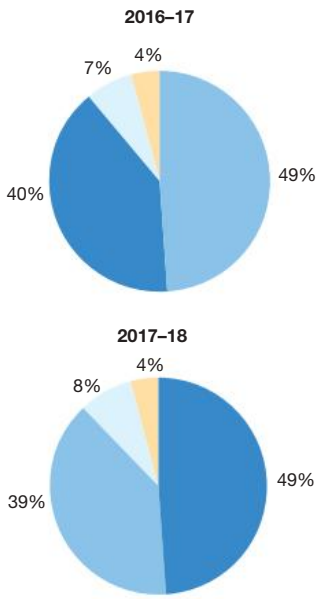
(b) Bioregions



Of Queensland's 13 bioregions, the Brigalow Belt and Mulga Lands recorded the highest woody vegetation clearing rates in the 2016–17 and 2017–18 periods. The Brigalow Belt's clearing rate was 193 000 ha/year in 2016–17, and 204 000 ha/year in 2017–18. The Mulga Lands' clearing rate was 73 000 ha/year in 2016–17 and 106 000 ha/year in 2017–18.

Source: © State of Queensland, 2018





The Murray–Darling and North-East Coast drainage divisions recorded the highest woody vegetation clearing rates in 2016–17 and 2017–18. The woody vegetation clearing rate in the Murray–Darling was 142 000 ha/year in 2016–17 and 192 000 ha/year in 2017–18. The North-East Coast division's clearing rate was 173 000 ha/year in 2016–17 and 154 000 ha/year in 2017–18.

Source: © State of Queensland, 2018

FIGURE 2.42 Harvesting of sugar cane near Innisfail

FIGURE 2.43 The Menindee fish deaths in early 2019

Source: Graeme McCrabb / AAP

Sample responses for this chapter are available online.

3 Population challenges in Australia

UNIT 3 TOPIC 3

SUBJECT MATTER

In chapter 3, students:

- **explain** geographical processes and interactions that result in patterns of demographic and/or population change
- **comprehend** geographic patterns by recognising spatial patterns of demographic and/or population change, identifying relationships and implications for people and places
- **analyse** data and information to infer how patterns, trends and relationships represent geographical challenge/s for specific places
- **apply** geographical understanding from the analysis to generalise about the impacts of demographic and/or population change for places
- **propose** action/s in response to generalisations to address an identified challenge/s for a place in Australia
- **communicate** understanding using appropriate forms of geographical communication.

LESSON SEQUENCE

Fully worked solutions for this chapter are available in the Resources section at www.jacplus.com.au.

LESSON
3.1 Overview

Hey students! Bring these pages to life online

Watch videos

Engage with interactivities

Answer questions and check results

Find all this and MORE in jacPLUS

3.1.1 Introduction

Demography is the study of population, and especially human population. It involves statistical analysis of demographic characteristics such as population size, composition and distribution, and the processes through which populations change. In this chapter, you will examine key demographic features of places in Australia, analyse the geographical processes that have resulted in population change in these places, and investigate the challenges for people and places which may occur because of these changes.

As part of your study, you will investigate a specific challenge arising from demographic or population change for a place in Australia using primary data. You will be asked to propose actions to manage an identified challenge for that place. Through your geographic inquiry, you will be able to understand the nature of demographic and population change over time, and the impacts of change on people and places in Australia.

demography the study of population, especially human population. Demography involves statistical analysis of characteristics such as population size and composition, distribution across space and the processes through which populations change over time

3.1.2 Syllabus links

Syllabus links	Lesson
Explain key demographic concepts, including birth, death and fertility rates, life expectancy, age/sex structure, and migration rates.	**3.2**
Explain how demographic processes result in changes to populations, including rates of natural increase and decrease, and overall population change.	**3.3**
Explain how changes to populations are influenced by factors such as advances in health care and life expectancy, the changing role of women in society and birth rates, the impact of disease on death rates, migration policies over time, and amenity.	**3.4**
Analyse primary data (ABS census data) relating to each of the key demographic concepts (birth, death and fertility rates, life expectancy, age/sex structure, and migration rates) to identify population patterns and trends in Australia.	**3.5**
Recognise and represent the population patterns and trends in each key demographic concept for Australia, using spatial technologies and information and communication technologies.	**3.5**
Explain implications of demographic and population change (e.g. ageing population, youth population, declining population, rapid population growth, migration) for people and places.	**3.5, 3.7**

○	Conduct a geographic inquiry using primary data (for assessment purposes) to investigate a specific geographic challenge arising from demographic or population change for a selected place in Australia at a local scale and suitable population size (e.g. a regional city, a suburb or a rural town). As part of this inquiry students must: • describe the demographic and/or population characteristics for the selected place in Australia • recognise and represent the population patterns and trends in each key demographic concept for Australia, using spatial technologies and information and communication technologies • analyse primary data to identify and explain a demographic and/or population change for the place in Australia (e.g. ageing population, youth population, population decline, rapid population growth) • explain the geographical and/or demographic factors that have contributed to the change (e.g. birth and death rates, migration flows, amenity, employment) • apply geographical understanding from their analysis to generalise about the impacts of the demographic or population change in the selected place (e.g. resource management, workforce participation, housing, infrastructure) • propose action/s to address the impacts arising from the identified challenge for the place in Australia • manipulate, adapt or transform the initial provided data and further gathered primary data using spatial and information and communication technologies to prepare data for analysis using cartographic, graphic and mathematical skills, spatial and information and communication technologies to communicate geographical understanding in a data report.	**3.6, 3.7**

KEY QUESTIONS

- What is demography? What are the key demographic concepts?
- What are Australia's population patterns and trends?
- What demographic processes are responsible for changes in population in Australia?
- What factors influence changes in population in Australia, both spatially and over time?
- What are the implications of population change for people and places in Australia?
- What are the demographic characteristics of a particular place in Australia?
- What challenges occur because of demographic and/or population change in a particular place in Australia?
- What actions might be taken to manage these challenges?

LESSON
3.2 Demographic concepts

LEARNING INTENTION

By the end of this lesson you should be able to explain key demographic concepts, including birth, death and fertility rates, life expectancy, age/sex structure and migration rates.

3.2.1 Birth and death rates

Rates — that is, the fixed ratio between two measurements — are used in demography so meaningful comparisons can be made between places and over time. While the actual numbers for a demographic concept will provide some information, they are often not useful for comparisons. For example, in 2022, 3577 births occurred in the Northern Territory, while significantly more, 95 758, occurred in New South Wales. However, because the Northern Territory's population was far smaller than New South Wales', comparing the birth rates for the two places paints a different picture. In 2022, the birth rate in the Northern Territory was 14.3 per 1000 people, while in New South Wales, the birth rate was 11.6 per 1000.

rates the fixed ratio between two measurements

birth rates also known as crude birth rate; the annual number of live births in a particular place per 1000 people

death rates also known as crude death rate; the annual number of deaths in a particular place per 1000 people

Birth rates (or crude birth rates) are the annual number of live births per 1000 people. They are calculated using the formula:

$$\text{Births per } 1000 = \frac{\text{births per year}}{\text{total population}} \times 1000$$

Death rates (or crude death rates) the annual number of deaths per 1000 people, are calculated in a similar way:

$$\text{Deaths per } 1000 = \frac{\text{deaths per year}}{\text{total population}} \times 1000$$

As was the case with births and birth rates in New South Wales and the Northern Territory, deaths and death rates also vary across places in Australia. For example, the death rate in Tasmania in 2022 was 9.0 per 1000, while in the Northern Territory it was 5.3 per 1000. However, much more significant differences exist among countries around the world.

Table 3.1 provides some examples of different countries' birth and death rates. The reasons for these differences will be considered in more detail in chapter 4.

TABLE 3.1 Birth and death rates for selected countries, 2024

Country	Birth rate (per 1000 population)	Death rate (per 1000 population)
Central African Republic	44	20
Angola	38	7
Papua New Guinea	25	7
Australia	11	7
Serbia	9	15
Qatar	9	1
Greece	7	13
South Korea	5	7

Data source: www.prb.org

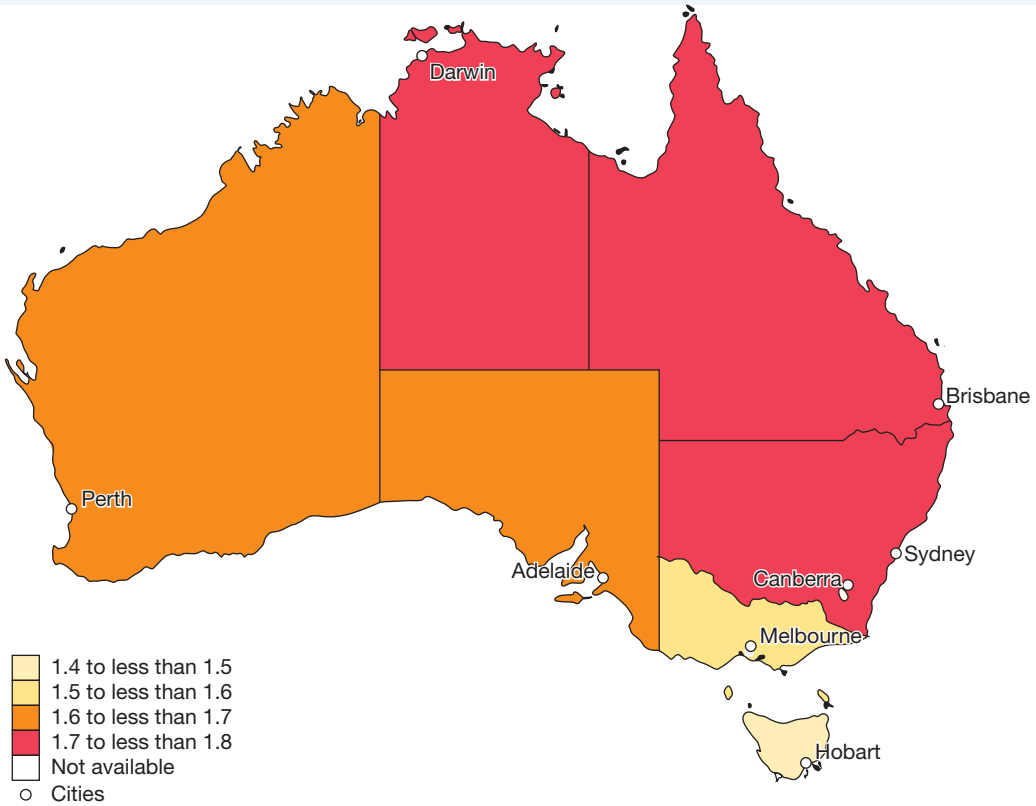
The birth rate minus the death rate is referred to as the **rate of natural increase** in a population (see section 3.3.1). Unlike birth and death rates, this rate is expressed as a percentage. For example, Australia's rate of natural increase in 2024 was 0.4 per cent, Greece's was –0.6 per cent and Angola's was 3.1 per cent. As you can see, rates of natural increase can be positive or negative, so the concept can also be referred to as the rate of natural population change.

3.2.2 Fertility rates

Fertility rates are calculated using the number of children a woman has during her child-bearing years. The demographic concept used for fertility rates in Australia is known as the **total fertility rate**. This is the average number of children a woman would have, assuming the current age-specific birth rates remain constant throughout her child-bearing years (usually considered to be ages 15 to 49). In 2024, Australia's total fertility rate was 1.50 babies per woman. The total fertility rate required for a population to replace itself is considered to be around 2.1 babies per woman. In the absence of migration, Australia's population would decline in size if its current fertility rate persisted over time.

Figures 3.1 and 3.2 show that total fertility rates vary across Australia. As you would expect, and as table 3.2 illustrates, even greater variations exist among countries around the world.

FIGURE 3.1 Total fertility rate by state or territory of usual residence, 2022



rate of natural increase the birth rate minus the death rate, expressed as a percentage: (crude birth rate minus crude death rate) × 100/1000

total fertility rate the number of children born per woman of child-bearing age

FIGURE 3.2 Total fertility rate by state or territory of usual residence, 2022

a. Birth registrations in Tasmania in 2022 were affected by a change in the way births were assigned to the reference year. This change resulted in a lower number of births than recorded in previous years.

b. Includes other territories.

TABLE 3.2 Total fertility rates for selected countries, 2024

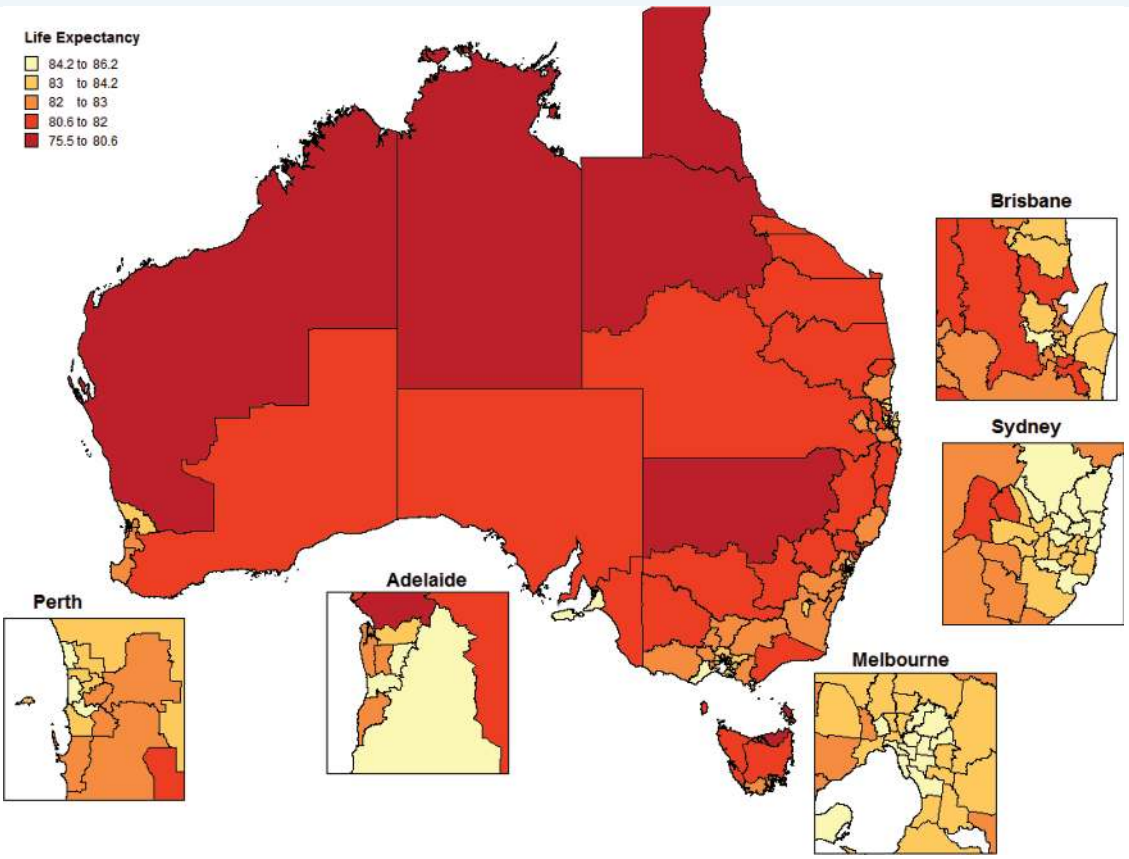
Country	Total fertility rate (births per woman)
Niger	6.1
Mali	5.7
Samoa	4.4
Papua New Guinea	3.1
Paraguay	2.4
Spain	1.1
South Korea	0.7

Data source: www.prb.org

3.2.3 Life expectancy

Life expectancy is the average number of years a newborn infant is expected to live, given the mortality rates at the time of their birth. Australia's average life expectancy at birth in 2024 was 83 years. This was amongst the world's highest (see table 3.3). Within Australia, life expectancies are generally higher in capital cities, and lower in more remote places (see figure 3.3). Life expectancy is also higher for females than males across Australia. In 2022, the highest life expectancies for both females and males (88.2 years and 85.7 years), occurred in Sydney. Unfortunately, life expectancies were much lower in remote parts of the Northern Territory (75.8 years for females and 71.6 years for males in 2022).

FIGURE 3.3 Life expectancy at birth by Commonwealth Electoral Divisions, 2016–18



Source: https://www.aph.gov.au/About_Parliament/Parliamentary_departments/Parliamentary_Library/Research/Statistical_Snapshots/2019-20/LifeExpectancyAustraliasCommonwealth

TABLE 3.3 Life expectancy at birth in selected countries, 2024

Country	Life expectancy at birth (years)
Monaco	84
Japan	84
Australia	83
Central African Republic	57
Chad	54
Nigeria	54

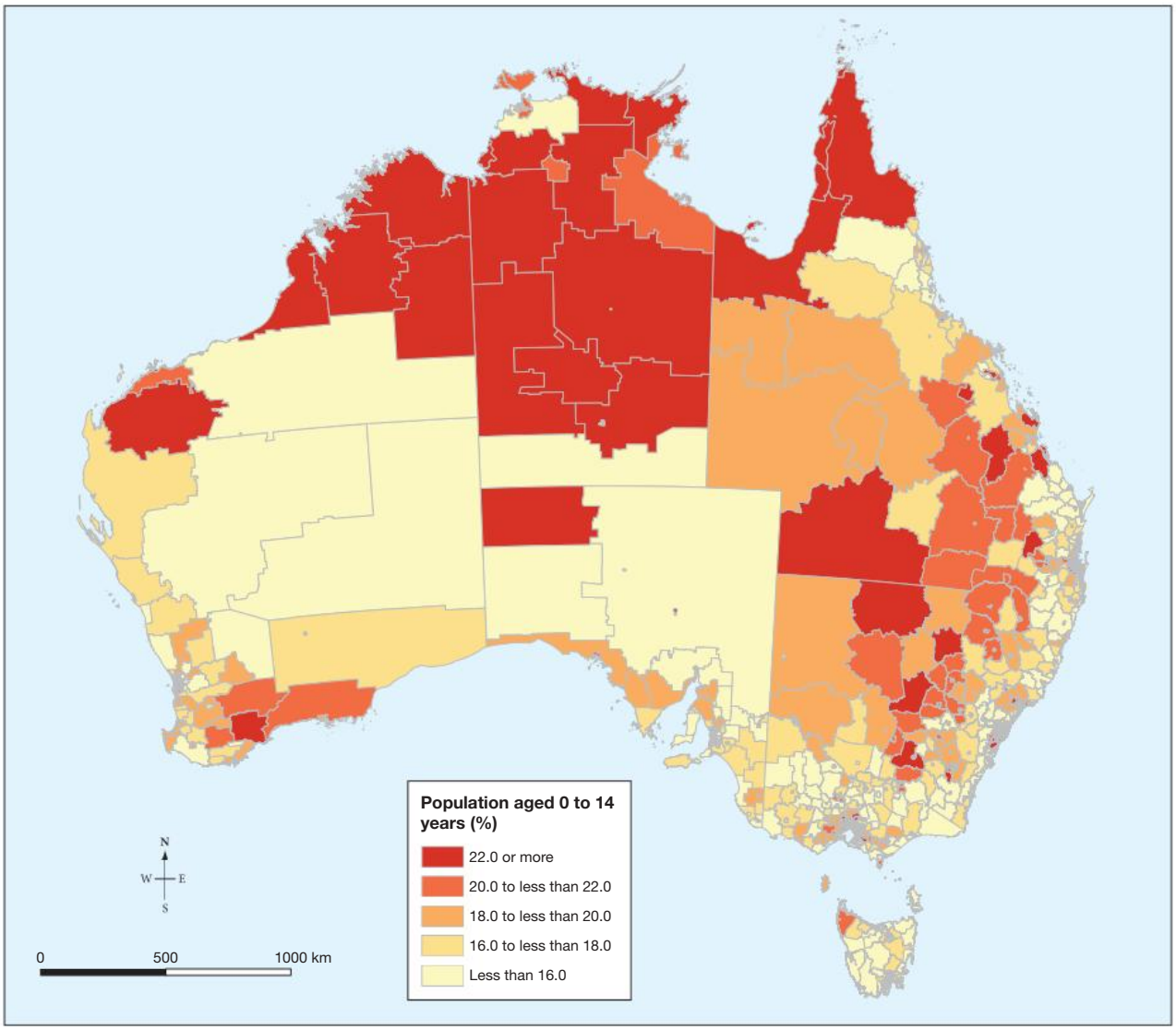
Data source: www.prb.org

3.2.4 Age/sex structure

Age/sex structure is the composition of a population by age (e.g. 0–19 years, 20–44 years, 55 years and above), and sex (male and female). In general, Australia's capital cities have a greater percentage of people aged between 20 and 44 than the rest of Australia (38 per cent in 2023 compared with 30 per cent), and a lower percentage of people aged over 55 years (26 per cent compared with 34 per cent). Percentages of the population aged below 20 years are relatively similar in both capital cities and the rest of Australia.

As you can see in figure 3.4, when Australia is divided into smaller population areas — called Statistical Areas Level 2, (SA2s) — large variations in age structure are seen across Australia. Places with a high proportion of Aboriginal and Torres Strait Islander Peoples tend to have much younger populations, while retirement destinations, especially along the coast, generally have the oldest populations.

FIGURE 3.4 Australia population aged 0 to 14 years, SA2s*, 2023



Source: Australian Bureau of Statistics. Map drawn by Spatial Vision.

**Note:* Statistical Areas Level 2 (SA2) are medium-sized areas used by the Australian Bureau of Statistics to represent communities that interact together socially and economically. Most SA2s have a population range of 3000 to 25 000 people.

The number of males per 100 females in a population is called the **sex ratio**. Australia's sex ratio in 2023 was 99.1; that is, on average, Australia had 99.1 males for every 100 females. Across the capital cities, the average sex ratio was lower, at 98.4. Darwin, at 104.7, had the highest while Hobart, at 95.6, had the lowest. The lowest sex ratios in Australia are generally found in places with older populations, reflecting longer female life expectancies — for example, 80.9 at Woollahra in Sydney, and 82.2 at Robina West in Queensland. The highest sex ratios in 2023 occurred in places with mining activity or male correctional facilities — for example, 274.2 at East Pilbara in Western Australia, and 278.1 at Wacol in Brisbane.

sex ratio number of males per 100 females in a population

Population pyramids

The most common method of illustrating the age/sex structure of a place is an age/sex or **population pyramid**. Population pyramids show both age groups (or age cohorts) and the male–female breakdown of the population. As you can see in figure 3.5, population pyramids are divided horizontally into two parts: the left side for the male population and the right side for the female population. The scale for these two sections of the graph can be population numbers or percentage of population. (Figure 3.5 uses population in millions.) Whichever scale is used, the structure of the pyramid will remain the same. Within the male and female sections, the population is then divided vertically into five-year age cohorts (0–4 years, 5–9 years, 10–14 years and so on).

Figure 3.6 illustrates the contrasting age/sex structures of two places in Australia. As you can see, Victor Harbor in South Australia has a much older population than Springfield Lakes in Queensland. On the other hand, Springfield Lakes has a much greater number of children and people aged between 30 and 44 years (the parents of the children aged 0 to 14 years). The contrasting demographic structure of these two places is a result of their location and function. Victor Harbor is a coastal retirement destination, while Springfield Lakes is a relatively new, family-oriented suburb on the outskirts of Brisbane.

population pyramid also known as age/sex pyramids; a compound bar graph illustrating the age/sex structure of a place's population

FIGURE 3.5 Australia population pyramid, 2020

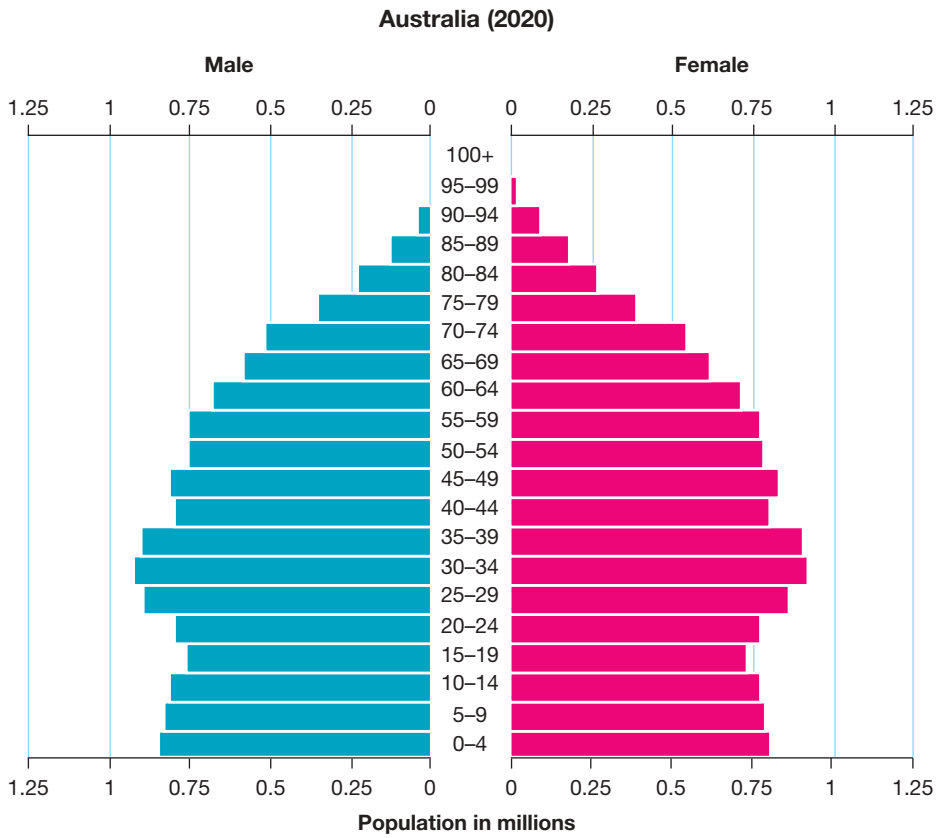
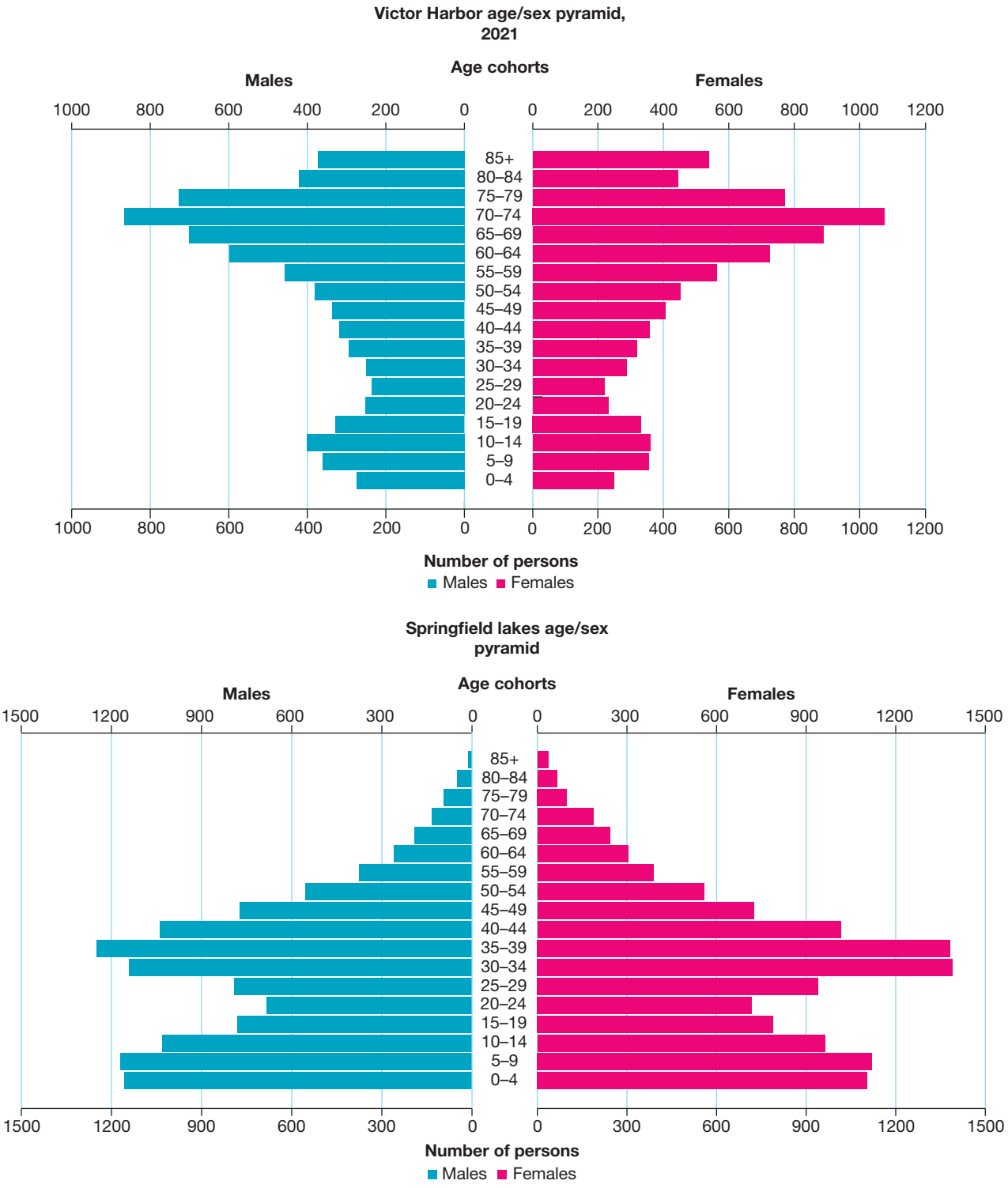


FIGURE 3.6 Age/sex pyramids for Victor Harbor and Springfield Lakes, 2021



3.2.5 Migration rates

Migration is the movement of people from their current place of residence in order to settle in a new place, either permanently or semi-permanently. The **migration rate** (or net migration rate) is the immigration (incoming) number minus emigration

migration rate immigration (incoming) number minus emigration (departing) number, per 1000 people

(outgoing) number, divided by the total population and multiplied by 1000 — that is, the rate per 1000 people. People migrate for a variety of social, economic, environmental and political reasons. For example, people in Australia move for family, work or educational reasons. They may move overseas (international migration) or within Australia (internal migration). Internal migration might be intrastate or interstate, from rural to urban areas, or between urban areas. Many older and other people in Australia move to coastal locations (known as a **sea change**), or to rural areas near capital cities (a **tree change**). You will be analysing the causes and effects of both international and internal migration in more detail in topic 4.

The vast majority of people who moved location between 2016 and 2021 moved within the same state or territory. For example, as figure 3.7 shows, over 50 per cent of departures from Brisbane were to a place in the rest of Queensland. Figure 3.8 shows that only three states and territories had positive migration rates between 2016 and 2021, and that Queensland was the predominant destination. Within Queensland, the Gold and Sunshine coasts were the first and second most popular destinations for interstate migrants.

sea change a change in lifestyle, especially a move from the city to a seaside location

tree change a change in lifestyle, especially a move from the city to a rural location

FIGURE 3.7 Departures from Brisbane, 2016–21

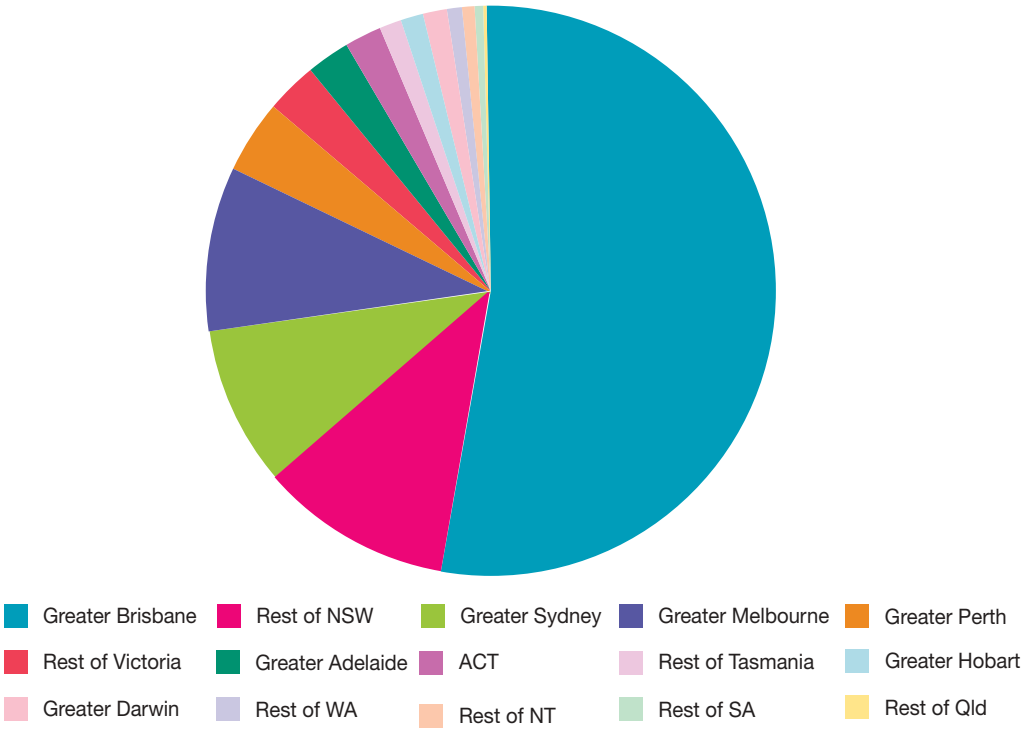
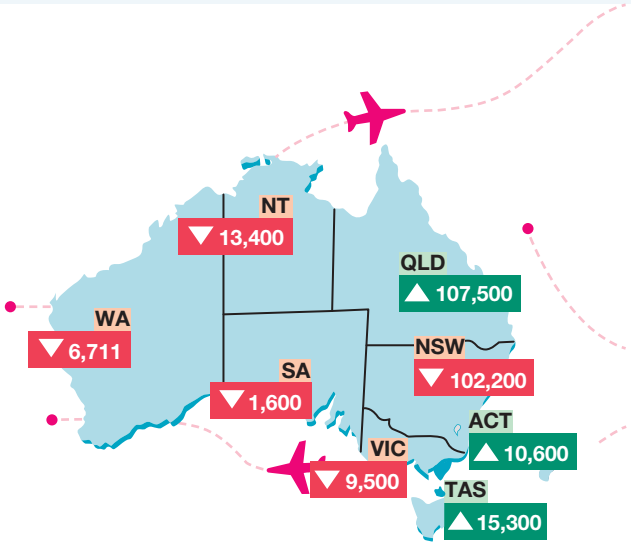


FIGURE 3.8 Interstate migration rate of people in Australia, 2016–21



SKILLS ACTIVITY: Analyse geographic data and information

Comparing demographic statistics

Use the data in figures 3.1 and 3.3 and table 3.3 to describe the key features of Australia's demography. Use other relevant data available at the Australian Bureau of Statistics to help you.

Download the latest World Population Data Sheet from the Population Reference Bureau website in the Resources tab.

Write a paragraph to compare Australia's demography with that of another country of your choice. Tables 3.2 and 3.3 will help to get you started.

Compare the demographic features of your selected country with those of Australia.

3.2 Exercise

learnon

3.2 Exercise

Learning pathways

LEVEL 1	LEVEL 2	LEVEL 3
1, 4, 7	2, 5, 8, 10	3, 6, 9, 11

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Explain and comprehend

1. **List** and **define** the key demographic concepts discussed in this lesson.
2. **Show** your understanding of the concept of rate of natural increase by calculating the rates of natural increase in the countries listed on table 3.1. Make a list of the countries ranked from highest to lowest.
3. **Explain** the implications for countries with a negative rate of natural increase.
4. Refer to figure 3.2 and **describe** the pattern shown on the graph.
5. Refer to figure 3.3 and **describe** the pattern shown on the map.
6. **Explain** the difference between numbers of migrants and net migration rate.

Analyse and apply

7. **Analyse** the data provided in table 3.2 and suggest the possible impact of fertility rates on population change in Niger and South Korea.
8. **Analyse** the data provided in tables 3.1 and 3.3 and suggest, with reasons, possible birth and death rates for Japan and Nigeria.
9. Refer to figure 3.6. **Identify** the largest and smallest age cohorts in Victor Harbor and Springfield Lakes.
10. **Compare** the relative size of these age cohorts with those in Australia as a whole (figure 3.5).

Propose and communicate

11. Refer to figure 3.7. **Identify** general patterns of migration from Brisbane to other states and territories in Australia. Identify any state and/or territory that doesn't fit the pattern. Suggest reasons for the patterns of migration.

Samples responses for this chapter are available online.

LESSON
3.3 Changes in populations

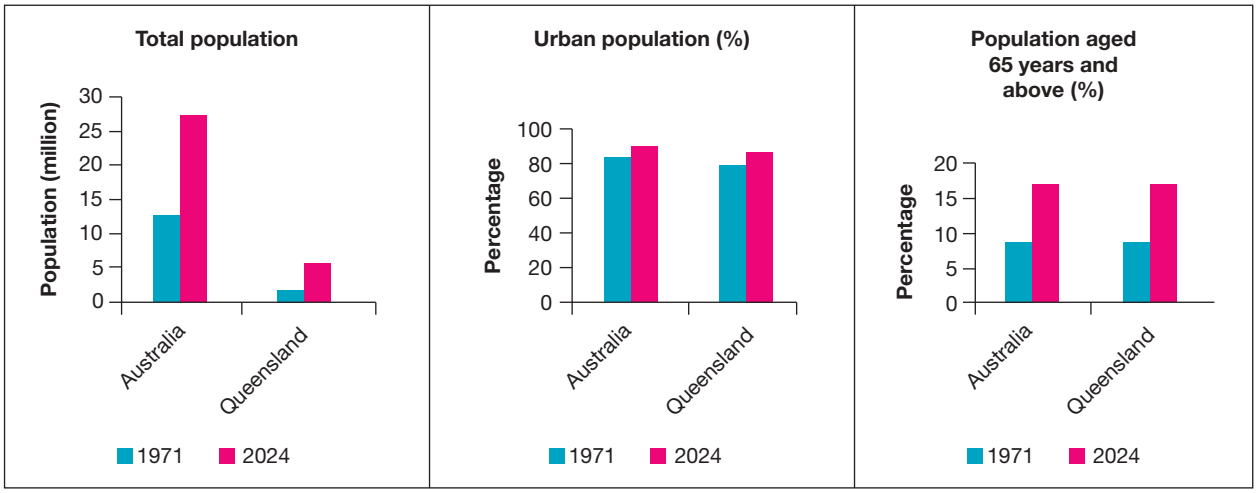
LEARNING INTENTION

By the end of this lesson you should be able to explain how demographic processes result in changes to populations, including rates of natural increase and decrease, and overall population change.

3.3.1 Population change

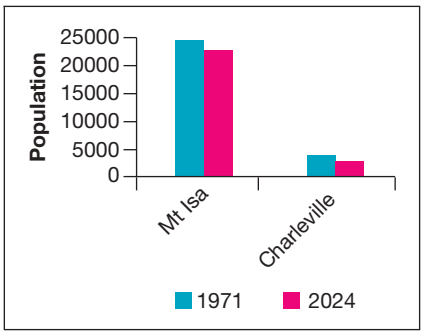
Populations change over time and space in size, composition and distribution. For example, Australia's population in 1971 was 12.6 million. By 2024, it had more than doubled to 27.3 million — an increase of 117 per cent. Over the same period, the percentage of Australia's population aged 65 years and above increased from 8.7 per cent to 17 per cent, and the percentage of people living in urban areas rose from 84 per cent to 90 per cent. As you would expect, Queensland experienced similar changes. Its population grew from 1.7 million in 1971 to around 5.6 million in 2024, while the percentage of people aged 65 years and above increased from 8.8 per cent to 17.2 per cent, and the percentage of people living in urban areas increased from 79.4 per cent to 86.9 per cent.

FIGURE 3.9 Population change in Australia and Queensland, 1971–2024



As section 3.2.1 illustrated, population change can be negative as well as positive. For example, while the population of Townsville increased from 72 023 in 1971 to 202 000 in 2024, the population of Charleville declined by 24 per cent, from 3948 to 2992, and Mt Isa by 7 per cent, from 24 502 to 22 785. In contrast to the increased percentage of Australia's population aged 65 years and above between 1971 and 2024, the population aged below 15 years declined from 28.7 per cent to 18.6 per cent. As the percentage of people living in urban areas in Australia increased, the percentage living in rural areas declined. Such differences in population change in different places are largely due to changes in birth, death, fertility and migration rates, and life expectancy.

FIGURE 3.10 Population change in Mt Isa and Charleville, 1971–2024



3.3.2 Rates of natural increase and decrease

As outlined in section 3.2.1, rates of natural increase and decrease are calculated using a place's birth and death rates. When birth rates are higher than death rates, populations will increase; when death rates exceed birth rates, the rate of natural increase is negative, and populations may decrease in size. Changes in birth and death rates over time are commonly shown on a line graph, with one line for birth rates and a second line for death rates (see figures 3.11 and 3.12).

The gap between the lines indicates the extent to which the population is growing or declining (the rate of natural increase or decrease). In Queensland, birth rates have consistently been greater than death rates, so a natural increase in population has occurred. In comparison, a natural decline has occurred in Spain's population since 2014.

Note: You will examine demographic changes in populations in more detail in Topic 4.

FIGURE 3.11 Changes in Queensland's birth and death rates and total population, 1971–2021

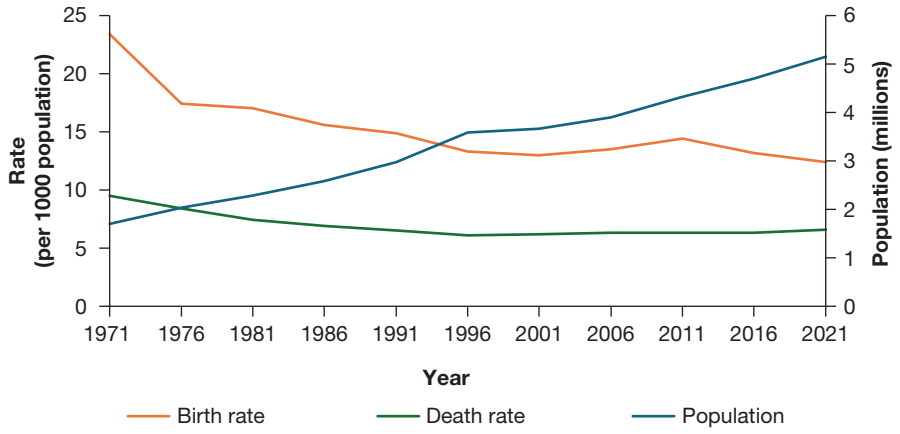
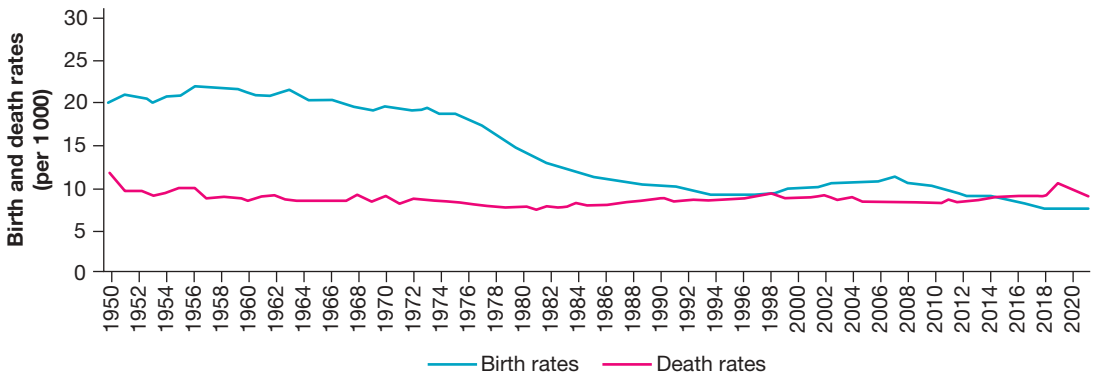


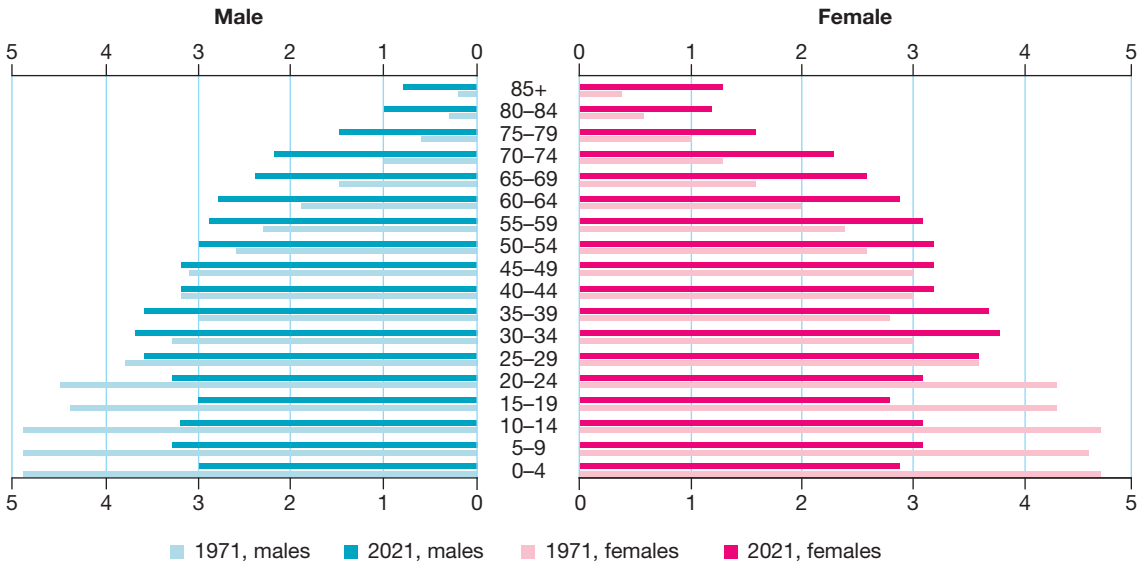
FIGURE 3.12 Changes in Spain's birth and death rates, 1950–2021



3.3.3 Changes in age/sex structure

As figure 3.13 illustrates, significant changes in Australia's age/sex structure have occurred over time. In particular, a dramatic decline has been seen in the proportion of the population in younger age cohorts, ages 0 to 24, and a large increase in the cohorts aged 55 years and above. These changes reflect the fall in Australia's fertility rates and the rise in life expectancy. In 1971, Australia's total fertility rate was 2.9 per woman, and average life expectancy was 71.5 years. By 2021, the former had fallen to 1.6 and the latter had risen to 83.3.

FIGURE 3.13 Changes in Australia's age/sex structure, 1971–2021



3.3.4 Overall population change

If you look at figure 3.11, you will see that, between 2011 and 2021, Queensland's birth rate declined quite sharply, but the total population increased rapidly. This overall growth in population occurred primarily through migration rather than natural increase. Figure 3.14 shows how important both interstate and international migration are to Queensland's population growth, in comparison to natural increase. As you can see, this pattern of overall population change, while more pronounced in Queensland, is common to most of Australia's states and territories.

Figure 3.15 illustrates overall population change in Australia between 2004 and 2024. The graph shows that fluctuations in Australia's overall population growth closely parallel changing rates of net overseas migration; the role of natural increase is much more consistent over time. Unlike natural increase, rates of migration largely depend on government migration policies. For example, during 2020 and 2021, Australia's borders were closed due to the COVID-19 pandemic. During this time, migration rates fell sharply.

You will see on figure 3.16 that a similar sharp fall in Australia's population occurred in 1915–16, during World War I. In this case, not only did overseas immigration almost stop, but large numbers of Australian soldiers also left to fight in Europe. In contrast, following World War I and World War II, Australia's population rose sharply, as soldiers returned and immigration numbers rose. Another rapid increase in population occurred in the years preceding the 2008 global financial crisis (GFC). This was because of a significant increase in the number of temporary migrants to Australia, primarily students and skilled workers. For example, in 2007–08, international students represented almost 40 per cent of all migrants to Australia.

FIGURE 3.14 Components of annual population change for Australia's states and territories, 2022

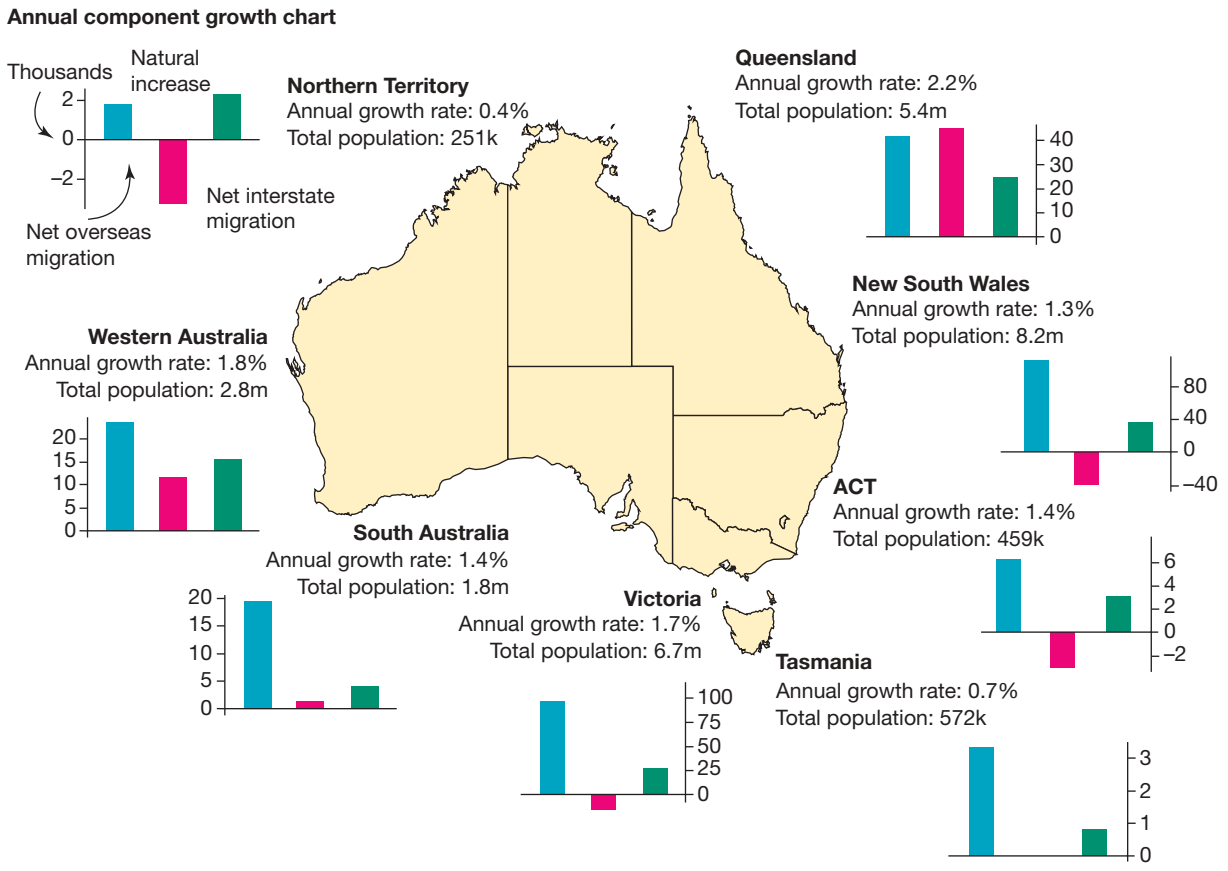
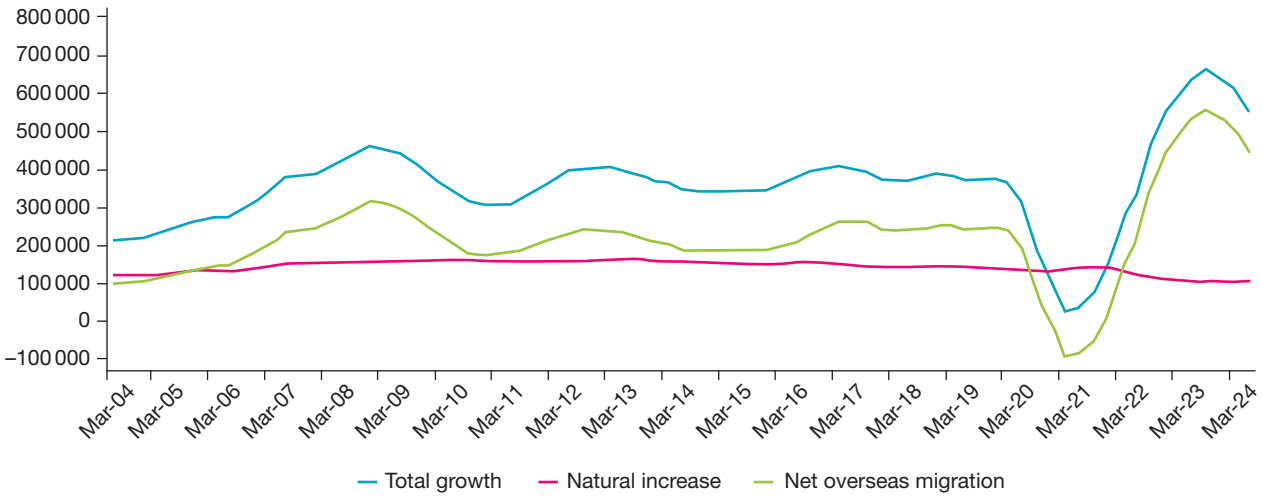
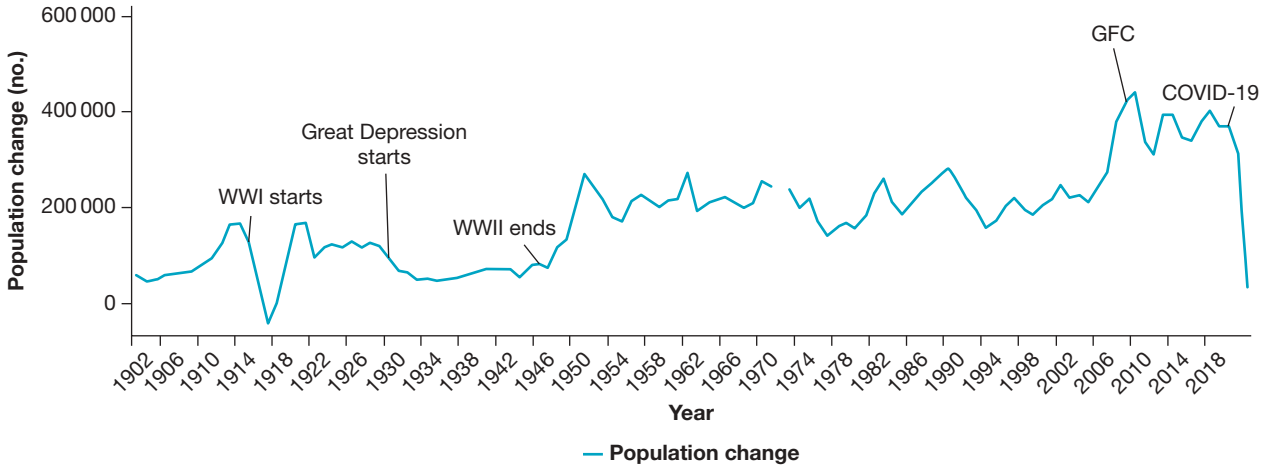


FIGURE 3.15 Components of Australia's annual population change, 2004–24



Annual components calculated at the end of each quarter.

FIGURE 3.16 Australia's annual population change, 1902–2021



Data for 1971 was not included in this graph due to a conceptual break in series with the introduction of the Estimated Resident Population and the inclusion of Aboriginal and Torres Strait Islanders in official population counts.

SKILLS ACTIVITY: Analyse geographic data and information

Identifying population trends over time

1. The rate of natural increase is the birth rate minus the death rate, expressed as a percentage. Calculate the rates of natural increase for Australia and add these figures to table 3.4.
2. In which years were the birth and death rates and the rate of natural increase highest and lowest in Australia?
3. Describe how the rates of natural increase have changed over time. How might these changes relate to population changes in Australia? What other factors need to be considered to explain the growth in population?
4. a. Construct a multiple line graph for birth and death rates in Australia, similar to that for Queensland as shown in figure 3.11. Add a scale for population on the right side of the graph and draw a line to show the change in population over time.
   b. Describe the pattern of population change illustrated by your completed graph. In particular, look at the gap between the birth and death rates and at the line showing population change.
5. Analyse population change over time in Australia. Can a constant downward trend in both birth and death rates be seen? Have upward spikes occurred in either of the rates? If spikes have occurred, what might account for them?

TABLE 3.4 Birth and death rates and population change in Australia

Year	Australia			
	Birth rate (per 1000)	Death rate (per 1000)	Rate of natural increase (%)	Total population (millions)
1891	34.5	16.6	1.79	3.2
1901	27.2	12.1		3.6
1911	27.2	10.8		4.6
1921	25.0	9.8		5.5
1931	18.2	8.5		6.5
1941	18.9	10.0		7.1
1951	23.1	9.6		8.5
1961	21.3	8.7		10.6

(continued)

TABLE 3.4 Birth and death rates and population change in Australia *(continued)*

Year	Australia			
	Birth rate (per 1000)	Death rate (per 1000)	Rate of natural increase (%)	Total population (millions)
1971	18.8	8.3		12.6
1981	15.8	7.6		15.0
1991	14.9	6.9		17.4
2001	12.7	6.6		19.4
2011	13.3	6.5		21.5
2018	13.0	7.0		24.7
2019	12.7	6.6		25.4
2020	12.6	6.6		25.7
2021	12.4	6.6		25.9
2022	12.2	6.7		26.2
2023	12.1	6.7		26.5
2024	11.9	6.8		26.7

Source: Australian Bureau of Statistics

3.3 Exercise

learnon

3.3 Exercise

Learning pathways

LEVEL 1	LEVEL 2	LEVEL 3
1, 4, 7	2, 5, 8	3, 6

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Explain and comprehend

1. **Identify** ways in which Australia's population has changed over time.
2. **Explain**, using examples, the difference between positive and negative population change.
3. **Identify** two changes in Australia's age/sex structure over time.
4. **Explain** possible reasons for changes in Australia's age/sex structure.
5. **Describe** the role played by overseas migration in changes to Australia's population.

Analyse and apply

6. **Analyse** figure 3.11 and describe how Queensland's birth and death rates have changed over time.
7. **Explain** how and why Queensland's overall population increase differs from its rate of natural increase.
8. Refer to figure 3.14. Select two contrasting states or territories and **describe** the differences in the components of annual population change in the two places.

Sample responses for this chapter are available online.

LESSON
3.4 Factors influencing population change

LEARNING INTENTION

By the end of this lesson you should be able to explain how changes to populations are influenced by factors such as advances in health care and life expectancy, the changing role of women in society and birth rates, the impact of disease on death rates, migration policies over time, and amenity.

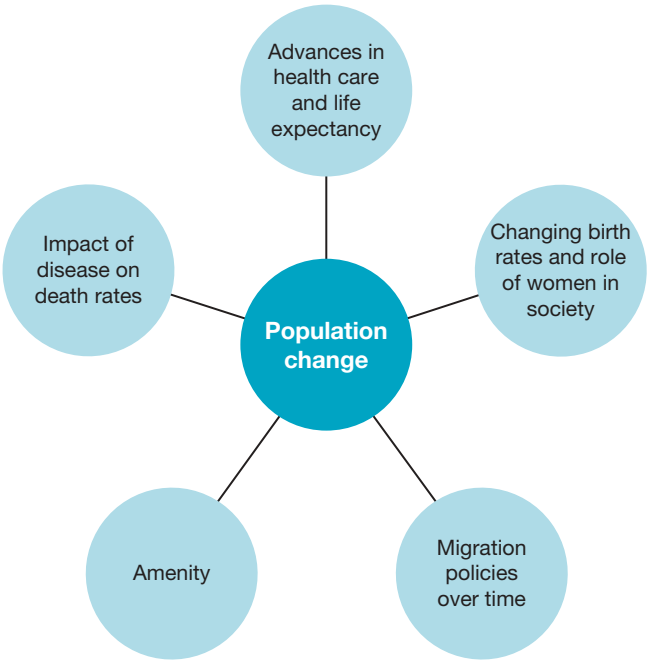
3.4.1 Factors influencing population change

Population change is influenced by a combination of economic, social, cultural, political and epidemiological (public health) factors. These factors include things such as increased family incomes, farm consolidation and rural decline, and higher levels of education. More specifically, population change is influenced by:

- the impact of disease on death rates
- advances in health care and life expectancy
- the changing role of women in society and birth rates
- migration policies over time
- amenity

These factors (shown in figure 3.17) are often linked. For example, as women's roles in Australian society changed from the 1960s, birth and fertility rates declined. Improved health care has resulted in both improved life expectancy and declining death rates. Migration policies have increased Australia's population, but also slowed its ageing.

FIGURE 3.17 Factors influencing population change



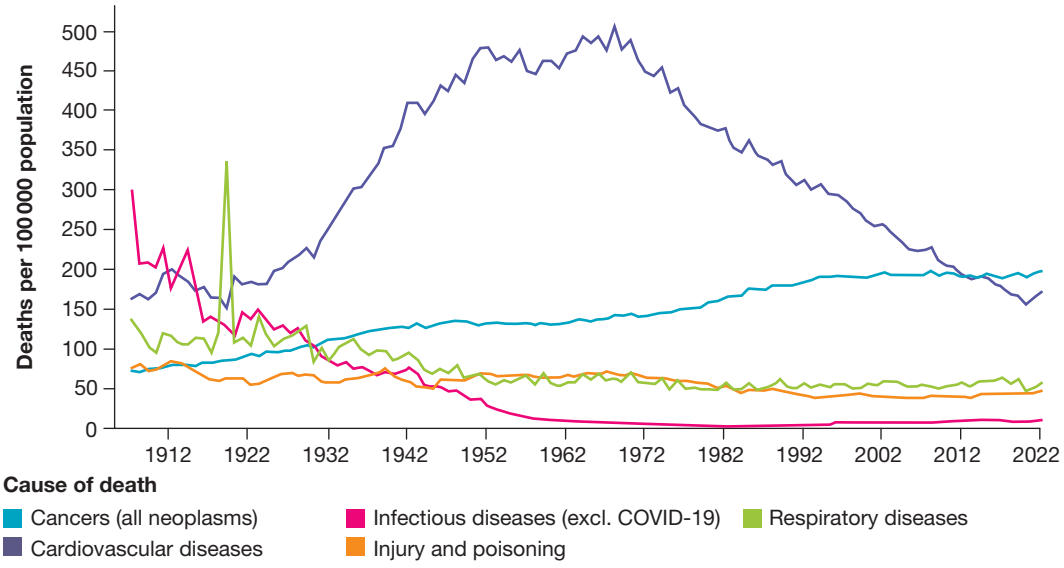
3.4.2 The impact of disease on death rates

Death rates have declined over time in Australia, from 20 per 1000 people in 1907 to around 5 per 1000 today (see figure 3.18). Figure 3.19 highlights one important factor in the fall in Australia's death rates. In the early part of the twentieth century, the second most common cause of deaths in Australia was infectious diseases, such as tuberculosis, typhoid, diphtheria, measles, scarlet fever and pneumonia. These were responsible for a quarter of all deaths, many of them children and young adults. However, by the 1950s, these diseases had become much less common and were responsible for relatively few deaths.

FIGURE 3.18 Age-standardised death rates* in Australia by sex, 1907–2022

* Age-standardised death rates are used to compare death rates over time. The Australian Bureau of Statistics defines age-standardised rates as 'hypothetical rates that would have been observed if the populations being studied had the same age distribution as the standard population, while all other factors remained unchanged.'

FIGURE 3.19 Crude death rates in Australia, by broad cause of death, 1907–2022



A link exists between infectious diseases in Australia and the decline in death rates over time. If you compare the death rate line of the graph constructed for the 3.3 skills activity with that for death rates from infectious disease in figure 3.19, you will see that they closely correspond.

Factors such as control of infectious disease, better hygiene and better nutrition were responsible for the decline in deaths from infectious diseases. By the 1950s, immunisation against infectious diseases was almost universal in Australia, as was the use of recently discovered antibiotics such as penicillin.

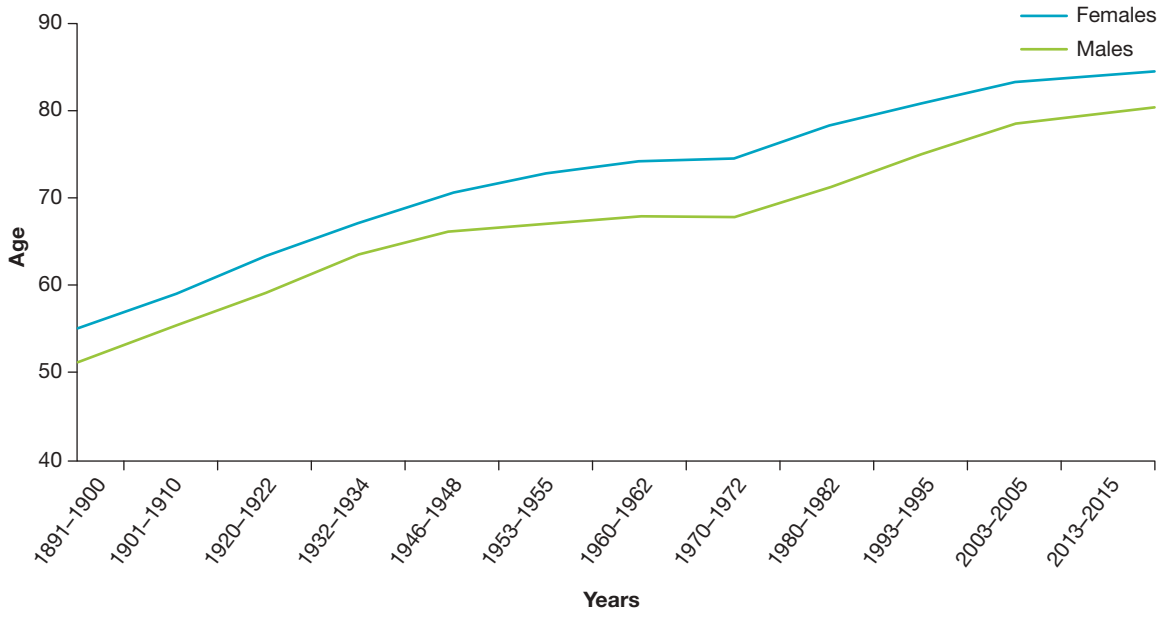
As deaths from infectious diseases decreased from the 1920s, deaths from cardiovascular diseases (e.g. heart attacks and strokes) increased sharply and became the leading cause of death in Australia. By the 1970s, improvements in the detection and treatment of cardiovascular disease, as well as improvements in its prevention, meant that the number of deaths fell sharply. Falling rates of smoking also contributed to the decline.

While death rates have gradually declined over time in Australia, upward spikes have occasionally occurred. One spike occurred in 2021–22 because of the COVID-19 pandemic. Another, much greater, spike occurred in 1918–19 because of a virulent strain of influenza that affected most of the world. Experts estimate that this 'Spanish flu' pandemic was responsible for over 15 000 deaths in Australia over a six-month period (see the spike in respiratory diseases during this period on figure 3.19). Unlike most outbreaks of influenza, more than 50 per cent of deaths from the 1918 flu occurred in people aged between 20 and 39 years, rather than infants or older people. Death were also more common in males than females. Despite these occasional upward spikes, better management and control of disease over time have led to declining death rates in Australia.

3.4.3 Advances in health care and life expectancy

Improved disease control not only led to a reduction in Australia's death rates over time, but also contributed to dramatic improvements in life expectancy (see figure 3.20). Girls and boys born in 2024 can expect to live 34 and 33 years longer respectively than the babies born in the late nineteenth century.

FIGURE 3.20 Life expectancy at birth, Australia, 1891–2015



Advances in health care have also contributed to increased life expectancy and the decline in death rates in Australia. Improvements in health infrastructure such as hospitals and aged-care facilities, high-quality medical training and research, and advances in medical technology and treatment techniques have all helped. Even public health campaigns designed to reduce rates of smoking and warn about the risks of skin cancer form part of

Australia's advances in health care. Figure 3.21 shows the range of demographic, social, economic and political factors involved in Australia's current health care system.

FIGURE 3.21 Australia's health landscape

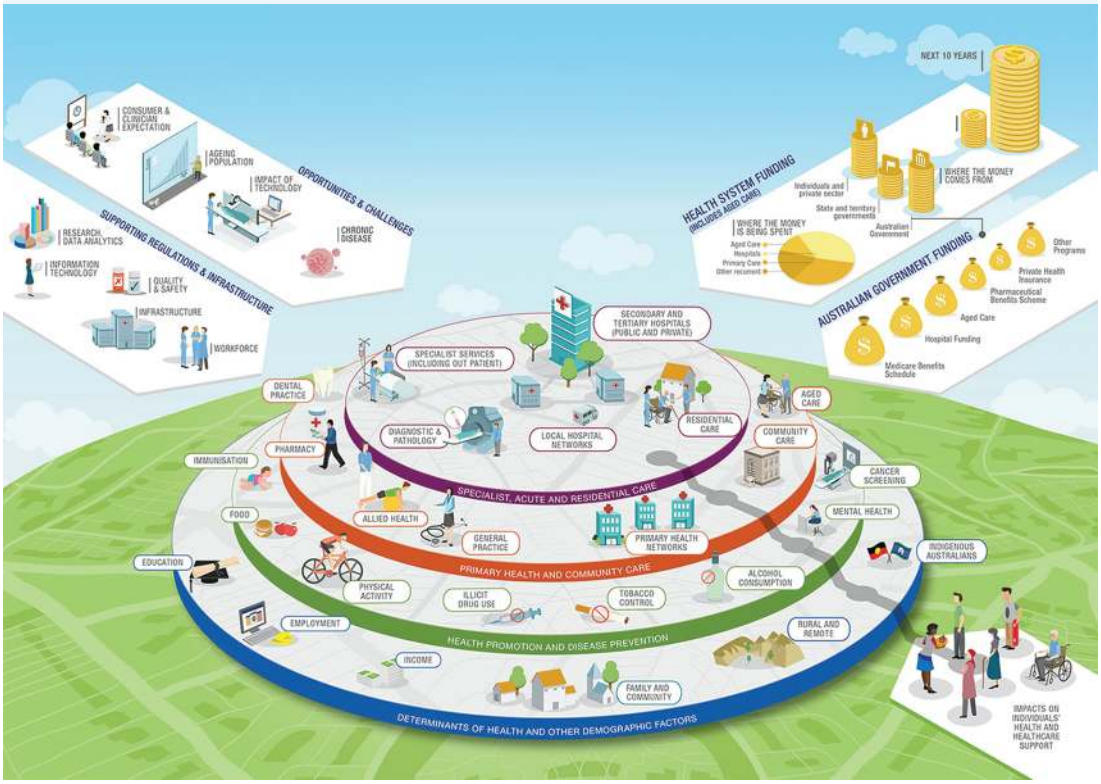


FIGURE 3.22 Australia's health care, past and present: (a) Sydney Hospital surgery, 1914, (b) hospital surgery, twenty-first century, (c) hospital ward, late nineteenth century, (d) hospital ward, twenty-first century

3.4.4 The changing role of women in society and birth rates

Birth rates in Australia have fallen over time, from a high of 34.5 in 1890 to a low of 12.4 in 2021. Overall, the trend has been downwards, although more fluctuations have occurred in birth rates than in death rates. For example, after a low point in 2001, birth rates rose to 13.3 in 2011, before falling again in 2021. A pronounced upward movement in birth rates occurred after World War II. This is known as the **baby boom** period. Birth rates were higher in the 1950s and 1960s than they had been since the 1920s.

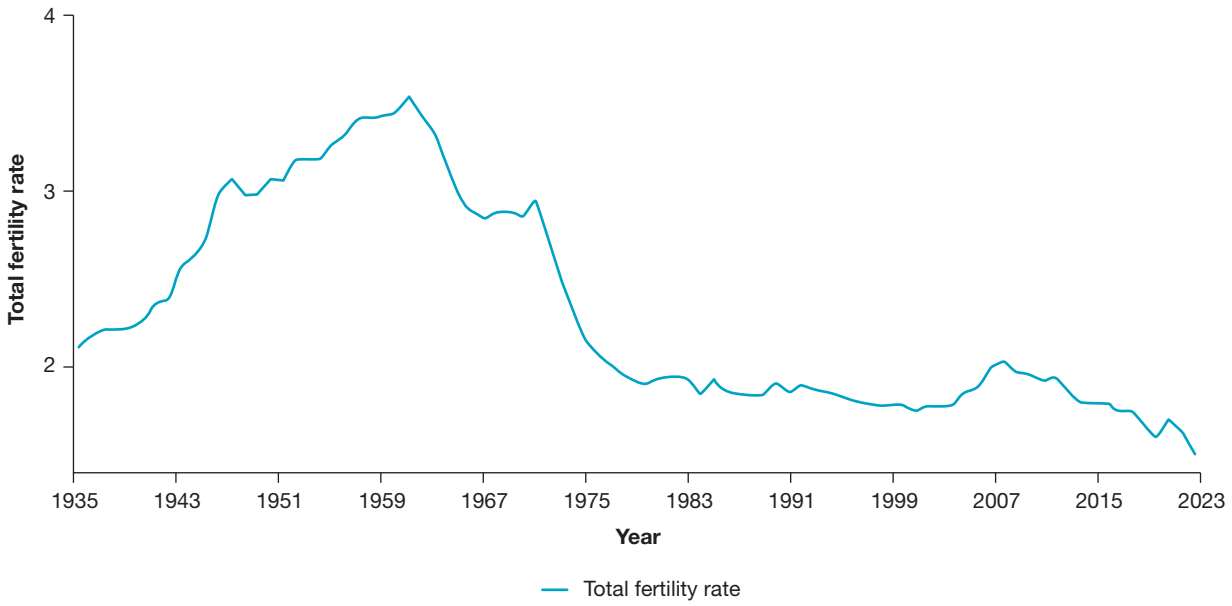
baby boom an upward spike for a number of years in birth rates; the period in Australia from the late 1940s to the early 1960s when birth rates were higher than they had been since the 1920s

A number of social, economic and cultural factors help explain changes in birth rates in Australia over time. These include:

- the changing role of women in society, including the increased participation of women in the workforce
- the availability of family planning techniques, including contraceptives
- an increase in the age at which women marry
- the use of government incentives such as baby bonuses
- increases in the compulsory schooling age
- increases in the costs associated with children, such as the cost of education
- reduced infant and childhood mortality rates
- increased urbanisation and the reduction in the number of farming families
- social disruption, especially that caused by war.

Some demographers consider that the most important factor for the decline over time in birth rates in Australia, and other countries with high levels of development, is the changing role of women in society. As educational opportunities for girls increased and more women entered and remained at work, women chose to marry later and to delay having children. On average, child-bearing is now occurring an average of ten years later compared to the 1950s, so many women now have their first babies in their 30s rather than their 20s. In addition, many women have chosen to have only one or two children, while others, perhaps up to 25 per cent, have chosen to have none at all. The impact of these decisions on Australia's fertility rates is shown in figure 3.23. The graph suggests that the most dramatic changes in the role of women in Australian society occurred in the 1960s and 1970s, when fertility rates declined rapidly.

FIGURE 3.23 Total fertility rate for Australia, 1934–2022



Source: https://www.abs.gov.au/statistics/people/population/births-australia/latest-release

One important change in the role of women in Australian society has been their increased participation in the workforce. Before the 1960s, most women remained at home and cared for their children. However, from the 1960s, as society changed culturally, socially and economically, increasing numbers of women entered the workforce. As figure 3.24 illustrates, female workforce participation rates have continued to trend upwards in the twenty-first century.

Table 3.5 shows that as workforce participation rates for women aged 25 to 64 have increased over the last 60 years — by around 40 per cent since the 1960s — both birth and fertility rates have fallen. Birth rates have fallen by 49 per cent (22.4 per 1000 in 1960 to 11.5 in 2020), and fertility rates by 54 per cent, from 3.45 to 1.58 per woman. While workforce participation has not been the only factor in changes in birth and fertility rates in Australia, it has been an important component.

FIGURE 3.24 Female workforce participation rates, 2000–21

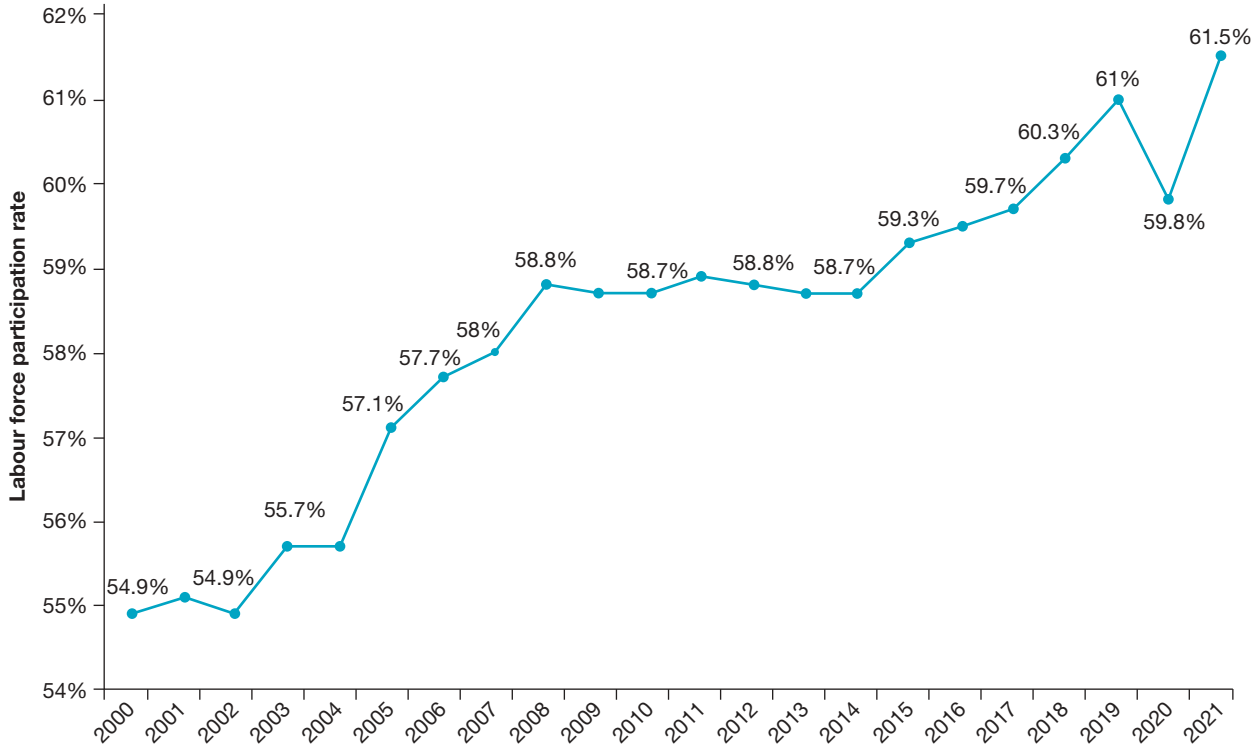


TABLE 3.5 Birth rates, fertility rates and female workforce participation rates, 1960–2023

Year	Birth rate (per 1000 people)	Fertility rate	Workforce participation rate (women aged 25–64)
1960	22.4	3.45	29.1 (est)
1965	19.6	2.98	34.3
1970	20.6	2.86	39.5
1975	16.8	2.15	44.6
1980	15.3	1.89	46.48
1985	15.7	1.92	49.42
1990	15.4	1.90	59.5

1995	14.2	1.82	61.7 (est)
2000	13.1	1.77	63.9
2005	13.1	1.87	68.08
2010	13.8	1.95	70.29
2015	13.1	1.81	71.68
2020	11.5	1.58	71.7
2023	10.8	1.50	N/A

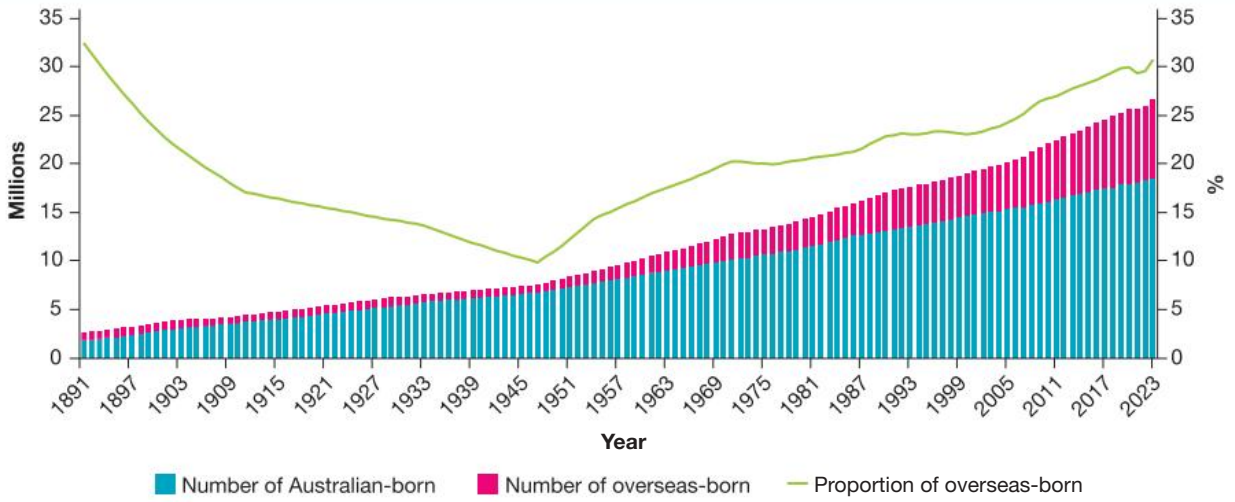
Source: Australian Bureau of Statistics, © Statista 2024

3.4.5 Migration policies over time

Over time, Australia's migration policies have resulted in major changes in both the size and composition of Australia's population. As well as now having a much larger population, Australia has also become much more culturally diverse because of migration. By 2023, 8.2 million people out of a total population of 26.6 million, or over 30 per cent, were overseas migrants. These migrants came from more than 150 countries around the world. In comparison to 1994, when nearly 40 per cent of Australia's migrants came from just three countries, United Kingdom, Ireland and New Zealand, by 2023, migrant source countries were much more varied, and India and China ranked second and third.

As you can see in figure 3.25, the total numbers of overseas-born people in Australia remained relatively constant until the 1950s. From then, both the total numbers and the proportion of Australia's population that was overseas-born began to increase. The rapid increase in the proportion in the 1950s and 1960s, and again since 2000 was largely a result of Australia's migration policies.

FIGURE 3.25 Population change in Australia, 1891–2023

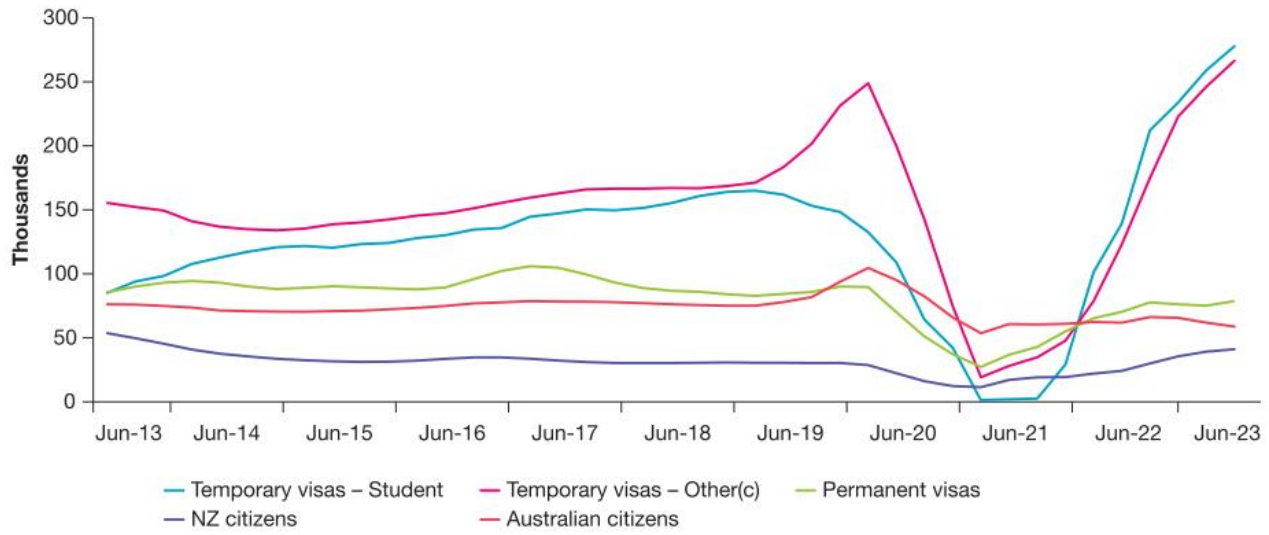


Australia has two main types of migrants: permanent and temporary. During the 1950s and 1960s, migration policies focused on permanent settlers to boost defence and economic growth. Over 2 million immigrants arrived between 1946 and 1966, helping to raise the population from 7.5 million to 11 million.

Since 2000, policies have shifted towards temporary migrants, particularly students. As shown in figure 3.26, from 2013 to 2023, the biggest migrant groups were students and those on temporary visas, such as skilled workers and working holiday-makers.

Economic factors have always influenced migration policies, but Australia also supports family reunification and humanitarian efforts. Key programs include accepting Indochinese refugees after the Vietnam War and, more recently, refugees from the Middle East and Ukraine. In 2023, humanitarian visas accounted for 9 per cent of permanent migrants, while family visas accounted for 32 per cent and skilled migrants 59 per cent.

FIGURE 3.26 Overseas migrant arrivals by visa and citizenship groups, 2013–23



Estimates from September quarter 2022 onwards are preliminary. See revision status on the methodology page.
Does not include unknown visas.
Temporary visas – Other, includes temporary skilled, working holiday-maker, visitor and bridging visas.

***Source*:** Australian Bureau of Statistics, Record high net overseas migration driven by temporary visa holders in 2022–23 15/12/2023

FIGURE 3.27 Migrants arrive in Australia post–World War II

FIGURE 3.28 Migrants working on the Snowy Mountains Scheme in the 1950s

3.4.6 Amenity

Amenity refers to the desirable features or facilities of places. According to the Australian Government's *State of the Environment* report, amenity includes access to shops, employment, health care, education, transport, cultural and leisure services, and green spaces. Environmental amenity includes the quality of environmental goods, such as clean air and water, which can improve residents' health and economic welfare.

amenity the desirable or useful features or facilities of places, including access to shops and other services required for daily living, employment, health care, educational services, transport, cultural and leisure services, and green spaces

push factors negative features of places that are responsible for people leaving

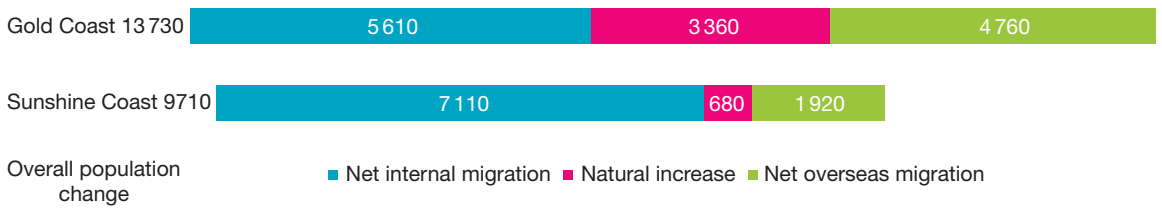
pull factors the positive features of places that are attractive to migrants; they draw people towards places

Amenity is crucial in migration decisions; high amenity areas attract migrants, while low amenity areas push people to leave. **Push factors** are negative aspects driving people away, while **pull factors** are positive features drawing them in.

Amenity is an important factor explaining the high levels of interstate migration to Queensland (refer to figure 3.8). Most migrants to Queensland, whether from interstate or overseas, settle in south-east Queensland, with the Gold and Sunshine coasts the second and third most popular destinations for all migrants after metropolitan Brisbane. Figure 3.29 shows that the largest component of population growth in both the Gold and Sunshine coasts in 2021–22 was net internal migration, providing 40 per cent of the growth for the Gold Coast and 73 per cent for the Sunshine Coast. This was followed by net overseas migration, with 34 per cent for the Gold Coast and 20 per cent for the Sunshine Coast. Natural increase played a smaller role in population growth, particularly for the Sunshine Coast.

Environmental amenity is an important pull factor for these coastal locations. Many Australians, especially older Australians, living in large cities are often attracted to coastal towns (sea-change migration), and to rural towns (tree-change migration), for work or retirement.

FIGURE 3.29 Components of population change, Gold and Sunshine coasts, 2021–22



SKILLS ACTIVITY: Analyse geographic data and information

Analyse and explain changes to Australia's population

1. Refer to figures 3.17 and 3.20.
   a. Explain why life expectancy gains in Australia levelled out, especially for males, in the period from the 1940s to the 1970s, before large gains in life expectancy were made from the 1970s.
   b. Based on what you know, identify possible links between the factors affecting overall population change in Australia by mind-mapping the interrelationships between factors.
2. Use table 3.5 to complete this question. Possible techniques to use for this task are scattergraphs and Spearman's rank correlation co-efficient.
   a. Choose a graphical or mathematical technique for examining the connection between changes in female workforce participation rates, birth rates and fertility rates over the period 1960–2023, and then draw the graphs or complete the calculations.
   b. Explain what your chosen technique shows about the connection between female workforce participation rates and birth and fertility rates.

Research and explain push and pull factors

3. The Australian Government's migration policies, especially regarding the number of migrants accepted, often change year to year. Research the government's current migration policies, including the main components of the migration program and the numbers of people accepted or planned for under the program.

3.4 Exercise

learnon

3.4 Exercise

Learning pathways

LEVEL 1	LEVEL 2	LEVEL 3
1, 4	2, 5	3, 6

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Explain and comprehend

1. Refer to the list of social, economic and cultural factors that affect changes in birth rates in Australia over time. Select one economic, one social and one cultural factor, and **explain** how each has had an impact on changes to Australia's birth rate.
2. **Explain** the connection between female workforce participation rates and birth and fertility rates.
3. **Explain** the role of overseas migration in changes to Australia's population over time.
4. **Identify** two migration policies between 1950 and 2021 and **explain** the role of each in changes to Australia's population.
5. **Identify** pull factors responsible for interstate migration to Queensland. **Suggest** possible push factors for the places from which migrants come.

Propose and communicate

6. **Propose** ways in which Australia could increase its birth and fertility rates, if the country decided this was needed to reverse declining rates of natural increase.

Sample responses for this chapter are available online.

LESSON
3.5 Finding and analysing data on population patterns and trends

LEARNING INTENTION

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

- analyse primary data (ABS census data) relating to each of the key demographic concepts (birth, death and fertility rates, life expectancy, age/sex structure, and migration rates) to identify population patterns and trends in Australia
- recognise and represent the population patterns and trends in each key demographic concept for Australia, using spatial technologies and information and communication technologies.

3.5.1 Population patterns and trends

As you have completed the previous lessons and their activities and exercises, you have been asked to analyse data and to recognise population patterns and trends for each of the key demographic concepts. For example, figures 3.1, 3.2, 3.4, 3.9 and 3.16 illustrated patterns and trends in birth, death and fertility rates, figure 3.20 illustrated life expectancy patterns and trends, figures 3.5, 3.6 and 3.13 showed age/sex structures, and figures 3.14 and 3.26 illustrated migration patterns and trends. You have also been asked to represent patterns and trends for two of the key demographic concepts (task 4 in 3.3 skill activity).

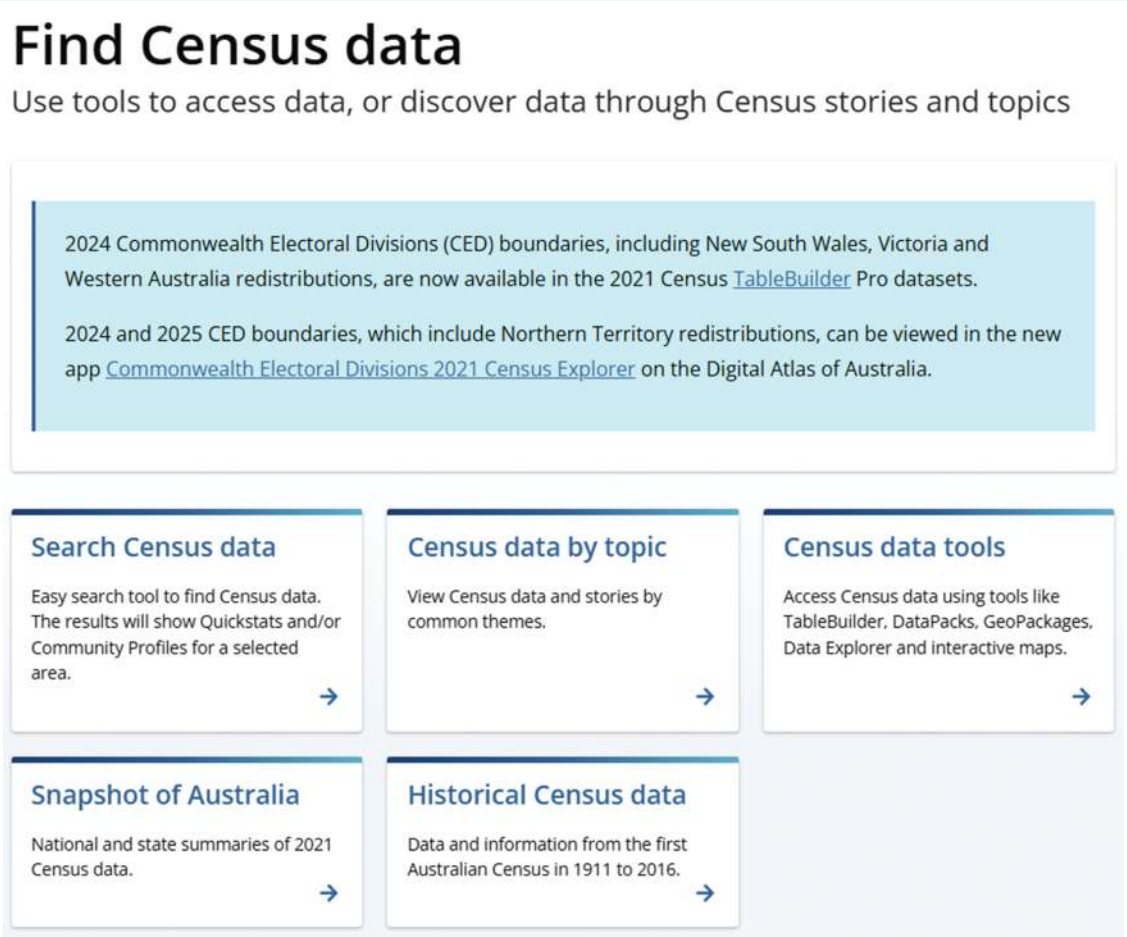
This lesson is designed to help you to locate primary data from the Australian Bureau of Statistics so you can continue to develop your ability to analyse primary data and recognise and represent population patterns and trends in Australia. It will assist you to locate data when you conduct your investigation of a specific geographic challenge arising from demographic or population change for a selected place in Australia at a local scale and suitable population size.

3.5.2 Finding primary data — ABS census data

The Australian Bureau of Statistics (ABS) is Australia's national statistical agency. It is an official source of information on Australia's demography as well as a range of other topics, including the economy, labour force, industry, health and the environment. The ABS conducts a census of Australia's population every five years, during which data is collected on such things as age, sex, marital status, family composition, level of education, country of birth, occupation and income.

The most recent census occurred in 2021. Data from this census, as well as censuses from 1911 to 2016, can be found on the ABS website. Census data can be found for a variety of places based on size, ranging from suburbs, urban centres and localities to significant urban areas. You can also find data for each state and territory, as well as for Australia as a whole.

FIGURE 3.30 Census data is available through the Australian Bureau of Statistics website. The website organises the data for ease of use.



The QuickStats functionality in the ABS website also provides data for various statistical areas, including medium-sized communities (SA2s), regional areas (SA3s), and labour markets or capital cities (SA4s). The ABS descriptions of these areas are as follows:

- Statistical Areas Level 2 (SA2s): Medium-sized, general-purpose areas built to represent communities that interact together socially and economically. Most SA2s have a population range of 3000 to 25 000 people.
- Statistical Areas Level 3 (SA3s): Designed for the output of regional data. Most SA3s have populations of between 30 000 and 130 000 people.
- Statistical Areas Level 4 (SA4s): Designed for the output of a variety of regional data, these areas represent labour markets and the functional area of Australian capital cities. Most SA4s have a population of over 100 000 people.

This breakdown allows you to search specific geographical areas based on the following:

- local government area
- state electoral division
- urban centre and locality
- significant urban area.

FIGURE 3.31 ABS 2021 Census QuickStats Australia provides 'local' area-based data.

People	**25,422,788**
Male	49.3%
Female	50.7%
Median age	38
Families	**6,730,187**
Average number of children per family	
for families with children	1.8
for all households (a)	0.7
All private dwellings	**10,852,208**
Average number of people per household	2.5
Median weekly household income	$1,746
Median monthly mortgage repayments	$1,863
Median weekly rent (b)	$375
Average number of motor vehicles per dwelling	1.8

(a) This label has been updated to more accurately reflect the Census concept shown in this data item. The data has not changed.
(b) For 2021, median weekly rent calculations exclude dwellings being occupied rent-free.

3.5.3 Population patterns and trends data

As outlined in previous lessons, you can use data provided by the ABS to analyse, recognise and represent population patterns and trends for each of the key demographic concepts.

Data for the concepts can be found in the 'Population' section of the ABS website. The information in figure 3.32 has been extracted from the website, and provides an introductory summary of patterns and trends for each aspect for the years identified.

FIGURE 3.32 Summary of population patterns and trends in Australia, based on ABS data

Births, Australia

- In 2023, 286 998 births were registered, a decrease of 4.6 per cent from 2022.
- For all Australian women, the total fertility rate was 1.50 births per woman.
- For Aboriginal and/or Torres Strait Islander women, the total fertility rate was 2.17 births per woman.

Deaths, Australia

- In 2023, 183 131 deaths were registered, a decrease of 7 808 since 2022.
- The standardised death rate decreased to 5.1 deaths, from 5.5 in 2022.
- Infant deaths decreased by 47 deaths to 911.

Life expectancy

- Life expectancy at birth was 81.2 years for males and 85.3 years for females in 2020–22, a decrease of 0.1 years for both from the previous year (2019–21).
- Life expectancy was highest in the Australian Capital Territory for both males (82.2 years) and females (86.0 years).
- Life expectancy was lowest in the Northern Territory for both males (76.2 years) and females (80.7 years).

Regional population by age and sex

- The median age for capital cities (37.0 years) was younger than the rest of Australia (41.9).
- The youngest capital was Darwin with a median age of 34.6 years, while Adelaide was the oldest (39.2).
- Darwin was the only capital with more males than females.

Migration, Australia

For the year ending 30 June 2020:

- Over 7.6 million migrants were living in Australia.
- 29.8 per cent of Australia's population were born overseas.
- Australia's population increased by 194 400 people due to net overseas migration.
- 368 700 people moved interstate, a decrease of 8.7 per cent from the previous year.

3.5.4 Representing population patterns and trends for infant mortality rates

To complement the lessons already completed, this section of the text illustrates ways in which spatial, and information and communication technologies can be used to represent demographic data. In this case, the demographic concept of **infant mortality** rates will be used, rather than one of the concepts already covered in this chapter. Infant mortality refers to the number of babies who die before one year of age per 1000 births. Table 3.6 provides ABS data for infant mortality rates between 2014 and 2023 in Australia and each state and territory. Because the infant mortality rates provided on the table have changed over a period of time, the correct graphic representation for the data is a multiple line graph. A graph representing the data, as shown in figure 3.33, can be created using the graphing tool in Excel. (Using Excel's graphing tools will be covered in more detail in lesson 3.8.)

infant mortality the number of babies who die before one year of age per 1000 births

TABLE 3.6 Infant mortality rates for Australia, and states and territories, 2014–23

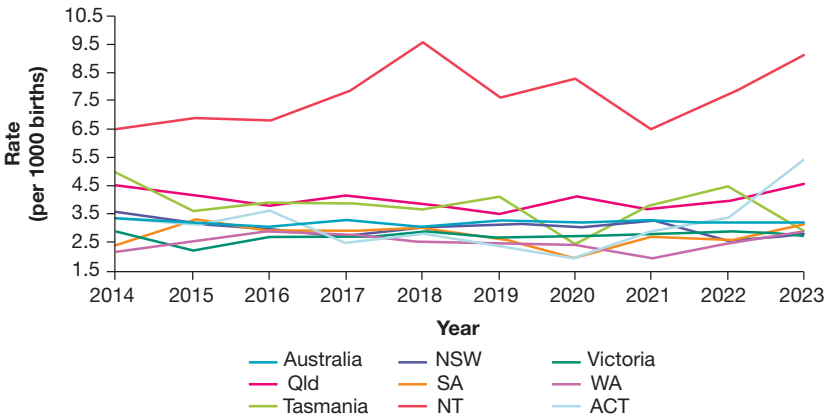
Year	Australia	New South Wales	Victoria	Queensland	South Australia	Western Australia	Tasmania	Northern Territory	Australian Capital Territory
2014	3.4	3.62	2.90	4.55	2.43	2.23	4.98	6.52	3.39
2015	3.2	3.27	2.26	4.22	3.31	2.56	3.65	6.93	3.18
2016	3.1	2.98	2.70	3.81	2.91	2.93	3.92	6.87	3.68
2017	3.3	2.75	2.71	4.18	2.93	2.80	3.94	7.87	2.50
2018	3.1	3.04	2.91	3.95	3.06	2.53	3.71	9.56	2.80
2019	3.3	3.23	2.70	3.56	2.64	2.50	4.15	7.62	2.43

(continued)

TABLE 3.6 Infant mortality rates for Australia, and states and territories, 2014–23 *(continued)*

Year	Australia	New South Wales	Victoria	Queensland	South Australia	Western Australia	Tasmania	Northern Territory	Australian Capital Territory
2020	3.2	3.04	2.77	4.16	1.97	2.42	2.49	8.29	2.01
2021	3.3	3.24	2.85	3.72	2.72	2.00	3.83	6.55	2.92
2022	3.2	2.62	2.92	4.00	2.58	2.48	4.46	7.78	3.40
2023	3.2	2.81	2.78	4.61	3.17	2.92	2.92	9.15	5.51

FIGURE 3.33 Infant mortality rates, 2014–23

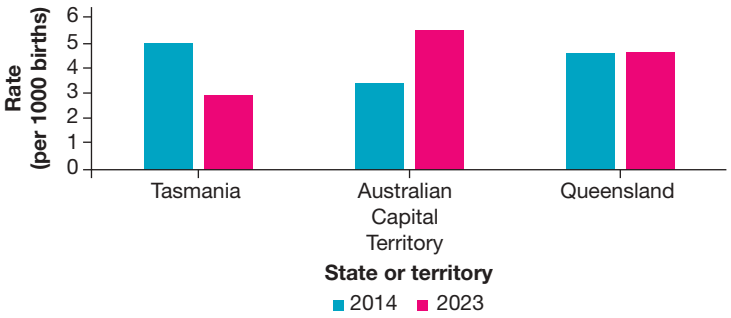


Data source: ABS

If instead you were representing the data for only the most recent year, you should use a bar graph, as shown on figure 3.34(a). Figure 3.34(b) shows an alternative version, with the states and territories still represented by bars, but data for Australia represented by a line on the graph. You might also want to represent and analyse the change in infant mortality rates between 2014 and 2023. Figure 3.35 shows this change for three contrasting places.

FIGURE 3.34 Infant mortality rates for Australia and states and territories, 2023

FIGURE 3.35 Infant mortality rates, Tasmania, Australian Capital Territory and Queensland, 2014 and 2023



The data for a particular year can also be represented using spatial technology. A choropleth map, as shown in figure 3.36, is one way of doing this. Choropleth maps can be created using a variety of technologies and tools, and allow data to be visualised spatially by shading regions based on specific values, such as population density, income or fertility rates. Figure 3.37 illustrates another way of representing the data, in this case using proportional bar graphs.

FIGURE 3.36 A choropleth map showing mortality rate per 1000 births, Australian states and territories

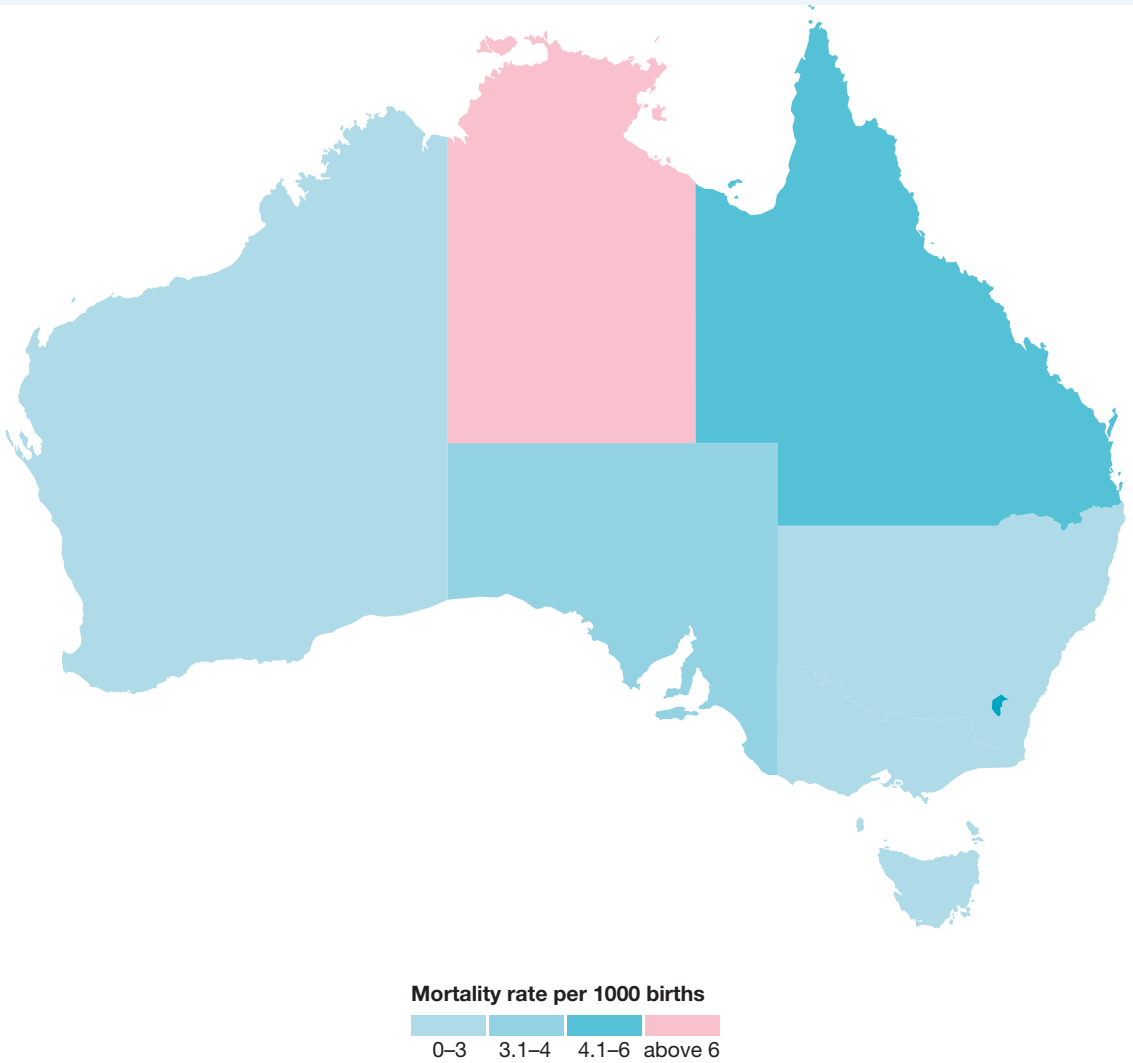
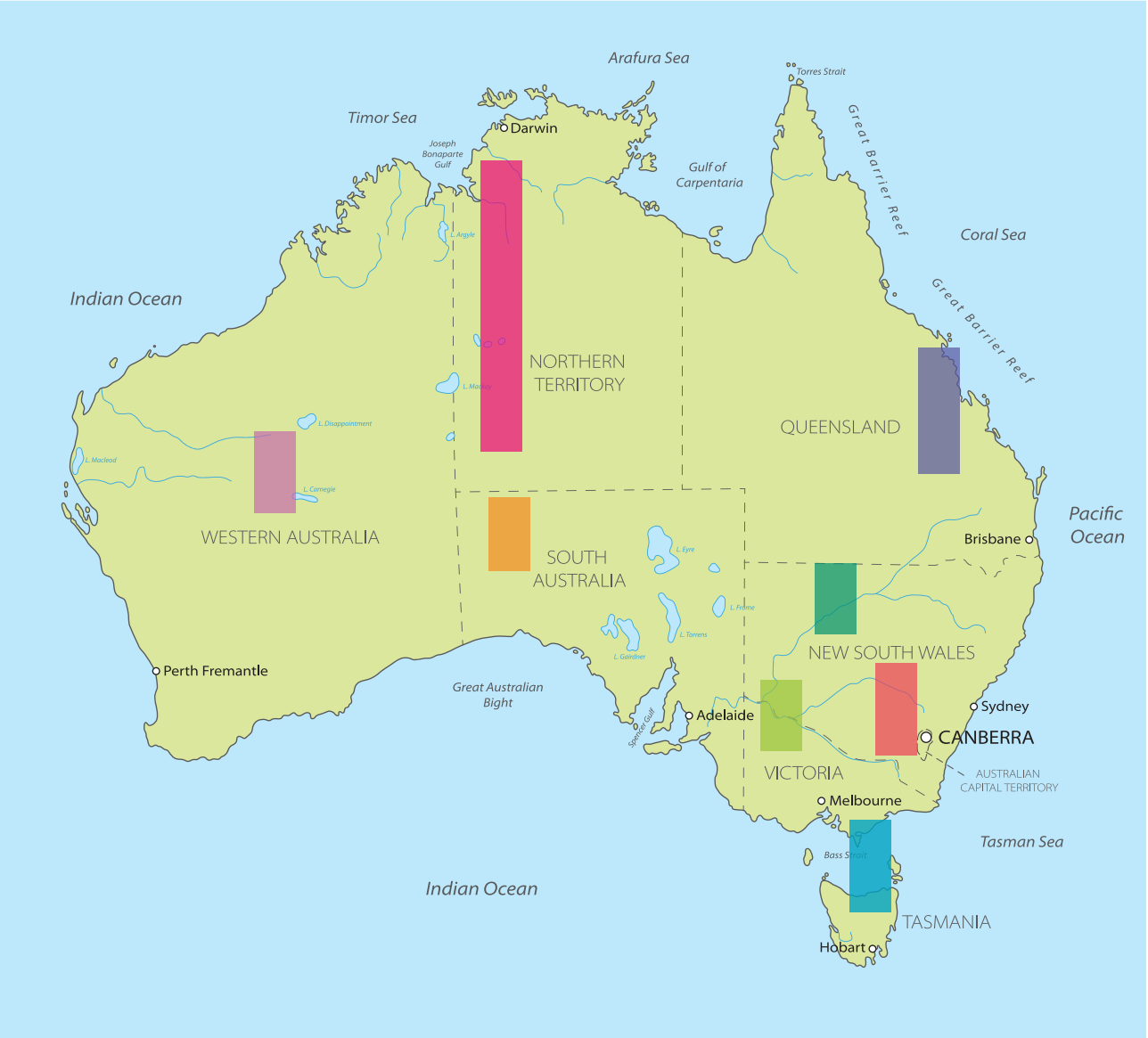


FIGURE 3.37 Mortality rates per state and territory for Australia, shown as proportional bar graphs



SKILLS ACTIVITY: Acquire and represent geographic data and information

1. Use information and communication technologies (e.g. Excel) to represent the ABS data for birth rates and total fertility rates between 1960 and 2023 provided in table 3.5.
2. Use spatial technologies and information and communication technologies to represent the data gathered to complete task 4 in the following 3.5 Exercise questions. Refer to figures 3.33 to 3.37 for example ways in which you might represent the data.

Note: lesson 3.8 outlines how to create a population pyramid to represent age/sex data. You may want to work through lesson 3.8 as part of this lesson.

3.5 Exercise

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3.5 Exercise

Learning pathways

LEVEL 1	LEVEL 2	LEVEL 3
1, 3	2, 4, 5	6

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Explain and comprehend

1. **Explain** the role of the Australian Bureau of Statistics in the collection and provision of population and demographic data in Australia.
2. **Explain** the difference between the statistical areas used by the ABS to provide census data.

Analyse and apply

3. **Analyse** the primary ABS data provided in table 3.5 relating to the demographic concepts of birth and fertility rates, and identify patterns and trends in Australia for these concepts.
   (Refer to the graph you created for task 1 in the skills activity for this lesson to assist with answering this question.)
4. Select one or more of the remaining demographic concepts and use the ABS website to find data similar to that shown in table 3.6 for infant mortality rates. Create a table to present the data.
5. **Analyse** the data in the table relating to your chosen demographic concept(s) from question 4, and identify patterns and trends in Australia for the concept(s).

Propose and communicate

6. **Evaluate** the effectiveness of the Australian Bureau of Statistics (ABS) census data in identifying and representing population patterns and trends for key demographic concepts such as birth, death and fertility rates, life expectancy, age/sex structure, and migration rates.

Sample responses for this chapter are available online.

LESSON
3.6 Implications of demographic and population change

LEARNING INTENTION

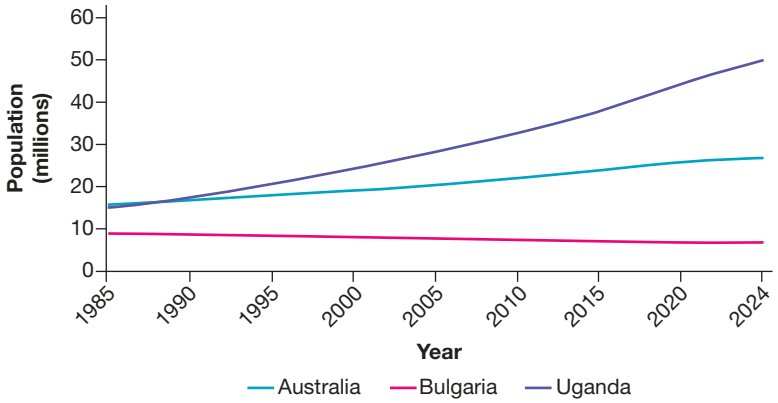
By the end of this lesson you should be able to explain the implications of demographic and population change (e.g. ageing population, youth population, declining population, rapid population growth, migration) for people and places.

3.6.1 Population and demographic change

Population change refers to the overall change in a population that may result in population decline or population increase. As figures 3.9, 3.14, 3.15 and 3.38 illustrate, Australia's population has increased over time because of both natural increase and overseas migration. In Queensland, population increase has also included interstate migration. In countries such as Bulgaria (see figure 3.38) and in some places in Australia (figure 3.42),

populations are declining. Other countries — for example, Uganda — and certain parts of Australia are also experiencing a much greater population increase than Australia as a whole (see figures 3.38, 3.39 and 3.40).

FIGURE 3.38 Population change, Australia, Bulgaria and Uganda, 1985–2024



Demographic change refers to changes in the composition of a population (e.g. age and sex), which result in change for a particular demographic group, such as older or youth populations. As figures 3.9 and 3.13 show, Australia's population has aged over time, while the proportion of the youth population has declined. Figure 3.6 shows that large variations to this overall pattern of change are seen in different places in Australia. Victor Harbor's population has aged over time, for example, while in Springfield Lakes the proportion of people in younger age groups has increased.

3.6.2 Implications of population and demographic change

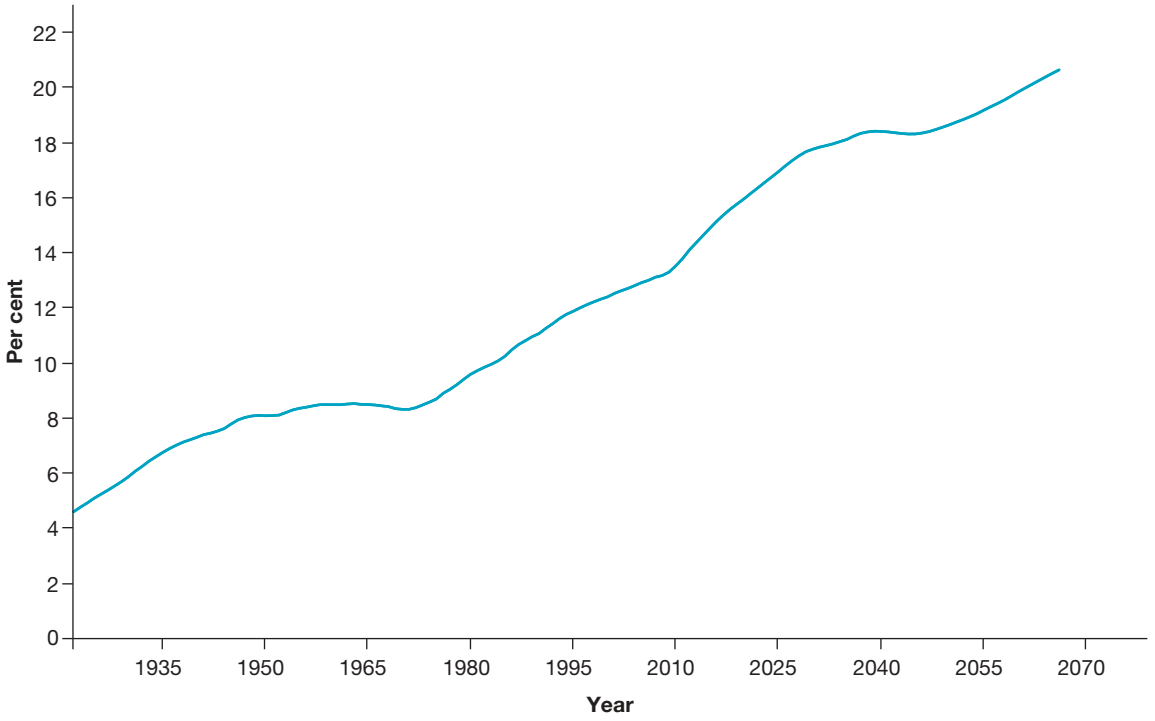
Population and demographic change can have both positive and negative implications for people and places. Social, economic, environmental and political benefits and costs of change exist for Australia and for particular places within Australia. For example, overseas migration helps fill workforce shortages, increases the number of skilled workers in Australia and increases government revenue. On the other hand, growth in migrant numbers may place pressure on housing and other infrastructure such as health care. The implications of different types of population and/or demographic change are covered further in this lesson, and lesson 3.7 provides examples of particular places in Australia experiencing challenges from these changes.

3.6.3 Ageing population

As figure 3.39 shows, not only has Australia's population grown older over time, other than during a period of higher migration from the 1950s to the 1970s, this ageing of the population is also expected to continue in future years. A positive implication of increased longevity in Australia is that older people now remain longer in the workforce, and thus continue to contribute to the economy. Between 2001 and 2021, workforce participation rates for people aged 65 years and above more than doubled, from 6.1 per cent to 15 per cent. For people aged 65 to 74 years, the workforce participation rate was over 20 per cent. The top areas of employment for older Australians — agriculture, general practice medical services, hospitals, aged care services and primary education — illustrate the contribution they make to Australian society. Older Australians may also provide unpaid childcare services, and often volunteer in community organisations.

On the other hand, as Australia's population ages, demand, of course, increases for health and aged care services. From around the late 70s in age, demand for retirement accommodation, aged care facilities, nursing homes and hospitals begins to increase. With the greater percentage of older Australians, this, in turn, means that demand for people who work in these areas also increases. Over time, more pressure will be placed on residential and aged care services, requiring more human and economic resources.

FIGURE 3.39 Percentage of the Australian population aged 65 years and above over time



Notes

1. Data for 1921 to 1970 are population estimates. Data from 1971 onwards are estimates of the resident population (ERP).
2. Population data from 1992 to 2011 are recast estimates following the rebasing of the 2011 Census. For more information, see the ABS explanatory notes.

3.6.4 Youth population

Although the proportion of people aged 15 to 24 years (the age groups used by the ABS to define youth population) will continue to fall over time in Australia, absolute numbers will increase (as shown in figure 3.40). The overall implications of this pattern are two-fold: relatively fewer younger people will be entering the workforce, while, at the same time, some places in Australia, particularly major cities, will continue to have large numbers of people in the youth age cohorts.

Around 75 per cent of people aged 15 to 24 live in major cities, another 16 per cent in inner regional areas, and fewer than 2 per cent in remote and very remote areas. This means that the implications of changes in youth population will vary according to location. More remote places (e.g. Charleville, in south-west Queensland) tend to have much a much lower proportion of the population in the youth age group, while some places in major cities (e.g. St Lucia, where the main campus for the University of Queensland is located) will have a much higher proportion (see figure 3.41). For places with low youth populations, social and economic implications include fewer workers for service industries and fewer sporting teams. Places with high youth population see increased demand for affordable accommodation, education services, and recreational and social activities.

FIGURE 3.40 Australian population aged 15 to 24 over time

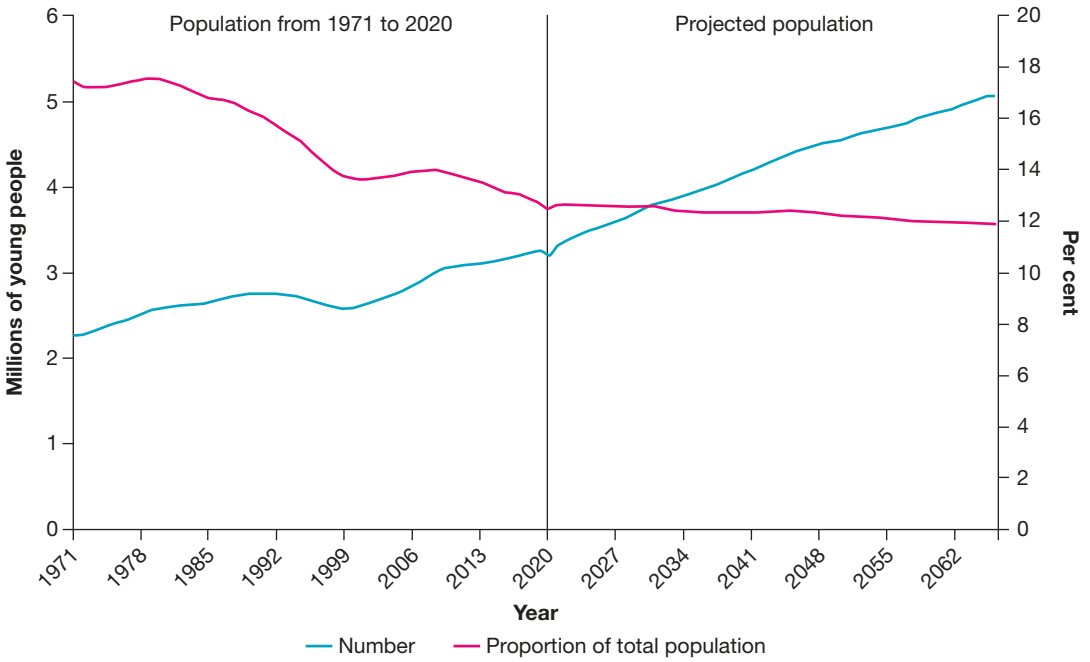
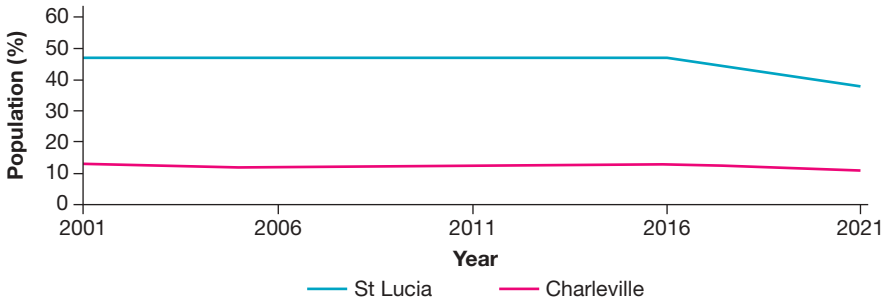


FIGURE 3.41 Youth population, St Lucia and Charleville, 2001–21 (as percentage of total population)

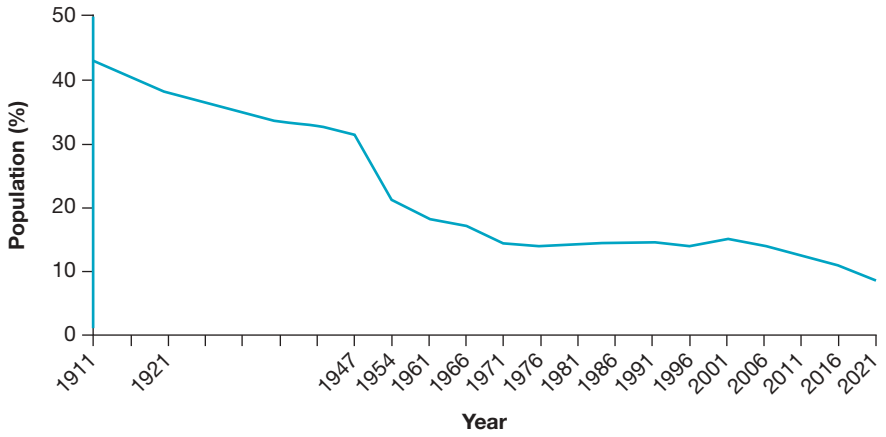


3.6.5 Declining population

As agricultural practices in Australia have changed over time, demand for farming and grazing labour has fallen. This has resulted in a long-term decline in Australia's rural population relative to the total population (see figure 3.42). One consequence of this change is that many places in inland Australia, especially small country towns, have experienced population decline over a long period of time. Figure 3.43 provides examples of such places, and figure 3.44 shows the location of Local Government Areas in which the population declined between 2022 and 2023.

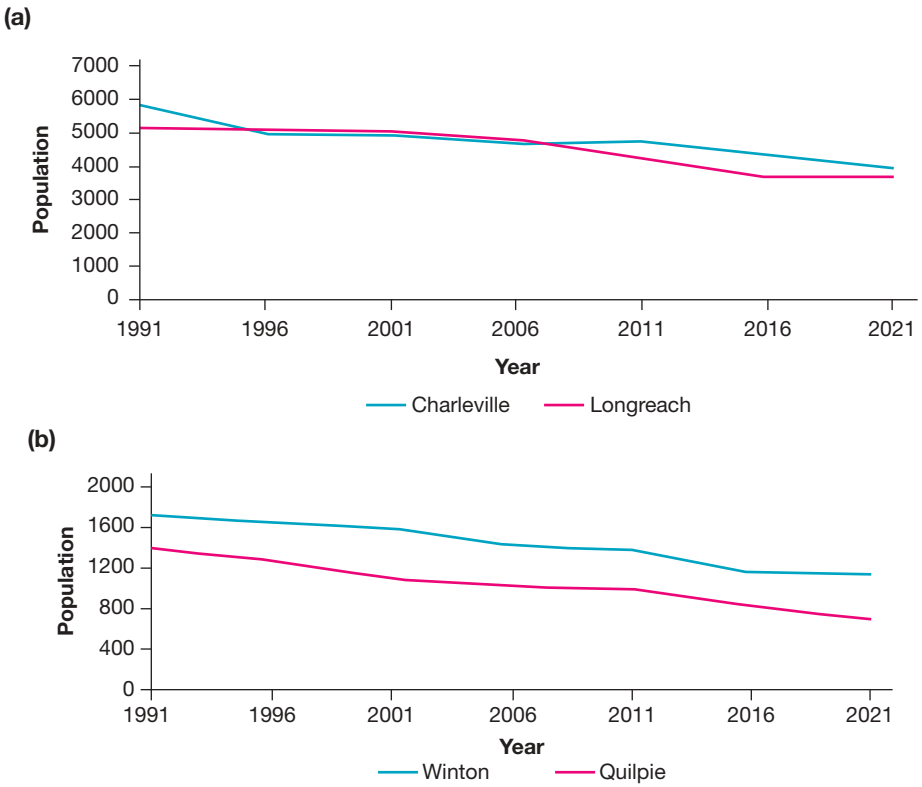
Implications of this population decline include ageing, and threats to community social and economic viability. People living in places with declining populations risk losing their livelihood and support systems as they face loss of jobs, deteriorating infrastructure and declining property values. In addition, declining towns often lose services such as schools, hospitals, retail establishments and banks. There may also be environmental implications: reduced income and a declining workforce make environmental management more difficult for local governments.

FIGURE 3.42 Australia's rural population change, 1911–2021



Data source: ABS

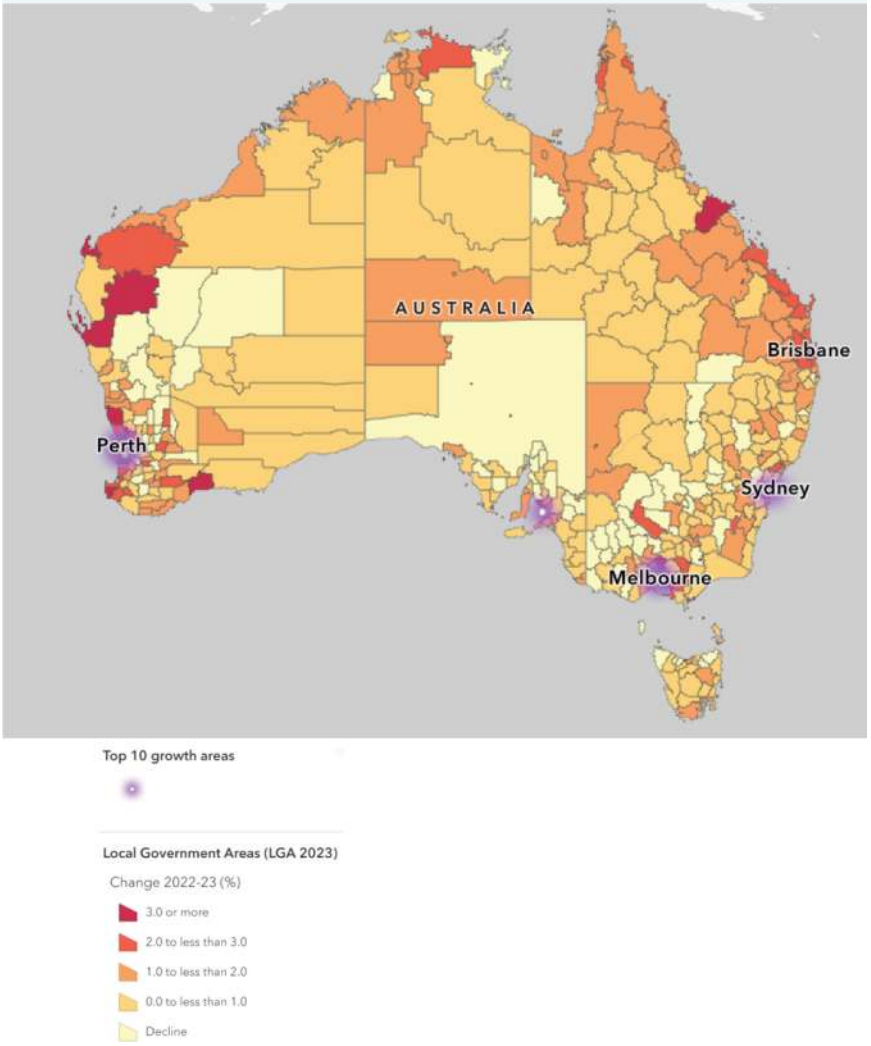
FIGURE 3.43 Population change in rural towns, 1991–2021, (a) Charleville and Longreach, and (b) Winton and Quilpie, 1991–2021



3.6.6 Rapid population growth

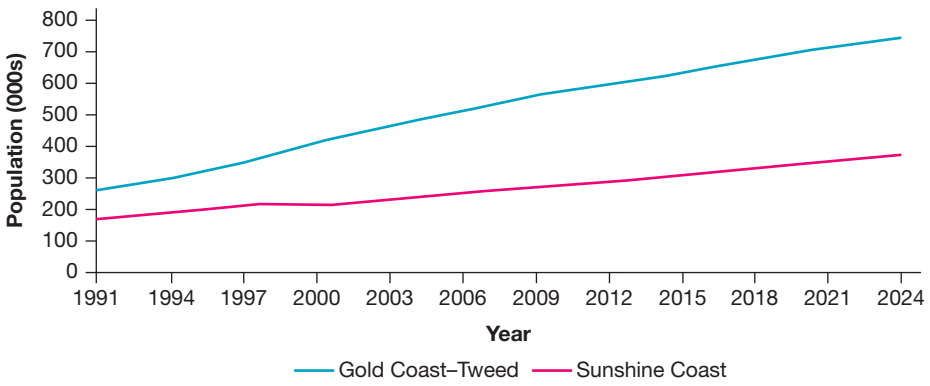
In contrast to rural and regional parts of Australia, many coastal areas and the fringes of capital cities are experiencing rapid population growth. The Gold and Sunshine coasts, for example, are among the fastest growing places in Australia (figure 3.45), as are some outer suburbs of the Brisbane metropolitan area. Caloundra West on the Sunshine Coast has one of the most rapidly growing populations in Australia.

FIGURE 3.44 Population change by percentage in Local Government Areas, 2022–23



In Australia, population change in places such as these is primarily occurring because of migration (see figure 3.47 and section 3.6.7), rather than natural increase. The Gold and Sunshine coasts have the highest net rates of internal migration of all regions in Australia.

FIGURE 3.45 Gold and Sunshine coasts population change, 1991–2024



Data source: ABS

Places experiencing rapid population growth face a variety of implications. As the population grows, demand for housing and basic infrastructure such as roads, electricity, telecommunications, water and sewage systems, and transport networks also increases. Demand also increases for health, education, retail and recreational services. State schools, as well as other services and infrastructure, are often provided by governments, so economic costs are associated with rapid population growth.

Rapid population growth may also have environmental implications. Because many of Australia's most rapidly growing places are located on the fringes of large cities, previously forested areas often need to be cleared. As seen in figure 3.46, some parts of the rapidly growing Ripley area west of Ipswich are expanding into previously uncleared greenfield sites.

FIGURE 3.46 Suburban population change for various areas, 2001–21, (a) Caloundra West, (b) North Lakes–Mango Hill and (c) Springfield Lakes

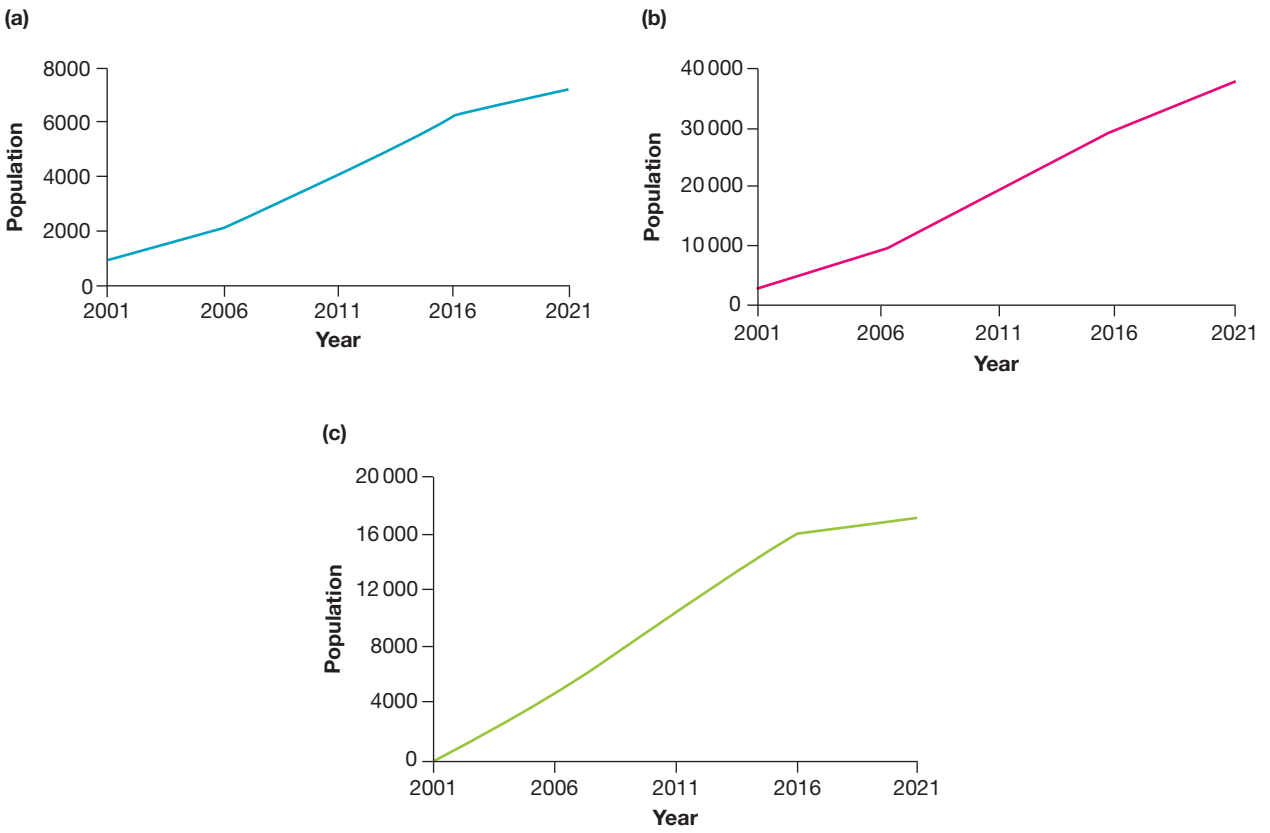


FIGURE 3.47 Sunshine Coast arrivals, departures and net internal migration five years prior to the census, 2011, 2016, 2021

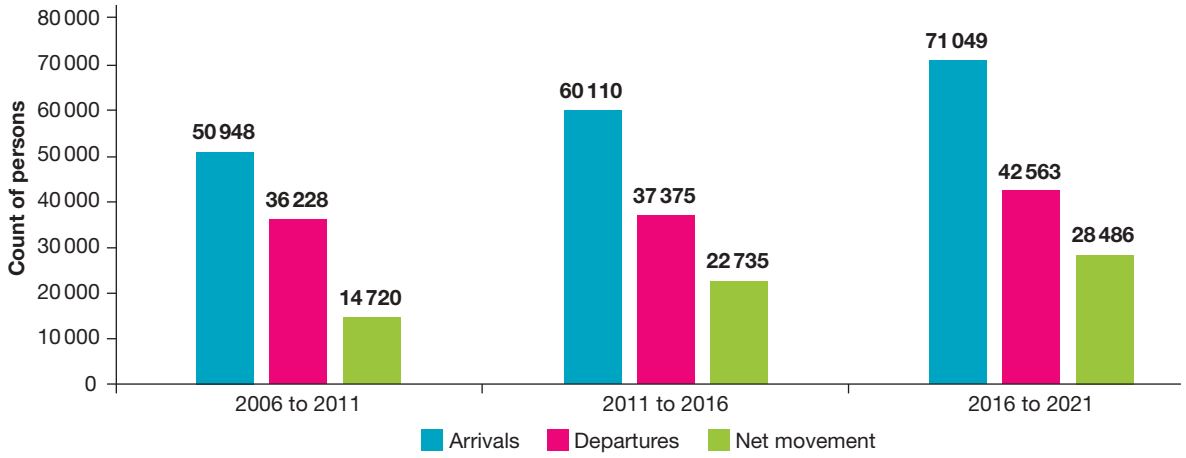


FIGURE 3.48 Urban growth in Ripley, Ipswich

3.6.7 Migration

Migration causes both population and demographic change. As figure 3.25 shows, overseas migration has contributed to population growth in Australia over a long period of time. Since 1945, more than 8 million people have migrated to Australia. Because migrants are predominantly from younger age cohorts, migration has kept Australia's population younger than it would otherwise be. In addition to this (and the implications of overseas

migration referred to in section 3.6.2), another important demographic change to Australia's population through migration is illustrated by figures 3.49 and 3.50. From the 1950s, the proportion of migrants from Southern and Eastern Europe increased significantly, and changed the ethnic composition of Australia's population. Ethnic diversity changed further from the 1980s, as migration from Asia began to increase.

FIGURE 3.49 European-born overseas population, 1901–2021

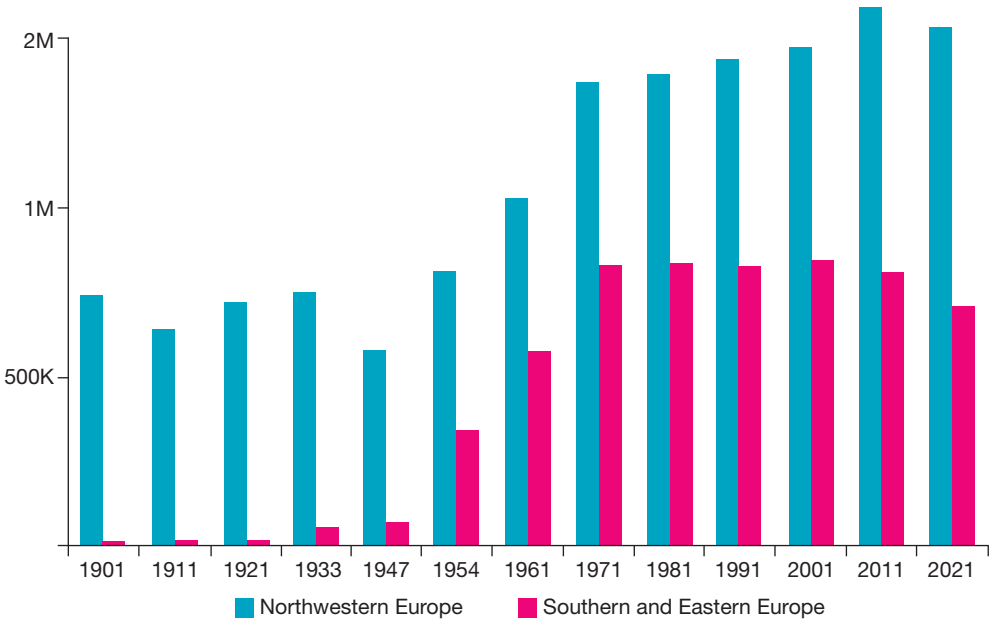
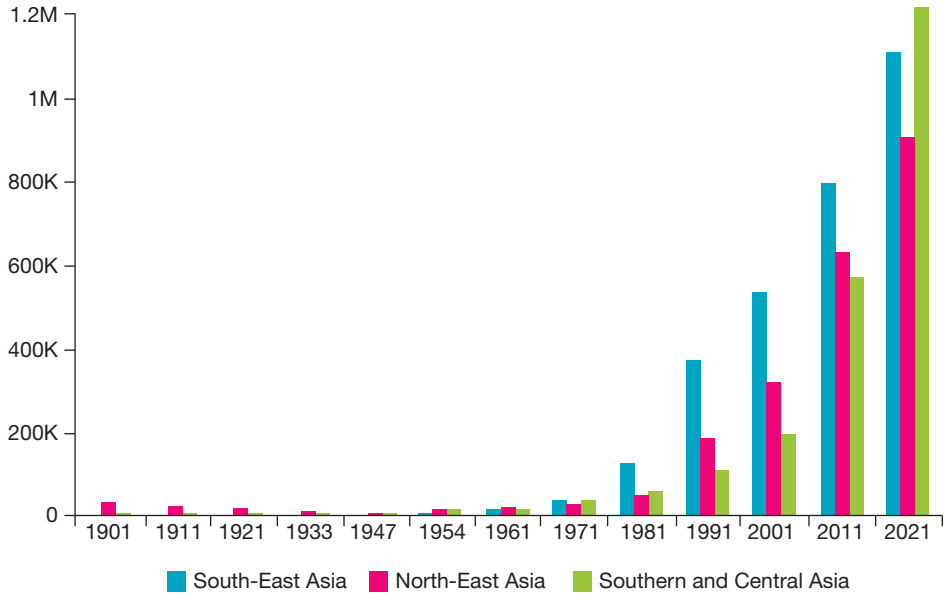


FIGURE 3.50 Asian-born overseas population, 1901–2021

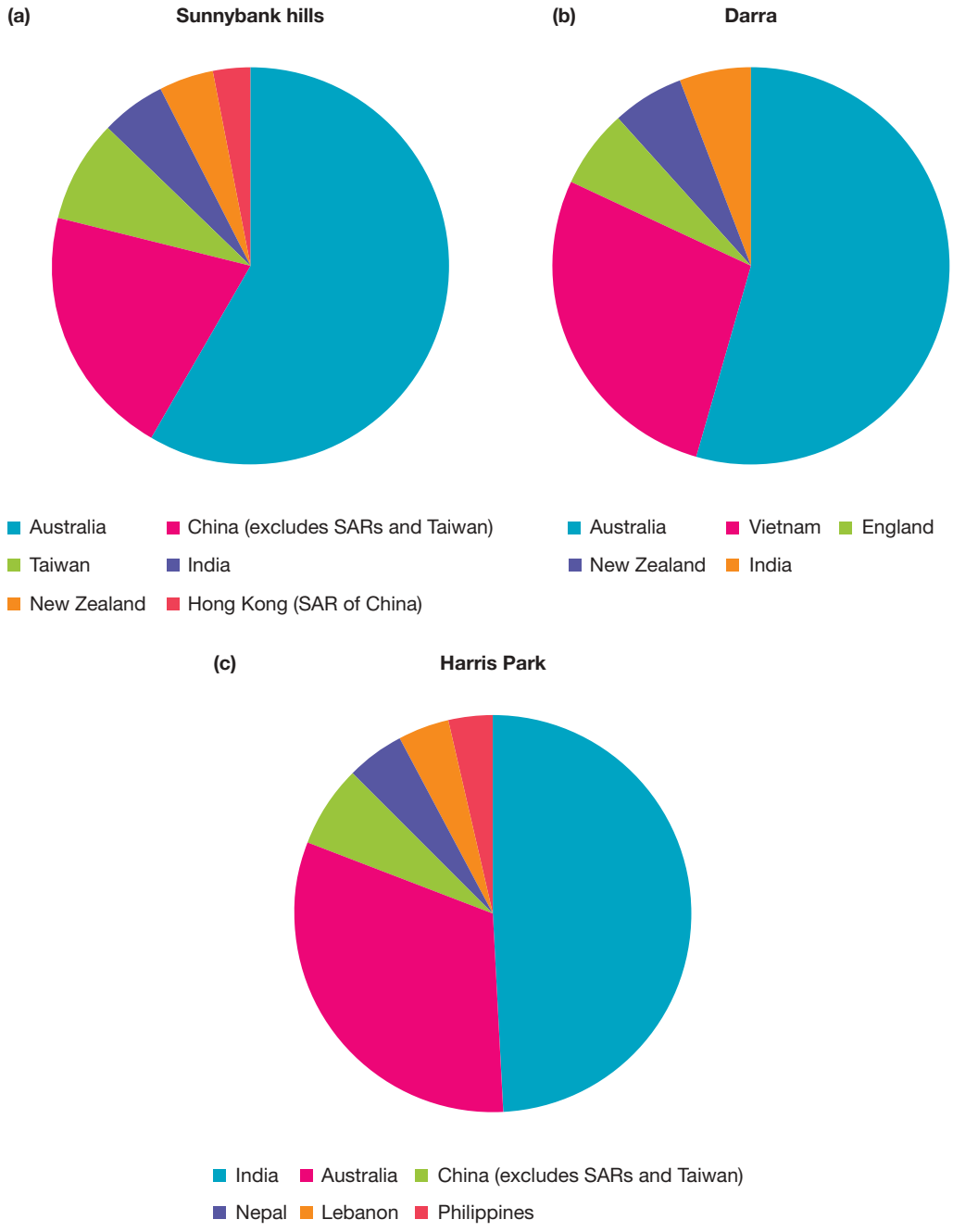


Migration has had an impact on the demographic composition of particular places in Australia. Figures from the Australian Bureau of Statistics (ABS) show that in Harris Park in Sydney, overseas migrants from India and Nepal made up over half the suburb's population in 2021. In Sunnybank Hills in Brisbane, Chinese and Taiwanese migrants represented around 21 per cent of the population, while in Darra, Vietnamese migrants

were the largest portion of overseas-born people. In comparison to these metropolitan suburbs, in some rural and regional parts of Australia, over 90 per cent of the population are Australian-born.

While the clustering of migrants from some countries in particular locations might lead to lower levels of engagement with Australian society, ghettoisation has not been an implication of Australia's migration policies. Permanent migrants have tended to disperse from their original places of settlement within a generation. The cultural diversity, as well as the skills and increased income resulting from migration, has largely been a positive for Australian society.

FIGURE 3.51 Top responses for country of birth in selected suburbs, 2021, (a) Sunnybank Hills, (b) Darra and (c) Harris Park



SKILLS ACTIVITY: Acquire and represent geographic data and information

This lesson has outlined some of the demographic features of and the challenges faced by several places in Queensland. This activity provides you with an opportunity to practise some of the skills needed for your geographic inquiry and data report assessment task.

1. Choose a location in Queensland to complete the following tasks.
   a. Describe the demographic characteristics of the selected place. You will most likely gather your information from the Australian Bureau of Statistics and other sources.
   b. Analyse the demographic data and describe the demographic challenges faced by the place. As part of your analysis, you should include some mathematical calculations (e.g. of the rate of population growth or decline and the dependency ratio). You should use spatial and information and communication technologies as part of your analysis of the data.
   c. Construct line or bar graphs or find data to use in constructing a catchment area map for one of the schools in the area that you have chosen. Google Maps or the ABS online mapping tool TableBuilder can be used for constructing maps.

3.6 Exercise

learnon

3.6 Exercise

Learning pathways

LEVEL 1	LEVEL 2	LEVEL 3
1, 4, 8, 11	2, 3, 5, 7, 9	6, 10, 12, 13

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Explain and comprehend

1. **Explain** the meaning of population change and demographic change.
2. **Explain** the causes of population change in Australia and places within Australia.
3. **Describe** changes over time in Australia's older population.
4. **Identify** two implications of an ageing population in Australia and places within Australia.
5. **Identify** two or three places in Australia that are experiencing population decline and rapid population increase.
6. **List** and **explain** two implications of population decline, and two implications of rapid population increase for places in Australia.
7. **Describe** the distribution of Australia's youth population.
8. **Explain** how Australia's youth population has changed over time.
9. **Identify** two implications of the distribution of and change over time in Australia's youth population.
10. **Explain** how overseas migration has caused changes in Australia's population and demography.
11. **Identify** two implications of changes over time in Australia's overseas migration.

Analyse and apply

12. Select any one of the places for which graphed population information has been provided in this lesson (e.g. Winton, Caloundra West or Springfield Lakes). **Analyse** the graph and **describe** the changes that have occurred over time in the population and demography of the place chosen.

Propose and communicate

13. **Identify** possible implications that the place chosen for question 12 may face because of population and demographic change, and **propose** actions to address the impact of any negative implications.

Sample responses for this chapter are available online.

LESSON
3.7 Geographic challenges arising from demographic and population change for places in Australia

LEARNING INTENTION

By the end of this lesson you should be able to investigate a specific geographic challenge arising from demographic or population change for a selected place in Australia at a local scale and suitable population size (e.g. a regional city, a suburb or a rural town).

3.7.1 Geographic challenges arising from demographic and population changes

Places that are experiencing ageing populations, rapid population increase or a declining population face different types of geographic challenges. For example, places with ageing populations may struggle to find enough aged and health care workers to assist older people, places where the population is growing rapidly may struggle to meet infrastructure demand, and places with a declining population can be challenged by closure of services. This lesson provides two case studies to assist with your geographic inquiry:

- regional town — Charleville, population decline
- suburb — Ripley South, rapid population growth.

3.7.2 Selected demographic features of Australia and Queensland

The purpose of this section is to provide you with some features of the Australian and Queensland populations so you can compare the population and demographic characteristics of your chosen inquiry place with those of Australia and/or Queensland. This may help you identify possible economic, social and environmental challenges faced by the place.

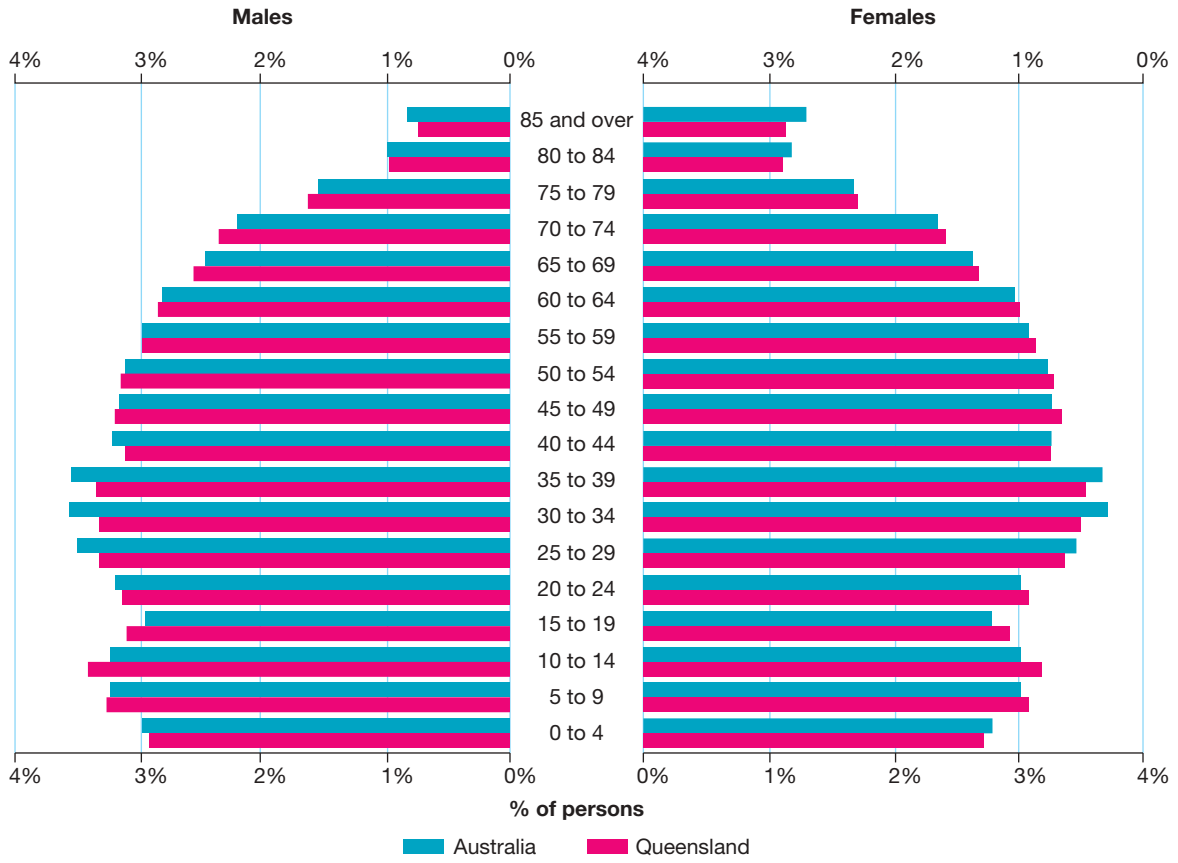
Table 3.7 and figure 3.52 indicate that the demographic features of Australia and Queensland in 2021 were generally similar. However, the features for Charleville have some differences. For instance, the median age in Charleville was 41, higher than that for Australia and Queensland of 35.

TABLE 3.7 Selected demographic features, Australia and Queensland, 2021

Demographic feature	Queensland	Australia
Median age (years)	35	35
Male population (%)	49.3	49.3
Female population (%)	50.7	50.7
Population 0–14 years (%)	18.7	18.2
Population 65 years and over (%)	17.0	17.2

Data source: ABS QuickStats

FIGURE 3.52 Australia and Queensland age/sex pyramid, 2021



CASE STUDY: Charleville — a regional town in population decline

Quick facts: Charleville

- **Population** 2551
- **Median age** 41 years
- **Male population** 46.8 per cent
- **Female population** 53.2 per cent
- **Population 0–14 years** 16.6 per cent
- **Population 65 years and over** 20.2 per cent

Charleville is the regional administrative and service centre of Murweh Shire in south-west Queensland. Over the 20 years between 2001 and 2021, Charleville's population declined by 27.2 per cent. Population decline brings with it a range of economic, social and environmental challenges for both the urban centre and locality (UCL) of Charleville, and Murweh Shire as a whole. Such challenges include:

- reduced income, lessening the local council's ability to provide services such as waste management, maintenance of local roads, control of weeds and feral animals, natural hazard response, and community engagement
- reduced employment and educational opportunities
- possible reduction in retail, health, aged care and other services.

FIGURE 3.53 Aerial view overlooking Charleville, Queensland in 2024

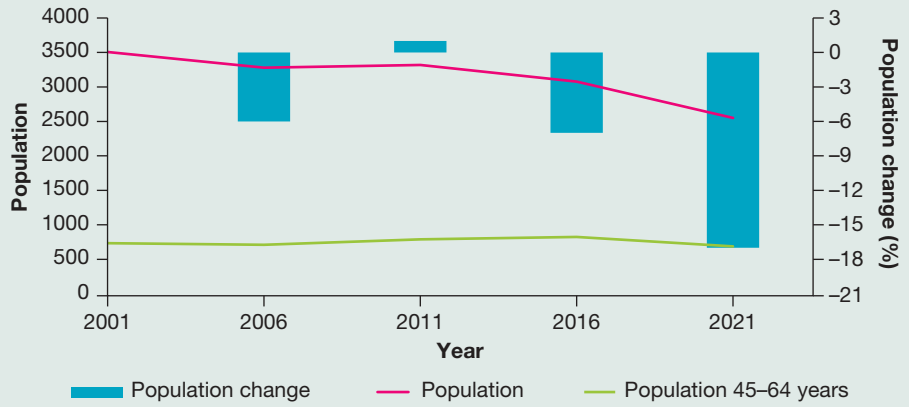
Changes in the age structure of the workforce illustrate one specific challenge for Charleville, as well as for the Murweh shire. Over ten years, the percentage of younger workers, those aged between 15 and 44 years, in Charleville declined by over 6 per cent, from 59.5 per cent in 2011 to 53.2 per cent in 2021. Murweh Shire as a whole has fewer younger workers than older workers. In 2021, 49.6 per cent of the workforce was aged between 15 and 44 years, and over half were aged 45 years and above. Table 3.8 and figure 3.54 show that the 45 to 64 years age group is also in decline in Charleville.

TABLE 3.8 Charleville population and demographic change, 2001–21

Year	Population	Population 45–64 years (total)	Population 45–64 years (%)
2001	3506	710	20.2
2006	3278	734	22.4
2011	3318	789	23.8
2016	3017	824	27.3
2021	2551	688	27.0

Data source: ABS QuickStats

FIGURE 3.54 Charleville population and demographic change, 2001–21



Data source: ABS QuickStats

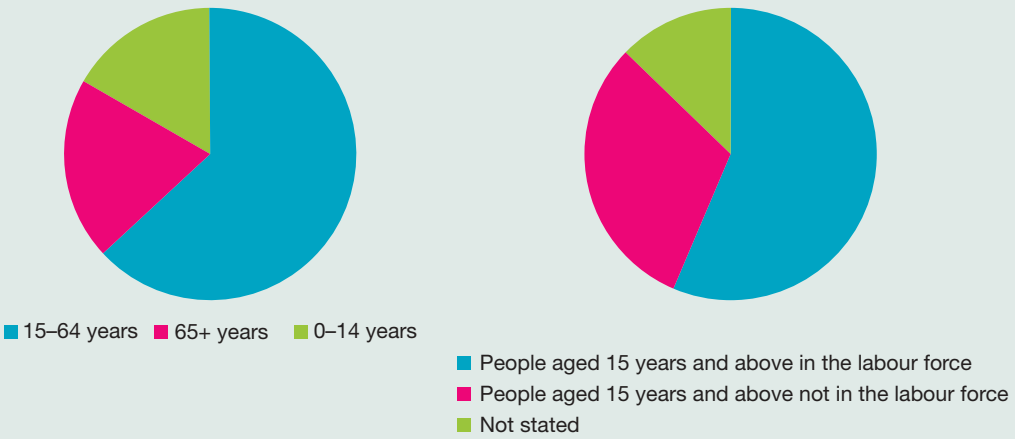
An ageing workforce may have a cumulative impact on the local community. As the workforce ages and retires, and it becomes increasingly difficult to attract and retain younger workers, businesses may be forced to close, leading to further population decline, and further reduction in services. At the same time, an older population will require more health and aged care facilities, and more workers in these sectors. Charleville and the Murweh Shire will need policies to attract workers to these industries.

The impact of Charleville's declining population is partly mitigated by the role the town plays as the major service centre for south-west regional Queensland. The town provides key retail, commercial and government services. This means that current critical health and educational services, such as the Charleville Hospital, Royal Flying Doctor Service and local schools, will continue to be funded by the governments and organisations responsible for these services. As figure 3.57 shows, because of the critical role Charleville's state high school plays in the region, it continues to maintain its enrolment numbers, even though numbers in the primary school are declining.

FIGURE 3.55 Charleville age/sex pyramid, 2021

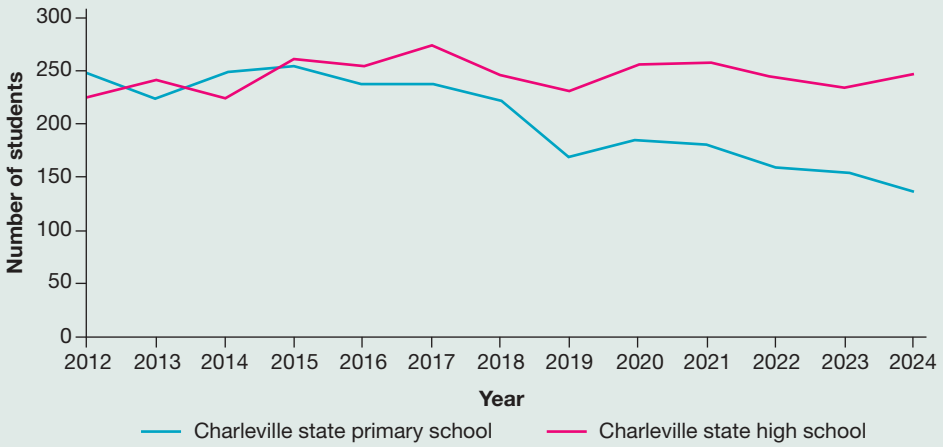
Data source: ABS community profile

FIGURE 3.56 Charleville demographic characteristics, 2021



Data source: ABS QuickStats

FIGURE 3.57 Charleville school enrolment numbers, 2012–24



Data source: School annual reports

CASE STUDY: South Ripley and rapid population growth

Quick facts: South Ripley

- **Population** 4069
- **Median age** 27 years
- **Male population** 48.1 per cent
- **Female population** 51.9 per cent
- **Population 0–14 years** 31.3 per cent
- **Population 65 years and over** 2.7 per cent

South Ripley is located approximately 10 kilometres southeast of central Ipswich and 30 kilometres southwest of the Brisbane CBD. The suburb is an example of a rapidly growing area on the urban fringe of Australia's metropolitan areas — in this case, the greater metropolitan area of Brisbane. Over the ten-year period between 2011 and 2021, South Ripley's population increased by more than 1000 per cent (see table 3.9 and figure 3.58).

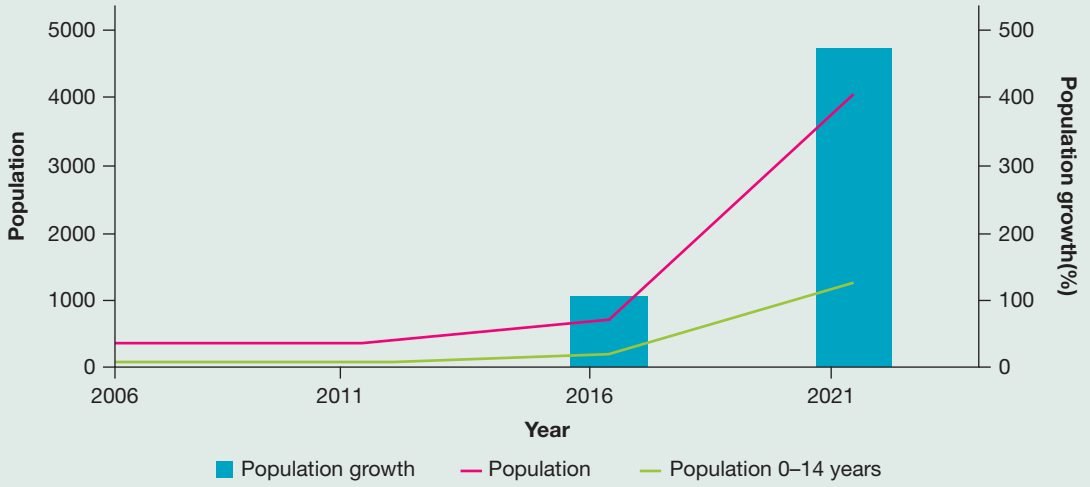
TABLE 3.9 South Ripley population and demographic change, 2006–21

Year	Population	Population, 0–14 years
2006	349	91
2011	344	76
2016	712	198
2021	4069	1266

Rapid population increase brings with it a range of economic, social and environmental challenges, including in the following areas:

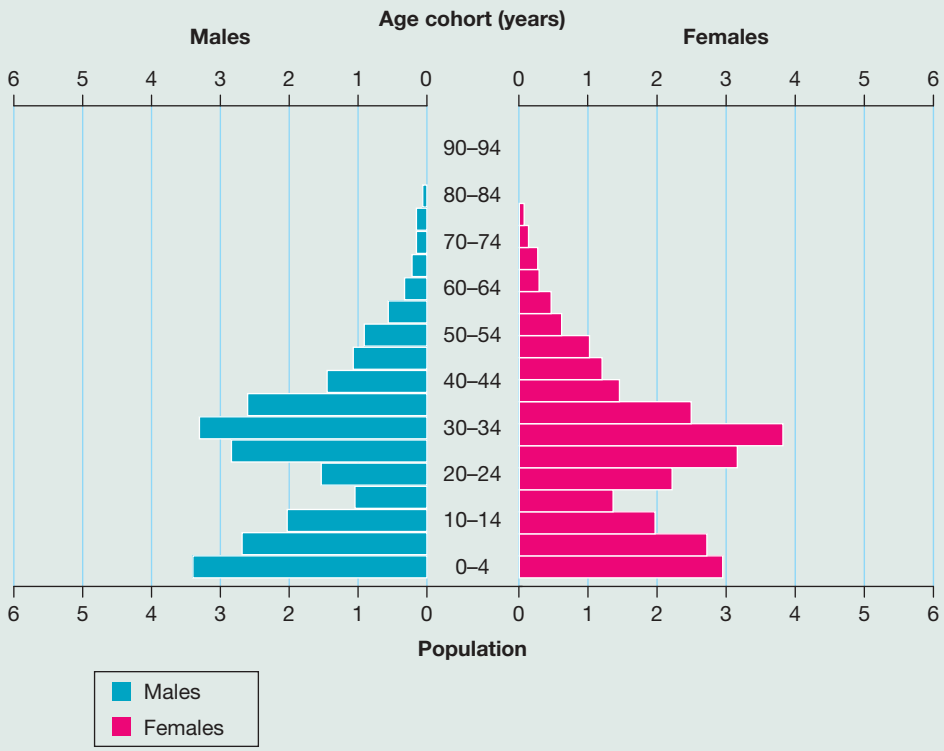
- the provision of transport, water, sewage and waste disposal infrastructure
- pressure on schools, childcare and recreational facilities
- maintaining the integrity of important environmental assets, such as waterways.

FIGURE 3.58 South Ripley population and demographic change, 2006–21



The rapid increase in numbers of school-aged children in South Ripley represents a specific challenge for the suburb. Student enrolments at South Ripley's two government schools reflect the impact of this increase. Between 2020 (when the schools were established) and 2024, the percentage of student enrolments in Ripley Valley State School increased by 123 per cent, and in Ripley Valley State Secondary College by 582 per cent. Such rapid growth in student numbers required the construction of additional facilities at each of the new schools. In addition, as student enrolment grew each year, increasing numbers of teachers and other staff needed to be employed.

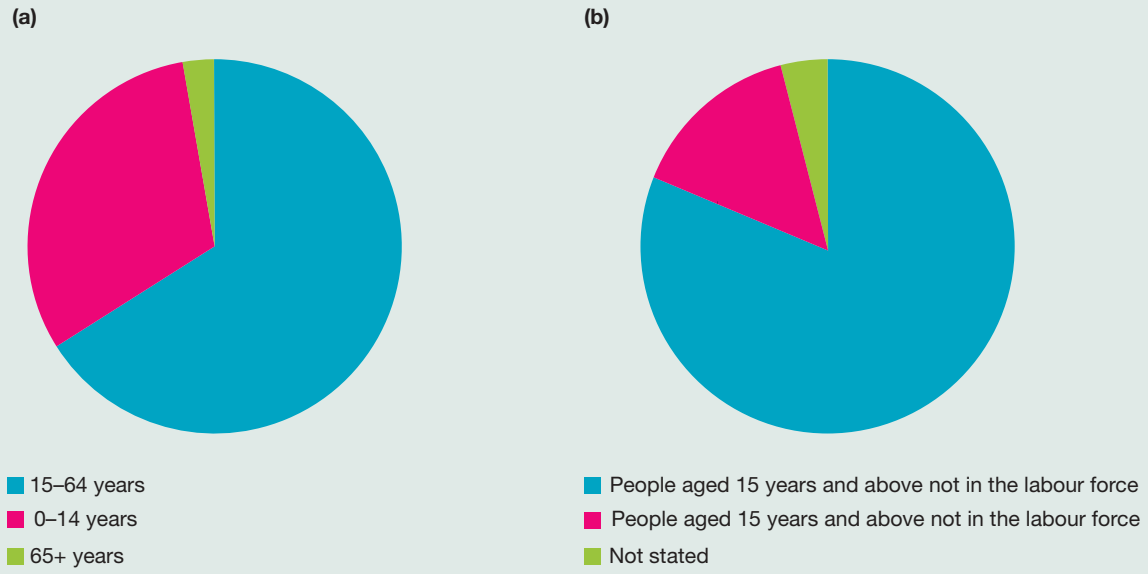
FIGURE 3.59 South Ripley age/sex pyramid, 2021



Data source: ABS Community profile

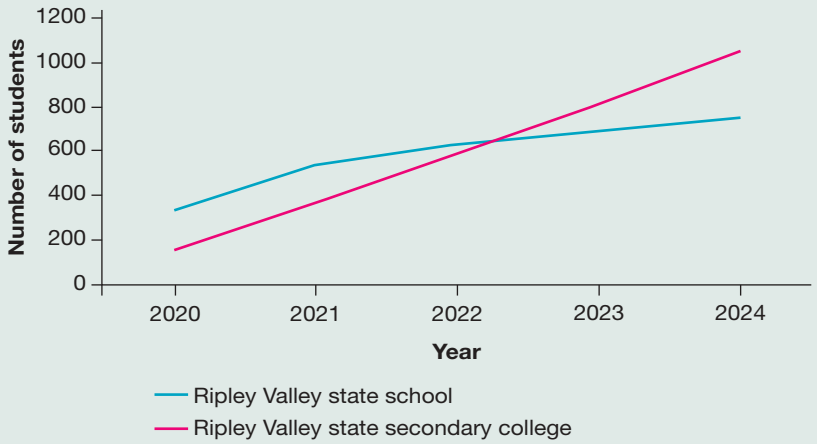
The impact of South Ripley's rapidly increasing population has, by and large, been mitigated by the role of planning in the suburb's development. Ripley Valley has been identified as a Priority Development Area in South East Queensland's western growth corridor, with development to be funded by a combination of local and state governments, and private developers. Ripley Valley was declared an Urban Development Area in 2010, and the suburb's growth has been controlled by the Ripley Valley Development Scheme. This means that residential, infrastructure and retail development has been controlled by urban planning authorities, as has the protection of important environmental assets such as areas of remnant natural vegetation, and the Bundamba Creek and Deebing Creek riparian zones.

FIGURE 3.60 South Ripley demographic characteristics, 2021: (a) population by age group and (b) labour force participation



Data source: ABS QuickStats

FIGURE 3.61 South Ripley school enrolment numbers, 2020–24



Data source: School annual reports

3.7 Exercise

learnon

3.7 Exercise

Learning pathways

LEVEL 1	LEVEL 2	LEVEL 3
1, 5, 6	2, 3, 4	7

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Explain and comprehend

1. Refer to figure 3.52 and **describe** the overall age/sex structure of Australia and Queensland.
2. **Identify** the most likely age cohorts and other groups who make up the people aged 15 years and above who are not in the labour force in Charleville (figure 3.56).

Analyse and apply

3. **Identify** which of the two case study places most closely resembles Queensland's age group and workforce participation structure. Suggest reasons this might be the case.
4. **Identify** which, if any, of the case study places resembles Queensland's age/sex structure. Suggest reasons this might be the case.
5. Select the age/sex pyramid for one of the case study places. **Analyse** the graph and identify the following.
   a. The age cohorts with the largest and smallest number of people.
   b. The age cohort with the greatest difference between the male and female population.
6. Given the population and demographic change that has occurred in the place chosen, suggest how the structure of its age/sex pyramid might have changed over time.

Propose and communicate

7. Refer to the age/sex pyramids (Figure 3.55 and Figure 3.59) for the two case study suburbs — Charleville and South Ripley. **Suggest** a possible challenge that might arise from the age/sex characteristics identified. **Propose** actions to address the impact of this challenge.

Sample responses for this chapter are available online.

LESSON
3.8 Apply your skills: Constructing population pyramids

LEARNING INTENTION

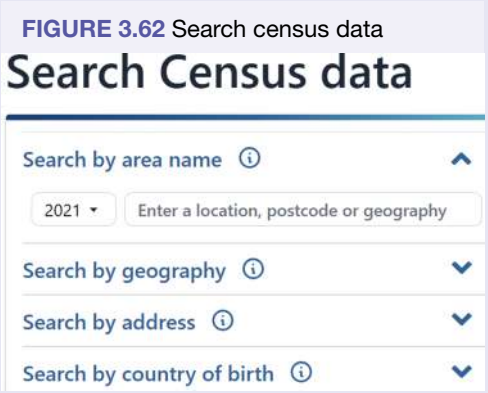
By the end of this lesson you should be able to use ABS data to construct an age/sex pyramid that shows the demographic structure of a particular place in Australia, and identify possible challenges arising from this structure.

SKILL ACTIVITY: Analysing graphic and statistical data

Obtaining age/sex data for a particular place

1. Choose the place for which you want to construct an age/sex pyramid. Use the ABS website to search for the place chosen (see figure 3.62). This activity uses Cooktown Urban Centre and Locality in North Queensland and 2021 census data as an example.

FIGURE 3.62 Search census data

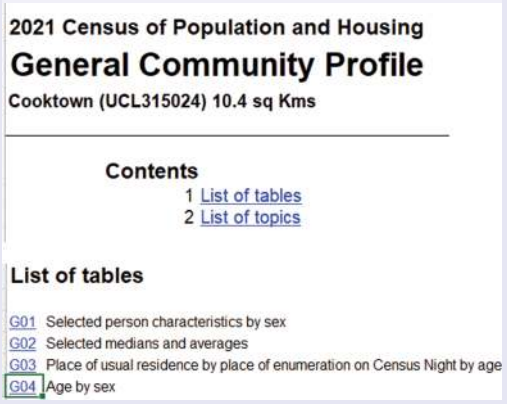


2. Once you have the search results, open the community profiles for your place (figure 3.63). These are made available as downloads for you to use.

FIGURE 3.63 Search results, Community Profiles

3. Once you have the community profile, open the Age by sex data (bottom of figure 3.64). You should now see the age by sex count of persons (figure 3.65).

FIGURE 3.64 Age by sex data in the Community Profile



2021 Census of Population and Housing

General Community Profile

Cooktown (UCL315024) 10.4 sq Kms

Contents

1 List of tables
2 List of topics

List of tables

G01 Selected person characteristics by sex
G02 Selected medians and averages
G03 Place of usual residence by place of enumeration on Census Night by age
G04 Age by sex

4. Open a new Excel spreadsheet and copy and paste the data you need to construct the age/sex pyramid. Because age/sex pyramids divide the population into males and females in five-year age cohorts, you will need to copy the relevant age bands — that is, 0–4 years, 5–9 years, 10–14 years and so on (as shown in figure 3.65). You will usually find the oldest age cohorts, from age 75–79 years, grouped together on the table. The data on your spreadsheet should look similar to the Cooktown example shown in figure 3.66.

FIGURE 3.65 Age by sex count of persons

G04 AGE BY SEX
Count of persons

	Males	*Females*
Age (years):		
0	8	8
1	8	12
2	10	18
3	9	10
4	6	10
0-4 years	*46*	*54*
5	12	9
6	13	20
7	11	9
8	13	10
9	12	8
5-9 years	*67*	*61*
10	10	15
11	11	12
12	7	12
13	17	11
14	13	11
10-14 years	*58*	*63*

FIGURE 3.66 Cooktown age/sex data, 2021

Age cohort	Males	Females
0-4 years	*46*	*54*
5-9 years	*67*	*61*
10-14 years	*58*	*63*
15-19 years	*56*	*57*
20-24 years	*31*	*54*
25-29 years	*41*	*37*
30-34 years	*38*	*63*
35-39 years	*45*	*60*
40-44 years	*55*	*65*
45-49 years	*57*	*64*
50-54 years	*59*	*63*
55-59 years	*66*	*49*
60-64 years	*66*	*75*
65-69 years	*69*	*54*
70-74 years	*73*	*45*
75-79 years	*39*	*28*
80-84 years	*23*	*7*
85-89 years	*3*	*4*
90-94 years	*4*	*0*

Constructing the age/sex pyramid

1. To construct the age/sex pyramid, you first need to change all the numbers for the male population to negatives on the spreadsheet, as shown on figure 3.67. This step is needed to ensure that the male population is shown on the left side of the pyramid.

FIGURE 3.67 Male age cohorts as negatives

Age cohort	Males	Females
0-4 years	-46	54
5-9 years	-67	61
10-14 years	-58	63
15-19 years	-56	57
20-24 years	-31	54
25-29 years	-41	37
30-34 years	-38	63
35-39 years	-45	60
40-44 years	-55	65
45-49 years	-57	64
50-54 years	-59	63
55-59 years	-66	49
60-64 years	-66	75
65-69 years	-69	54
70-74 years	-73	45
75-79 years	-39	28
80-84 years	-23	7
85-89 years	-3	4
90-94 years	-4	0

2. Highlight the male and female numbers for all age cohorts, then click Insert to insert a 2-D clustered bar graph (see figure 3.68). Your bar graph should look similar to the one for Cooktown shown on figure 3.69.

FIGURE 3.68 Inserting a 2-D bar graph with highlighted data

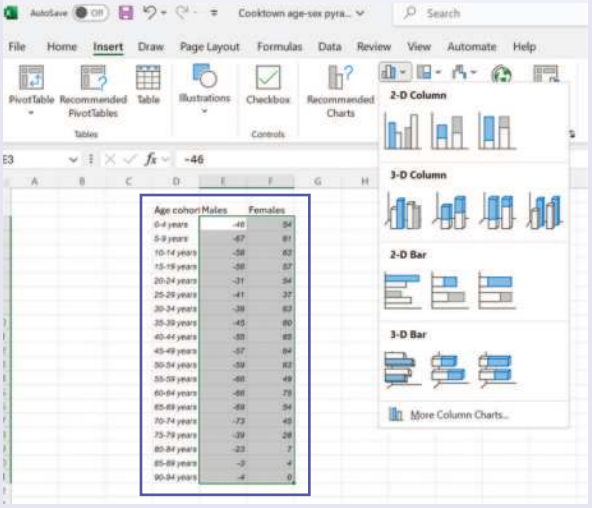
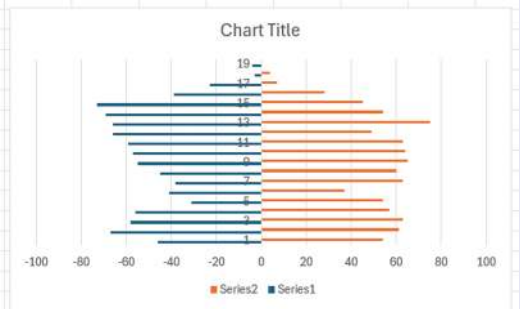


FIGURE 3.69 Cooktown age/sex pyramid 1



3. Before beginning this step, remove the word 'years' from the age cohorts on your spreadsheet, so you have only the numbers 0-4, 5-9 and so on. If, when you do this, 5-9 becomes 5-Sep and 10-14 becomes Oct-14, delete the dates and click the spacebar before you re-enter the ages.

   Right-click in the chart area and click on 'Select Data' (figure 3.70). Once the 'Select Data Source' screen is open (figure 3.71), click on Series 1, then Edit, and type 'Males' into the 'Series Name' box and click OK. Repeat this for Series 2, with the series name 'Females'.

   In the right column, click Edit, then highlight the age cohort column on the spreadsheet from 0-4 to the last age cohort. As you do this, the age cohort references will be shown in the 'Axis Label Range'. Once you have scrolled down the age cohort column, click OK. Then click the final OK button. Your graph should now show labels for the sexes and age cohorts (figure 3.72).

FIGURE 3.70 Select data

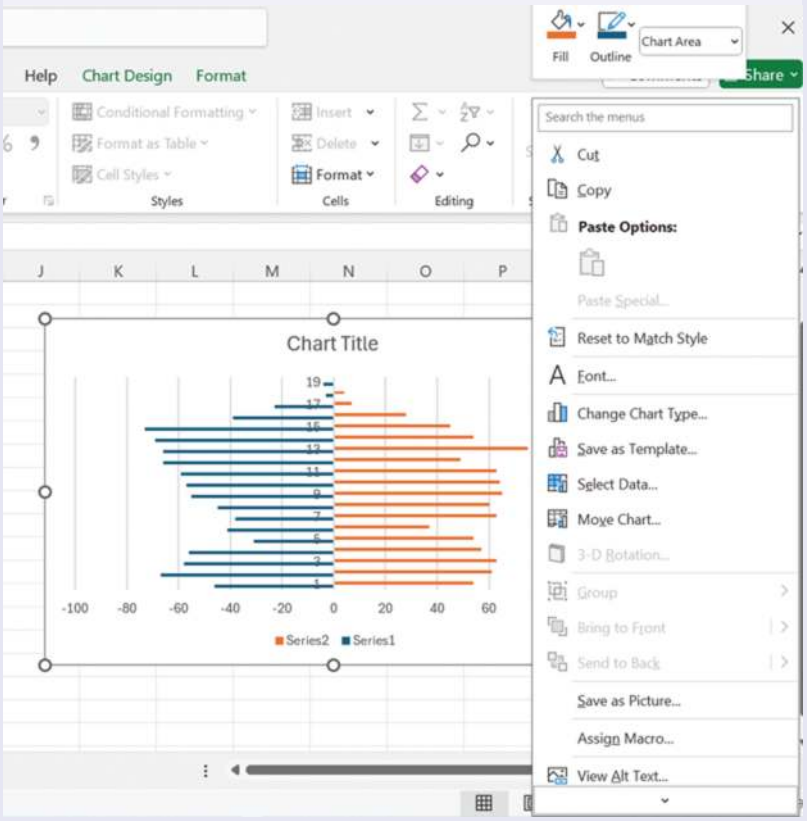


FIGURE 3.71 Select Data Source

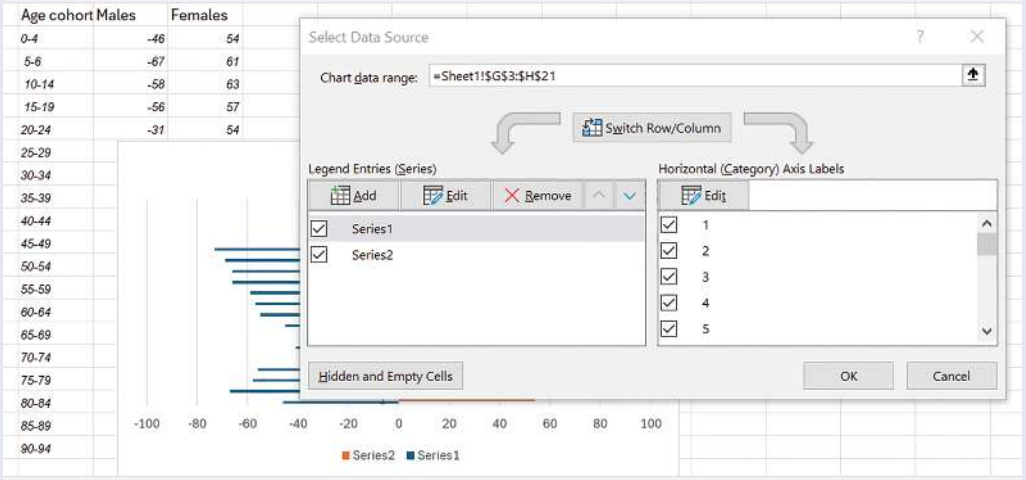
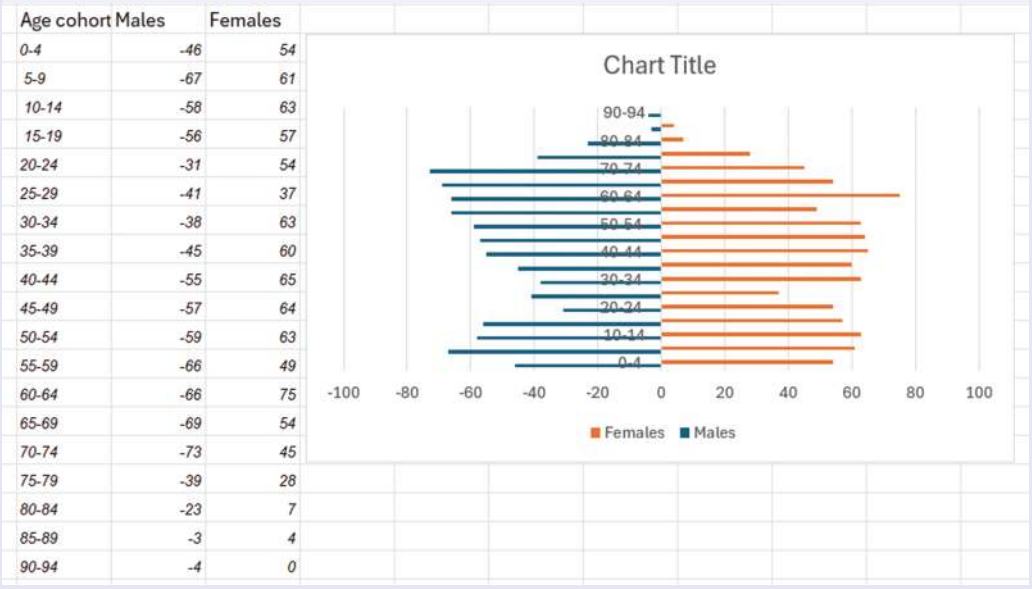
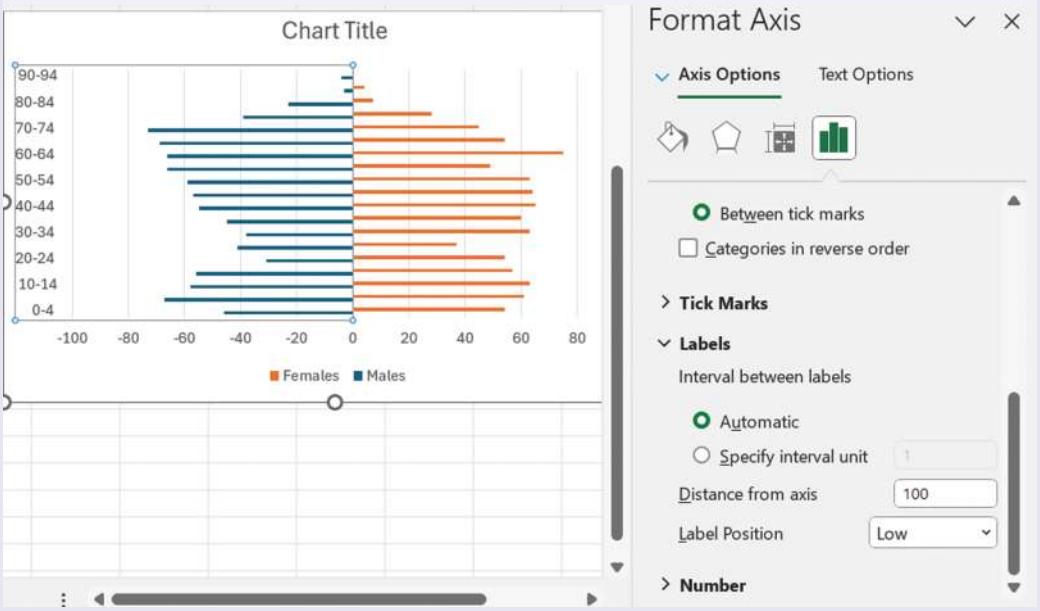


FIGURE 3.72 Age/sex pyramid with sex and age cohort labels



4. Double-click on the age cohort numbers in the middle of the graph. A ‘Format Axis’ box will appear. Scroll down to and open ‘Labels’ and change the ‘Label Position’ from ‘Next to Axis’ to ‘Low.’ Your graph will now look similar to figure 3.73.

FIGURE 3.73 Format Axis box



5. Double-click on any of the bars on the graph to open the ‘Format Data Series’ box (figure 3.74). In ‘Series Options’, change Series Overlap to 100% and Gap Width to 0% (figure 3.75).

FIGURE 3.74 Format Data Series box

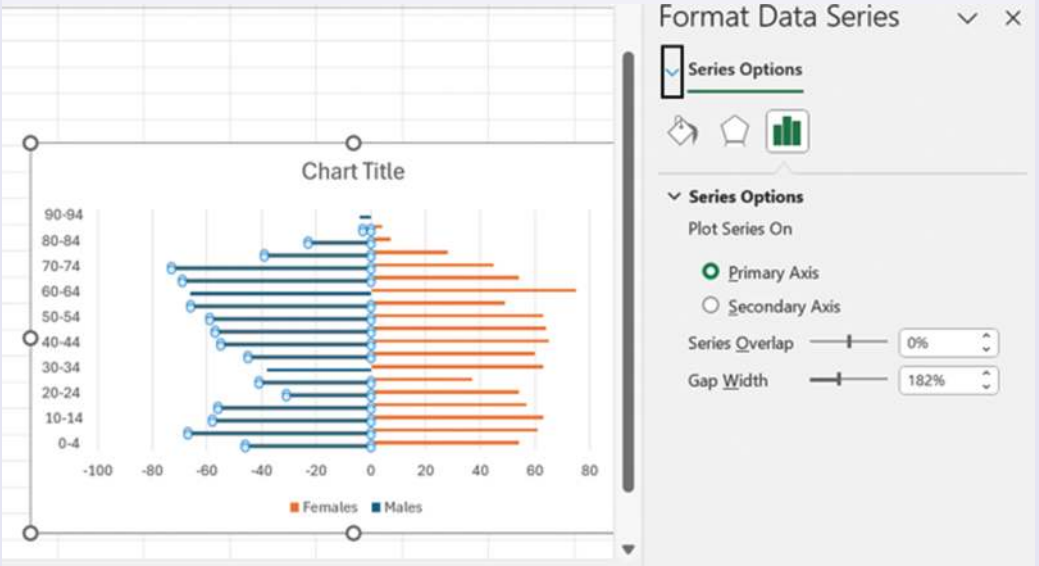
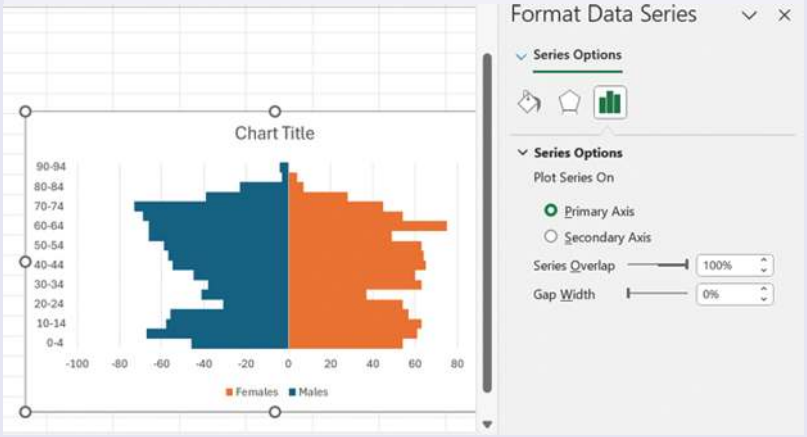


FIGURE 3.75 Age/sex pyramid with series options changed



6. While still in 'Format Data Series', click on the left icon to open Fill and Border options. Double-click on one of the male or female bars on the graph, and then open the Border options (figure 3.76). Change the border from 'Automatic' to 'Solid line'. Click on 'Colour' and change this to black (figure 3.77). Your age/sex pyramid should now look similar to figure 3.78.

FIGURE 3.76 Fill and Border options

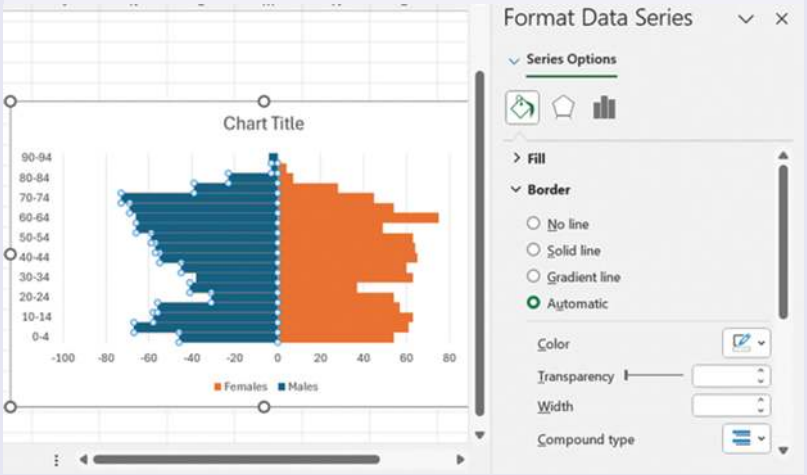


FIGURE 3.77 Border options changes

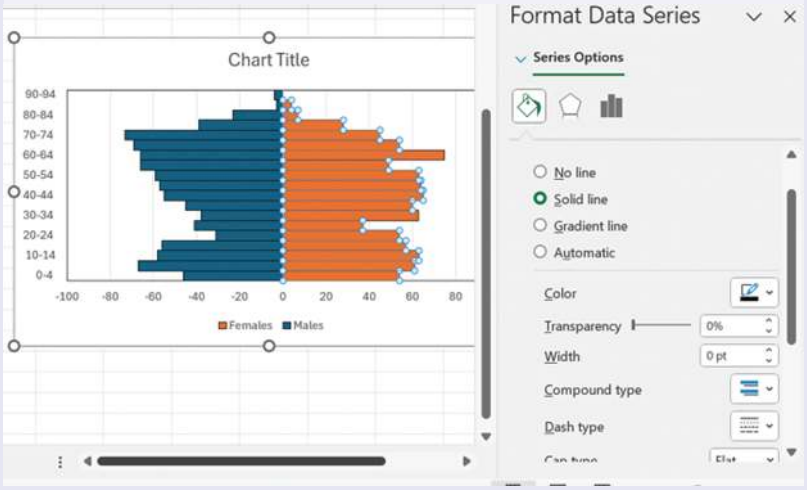
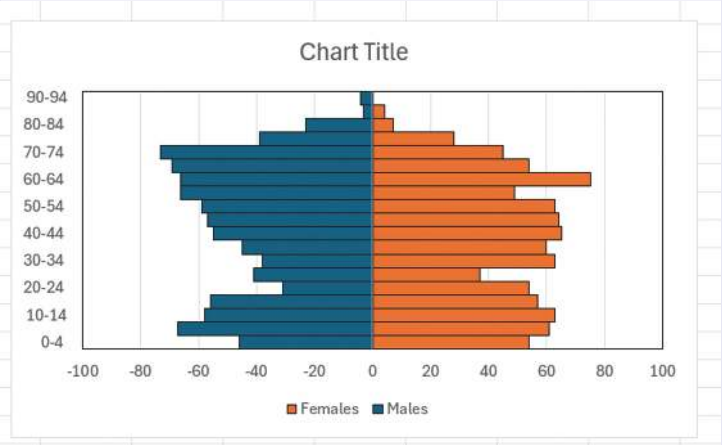


FIGURE 3.78 Cooktown age/sex pyramid with changed borders



7. Click on any number on the *x*-axis to bring up the 'Format Axis' box. Click on the far right icon for 'Axis Options' (figure 3.79). You can now adjust the 'Bounds', the minimum and maximum numbers your *x*-axis will go up to. In the case of Cooktown, the minimum and maximum numbers were -100 and 100. These were too high for the graph, so were changed to -80 and 80 (figure 3.80). You can also adjust the units, if needed. For Cooktown, the major units of 20 and minor units of 4 suited the graph, so no changes were needed.

FIGURE 3.79 Format Axis, Axis Options

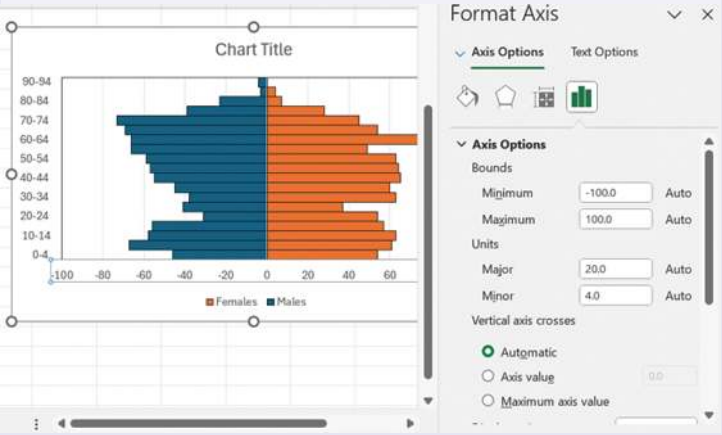
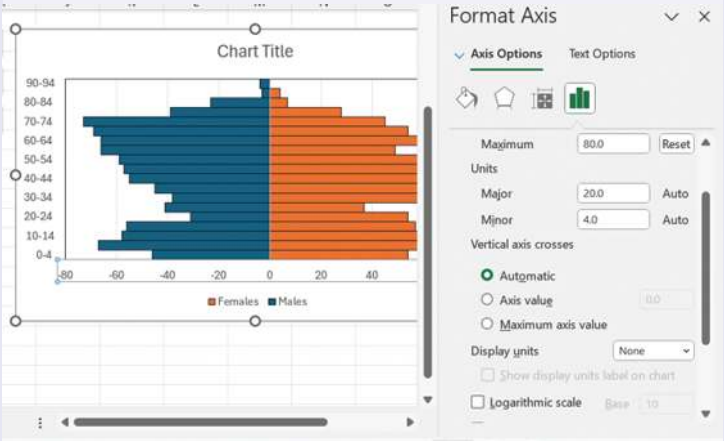


FIGURE 3.80 Axis options changes for Cooktown



8. While still in ‘Format Axis’ and ‘Axis Options’, click on ‘Number’. Change the ‘Category’ to ‘Custom’ and ‘Format Code’ to 0;0. When you do this, ‘Type’ should also show 0;0. If not, change ‘Type’ to 0;0 as well (figure 3.81). Your graph should now look similar to figure 3.82, with the negatives removed on the male axis.

FIGURE 3.81 Changes to Number options

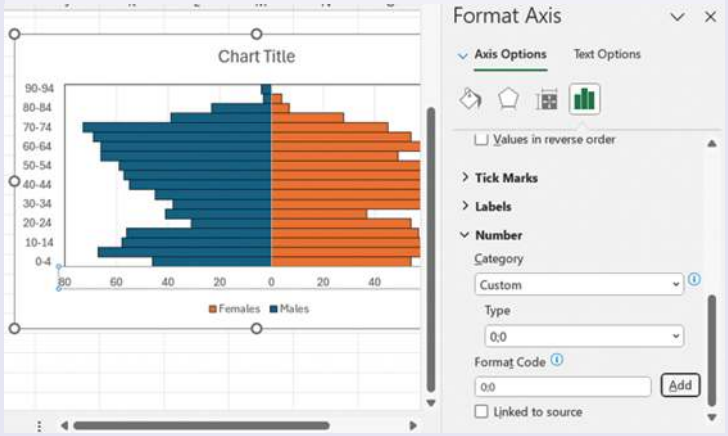
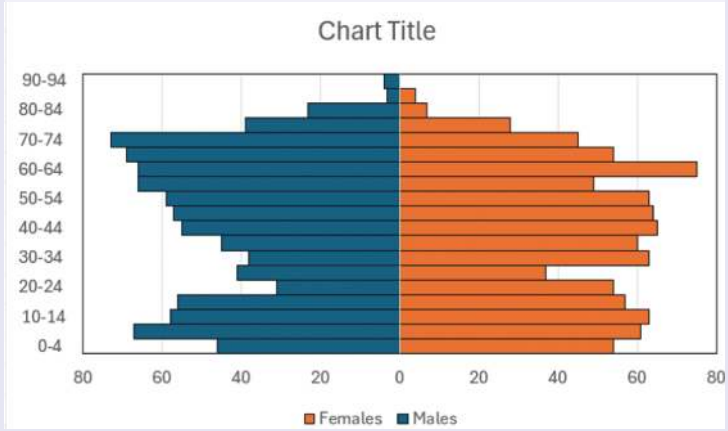


FIGURE 3.82 Number changes on the *x*-axis, Cooktown age/sex pyramid



9. Click anywhere in the graph area to bring up the three control buttons. Click on + to bring up ‘Chart Elements’, (figure 3.83). Add ‘Axis Titles’ to your graph. Double-click on each of the Axis Titles and the Chart Title and change them to the correct labels (figure 3.84).

FIGURE 3.83 Adding Chart Elements

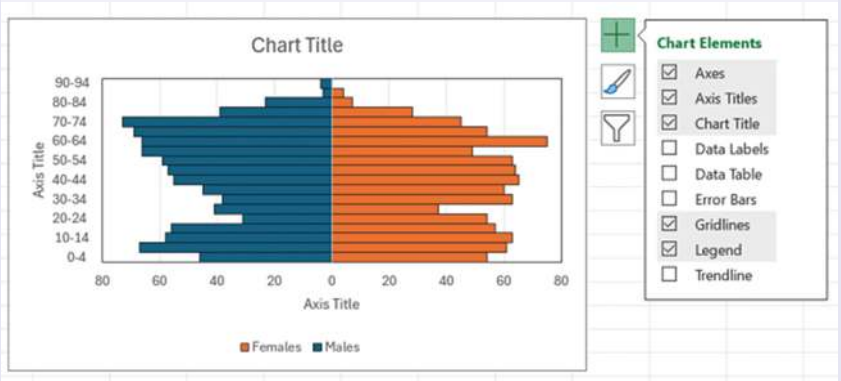
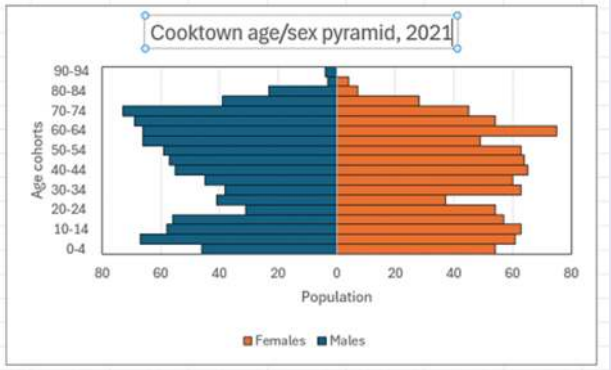


FIGURE 3.84 Cooktown age/sex pyramid with title and axes labelled



10. You can also make other adjustments to your final age/sex pyramid. For example, by highlighting the text for the title and axis labels (figure 3.85), you can bold the text, and change the font size and colour. You can drag the text boxes to a different position on the graph. You can also change the font size of the numbers on the axes by clicking on the axis numbers, and then right-clicking to bring up the 'Font' option box (figure 3.86). You can change the colour of the bars on your graph. Double-click on the male or female bars, click the 'Fill' section of 'Series Options' and change the colour as needed (figure 3.87). Figure 3.88 shows a final Cooktown age/sex pyramid where some of these adjustments have been made.

FIGURE 3.85 Adjusting graph text feature

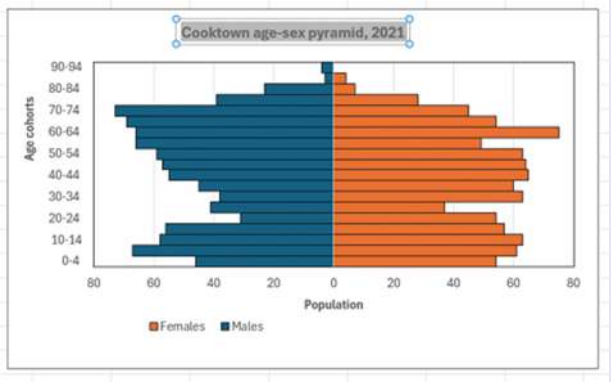


FIGURE 3.86 Changing axis features

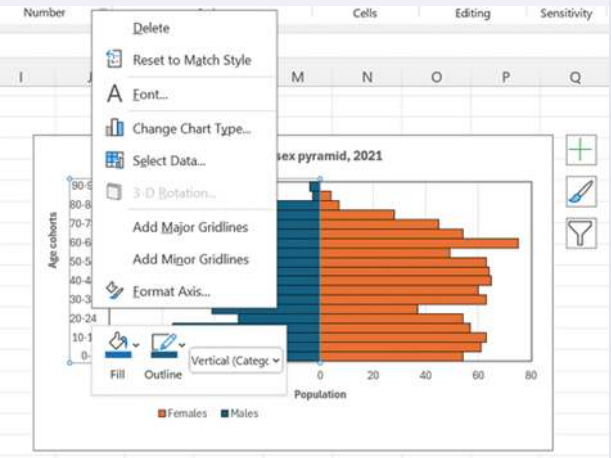


FIGURE 3.87 Changing colours of bars

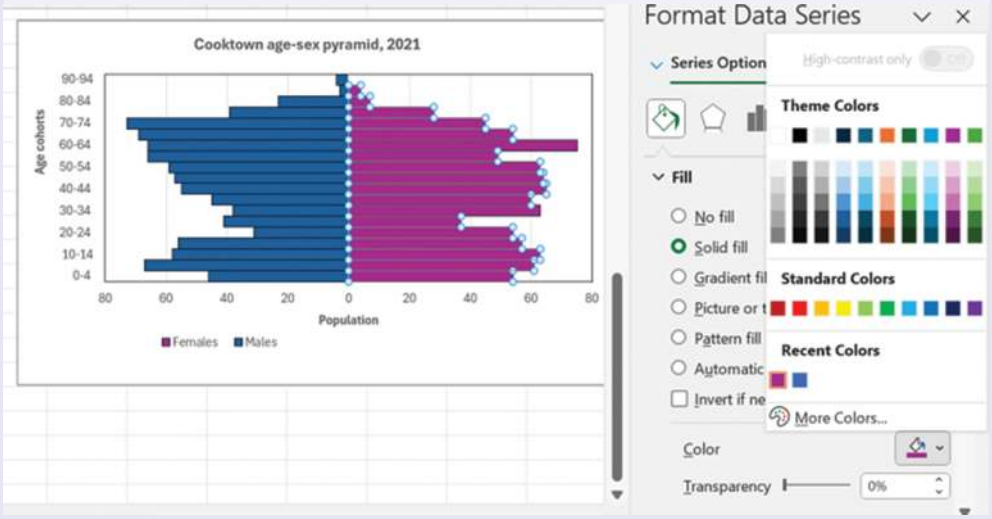
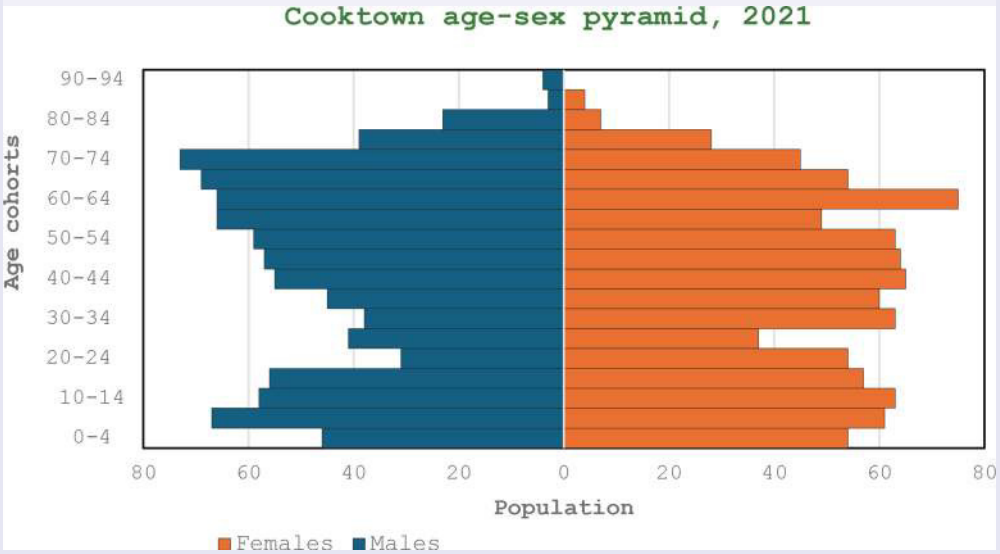


FIGURE 3.88 Cooktown age/sex pyramid with some text and colour changes



Analysing graphic and statistical data

1. Refer to the age/sex pyramid of Cooktown. Identify two or three key features of Cooktown's demography illustrated by the pyramid.
2. Suggest possible challenges that might arise from Cooktown's age/sex structure.
3. Use your completed pyramid to describe the age/sex structure of the place chosen for this skills activity.
4. Compare the age/sex structure of your chosen place with that of Australia as a whole (shown in figure 3.5). In what ways is the demography of your place similar to or different from that of Australia?
5. Identify possible challenges which might arise from the age/sex structure of your chosen place.

LESSON
3.9 Review

3.9.1 Summary

This chapter has covered some key points about Australia's population patterns and trends, including what is changing about our population and why.

Demographic concepts

- Demography involves statistical analysis of characteristics of populations such as size, composition and distribution across space, and the processes through which populations change over time.
- Key demographic concepts include birth rate, death rate, fertility rate, life expectancy, age/sex structure, migration rate, total population growth and rate of natural increase.
- Significant differences exist in countries and regions around the world in birth, death and fertility rates.
- Population pyramids show detailed data on the age of the population of countries and regions, as well as the male–female breakdown of the population.
- The age structure of a population illustrated by population pyramids often has implications for planning by governments, non-government organisations, businesses and individuals.

Changes in population

- Changes over time in birth rates and death rates in a country or region have an impact on the rate at which its population changes.
- The rate of natural increase or decrease in a country's or region's population depends on the relationship between birth and death rates.
- If birth rates are much higher than death rates for a lengthy period, the population will grow rapidly; if the death rate exceeds the birth rate, the population may decline. If the rates are close, the population will change slowly.
- Migration rates also have an impact on the rate at which a country's or region's population changes.
- Australia's population has more than doubled since the 1960s, although its relative contribution to global population growth is relatively insignificant.

Factors influencing population change

- Factors influencing population change in Australia include advances in health care and life expectancy, birth rates and the changing role of women in society, the impact of disease on death rates, migration policies over time, and amenity.

Finding and analysing data on population patterns and trends

- A high degree of geographical concentration exists in Australia's population, with over 70 per cent of the population located in the largest cities.
- Most of Australia's population lives on or near the coast, and a large area of Australia is sparsely populated.
- Both geographical and historical reasons exist for the distribution pattern of Australia's population.
- There are differences in the age structure of the populations of capital cities and other major urban areas compared with smaller towns and villages and rural areas.
- There are differences in the age structures of the states and territories, as well as between places within the states and territories.
- There is little difference between the capital cities and the rest of Australia in sex structure.
- A very high percentage of migrants to Australia live in the capital cities, particularly Sydney and Melbourne.
- The distribution of migrants across the capital cities varies, both in terms of location and countries of origin.
- In Queensland, Brisbane has the highest number of overseas-born people, followed by the Gold Coast, but all parts of Queensland have some migrants.

- The demographic characteristics of Australia's states and of regions within states can vary, as can the demographic character of smaller local areas such as regional cities, country towns and the suburbs of cities.
- Demographic challenges can occur as populations change spatially and over time.

Implications of demographic and population change

- Demographic challenges can include pressure from population growth on services, transport and other infrastructure, housing and employment, as well as pressures from ageing and population decline.
- Inner-city areas might face challenges of overcrowding and lack of schools and other services, while outer suburbs may face challenges of limited employment opportunities and long commutes to school and work.
- Regional and rural towns across Queensland and Australia face contrasting demographic challenges.
- Inland towns might face challenges of depopulation, demographic decline, ageing, and threats to community social and economic viability.
- Coastal and near-metropolitan towns might face challenges related to strong population growth, such as pressure on infrastructure, services and the natural environment, and changes to the social and cultural character of the community.

Geographic challenges arising from demographic and population change for places in Australia

- Demographic or population change for a selected place in Australia at a local scale and suitable population size (e.g. a regional city, a suburb or a rural town) can be used to investigate a specific geographic challenge.

Apply your skills: Constructing population pyramids

- ABS data can be used to construct an age/sex pyramid that shows the demographic structure of a particular place in Australia.

3.9.2 Key terms

amenity the desirable or useful features or facilities of places, including access to shops and other services required for daily living, employment, health care, educational services, transport, cultural and leisure services, and green spaces
baby boom an upward spike for a number of years in birth rates; the period in Australia from the late 1940s to the early 1960s when birth rates were higher than they had been since the 1920s
birth rates also known as crude birth rate; the annual number of live births in a particular place per 1000 people
death rates also known as crude death rate; the annual number of deaths in a particular place per 1000 people
demography the study of population, especially human population. Demography involves statistical analysis of characteristics such as population size and composition, distribution across space and the processes through which populations change over time
infant mortality the number of babies who die before one year of age per 1000 births
migration rate immigration (incoming) number minus emigration (departing) number, per 1000 people
population pyramid also known as age/sex pyramids; a compound bar graph illustrating the age/sex structure of a place's population
pull factors the positive features of places that are attractive to migrants; they draw people towards places
push factors negative features of places that are responsible for people leaving
rate of natural increase the birth rate minus the death rate, expressed as a percentage: (crude birth rate minus crude death rate) × 100/1000
rates the fixed ratio between two measurements
sea change a change in lifestyle, especially a move from the city to a seaside location
sex ratio number of males per 100 females in a population
total fertility rate the number of children born per woman of child-bearing age
tree change a change in lifestyle, especially a move from the city to a rural location

KEY QUESTIONS REVISITED

You should now be able to answer the following questions.

- What is demography? What are the key demographic concepts?
- What are Australia's population patterns and trends?
- What demographic processes are responsible for changes in population in Australia?
- What factors influence changes in population in Australia, both spatially and over time?
- What are the implications of population change for people and places in Australia?
- What are the demographic characteristics of a particular place in Australia?
- What challenges occur because of demographic and/or population change in a particular place in Australia?
- What actions might be taken to manage these challenges?

3.9.3 Exam questions

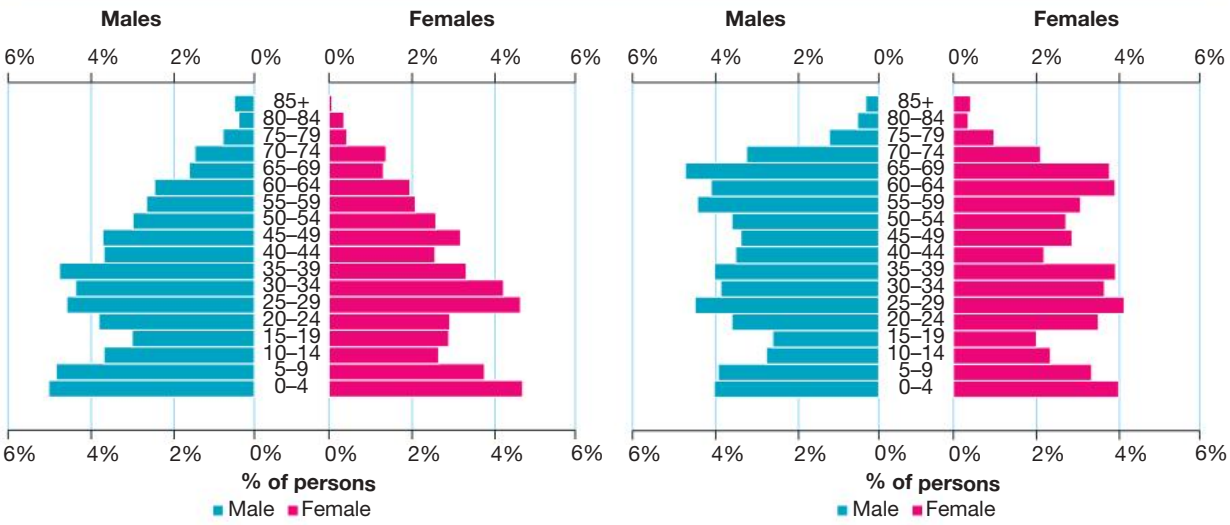
Section I – Short answer questions

Question 1 (5 marks)

Analyse the population pyramids shown in figure 3.89, and explain three challenges facing Cloncurry in relation to demographic change.

Provide evidence to support your response.

FIGURE 3.89 Population pyramids for Cloncurry, 2001 and 2021



Source: https://profile.id.com.au/cloncurry/age-sex-pyramid

Question 2 (6 marks)

Analyse the graphs shown in figures 3.90 to 3.92 to explain three features of the migration pattern evident for Australia.

Explain an implication of this pattern.

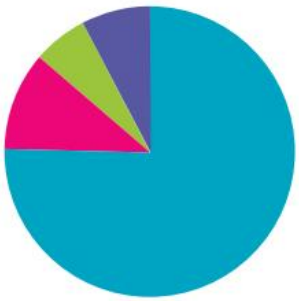
FIGURE 3.90 Overseas migrant arrivals in (a) 2012–13 and (b) 2022–23

(a)

- Temporary visa
- NZ citizens
- Permanent visa
- Unknown visa
- Australian citizens

Data source: ABS

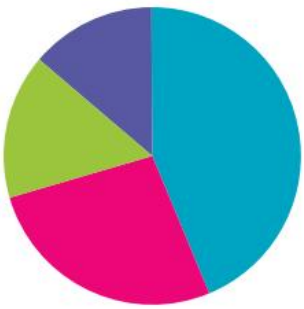
(b)



- Temporary visa
- NZ citizens
- Permanent visa
- Australian citizens

Data source: ABS

FIGURE 3.91 Permanent arrivals, 2022–23



- Skilled (permanent)
- Family
- Special eligibility & humanitarian
- Other (permanent)

Data source: ABS

FIGURE 3.92 Temporary arrivals, 2022–23

- Student — vocational education and training
- Working holiday
- Skilled — (temporary)
- Student — higher education
- Visitors
- Student — other

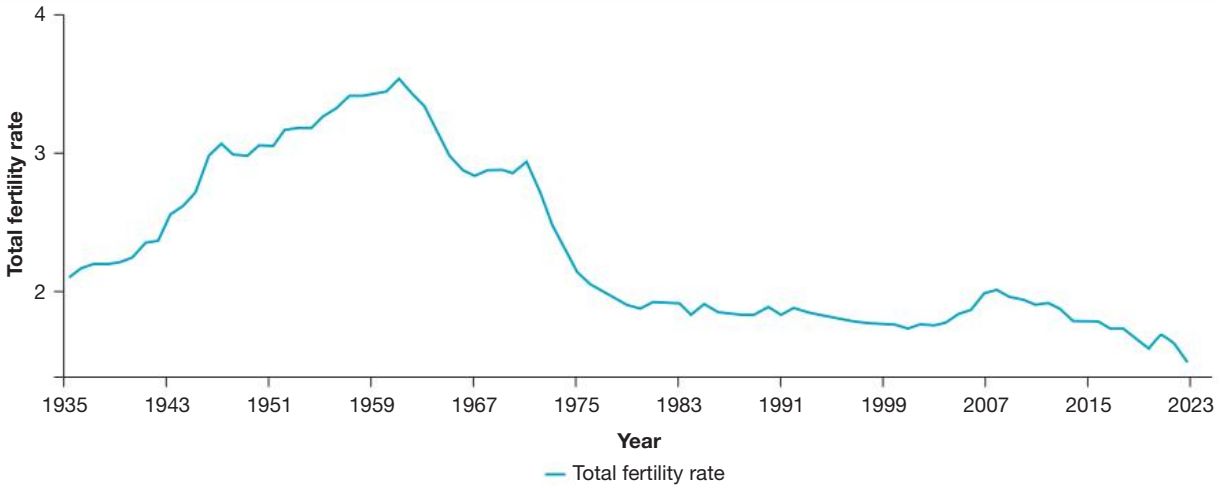
Data source: ABS

Section II – Extended response question

Question 3 (16 marks)

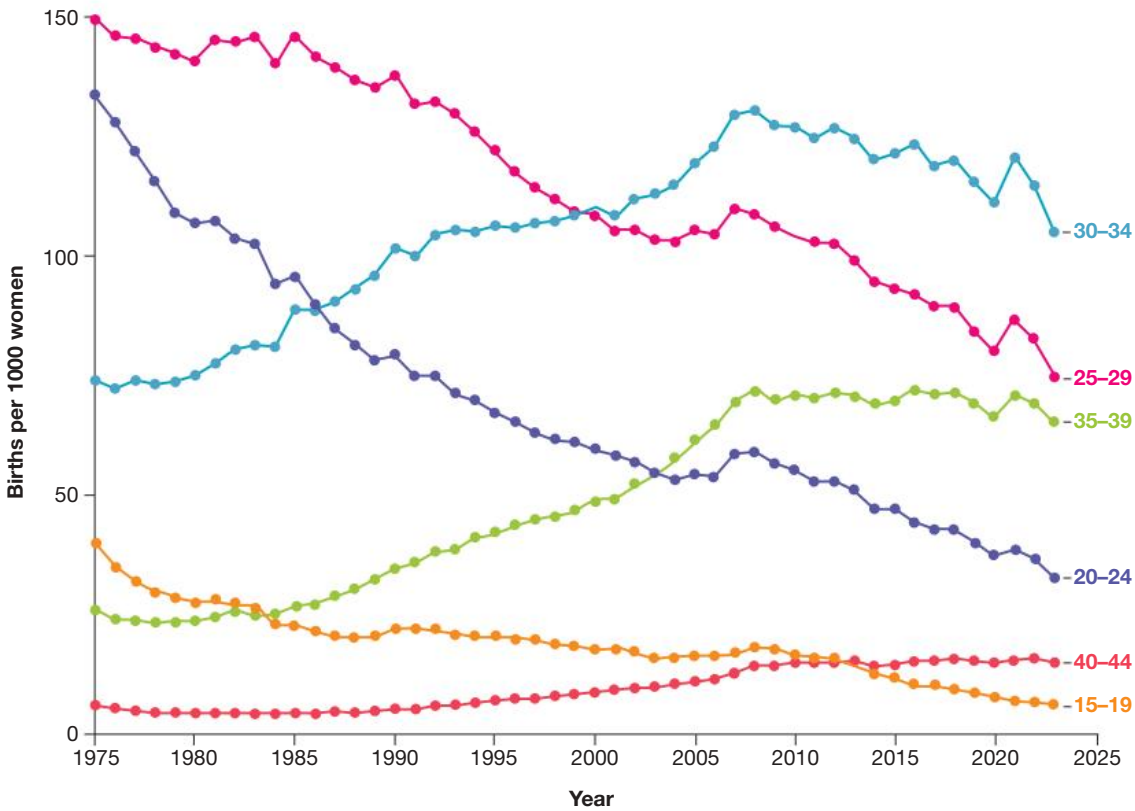
Analyse figures 3.93 to 3.97 to make inferences about geographical challenges arising from changes in fertility rates in Australia. Based on your analysis, make generalisations about the impacts of the identified challenges for places in Australia.

FIGURE 3.93 Australia total fertility rate, 1935–2023



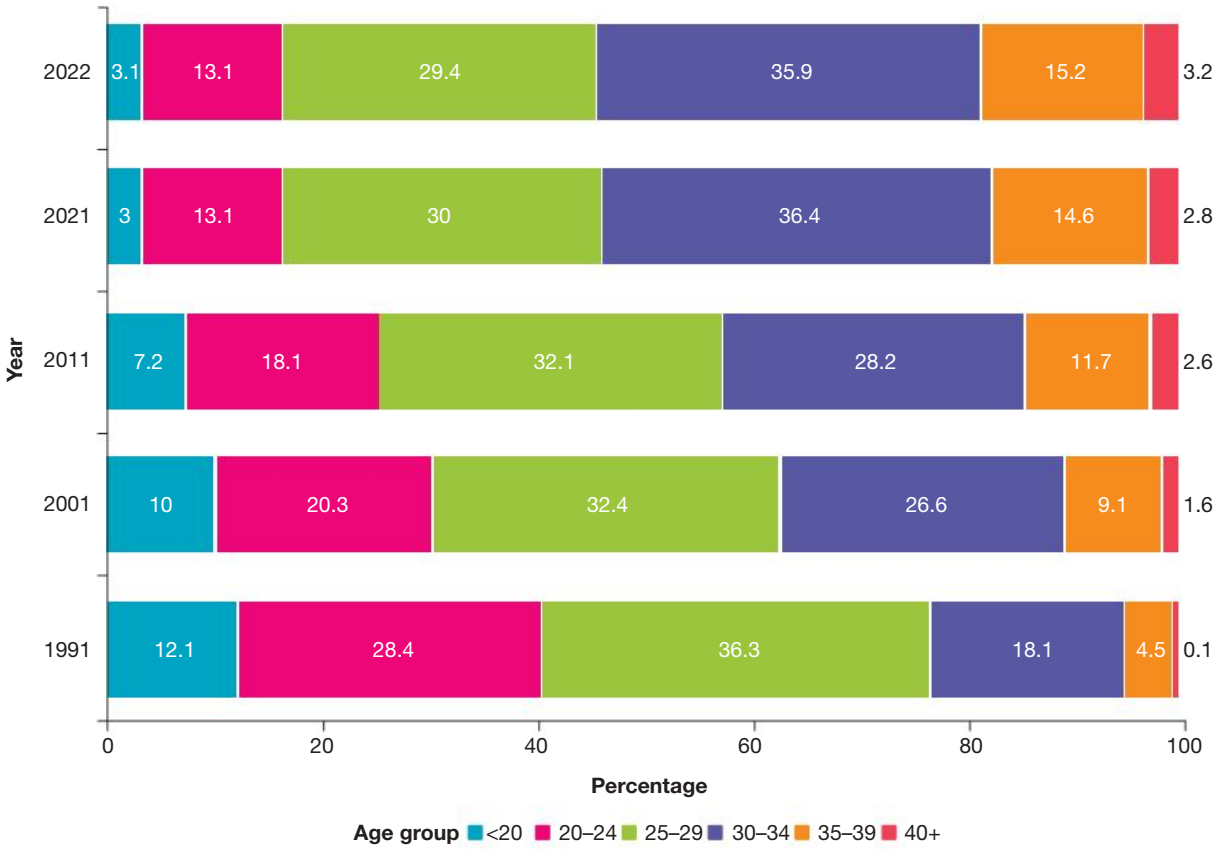
Source: https://www.abs.gov.au/statistics/people/population/births-australia/2023

FIGURE 3.94 Age-specific fertility rates, 1975–2023



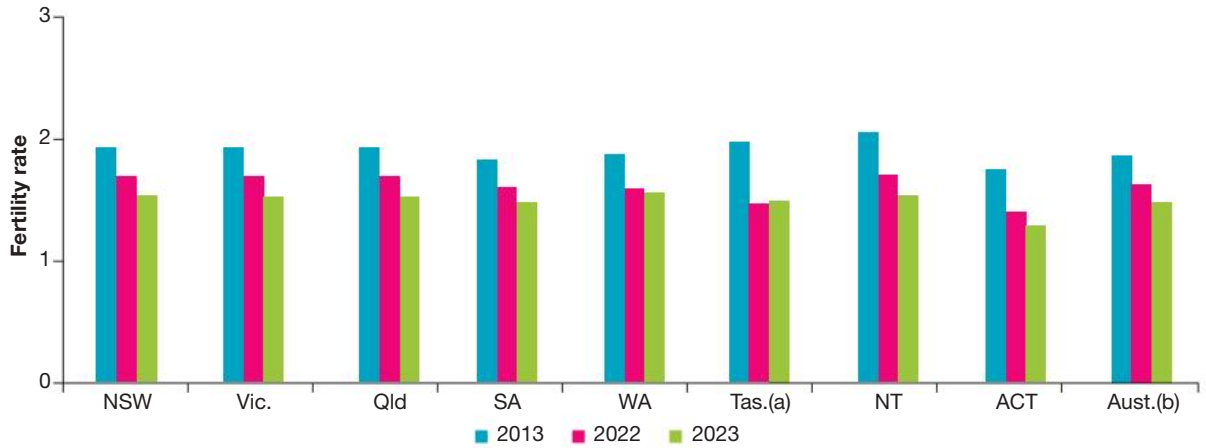
Source: https://aifs.gov.au/research/facts-and-figures/births-australia-2024#age-specific

FIGURE 3.95 Age of first-time mothers, selected years, 1991–2022



Source: https://aifs.gov.au/research/facts-and-figures/births-australia-2024

FIGURE 3.96 Total fertility rate by state or territory, 2013, 2022, 2023



Source: https://www.abs.gov.au/statistics/people/population/births-australia/2023

FIGURE 3.97 Fertility rates in states, capital cities and regions, 2023, and change, 2012–23

State		Capital city		Regional	
	Fertility rate 2023	Change 2013–2023	Fertility rate 2023	Change 2013–2023	Fertility rate 2023	Change 2013–2023
NSW	1.68	–14%	1.55	–16%	1.98	–8%
Vic	1.49	–18%	1.41	–18%	1.82	–14%
Qld	1.69	–15%	1.59	–15%	1.8	–14%
SA	1.6	–14%	1.54	–14%	1.93	–13%
WA	1.65	–14%	1.58	–14%	1.92	–13%
Tas	1.55	–24%	1.42	–29%	1.68	–20%
NT	1.71	–20%	1.69	–16%	1.67	–25%
ACT	1.4	–20%	1.4			

Data source: https://www.abs.gov.au/statistics/people/population/births-australia/2023

Sample responses for this chapter are available online.

4 Global population change

UNIT 3 TOPIC 4

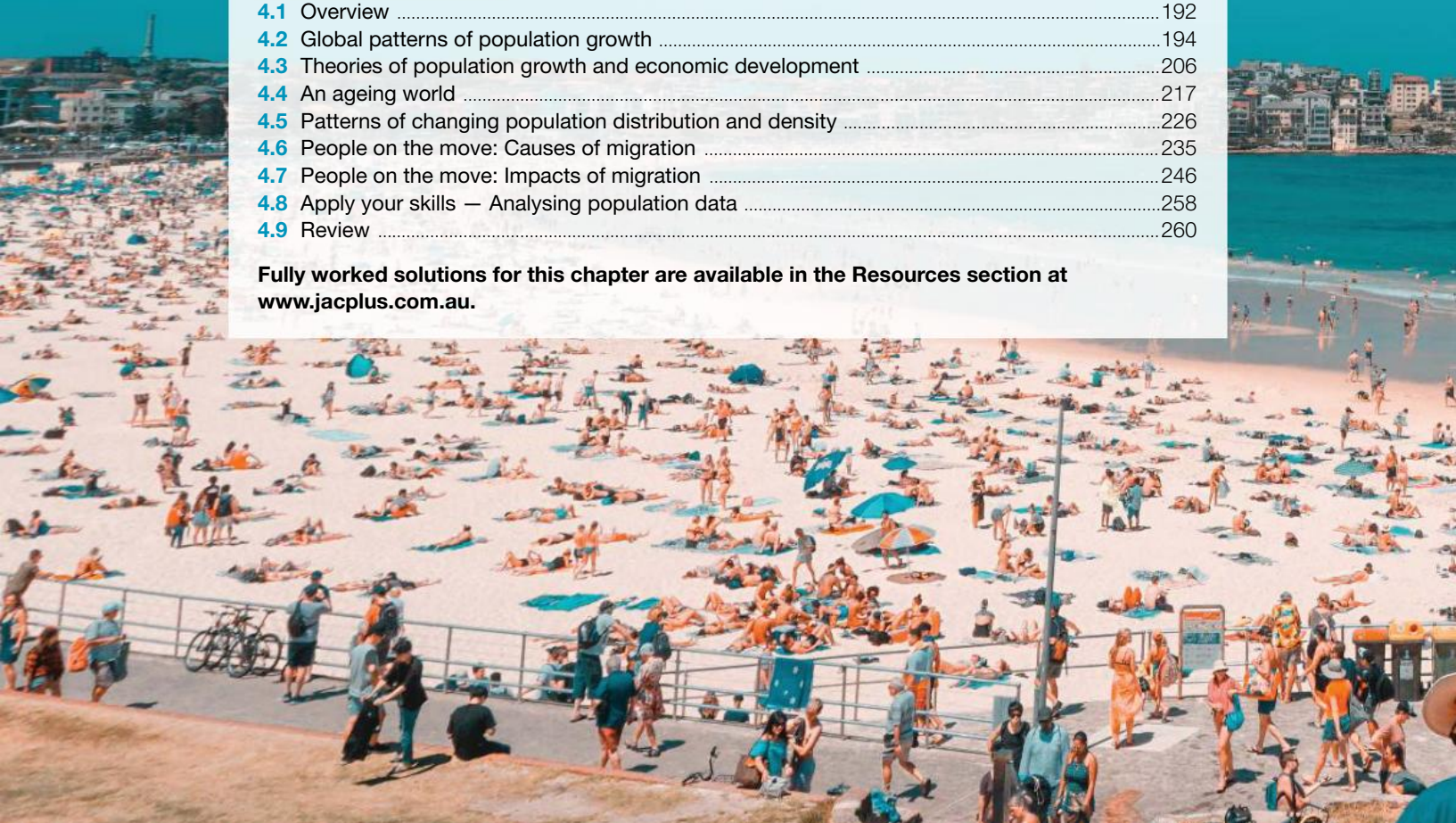
SUBJECT MATTER

In chapter 4, students:

- **explain** key demographic concepts, including birth, death and fertility rates, life expectancy, age/sex structure and migration rates
- **explain** how demographic processes result in changes to populations, including rates of natural increase and decrease, and overall population change
- **explain** how changes to populations are influenced by factors such as advances in health care and life expectancy, the changing role of women in society and birth rates, the impact of disease on death rates, migration policies over time, and amenity
- **analyse** primary data (ABS census data) relating to each of the key demographic concepts (birth, death and fertility rates, life expectancy, age/sex structure, and migration rates) to identify population patterns and trends in Australia
- **recognise** and represent the population patterns and trends in each key demographic concept for Australia, using spatial and information and communication technologies
- **explain** implications of demographic and population change (e.g. ageing population, youth population, declining population, rapid population growth, migration) for people and places
- **conduct** a geographic inquiry using primary data (for assessment purposes) to investigate a specific geographic challenge arising from demographic or population change for a selected place in Australia at a local scale and suitable population size, for example, a regional city, a suburb or a rural town.

LESSON SEQUENCE

Fully worked solutions for this chapter are available in the Resources section at www.jacplus.com.au.



LESSON
4.1 Overview

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Engage with interactivities

Answer questions and check results

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4.1.1 Introduction

In this topic, you will examine patterns and trends in world population change, the factors that have contributed to spatial variations in population growth and decline, and the relationships and implications for people and places as a result of this. You will also investigate the changing distribution of the world's population, the processes that have led to movements of people across the world, and the impact this has had on places of origin and destination.

FIGURE 4.1 The size of a country's population can determine the decisions the government makes.

4.1.2 Syllabus links

Syllabus links	Lesson
○ Explain global population characteristics, focusing on demographic concepts of the rate of natural change, including birth rate, death rate, infant mortality rate, fertility rate, life expectancy and age/sex structure.	**4.2**
○ Explain the demographic processes that cause variations in the spatial distributions of global population characteristics, including population momentum.	**4.2**
○ Explain changes in world population distribution, including internal and international migration since the 1700s, and the projected changes in the twenty-first century.	**4.2**
○ Explain how population trends and characteristics have been described over time using models (e.g. Demographic Transition model, Rostow's Stages of Growth model and Wallerstein's World-Systems theory) and decide whether these are still applicable to describe contemporary and projected population changes.	**4.3**
○ Recognise current population growth, distribution and density, represent global population patterns in maps and graphs using spatial technologies and information and communication technologies, and identify relationships and implications for people.	**4.4, 4.5**
○ Analyse geographic data represented in maps and graphs to infer how the patterns and trends represent specific challenges at global, regional and local scales.	**4.7**
○ Explain the causes of internal migrations, both forced and voluntary, as a result of human factors (including social, cultural, political and economic factors such as conflict, labour supply and demand, family reunion, religious or cultural persecution, poverty, food security, governance) and/or geographical and environmental processes (e.g. large-scale flooding or drought, ecological breakdown).	**4.6**
○ Explain the causes of international migrations, both forced and voluntary, as a result of human factors as for internal migrations (including social, cultural, political and economic factors such as conflict, labour supply and demand, family reunion, religious or cultural persecution, poverty, food security, governance), and other factors (e.g. educational opportunities and/or geographic and environmental processes such as large-scale flooding, drought or ecological breakdown) and other factors (e.g. climate change).	**4.6**

KEY QUESTIONS

- Why is accurate and reliable census data useful to governments?
- What trends and patterns can be identified in global population change?
- Which demographic concepts are critical in explaining population change?
- How can models help us understand the past and possible future changes in population across the world?
- What spatial patterns of population distribution and density result from population change?
- How do countries manage the challenges of changing characteristics of their populations such as ageing?
- What are the positive and negative impacts of migration of people on places of origin and destination?

LESSON
4.2 Global patterns of population growth

LEARNING INTENTION

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

- explain global population characteristics, focusing on demographic concepts of the rate of natural change, including birth rate, death rate, infant mortality rate, fertility rate, life expectancy and age/sex structure
- explain changes in world population distribution and the projected changes in the twenty-first century
- explain the demographic processes that cause variations in the spatial distributions of global population characteristics, including population momentum
- recognise current population growth, distribution and density, and represent global population patterns in maps and graphs.

4.2.1 The population census

A national population census is a count of the number of people living in a country at a particular point in time.

DID YOU KNOW?

The earliest known population census was conducted in ancient Babylonia (modern-day Iraq) in 3800 BC, while the oldest existing census took place in 2 AD during China's Han Dynasty, estimating nearly 60 million people.

National census accuracy has faced controversies. Nigeria's first post-independence census in 1962 showed a reduced northern population, disputed by its leaders, leading to a 1963 census adding 8.5 million northerners. A disputed 1973 census in the same country was declared null and void. These censuses influenced parliamentary representation and revenue allocation.

Today, governments throughout the world systematically conduct a census to determine not only the total number of people living in their country but also the characteristics of the population, such as age and gender. This data enables governments to make relatively accurate future population forecasts and plan for population growth — or, in some cases, population decline.

The United Nations (UN) uses census data from national governments to make global and regional forecasts of population change in terms of numbers and characteristics. UN forecasts have been a useful tool for national and international organisations for predicting the impact of population change on resource use and **sustainability**. Errors in UN forecasting have been surprisingly small in countries with large populations.

sustainability a process of maintaining balance in an environment while retaining the ability of current and future inhabitants to use that environment

4.2.2 Global population change

The following trends in global population change can be seen:

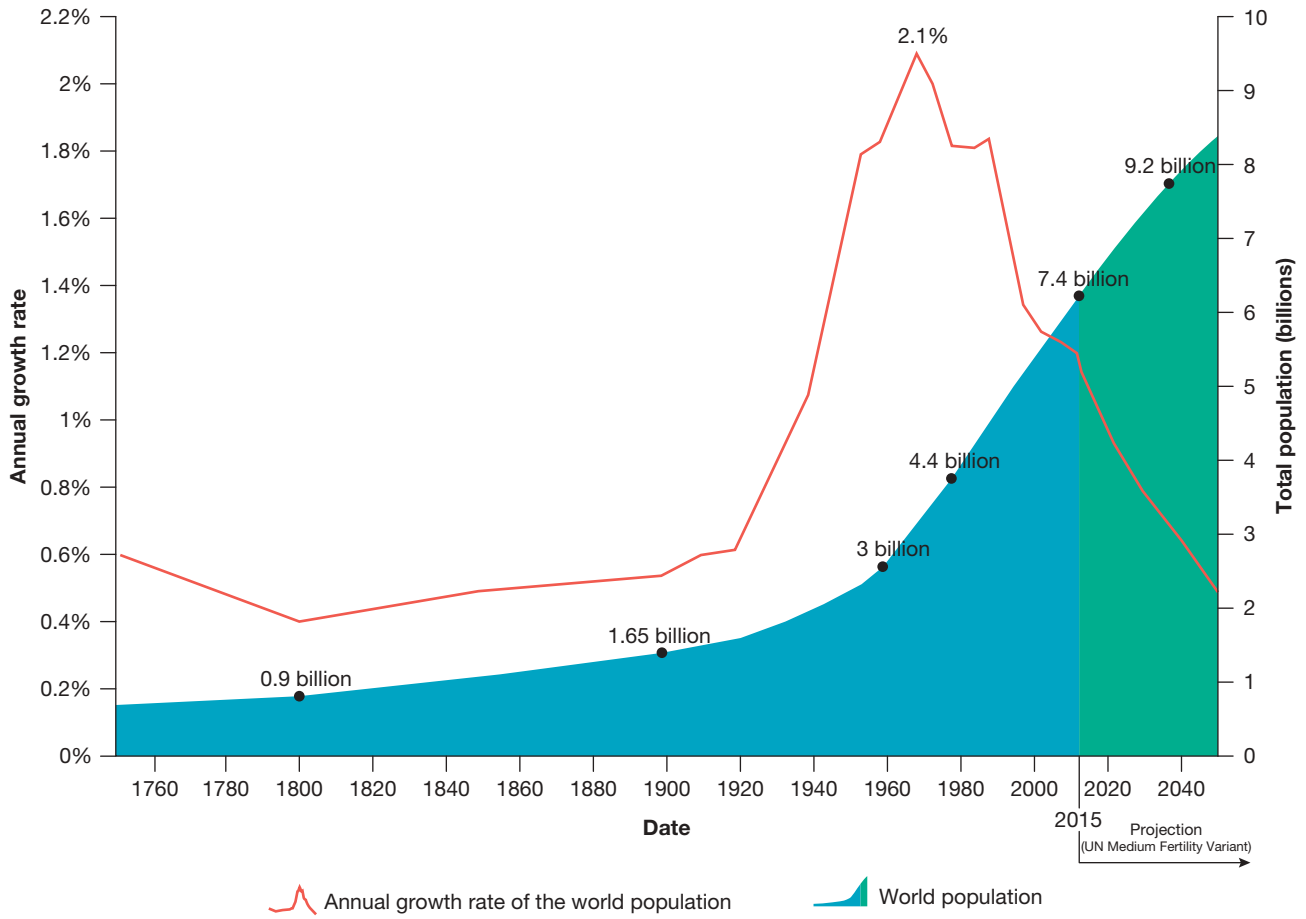
- In 2025, the global population was over 8.2 billion, but this growth has experienced several distinct phases over the last 300 years, as shown in figure 4.2. Before the late-1700s, the global population grew very slowly — the annual growth rate was less than 0.1 per cent.
- By the early nineteenth century, the global population had passed the one billion mark and global population growth accelerated, with an average annual rate of 0.5 per cent. This led to a dramatic increase in population during the first half of the twentieth century.

- Global population doubled in the 130 years from the middle of eighteenth century, but within 50 years it had doubled again.
- Despite the slackening of the demographic growth rate, the world's population has increased by one billion every 12 years since 1962, as a result of **population momentum**.
- Global population growth peaked in the early 1960s at an annual growth rate of just over 2 per cent, but since then it has fallen.

population momentum the continued growth of a population despite the fertility rate being below replacement level. It ceases once the segment of the population of reproductive years has moved beyond childbearing age.

Consequently, the UN has estimated that the global population is likely to continue to grow until it peaks at around 10.3 billion in the mid-2080s.

FIGURE 4.2 World and annual population growth 1750–2050



Source: Max Roser and Esteban Ortiz-Ospina/Our World in Data

Global population patterns conceal differences in growth rates between countries and regions (see figure 4.3). Countries in the **developed world** were the first to experience significant improvements in **life expectancy**, which in turn brought about a steady decline in **death rates** while **birth rates** remained high. This resulted in much higher population growth rates in these countries than in any other part of the world. The population growth rate of so-called **newly industrialised countries (NICs)** generally peaked in the mid-twentieth century, whereas the **least developed countries** experienced this peak towards the end of the twentieth century. In recent decades, population growth rates have generally been in decline in countries at all stages of development. This can be illustrated by the Demographic Transition model (see lesson 4.3).

4.2.3 The future world population size and composition

The UN has produced projections for global population growth rates since the 1950s. Using current data, the UN makes assumptions about how the population may change to produce what is the most likely future outcome. Traditionally, projection variants are used to show a range of possible population growth forecasts. The **medium variant** is the most likely population growth forecast, whereas the **high and low variants** are less certain and have upper and lower limits of reasonable projections (see figure 4.5).

Three factors determine the future global population size and composition. These are:

- fertility levels
- **mortality rates**
- **age/sex structure**.

Fertility rate

The **world fertility rate** is the number of children born per woman of childbearing age. This rate has declined from more than 5.0 in the mid-1960s to 2.3 in 2024. The rate falling to below 2.1 will contribute to population decline. To maintain what is known as **replacement fertility**, which is the rate required for a population to replace itself from one generation to the next (approximately 2.1 births per woman), one daughter must survive daughter at each pregnancy. This is because a slight gender imbalance exists at birth, skewed towards boys and the chances of survival from birth to the reproductive ages are less than 100 per cent.

developed world countries with mature industrialised economies, which exhibit a high gross domestic product (GDP) per capita

life expectancy the average number of years a newborn infant is expected to live, given the mortality rates at the time of their birth

death rates the annual number of deaths in a particular place per 1000 people; also known as crude death rate

birth rates the annual number of live births in a particular place per 1000 people; also known as crude birth rate

newly industrialised countries (NICs) countries where the economy has transitioned from that of a less developed country based on primary products to one increasingly based on the production of manufactured goods.

least developed countries the countries with the lowest gross domestic product (GDP) per capita and relatively lower life expectancy and higher birth, death and fertility rates

medium variant the most likely population growth forecast

high and low variants upper and lower limits of reasonable population growth projections

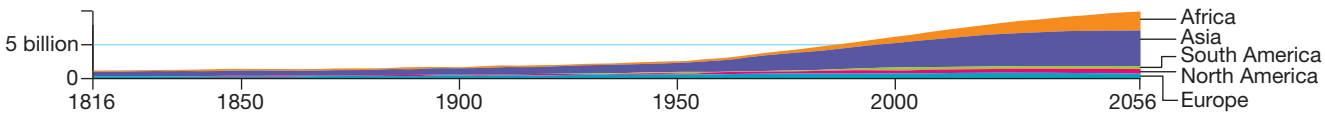
mortality rates death rate, usually for a specific group in a population; for example, maternal mortality rate

age/sex structure the composition of a population by age (0–4 years, 5–9 years, 10–14 years) and sex (male, female)

world fertility rate the number of children born per woman of childbearing age

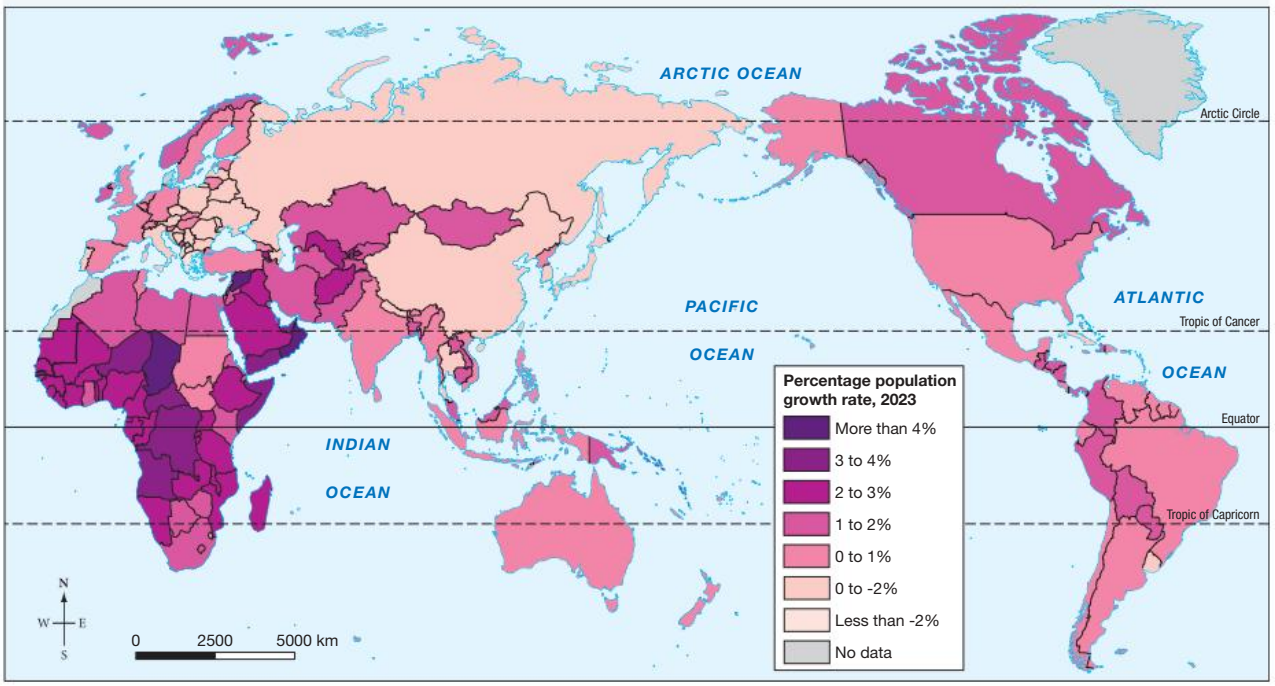
replacement fertility the rate required for a population to replace itself from one generation to the next (approximately 2.1 births per woman)

FIGURE 4.3 Population growth by world regions



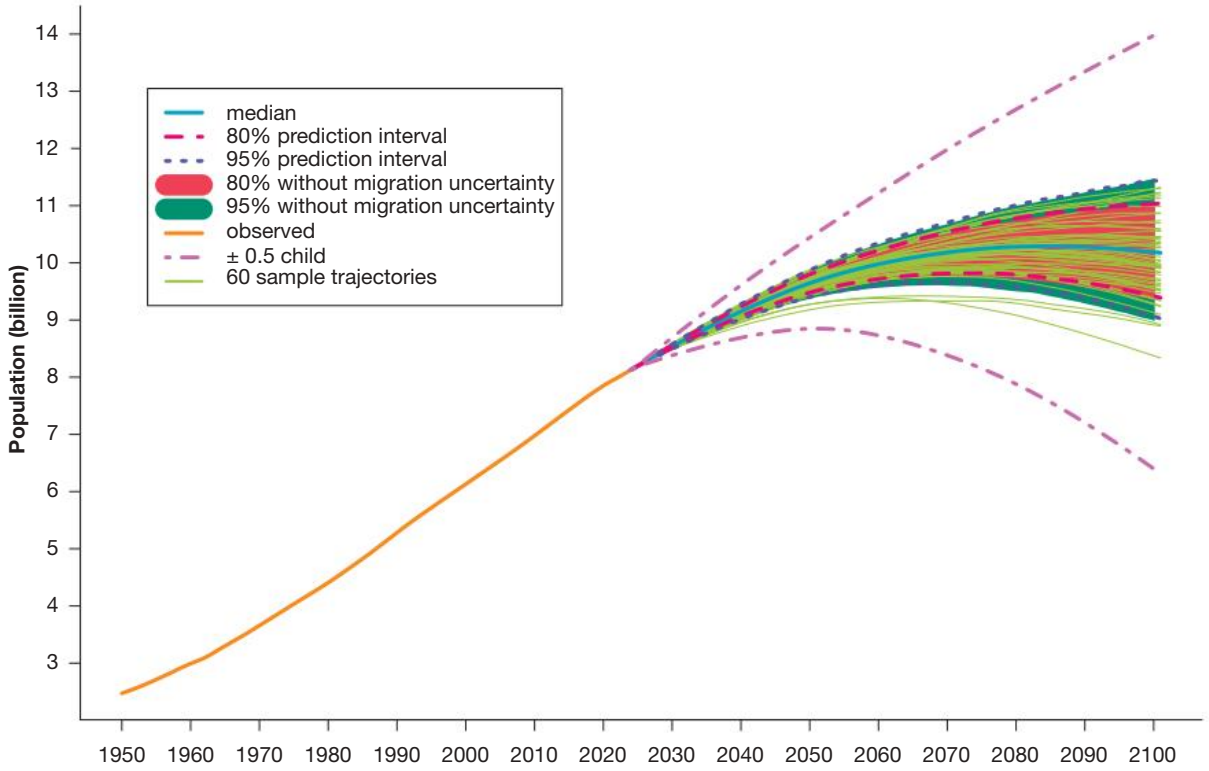
Source: Max Roser and Esteban Ortiz-Ospina/Our World in Data

FIGURE 4.4 Population growth rate, 2023



Source: UN, World Population Prospects (2024)—processed by Our World in Data. Map drawn by Spatial Vision.

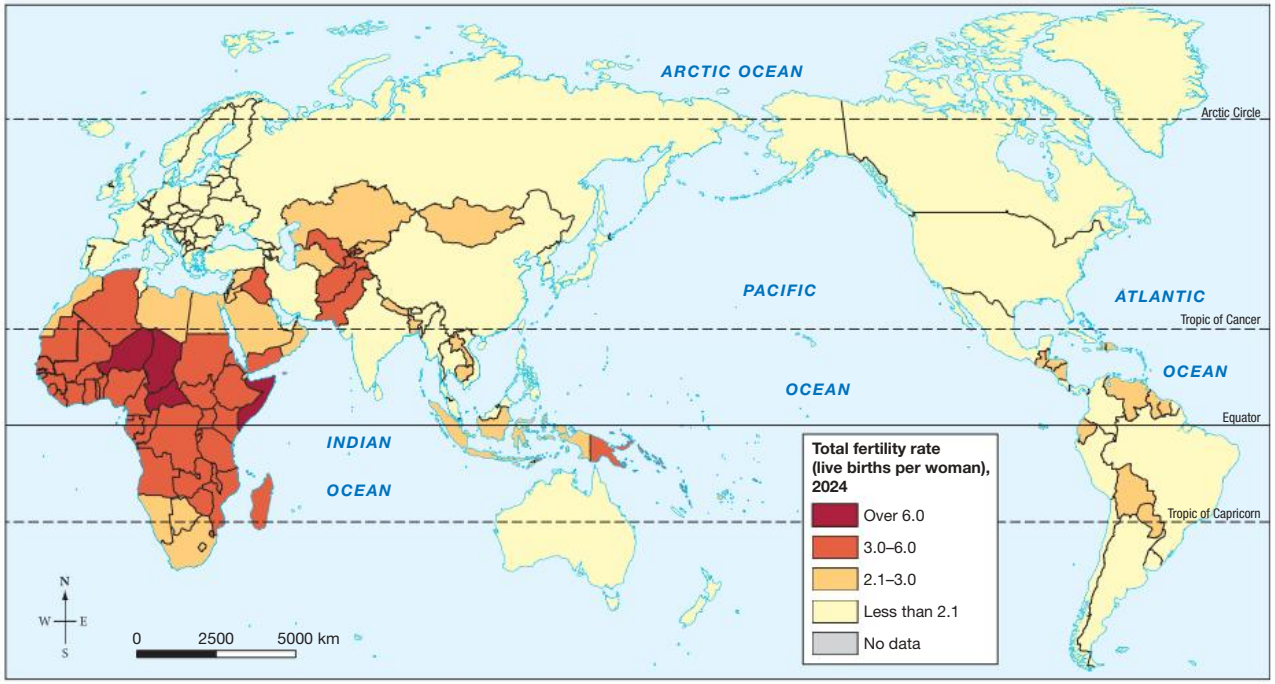
FIGURE 4.5 UN population forecast, 2024



United Nations, DESA, Population Division. World Population Prospects 2024. http://population.un.org/wpp/

Fertility rates vary between world regions and between countries (see figure 4.6). Least developed countries will likely continue to have relatively high levels of fertility; however, they are declining. This is in sharp contrast to the increasing number of countries, which account for nearly half the world's population, that have fertility rates below replacement level, such as China with a total fertility rate of 1.0.

FIGURE 4.6 Fertility rates, 2024



Source: Data Sheet Download—Population Reference Bureau. Map drawn by Spatial Vision.

CASE STUDY: Population growth in Uganda

Quick facts: Uganda

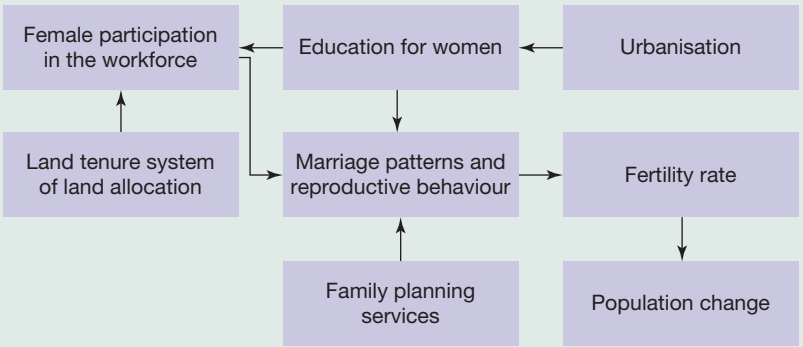
- **Population** 50 million
- **GDP per capita** US$1200
- **Fertility rate** 4.3
- **Population under 15 years** 44 per cent
- **Rate of natural increase** 3.0 per cent

Although the average African fertility rate fell from 5.1 in 2005 to 4.1 in 2024, the most youthful and fastest growing populations are still to be found in this region. In the east of Africa, Uganda is one of the fastest growing countries in Africa.

The 2011 Demographic and Health Report for Uganda highlighted teenage pregnancy rates and contraceptive use in the country. Nearly 20 per cent of women aged 15–19 have had a child in Uganda, and contraceptive use is low, with only one-third of married women and half of unmarried women using contraception. Misconceptions about infertility and cancer deter men from supporting contraceptive use. Urban areas have better access to family planning services and education, which delays first births by two years for educated women.

To combat these trends, the Ugandan Government launched initiatives such as the Family Planning 2020 Partnership, supported by the United Nations Population Fund (UNFPA), which aimed for universal access to family planning by 2022. In 2018, the United Kingdom pledged additional funding through a five-year agreement with the UNFPA.

FIGURE 4.7 Systems diagram* of population dynamics in Uganda



**Note:* A systems diagram is a flow diagram with inputs, outputs, stores and flows. It helps show complex systems and how components interact, and how changes in one factor affect the entire system.

In rural Uganda, 80 per cent of land is under customary tenure. Uganda's Ministry of Lands, Housing and Urban Development now issues certificates of customary ownership to regulate communal lands and reduce degradation. They are promoting land allocation to girls as an alternative to early marriage, allowing them to earn income from family land.

Uganda's fertility rate has declined from 7.1 in 1994 to 4.3 in 2024, and its population is growing at a rate 3 per cent per annum. This means the population is likely to grow from 50 million in 2024 to over 80 million by 2050; however, this is a much smaller increase than the once predicted 130 million.

In 2007, the Ugandan Government launched Vision Uganda 2040 to set out a development path that would create a modern and prosperous country within 30 years. In this agenda, Uganda's growing population was seen as an asset, sometimes known as a demographic dividend, and not a liability holding the country back. This view was based on trends seen in Asian countries, where remarkable economic growth has been achieved despite these countries having large and growing populations, and partly explains what some observers believe is the Ugandan Government's lack of commitment to family planning.

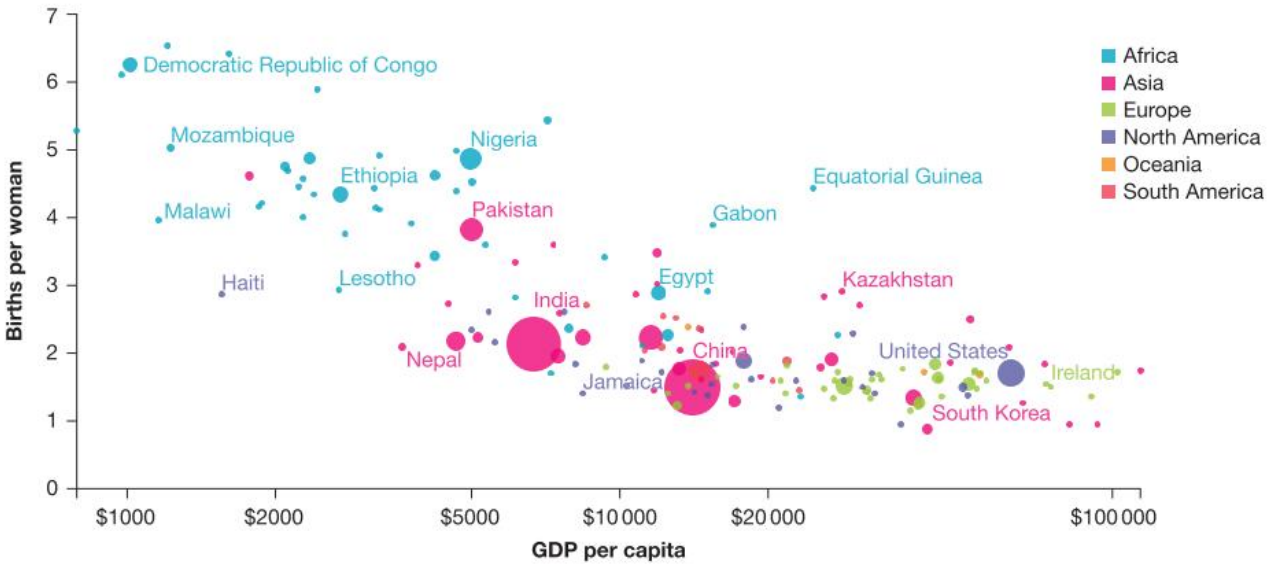
FIGURE 4.8 Villagers in rural Uganda

FIGURE 4.9 Female agricultural workers in Uganda

4.2.4 Population growth and levels of economic development

Total fertility is a key indicator of population growth. Figure 4.10 suggests that high population growth rates will continue in developing regions and account for most of the world's population increase. This is in sharp contrast to developed countries, which will experience lower growth of less than 5 per cent.

FIGURE 4.10 Fertility rates and GDP per capita



Source: UN, World Population Prospects (2024); Feenstra et al. (2015), Penn World Table (2021), https://ourworldindata.org/grapher/children-per-woman-fertility-rate-vs-level-of-prosperity.

The relationship between population growth and GDP per capita can be viewed as too simplistic. This is because GDP per capita is the total value of a country's economic output divided by population. Consequently, unless a country's economic growth is high, rapid population growth will result in a low value for GDP per capita. This supports the simplistic notion that developing countries must limit their population growth if they want to increase their rate of growth per capita GDP.

Mortality: death rates, infant mortality and life expectancy

Declining mortality rates contribute to population growth. Recent improvements in health, especially reducing infectious diseases such as HIV/AIDS and reducing infant mortality, have played a major role. However, not all age groups experience declining death rates uniformly. Socioeconomic development, increased public health and education spending aid this transition. Global life expectancy at birth averages 73 years, with regional variations (as shown in figure 4.11).

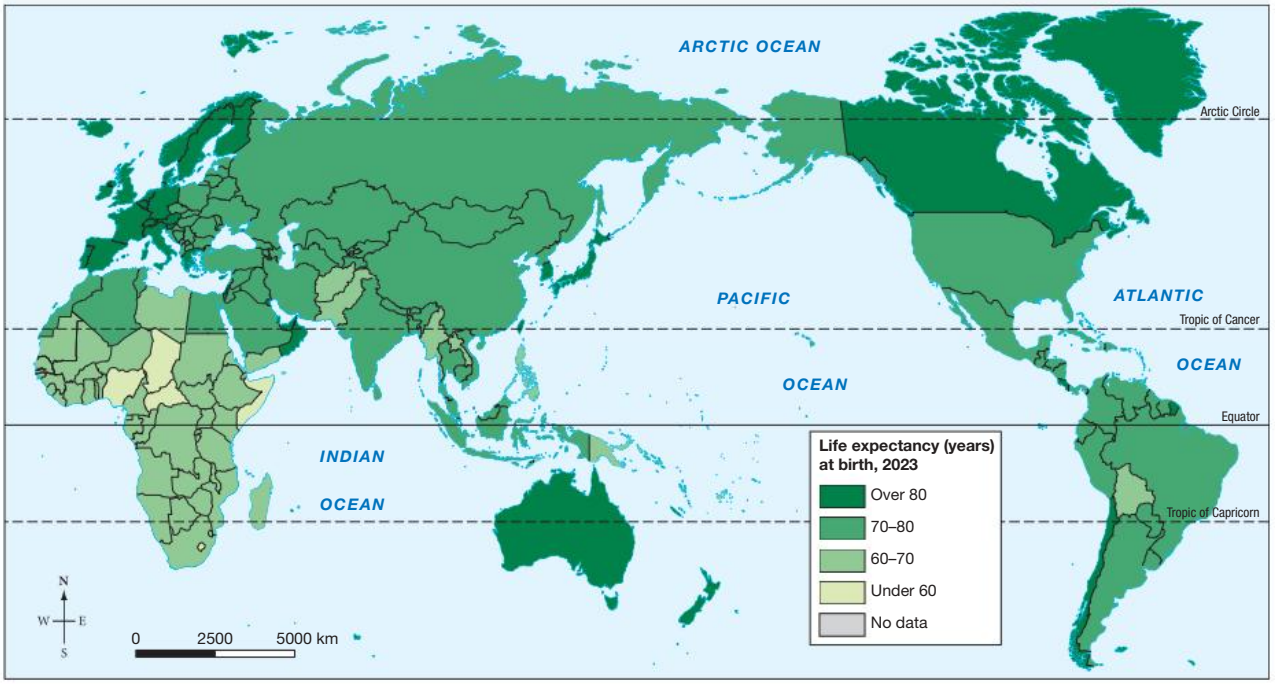
Africa has seen significant gains, with life expectancy increasing by over 12 years since 2000. The life expectancy gap between the least developed and other developing countries has narrowed to five years and continues to decrease.

Population theory

Thomas Malthus (see figure 4.12) was an English scholar and economist who developed theories about population growth. In *Essay on the Principle of Population*, first published in 1798, Malthus formulated probably the best known theory on population growth and wellbeing — that rapid population growth would exceed food production and, if population growth was not kept in check, this would result in war and famine.

However, the Industrial Revolution through the eighteenth and nineteenth centuries led to new agricultural developments and, as a result, food production increased, keeping pace with the growing population.

FIGURE 4.11 Life expectancy at birth



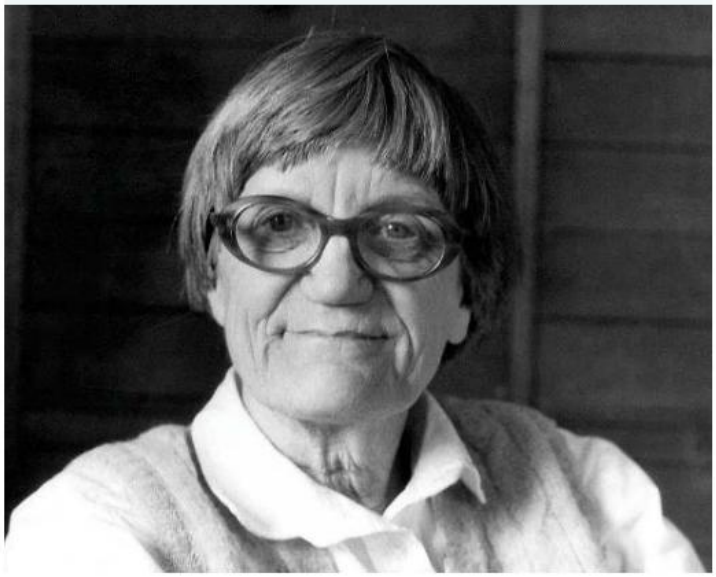
Source: Human Mortality Database (2024); UN, World Population Prospects (2024); Zijdeman et al. (2014); James C. Riley (2005)—with minor processing by Our World in Data. Map drawn by Spatial Vision.

An alternative view to Malthus was proposed by Ester Boserup (see figure 4.13), a Danish economist. In her 1965 book *The Conditions of Agricultural Growth* she suggested that as population grew, placing pressure on resources, new technologies would be invented to provide a solution, therefore driving innovation and technical progress.

FIGURE 4.12 Thomas Malthus

Source: Thomas Robert Malthus. Mezzotint by John Linnell, 1834. Credit: Wellcome Collection. CC BY

FIGURE 4.13 Ester Boserup



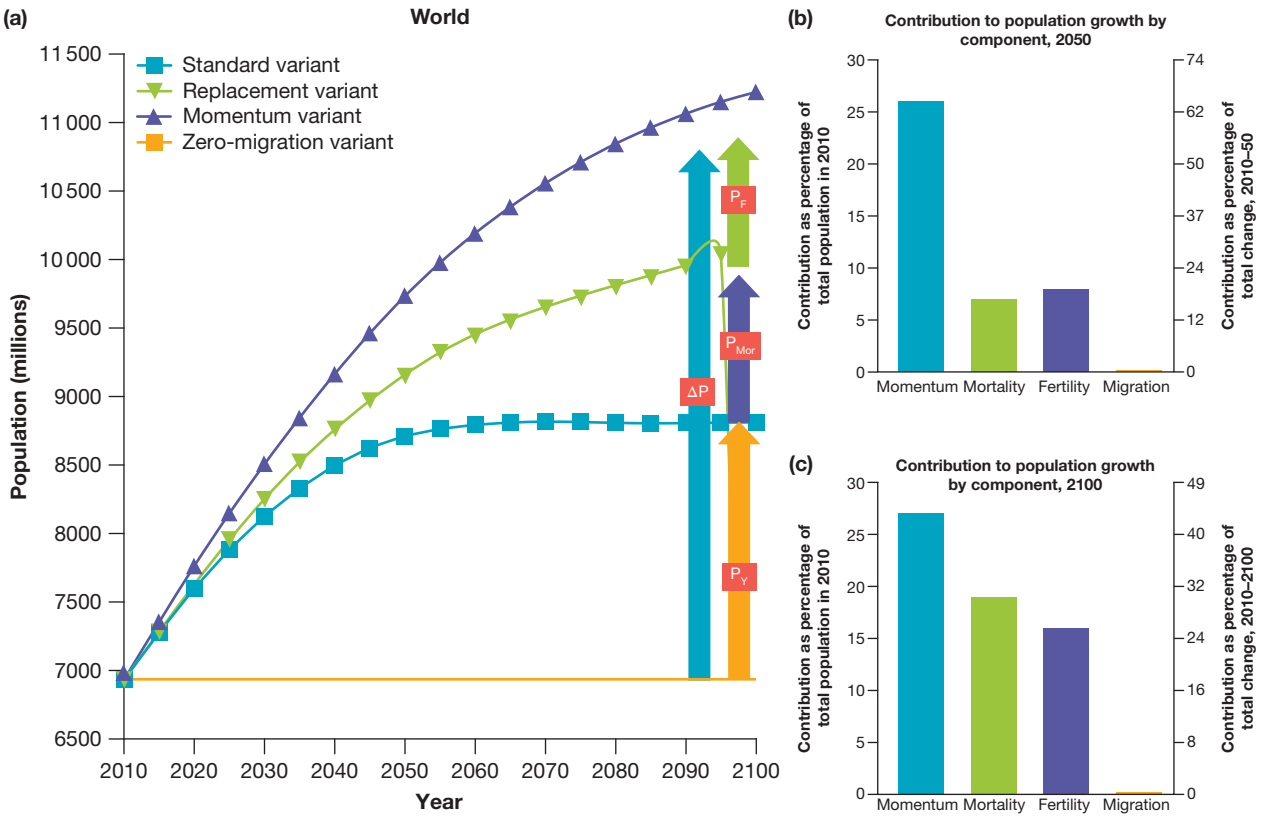
Age/sex structure

The age/sex structure of a population, defining the numbers of young and old and the balance of males and females, impacts birth and death rates. The male-to-female birth ratio is 105:100, with a replacement level at 2.1. Even if fertility reached this replacement level, global population would continue to rise for a certain period due to population momentum. A high percentage of young people (under 15) would lead to continued population growth as they entered reproductive years (15–49). This momentum would slow once this group passed childbearing age, stabilising births and deaths if fertility rates remained at or below replacement levels.

The UN's 2024 World Population Prospects outlines population momentum growth, predicting a global population increase to 10.3 billion by 2080 before stabilisation. Figure 4.14 illustrates the diminishing impact of population momentum over time, levelling out after 2060.

The contribution of population momentum to population growth will vary between countries. Those with young age structures and total fertility at replacement level are projected to grow because births produced by a large number of females of reproductive age will exceed deaths.

FIGURE 4.14 Demographic components of future population growth



Source: United Nations, Department of Economic and Social Affairs, Population Division (2017). World Population Prospects: The 2017 Revision.

EXAMPLE: Malaysia

Malaysia reached replacement level fertility in 2000. However, with a quarter of its population under age 15, its population is expected to grow until 2070. In contrast, for countries with high fertility levels, such as those in Africa, the impact of population momentum in the coming decades will be small because most of the projected growth will be driven by the fertility level rather than the age of the population.

SKILLS ACTIVITY: Analyse geographic data and information

1. **a.** Explain why the population pyramid for Uganda (figure 4.15) is indicative of a fast-growing population.
   b. Use the population pyramid for Australia shown in figure 4.16 to describe the main features of Australia's population.
   c. Uganda's Ministry of Lands, Housing and Urban Development promotes land allocation to girls as an alternative to early marriage, allowing them to earn income from family land and delay pregnancy. What is the likely impact on Uganda's population growth?
   d. Discuss with a partner what you think will happen to Australia's population pyramid in the next 25 years.

FIGURE 4.15 Uganda population pyramid, 2024

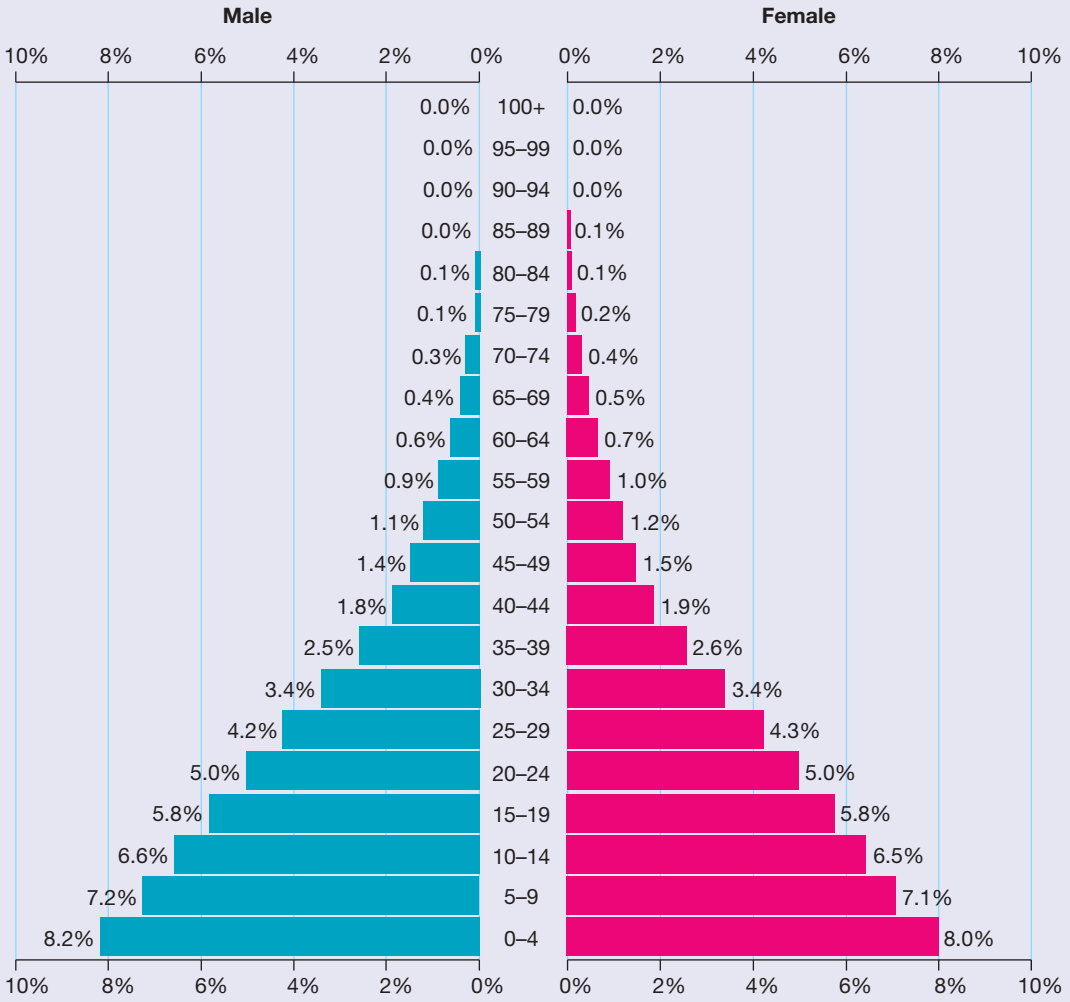
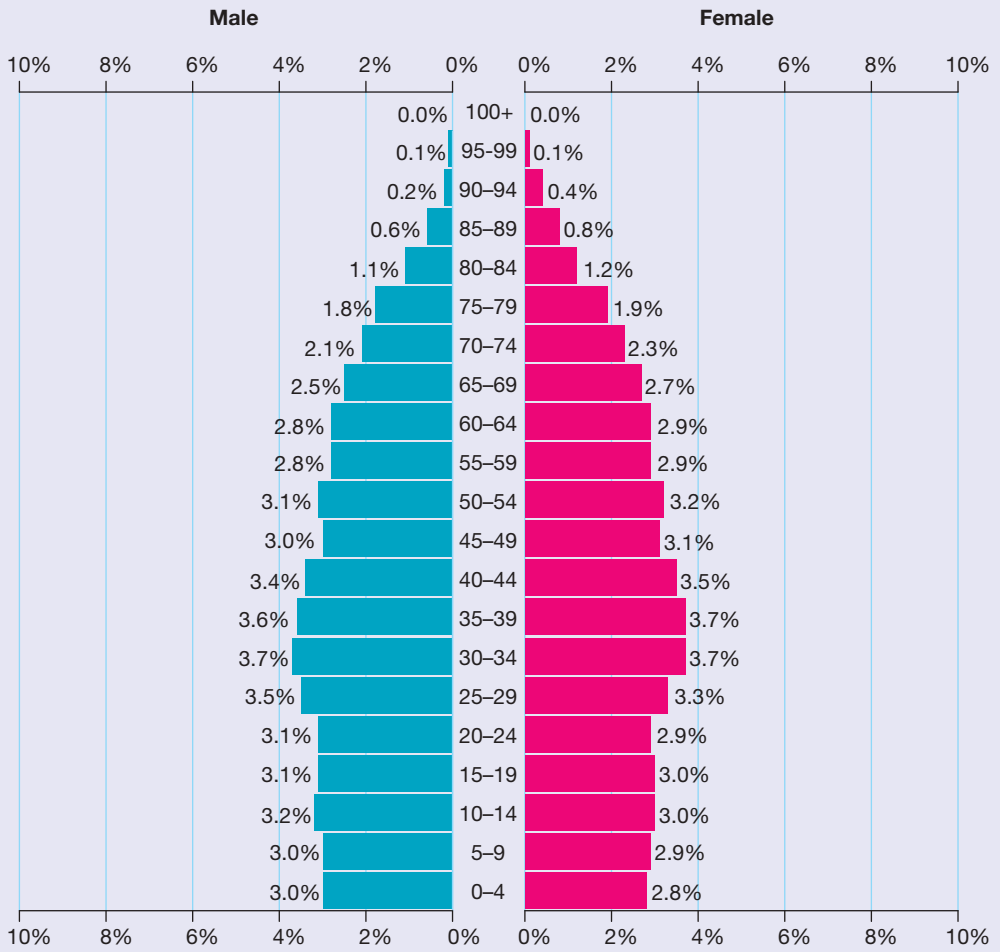


FIGURE 4.16 Australia population pyramid, 2024



4.2 Exercise

4.2 Exercise

Learning pathways

LEVEL 1	LEVEL 2	LEVEL 3
1, 3, 8	2, 4, 6, 9	5, 7, 10

These questions are even better in jacPLUS!

- Receive immediate feedback
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Explain and comprehend

1. **Identify** the three main factors that determine population size and composition.

Analyse and apply

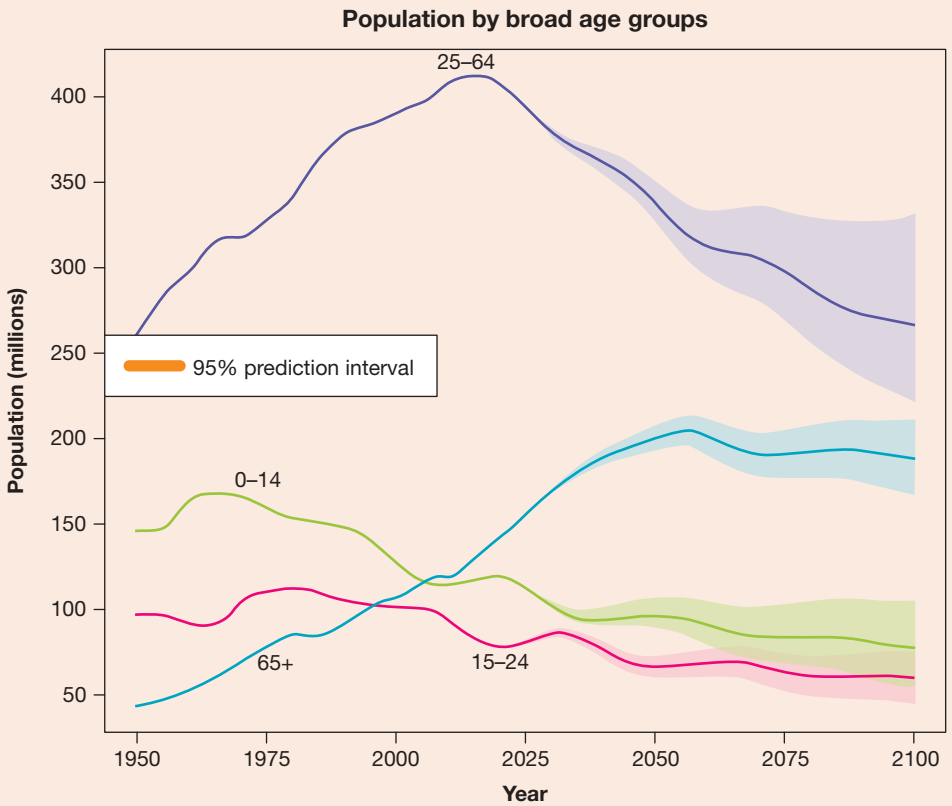
2. Study figure 4.2. **Describe** the growth of world population in relation to the annual growth rate. Suggest reasons for the patterns you have described.
3. Study figure 4.3. **List** the world regions in rank order according to their share of global population in 1820, 1950 and 2024. **Explain** how the rank order for the five world regions has changed since 1820.

4. Study figure 4.3. **Compare** the growth of Asia's population since 1820 with one of the other world regions. How is Asia's pattern of demographic growth similar and different?
5. Study figure 4.6. **Identify** which countries have a fertility rate of less than 2.1. **Outline** the possible implications for the countries below the fertility rate of 2.1 and those above?
6. **Explain** why the population pyramid for Uganda (figure 4.15) is indicative of a fast-growing population.
7. With the aid of figure 4.15, **explain** the likely impact of increased female participation in the workforce and increased urbanisation on Uganda's population growth.
8. Using figure 4.14, **explain** how the population characteristics in Malaysia are expected to change between 2000 and 2070.

Propose and communicate

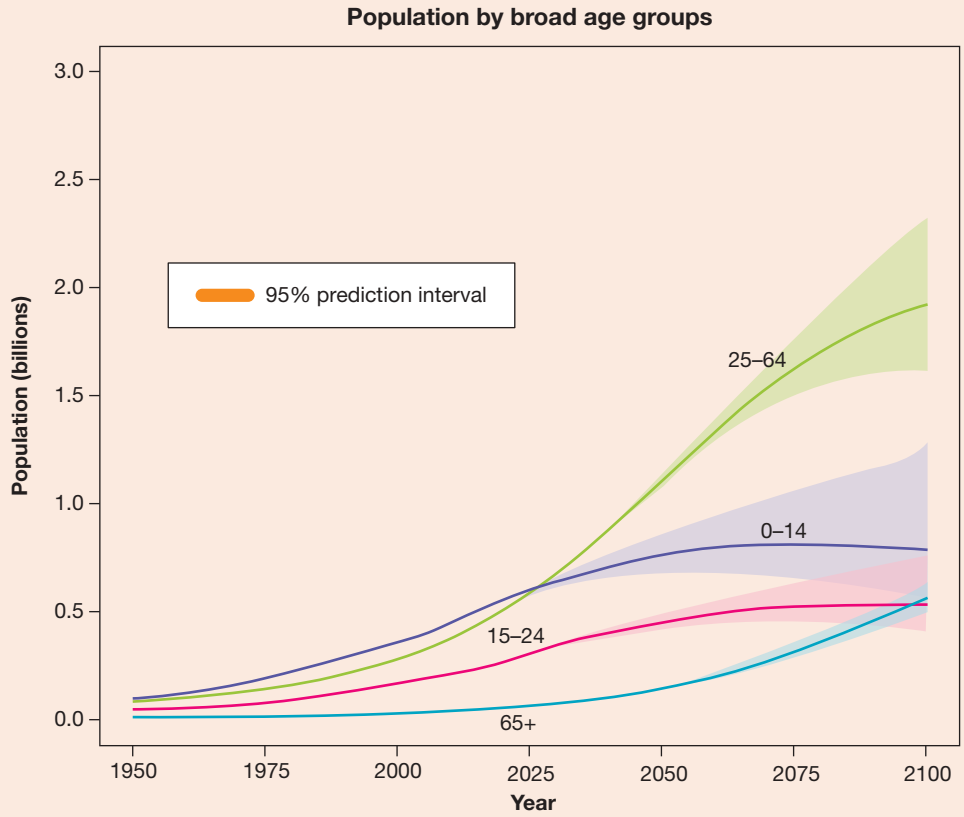
9. **Explain** why a country's population may still continue to grow, despite the fertility rates falling below replacement level.
10. Study figures 4.17 and 4.18.
    a. **Identify** the predicted demographic trends shown for each region.
    b. With reference to figure 4.18, **explain** why the population in Africa will continue to grow despite fertility rates falling below replacement level.
    c. With reference to figure 4.17, **explain** why Europe will see a decline in population by 2100.

FIGURE 4.17 Europe, population by broad age group



Source: World Population Prospects — Population Division — United Nations

FIGURE 4.18 Africa, population by broad age group



Source: World Population Prospects — Population Division — United Nations

Sample responses for this chapter are available online.

LESSON

4.3 Theories of population growth and economic development

LEARNING INTENTION

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

- explain how population trends and characteristics have been described over time using models, and decide whether these are still applicable to describe contemporary and projected population changes.

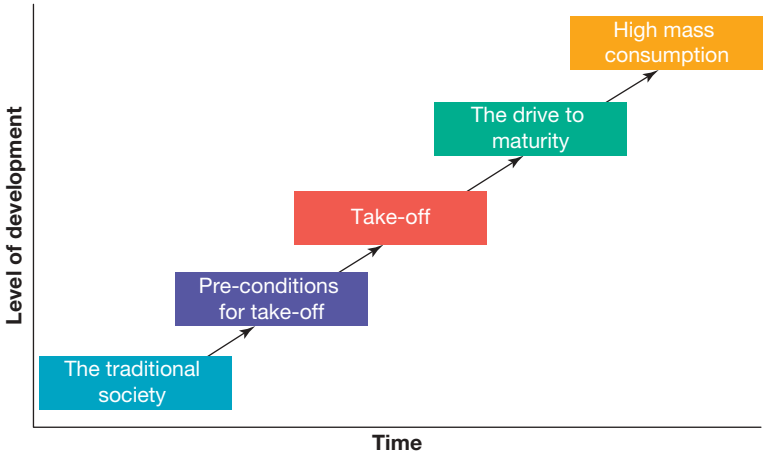
4.3.1 Rostow's Stages of Growth model

Modernisation theory was developed in the mid-twentieth century primarily to provide an alternative to communism as a solution to poverty in the developing world. It touched on the link between population growth and economic development, and argued that low-income countries needed to follow the same economic path as developed countries. In other words, they needed to follow the Western development process and industrialise.

modernisation theory developed in the mid-twentieth century with the aim of showing that low-income countries needed to follow the same path to development as Western countries

The most well-known modernisation theory was developed in 1960 by Walt Rostow, an American economist. Rostow's five stages of economic growth outlined the evolutionary process, lasting about 60 years, that countries would move through after initial capital investment (see figure 4.19).

FIGURE 4.19 Rostow's Stages of Growth model



Rostow believed that every country would lie somewhere on his development spectrum and, during the process of economic development, would progress through each stage. These stages had specific characteristics, shown in table 4.1.

TABLE 4.1 Characteristics of each stage in Rostow's Stages of Growth model

Stage	Description
Traditional society	Labour-intensive agrarian economy, relatively static population with limited technology
Pre-conditions for take-off	Western development aid and investment assist improvements in agriculture and economic infrastructure, and encourage further overseas investment; improvements in life expectancy and declining death rates
Take-off	Short industrialisation period of rapid economic growth, and new urbanised entrepreneurial and middle class; high demographic growth and migration from rural areas to industrial cities
Drive to maturity	Long period of increasing standards of living; a diversifying economy leads to social changes such as later marriage and slowing population growth
High mass consumption	Highly urbanised consumer economy

DID YOU KNOW?

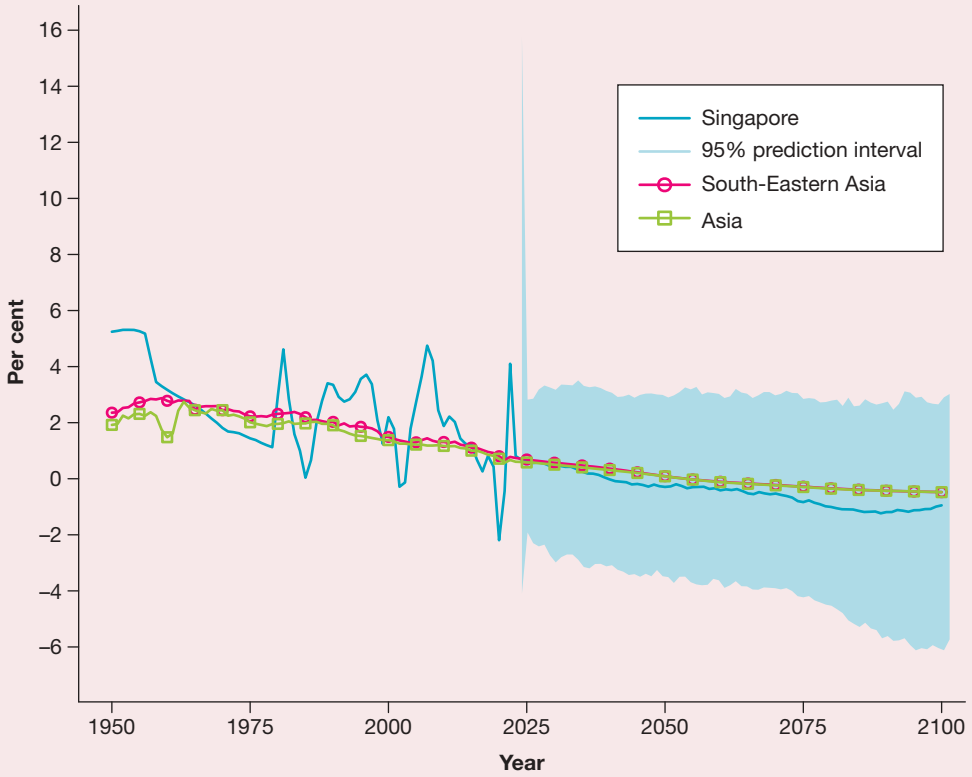
Rapid population growth can drive economic development — but only when infrastructure and services keep pace. In many developing nations, expanding urban populations create new markets, increase labour supply, and attract foreign investment. However, without sustainable planning, this growth can also lead to overcrowding, inequality, and environmental stress. The balance between population and infrastructure is key to long-term prosperity.

cumulative causation the snowballing of positive benefits associated with the establishment of new economic activity in a place. The newly established activity attracts associated economic activity, which in turn attracts further activity.

EXAMPLE: Singapore and the Rostow Stages of Growth model

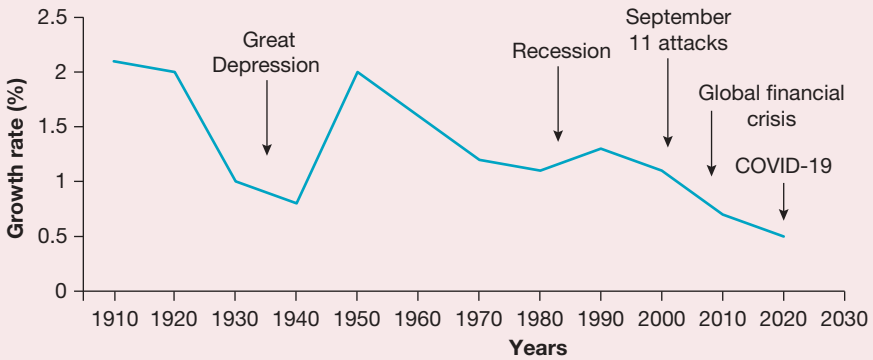
Following Singapore's independence from Britain in 1959, the country has seen the kind of economic development predicted by the Rostow model. In turn, this has had an impact on their population growth. With financial direct investment (FDI) flowing into the country, Singapore invested in infrastructure and basic industry. By the 1970s, they started to diversify and focus on the service industries. As the economy grew, their birth rates and death rates decreased, slowing population growth (see figure 4.20). This aligns with Rostow's predictions of development and the population growth trends seen in the United States (see figure 4.21). Singapore could now be said to be in Rostow's fifth stage of economic growth — the stage of high mass consumption.

FIGURE 4.20 Annual rate of population change in Singapore



Source: United States Census Bureau

FIGURE 4.21 Population growth for the United States, 1910–2020



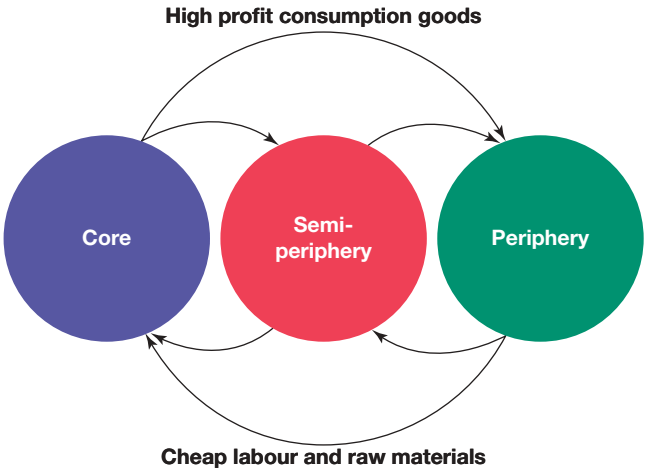
Source: United States Census Bureau

FIGURE 4.22 Singapore is now in the stage of high mass consumption

4.3.2 Wallerstein's World-Systems theory

In 1974, Immanuel Wallerstein's *The Modern World System* was published. Wallerstein was an American sociologist who produced a theoretical framework to explain how the modern capitalist world economy evolved from the age of feudalism to the present day. Wallerstein argued that, through international trade, a world economic system had developed with increasing economic and social disparities. He identified three different types of region, which each possessed certain political, economic and demographic characteristics (see figure 4.23).

FIGURE 4.23 Wallerstein's three different types of region



These regions and their characteristics are as follows:

- **core** refers to technologically advanced countries such as the United States that export capital intensive products to the semi-peripheral and peripheral regions.
- **semi-peripheral** refers to second-tier industrialised countries such as Brazil that are not as advanced as those of the core.
- **peripheral** are agricultural countries, such as those found in Africa, that export labour and commodities to the core and semi-peripheral regions.

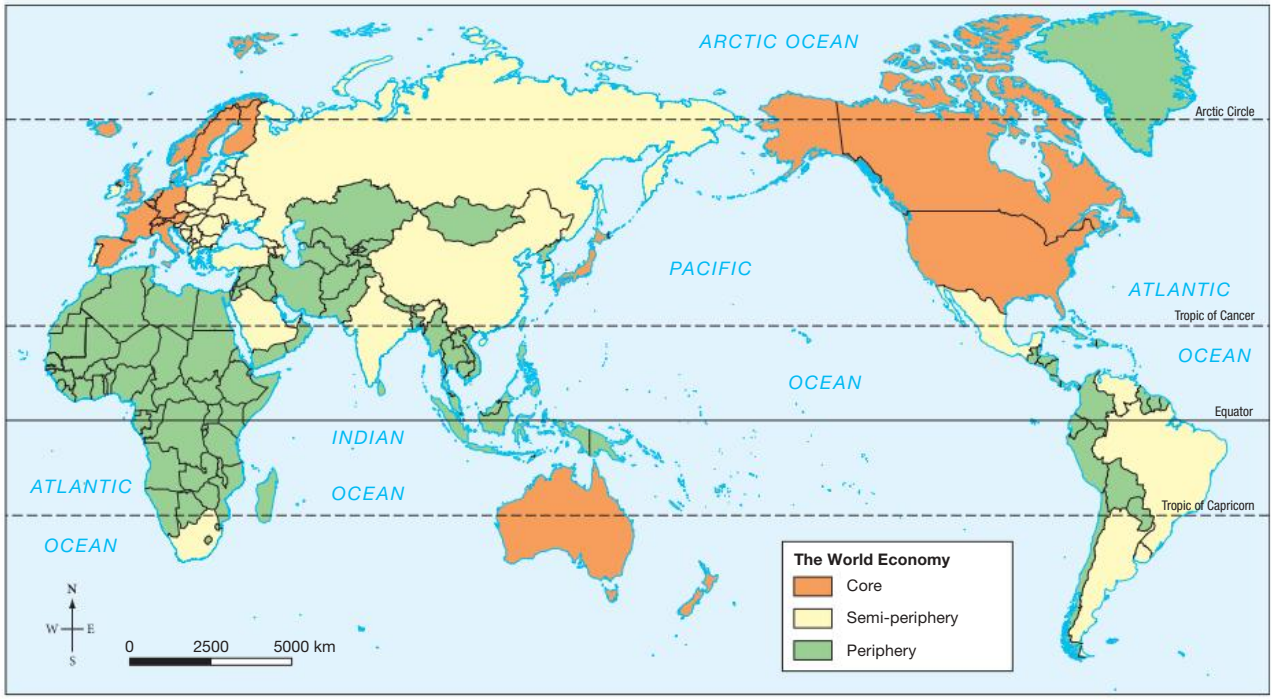
core describes the advanced economic core of a country or region surrounded by the less economically developed periphery

semi-peripheral second-tier industrialised countries

peripheral agricultural countries

Wallerstein's theory focused on trade between countries. The collapse of feudalism in Europe ushered in a new world economy with empires, initiating a flow of raw materials from the periphery to the north-west European core region. The economies of this core diversified, and a wealthy merchant class emerged. Over time, this wealthy class provided the necessary capital for industrialisation, leading to the Industrial Revolution. When South America, Asia and Africa entered the world system in the nineteenth century, they were peripheral zones. However, investment in the peripheral and semi-peripheral zones during the twentieth century encouraged the development of industry in these regions, allowing some countries to transition to the semi-periphery. Today, many African nations remain in the periphery, supplying raw materials to the semi-periphery countries, which manufacture goods for the core.

FIGURE 4.24 Wallerstein's world regions



Source: Erin H. Fouberg, Alexander B. Murphy, Harm J. de Blij, Figure 8.10, Human Geography: People, Place, and Culture, 9th Edition, John Wiley & Sons.

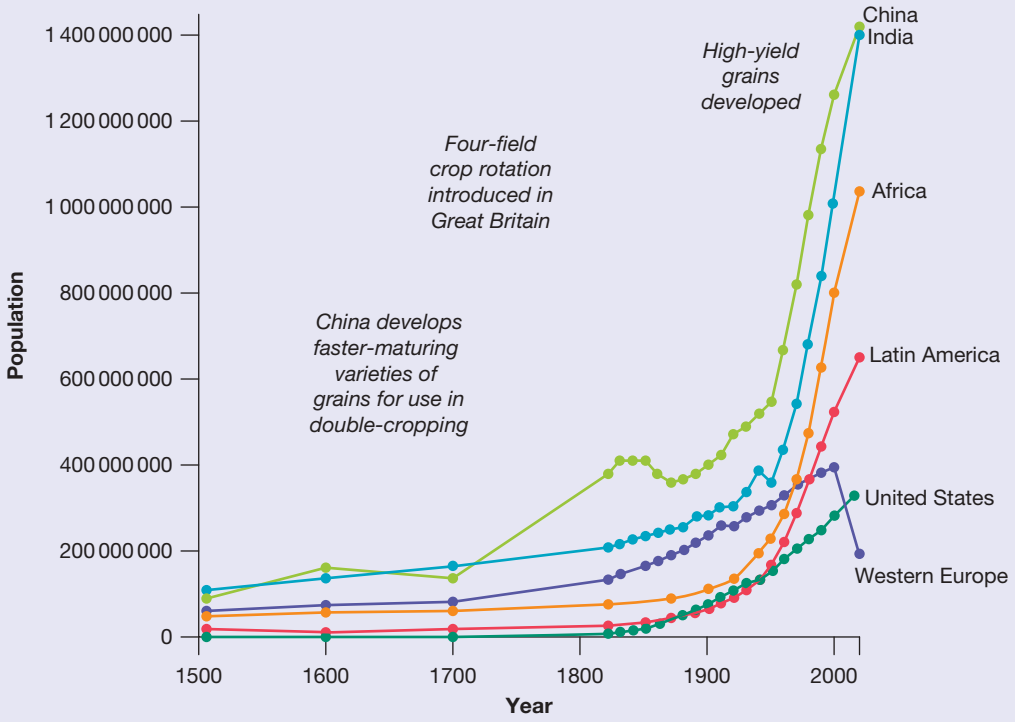
SKILLS ACTIVITY: Compare and interpret different maps

A **curvilinear relationship** is a relationship between two or more variables that is depicted graphically by anything other than a straight line. These relationships are variable, more complex and less easily identified than simple linear relationships, where the ratio of change is constant. At the higher ends of each variable in a curvilinear relationship, little variation exists, whereas at the lower end more variability is seen.

curvilinear relationship relationship in a correlation that is more complex than a simple linear relationship. In the higher ends of each variable in a curvilinear relationship, there is little variation, whereas at the lower end there is more variability.

Figure 4.25 shows population growth for selected countries and regions. Up until the 19th century, the growth levels were low; however, with developments in industry and science during the nineteenth and particularly twentieth centuries, accelerated growth is seen in all regions.

FIGURE 4.25 Population growth of selected countries and regions, 1500–2000



1. Study figure 4.25. Compare the pattern of population growth during the period 1500–2020 between the following.
   i. Western Europe and the United States
   ii. Latin America, India and China
2. a. With the aid of Excel and using data from table 4.2, create a scattergraph to examine the correlation between population growth and economic development for the sample of 20 countries.
   b. Refer to the information on curvilinear relationships and interpret your result.

TABLE 4.2 GDP per capita versus total fertility rate

Country	GDP per capita ($US PPP), 2023	Total fertility rate, 2022
Australia	69 115	1.5
Bolivia	10 727	2.5
Brazil	20 584	1.6
Burundi	950	4.9

(continued)

TABLE 4.2 GDP per capita versus total fertility rate *(continued)*

Country	GDP per capita ($US PPP), 2023	Total fertility rate, 2022
China	24 557	1.0
Czechia	53 816	1.4
Ecuador	15 870	2.2
France	61 156	1.6
Ghana	7466	3.9
India	10 175	2.0
Indonesia	15 612	2.2
Liberia	1819	4.0
Malaysia	37 247	1.6
Netherlands	78 215	1.4
Niger	1817	6.1
PNG	4607	3.1
Thailand	23 423	1.0
Türkiye	44 151	1.5
United Kingdom	58 906	1.6
United States	81 695	1.6

Source:

4.3.3 The Demographic Transition model

In the early twentieth century, Warren Thompson, an American demographer, observed changes in population growth rates in the United States and other countries for which census data was available. He subsequently used the birth and death rate data to devise a threefold classification of countries according to their rates of natural change. The categories he grouped countries into are as follows:

- countries with high birth and death rates
- countries with declining and therefore lower death rates
- countries with low birth and death rates.

According to Thompson, countries transitioned from having high birth and death rates to low birth and death rates as they became increasingly industrialised and democratic.

In the 1950s, another American demographer, Frank Notestein, was credited with refining Thompson's theory of population transition. The **Demographic Transition model**, as it is now known, has four distinct phases and has been a useful tool for analysing patterns of population dynamics. However, the birth rate of some countries in the developed world, particularly in Europe, has become so low that natural change is negative. Without an influx of migrants, the populations in these countries would decline. Some experts now suggest that these countries are indicative of a fifth stage in the transition model. These five stages are summarised in table 4.3. Example demographic transitions for five countries are shown in figure 4.26.

Demographic Transition model describes how changes in population growth respond to relative differences in birth and death rates, which themselves change over time

TABLE 4.3 The updated five stages of the Demographic Transition model

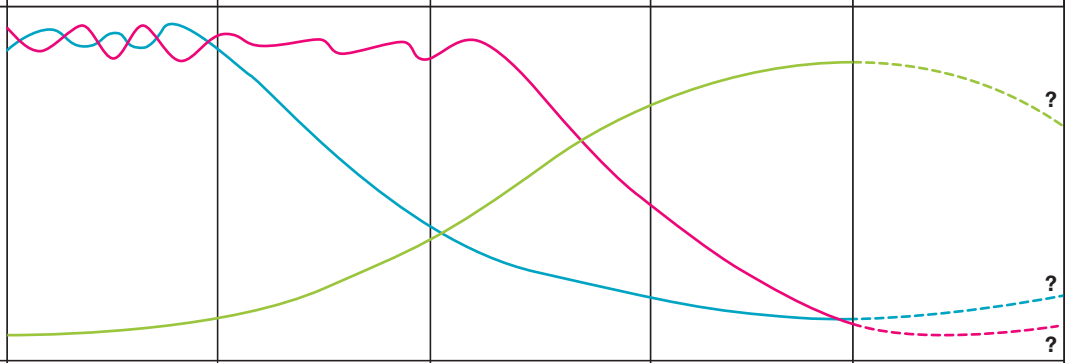
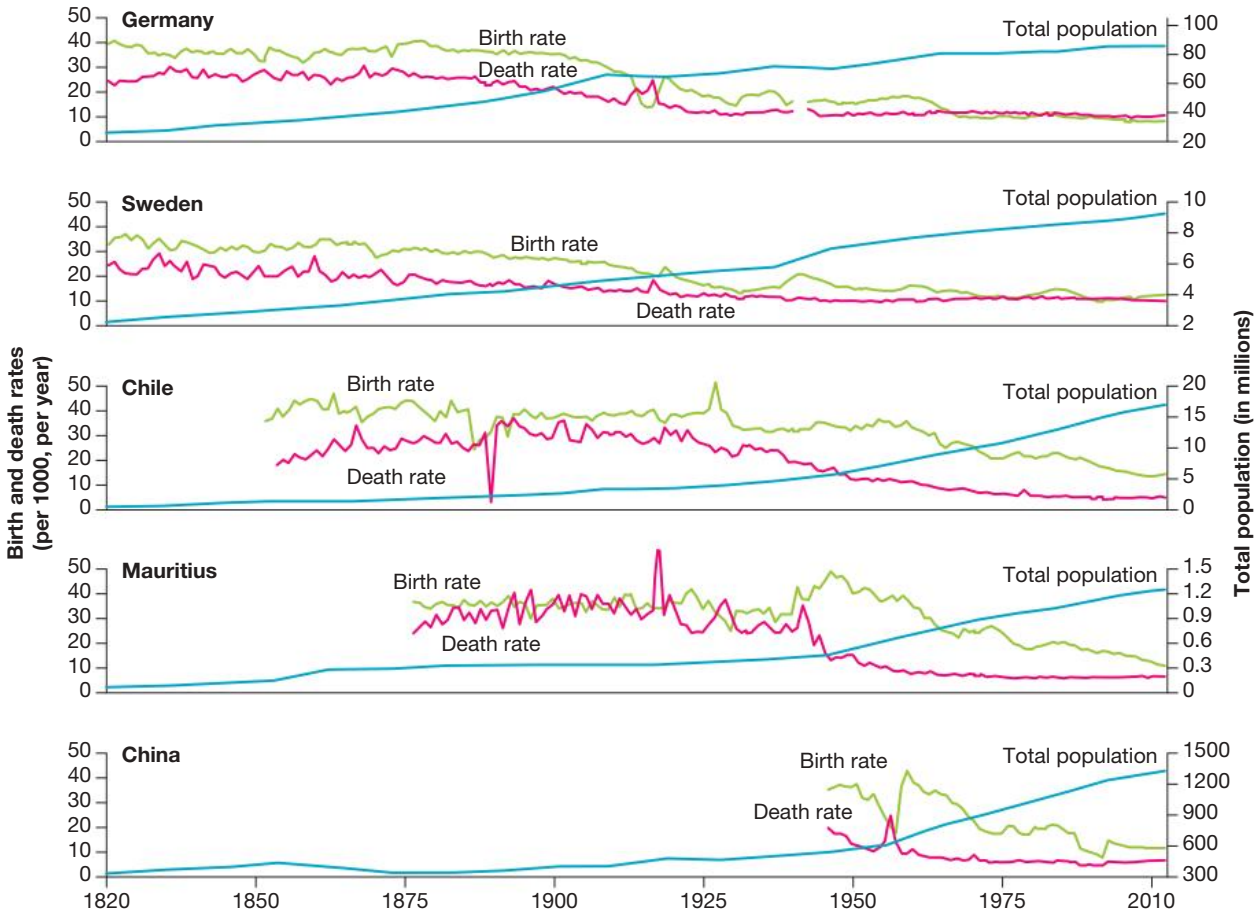
Stage	1	2	3	4	5
Population pyramid					
Descriptor	High stationary	Early expanding	Late expanding	Low stationary	Declining
Key Death rate Birth rate Population					
Birth rate	High	High	Falling	Low	Very low
Reasons for birth rate	High due to: • Lack of family planning • High Infant Mortality Rate: putting babies in the 'bank' • Need for workers in agriculture • Religious beliefs • Children as economic assets		Birth rate falls due to: • Family planning available • Lower Infant Mortality Rate • Increased mechanisation reduces need for workers • Increased standard of living • Changing status of women	Birth control is widely available and there is a desire for smaller families. Women more likely to have education & careers. Later marriages.	May drop to well below replacement level
Death rate	High	Falling rapidly	Falling slowly	Low	Low
Reasons for death rate	High due to: • High levels of disease • Famine • Lack of clean water and sanitation • Lack of health care • War • Competition for food from predators such as rats • Lack of education	Falling due to: • Improved health care (e.g. Smallpox Vaccine) • Improved Hygiene (Water for drinking boiled) • Improved sanitation • Improved food production and storage • Improved transport for food • Decreased Infant Mortality Rates	Death rate stays at low level		Remain consistently low or increase slightly due to increases in lifestyle diseases like obesity, stress and diabetes.
Natural change	Stable, or slow increase	Very rapid increase	Still rises rapidly due to population momentum	Stable, or slow increase	Slow decrease
Example countries	**Isolated tribes in the Amazon**	**Afghanistan, Haiti, sub-Saharan Africa**	**Mexico, Philippines, Indonesia, Malaysia**	**United States, UK, France, Argentina, Australia**	**Germany, Italy, Japan, Russia, South Korea**

FIGURE 4.26 The demographic transition of five selected countries



Source: https://ourworldindata.org/birthrates/deathratesandtotalpopulationforselectedcountries/years

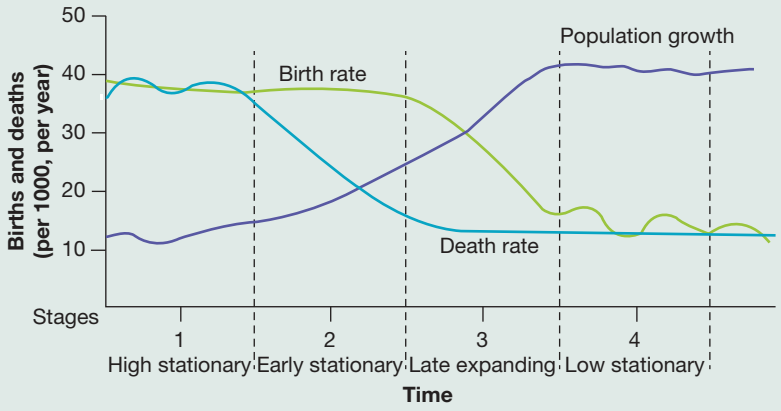
CASE STUDY: Population trends in the United Kingdom

Quick facts: United Kingdom

- **Population** 70 million
- **GDP per capita** US$59 000
- **Life expectancy** 81
- **Fertility rate** 1.6
- **Rate of natural increase** 0.1 per cent

The British population increased slowly until around 1800. Prior to this, poor diet, famines, wars and diseases restricted population growth. Both birth and death rates were high, due to the bulk of the population living in rural areas, high rates of infant mortality and families needing to be self-sufficient to survive. Furthermore, the Black Death, which spread across Europe in the mid-fourteenth century, is estimated to have wiped out half of the British population.

FIGURE 4.27 Population growth in the United Kingdom, aligned with the original four stages of Notestein's Demographic Transition model

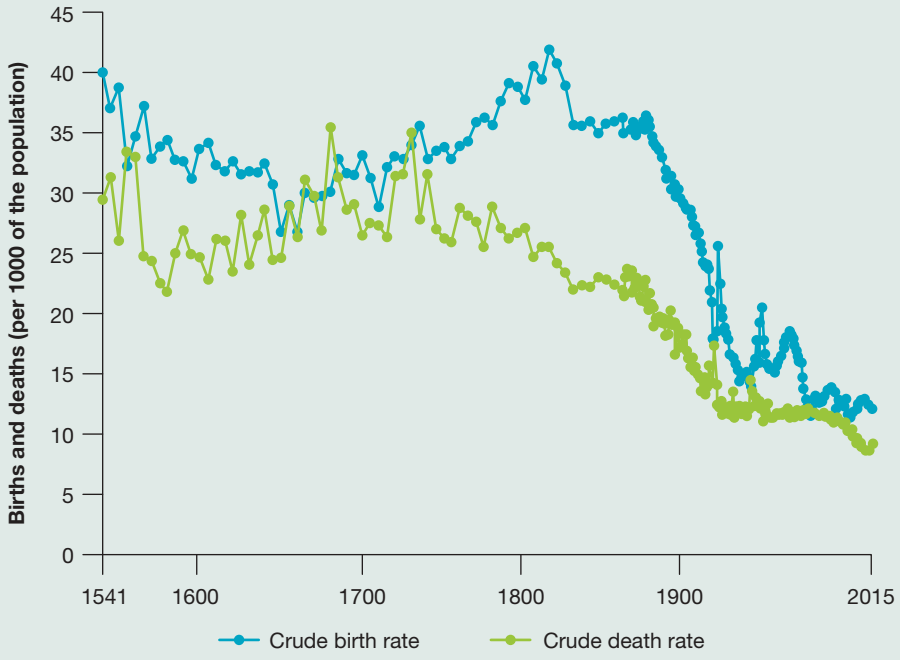


Industrialisation and **urbanisation** in the 1800s brought about important, although slow, changes to public health and food supply in Britain, which helped to bring down the death rate and increase life expectancy. The consequence of this was rapid population growth. However, falling birth rates in the 1900s, as a result of changing social attitudes and conditions such as the emancipation of women, led to a slackening of population growth. This decline was later furthered by access to contraceptives and the changing role of women in a previously male-oriented workforce. At the same time, the development of medicines, such as antibiotics to combat disease, helped to reduce death rates and increase life expectancy. Despite birth and death rates remaining low in recent decades (see figure 4.28), the UK population has continued to grow, largely through **net migration**. In 2024, the total population of the United Kingdom reached 69 million.

urbanisation an increase in the total population or the percentage of a country's population living in urban areas

net migration the number of immigrants minus the number of emigrants

FIGURE 4.28 The demographic transition in England and Wales



Source: Our World in Data

Rostow's Stages of Growth model and Wallerstein's World-Systems theory are early theories about economic development and population with a focus on the economic system. The Demographic Transition model then used demographic data to classify countries. However, this model doesn't adequately account for the shrinking population in some developed countries. These models represent early thinking about population; a more contemporary model is discussed in 4.7.4.

4.3 Exercise

4.3 Exercise

Learning pathways

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 3	4, 5, 7	6, 8, 9

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Explain and comprehend

1. **Identify** the reasons for birth rate in a country to fall.
2. Study figure 4.26. For each country or region, **identify** which stage of the Demographic Transition model they were in in 2010.
3. **Suggest** reasons a country may be in the fifth transition stage.
4. **Explain** why few places in the world are still in stage 1 of the Demographic Transition model.
5. **Outline** what Rostow's Stages of Growth' model states
6. **Explain** the relationship between economic development and population growth, referring to Rostow's model in your response.

Analyse and apply

7. Study figure 4.24. **Describe** the distribution of the core and periphery countries according to Wallerstein's World-Systems theory and suggest reasons for this pattern.
8. Study figure 4.24 and compare to a world map showing GDP per capita. **Explain** whether Wallerstein's concept of core and periphery remains relevant.

Propose and communicate

9. **Outline** whether you think all countries need to pass through each stage of the Rostow model to reach the fifth stage of high mass consumption. Give reasons for your answers.

Sample responses for this topic are available online.

LESSON
4.4 An ageing world

LEARNING INTENTION

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

- analyse geographic data represented in maps and graphs to infer how the patterns and trends represent specific challenges at global, regional and local scales, and identify relationships and implications for people
- identify and describe current or future responses to population change.

4.4.1 Declining fertility and increasing life expectancy

Many parts of the world have witnessed increasing life expectancy and falling fertility rates, which has led to an ageing population. This means the proportion of older people in a population is increasing. The UN has estimated that by 2050 the proportion of the world's population aged 60 and over will have doubled since 2015, to be an estimated 2.1 billion. This translates into every major region in the world, except Africa, having at least a quarter of its population aged 60 and over. Europe has already reached this figure. Table 4.4 shows the current percentage of the population over 65 in different macro regions around the world, and the predicted 2050 percentage, while table 4.5 shows data for developed countries versus other developing countries and least developing counties. Figure 4.29 shows the current and predicted percentage of people over 65 versus children under five.

TABLE 4.4 Percentage of population 65 years of age and over, 2023 and 2050

Macro-region	2023	2050
Africa	5.4	8.9
Asia	11.6	24.6
Europe	23.9	34.2
South America and the Caribbean	11.2	25.5
Oceania	16.5	23.3
North America	20.8	28.3
World	12.3	21.5

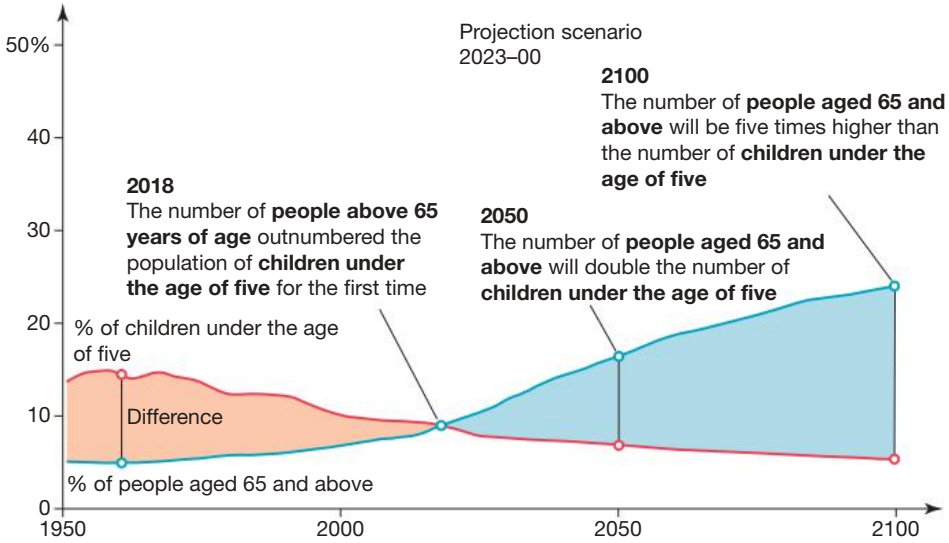
TABLE 4.5 Number (in thousands) and proportion of persons aged 65 years and over by development group, 2023 and 2050

Region/year	*2023*		*2050*	
	Number	*Percentage*	*Number*	*Percentage*
Developed countries	258 311	20.2	351 500	27.8
Other developing countries	506 841	9.0	1 132 877	17.4
Least developing countries	42 637	3.7	118 566	6.1

***Source**: World Population Ageing 2023* (United Nations)

The older population is growing at a faster rate in urban areas than in rural areas. Globally, between 2000 and 2018, the number of people aged 60 years and over increased by nearly 70 per cent in urban areas, whereas the increase in rural areas was only 25 per cent. This means that older persons are increasingly concentrated in urban areas.

FIGURE 4.29 Global population share of children under the age of five versus the global population of people over the age of 65



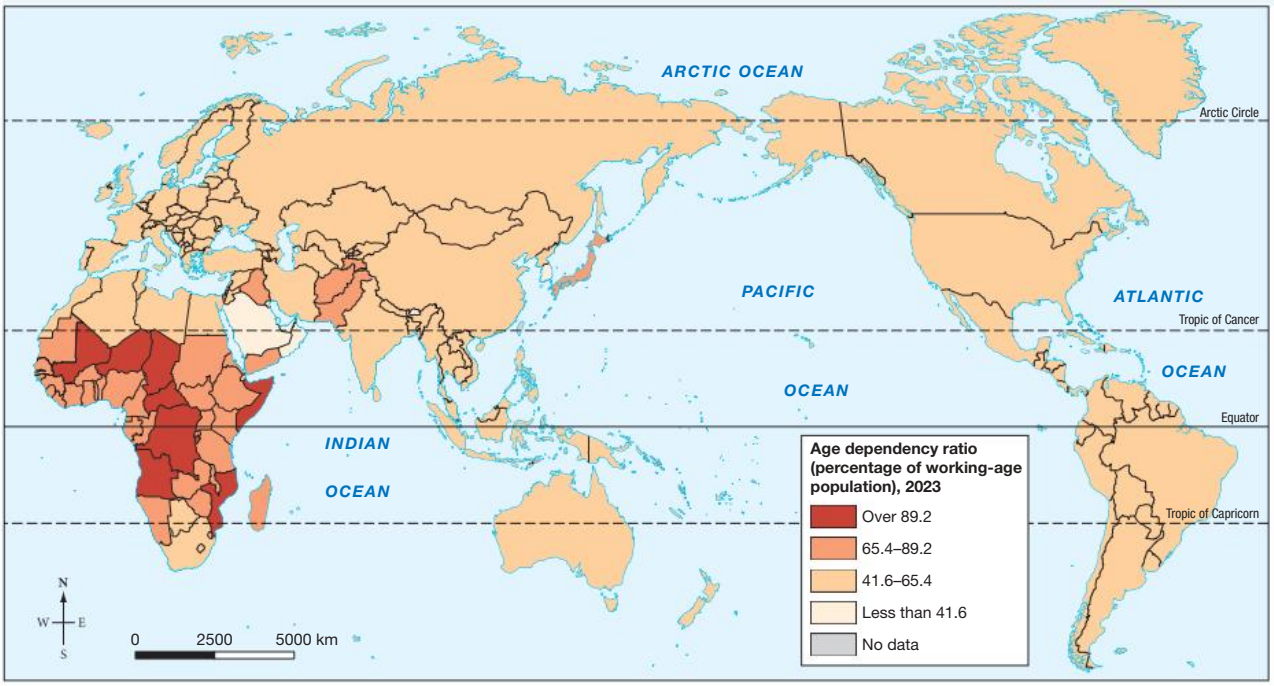
Source: https://www.visualcapitalist.com/cp/charted-the-worlds-aging-population-1950-to-2100/

4.4.2 The challenges of an ageing population

Life expectancy is a key indicator of development, reflected in the United Nations Development Program's Human Development Index. An ageing population often signifies successful development. In 2024, the global life expectancy was 73 years, with significant disparities across countries.

The dependency ratio measures dependants (under 15 and over 64) compared to working-age people, highlighting economic burdens on workers. High fertility rates in Africa result in a higher young dependency ratio, while developed countries face higher old dependency ratios.

FIGURE 4.30 Age dependency ratio, young



Source: The World Bank: Age dependency ratio: Data source: United Nations Population Division's World Population Prospects: 2024 Revision. Map drawn by Spatial Vision. https://data.worldbank.org/indicator/SP.POP.DPND.YG?view=map>

Japan, with an old age dependency ratio of 51.43 per cent, has the highest proportion of elderly due to its reduced birth rate, low-fat diet and national healthcare program. This poses challenges for government resources. Australia's old dependency ratio stands at 26.6 per cent, with aged care costs expected to double to $40 billion by 2028. Countries fund social security payments through taxes, and may raise the pension age to manage costs. In Australia, the pension age is 67, though many continue working beyond that age.

4.4.3 Ageing populations in China and Japan

Demographic transition in China

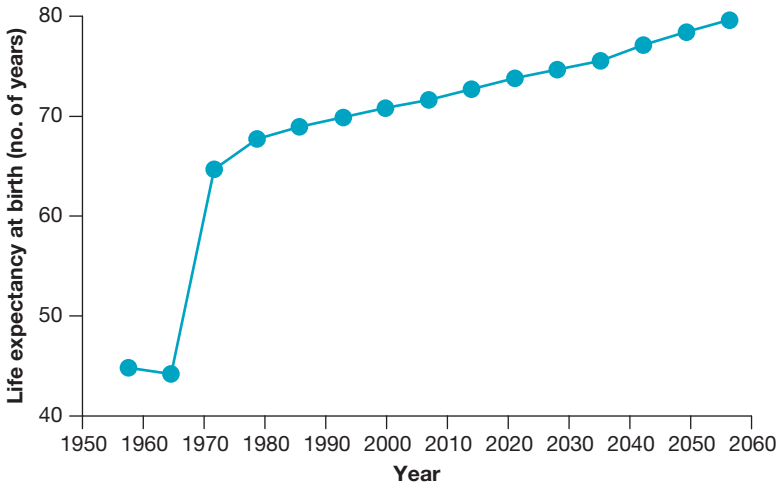
The People's Republic of China was founded in 1949. Little reliable data is available on the Chinese population before this time and, consequently, it is not possible to accurately determine when the death rate began to decline and when stage two of the Demographic Transition model started. What we do know is that not long after the launching of The Great Leap Forward in 1958, the birth rate plummeted and the death rate spiked. The Great Leap Forward was an ambitious but short-lived project conceived by leader Mao Zedong to modernise the centrally planned Chinese economy. The aim was to boost both farm and industrial production by a series of major reforms using labour-intensive methods. This involved the development of small backyard steel furnaces in every village and urban neighbourhood, and the controversial forced movement of villagers into agricultural collectives or farming communes. Although initially successful, production failures such as in the grain harvest led to a widespread and devastating famine. The death rate spiked, especially among infants and the elderly.

The mortality rate returned to a declining pattern when food production improved and life expectancy increased (see figure 4.32). Further increases can be attributed to social improvements — notably education, the expansion of primary healthcare services, which included the formation of so-called barefoot doctors during the late 1960s, and childhood immunisation programs against diseases such as tuberculosis, polio and measles.

FIGURE 4.31 An aged Chinese farm labourer

Source: Michael Morrish

FIGURE 4.32 Life expectancy in China, 1950–2050



The one-child policy

China's one-child policy was established by Chinese leader Deng Xiaoping in 1979 to restrict population growth. As its name suggests, it was designed to limit couples to only one child. Public posters throughout China reminded its citizens of the government policy (see figure 4.33). Couples who did not comply faced fines and possible sterilisation of the female partner if found guilty of a subsequent pregnancy. However, the one-child policy only affected about a third of Chinese households, largely restricted to the ethnic Han Chinese living in urban areas.

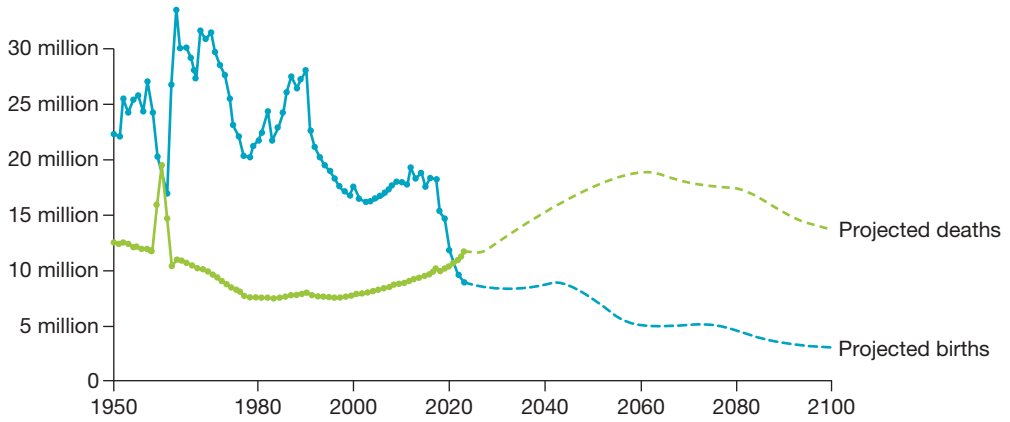
FIGURE 4.33 Public poster promoting the one-child policy in China

Source: Michael Morrish

The policy was abandoned in 2015. Although credited with successfully curbing population growth, the country's fertility rate was already falling before the policy began. Furthermore, the policy has been held responsible for creating today's gender imbalance. Nationally, the male to female ratio in China is 106:100, but in the under 25 age group it is 114:100. Given the Chinese cultural preference for male heirs, the one-child policy was blamed for sex-selective abortions and even infanticide of female infants.

After 30 years of the one-child policy, China now faces the problems of a shrinking workforce and an increasingly ageing population. According to the Chinese National Bureau of Statistics, the total working population, aged between 15 and 64 years, has been falling since 2014. Meanwhile, the proportion of the population aged 65 and older has increased to more than 11 per cent. Increased life expectancy in China is partly responsible for growth in the elderly population. The ageing population is a phenomenon that is particularly acute in some cities and in the heavy industrial areas of China. The Shanghai Population and Family Planning Committee, for example, predicted that by 2020 more than a third of Shanghai's population would be over 60. Figure 4.34 shows tracked and predicted birth and death rates for China.

FIGURE 4.34 Birth and death rates in China, 1950–2100



China's dependency ratio for those aged 65 and older is rising. It was 20 per cent in 2024 and the UN has estimated that this could rise as high as 44 per cent by 2050. This ratio is important because it is an indicator of the number of dependants each person of working-age will, on average, need to support. Average life expectancy will have reached 80 years by 2050 (see figure 4.32).

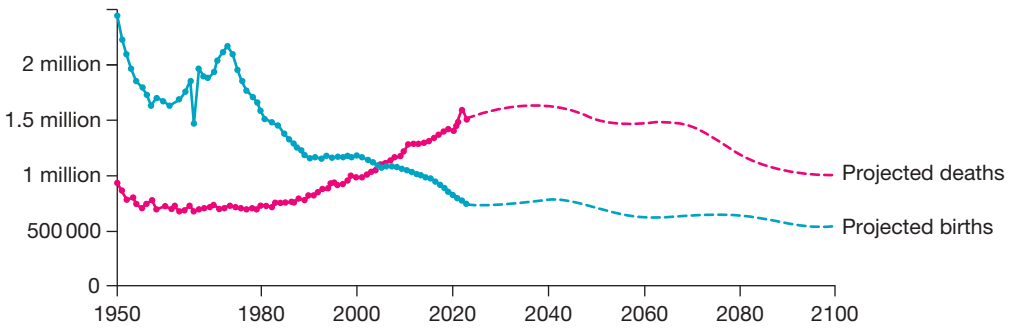
China's total fertility rate is currently 1.0 births per woman, which is well below the replacement level of fertility. This means that the population will be declining unless more people are migrating to China than leaving China. However, the quota for permanent residence permits is limited.

Demographic transition in Japan

Japan has been experiencing a decline in population growth since the end of World War II. In the late 1940s, population growth dropped to the replacement level of about 2.1 children per woman. This has been primarily attributed to declining rates of childbearing among married couples. Japan's fertility transition in the mid-1970s marked the beginning of absolute population decline associated with what some demographers believe is an additional fifth stage of the Demographic Transition model. The latest phase in Japanese population change has been associated with decreasing rates of marriage. Delayed marriage appears to have resulted, in part, from employment conditions. As the number of women with higher education has grown, so have their employment opportunities. At the same time, male employment rates have declined, which has impacted on men's marriage prospects. Coupled together, these two factors have contributed to the decline in the number of marriages and, therefore, the national fertility rate.

Japan has one of the highest rates of life expectancy in the world at 84 years; however, the number of births continues to fall year on year (see figure 4.35).

FIGURE 4.35 Birth and death rates in Japan, 1950–2100



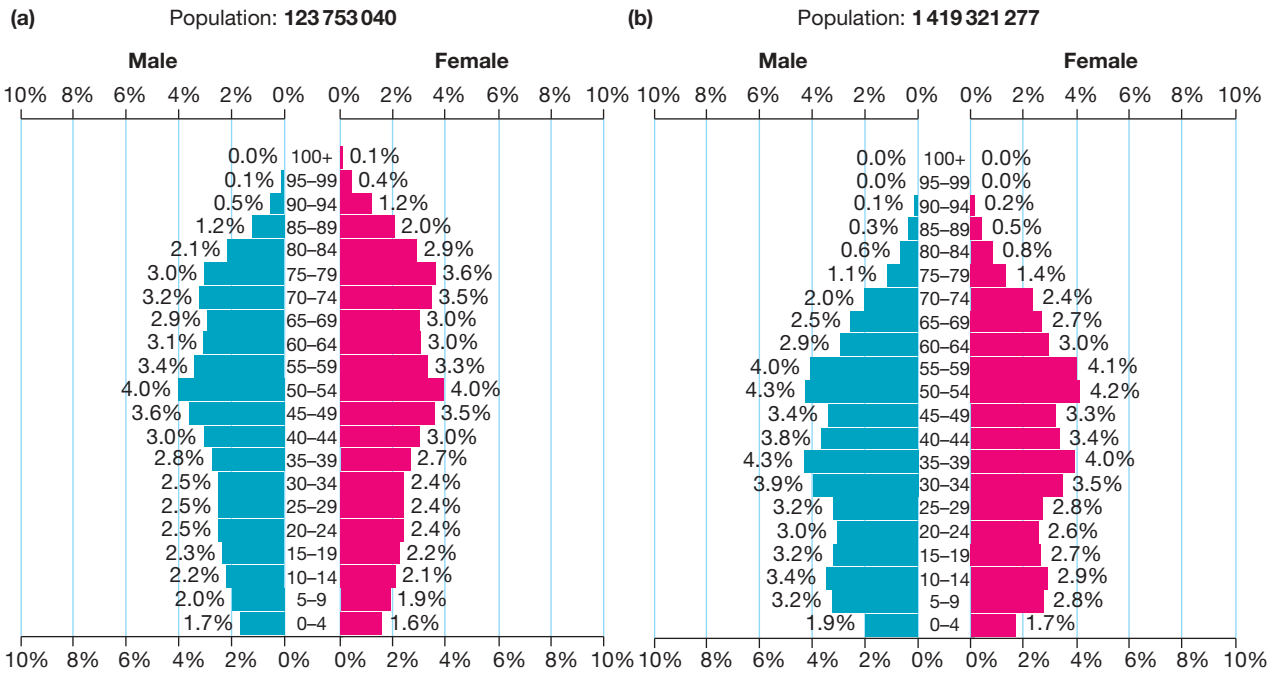
The Japanese Ministry of Health, Labour and Welfare is examining ways to improve support for younger generations of married Japanese couples in employment. Japanese corporate culture has never made it easy for married women to achieve a good work–life balance, particularly surrounding maternity. Since the mid-1990s, the government has encouraged the provision of more childcare services, helping to stabilise the fertility rate between 1.2 and 1.4. In 2023, Japan introduced the Children's Future Strategy, aimed at increasing financial support for parents and encouraging men to take up childcare leave. Japan has one of the best parental leave systems in the world, with paid paternity leave of 50 weeks, but uptake remains low.

The Japanese Government has sought a number of further solutions, which include:

- making access to childcare easier for women, to allow them to return to work after their child is born
- raising GST by 2 per cent to help offset the spiralling cost of its social security and health services
- considering a reduction in the tax burden for part-time employees and making interest-free loans available for higher education.

FIGURE 4.36 'Silver Zone' traffic safety for the elderly sign on Naoshima Island, Japan

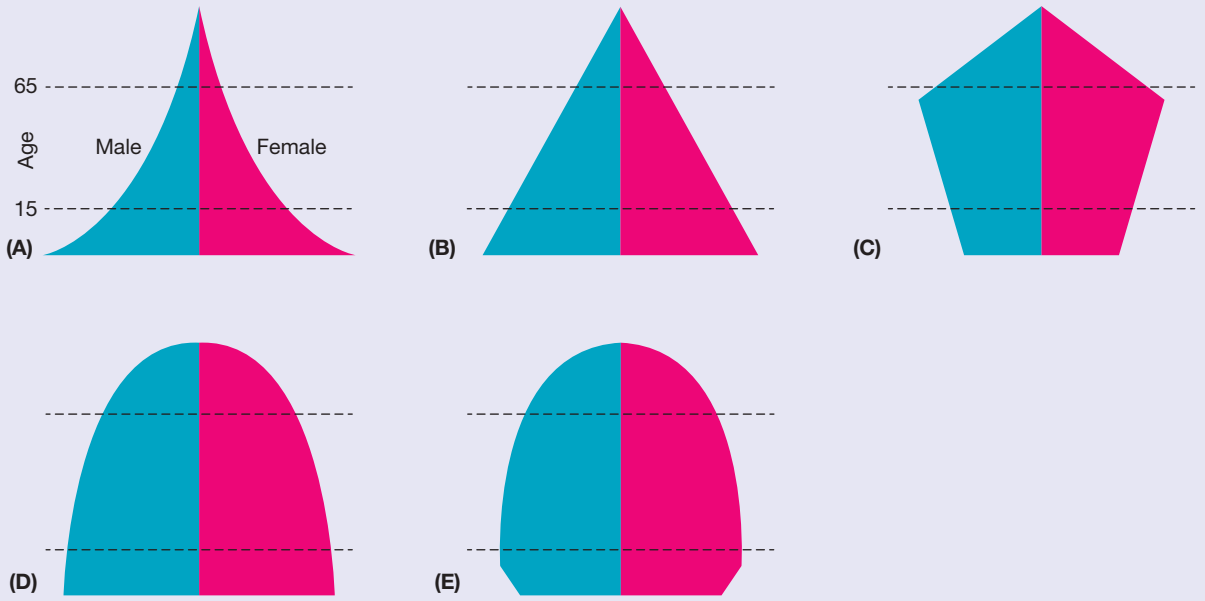
FIGURE 4.37 Population pyramids for (a) Japan and (b) China, 2024



Source: PopulationPyramid.net

SKILLS ACTIVITY: Identifying trends

FIGURE 4.38 Population pyramids



1. **a.** Using data from table 4.6, construct a double line graph for Japan.
   b. Compare the changes in total fertility and population growth between China and Japan.
   c. Explain the similarities and/or differences between the two countries.

TABLE 4.6 Fertility rates and population growth in China and Japan, 1950–2015

Year	China		Japan	
	Fertility rate (%)	Population growth rate (%)	Fertility rate (%)	Population growth rate (%)
1950	6.0	2.0	3.5	+1.8
1955	5.4	1.9	2.5	+1.1
1960	6.2	1.8	2.0	+0.9
1965	6.2	2.4	2.1	+0.9
1970	4.7	2.7	2.1	+1.1
1975	3.0	1.8	1.9	+1.6
1980	2.5	1.3	1.7	+0.8
1985	2.7	1.4	1.8	+0.6
1990	1.9	1.5	1.5	+0.3
1995	1.5	1.1	1.4	+0.4
2000	1.5	0.8	1.3	+0.2
2005	1.6	0.6	1.3	+0.0
2010	1.6	0.5	1.4	+0.0
2015	1.6	0.5	1.4	-0.1

Source: United Nations Statistics Division, 2017

2. Refer to the data in table 4.7, which shows the change in dependency rates in China and Japan since 1960.
   a. Construct a double line graph to show changes in the dependency ratios of China and Japan, 1960–2015.
   b. Compare the change in total dependency between China and Japan since 1960.
   c. Explain the link with fertility trends shown in your answer to question 1.

TABLE 4.7 Dependency ratios in China and Japan, 1960–2015

Year	China	Japan
1960	76	56
1965	80	47
1970	79	45
1975	78	47
1980	68	48
1985	56	47
1990	52	43
1995	51	44
2000	46	47
2005	38	50
2010	36	56
2015	38	64

Source: © 2019 The World Bank Group

4.4 Exercise

4.4 Exercise

Learning pathways

LEVEL 1	LEVEL 2	LEVEL 3
1, 4, 6	2, 7, 9, 10	3, 5, 8

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Explain and comprehend

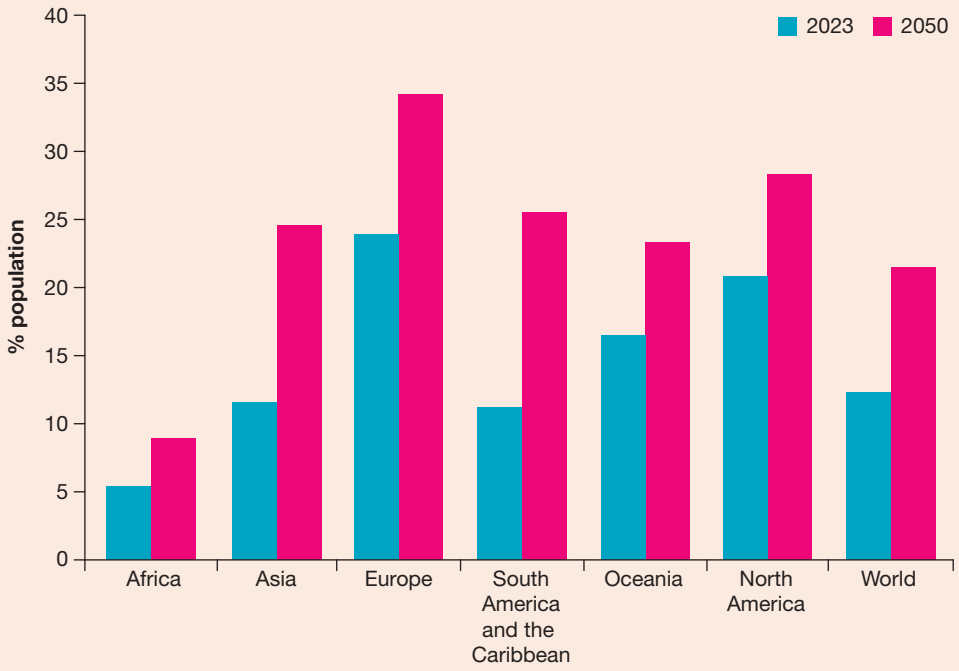
1. **Define** dependency ratio.
2. **Explain** the difference between old dependency ratio and young dependency ratio.
3. Use figure 4.30 to **describe** the main patterns of age dependency across the world. What reasons can you apply to explain these patterns?

Analyse and apply

4. **Identify** reasons for Japan's low fertility rates.
5. **Explain** how the one-child policy contributed to China's shrinking workforce.

6. Study figure 4.39.
   a. **Describe** the regional differences in the percentage of the population over 65 years in 2023.
   b. **Explain** how the regional pattern is expected to change by 2050 in terms of differences in growth between the regions.

FIGURE 4.39 Percentage of the population over 65 years



Propose and communicate

7. **Compare** the population pyramids for Japan and China shown in figure 4.37. **Explain** what the two pyramids tell us about each country's future age structure.
8. With reference to figure 4.32, **explain** China's demographic transition from 1950 to 2050.
9. **Identify** challenges that a country with a high old dependency ratio faces.
10. **Suggest** ways that a country could prepare for an ageing population.

Sample responses for this chapter are available online.

LESSON
4.5 Patterns of changing population distribution and density

LEARNING INTENTION

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

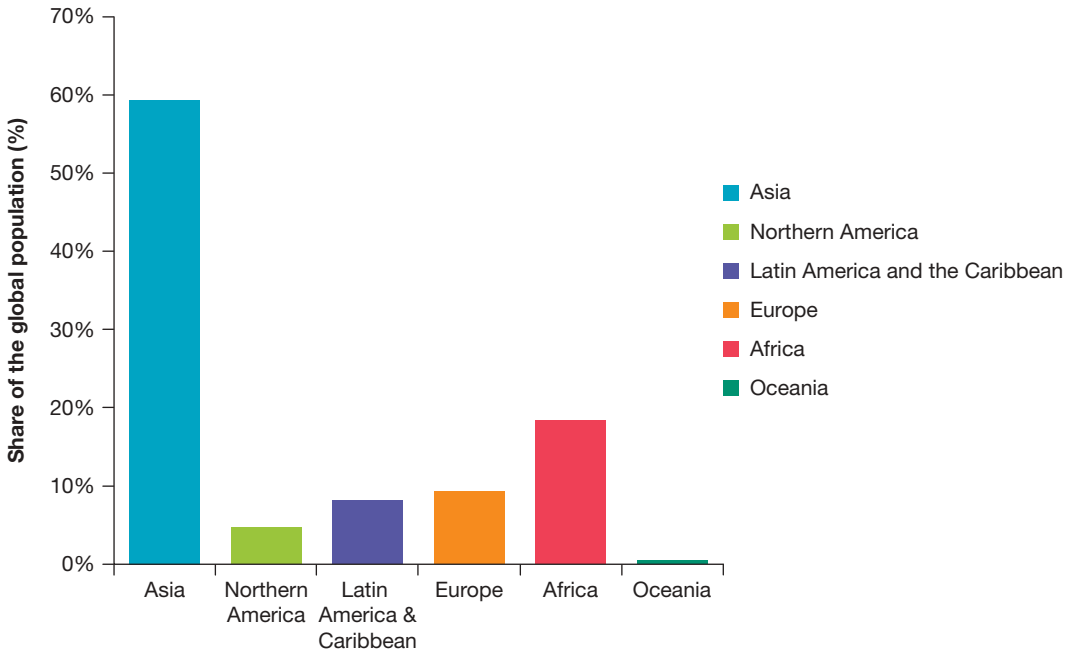
- recognise current population distribution and density, represent global population patterns in maps and graphs using spatial and information and communication technologies, identify relationships and implications for people, and describe current or future responses to population change.

4.5.1 Factors influencing population distribution

Over time, physical, political and socioeconomic factors have influenced both the distribution and density of the world's population. At one end of the spectrum are the densely populated regions, which include the highly urbanised and industrial regions of north-west Europe, north-east United States and Canada, and the agricultural heartland of Asia. At the other extreme lies the high latitude and high altitude regions, which include the frozen polar north and continent of Antarctica, the mountainous belts of the Andes, Rockies and Himalayas, and the hot desert zones of Saharan Africa and central Australia.

The staggering growth of the global population has been accompanied by significant shifts in its geographical distribution. According to the UN, developing countries accounted for about two-thirds of the world's population in 1950, but by 2030 this figure is expected to have increased to 85 per cent. Since 2000, 95 per cent of the world's population growth has occurred in developing countries. (See figures 4.40 and 4.41 for more on the distribution of the global population.)

FIGURE 4.40 Distribution of the global population by continent

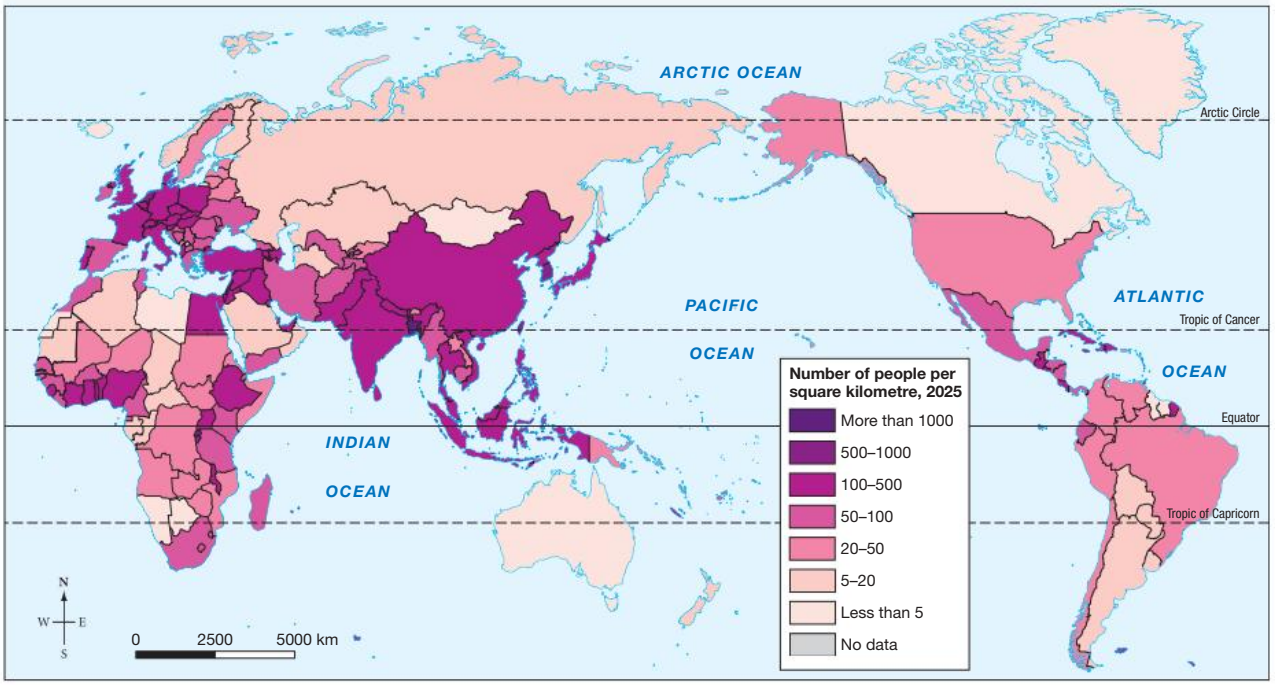


Source: Created by John Wiley & Sons based on statistics from United Nations 2024

4.5.2 Physical factors affecting population distribution

Global population distribution is heavily influenced by climate and topography (see figure 4.41). Areas with more temperate climates, such as Europe, tend to have higher populations, as temperate climates usually have reliable water sources and are more conducive to producing food. Land around rivers and volcanic areas, such as in Indonesia, tends to have more fertile land, and therefore higher population density. Areas with rugged terrain, such as the Himalayas, have lower populations due to the difficulties with farming and traversing the land. Generally, the further you are from the equator, the lower the population density, with the exception of the desert zone.

FIGURE 4.41 World population distribution



Source: HYDE (2023); Gapminder (2022); UN WPP (2024); UN FAO (2024)—with major processing by Our World in Data. Map drawn by Spatial Vision.

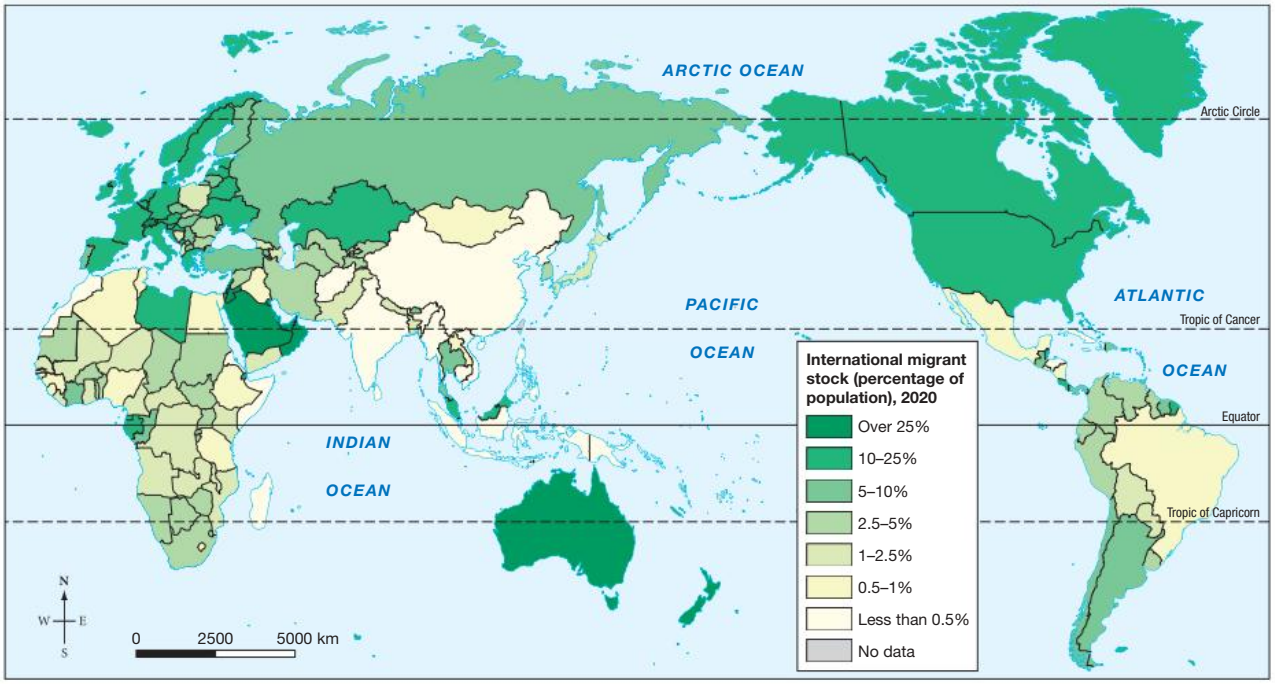
4.5.3 Other factors affecting population distribution

By 2020, more than 280 million people were living in a country other than their country of birth, altering the patterns of population distribution and density within regions. The 2022 United Nations International Migration Report estimated that international migrants as a proportion of the world's population had increased from 2.8 per cent in 2000 to 3.6 per cent in 2020.

Moreover, most of the growth in the global population of international migrants has been caused by movements towards high-income countries. This trend is expected to continue as a result of increasing connectivity, continued regional inequalities and demographic imbalances.

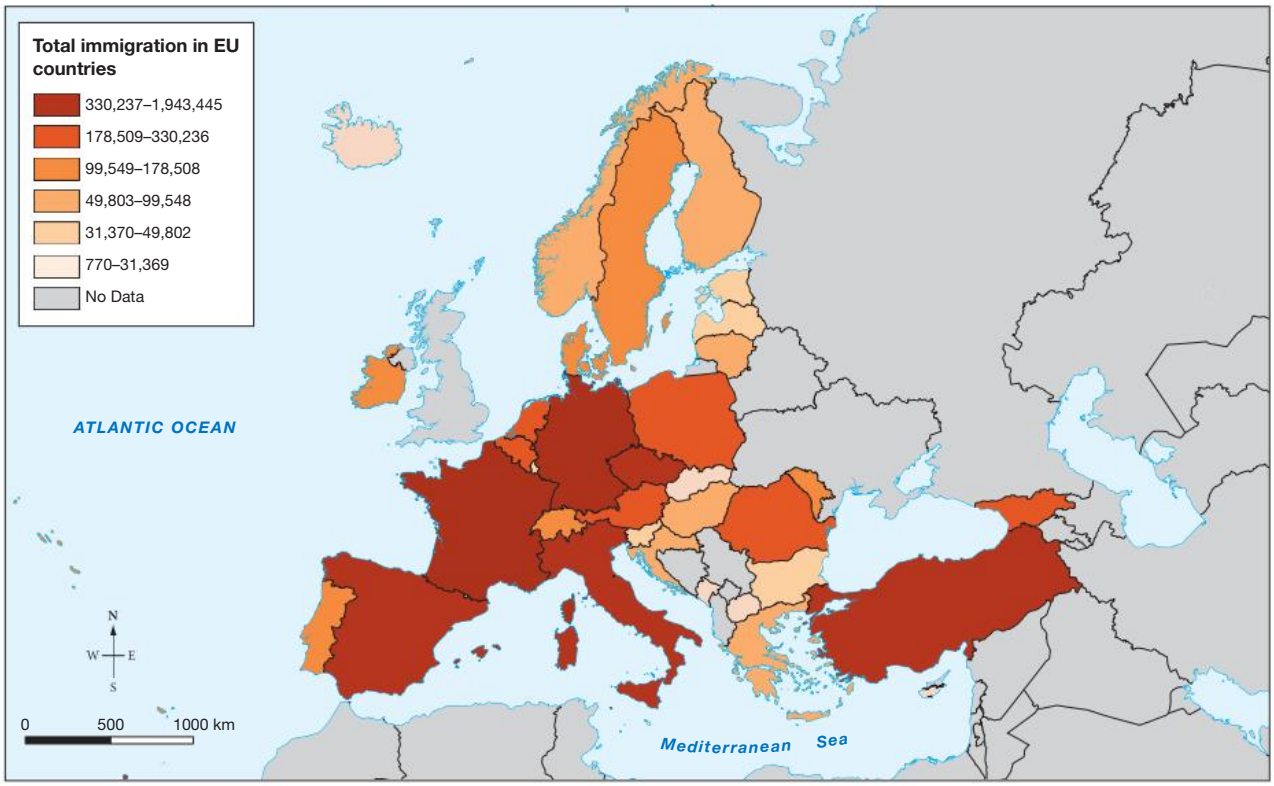
Although different regions have general trends in population distribution, individual countries can also have patterns and variations in population distribution. The distribution and density of population within countries also reflects the political and socioeconomic factors that influence world population trends. For example, in China a major demographic divide exists between the west and the east. Provinces to the east of the Heihe–Tengchong line account for a third of the country's land area but are home to more than 90 per cent of the country's total population. The eastern provinces offer many more employment opportunities, attracting people from the inland areas, which have harsher environmental conditions and lower socioeconomic opportunities. Unequal population distribution is also evident in countries following political challenges, such as Cambodia.

FIGURE 4.42 Share of a country's population that is born in another country, 2020



Source: United Nations Department of Economic and Social Affairs (2020)—with minor processing by Our World in Data. Map drawn by Spatial Vision.

FIGURE 4.43 Total immigration in European Union countries



Source: Eurostat © European Union, 1995—2025. Map drawn by Spatial Vision.

CASE STUDY: Cambodia — measuring unequal distributions

Quick facts: Cambodia

- **Population** 18 million
- **GDP per capita** US$8100
- **Life expectancy** 71
- **Rate of natural increase** 1.4 per cent

Located in South-East Asia (see figure 4.45), Cambodia was once part of the French colony of Indochina, gaining its independence in 1953. Bisected by the Mekong River, Cambodia is physically dominated by its extensive and fertile central lowlands, on which two-thirds of the country's 16 million inhabitants live.

FIGURE 4.44 Cambodia's rural landscape

In the 1970s, Cambodia's population distribution changed significantly. Many people migrated to Phnom Penh to escape the Vietnam War. In 1975, the Khmer Rouge, led by Pol Pot, aimed to create a communist agrarian utopia by forcing over a third of the population from urban to rural areas to establish collective farms. This regime resulted in an estimated death toll of one to three million people.

Vietnam invaded Cambodia in 1978, deposing Pol Pot. Post-war, Phnom Penh was repopulated in the 1980s by rural migrants, though property rights were not officially recognised until 1989. Economic reforms and improved infrastructure since 1993 have reduced agricultural employment from three-quarters in 1993 to two-thirds in 2010. High population densities in Phnom Penh, Kampong Cham and Takeo correlate with more industrial enterprises, whereas provinces such as Kratie and Stung Treng have low densities and fewer industries.

Growing competition for land and natural resources in rural areas has led to an increasing number of forced evictions. In 2012, thousands of people in Koh Kong province were relocated to new villages in the mountains to make way for a Chinese resort development. The US$3.8 billion tourism project stretches across 45 000 hectares of pristine coast along the Gulf of Thailand.

FIGURE 4.45 Cambodia borders Thailand, Laos and Vietnam

Source: Made with Natural Earth. Free vector and raster map data @ naturalearthdata.com.

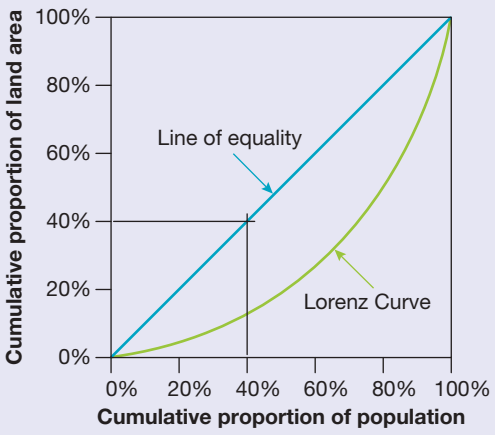
SKILL ACTIVITY: Interpreting graphs

The Lorenz Curve

The Lorenz Curve was developed by Max Lorenz to measure the degree of inequality of wealth within a country. It has also proved useful in fields such as geography and ecology, helping to identify uneven distributions of plant species.

The 45° line indicates a perfectly even distribution. All the points along the line are of equal percentages. For example, 40 per cent of the population inhabits 40 per cent of the land area. Therefore, the further away the Lorenz Curve is from the 45° line, the more uneven the distribution.

FIGURE 4.46 Lorenz Curve for a population distribution



Constructing a population distribution Lorenz Curve

To construct a population distribution Lorenz Curve, follow these steps:

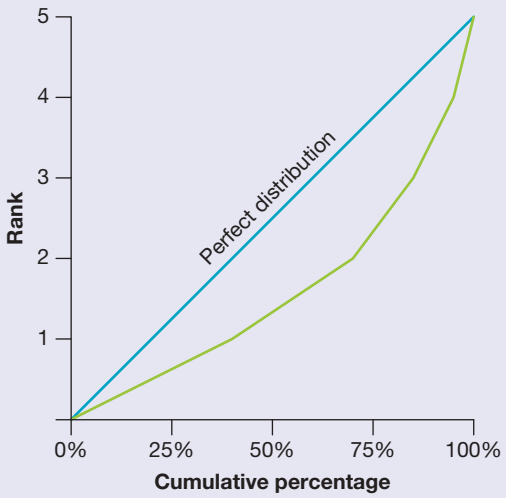
1. Rank the census districts in declining order. The district with the largest population is rank 1, the second largest is rank 2 and so on.
2. Calculate the percentage of people in each district.
3. Calculate the cumulative percentage by adding successive percentages from rank 2 onwards. In the example shown in table 4.8, the cumulative percentage for rank 2 is 40 + 30 = 70 per cent.

TABLE 4.8 Example population distribution data

Census district	Rank	Number of people	Percentage of total population	Cumulative percentage
A	1	800	40	40
B	2	600	30	70
C	3	300	15	85
D	4	200	10	95
E	5	100	5	100
		2000		

4. Plot the cumulative data on the graph against the rank order and join the points.
5. Interpret the graph. The further the Lorenz Curve is from the 45° line (when both axes are of equal length), the more uneven the distribution of population.

FIGURE 4.47 Plotting data on a Lorenz Curve graph



To read the graph and find out how many people live in what amount of the land, start on the *x*-axis, which shows the cumulative proportion of the population, and measure up to the Lorenz Curve. Then measure across to the *y*-axis to find the proportion of land that proportion of people live in. For example, in 1998, 40 per cent of the people lived in 10 per cent of the land. However, in 2008 only 34 per cent of people lived in the same amount of land.

1. Access Gap Minder in the Resources tab. Select Cambodia and look at the trends icon and income per person (GDP).
2. How does this graph help explain the link between changes in population distribution after the conflict with Vietnam and GDP?
3. Using the information provided on the Lorenz Curve and the data in figure 4.48 construct the Lorenz Curve for Cambodia's population in 2023.

4. **a.** Using the data in table 4.9, calculate the cumulative percentage share of population for each province in Cambodia in 2008.
   b. Construct a Lorenz Curve for the 2008 data on the same graph you used for question 3.
   c. How does the distribution in 2008 compare with that of 2023?
   d. Explain why you think the distribution has changed.

Table 4.9 Cambodia's population distribution

Province/Municipality	Population, 2023	Share of total (%)	Population, 2008	Share of total (%)	Land area (km^2)	Share of total (%)	Population, 1998
Mondul Kiri	80 000	0.46	61 107	0.46	14 288	8.03	28 576
Stung Treng	130 000	0.75	111 671	0.83	11 092	6.23	77 644
Koh Kong	125 902	0.73	117 481	0.88	10 090	5.67	121 080
Preah Vihear	250 000	1.45	171 139	1.28	13 788	7.74	124 092
Ratanak Kiri	200 000	1.16	150 466	1.12	10 782	6.06	97 038
Kratié	377 222	2.18	319 217	2.38	11 094	6.23	266 256
Otdar Meanchey	185 819	1.07	185 819	1.39	6158	3.46	67 738
Pursat	435 000	2.52	397 161	2.96	12 692	7.13	355 376
Kampong Thom	681 549	3.94	631 409	4.71	13 184	7.76	540 544
Kampong Chhnang	527 027	3.05	472 341	3.53	5521	3.10	419 556
Siem Reap	1 000 000	5.79	896 443	6.69	10 299	5.78	700 332
Battambang	997 169	5.77	1 025 174	7.65	11 702	6.57	795 736
Pailin	72 000	0.42	70 486	0.53	803	0.45	23 287
Banteay Meanchey	861 883	4.99	677 872	5.06	6679	3.75	581 073
Kampong Speu	877 523	5.08	716 944	5.35	7017	3.94	596 445
Kep	42 665	0.25	35 753	0.27	336	0.19	28 560
Preah Sihanouk	310 000	1.79	221 396	1.65	1938	1.09	172 482
Kampot	593 829	3.44	585 850	4.37	4873	2.74	526 284
Svay Rieng	550 000	3.18	482 788	3.60	2966	1.67	477 526
Kampong Cham	899 791	5.21	1 679 992	12.54	9799	5.50	1 607 036
Prey Veng	1 100 000	6.37	947 372	7.07	4883	2.74	947 302
Takéo	1 000 000	5.79	844 906	6.31	3563	2.00	790 986
Kandal	1 201 581	6.95	1 265 280	9.45	3564	2.00	1 076 328
Phnom Penh	2 281 951	13.21	1 327 615	9.91	294	0.17	999 894
Tboung Khmum	75 000	4.34	13 395 682		178 035		11 421 161

Source: Ministry of Internal Affairs and Communications Statistics Bureau Japan https://www.stat.go.jp/info/meetings/cambodia/pdf/ci_fn02.pdf

Planned migration

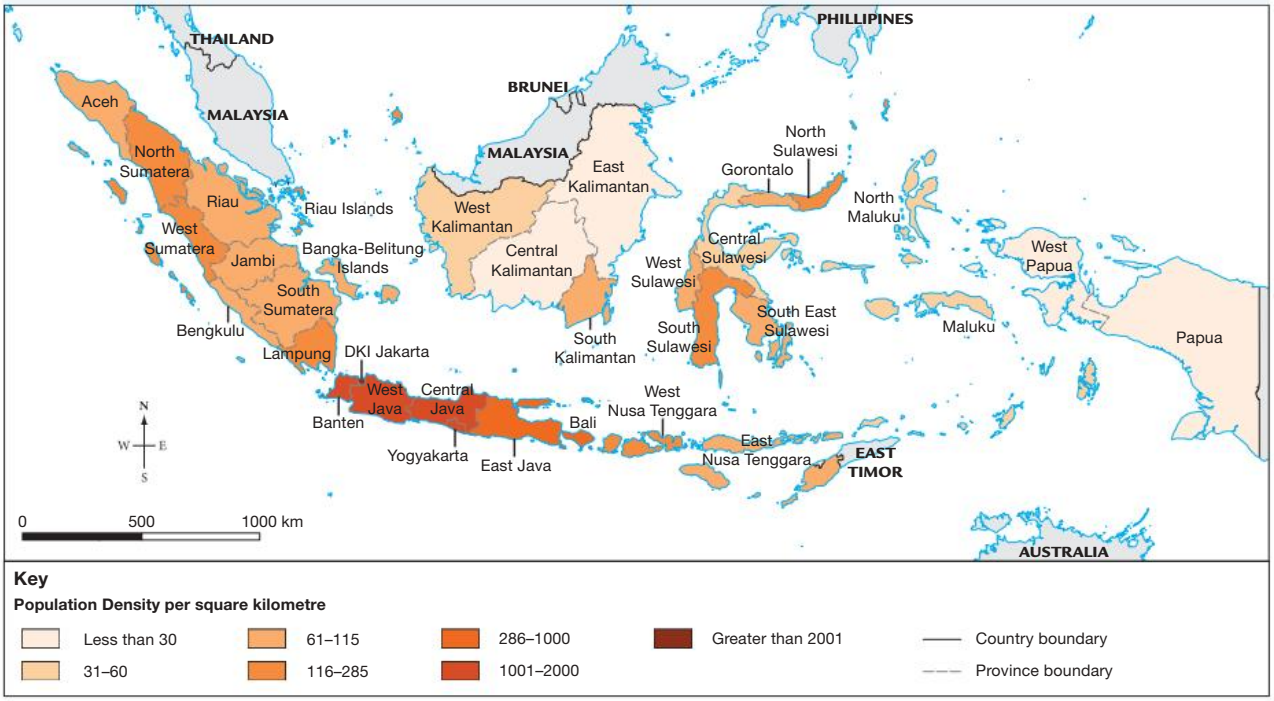
transmigration the coordinated movement of people to better use resources or fill labour shortages, overseen by a government body

Planned migration is usually the coordinated movement of people to better use resources or fill labour shortages. This is overseen by a government body. In 1905, during colonial rule of what is now Indonesia, the Dutch began an experimental program of colonising and developing the outer islands with peasant farmers from the densely populated island of Java. (Figure 4.48 shows the population density in different regions in Indonesia.) This process is known as **transmigration**, and in the case of Indonesia was taken over and expanded by the newly formed Indonesian government after independence in 1949. The Indonesian government's goals were:

- to relieve overcrowding of inner islands such as Java and Bali
- to alleviate poverty by providing land and new opportunities to generate income for poor landless settlers
- to exploit the resource potential of the outer islands.

By the end of the twentieth century, more than 3.6 million Indonesians had been resettled. On arrival, the migrants received houses, land for farming, and a subsistence and production package to help them get started. Most applicants for transmigration were young landless agricultural workers and their families.

FIGURE 4.48 Indonesia's population density



Source: Statistics Indonesia and Asian Development Bank

Indonesia's transmigration scheme was not a success. In the 1980s, the World Bank provided considerable financial support to help increase the number of migrants leaving Java. However, in the following decade, environmental, social and economic concerns emerged. The scheme failed to achieve targets, and financial assistance to support further resettlement began to dry up. The criticisms of Indonesia's transmigration scheme can be summarised as follows.

- Its impact on Java's population density was minimal.
- Poor farming conditions and lack of infrastructure did not alleviate poverty; instead, it was only redistributed.
- Land clearing of the outer islands threatened 10 per cent of the world's remaining rainforest.
- Resettlement was expensive and increased the country's foreign debt.
- The scheme camouflaged the government's desire to politically control the outer islands.
- The scheme violated local land rights.
- Wetland drainage increased carbon emissions from dehydrated peat soils.
- The scheme caused the demise of traditional ethnic culture in the outer islands.

It would appear that some of the coercive elements of transmigration have waned. However, the government's desire to exploit natural resources to generate much needed revenue may trigger a new wave of migration.

West Papua is an ideal region for continued transmigration efforts in Indonesia. West Papua comprises 24 per cent of Indonesia's total landmass but only 1.7 per cent of the country's population. It is well-endowed with natural resources, including the largest extant tracts of rainforest in South-East Asia, vast oil and gas reserves, and large deposits of copper and gold. In 1959, only 2 per cent of the population was from outside the province, but by 2011 the proportion of migrants (see figure 4.49) had reached 53 per cent. Critics argue that the continuing transmigration program has led to large numbers of migrants controlling the economy in towns and villages. Consequently, local Papuans feel increasingly marginalised, which has led to violence. In early 2019, direct conflict in the mountainous Nduga region led to the violent deaths of an estimated 20 migrant road construction workers. This sparked retaliation from the Indonesian Army, which is endeavouring to suppress an independence movement in the province.

FIGURE 4.49 Transmigrants in West Papua

4.5 Exercise

4.5 Exercise

Learning pathways

LEVEL 1	LEVEL 2	LEVEL 3
1, 3, 6	2, 7, 9	4, 5, 8

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Explain and comprehend

1. **Identify** geographical features that may attract a higher population density.
2. Study figure 4.40. **Describe** the distribution of population by continent and suggest reasons for this pattern.
3. **Explain** how latitude impacts population distribution.

Analyse and apply

4. With reference to figure 4.41, **analyse** the population density for Africa to suggest how physical factors can impact where people live.
5. Read the case study on Cambodia.
   a. **Identify** the factors that have caused the population distribution to change over the years.
   b. **Explain** how the planned Chinese resort development along the coast may impact population distribution in the future.
6. **Explain** planned migration.

Propose and communicate

7. **Explain** the reasons that a country might use planned migration.
8. **Outline** whether you think planned migration is an effective way to manage the challenges of high population density.
9. **Suggest** why countries may not have an even population distribution within the country.

Sample responses for this chapter are available online.

LESSON
4.6 People on the move: Causes of migration

LEARNING INTENTION

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

- explain changes in world population distribution, including internal and international migration
- explain the causes of internal and international migrations, both forced and voluntary, as a result of human factors (including social, cultural, political and economic factors such as conflict, labour supply and demand, family reunion, religious or cultural persecution, poverty, food security, governance and educational opportunities) and/or geographical and environmental processes (e.g. large-scale flooding or drought, ecological breakdown), and climate change
- analyse data and information to explain the changing characteristics of populations.

Migration is often explained using two main types of factors: push factors, which drive people away from their place of origin, and pull factors, which attract them to a new location. Both factors help us to understand why people migrate.

Migration can be

- **forced** or **voluntary** (see figure 4.50)
- internal or international
- temporary or permanent.

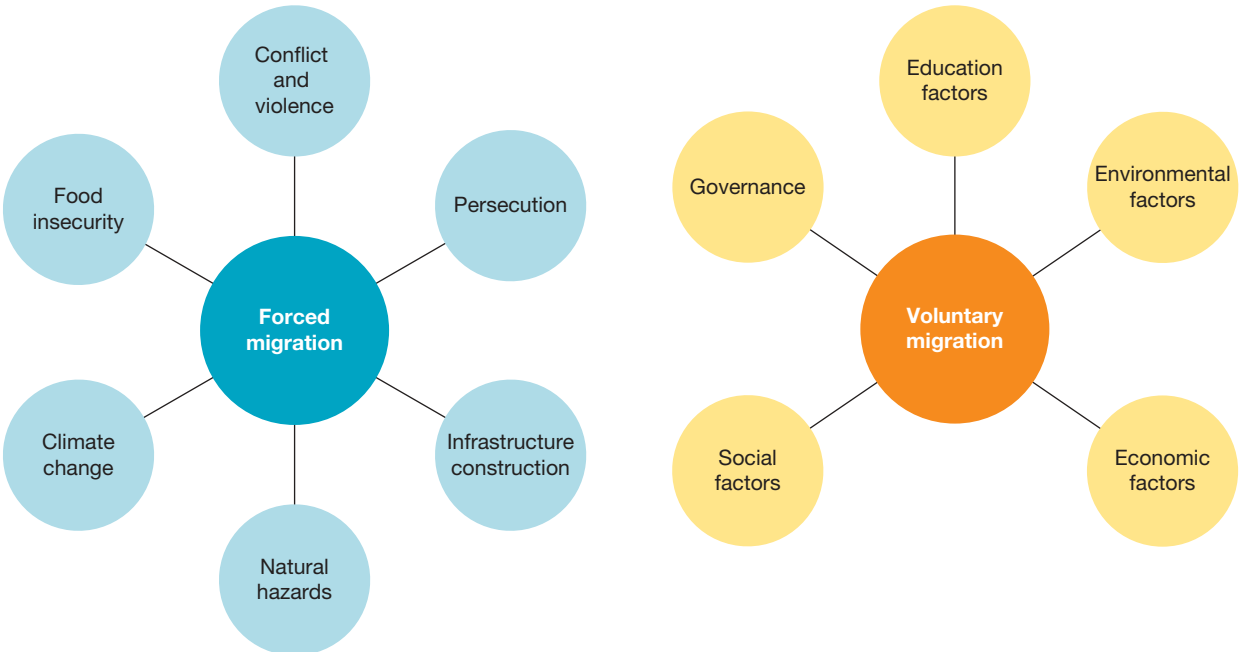
push factors negative features of places that are responsible for people leaving

pull factors positive features of places that are attractive to migrants; they draw people towards places

forced migration when people are forced to leave an area against their will or as a result of life-threatening circumstances

voluntary migration when people migrate from one location to another by their own choice

FIGURE 4.50 Reasons people migrate



4.6.1 Forced migration

Forced migrations are those where people have been forced into leaving an area against their will or as a result of life-threatening circumstances. If they stay within their country, they are an internally displaced person, or IDP. If they are forced to leave their country, they may seek asylum in another country. If this asylum is granted, they are a refugee. The number of displaced people in the world is now over 117 million. People are forced to move from their homes for many reasons. Table 4.10 outlines some of these reasons. Figure 4.56 highlights the influence of climate-related hazards that can displace people from their homes across the world, while figure 4.57 shows the top origin countries for people seeking asylum and the countries they migrate to.

TABLE 4.10 Reasons people are forced to migrate

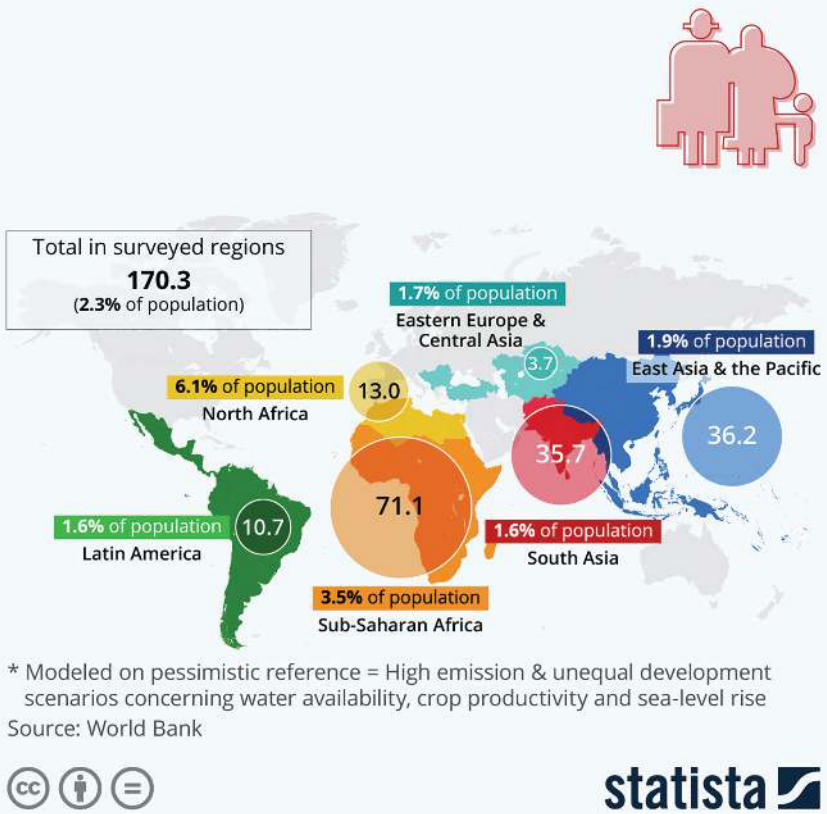
Reason behind forced migration	Explanation	Example
Natural hazards **FIGURE 4.51** The residential red zone, which experienced severe damage in the Christchurch earthquakes 	Living in areas that are prone to natural hazards, such as on plate boundaries, coastal areas or by rivers, can have its benefits, such as fertile soils; however, when a disaster occurs, this can force people to relocate.	New Zealand's Christchurch earthquake of 2011 caused a population exodus of almost 10 000 people. Liquefaction had caused so much damage in the so-called red zone next to the river that it required engineering solutions considered not to be cost-effective. The New Zealand Government purchased the area and nearly 8000 homes have subsequently been demolished.
Climate change **FIGURE 4.52** Funafuti, the capital of island-nation Tuvalu, flooded by sea water incursion 	Climate change impacts such as variability in food growing conditions and sea level rise is causing the displacement of many people across the world. The effects of sea level rises are particularly acute in the Pacific Islands region, where people are already migrating from island chains and low-lying coastal areas that flood regularly.	In 2023 the Australia–Tuvalu Falepili Union treaty was signed, which will allow Tuvaluns to migrate to Australia should they need to leave their island due to climate change. It is predicted that by 2050 up to 1.2 billion people could be displaced due to weather-related events.

(continued)

(continued)

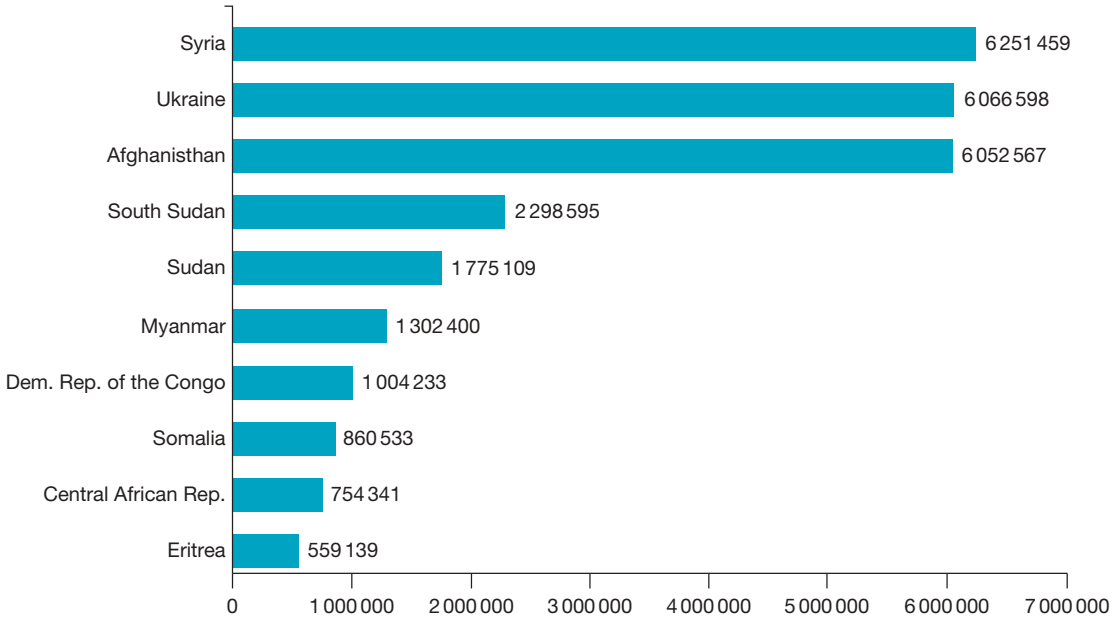
Reason behind forced migration	Explanation	Example
Development-induced displacement **FIGURE 4.53** The Three Gorges Dam, Yichang, China 	Experts estimate that more than 15 million people each year are forced to relocate due to infrastructure projects, such as urban development, transport routes or dam creation.	China is estimated to have resettled more than 20 million people since 1949 to make way for water storage reservoirs and hydropower projects. The massive HEP Three Gorges Dam Project on the Yangtze River alone has resulted in the forced resettlement of more than 1.2 million people since 1993.
Persecution **FIGURE 4.54** Rohingya refugees at Balukhali camp in Cox's Bazar, Bangladesh 	Many people are subjected to persecution due to their race, religion, nationality, social group or political opinion, and therefore are forced to flee their homes. If they seek asylum in other countries, they become refugees. Refugees are now estimated to make up 10 per cent of all international migrants.	The Rohingya people are an ethnic group in Myanmar. Following decades of persecution, and large-scale attacks in 2017, 2.6 million have been displaced, including 1 million who have been forced to flee to neighbouring Bangladesh to seek refuge.
Food insecurity **FIGURE 4.55** Food aid, Somalia 	The increasingly variable rainfall patterns and rising temperatures have affected many agricultural production systems, resulting in food insecurity episodes, many of which have been severe. Migration due to famine tends to be short-term and temporary, and is the last option left to people at the risk of starvation.	Estimating how many people are displaced as a direct result of food insecurity is difficult; however, in 2016, more than one million internally displaced persons were estimated to be living in Somalia. Drought and food insecurity were identified as the main push factors, along with tribal clashes.

FIGURE 4.56 The average number of internal climate migrants by 2025 per region (in millions)



Source: https://www.statista.com/chart/26117/average-number-of-internal-climate-migrants-by-2050-per-region/
Chart: Climate Change, the Great Displacer | Statista

FIGURE 4.57 Topic 10 source countries of refugees in 2024



CASE STUDY: Syrian refugees in Europe

Quick facts: Syria

- **Population** 25 million
- **GDP per capita** US$6370 (estimated)
- **Life expectancy** 72
- **Rate of natural increase** 1.7 per cent

FIGURE 4.58 Asylum seekers crossing the Aegean Sea from Turkey to Greece

More than one million asylum seekers entered the European Union (EU) in 2023. The largest number of refugees in one year was seen in 2015, as a result of the war in Syria. The sheer volume of asylum seekers took many EU governments by surprise, and resulted in different responses to the crisis. Germany adopted an open-door policy, accepting nearly 900 000 people, and the city of Mannheim became the terminus for special trains carrying refugees travelling via the Balkan route until it was closed in 2015. Three former sprawling US army barracks were converted into emergency accommodation to help house 12 000 refugees.

Landings by asylum seekers peaked in 2016 as containment measures began to take effect. The enforcement of registration in Italy helped stem the flow of migrants northwards. The migration crisis had already become a housing crisis, with informal camps established across Italy and in key border crossings such as Calais in France. This camp, which housed more than 10 000 people, was demolished by French authorities in late 2016 and the residents were forcibly removed to other reception centres across the country. In 2022 and 2023 another peak occurred (see table 4.11), as asylum seekers also came from Afghanistan and Türkiye, leading to a resurgence of issues such as those seen in 2016. In recent years, government policies in many EU countries regarding asylum seekers have received increased attention. Greece and Italy struggled with accommodating the influx of people, and Germany, which often accepts many refugees, struggled to ensure they could sustainably resettle them.

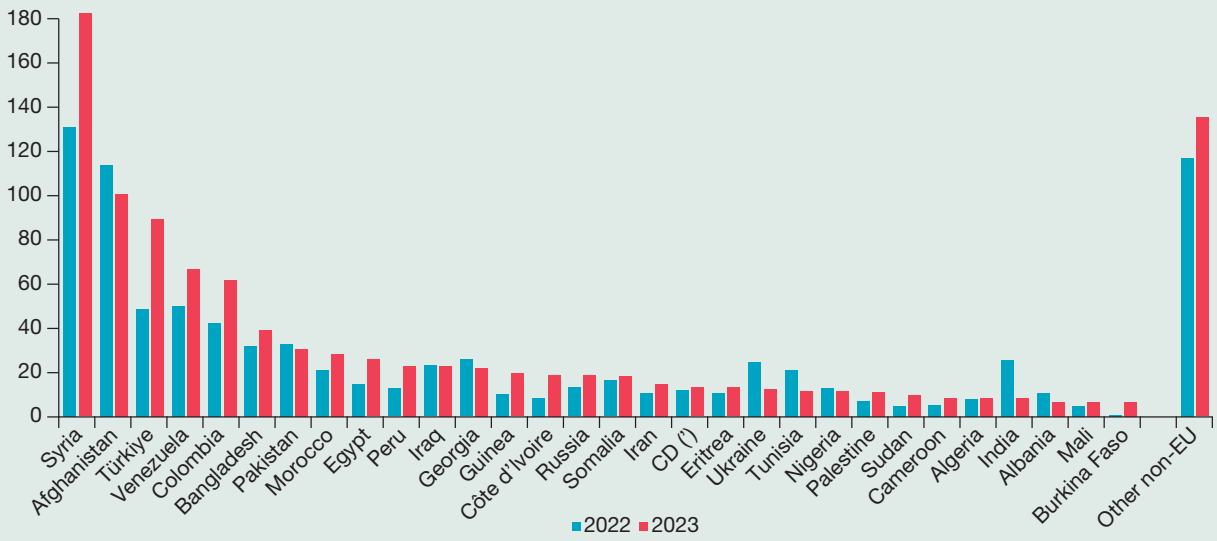
TABLE 4.11 Number of asylum applications in the EU, 2011–2023

Year	Number of first time asylum applications to EU ('000)
2011	273.3
2012	250.4
2013	338.2
2014	530.6
2015	1216.9
2016	1166.8
2017	620.3
2018	564.1
2019	631.3
2020	417.1
2021	536.0
2022	873.7
2023	1048.9

Source: European Commission, Eurostat

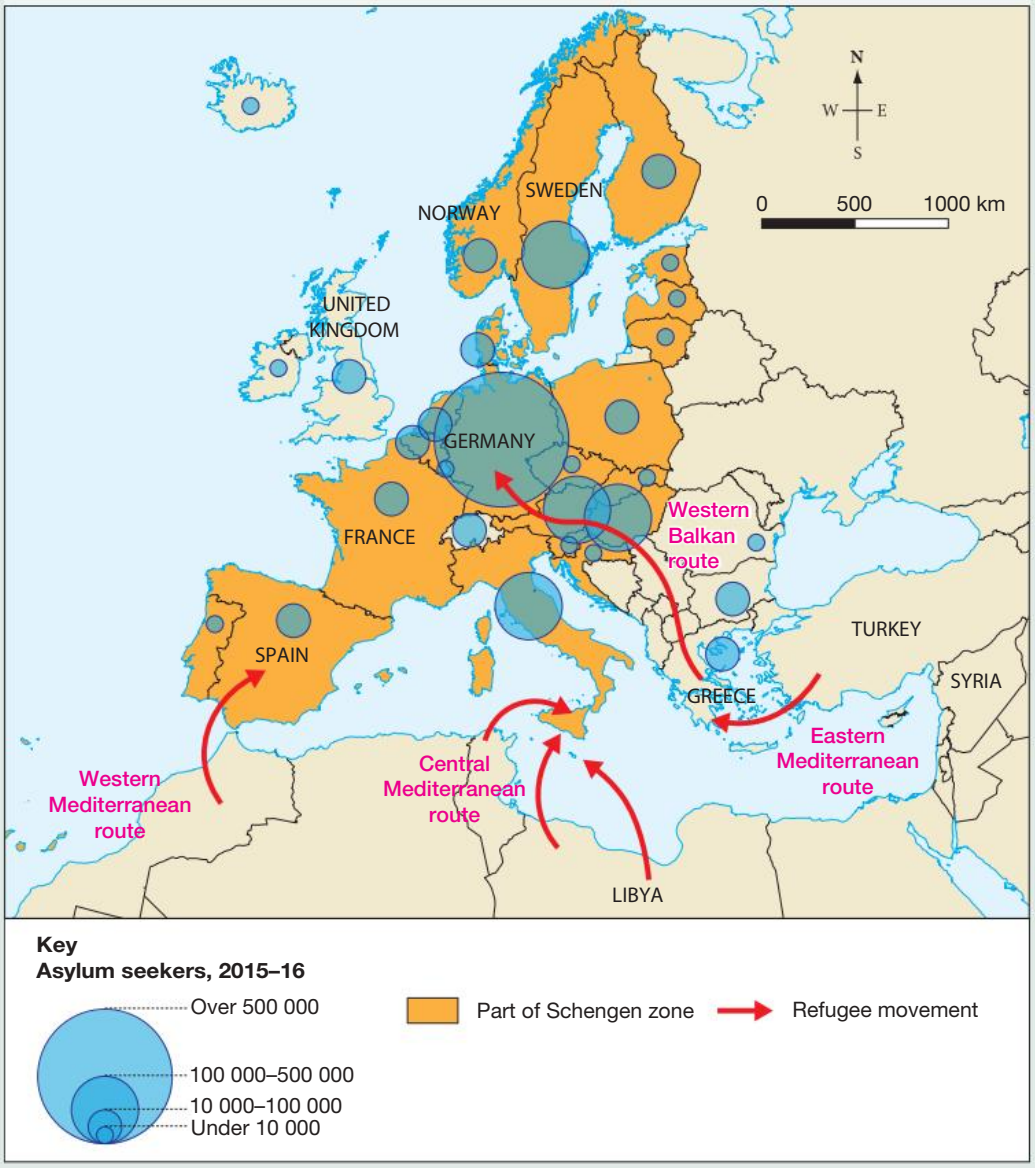
In 2023, most refugees were still coming from Syria, as well as Afghanistan and Türkiye. These refugees reached the EU via Türkiye, having crossed Balkan countries, such as Serbia and Macedonia, by foot. However, another 100 000 asylum seekers migrated from sub-Saharan African countries, reaching Italy and Greece by making perilous crossings of the Mediterranean Sea from North Africa. (Figure 4.59 shows the main countries of origin for first-time asylum applicants in the EU.)

FIGURE 4.59 Top 30 citizenships of first-time asylum applicants in the EU (non-EU citizens), 2022 and 2023 (thousand persons)



Many migrants used these seaboard countries as a stepping stone for their preferred destination, Germany (see figure 4.60 for 2015–16 movements and destinations).

FIGURE 4.60 Movement and destination of asylum seekers into Europe, 2015–16



Source: Eurasian Research Institute, UNHCR, Eurostat

4.6.2 Voluntary migration

Voluntary migration occurs when a migrant has a choice as to whether or not they migrate to a particular place. Several factors can influence a migrant's decision-making, and they often do not operate in isolation. Instead, a combination of factors is likely to influence a migrant's decision to move. Pull factors that encourage voluntary migration at internal and international level are outlined in table 4.12.

TABLE 4.12 Pull factors behind voluntary migration

Factor	Explanation	Example
Economic factors	Migrants are often attracted to destinations that offer better employment opportunities and higher wages. However, high levels of income and other taxes may distort the flow of migrants despite the better employment opportunities.	When Poland joined the EU in 2004, Polish citizens gained the right to move to the United Kingdom for work. This led to a significant influx due to the country's booming economy and job vacancies exceeding 600 000. In 2005, the United Kingdom had an unemployment rate of 5.1 per cent, compared to 18.5 per cent in Poland. The minimum wage in the United Kingdom was also double the average Polish salary. By 2007, 350 000 Poles had applied for work in the United Kingdom, and by the 2011 census, the Polish community numbered 579 000, primarily working in industrial sectors. After the 2016 Brexit vote, net migration dropped sharply as many Polish and other EU citizens left the United Kingdom, reducing net migration to under 250 000.
Education	Students are the fastest growing group of international migrants. According to the Organisation for Co-operation and Development (OECD), the growth in the number of students enrolled in tertiary education outside their country of citizenship has grown on average by 7 per cent each year since 2000. Many universities across the world have been keen to attract students from overseas because they are an important source of revenue. This phenomenon is known as the globalisation of education.	Australia receives the third-highest number of international students, after the United States and the United Kingdom. In 2024, 717 500 international students were living in Australia. Due to this high number, Australia has introduced a cap on the number of student migrants.
Social	Social factors such as friendships and family reunions can be significant in determining where a migrant chooses to live, particularly within the host country. Migrants are more likely to settle in their new home when they are surrounded by people of similar culture, beliefs and language. This can lead to the creation of ethnic enclaves (see section 4.7.2).	The Australian Government includes a family migration program as part of its overall migration program. Partner and child visas can be applied for, along with parent and other family visas, to help with family reunification. For the 2023–24 program year, 40 500 partner visas and 3000 child visas were estimated for planning purposes.
Environmental	In the developed world, positive socio-environmental factors have influenced internal migration patterns, usually in tandem with economic prosperity. Lifestyle, lower costs of living and good employment prospects have been significant factors in the high volume of interstate migrants to Queensland since the 1960s.	Each year, about 14 per cent of the US population relocates. Many move within cities, but migration to the Sun Belt — spanning from Florida to California — has shaped trends in recent decades. States such as Texas saw half their population growth from migration between 2010 and 2016, indicating a potential for continued growth similar to pre-2006 levels. Unlike other Sun Belt states, California is seeing its residents migrate to more affordable places such as Nevada, Arizona and Oregon as these economies expand.

(continued)

TABLE 4.12 Pull factors behind voluntary migration *(continued)*

Factor	Explanation	Example
Governance	Governments significantly influence migration. The EU's free movement of citizens began with the 1957 Treaty of Rome, establishing the European Economic Community (EEC). Initially a customs union to promote free trade among France, Germany, Italy, Belgium, the Netherlands and Luxembourg, it aimed for the free movement of goods, services, capital and labour.	EU citizens have the right to free movement in the EU and to establish their residence in any EU country. In 2022, 1.5 million people moved from one EU country to another. This was an increase of 7 per cent compared with 2021.

CASE STUDY: Indian workers in the UAE

Quick facts: UAE

- **Population** 11 million
- **GDP per capita** US$49550
- **Life expectancy** 83
- **Proportion of foreign citizens to destination population** 88.1 per cent

The economy of the United Arab Emirates (UAE) is heavily based on exporting raw materials — 45 per cent of their GDP comes from oil products. The money generated from this has allowed the country to develop rapidly and, as a consequence, they have a large construction industry. These opportunities have attracted many economic migrants, particularly from India. The wages in the UAE are generally higher than those in India, so many people migrate and send remittances back to their families.

This economic migration between these two regions has been occurring for centuries, and in 2022, 3.47 million Indians were in the UAE, making up over a third of the country's population.

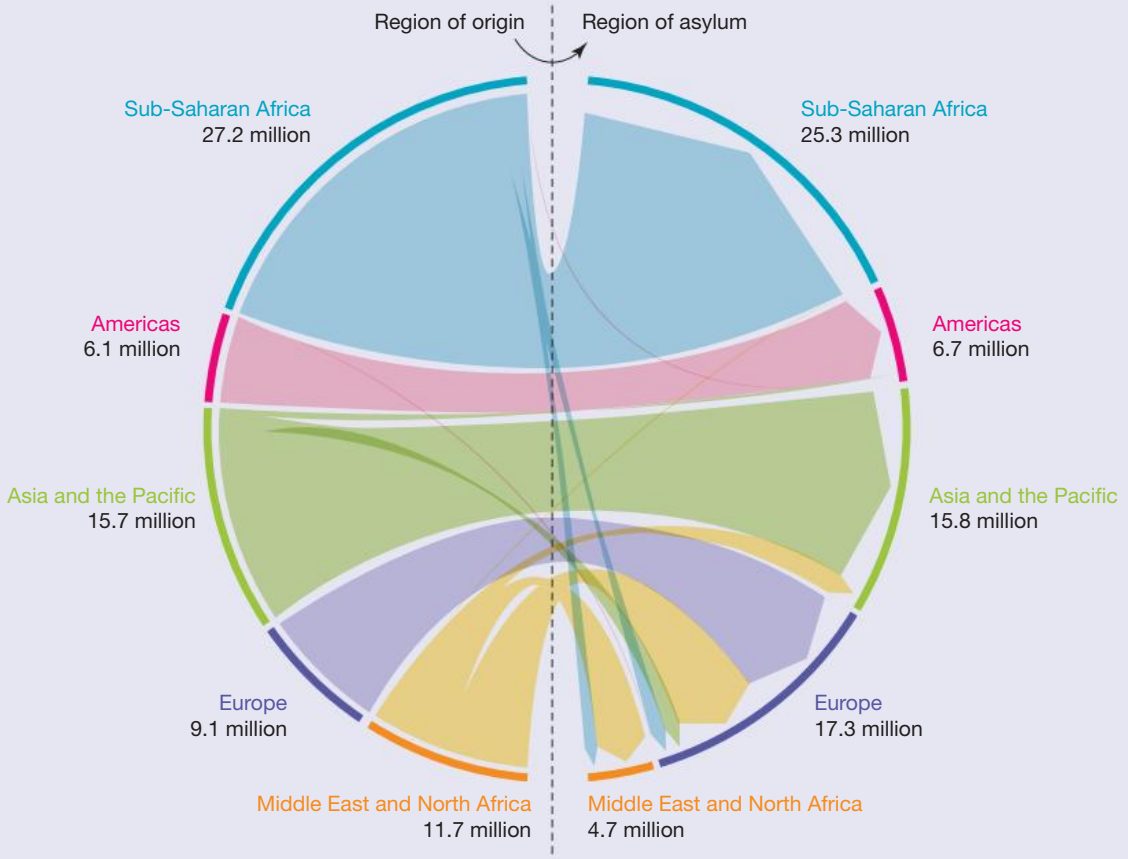
FIGURE 4.61 Indian and Pakistani workers in the UAE

SKILLS ACTIVITY: Analyse geographic data and information

Sankey diagrams show patterns of movements, flows and change. They usually show the change from one side of the chart to the other, and the width of the band used is representative of the proportion of the flow between the categories. Originally they were created as a variation on the flow diagram, but now can be used for a variety of purposes.

Figure 4.62 shows a Sankey diagram outlining the movement of refugees. On the left side are the places of origin, categorised by region. On the right are the destination regions. The arrows (and their thickness) show the proportion of refugees and their movement between the origin region and destination region. For example, the largest number of refugees from the Middle East and North Africa have migrated to Europe, followed by other destinations within the same regions, and then some to Asia and the Pacific. A very small number (as represented by the thinnest arrows) have migrated to Sub-Saharan Africa or the Americas.

FIGURE 4.62 A Sankey diagram showing the movement of refugees



1. **a.** Using the Sankey diagram provided in figure 4.62, identify the region from which the largest proportion of refugees originate.
   b. Explain the primary destination for these refugees and discuss the possible factors influencing these migration patterns.

4.6 Exercise

4.6 Exercise

Learning pathways

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 6	3, 5, 7	4, 8

These questions are even better in jacPLUS!

- Receive immediate feedback
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Explain and comprehend

1. Draw up a table similar to the one provided and **categorise** the following factors into the correct column.
   - Lack of education opportunities
   - War
   - Drought
   - Temperate climate
   - Higher paying jobs

- Universities
- High crime rate
- Cheaper housing
- Religious persecution
- Better healthcare

Push factors	Pull factors

2. **Identify** the difference between forced and voluntary migration, providing examples.
3. **Explain** how employment opportunities can impact migration patterns.
4. **Explain** how climate change might impact migration patterns in the future and how governments might manage this.

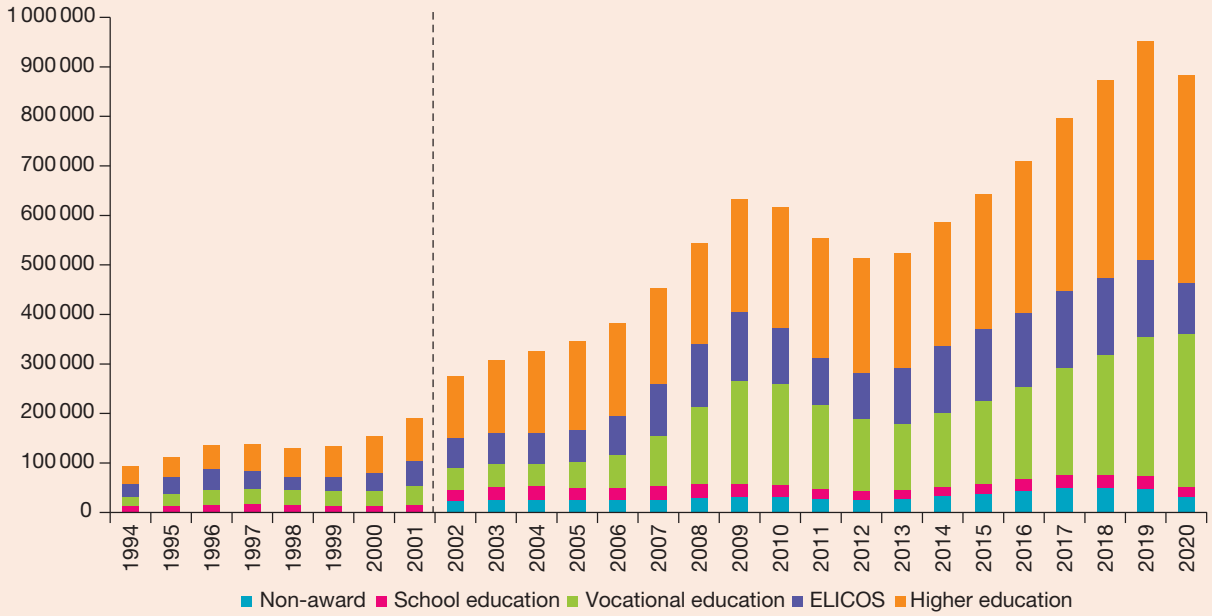
Analyse and apply

5. Analyse figure 4.56 to **identify** the pattern of climate-related hazards across the world.
6. a. Use figure 4.57 to **identify** the top three countries of origin for refugees.
   b. **Suggest** what the main reason might have been for people seeking refuge.

Propose and communicate

7. **Describe** the trends of international student enrolments in Australia from 1994 to 2020 shown in figure 4.63. **Suggest** reasons for these trends.

FIGURE 4.63 International student enrolments in Australia, 1994–2020



Note: There is a break in series between 2001 and 2002

8. The European Union allows people to migrate between its member states. **Explain** how this might have impacted migration patterns between EU countries.

Sample responses for this chapter are available online.

LESSON
4.7 People on the move: Impacts of migration

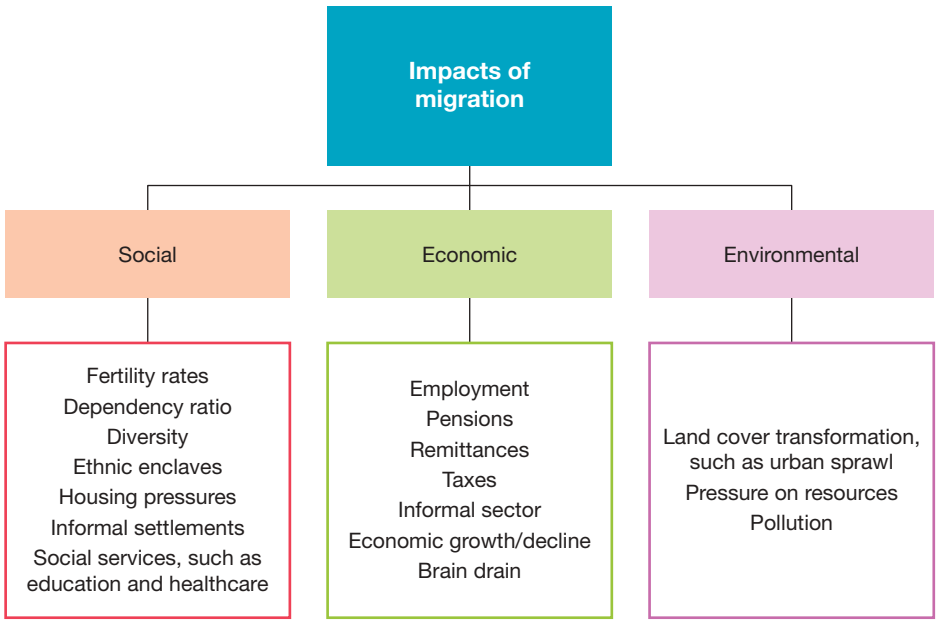
LEARNING INTENTION

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

- identify the impacts of migration on places of origin (e.g. workforce structure, population momentum) and the impacts on the place of destination (e.g. ghettoisation, urbanisation, cultural and ethnic diversity)
- analyse geographic data represented in maps and graphs to infer how the patterns and trends represent specific challenges at global, regional and local scales
- identify implications for people.

Migration affects both the host area to which people move and the area from which they have moved (see figure 4.64). These impacts can be positive or negative, depending on the direction of the movement. For example, negative net migration may result in less pressure on job availability for an area, while a place receiving more migrants may see an increase in competition for jobs.

FIGURE 4.64 Social, economic and environmental impacts of migration



4.7.1 Economic impacts

Population growth from net migration can boost the economy. Migrants, like other people, spend on goods and services, increasing real gross domestic product (GDP). Employed migrants pay taxes such as income tax and GST but usually don't qualify for welfare unless their families meet certain criteria.

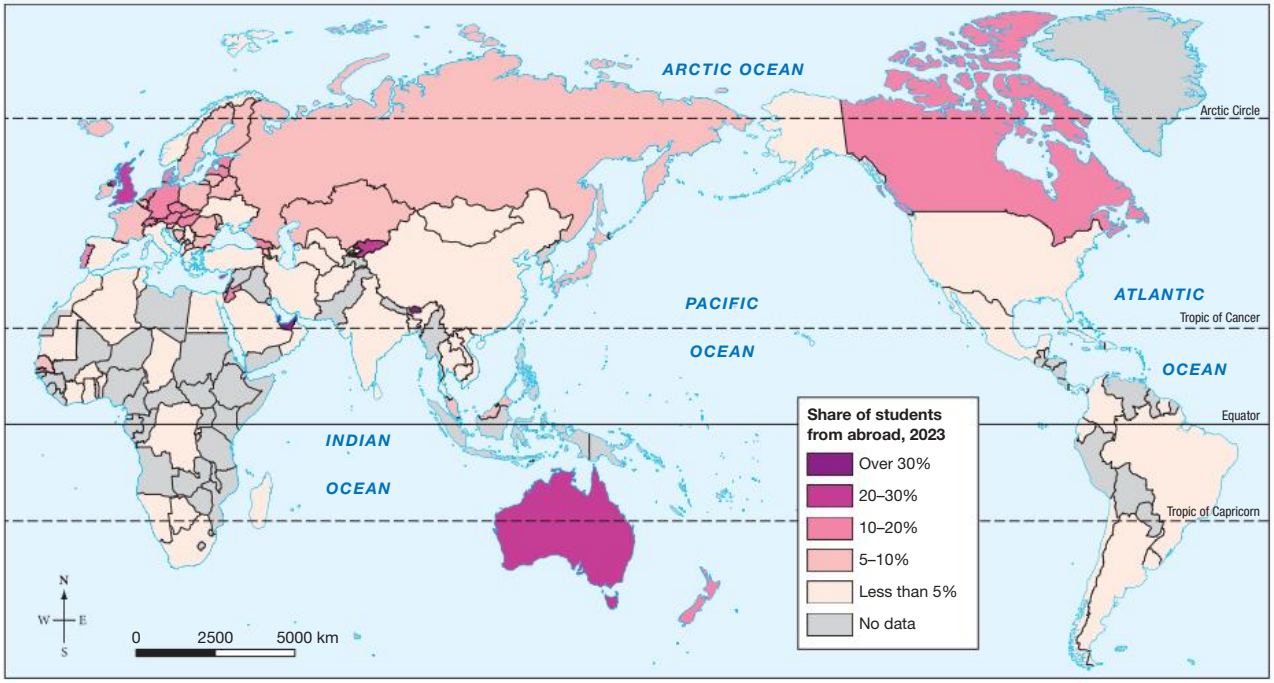
Governments often seek migrants to fill skill shortages. In the 1950s, Britain recruited workers from the West Indies for transport, postal services and hospitals. By 2018, over a third of UK doctors were trained abroad. On the other hand, 'brain drain' occurs when skilled workers leave for better opportunities, such as European scientists moving to the United States following World War II or skilled refugees fleeing Syria.

Apart from reducing unemployment in countries of origin, it is not unusual for migrants working abroad to send **remittances** to the families they have left behind, particularly if they view their relocation as only short-term. The importance of migrant remittances as an external source of capital for developing countries has been recognised by the International Monetary Fund (IMF) since the 1980s. They are the second-largest source of external financing in developing countries after foreign direct investment, and amount to more than twice the size of official aid.

FIGURE 4.65 West Indian migrants in London in 1950

The overseas student component of international migration has grown significantly in recent years (see figure 4.66). Nearly 5 million students are studying abroad worldwide and they have become an important source of income for many educational establishments. In the United Kingdom, international students now make up a quarter of total immigration and contribute more than $35 billion to the UK economy each year.

FIGURE 4.66 Share of students from other countries, 2023



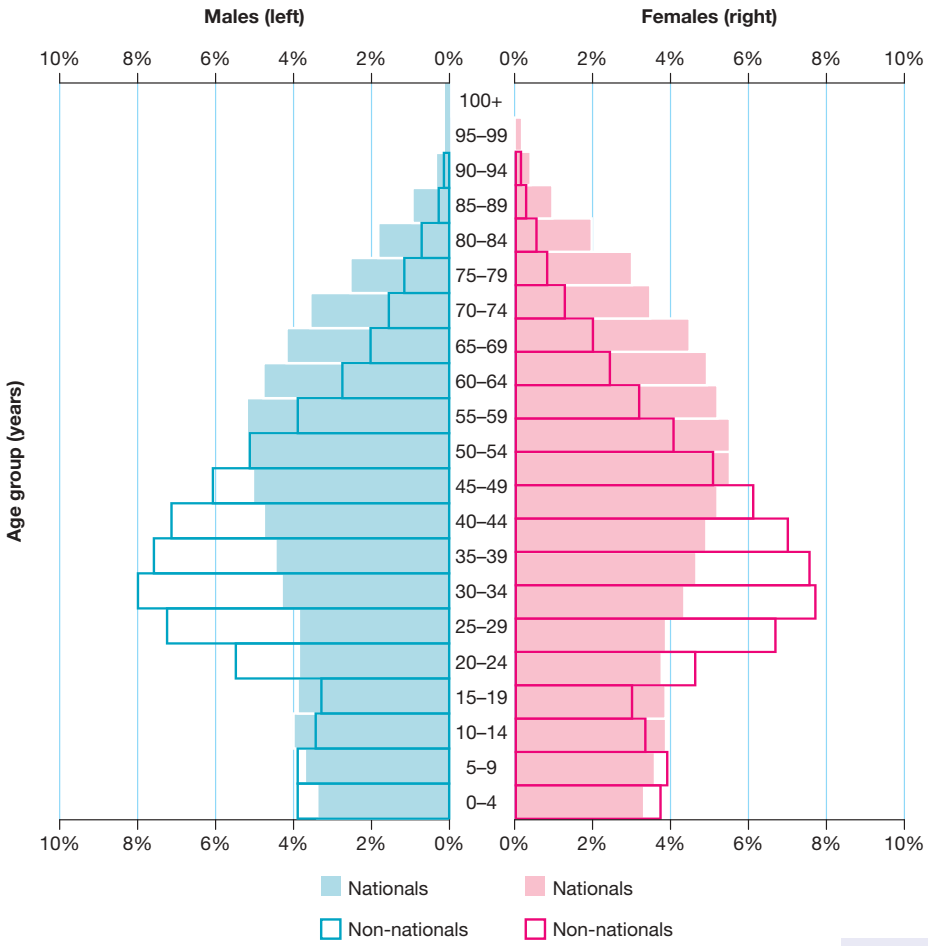
Source: UNESCO Institute for Statistics (2024)—processed by Our World in Data. Map drawn by Spatial Vision.

4.7.2 Social Impacts

Migration tends to be age-selective, which means that, all things being equal, the more youthful elements of a population are more likely to migrate than the aged. The median age of migrants who move from one country to another is 39 years, but the age varies across the world. The average age of immigrants into the EU, for example, is 27 years (see figure 4.67). Consequently, migrants can help to reduce the age dependency ratio in countries that have an ageing population. They can, as witnessed in parts of Europe, even reverse population decline when the fertility rate falls below the replacement level.

remittances the transfer of money by a foreign worker to help increase the household income in their home country

FIGURE 4.67 Age structure of migrants to the EU, 2022 (nationals and non-nationals)

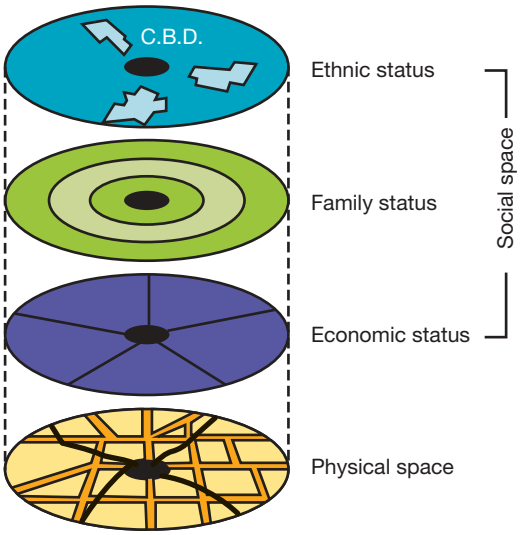


enclaves communities of migrants already established in particular neighbourhoods

Ethnic enclaves and ghettos

International migrants mostly flock to the large towns and cities of their host country. This is because work is more likely to be found in these urban centres and communities of migrants are likely already established in particular neighbourhoods. These communities are known as **enclaves** and allow the new arrivals to network. Migrants who move to these areas commonly settle into their new surroundings more quickly because they are surrounded by people speaking the same language and sharing the same culture and religious beliefs.

FIGURE 4.68 Murdie's model of residential structure in a city



Enclaves in Chicago

The United States, like Australia, has a particularly long history of international migration and the development of enclaves. During the first half of the nineteenth century, migrants to Australia were mostly from Britain, Ireland and Germany. They were followed by another wave of European migrants in the late nineteenth and early twentieth centuries, and then in the mid-twentieth century, particularly from eastern and southern Europe. At the time, in Australia and in the United States, the Italian and East European Jewish settlers became highly segregated from other residents (see figure 4.69).

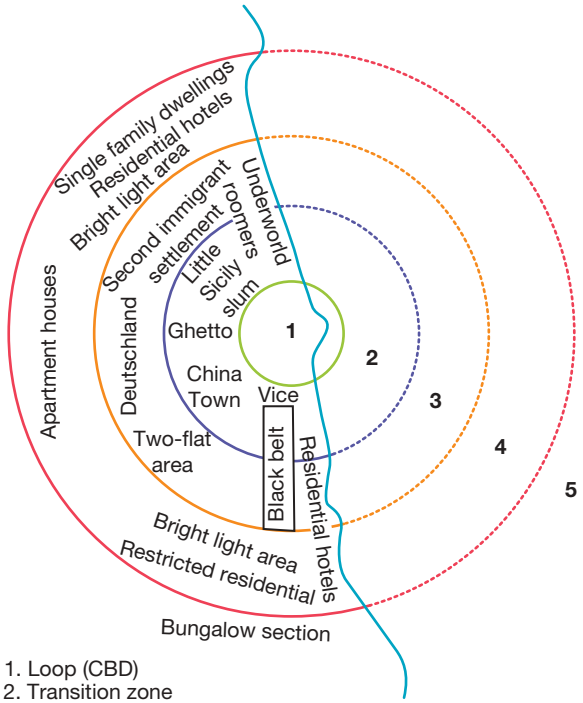
FIGURE 4.69 'Little Italy', New York, circa 1900

DID YOU KNOW?

Ghettos are defined as extreme forms of residential concentration by culture, religious belief or ethnicity. To qualify as a ghetto, the area must have a high proportion of a particular group living in that area and the group must also account for most of the population of that area.

The 1930 census data for Chicago (see table 4.13) provides a useful illustration of the difference between a ghetto and an enclave. The Polish migrants were the most concentrated for an individual European ethnic group, with 61 per cent of Chicago's Poles living in the Polish district. Furthermore, 54 per cent of the population of the Polish district was Polish. However, the situation was different for the African American population. For the Black population, 92 per cent lived in the so-called Black ghetto, where they accounted for 81 per cent of the population. Ernest Burgess used data such as that shown in table 4.13 to develop his Burgess model or concentric zone model (see figure 4.70). Developed in 1925 and applied to Chicago, Burgess used his model to explain urban social structures.

FIGURE 4.70 Burgess' model of Chicago



1. Loop (CBD)
2. Transition zone
3. Workingmen's homes
4. Better residences
5. Commuter's zone

ghettos extreme forms of residential concentration by culture, religious belief or ethnicity

TABLE 4.13 Ethnic groups, Chicago, 1930

Ethnic group	Total population of ethnic group	Population of ethnic group in its enclave or ghetto	Total population of the enclave or ghetto	Percentage of ethnic group living in the enclave or ghetto	Ethnic group's percentage of total population of the enclave or ghetto
Irish	169 568	4 993	14 595	2.9	33.8
German	377 975	53 821	169 649	14.2	31.7
Swedish	140 013	21 581	88 749	15.3	24.3
Russian	169 736	63 416	149 208	37.4	42.5
Czech	122 089	53 301	169 550	43.7	31.4
Italian	181 161	90 407	195 736	49.7	46.2
Polish	401 306	248 024	457 146	61.0	54.3
African American	233 903	216 846	266 051	92.7	81.5

CASE STUDY: Ethnic enclaves in the United Kingdom and population momentum

Quick facts: United Kingdom

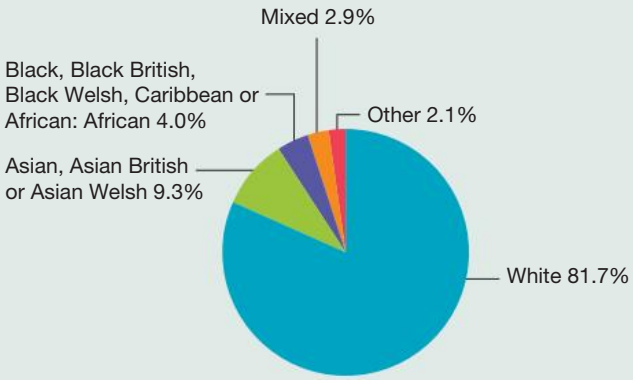
- **Population** 69.2 million
- **GDP per capita** US$66 200
- **Life expectancy** 81
- **Rate of natural increase** 0.1 per cent

The United Kingdom now has a large migrant population (see figure 4.71).

In 1947, the Indian sub-continent was granted independence from the British Empire. This resulted in the establishment of India and Pakistan as independent dominions but was accompanied by large-scale inter-communal violence and dislocation of thousands of people, particularly in the north-east province of Punjab. Many people decided to settle in the United Kingdom, and the Indian and Pakistani community now accounts for 60 per cent of the Asian population there.

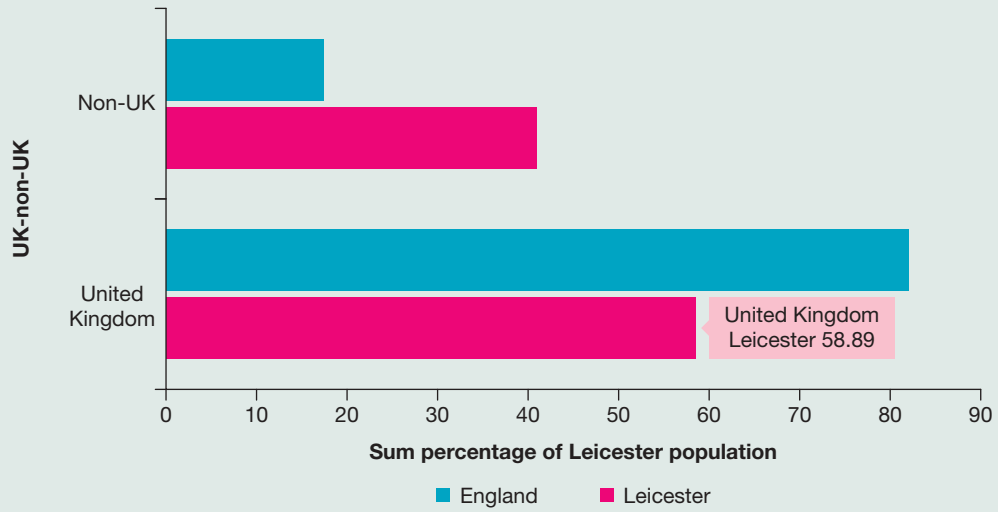
Cities such as Leicester in the East Midlands attract large numbers of migrants. By 1951, the ethnic minority population in Leicester numbered about 80 000. In 1972, 20 000 Asian migrants from Uganda also settled in Leicester. The city's minority ethnic population has continued to grow, measuring 368 600 in 2021. The largest ethnic minority group is Indian. The city's 6500 Polish residents are the third-largest overseas-born migrant minority, after India and Kenya.

FIGURE 4.71 Ethnic groups in England and Wales, 2021



Source: The Office for National Statistics

FIGURE 4.72 Percentage of Leicester population based on country of birth versus England, 2021



The four main factors that have accentuated the demographic structure of ethnic enclaves in the United Kingdom are as follows:

- net migration
- mortality
- natural increase
- family formation.

Commonwealth migrants to Britain in the 1950s and 1960s, described as a replacement population, mostly settled in inner-city areas that were already in demographic decline. The inner city was attractive to newly arrived migrants because housing was relatively cheap and jobs were accessible. Later, members of the replacement population would commonly follow the path of their predecessors and move into more desirable suburbs.

FIGURE 4.73 Workers' terraced housing in Belgrave, Leicester, UK

The replacement population soon held a larger proportion of the inner-city's total population (see figure 4.75, which shows the population profile for the city of Leicester). Migration of the original residents from the inner-city areas was age-selective; therefore, those who remained were generally older than the younger replacement population. Consequently, the difference in mortality rates between the two populations contributed to the increase in the proportion of the replacement population in the area's total population. The new migrant population, being younger, also had higher fertility than the population it replaced and this helped to increase its proportion of the total population of inner-city areas. People in the replacement population, due to their younger age and cultural traditions, tended to marry early, which meant new family formation for migrants was more rapid compared with that of the original residents. Furthermore, strong pressures to keep the new families close to the parental homes, especially for the Pakistani and Bangladeshi population, further accentuated the degree of ethnic concentration. Figure 4.75 highlights some of these trends.

FIGURE 4.74 Population profile Leicester, 2021

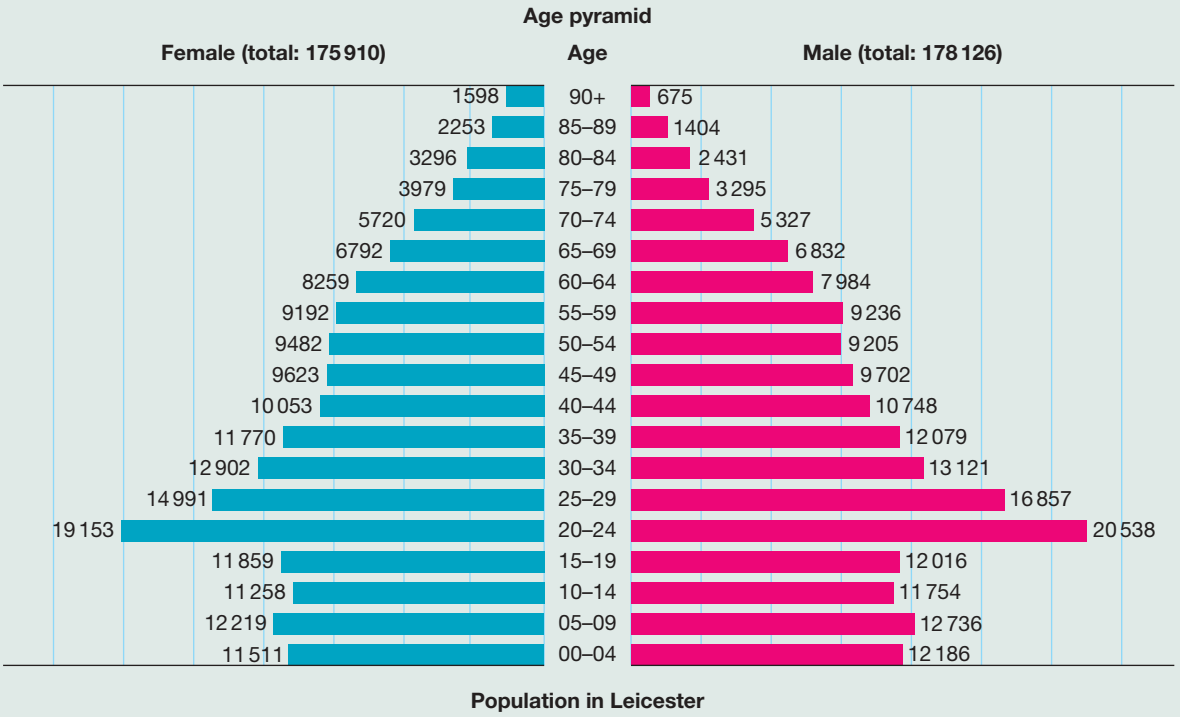
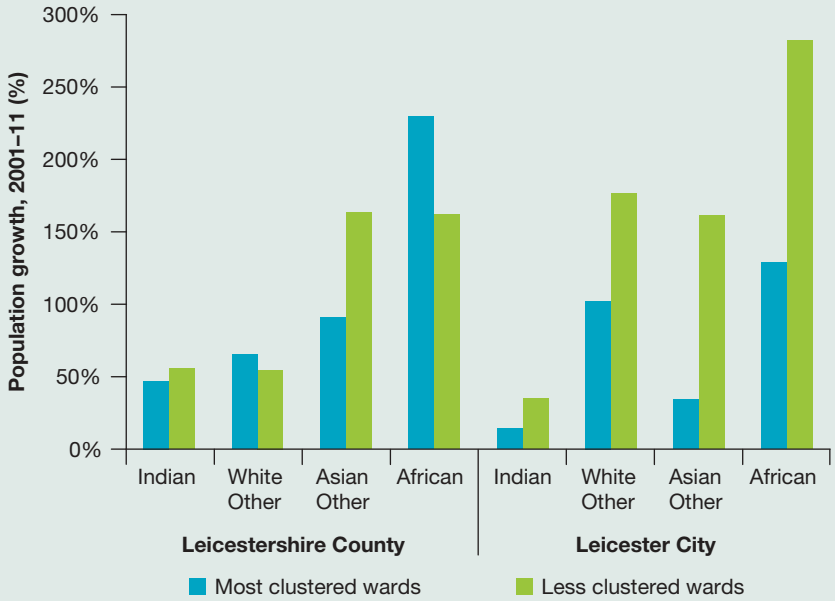


FIGURE 4.75 Growth of population by largest ethnic group, Leicestershire County and Leicester City, 2001–11



EXAMPLE: Measuring ethnic segregation

Ethnic segregation can be statistically measured by an index of dissimilarity. The index score translates as the percentage of one of two groups included in the calculation that would have to move to other areas in order to produce a distribution that matches that of the larger area. The index score ranges between 0 and 1. When both distributions are perfectly equal, the index score is zero. Therefore, the higher the value of the index, the higher the degree of disparity between the distribution of the two populations.

4.7.3 Environmental impacts

Migration can help to ease the pressure on resources in areas, such as reducing the strain on water supplies and less intensive use of land for farming. However, the areas receiving migrants may see the opposite, with increasing pressure on water and land resources, plus increased waste.

Increasing urbanisation can lead to a multitude of impacts on the environment (refer to unit 2, topic 2). Interstate migration in Australia has led to urban sprawl in places such as south-east Queensland. This can lead to habitat destruction and impact on native wildlife, including koalas. Increasing urbanisation can also add to the urban heat island effect.

CASE STUDY: Voluntary migration in Europe

Quick facts: European Union

- **Population** 450 million
- **GDP per capita** US$66 200
- **Life expectancy** 81
- **Rate of natural increase** –0.3 per cent

Within the EU, an agreement known as the Schengen Agreement, between many member states, allows citizens to move between countries in the Schengen Area to live, study and work. In 2023, 14 million of the EU's birth population lived in a member country in which they were not born. The top three EU countries with the highest number of migrants from other EU countries were Germany, with 6.2 million migrants, France, with 2.3 million migrants, and Spain with 1.58 million migrants.

This movement of EU citizens is of huge economic benefit, and also allows for cultural diversity and a wide variety of opportunities in other countries.

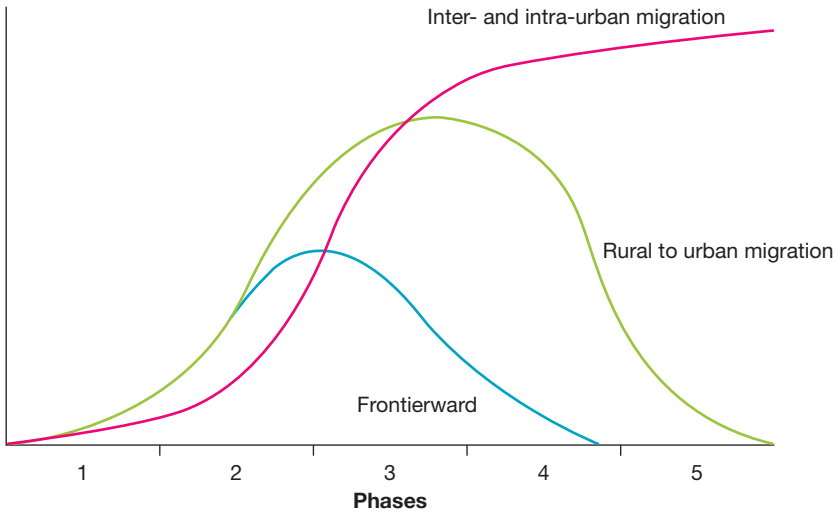
FIGURE 4.76 The Schengen Area, January 2023 where EU citizens can move between countries

Source: https://en.wikipedia.org/wiki/Schengen_Area#/media/File:Map_of_the_Schengen_Area.svg/2

4.7.4 Modelling migration patterns

In 1971, Wilbur Zelinsky, an American demographer, devised the Mobility Transition model (see figure 4.77), which comprises five stages. The first four stages broadly align with the four stages of the Demographic Transition model and a country's progress along the path to economic development, as witnessed in North America and Europe. The fifth stage was Zelinsky's prediction of what movements would occur in what he called a future super advanced society.

FIGURE 4.77 Zelinksy's Mobility Transition model



The stages of the Mobility Transition Model are:

- Stage 1: Pre-modern traditional society aligns with the first stage of the Demographic Transition. Natural increase is low and mobility is limited to nomadic movements in rural areas.
- Stage 2: Early transitional society is marked by a rising population and surge in rural to urban migration as a result of rapid industrialisation and urbanisation. Migration flows to settlement frontiers and overseas also occur.
- Stage 3: Late transitional society is marked by a slackening rate of movement to settlement frontiers and overseas migration. Rural populations begin to fall and rural to urban migration is replaced by inter-urban and intra-urban migration.
- Stage 4: Advanced society sees the **rate of natural increase** flatten. The volume of migration within urban areas remains high as urban centres merge but counter-urbanisation begins to emerge in response to urban diseconomies and lifestyle-based movements.
- Stage 5: Future super advanced society is marked by mostly inter-urban or intra-urban movement of people as well as a range of short-term migratory movements, which Zelinsky called 'circulation'.

4.7.5 Migration within countries: internal migration

About 3 per cent of the world's population are estimated to be internal migrants, which is much greater than the world's international migrants. According to the UN, Latin America has a higher rate of internal migration than any other world region.

A major concern for the World Bank is the possibility of up to 140 million people migrating within regions that have experienced ecological disasters such as floods and droughts associated with climate change. For more information, watch the documentary about preparing for internal climate migration — go to the **World Bank Groundswell**, available in the Resources tab, to access.

Population distribution around the world is changing. Although Asia is by far the most populous continent, Africa is the fastest growing region in the world and its share of global population is expected to rise to 20 per cent by 2050. The population of sub-Saharan Africa alone is predicted to double to more than 2 billion by 2050. In contrast, Europe's share of world population is expected to fall from about 20 per cent in 1960 to less than 10 per cent by 2050.

rate of natural increase the birth rate minus the death rate, expressed as a percentage: (crude birth rate minus crude death rate) × 100/1000

population distribution the way a population is spread over space (sparsely populated, densely populated, etc)

Demographic shifts in population distribution will impact different parts of the world in different ways. Shifts in population distribution also result in changes in population density, given that population density is a measure of population distribution in a particular geographic area. For example, the increasing concentration of the world's population in towns and cities has aggravated existing problems, such as inadequate housing, and poor air and water quality. In sub-Saharan Africa, one of the most pressing challenges will be reducing **food insecurity**, particularly in cereals, and reliance on imported food. This will require increased productivity, which involves closing the gap between current farm yields and **yield potential**.

food insecurity a situation in which people do not have physical and economic access to the basic food they need to work and function normally

yield potential the output of a crop that can be achieved by regulation of genetic characteristics and temperature

yield gap the difference between current yield and yield potential

Rainfed maize is the dominant cereal in sub-Saharan Africa. It has the greatest yield potential but the largest **yield gap**. Millet, another cereal staple in the region, has the smallest yield potential and the smallest yield gap. Sub-Saharan Africa needs a green revolution but economists from the UN's Food and Agriculture Organization (FAO) say that the chances of this are slim. To achieve the same success as other parts of the world, such as Asia, there needs to be financial incentives for the necessary genetic engineering, improvements in water supply and a substantial reduction in the extent of the region's degraded soils.

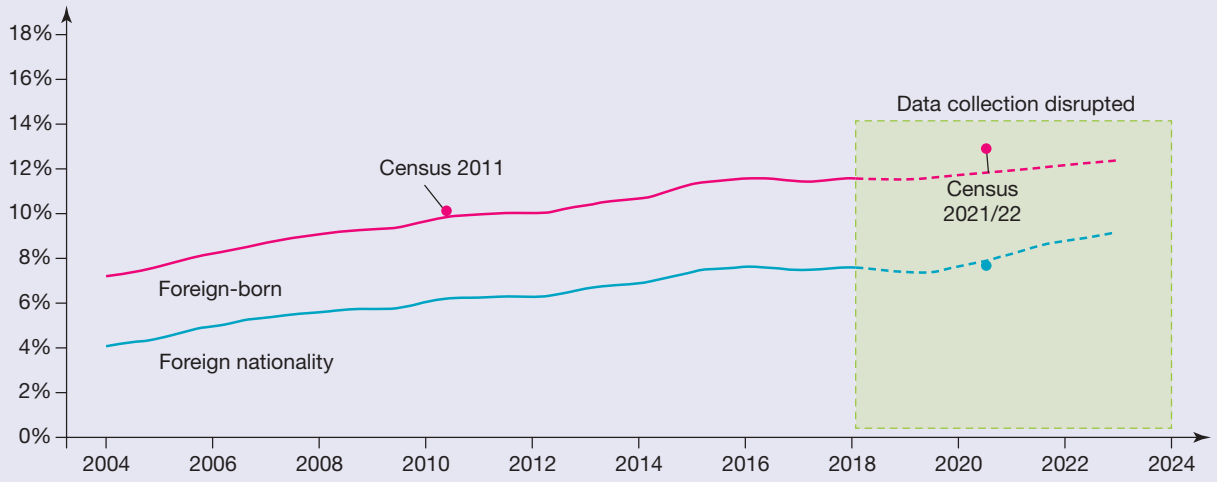
SKILLS ACTIVITY: Analyse geographic data and information

According to UK census data from 2021 (2022 in Scotland), 32 per cent of all foreign-born residents in the United Kingdom came from the following five countries:

- India (9 per cent)
- Poland (8 per cent)
- Pakistan (6 per cent)
- Romania (5 per cent)
- Ireland (4 per cent).

Data from the same census shows London is the most popular destination for migrants. Figure 4.78 shows the migrant population of the United Kingdom, broken down into either foreign born or foreign nationality.

FIGURE 4.78 Share of migrant population in the UK, by country of birth and nationality



1. Using figure 4.78, explain the trend in the migrant population of the United Kingdom. Access the latest information from the UK census and population estimates to add to your answer. Explain how this information might be useful for policymakers.
2. According to the census data, where are most of the UK migrants from? While these percentages may appear small, given the population of the United Kingdom, can you estimate how many people might be represented for each country?

3. Compare and contrast the share of populations from different nationalities in the United Kingdom. What factors might contribute to these variations?
4. Analyse how the distribution of migrant populations by country of birth and nationality might impact cultural diversity in various regions of the United Kingdom.

4.7 Exercise

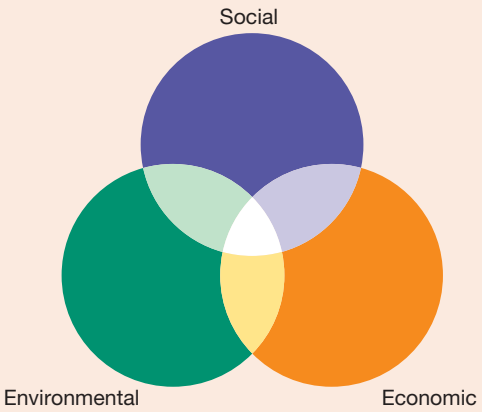
4.7 Exercise

Learning pathways

LEVEL 1	LEVEL 2	LEVEL 3
1, 3	2, 4, 6	5, 7, 8

Explain and comprehend

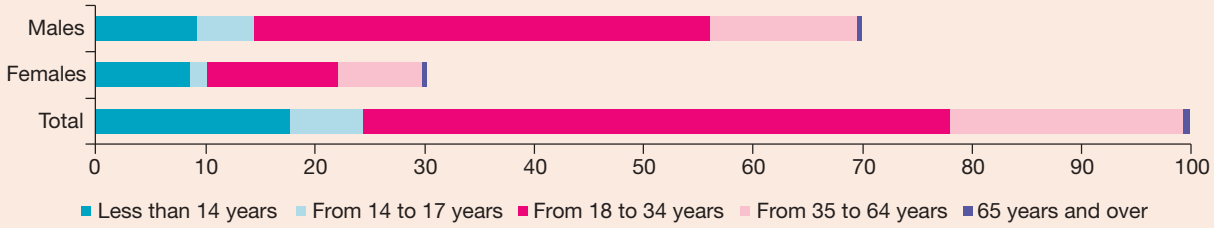
1. **Identify** the following impacts of migration by sorting them into the correct part of the Venn diagram shown.
   - Increased pressure on farmland
   - 'Brain-drain'
   - Increased fertility rate
   - Increased age dependency ratio
   - Remittances
   - Growth of informal sector
   - Increased water pollution
   - Development of ghettos
   - Lower unemployment rate
   - Decreased housing pressure
2. **Suggest** how migration may relieve pressures on the origin area.
3. **Explain** how an influx of refugees might create pressure on the environment.



Analyse and apply

4. a. **Analyse** figure 4.79 to describe the demographics of asylum seekers in the EU in 2023.
   b. **Suggest** an economic impact of this pattern.

FIGURE 4.79 First-time asylum seekers in the EU by age and sex, 2023



Note: First-time asylum applicants with either unknown sex (275 persons) or unknown age (65 persons) are not presented in the graph.
***Source*:** Eurostat (online data code: migr_asyappctza)

5. a. Using figure 4.66, **analyse** the distribution of the share of students from other countries in 2023.
   b. Identify the economic impacts this pattern of distribution might create.

Propose and communicate

6. a. **Discuss** the potential social implications for a country with a high share of international students.
   b. **Suggest** how this might affect the native population's perception of cultural diversity and integration.
7. Thinking about Australia, **evaluate** the environmental impact of an increasing number of international students in urban areas. Consider aspects such as housing, transportation and resource consumption.
8. Based on the patterns observed in figure 4.66, **outline** strategies a government could implement to maximise the benefits and mitigate the challenges associated with the migration of international students. Provide examples to support your suggestions.

Sample responses for this topic are available online.

LESSON
4.8 Apply your skills — Analysing population data

LEARNING INTENTION

By the end of this lesson you should be able to identify trends, relationships and correlations.

SKILLS ACTIVITY: Apply and analyse the data

Demographers at Queensland University's Centre for Population Research have examined migration intensity for a sample of countries over a one- and five-year period. The intensity takes into account all changes of address irrespective of the direction. Since demographic mobility is considered an integral part of the development process, a positive correlation would be expected between the percentage of migrants in a country and its rating on the Human Development Index.

TABLE 4.14 Migration intensity versus HDI, 2022

Country	Migration intensity	Human Development Index (HDI)
South Africa	18.3	0.71
Sudan	10.2	0.42
Cambodia	13.5	0.61
Indonesia	15.8	0.69
France	20.1	0.89
Ireland	21.4	0.92
El Salvador	14.7	0.66

1. Using data from table 4.14, use a correlation technique (such as a scattergraph and best fit line or Spearman's rank) to examine the relationship between migration intensity and human development.
2. Interpret your result and explain why a relationship exists between the two variables.

4.8.1 Internal migration in Vietnam

Since the 1980s, internal migration in Vietnam has risen sharply, contributing to urbanisation. In 1960, 80 per cent of the population was rural, dropping to 64 per cent by 2017. Previously, Vietnamese people needed local authority permission to travel between provinces, but now they need a hộ khẩu (a legal identification and registration system in Vietnam) to access public services in new areas. Economic reforms in 1986 increased demand for labour, but hộ khẩu registration remains cumbersome. Many migrants in cities such as Ho Chi Minh City, Hanoi and Da Nang lack or don't update their hộ khẩu. The government announced plans to replace the system with a national citizen database by 2020 to aid economic growth. However, by 2024, the hộ khẩu system was still in the process of being replaced with a new digital resident registration system.

Even with these barriers, from 1999 to 2009, internal migration in Vietnam doubled to over 8 million, mostly moving to south-east Vietnam, and especially Ho Chi Minh City. International migration remains low at under 3 per cent.

Vietnamese migrants are generally young, averaging 29 years, with most aged between 15 and 39. Men are more likely to migrate for work, while women move for family or education. The Kinh and Hoa people migrate the most, despite the Hoa making up only 1 per cent of the population. Migration boosts the economy as migrants send money back home, though it increases the agricultural workload for the elderly and children. Internal migration shifts the population towards industrial regions such as Hanoi and Ho Chi Minh City, straining housing resources. Many migrants face high rent and utility costs, as well as cramped living conditions, with over 40 per cent having less than 10 square metres per person, compared to 16 per cent for non-migrants.

SKILLS ACTIVITY: Explain and analyse the data

1. Using data from table 4.15, and your own sources for more recent data, construct four double column graphs to show how the direction of migratory movement has changed since 1999.
   Apply and communicate your knowledge of types of migration

TABLE 4.15 Types of migration in Vietnam, 1999–2015 (%)

Period of census (years)	Moves within rural areas (rural–rural)	Moves from rural to urban (rural–urban)	Moves within urban areas (intra–urban)	Moves from urban to rural (urban–rural)
1999–2009	33.7	31.6	26.3	8.4
2010–2015	19.6	36.2	31.6	12.6

2. To what extent do you think Vietnam appears to conform to Zelinsky's Mobility Transition model (from lesson 4.7)?

LESSON
4.9 Review

4.9.1 Summary

This topic has covered some key points about global population change.

Global patterns of population growth

- Census data enables governments to make relatively accurate future population forecasts and plan for population growth or, in some cases, population decline.
- The UN has estimated that the world population is likely to peak at just over 10 billion in the mid-2080s.
- The world fertility rate — the number of children born per woman of childbearing age — has declined from over 5.0 in the mid-1960s to 2.2 now.
- Fertility rates vary between world regions and between countries. Least developed countries will continue to have relatively high levels of fertility but they are declining.
- Declining mortality (death rates) contributes to population growth. Improvements in health have been significant factors in recent years to declining mortality.
- The reduction in global fertility and mortality is not only slowing the pace of population growth but also producing an older population.
- The age/sex structure of a population is important because it defines the relative numbers of young and old, and the balance of males and females, which in turn influence the overall number of births and deaths.

Theories of population growth and economic development

- Rostow's Stages of Growth model suggested that after initial capital investment, countries would embark on an evolutionary process lasting about 60 years, in which they would move up through five stages of development.
- In 1974, Immanuel Wallerstein's *The Modern World System* was published. This is a theoretical framework comprising four stages in which he attempted to explain how the modern capitalist world economy evolved from the age of feudalism to the present day.
- In the early twentieth-century, American demographer Warren Thompson devised the Demographic Transition model, in which countries transitioned from having high birth and death rates to low birth and death rates as they became increasingly industrialised and democratic.
- The four-stage transition model, which builds on Thompson's model, has been a useful tool for analysing patterns of population dynamics.

An ageing world

- Challenges of an ageing population include the dependency ratio.
- The dependency ratio is the number of dependants in a population divided by the number of working age people. The higher the ratio, the greater the economic burden carried by working age people.
- After three decades of the One Child Policy, China now faces the problems of a shrinking workforce and an increasingly ageing population.
- In 2011, Japan's population started to decline due to low fertility rates.

Patterns of changing population distribution and density

- Physical socioeconomic and political factors have influenced both the distribution and density of the world's population.
- In 1950, about two-thirds of the world's population lived in developing countries. By 2030 this figure is expected to have increased to 85 per cent.

- Although Asia is by far the most populous continent, Africa is now the fastest growing region in the world and its share of the global population is expected to rise to 20 per cent by 2050.
- Demographic shifts in population distribution will impact different parts of the world in different ways.

People on the move: Causes of migration

- Global migration is increasing as a result of increasing connectivity, continued regional inequalities and demographic imbalances.
- Migration can be forced or voluntary.
- Reasons for forced migration include natural hazards and disasters, dam construction, conflict, persecution (religious or cultural), and food and water insecurity.
- Voluntary migration is when a migrant has a choice as to whether or not they wish to migrate to a particular place. Reasons for voluntary migration can be economic, education, social, environmental or related to governance.
- Migration can be internal (within a country) or international (to a different country). Rates of internal migration are higher than international migration.

People on the move: Impacts of migration

- Migration has social, economic and demographic impacts on the host area and the home area.

4.9.2 Key terms

age/sex structure the composition of a population by age (0–4 years, 5–9 years, 10–14 years) and sex (male, female)
birth rates the annual number of live births in a particular place per 1000 people; also known as crude birth rate
core describes the advanced economic core of a country or region surrounded by the less economically developed periphery
cumulative causation the snowballing of positive benefits associated with the establishment of new economic activity in a place. The newly established activity attracts associated economic activity, which in turn attracts further activity.
curvilinear relationship relationship in a correlation that is more complex than a simple linear relationship. In the higher ends of each variable in a curvilinear relationship, there is little variation, whereas at the lower end there is more variability.
death rates the annual number of deaths in a particular place per 1000 people; also known as crude death rate
Demographic Transition model describes how changes in population growth respond to relative differences in birth and death rates, which themselves change over time
developed world countries with mature industrialised economies, which exhibit a high gross domestic product (GDP) per capita
enclaves communities of migrants already established in particular neighbourhoods
food insecurity a situation in which people do not have physical and economic access to the basic food they need to work and function normally
forced migration when people are forced to leave an area against their will or as a result of life-threatening circumstances
ghettos extreme forms of residential concentration by culture, religious belief or ethnicity
high and low variants upper and lower limits of reasonable population growth projections
least developed countries the countries with the lowest gross domestic product (GDP) per capita and relatively lower life expectancy and higher birth, death and fertility rates
life expectancy the average number of years a newborn infant is expected to live, given the mortality rates at the time of their birth
medium variant the most likely population growth forecast
modernisation theory developed in the mid-twentieth century with the aim of showing that low-income countries needed to follow the same path to development as Western countries
mortality rates death rate, usually for a specific group in a population; for example, maternal mortality rate

multiplier effect the snowballing of positive benefits associated with the establishment of new economic activity in a place. The newly established activity attracts associated economic activity, which in turn attracts further activity.
net migration the number of immigrants minus the number of emigrants
newly industrialised countries (NICs) countries where the economy has transitioned from that of a less developed country based on primary products to one increasingly based on the production of manufactured goods.
peripheral agricultural countries
Planned migration To come
population distribution the way a population is spread over space (sparsely populated, densely populated, etc)
population momentum the continued growth of a population despite the fertility rate being below replacement level. It ceases once the segment of the population of reproductive years has moved beyond childbearing age.
pull factors positive features of places that are attractive to migrants; they draw people towards places
push factors negative features of places that are responsible for people leaving
rate of natural increase the birth rate minus the death rate, expressed as a percentage: (crude birth rate minus crude death rate) × 100/1000
remittances the transfer of money by a foreign worker to help increase the household income in their home country
replacement fertility the rate required for a population to replace itself from one generation to the next (approximately 2.1 births per woman)
semi-peripheral second-tier industrialised countries
sustainability a process of maintaining balance in an environment while retaining the ability of current and future inhabitants to use that environment
transmigration the coordinated movement of people to better use resources or fill labour shortages, overseen by a government body
urbanisation an increase in the total population or the percentage of a country's population living in urban areas
voluntary migration when people migrate from one location to another by their own choice
world fertility rate the number of children born per woman of childbearing age
yield gap the difference between current yield and yield potential
yield potential the output of a crop that can be achieved by regulation of genetic characteristics and temperature

KEY QUESTIONS REVISITED

You should now be able to answer the following questions.

- Why is accurate and reliable census data useful to governments?
- What trends and patterns can be identified in global population change?
- Which demographic concepts are critical in explaining population change?
- How can models help us understand the past and possible future changes in population across the world?
- What spatial patterns of population distribution and density result from population change?
- How do countries manage the challenges of changing characteristics of their populations such as ageing?
- What are the positive and negative impacts of migration of people on places of origin and destination?

4.9.3 Exam questions

Section I — Short response questions

Question 1 (3 marks)

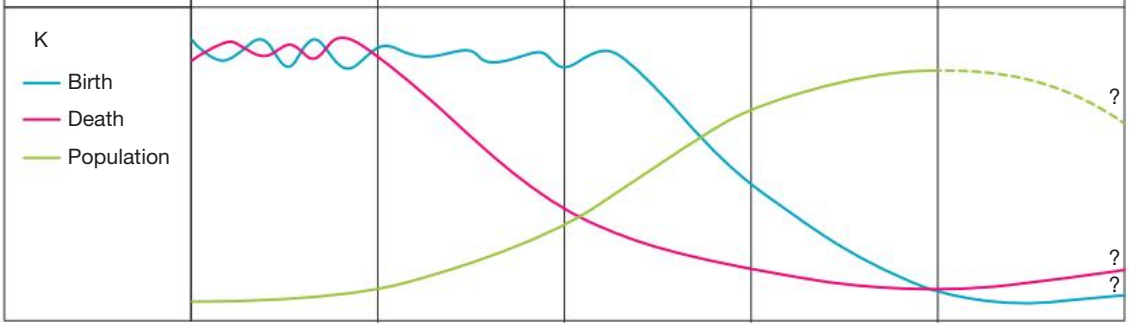
Explain the processes that cause population distribution to vary within a country.

Question 2 (10 marks)

Complete the provided Demographic Transition model with the descriptor and population pyramid for each stage.

FIGURE 4.80 Demographic Transition model

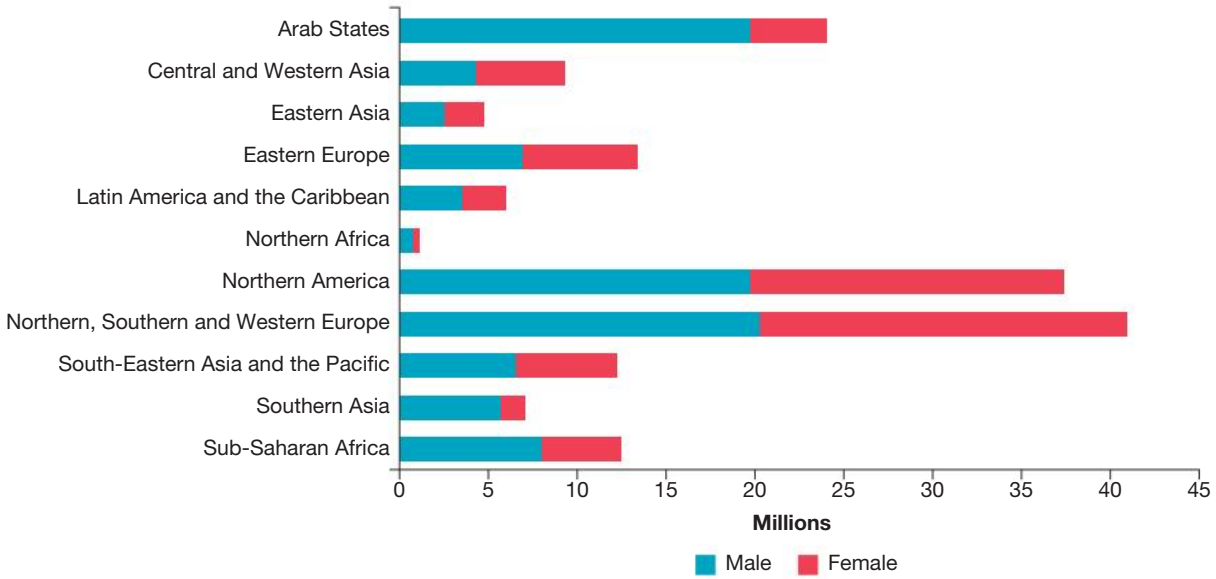
Stage	1	2	3	4	5
Population pyramid					
Descriptor					



Question 3 (5 marks)

Analyse the graph to identify the trends in the destination of economic migrants. Suggest a reason to explain the trend for one region, and identify a possible impact of this trend.

FIGURE 4.81 Geographic distribution of migrant workers by sex (millions)



Section II — Extended response

Question 4 (15 marks)

Analyse the stimulus material to infer demographic challenges for the Democratic Republic of Congo.

Apply geographical understanding from your analysis to suggest impacts of these challenges for the people.

FIGURE 4.82 Population pyramid for Democratic Republic of the Congo, 2024

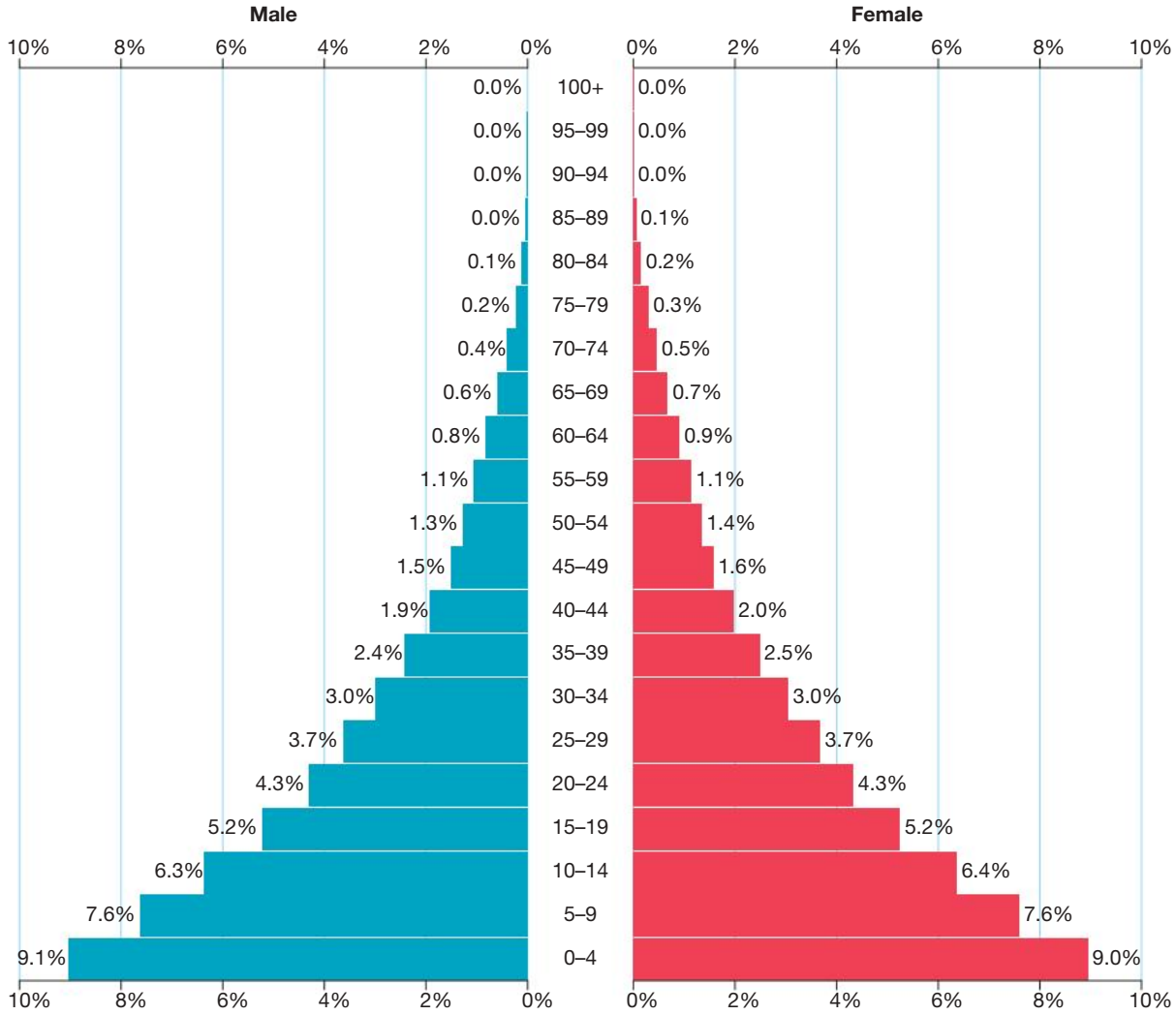


FIGURE 4.83 Population types in the Democratic Republic of the Congo, 2024

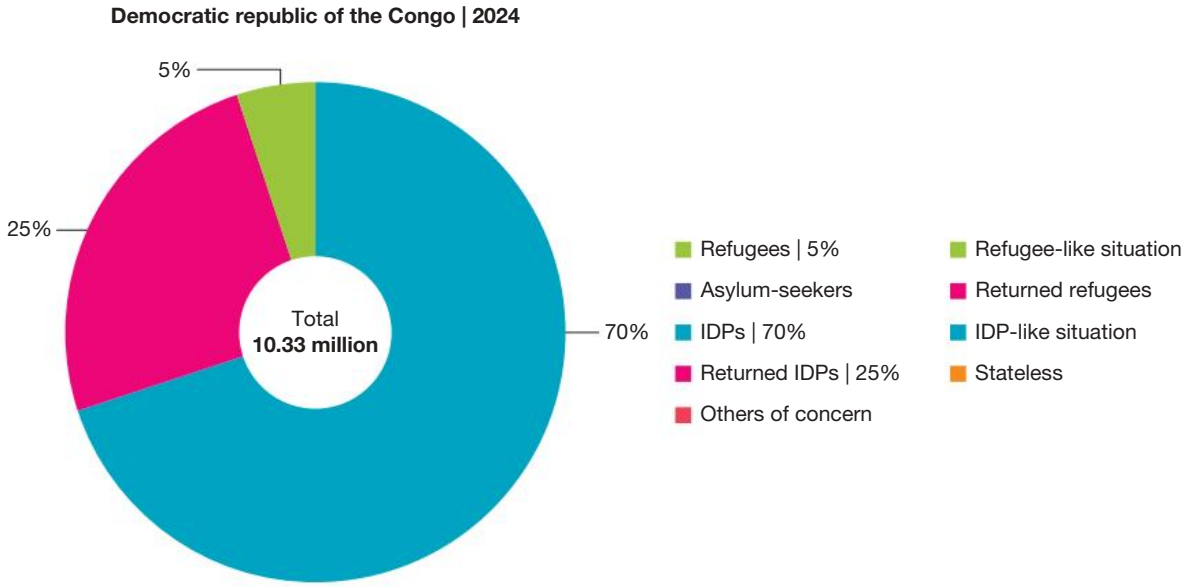
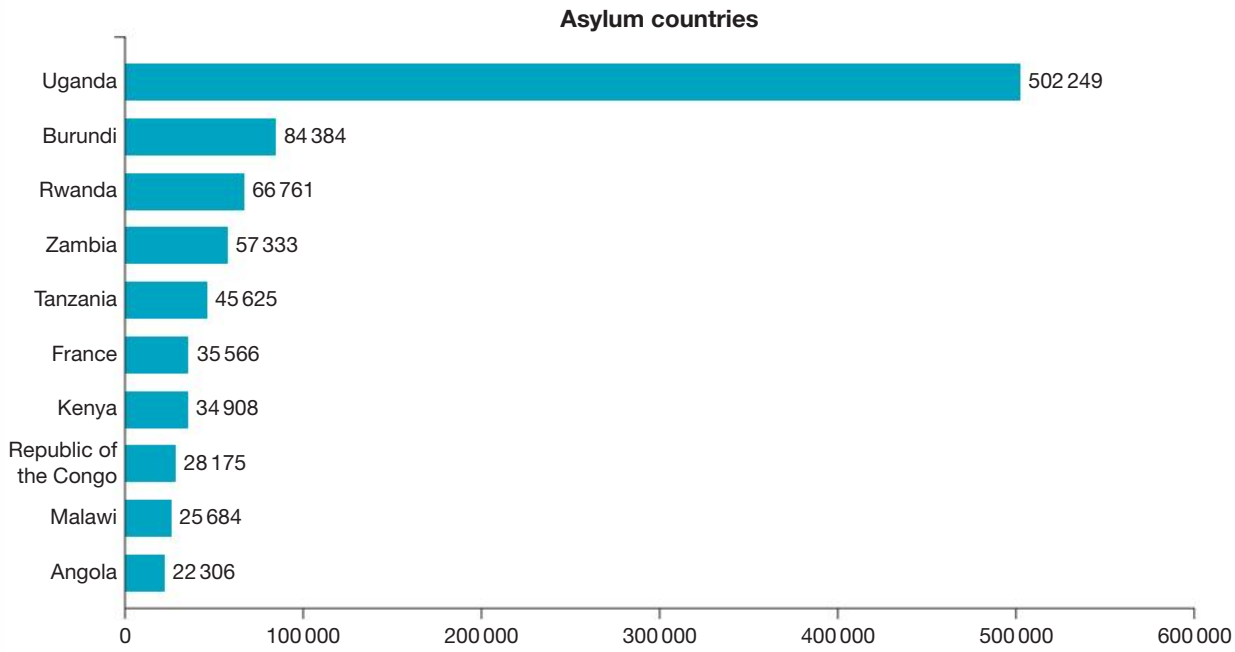


FIGURE 4.84 Top 10 destination countries for refugees from the Democratic Republic of the Congo, 2023



Sample responses for this chapter are available online.

GLOSSARY

activism efforts to affect societal change through grass roots action

age/sex structure the composition of a population by age (0–4 years, 5–9 years, 10–14 years … and sex (male, female)

albedo a measure of the ability of surfaces to reflect sunlight (heat from the sun). Light surfaces return much of the heat back to the atmosphere and dark surfaces absorb heat from the sun.

algal blooms rapid increases in the accumulation of algae in a water body due to some external pressure (e.g. rapid increase or decrease in temperature or increased nutrients)

amenity the desirable or useful features or facilities of places, including access to shops and other services required for daily living, employment, health care, educational services, transport, cultural and leisure services, and green spaces

anthropogenic caused by human beings

anthropogenic biome the human biome, created by human interaction with the biosphere

archipelago an island group or chain of islands, such as Indonesia

baby boom an upward spike for a number of years in birth rates; the period in Australia from the late 1940s to the early 1960s when birth rates were higher than they had been since the 1920s

biodiversity biological diversity; describes the variation of living plant and animal species that occupy an area or ecosystem

biogeographic areas smaller regions where the distribution of plants, animals and geology reveals many shared or common features, such as Wallum country of southern Queensland

biomes very large regions of the Earth where area-specific plants and animals have adapted to the climate, soil and relief of that environment; deserts and rainforests are biomes

biophysical of or relating to the physical environment, which includes the living organisms that inhabit it

birth rates the annual number of live births in a particular place per 1000 people; also known as crude birth rate

broadscale clearing indiscriminate clearing of large tracts of land, usually to prepare that land for agricultural production. A heavy chain strung between two heavy bulldozers is the favoured method of broadscale clearing in Queensland.

carbon cycle the chain of biogeochemical processes that exchange or move carbon between the biosphere, the atmosphere, hydrosphere and lithosphere

chaparrals the hot, dry shrublands and heath country in the US and South Africa

climate the average state of weather conditions over a long period of time

continents the largest landmasses on Earth: Africa, Antarctica, Asia, Australia, Europe, North America and South America

core describes the advanced economic core of a country or region surrounded by the less economically developed periphery

Coriolis effect a force like inertia that deflects objects moving across the surface (air, ocean currents, etc) to the left in the southern hemisphere and to the right in the northern hemisphere. It is caused by the rotation of the Earth.

crops plant or animal products that can be grown and harvested for consumption and/or profit

cumulative causation the snowballing of positive benefits associated with the establishment of new economic activity in a place. The newly established activity attracts associated economic activity, which in turn attracts further activity.

curvilinear relationship relationship in a correlation that is more complex than a simple linear relationship. In the higher ends of each variable in a curvilinear relationship, there is little variation, whereas at the lower end there is more variability.

death rates the annual number of deaths in a particular place per 1000 people; also known as crude death rate

deforestation the intentional clearing or removal of forests to make way for some other purpose such as farming, housing, constructing a dam, and so on. Deforestation is regarded as a permanent loss of forest and is most common in countries with large areas of rainforest such as Brazil and Indonesia.

Demographic Transition model describes how changes in population growth respond to relative differences in birth and death rates, which themselves change over time

demography the study of population, especially human population. Demography involves statistical analysis of characteristics such as population size and composition, distribution across space and the processes through which populations change over time.

deposition when seas, rivers or the wind drop the material they have been carrying, creating or changing landforms

developed world countries with mature industrialised economies, which exhibit a high gross domestic product (GDP) per capita

development the process of changing the purpose of a piece of land by constructing or removing something

diversity a variety of different things or species

ecosystems communities of biotic (living organisms) and abiotic (non-living things like water and soil) that are linked through nutrient cycles and energy flows. An ecosystem may be large like a barrier reef or small like a garden.

enclaves communities of migrants already established in particular neighbourhoods

erosion the wearing down of rocks and soils on the Earth's surface by the action of water, ice, wind, waves, glaciers and other processes

evapotranspiration the process of water transferring from the land to the atmosphere via evaporation and transpiration

food insecurity a situation in which people do not have physical and economic access to the basic food they need to work and function normally

forced migration when people are forced to leave an area against their will or as a result of life-threatening circumstances

fossil fuels fuels formed by natural processes that contain energy originally captured during photosynthesis (e.g. decomposition of living matter into coal or oil)

geospatial technologies tools that allow the user to collect, manipulate, distribute, analyse and communicate geospatial information, such as GPS receivers, GIS applications or UAV drones

ghettos extreme forms of residential concentration by culture, religious belief or ethnicity

greenhouse gases gases such as water vapour, carbon dioxide, methane, nitrous oxide and ozone found in the atmosphere; because they absorb radiant energy and trap heat, they help warm the Earth and cause the greenhouse effect

high and low variants upper and lower limits of reasonable population growth projections

hydrological cycle the process of exchanging water between the air, land and sea through evaporation, condensation and precipitation

infant mortality the number of babies who die before one year of age per 1000 births

Intertropical Convergence Zone (ITCZ) the large region of low pressure close to the equator where the trade winds of both the northern and southern hemispheres meet. Due to high temperatures, warm ocean water and trade wind convergence, the region has unstable air that rises, forming thunderstorms. It moves either side of the equator according to the summers and often appears on weather maps as a monsoon trough.

land cover what is covering the land (e.g. vegetation, human infrastructure or development, agriculture or bare earth)

land use how people use an area for economic, social or cultural purposes

least developed countries the countries with the lowest gross domestic product (GDP) per capita and relatively lower life expectancy and higher birth, death and fertility rates

life expectancy the average number of years a newborn infant is expected to live, given the mortality rates at the time of their birth

littoral drift the movement of sedimentary materials into the littoral zone (shoreline) under the influence of waves and tides

medium variant the most likely population growth forecast

migration rate immigration (incoming) number minus emigration (departing) number, per 1000 people

mineralisation the process by which chemicals present in organic matter are broken down into easily available forms to plants

minerals naturally occurring solid chemical compounds (e.g. salt, quartz)
modernisation theory developed in the mid-twentieth century with the aim of showing that low-income countries needed to follow the same path to development as Western countries
mortality rates death rate, usually for a specific group in a population; for example, maternal mortality rate
net migration the number of immigrants minus the number of emigrants
newly industrialised countries (NICs) countries where the economy has transitioned from that of a less developed country based on primary products to one increasingly based on the production of manufactured goods.
nitrogen cycle the biogeochemical loops where nitrogen in its various forms is circulated between the atmosphere, hydrosphere, lithosphere and biosphere
nutrients substances used by an organism to survive, grow and reproduce
oceans the largest bodies of water on the Earth, holding more than 96 per cent of all water; ocean water is approximately 3.5 per cent salt
peripheral agricultural countries
permafrost any ground (rock, soil, sediment) that is frozen or remains 0 °C or colder for a period of two years. It is most common in regions in the high latitudes, such as the tundra. Global warming is threatening to thaw out large areas of permafrost.
population density a measurement of the number of people located in a given area, usually the number of people per square kilometre
population distribution the way a population is spread over space (sparsely populated, densely populated, etc)
population momentum the continued growth of a population despite the fertility rate being below replacement level. It ceases once the segment of the population of reproductive years has moved beyond childbearing age.
population pyramid a compound bar graph illustrating the age/sex structure of a place's population; also known as age/sex pyramid
prairie vast stretch of temperate grassland with few trees. Prairies are fertile due to the thousands of years of decaying grasses. Because soils are highly compacted with few air spaces, it is difficult for trees to grow.
precipitation rainfall
primary data data collected by the author directly from the source
pull factors positive features of places that are attractive to migrants; they draw people towards places
push factors negative features of places that are responsible for people leaving
rangelands a broad term describing remote country used for grazing domestic livestock or wild animals. They include tallgrass and shortgrass prairies, semi-desert grasslands, shrublands, woodlands, savannas, chaparrals and steppes. Much of Australia's inland could be classed as rangeland.
rate of natural increase the birth rate minus the death rate, expressed as a percentage: (crude birth rate minus crude death rate) × 100/1000
rates the fixed ratio between two measurements
remittances the transfer of money by a foreign worker to help increase the household income in their home country
replacement fertility the rate required for a population to replace itself from one generation to the next (approximately 2.1 births per woman)
resources sources from which some benefit is produced (e.g. wood, minerals, water)
riparian zone the interface between a waterway and the land that provides habitat, prevents erosion and blocks nutrients and sediments from entering the waterway
savanna the region of tropical grasslands intermixed with woodlands; trees are widely spaced and there is no distinct canopy
sea change a change in lifestyle, especially a move from the city to a seaside location
secondary data data collected by someone other than the author
semi-peripheral second-tier industrialised countries
sex ratio number of males per 100 females in a population
Southern Oscillation Index (SOI) a measure of the development and intensity of El Niño or La Niña events in the Pacific Ocean. It is based on the pressure differences between Tahiti and Darwin.
steppes flat grassland with no trees

sustainability a process of maintaining balance in an environment while retaining the ability of current and future inhabitants to use that environment

synoptic chart a weather chart that shows a summary of weather detail over a large area; for example, the daily weather map of Australia shows a summary of air pressure, rainfall, winds and temperature

thermocline the cool layer of ocean water below the surface; it is still warmer than the very cold layer on the ocean floor

total fertility rate the number of children born per woman of childbearing age

trade winds the easterly prevailing winds (north-east and south-east) blowing from sub-tropical areas towards the tropics

transmigration the coordinated movement of people to better use resources or fill labour shortages, overseen by a government body

tree change a change in lifestyle, especially a move from the city to a rural location

troposphere the lower 10–12 km of atmosphere where most weather activity takes place

tundra the very cold, flat and almost treeless biome below the northern Arctic. Because of the permafrost and snow cover for much of the year, there is only a short growing season for some mosses, lichens and grasses.

urbanisation an increase in the total population or the percentage of a country's population living in urban areas

voluntary migration when people migrate from one location to another by their own choice

Walker Circulation a model of air flow in the lower atmosphere across the oceans, consistent with differences in air temperature between continents and oceans. It is used as a measure for determining the onset of an El Niño event.

water cycle a model that demonstrates the movement of water on, above and below our environment

weather conditions in the air above the Earth over a short period of time

wetlands low-lying areas containing salt marshes, swamps, bogs, peatlands and mangroves; regularly inundated by water

world fertility rate the number of children born per woman of childbearing age

yield gap the difference between current yield and yield potential

yield potential the output of a crop that can be achieved by regulation of genetic characteristics and temperature

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