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VCE GEOGRAPHY SERIES

3rd Edition

UNIT 3

Changing the Land

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Changing the Land

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1 Geographical concepts and questions

Geographers investigate and interpret the *places* that make up our world by exploring, analysing and understanding their characteristics and the *processes* that shape them. Geographers use a number of concepts in this process. These concepts are the big organising ideas which, together, uniquely belong to Geography as a field of study.

VCE Geography is underpinned by twelve interrelated key geographical concepts. These should form part of your vocabulary and guide you in your thinking, description, analysis, synthesis and communication in Geography. The concepts are used in conjunction with skills and are applied to topics of study to create a uniquely geographical way of investigating and understanding the world.

In VCE Geography, the twelve key geographical concepts are: *place*, *scale*, *distance*, *distribution*, *environment*, *interconnection*, *movement*, *region*, *change*, *process*, *spatial association* and *sustainability*. It will become clear through your work with the concepts in this chapter that they *interconnect* with and support one another extensively.

The purpose of this chapter is to provide an understanding of, and some experience with, using key concepts that are important to the study of Geography, particularly as they relate to *changing* land use and land cover. Your aim should be to understand and apply each concept as a means of thinking and working geographically.

Key geographical concepts in context

Place

'Where's your *place*?' It is a common enough question to ask someone where they live, but there is more behind this question than you might think. A reply might be as generic as a suburb or as specific as a street address. Or even a latitude and longitude which are regarded as absolute locations, there being no other *place* on Earth that meets that locational definition. In addition, a six-figure grid reference from a topographic map will allow you to give an absolute location. Location is the 'where of *place*' and is an important component of *place* in its own right. For example, Chadstone Shopping Centre is the biggest

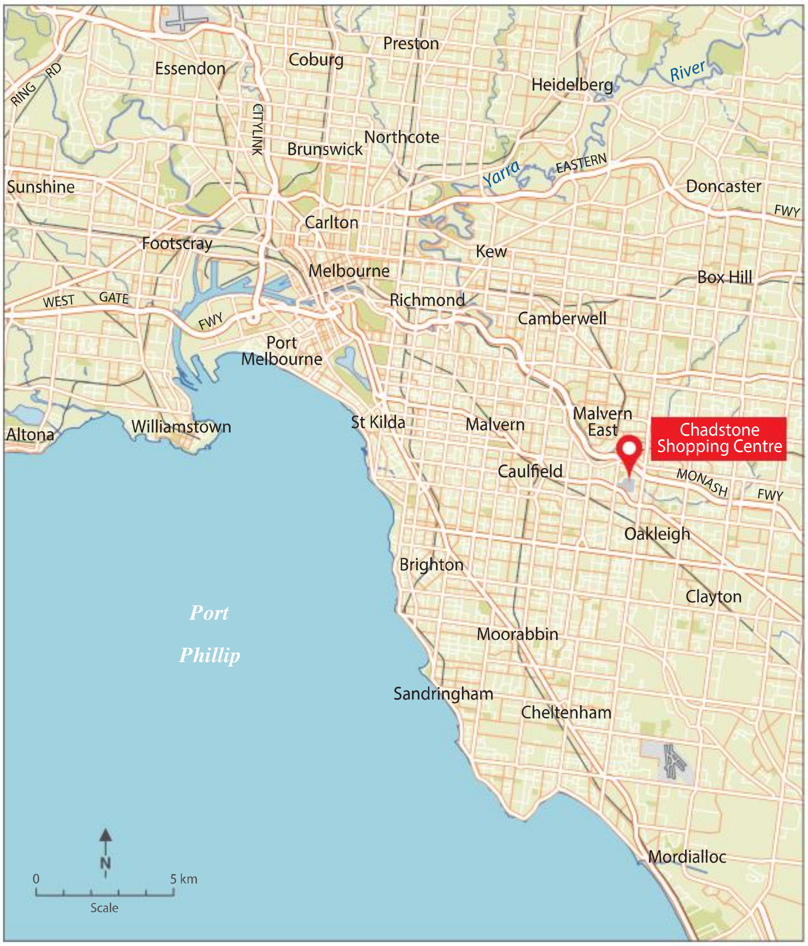
▲ **Figure 1.1** Aerial view of the *place* of Chadstone Shopping Centre in **(a)** 1945 and **(b)** 2019 shopping centre in Melbourne and claims to be the largest in the Southern Hemisphere. The centre opened on 3 October 1960 and was the first self-contained regional shopping centre in Melbourne. The latitude and longitude of Chadstone is 37°53′9″ S latitude and 145°4′57″ E longitude. Figure 1.1 shows the *change* in land use for this *place* between 1945 and 2019. In 1945 the land use for this *place* was agricultural with some nearby residential development. By 2019 the land use in this *place* had *changed* and was fully urbanised. The shopping centre occupies a large area with a major road to the south and a freeway to the north east.

Relative location refers to the *distance* and direction from one *place* to another. The use of *place* names, landmarks and *regions* helps to specify the relative location of one *place* by comparing to the location of another *place*. For example, Figure 1.2 shows the location of Chadstone Shopping Centre relative to Melbourne's suburbs. Chadstone is located to the south-east of Melbourne's central business district and is located within the suburb of Malvern East.

Understanding a *place* relates to how people perceive and attach meaning to a location and its immediate surroundings; this creates their 'sense of *place*'. Though people may recognise the significance of a *place* as a home, the sense of *place* is naturally much greater for the person living there because of their direct attachment to, experiences in, and valuing of that *place*.

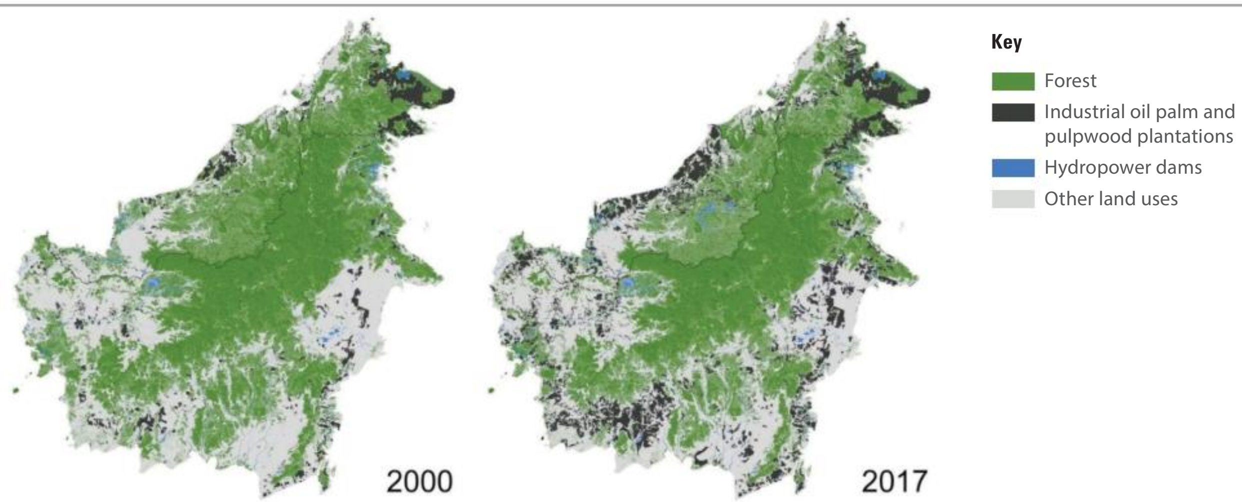
With the meaning of *places* comes value. A value could be the monetary value for a property, or a *place* could be valued for its aesthetic beauty, untouched remoteness or, for some people, a spiritual significance and attachment to *place* going back many generations.

Place is important when considering land use *change*. *Places* on rural–urban fringes are often under pressure of development particularly near large, growing urban areas. Perceptions about *change* in some *places* will be affected depending on the impact on the *environment* and their significance to others. For example, is the *change* close to a national park or sites of Indigenous significance?



▲ **Figure 1.2** Location of Chadstone Shopping Centre within Melbourne

There are also significant *places* undergoing land cover *change*. For example, the extent of forest removal in Borneo shown in Figure 1.3 has produced different responses depending on individual values, beliefs and circumstances of people living close by and further away. People gaining employment and an income from forest products have one view about the *change* in land cover in Borneo compared to geographers and biologists studying the same forests for biodiversity loss and water quality deterioration.



New maps of Borneo reveals expansion of industrial oil palm and pulpwood plantations (black) and forest loss (green to another color) every year since year 2000 until 2017. Green to white= forest loss, green to black= forest cleared and converted to plantations in the same year, green to blue= forest permanently flooded by hydropower dams (see in the state of Sarawak, Malaysia). CIFOR/ David Gaveau et al

▲ **Figure 1.3** Land cover *change* in Borneo 2000–2017

Scale

Scale refers to the size of something compared with something else and is used in one of two practical ways in Geography.

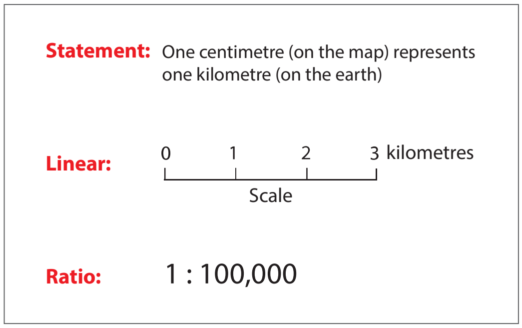
In one sense, we use *scale* on maps to determine the size relationship between the reality of something on the Earth's surface and the size at which that thing can be represented on a much smaller map. The *scale* of a map influences how it can be used. Smaller-*scale* maps depict a larger area in less detail, often being useful to show an overview or context for what is being studied. A map of Australia and surrounding islands would be a small-*scale* map. The *scale* of such a map may be 1:16,000,000. Large-*scale* maps show smaller areas in greater detail. For example, topographic maps showing individual buildings and minor as well as major roads are usually large-*scale* maps. The *scale* of a topographic map may be 1:25,000. *Scale* on a map can be expressed in various ways, as shown in Figure 1.4.

The second use of *scale* is observational. These are the logical and descriptive size-based units into which geographers divide the world in order to structure the study and understanding of *places*, *regions* and phenomena. The *scales* geographers use are summarised in Figure 1.5.

Land cover *changes* resulting from deforestation and melting glaciers and ice sheets vary in their *scale*, *distribution* and impact. At times these events are observed and measured at a local or national *scale*. A number of case studies in this textbook are provided at a range of *scales*. The example of land use *change* with the development of Chadstone Shopping Centre (see Figures 1.1 and 1.2) occurred at a local *scale*. The example of loss of forest cover in Borneo is a *regional scale* (see Figure 1.3). Sometimes the *change* can be observed at a global *scale* such as surface temperature *changes* shown in Figure 1.6.

Geographers require the ability to freely zoom in and zoom out in their *scale* view, when seeking explanations, relationships, influences and outcomes of and between phenomena.

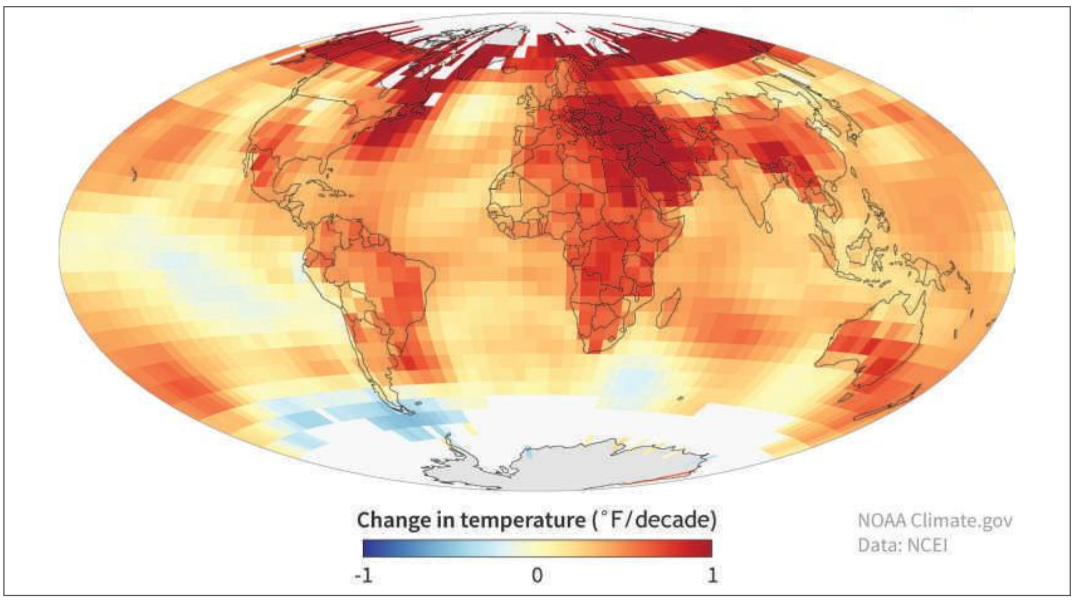
▼ **Figure 1.4** Map *scale* can be expressed as a statement, a ratio or in linear format



▼ **Figure 1.5** Applying observational *scale* in Geography

Observational *scale*	Examples
Local	Involving a limited area such as a farm, shopping centre, a suburb or rural town; the immediate area around a location
National	Involving an entire county, or being of national significance and impact
International	Involving two or more countries, crossing national borders
Global	Involving the entire Earth, or impacting on the planet as a whole
Regional	Flexibly defined, varies in size and nature; may be inter-national i.e. covering more than one nation, or intra-national i.e. within a nation (see *Region* page 8)

Changing scale



▲ **Figure 1.6** Observed *change* in global average surface temperature between 1990 and 2019

Distance

Distance is measured in a number of ways. In its simplest form, it is the space between two locations and can be determined using an absolute measure such as kilometres. *Distance* is used to assist with defining where things are located, often also using direction. As an example, Chadstone Shopping Centre (Figure 1.2) is located 14 kilometres south-east of central Melbourne.

Distance is used as an indication of proximity, which often suggests the existence of relationships (e.g. *spatial association*) between things. Greatly distant phenomena are less likely to directly influence one another.

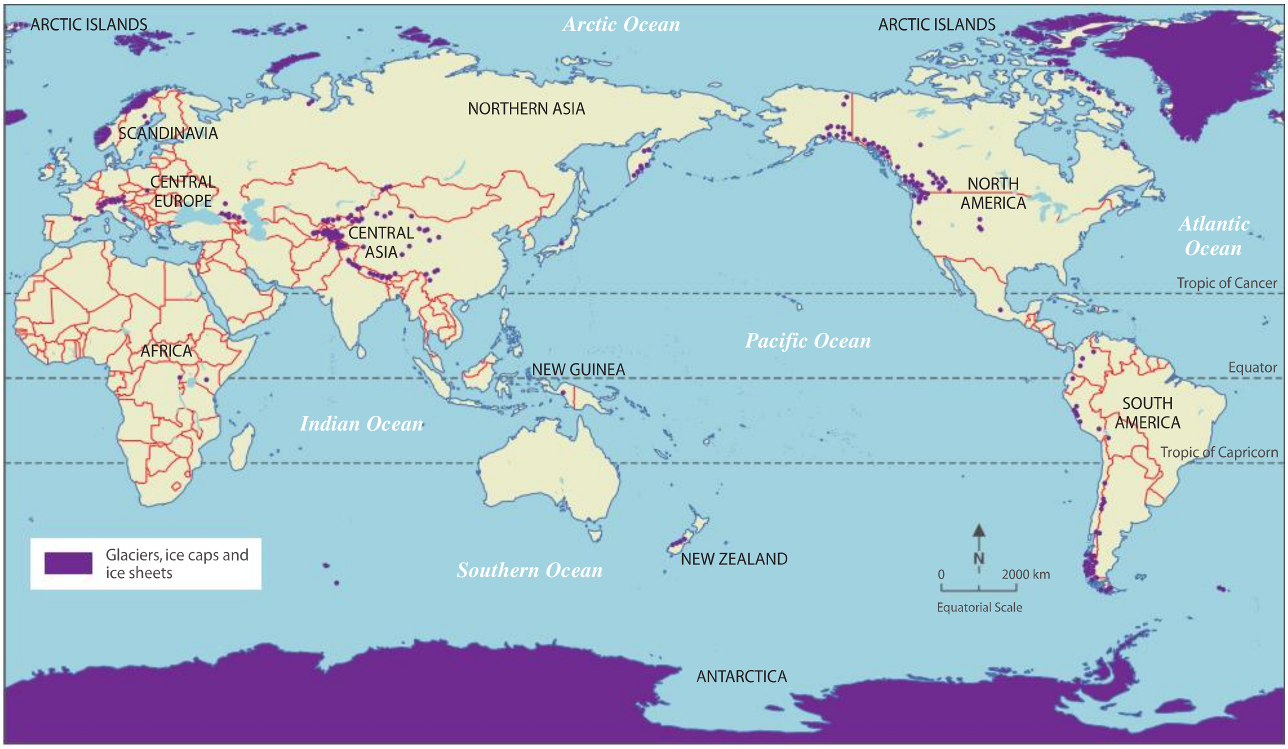
Relative *distance* is a second broad category that can be measured in other ways. The amount of time it takes to travel a given *distance* (e.g. 'I live 20 minutes away from here') is an example of relative *distance*. It is also possible to use less tangible measures such as psychological *distance*, where familiar *places* seem closer than less familiar ones (e.g. Until I travelled there, I didn't realise Mildura was so far from Melbourne).

Distance can be applied in various ways to understand land use *change*. For example, when planning for growth in Melbourne's urban area, planners need to consider the extent and *distance* of key transport infrastructure such as ports, airports, railways, and major highways and local roads. *Distances* from the CBD and other major cities and towns also need to be considered. Figure 1.7 shows the relevance of *distance* when considering Melbourne's future growth corridors.

Distribution

Distribution involves the arrangement of features or objects on the Earth's surface. *Distribution* can occur at all *scales*, and often patterns can be observed and described as the arrangement or density of phenomena. Figure 1.8 shows the global *distribution* of glaciers, ice caps and ice sheets. Using the PQE method of describing the *distribution* of data – general pattern, quantification and exceptions – in general, the majority of glaciers, ice caps and ice sheets are *distributed* in a dispersed pattern north of the Tropic of Cancer in the northern hemisphere in the *regions* of North America, Central Asia, Scandinavia and Central Europe.

Figure 1.7 Plan Melbourne showing the predicted corridors of urban growth for Melbourne until 2050

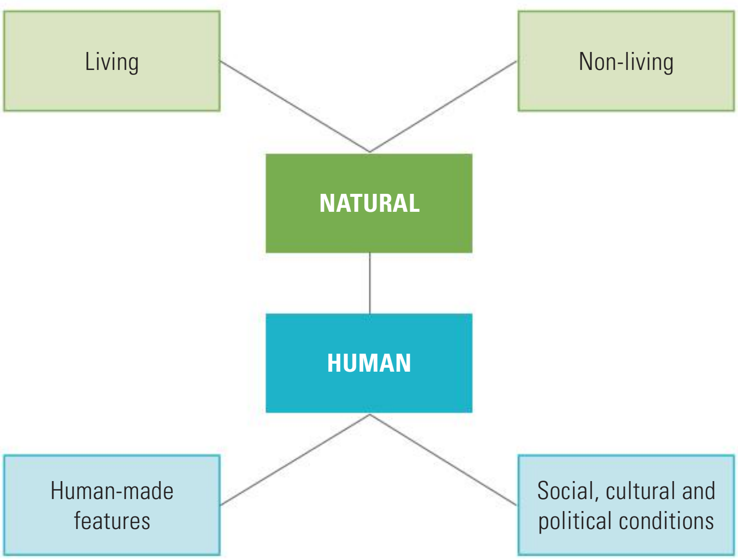


▲ **Figure 1.8** The global *distribution* of glaciers, ice caps and ice sheets

There is a clustered pattern of ice sheets in the polar areas of Antarctica and Greenland as well as a cluster of glaciers in parts of central Asia. There is a lineal pattern of glaciers along the west coast of the Americas (general pattern). Antarctica has the most extensive area of ice sheet (quantification). There are also scattered areas of glaciers and ice sheets in Europe and New Zealand. Australia is the only continent without glaciers, ice sheets or caps (exceptions).

The *distribution* of land use *change* and land cover *change* is not uniform across the Earth or within a given country or *region*. This is due to a range of factors including differences in the physical landscape and natural *environments*. Significant differences in policies, management strategies and socioeconomic conditions also have an impact on the location and extent of land use *change* and land cover *change*.

▼ **Figure 1.9** Components of the *environment*

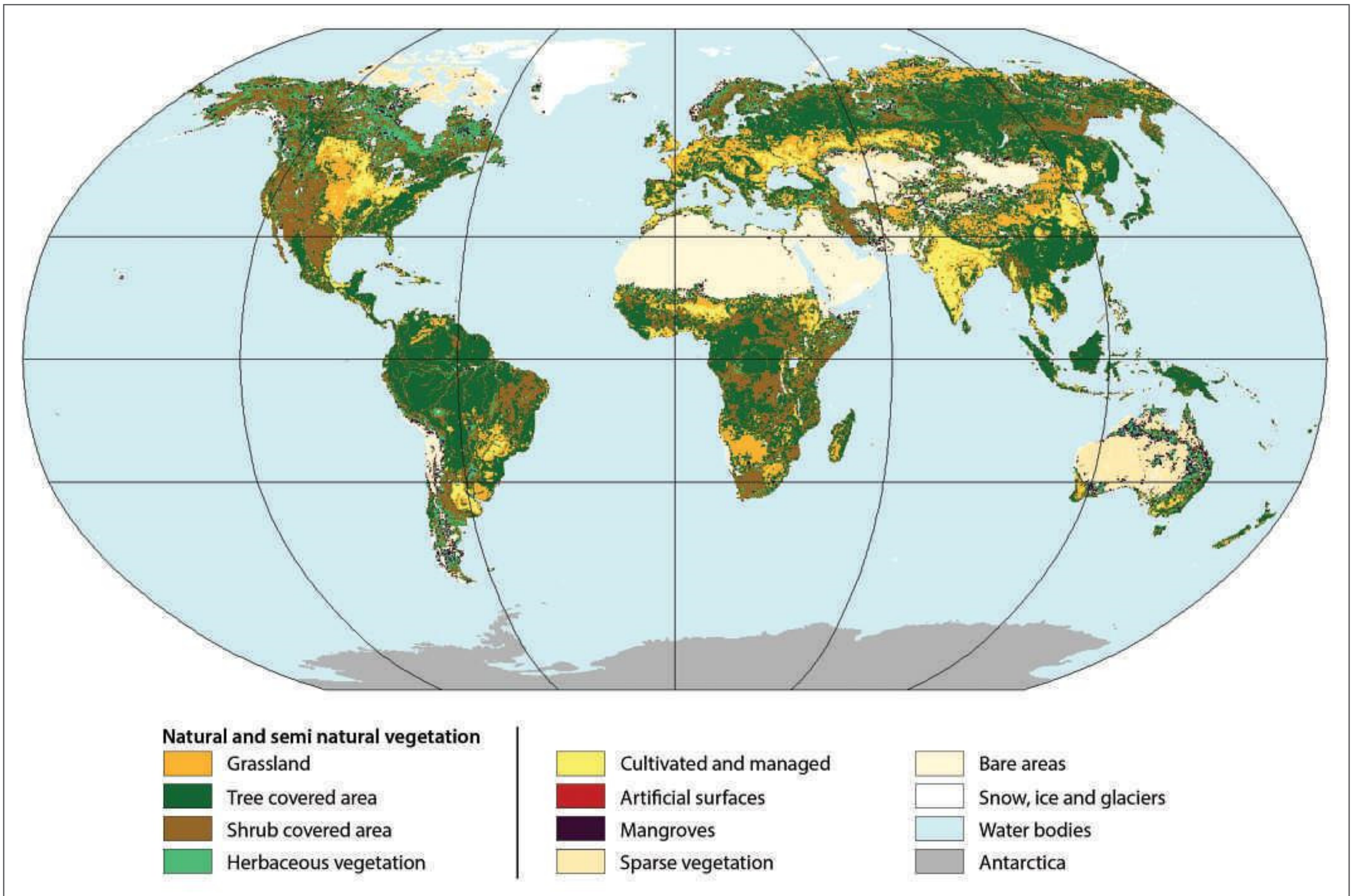


Environment

Environment refers to the world around us. It comprises the *interconnected* living and non-living physical elements of the Earth's surface and atmosphere as well as human-made features and the human conditions of *places* (see summary in Figure 1.9). The natural *environment* includes weather and climate, landforms, water features, natural vegetation and soils, and these features can be classified as living or non-living. The human *environment* includes surroundings made by people such as settlements, transport routes and nodes, and farmlands as well as the social, cultural and political conditions affecting a *place*. These conditions may be located in or beyond a particular *place* and may include economic influences.

There are many different types of *environments* that make up our world. At a global *scale* the *environment* can be classified into to the different types of land cover that exist on the land surface. Figure 1.10 shows the *distribution* of dominant land covers. Some are grouped as natural and semi-natural vegetation. Other areas include those altered by humans such as cultivated and managed areas and artificial surfaces such as those found in settlements. Many *environments* are a mix of human and natural features. Even harsh natural *environments* such as glaciers, ice caps and ice sheets as shown in Figure 1.8 include human-made features such as buildings and air strips to accommodate scientists who study this *environment*.

Some *environments* have been so *changed* by humans that very few features of the natural *environment* remain. For example, Figure 1.1 shows the *change* in the *environment* in the *place* of Chadstone Shopping Centre between 1945 and 2019. In 2019, this *environment* was more dominated by human features as this *place* has become fully urbanised by the development of the large Chadstone Shopping Centre and features of the natural *environment* have been reduced.



▲ **Figure 1.10** *Distribution* of dominant land covers (modified from FAO data, 2014)

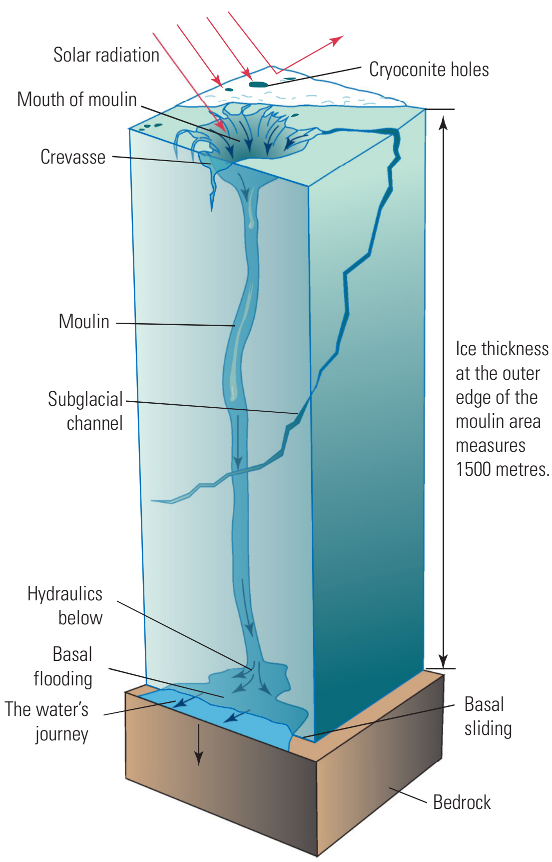
Interconnection

The concept of *interconnection* emphasises that all *places* and *environments* are *interconnected* in some way and that they do not exist in isolation, whether at a local or global level. Geographical phenomena are connected to each other through *environmental processes* or human activities.

An example of *interconnection* as a result of *environmental processes* can be seen with reference to Figure 1.11. Cryoconite is a mineral formed from the dust, volcanic matter and air pollution deposited by the wind on the surface of an ice sheet. The dark colour of the cryoconite decreases the reflectivity (albedo) of the ice, which increases the absorption of heat. This can cause holes to form in the ice sheet surface. If this hole is near a crevasse then a roughly circular, vertical well-like shaft within a glacier or ice sheet, known as a moulin, may form. The subglacial channel of the crevasse enables the moulin to channel meltwater from the ice surface deep into the ice sheet which may then reach the base bedrock and flow between the base of the ice sheet and the bedrock (basal flooding). This lubricates the ice sheet and allows faster basal sliding of the ice sheet and the accelerated *movement* of ice sheets and glaciers. Thus, the deposits of cryoconite on ice sheets is *interconnected* with the melting of the ice sheet from its base.

Human activities such as the *movement* of people, flows of trade and investment, the purchase of goods and services, cultural influences, the exchange of ideas and information, political power and international

▼ **Figure 1.11** Cryoconite and the formation of moulins



agreements are all examples of *interconnection* in the human *environment*. For example, Figure 1.7 of Plan Melbourne can be used to show *interconnection* between human activities and this illustrates various *spatial associations*. For example, seaports are *interconnected* to key transport connections (road and rail) and key industrial precincts to allow the *movement* of goods.

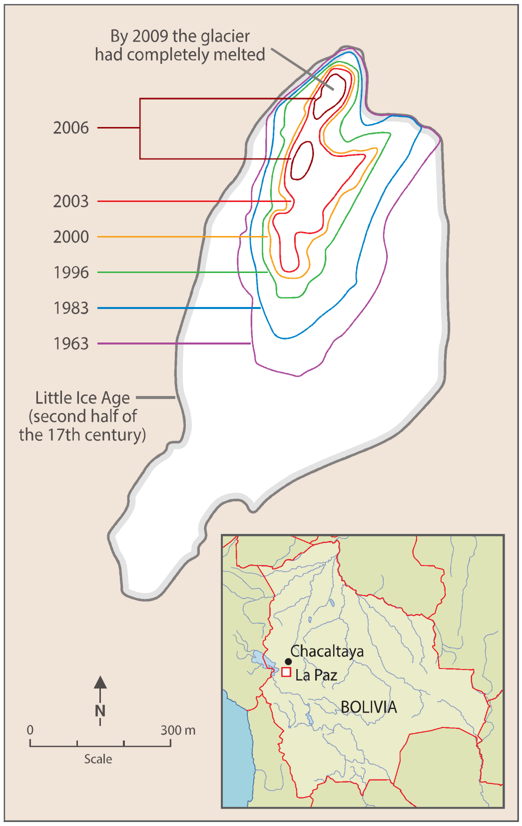
These *interconnections* have significant influences on the characteristics of *places* and on *changes* in these characteristics. Use of the concept of *interconnection* enables us to have a better understanding of the complex links between *environments* and human activities in our world.

Movement

Movement involves a *change* in the location of phenomena such as people, goods and ideas. The development of transport infrastructure and modes of transport can have an impact on the *movement* of goods and services and is an important consideration in urban planning and land use *change*. The *movement* of people to outer suburbs and urban–rural fringes can rapidly alter land use.

Movement is an important consideration in land cover *change*. Consider *regions* that are increasingly affected by melting glaciers. Figure 1.12 shows an example of the *movement* of ice in the Chacaltaya Glacier located in Bolivia over time. Between 1963 and 2009 the glacier moved and reduced its cover until it disappeared completely in 2009. The concepts of *movement*, *change* and *distribution* are demonstrated in this example.

Where *movement* is concerned, *distance*, direction, the mechanism bringing about *movement*, in addition to the frequency, volume or magnitude of *movement*, may all be considered. *Movement* is represented in different ways graphically – colour and lines can show the date of spread while arrows can show the *distance* and direction of *movement*.



▲ **Figure 1.12** *Movement* of ice in the Chacaltaya Glacier, Bolivia

Region

A *region* is a definable area containing one or more characteristics that distinguish it from surrounding areas. *Regions* can be defined by physical characteristics such as mountain ranges and drainage basins, politically by official decisions about boundaries and names, and by common usage such as the western suburbs of Melbourne. Smaller *regions* can exist within larger ones, and different *regions* can overlap.

Region is important in terms of *scale*. *Regions* can be seen and defined at each of the local, national and international *scales*. Figure 1.13 provides examples of *regions* at a variety of *scales* that can be classified into various types. In this way, *region* itself can be used to represent a *scale*.

Deforestation, a land cover *change*, varies from *region* to *region* across the globe. The reasons for the differences can be associated with the amount of forest cover in each *region*, the policies in place to manage forests, socioeconomic pressures in each *region*, the use made of the wood and the type of land use replacing the forest. Figure 1.14 provides some information on the trees removed for industrial use and woodfuel and shows patterns across major world *regions*.

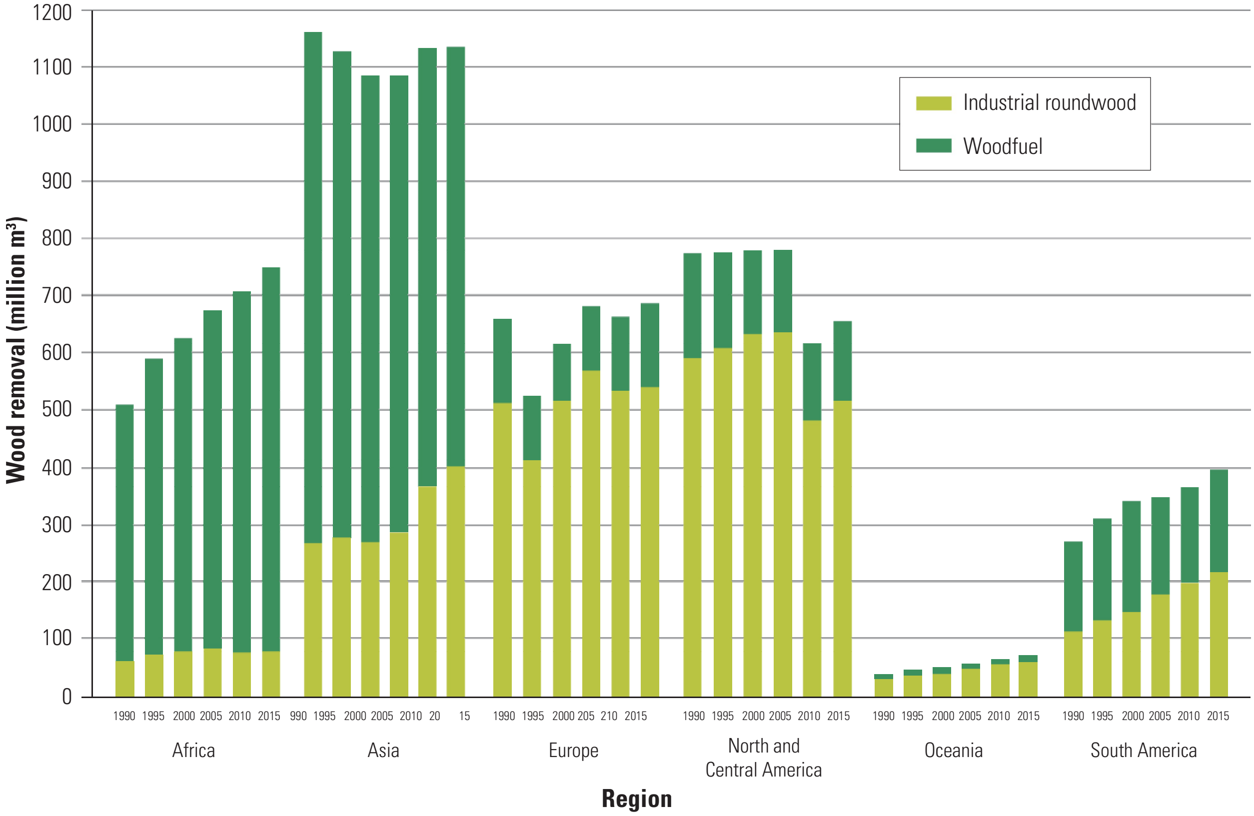
Change

Change relates to the degree to which something alters, or is modified, over time. As phenomena studied in Geography are dynamic, they are often best understood by investigating how the focus of investigation has developed over space and time. It is also valuable to examine the effects and impacts of *change*.

▼ **Figure 1.13** Examples of *regions* at different *scales* and how they are defined

Region	*Scale* relationship	Defined by…
Inter-tidal zone	Local	Physical
Chadstone Shopping Centre	Local	Land use
Otways rainforest	Local	Vegetation
Melbourne Central Business District	Local	Political/administrative, land use
Victorian Central Highlands	National	Political/administrative, physical
Great Victoria Desert	National	Climate, physical
South-eastern Australia	National	Location, common use
Amazon Basin	International	Physical
Tropics	International	Location, climate
Sub-Saharan Africa	International	Location, common use

▼ **Figure 1.14** Trends in wood removal by *region*, 1990–2015

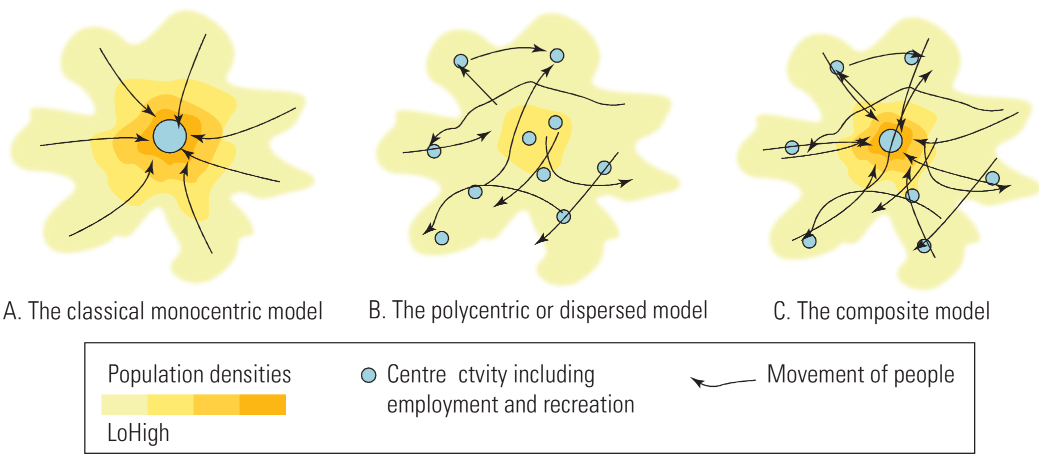


Change can be spatial and *place*-related. This can include *changes* in the location (that is, *movement*), size, *distribution*, density or pattern of phenomena. The transformation of the use, nature or quality of a *place* can also be identified. *Change* can be non-spatial and still be of relevance to Geography such as *changes* in land use policies. Varying occurrences of something over time can provide important information for geographers. Temporal *change* – or *change* over time – is one such example, such as the *change* in natural forest cover in Borneo shown in Figure 1.3.

Rates, and the duration, of *change* are important. In Geography *change* can be studied in time *scales* which range from millions of years for geological and landscape *change*, to a matter of a few years, months, days or even hours. Figure 1.12 shows the retreat of the Chacaltaya Glacier. The rate of *change* that has occurred in this *region* can be investigated using the PQE method of describing the *distribution* of data – general pattern, quantification and exceptions. There has been a north easterly retreat of the glacier over time (general pattern). Although the glacier retreated to some extent in the period between the Little Ice Age in the second half of the 17th Century and 1963 (exception), the most dramatic *change* occurred between 1963 and 2009 when the glacier rapidly retreated by over 600 metres to the north east in over 46 years (quantification). By 2009 the glacier had completely melted. Some *changes* are temporary, while others are longer in duration and may be permanent.

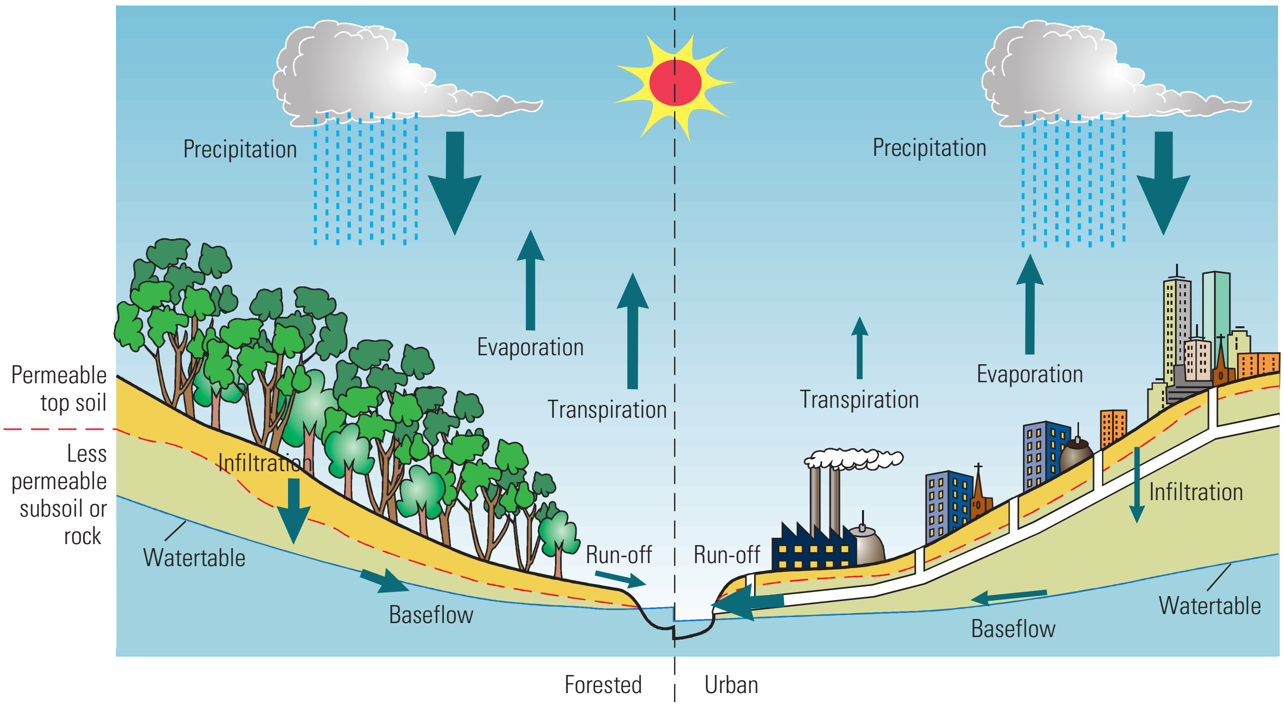
Process

Processes involve a series of ongoing events or steps that lead to the development, *change* or preservation of something. Often *processes* create cause-and-effect relationships between things. *Processes* can operate within and between *places*, and at various *scales*. For example, choices about the *distribution* of activity centres, as part of the planning *process*, can impact on patterns of *movement* of people and have an impact on population densities. Examples of this can be seen in Figure 1.15.



◀ **Figure 1.15** Processes involved in models of urban morphology

▼ **Figure 1.16** The impact of urban development on the water cycle



Complex *interconnections* between different *processes* can have an impact on one another. The water cycle is a complex *process* which involves the *movement* of water in different physical states in the *environment*. Figure 1.16 shows the impact of urban *change* on the water cycle. *Changes* in land use can alter this *process* quite dramatically. It is possible to view this *change* in terms of a variety of geographic factors – social, historic, economic, environmental, political and technological (SHEEPT). Socially, an increase in population has created a demand for the buildings to house the population. Over time (historic) an urban *environment* has developed. Economic growth has occurred as the demand for residences provides jobs for the rising number of residents. Political decisions about the layout of the area have been made as part of the urbanisation *process*. Due to the *change* in land use from a natural to a human *environment*, there has been a *change* in land cover from forest to a built-up landscape. This has had an impact on the *environment* as there is less infiltration, transpiration and base flow as well as a lowering of the water table. Underground pipes (technology) have also been used to transport increased run-off and thereby help divert flash floods.

Changes to complex *processes* have far-reaching impacts on the *environment* including people. For example, increased greenhouse gas concentrations have resulted in measurable *changes* to the Earth's climate. There are also complex *interconnections* between deforestation *processes* and climate *change*. Climate *change*, in turn, can cause disturbance such as accelerated melting of glaciers and ice sheets. Chapters 2–8 investigate these *processes* further.

Spatial association

It is common to find things occurring together on the Earth's surface. *Spatial association* is the degree to which two or more phenomena are similarly *distributed* or arranged on the Earth's surface. Where *distribution* patterns of phenomena are consistently similar, a strong or high degree of *spatial association* exists. For example, there is generally a strong *spatial association* between areas of the Earth with low rainfall and low population density because arid *regions* have little water for agriculture or domestic consumption. When one phenomenon has a high frequency and another phenomenon is lower in frequency, there is a weak or low degree of *spatial association*. For example, there is a weak *spatial association* between urban areas and the *distribution* of native animals in Australia, because urbanisation involves habitat destruction. It is also possible for there to be no *spatial association* at all. The task of the geographer is to determine the degree of *spatial association* and explore potential underlying reasons, or causes, for the existence of a relationship, or lack thereof.

Spatial association can also be viewed through the perspective of impacts. The coincidence between phenomena spatially might occur by chance, but the fact that they do have overlapping *distributions* has consequences. Figure 1.8 shows the *distribution* of glaciers, ice caps and ice sheets. The study of topographic and temperature maps in an atlas will show a strong *spatial association* between the location of ice areas and the *distribution* of high elevation areas.

Sustainability

Sustainability is the capacity of the *environment* and social systems to support people and other living things now and into the long-term future. It involves environmental, social, economic and political criteria to judge the wisest use of resources. For example, Figure 1.14 shows the increasing removal of wood in major world *regions*. If this trend were to continue then this resource would not be available in the future if it is being removed at an *unsustainable* rate. Chapter 8 examines the *distribution*, causes and impacts of the land cover *change* of deforestation with *regional* examples.

Local land use *change* can have an impact on people and the *environment*, and the ability of the land to respond in the medium and long term. Clearing land for housing on the rural–urban fringe can trigger feedback mechanisms in surface water flow, infiltration rates and erosion. *Changing* land use from rural production to urban housing (see Figure 1.1) can have an impact on soil health and agricultural productivity. Careful planning must be included in any land use decisions for the best *sustainable* outcomes to be achieved from the *change*.

ACTIVITIES

1. Refer to Figure 1.1. Describe the *change* in land use in the area of Chadstone Shopping Centre between 1945 and 2019.
2. Refer to Figure 1.3. Describe the *change* in land cover in Borneo between 2000 and 2017.
3. Explain how land use *change* is different from land cover *change*.

Place

4. Refer to an atlas or Google Maps in order to complete the following table:
   (The first example has been completed for you)

Figure	*Place*	Absolute location	Relative location
1.1	Chadstone, Melbourne	37°53′9″ S 145°4′57″ E	South-east of Melbourne's central business district in the suburb of Malvern East.
1.3	Brunei, Borneo		
1.7	Geelong, Victoria		
1.12	La Paz, Bolivia		

5. Describe your perception of each of the *places* listed in question 4.

Scale

6. Refer to each of the places in question 4. Classify each map as either large-*scale* or small-*scale* maps.
7. Allocate an observational *scale* (see Figure 1.5) for the following land use and land cover *changes* listed below.
   (You may have to research the event)
   - expanding urbanisation on Melbourne's rural-urban fringe
   - redevelopment of inner urban areas to residential uses
   - melting of Greenland ice sheet
   - removal of Indonesian rainforests for palm oil plantations
   - thawing permafrost in the Arctic Circle
   - glacial retreat in the European Alps.

Distance

8. Use the map *scale* in Figure 1.2 to measure the approximate *distance* between Williamstown and St Kilda.
9. Use the map *scale* in Figure 1.12 to measure the *distance* the glacier retreated between 1963 and 2003, and between 2003 and 2009. Comment on the difference in the *distances* retreated by the glacier between these two time periods.

Distribution

10. Refer to Figure 1.3. Using the PQE method describe the *distribution* of forest areas in Borneo in 2000.
11. Refer to Figure 1.3. Using the PQE method to describe the *distribution* of oil palm plantations in 2017.

Environment

12. Refer to the following figures and classify the type of *environment* shown as natural, human or mixed.

Figure	Natural, human or mixed *environment*
1.1	
1.2	
1.3	
1.6	
1.7	
1.8	
1.12	
1.16	

13. Refer to Figure 1.9 showing components of the *environment*. Provide examples of each of the components.

Interconnection

14. Refer to Figure 1.6 showing the observed *changes* in global average surface temperature between 1990 and 2019 and Figure 1.12 showing the *movement* of ice in the Chacaltaya Glacier, Bolivia. Describe the *interconnection* between these two items of data.

15. Refer to Figure 1.7. Describe the *interconnection* evident in Plan Melbourne.

Movement

16. Refer to Figure 1.7. Describe the pattern of *movement* of goods and people planned for Melbourne until 2050.

17. Refer to Figure 1.12. Describe the rate and direction of *movement* of the Chacaltaya Glacier in Bolivia.

Region

18. Study Figure 1.14 and answer the following questions with reference to data from the graph:

a. Which *region* has produced the greatest amount of industrial roundwood over time? Which *region* has produced the least?

b. Name two *regions* that rely most heavily on removing wood for fuel, and explain why they might not use other types of fuel.

c. Which *region* has shown the greatest *change* in industrial roundwood production?

19. Using the information in Figure 1.13 to guide you, complete the following table:

Figure	*Region*/ *Place*	*Scale* relationship	Defined by…
1.3	Borneo rainforest		
1.7	Melbourne, Australia		
1.12	Chacaltaya Glacier, Bolivia		

Change

20. Refer to Figure 1.3. Describe the *change* in the land cover of Borneo between 2000 and 2017.

21. Study Figure 1.6. Write a short paragraph that analyses the global *changes* in average surface temperatures between 1990 and 2019.

▶ ACTIVITIES *continued*

Process

22. Refer to Figure 1.15. Each planning model has a different *distribution* of activity centres. For each model, describe the impacts on population densities and the *movement* of people.

23. Study Figure 1.7. Using SHEEPT factors, suggest possible factors that may have influenced the direction and features for the planned growth of Melbourne.

24. Using the information provided in Figure 1.16, outline why the water cycle *process* has altered as a result of urbanisation.

Spatial association

25. Source world maps that show current world temperatures and elevation at a global *scale*. Use these maps and Figure 1.8 to describe the degree of *spatial association* between the *distribution* of glaciers, ice caps and ice sheets with elevation and temperature.

Sustainability

26. Refer to Figure 1.14. What indicators, not included in this graph, would you need to determine whether or not the wood is being removed at a *sustainable* rate? What human actions or decisions might prevent *sustainable* wood removal in one of those *regions*?

Analysing and interpreting data

In many cases in Geography, analysing and interpreting data relates directly or indirectly to the key geographical concepts. Developing a conceptual understanding and applying concepts to information analysis is the basis of many activities in this textbook. Some questions or tasks will include a concept by name, while others imply the use of one or more concepts in your thinking.

Tips for using concepts:

- In written responses to tasks that name a particular concept, it is usually appropriate to use that concept by name in your answer.
- Conceptual understanding can often be demonstrated visually; for example, in a map, graph or diagram. Examples of concepts shown well on maps include *scale*, *distance*, *distribution*, *region*, *movement*, *change* and *spatial association.* Commonly graphed examples include *distribution*, *movement* and *change*, particularly those involving a time *scale*. *Process* might be appropriately shown in a flow diagram.
- Higher quality written responses often communicate clear conceptual understanding, without necessarily using the concept by name.
- Avoid using concepts in responses unnecessarily. Doing so does not always show an understanding of the concept.

Throughout the chapters in this book, instructional (or directive) words are used in many activities. They specify how you should approach and complete a given task. Understanding these words and knowing what is expected of a response are important skills and will improve the quality of your answers as well as enhancing your geographical understanding.

The following table (Figure 1.17) provides explanations for instructional or directive terms found in this book, or likely to be used in class activities, assessments or fieldwork.

▼ **Figure 1.17** Instructional terms used in Geography

Account for	State reasons to explain an event or why something exists.
Analyse	Show the essence of something (e.g. a situation or a map) by breaking it down into separate points and critically examining the relationship between each part.
Annotate	Add labels, comments or explanatory notes to images, maps, graphs, diagrams or text.
Apply	Use particular skills or incorporate specific information and ideas to a situation.
Assess	Weigh up the value of or judge the strengths and weaknesses of something. Similar to 'evaluate', but more about the overall situation.
Calculate	Use data or statistics provided in various forms to determine an answer.
Categorise	Arrange or group by distinctive characteristics.
Clarify	Make clear or simplify facts, opinions, issues or arguments.
Classify	See 'categorise'.
Comment on	Give an opinion and explain reasons for support or a lack of support for an idea or issue. Can involve discussing the relevance or merit of a provided statement.
Compare	Show the similarities or differences when examining two situations, events, ideas, features or processes.

▼ **Figure 1.17** *continued*

Consider	Think about what has been observed about something, being able to support observations using appropriate evidence.
Construct	Put together an argument, point of view or a series of reasons to account for a particular situation. It also means to create, develop or draw a map, diagram, graph or table.
Contrast	Highlight the differences when examining two or more situations, events, ideas, features or processes.
Define	Provide a meaning or identify the essential qualities of a key term, word or expression.
Demonstrate	Show or provide proof by using examples from specific case studies, events or issues.
Describe	Provide characteristics of a situation explaining what is observed.
Design	Decide upon the look and functioning of a product such as a map, diagram or social survey.
Distinguish	Identify what is different between one or more similar situations or phenomena.
Discuss	Show understanding of a situation, where appropriate, by presenting both sides of a situation, issue or event. Include the strengths and weaknesses of available data. Usually involves more detail than 'explain'.
Evaluate	Weigh up and interpret a statement, viewpoint or situation and state a conclusion about its value or importance. Similar to 'assess', but with a focus on the outcome or result. Include consideration of different opinions.
Evaluate the relative importance of	A combination of 'rank' and 'evaluate'.
Explain	Relate cause and effect. Give reasons why a situation exists or a *process* occurs.
Explore	Adopt a questioning approach, looking at all aspects of the situation, including points for and against. Similar to 'discuss'.
Identify	Establish the nature of a situation by distinguishing its features and naming them.
Illustrate	Make something clear and explicit, by providing examples or evidence. May require the use of visual representations (e.g. maps, diagrams, tables, graphs and statistics).
Interpret	Examine visual data such as a map, graph or diagram, to make sense of what is being depicted and to draw conclusions.
Justify	Use examples or find sufficient evidence to show why, in your opinion, a viewpoint or conclusion is correct.
Observe	Identify significant items from numerical or visual data, or fieldwork.
Outline	Summarise the main points of given information, or events, in a situation.
Predict	Suggest what may happen in a given situation based on evidence gathered.
Quantify	Use numbers or statistics to describe a phenomenon and support conclusions.
Rank	Arrange factors, outcomes or elements in order of importance.
Recommend	Provide reasons in favour of a proposal.
Reflect on	Think about what has been presented, considered or observed and communicate those thoughts.
Sketch	Refers to a map, diagram or field drawing; a relatively simple, quick, hand-drawn representation that follows accepted, relevant conventions, but without an accurate *scale*.
Suggest	Present a hypothesis or theory about a particular situation.
Summarise	Retell concisely the relevant and major details of arguments, events and patterns.
To what extent do you agree?	A clear statement of agreement, disagreement or partial agreement concerning a proposition is required. See 'assess'.

Issues, challenges and evaluating responses

Geographers are often concerned with issues and challenges of geographical phenomena and events. Natural *processes* and human activity within *places* vary over time and affect the natural and built *environments* differently. When human activity produces a *change* in land cover a series of impacts can result. Some of these impacts might be planned, others might result from the initial aims of the *change*.

In Figures 1.18 and 1.19, a small part of the northern Queensland rainforest has been cleared to develop a tourist retreat. There are individual cabins built within the rainforest, a central car park, swimming pool, restaurant and administration block. Although this land cover and subsequent land use *change* occurs at a local *scale*, a range of impacts on the natural *environment*, economic activity and social conditions is likely. For instance, there was disturbance and destruction of local natural habitats to accommodate the retreat's infrastructure, local employment opportunities arose and there was increased interaction between local populations and a transient visiting population.

There are a range of impacts from this rainforest development that could be considered, including:

- the *scale* of impacts appears to be local, affecting the immediate rainforest area and its surrounds
- there were short term impacts with the forest clearance, but possibly also longer term ones that may extend over many decades
- which groups or stakeholders stood to gain or lose? Were they locals or ones further afield including investors and potential users of the site?

In turn these impacts can generate issues e.g. problems requiring discussions involving people and organisations over the consequences of *change*. And the issues *interconnect* to challenges, i.e. the action that could be undertaken by people and organisations to overcome the consequences of the *change* and the problems, and disagreements that these might generate. The issues in the above example will be closely related to the impacts of *change*. These issues could include:

- to what extent has the natural *environment* been disrupted or destroyed? How permanent will its effects be?
- is the local economy becoming dependent on this development? What if the development fails? Is employment only seasonal?
- is this a facility for wealthy visitors? People may only stay a few nights and remain strangers in the local community.

The challenges are how to resolve or mitigate the issues. The range of responses could be considerable for any issue. Planning to accommodate likely issues before the land cover *change* takes place is one strategy. This was very possible in the rainforest example.

When the *changes* in land cover are more complex and extend beyond the local *region*, the associated issues and challenges are similarly complex. No one planned the land cover *change* from ice to bare rock that is occurring in Figure 1.20. The issues here include the *scale* of the impact that has both local and global aspects. The challenges here include what to do with the enormous volume of water flow coming from the melting ice, as well as what happens downstream if the meltwater ceases to flow. Since this *process* is occurring at many other *places* and at considerably larger *scales*, a global response is likely. Chapter 7 details the range of responses that have occurred or are likely to occur with this land cover *change*.

▲ **Figure 1.18** A rainforest retreat in northern Queensland

▲ **Figure 1.19** The car park for the rainforest retreat in northern Queensland

▲ **Figure 1.20** One of Iceland's retreating glaciers

How effective responses have been or are likely to be when the response is only a concept or is not fully implemented, requires evaluation. Responses can be evaluated by developing and applying appropriate criteria. A criterion is a single standard or principle that something is judged by. Developing appropriate criteria requires considering more than one standard or principle.

Criteria can be constructed using a wide or narrow range of components. They may include the original aims or objectives of a specific program and estimating to what extent these are met. The evaluation can occur when evidence such as data is collected, or actions undertaken are put against the aims or objectives of the program. For example, an issue linked to Figures 1.18 and 1.19 was that the natural rainforest habitat was disturbed or destroyed. The linked challenge is how the natural habitat can be maintained. If an *environmental* survey of the habitat was undertaken before development commenced, a subsequent survey might produce enough evidence for an evaluation to be made. This evidence could include the presence of bird life and the number of nesting points.

The issues raised in relation to Figure 1.20 may be the rate of ice melting and its consequences – with the challenges of how to deal with the volume of meltwater as well as slow the rate of melting. Local or national plans need to be considered together with global responses. The latter could include the Intergovernmental Panel on Climate Change (IPCC) reports, specific international protocols and accords together with examples of recommendations, evidence of actions carried out or planned. A full evaluation should look at strengths, as well as weaknesses, of actions undertaken or planned to be undertaken. For example, is the response too costly, culturally inappropriate, or technically too complex for local people to manage? Consideration of the time *scales* involved as well as different interest groups in different locations should be included.

▶ ACTIVITIES

1. What is the difference between an issue and a challenge? Identify one issue and one *interconnected* challenge using either of the case studies discussed above.
2. The owners of the retreat in Figures 1.18 and 1.19 plan an expansion with more cabins, space for several tour buses and more walking trails into the existing rainforest.
   a. Suggest a range of possible issues that this planned expansion might produce.
   b. What additional information would you need to know about this expansion before developing a series of responses to the issues?
   c. Suggest criteria involving at least five (5) aspects of the issues. Rank them in importance, justifying which you consider is the most important.
3. How could the phenomena of melting ice and glaciers be an issue and challenge at both the local and global *scale*?

What is geospatial technology?

All geography students need to have the ability to interpret spatial data – information that includes location and can be shown via maps. You may have used a form of spatial data when booking and tracking transport using rideshare apps or when using Google Earth. Geospatial technologies are the digital tools for geographical inquiry that include software and hardware interacting with real world locations. This includes any form of technology that organises and collects data that is referenced to a point on the Earth's surface via latitude and longitude. Geospatial technologies enable the visualisation, manipulation, analysis, display and recording of spatial data. The digital (rather than analogue) nature of the data ensures that the information can be used in computers and similar devices such as Global Positioning Systems (GPS). Old maps or other spatial information have to be digitised before they can be used by modern geospatial technologies such as a Geographical Information Systems (GIS). It is important to be able to interpret and analyse spatial information as more decisions in our world are spatially based.

The different forms of geospatial technology are summarised in Figure 1.21.

Good sites for further information on geospatial technology

GNSS

- www.youtube.com/watch?v=CCKisghkcA4

  This YouTube clip by Geospatial Media offers a simple explanation of GNSS. (2.44 minutes)

GIS

- ESRI What is GIS?
  www.esri.com/en-us/what-is-gis/overview

  This site offers a clear explanation of how GIS works.

  Follow this up by selecting an example from the link to GIS showcase.

- National Geographic MapMaker Interactive:
  http://mapmaker.nationalgeographic.org/

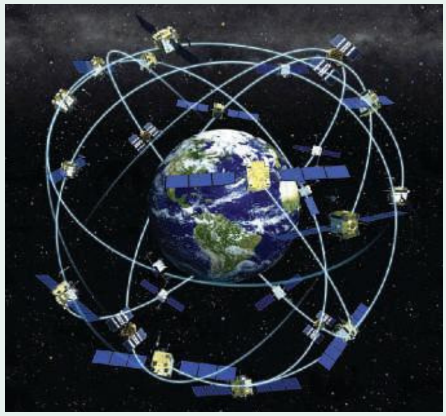
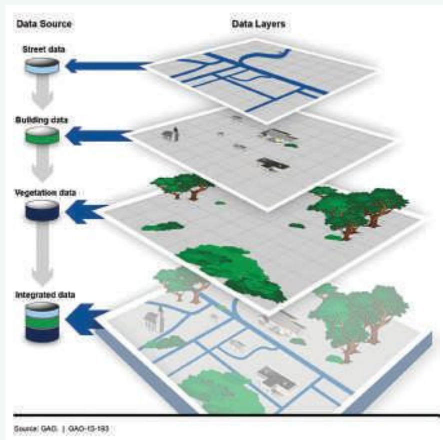
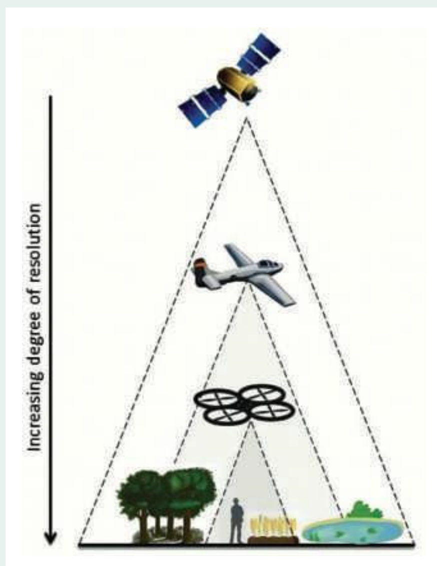
  A very simple but useful GIS tool with some basic tools such as measuring *distance*, adding labels and place-marks.

Remote sensing

- NASA Earth Observatory
  http://earthobservatory.nasa.gov

  This site provides access to an enormous number of satellite images. The site provides featured images each day, as well as breaking news articles that feature satellite imagery. Current topical stories are also provided, with satellite imagery. Topics include climate *change*, natural disasters, deforestation, pollution and more.

▼ **Figure 1.21** Different forms of geospatial technology

Geospatial technology	Explanation
GNSS Global Navigation Satellite System	Often inaccurately referred to as the Global Positioning System, this network is based on a system of at least 24 satellites that circle the Earth. The GNSS system can determine a user's position in terms of latitude and longitude as well as altitude. This enables users to identify their exact location on the Earth via a smart phone or in-car navigation unit. Once the system has determined a user's position, software can then calculate other information such as speed, bearing, track, *distance*, *distance* to destination, and many more features. GNSS forms the basis of modern mapping and can be used in mobile apps or for specific purposes such as tracking the *movement* of cyclones. 
GIS Geographic Information System	This is the most common geospatial technology tool used today. Geographic Information Systems use computer-based mapping software that collect, store and analyse previously unrelated information and display this information as easily-understood maps. The GIS program represents the data as layers of information that can be turned on or off, according to what the user wants to look at and the relationships they are trying to find. For example, layers could include road layout, buildings and vegetation *distribution*. Google Earth and ArcGIS are examples of GIS. Associated with this technology are many online interactive mapping applications usually focussed on a particular topic – for example, weather forecasting, town planning or monitoring emergencies. 
Remote sensing	Remote sensing obtains information about the Earth's surface without being in contact with it. This involves data collected above the Earth from space or by an aircraft and includes satellite images and aerial photographs. A recent development in this area has been the development of drones that include cameras or sensors to record information. Remote sensors can be either passive or active. Passive sensors respond to external stimuli and record natural energy from the Earth's surface such as reflected sunlight or re-radiated heat (infra-red radiation). In contrast, active sensors use internal stimuli to collect data about Earth. For example, a laser-beam remote sensing system projects a laser onto the surface of Earth and measures the time that it takes for the laser to reflect back to its sensor (known as LiDAR or light detection and ranging). Remote sensing data is often then used to provide a base layer for a GIS map. Remotely sensed data is useful for hazard management and monitoring data about oceans and the atmosphere. 

2 Land use change: an overview

Geographers study land use *change* for many reasons, including:

- developing knowledge of a local area and the *processes* of *change* at work
- identifying trends that enable more effective planning that enhances wellbeing and promotes *sustainability*
- monitoring *changes* and thereby identify areas of potential heritage loss and conflict
- evaluating the impact of *change* on people and *environments* in the surrounding *region*.

Figure 2.1 Central Melbourne's multiple land uses

Figure 2.2 (a), (b), (c) Some land uses in Victoria

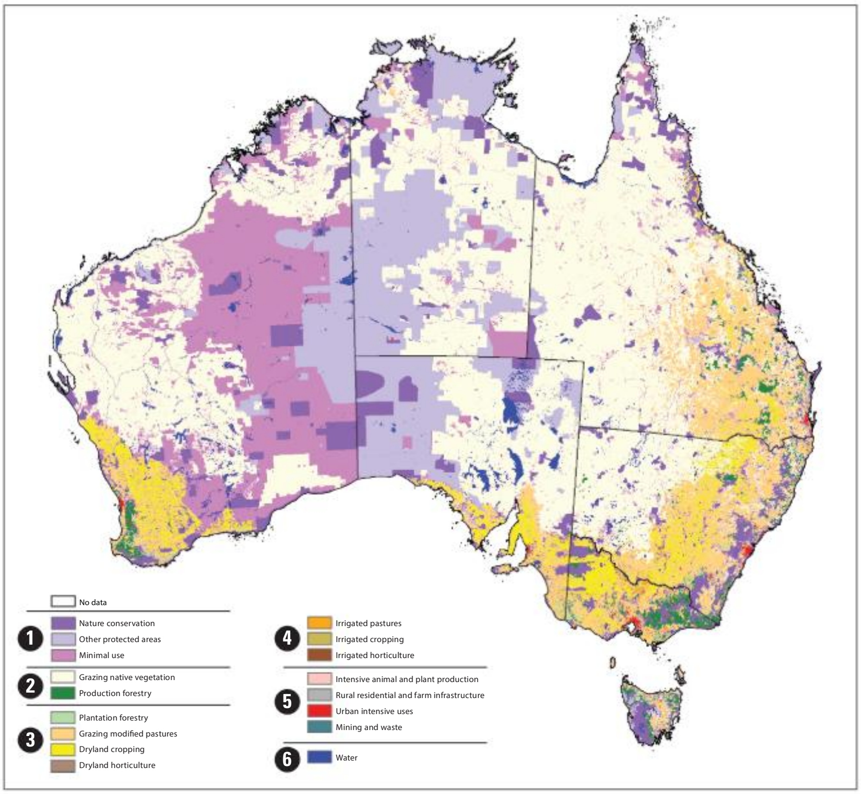
The United Nations Food and Agricultural Organization (FAO) defines land use as being "characterized by the arrangements, activities and inputs people undertake in a certain land cover type to produce *change* or maintain it." Put simply, land use is how people use land areas, although this also includes the use of natural and artificial inland water surfaces. Look at Figures 2.1 and 2.2. There are many different land uses to be seen. You should be able to quickly identify broad categories of land use such as urban or industrial. Typical categories, or 'zones' classified for land use are:

- nature protection areas, such as Kakadu National Park
- cultivated lands, such as vineyards in the Yarra Valley
- recreational areas, such as the Victorian Alps and coastal beaches
- transport routes, such as the Hume Freeway
- urban areas that include residential suburbs, office buildings, retail centres and industry
- mining areas, such as the Latrobe Valley in Gippsland.

All these land uses have involved human interventions or activities to alter or modify the original land cover or *change* a past land use. These *changes* or modifications are very likely to involve an *interconnection* between the natural *environment* of landforms, soil, vegetation and water, with the needs of people. Think of where you are at present: has it always had this land use? Perhaps the use of the land has *changed* more than once. There may even be remnants of past land uses to be seen. For example, your school or house may have been built on land that was once farmland, and before that a mixture of grasses and trees used by an indigenous group for hunting and collecting food.

Some parts of the original land cover of vegetation or water may appear to be in their original natural state. A national park or coastal *region* may appear to be 'natural' or undisturbed by humans but they are likely now to be managed or regulated by people because of people exploiting their *environmental,* ecological, recreational or aesthetic values.

Figure 2.3 shows the *distribution* of Australia's land uses. In Figures 2.3 (a) and 2.3 (b), land uses have been generalised into five primary land use categories together with water because of its importance for natural resource management. Each primary land use category is subdivided into further sub-categories. These sub-categories could be further subdivided. Think again of the area you live in. Apart from housing, the land is also likely to be used for transport networks, retailing and open space – and possibly several other land uses. But there are many other land uses evident when you examine smaller, local areas. Figure 2.4 shows there can be many different uses of land even in a small area.

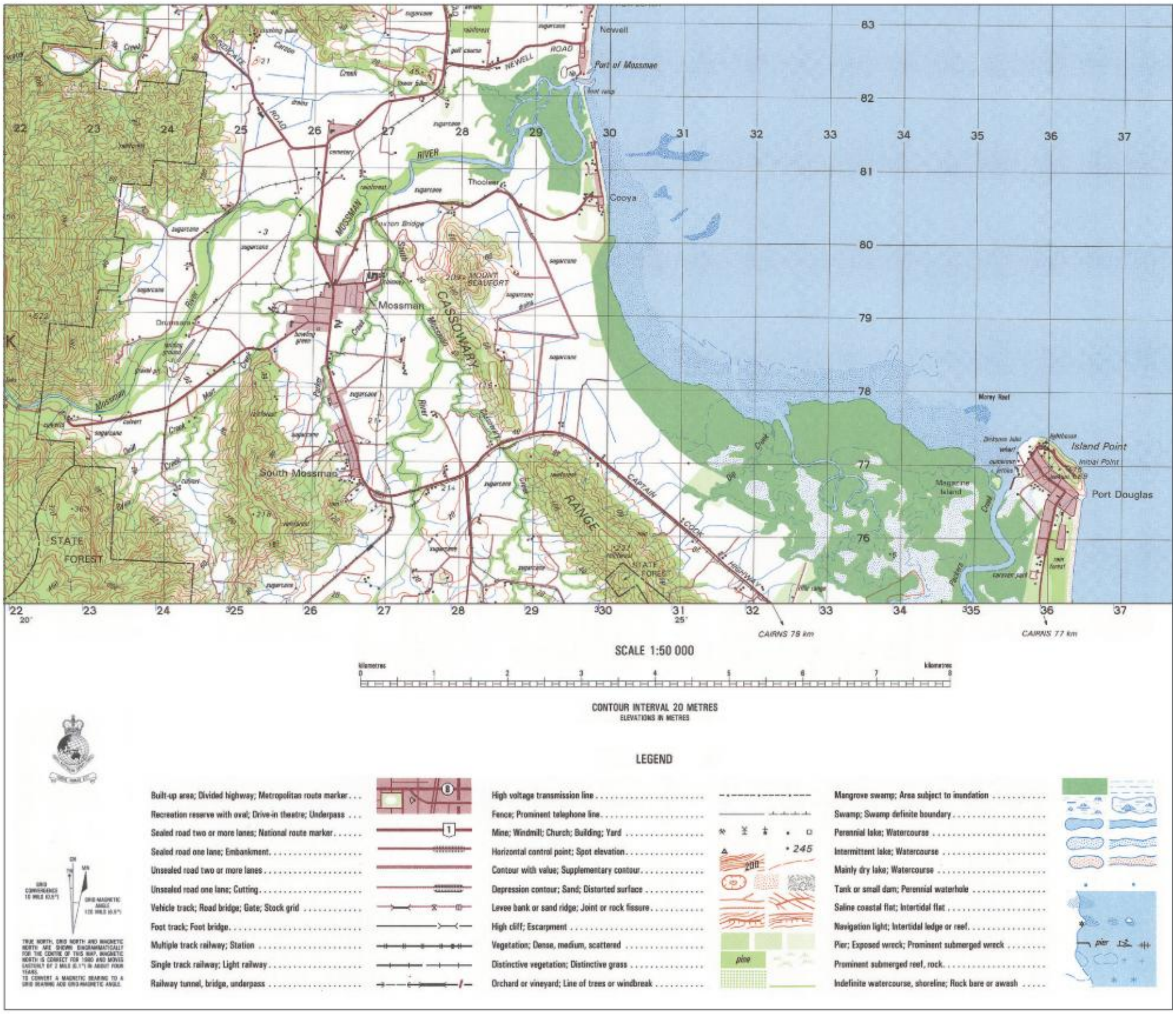


▲ **Figure 2.3 (a)** The *distribution* of Australian Land Use Mapping (ALUM) classifications (based on Land Use of Australia 2010–11, Version 5, ABARES 2016)

▼ **Figure 2.3 (b)** Land use classification by proportional area

Land use 2010–11	Area (square kilometres)	Percentage
Land use category 1		
Nature conservation	604,671	7.87
Other protected areas	1,163,676	15.14
Minimal use	1,172,679	15.26
Land use category 2		
Grazing native vegetation	3,448,896	44.87
Production forestry	103,494	1.35
Land use category 3		
Plantation forestry	25,752	0.34
Grazing modified pastures	710,265	9.24
Dryland cropping	275,928	3.59
Dryland horticulture	743	0.01
Land use category 4		
Irrigated pastures	6048	0.08
Irrigated cropping	9765	0.13
Irrigated horticulture	4552	0.06
Land use category 5		
Intensive animal and plant production	1414	0.02
Rural residential and farm infrastructure	17,632	0.23
Urban intensive uses	13,806	0.18
Mining and waste	1860	0.02
Land use category 6		
Water	125,542	1.63
No data	401	0.005
Total	**7,687,124**	**100.00**

Figure 2.4 Mossman, topographic map extract 1:50,000 and legend



ACTIVITIES

1. Look at the images in Figures 2.1 and 2.2.
   a. What is the main type of land use you can identify in each image?
   b. Investigate each image and identify minor types of land use evident.
   c. Now look at the Australian land use map in Figure 2.3 (a). Place each of the images into one of the listed categories.
2. Refer to Figures 2.3 (a) and 2.3 (b).
   a. State the largest land use category in Victoria.
   b. How does land use vary to the north-west and to the east of the state? Suggest at least three major reasons for this variation.
   c. Compare Victoria's land use category *distribution* with one other state.
   d. In which state or territory is there the largest area of minimal use? Suggest why this might be so.
   e. Approximately what proportion of Australia's land use is grazing on native vegetation? Describe its *distribution*.
   f. Estimate the proportion of Australia's land use that is urban intensive.
3. Look back to Figure 2.1.
   a. What *interconnection* might there be between the area in the lower right-hand corner and the high rise buildings at the centre?
   b. What major features shown in the image could promote *interconnection* between different areas?
4. Refer to Figure 2.4.
   a. Identify at least five (5) different types of land use represented.
   b. The white areas on the map are not identified in the legend. Use Google Earth to help identify their likely use.
   c. Estimate the proportion of the map area covered by the three largest land uses.
   d. Which human feature connects at least three different land uses?
   e. Which land use is strongly *spatially associated* with steep land?

Land use *change*

Much of the Earth's land surface is used or managed by people in some way. Its natural cover of forests, grasslands and wetlands has been altered to suit our needs for food and shelter, *movement* and trade. Over time these new land uses may *change* and could *change* again and again as people's needs alter.

Some examples of land use *change* include:

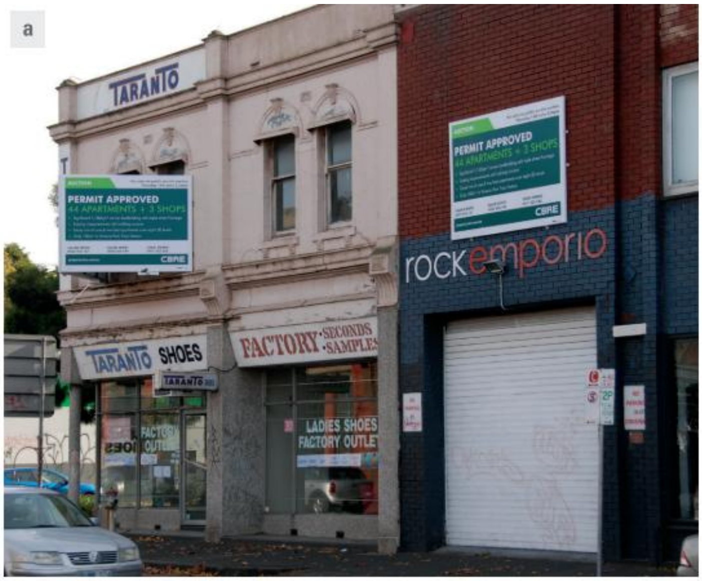
- an old industrial area converted to housing and community uses in an inner urban location
- a freeway interchange built on land previously used for grazing animals
- farmland on the urban fringe *changed* to a new housing estate
- forest cleared and the area used for farming
- a sporting complex built on vacant land
- wetlands drained to support new farming activities
- hiking and walking trails, camp sites and car parks developed on a mountain wilderness site.

Land use *change* occurs at varying *scales*, rates of *change* and degrees of intensity and impacts. For example, the old shops and factory outlets shown in Figure 2.5 (a) are targeted to *change* into new apartments with some street level retailing. The *scale* is local, the rate of *change* is likely to take place within 12–18 months and significantly *change* the appearance and daily function of this local part of inner Melbourne. This type of *change* is taking place in the context of similar *changes* within the inner Melbourne *region*.

Large-*scale* land use *changes* such as the ones in Figure 2.5 (b) may generate major *changes* to the *environment* such as the clearing of natural vegetation and the building of supporting infrastructure include roads and energy networks. These *changes* can be termed intensive since they involve large inputs of resources and energy per unit of area (for example, a hectare) at a site. Compared to extensive *changes* where inputs per unit area are low, intensive *changes* of the same duration may have a disproportionately high impact on the landscape. Specific rules developed by local, state and national governments governing the way land can be used may help safeguard against ad hoc or makeshift development and reduce potential conflicting land uses and their negative impacts. Planning zones, development policies, *environmental* impact studies and careful monitoring of *change* from an original baseline can help in these *processes*.

ACTIVITIES

1. Compare Figures 2.5 (a) and 2.5 (b). Which construction would have made the larger impact on the immediate area and the surrounding *region*? Be sure to justify your decisions. What other information would you need to have to be sure of your decisions?
2. What is the land use *change* that occurred at the site of Figure 2.5 (b)? What factors might have caused this *change*?
3. What supporting land uses are likely to develop because of the urban *changes* occurring in Figure 2.5 (a)?



▲ **Figure 2.5 (a)** *Changing* land use in Melbourne's inner suburbs

▲ **Figure 2.5 (b)** Large *scale* constructions have been built in Dubai (United Arab Emirates) on land that was sandy desert scrub until the 1960s

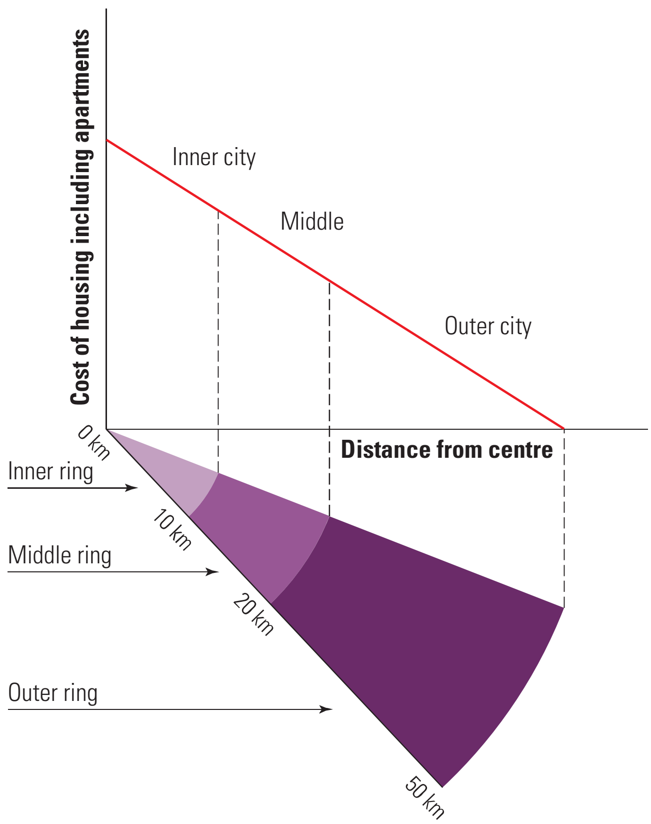
▲ **Figure 2.5 (c)** A megalithic tomb or gallery grave in Brittany, France. Its purpose 6000 years ago has *changed* to today's one of a reminder of history to local residents and visitors

Reasons for land use *change*

Land use *change* occurs as a result of the interaction of different factors. Depending on the particular *change*, some factors will be judged by the various stakeholders as more important than others. Furthermore, as the *change process* develops it is possible the relative importance of factors will alter and this can cause difficulties. For instance, *environmental* or heritage issues may begin to emerge only after a *change* has been approved by authorities or physical *changes* have commenced. Factors determining land use *change* can be broadly categorised as follows.

Social factors

Social factors are the features and values of a society, and include population structure and *movement*, ethnicity, cultural attitudes and traditions, language, religion and work skills. These factors may result in pressure for new residential areas to be developed on the fringe of existing towns and cities, or for an industrial estate to be expanded to provide for local employment. Over time, society's needs and values may *change*, thus forcing land use *changes*. For example, in Australia car and house ownership became major ambitions of households especially after World War II. With increased prosperity and cheap credit these ambitions could be more easily realised. As a result of government rezoning of farmland, forest and scrubland, Australia's urban areas grew rapidly outwards. Since the 1980s, most major Australian cities have experienced a renewal of population growth in the inner areas. With access to work and recreation facilities in the CBD and nearby, a redevelopment of old industrial and retail areas has occurred along with the construction of higher density housing. The *change* in Figure 2.5 (a) is part of this *process*.



▲ **Figure 2.6** Alonso's Bid Rent theory of land value

Historic factors

Historic factors are evident when past actions or thinking have influenced the present characteristics of a natural or human *environment*. The current land uses of an area are therefore the product of past decisions, and sometimes the altered landscape and built infrastructure made from these decisions in the past may influence current activities and decisions. It may be that communities, developers and governments see a need to *change* these land uses to ones they believe are more appropriate to today's needs. At the same time past land uses may represent an important reminder of a community's heritage. As a result, land use becomes conserved for local people but might also be altered to accommodate interested visitors – like the site in Figure 2.5 (c).

Economic factors

Economic factors are the activities linked to the creation of wealth, production and the spending of money. Employment, income, profit, production of goods and services, trade, government and household spending are all economic factors. Economic factors have major influence in the *process* of land use *change*, especially in market economies such as Australia. The owners of land, and the potential buyers of land, may be driven by profit motives to *change* existing land uses to ones perceived as more profitable.

In Alonso's model (see Figure 2.6), one of many economic models used by geographers, land uses are *spatially associated* with the cost of land, travel time to and from the urban centre, and *distance*. This theoretically results in a series of land uses with high-value commercial uses (who can afford to buy or rent the space) closest to the centre, followed by residential and commuter zones further away from the centre in more affordable locations. In reality, urban land uses are never determined so easily, or all at once. But, for Australian cities, the high affordability of petrol for most of the period since the 1950s, together with the building of public road infrastructure, have allowed outward urban growth to occur and may contribute to *unsustainable* urban sprawl. Current and future urban growth areas need to consider the provision of, and access to, services such as health, education, recreation, retailing as well as transport and employment. All these variables add to the complexity of land use in a *region*.

Environmental and physical factors

Environmental factors are the characteristics of a natural or human *environment*. The natural factors are often referred to as physical factors and include the shape of the land (topography), drainage, soils, indigenous vegetation and climate. *Environmental* factors have major influences on land use. The nature of a *regon's* natural *environment* may prohibit some land uses. Arable farming on steep land may be very difficult, as the area in Figure 2.7 (a) suggests. A *region* with low and unreliable rainfall may limit human activity to extensive grazing or remain a wilderness area prized for its rare plants and animals. Urban growth may be curtailed by a lack of reliable water for residents and industry. Technology, however, has been able to help overcome some *environmental* limitations. The likelihood of negative impacts of land use *change* on biodiversity, downstream users of water, community wellbeing and the character of a *region* are, however, now major considerations in determining the *scale* and functioning of land use *change* (Figure 2.8). Will a proposed waste treatment plant have an impact on underground water, or air quality? Will urban expansion lead to the loss of farmland and ultimately higher food costs and more greenhouse gas emissions due to the longer *distances* food will need to travel? Will residential development on the urban fringe, as in Figure 2.7 (b), only provide new housing, or a combination of housing, retailing, personal services and community facilities? Residents living at a considerable *distance* from work, education and retail services will spend a larger proportion of their week travelling than people living in more established and better serviced areas.

Political factors

Political factors are the work of individuals, government agencies and non-government organisations which help determine the use of natural and human *environments*. Political influence can protect an existing land use as easily as it can grant permission for it to *change*. Government policy, legislation, planning regulations and permission, election promises and protest activities are all political actions that can directly determine the nature of land use *change*. A government decision to build or expand a road can alter farmland, residential land or open space to land transport, for instance. And whether or not politicians want to make particular decisions is influenced by their 'political will'. Land use *changes* may also have an impact on land use along a transport route both negative, such as additional traffic noise and/or the need to remove trees, and/or positive, such as improved access to other areas and reduction in traffic on other roads. These impacts can then lead to further pressure for land use *change.* Decisions by government authorities can have enormous impacts on land use *changes* by encouraging or discouraging them.

▲ **Figure 2.7 (a)** Steep land may limit the choices for farming

▲ **Figure 2.7 (b)** New residential developments need health, education, retail and recreation facilities as well as housing for their residents

◀ **Figure 2.8** Even a small *scale* dam can *change* land use within a *region*

The land use *changes* shown in Figures 2.9 (a) and 2.9 (b) could only occur because government authorities altered zoning laws. These laws allowed residential development on land that had previously been zoned for agricultural purposes.

Technological factors

Technological factors are the application of developments in science, engineering and communications. Technology has widened the options for land use *change* in a significant way. Large-*scale* water conservation and irrigation projects might allow land to be converted to arable cropping. Intensive building of high-rise apartments can take place on land once considered as unsuitable for such construction.

Freeways and fast trains can reduce travel time and allow residential developments further away from major work *places* to develop. Information technology enables some people to work from home and at considerable *distances* from central offices. Geospatial technologies have become valuable tools in planning for, and evaluating, land use *changes*, as page 31 shows. Mining companies can achieve profit from large *scale* development of resources, building transport routes, storage facilities and ports in *environments* once considered too hostile for development. The iron ore deposits of the Pilbara in northwest Australia and the natural gas fields of the Cooper Basin of northeast South Australia and south-west Queensland are two Australian *regions* where such resource developments have occurred.

▶ ACTIVITIES

1. Identify an area of *change*, or proposed *change*, in your school or home area. What factors do you think might be dominant in causing this *change*?
2. Discuss in a group which are the main factors that would play a role in each of the following proposed land use *changes*. Try to establish and justify a rank order for these proposals:
   - building a rail link from Melbourne's central business district to Melbourne Airport
   - allowing cattle grazing in national parks
   - developing housing on grazing land near Ballarat
   - establishing a chemical waste dump on poor quality farmland
   - preserving mining relics to promote tourist activities.
3. Use the internet to search for your local council or shire name along with the term 'strategic plan'.

   After reviewing the document, comment on whether you agree or disagree with the directions that land use *change* is occurring in your community. Write a suggestion about how one site (or more) could be better used.
4. Why do you think communities and authorities see historic sites, like the one in Figure 2.5 (c), as important to preserve? What measures would be needed to sustain such sites for future generations?
5. In what way has the *environment* limited choices for farmers to use the land area shown in Figure 2.7 (a)? How have farmers *changed* the shape of the land to allow agricultural activity to take place? What factors outside of the area shown could encourage farmers to make different use of this land?
6. a. What physical factors would have been considered before the dam in Figure 2.8 could have been constructed?

   b. How could the dam's water reserves aid land use *change* in the nearby *region*?

Impacts of land use *change*

Land use *change* can have far-reaching and long-term impacts. These impacts particularly depend on their duration, intensity, location, *distribution* and materials used. These may be negative and/or positive and they may occur locally or beyond. Population growth and *movement* can either cause or be the result of land use *change*. If a rural *region changes* the type of primary industry from grazing to blue gum plantation, the different workforce requirements may force some to look for jobs elsewhere, or attract others. Converting grazing land to intensive irrigation cropping of fruit and vegetables can impact water table levels and soil nutrients, but also produce higher financial returns together with higher production costs per hectare. Land use intensification can also occur when converting agricultural land into suburban housing developments, as in Figures 2.9 (a) and 2.9 (b). This is a long-term land use *change* that removes an area's ability to produce agricultural products but allows for other forms of community development. High impact land uses such as mineral processing, refining and thermal power generation can leave contaminants in the soil and water table which may need expensive and protracted remediation before other land uses can occur there; airborne pollutants might be *distributed* over great *distances* depending on wind patterns, or combustion might contribute to atmospheric warming. Planners need to consider all these potential impacts.

Instances of land uses *changing* in order to have decreasing levels of intervention can occur when land is restored to a natural habitat. The *environmental* impacts of restoration projects can provide ecosystem services, such as air and water purification, carbon uptake (sequestration) and storage, decomposition of waste, and pollination. If the restored habitat generates visitors other land uses may be needed: roads, walking trails and accommodation facilities, for example. A *spatial association* of natural habitat and human facilities develops. The addition of the walkway in Figure 2.10 has allowed people to have an *interconnection* with a natural habitat. This coastal landscape is now used for recreation.

Land use intensification has major impacts on natural habitats and can have negative impacts such as soil erosion, flood events, salinisation, smog, habitat fragmentation, and species loss. A land use *change*

▲ **Figure 2.9 (a)** Point Cook, Victoria, 2002

▲ **Figure 2.9 (b)** Point Cook, Victoria, 2020

in Western Victoria which had severe *environmental* impacts was the clearing of the Mallee scrub. Before European settlement in the 19th Century, the ecosystem was *sustainable* and dominated by the short, bushy eucalyptus species. The practice of land clearing for agriculture fragmented the natural habitat to a point where much of the topsoil was denuded. The problems associated with this land practice included erosion and sand drift, as well as dryland and irrigation salinity (refer to Figure 2.11), weed invasion on both crops and pastureland, and with the addition of abundant cereal crops and destruction of predators some of the worst rabbit and mouse plagues in the state's history. The Mallee now has even lower soil fertility in comparison to the more fertile and higher rainfall areas to the south. Major tree-planting campaigns were begun in the 1920s and are being extended to help stabilise the soils and restore habitat.

Land use may alter *movements* of people and goods. People need somewhere to live, shop, play, learn and work and these activities also help determine land use. A *change* in land use can lead to an increase in *movement* of people into, and out of, an area on a daily or seasonal basis. A road and/or rail system may be developed to cope with this *change*, adding to the mix of land use *change*. The new roads developed in the rapidly growing Point Cook community between 2002 and 2020 are an example of these *changes*.

▲ **Figure 2.10** A walkway allows people to access a part of Victoria's coast

▲ **Figure 2.11** An example of dryland salinity and soil erosion in the Mallee. Land clearing occurred between 1880 and 1980, until government regulations prohibited the removal of native vegetation

▶ ACTIVITIES

1. a. From Figure 2.9 (a) construct a transect from the north-west corner to the south-east corner of the image. Annotate the land uses crossed by the transect. Note the areas affected by the *process* of *change* as indicated by the fine network of roads on otherwise unoccupied land.
   b. Using a contrasting labelling colour, label the land uses from Figure 2.9 (b). Title the completed transect appropriately.
   c. Suggest two other locations on the image where transects would show significant land use *change*.
   d. Comment on:
      - the proportion of the image area that appears to have remained *unchanged*, and its likely future
      - the proportion of land that is more intensively used by 2020.
   e. What impacts could the *changing* land use have on road traffic in the area, such as the main north-south road? What additional land use *changes* might result?
2. Suggest a negative impact the construction of a walkway into a coastal area, similar to Figure 2.10, might have. Explain whether the positive impacts could outweigh the negative ones.

Con Charalambou
Geospatial analyst

CAREER PROFILE

I work in a team that develops National Exposure Information System (NEXIS). Using Geographic Information Systems (GIS) and other software applications, the work is a mixture of synthesising building and land information (residential, industrial, commercial), demographic and socio-economic data, agricultural data, and spatial data to develop information that feeds into the NEXIS modelling framework. Much of the work is analytical and requires problem solving, so it is challenging but, because we are problem solving with visual tools (GIS), it is interactive and fun.

Using Geography skills I can interpret patterns or trends over time and identify the factors that were influential in changing the dynamic in a given region. I can identify the advantages and disadvantages of proposed changes (such as new subdivisions, new building and new transport corridors) and the flow-on effects to communities and business.

My interest in Geography began as a teenager interested in land formations. In Years 11 and 12, I was fortunate to have a teacher who taught Geography exclusively, and I started learning about the interaction of people, place/space, and the land. When I realised Geography could lead me towards urban and regional planning, I was hooked. I completed a Geography major at university (Bachelor of Applied Science) focussing on physical and economic geography, and demography, and an Advanced Diploma of Spatial Information Services.

There are many great opportunities for geographers for careers in government, media, advertising, research and planning – including demography, urban and regional planning/community development and GIS. In the GIS field specifically, career opportunities exist in cartography, data management/creation and as an IT developer/customiser.

Planning strategies for land use *change*

In future years land uses in Australia will continue to *change* due to many *interconnected processes*, mainly:

- a growing population from 26 million in 2020 to an estimated 40 million in 2050
- *changing* market demands within Australia and elsewhere could affect the amount and types of grains, meat, fruit and vegetables produced from farms, as well as the type and size of housing in cities
- climate *change* is likely to alter the *distribution* of water resources and temperature regimes forcing the relocation of natural and introduced plants and animals
- new regulations by federal, state, territory and local governments about the way land is used and the way people and goods *move* from *place* to *place*.

Victoria's urban areas are predicted to grow substantially. Melbourne's population could reach 8 million by 2050, up from its 2018 total of 4.5 million. This population will need at least 1.6 million new homes. As many as half these homes are likely to be in the outer urban areas north, west and southeast of existing urban areas, as Figure 2.12 shows. The transport network will possibly be handling another 10 million trips a day by 2050. The established inner areas are likely to undergo further redevelopment into higher density residential and service areas. Plan Melbourne 2017–2050 envisages the urban area becoming a mix of '20-minute neighbourhoods' providing peoples' daily needs within a short walk, ride or public transport trip of their homes. People are likely to commute outside their neighbourhoods, most likely to one of the city's activity centres (see Figure 2.12) rather than to the central city.

Without strategic planning Victoria could be the home of a massive conurbation stretching from the coastal *regions* south of Geelong, northwards past Melton and Lockerbie, and eastwards and south-eastwards into west Gippsland. Immense problems including transport provision, water and power supplies plus waste management could negatively impact on levels of wellbeing as well as existing land uses. *Regional* urban centres such as Ballarat, Bendigo, Shepparton, Horsham and in the LaTrobe Valley are expected to grow with some migration of population from the main urban centres of Geelong and Melbourne. Plan Melbourne 2017–2050 includes strategic land use plans for *regional* Victoria.

To accommodate these developments, strategic planning is required together with collaboration with local communities to ensure the maintenance of the local character, amenities and quality of life. One instrument planners use to do this is to set the Urban Growth Boundary around Metropolitan Melbourne to contain development and to ensure productive land uses like agriculture and grazing can continue (see Figure 2.12). This boundary separates urban land uses from rural farms, conservation areas and green wedges where different policies and rules apply.

Victoria's local governments are the responsible authorities in charge of the land use and management in their area. Official *changes* to land use generally need

▼ **Figure 2.12** Melbourne's Metropolitan area and major activity centres

planning permits. Victoria has a State Planning Policy Framework (SPPF) and each municipality has its own Local Planning Policy Framework (LPPF). These two policy documents are found in the municipality's Planning Scheme, along with Zone and Overlay requirements and other planning provisions. The Planning Scheme lists which land uses are allowable with and without a permit. For example, in the City of Moreland you may not have panel beating within 100 metres, or fireworks production within one kilometre, of a residential zone.

In the management of natural *environments*, parks and waterways, joint management arrangements among various stakeholders ensure the best land management practice. For example, the Barmah National Park in north central Victoria is jointly managed by the Yorta Yorta Nation Aboriginal Corporation and Parks Victoria. They may collaborate on projects with specialist groups including the Murray–Darling Basin Authority, the Goulburn Broken Regional Catchment Management Authority, and other municipal and *regional* authorities. Any *changes* to structures, additional facilities such as road and path access routes, car parks and on-site accommodation need to meet with their approval.

The Planning minister of the Victorian Government can override many decisions made by local governments. As well, the Minister can initiate *changes* to land use through policy decisions. For example, in 2017, farming land to the north of Melbourne was rezoned for 17 new residential suburbs.

▶ ACTIVITIES

1. Suggest why the following land uses are often restricted in urban areas: abattoir, waste treatment, power generation.
2. 'Australia has a market economy. Entrepreneurs should not be restricted by the red tape of planners and legislators in developing land they own.'

   Discuss this statement.
3. a. What is the purpose of the Urban Growth Boundary for Melbourne?

   b. Research on the internet to discover when and why it has been modified.

   c. Explain why some stakeholders would be in favour of urban expansion.
4. Discuss how a '20-minute neighbourhood' plan might impact on land uses in your local area? What would have to *change* to achieve this situation? Visiting the Plan Melbourne 2017–2050 website will help you expand this discussion.
5. As a rural landowner near an urban area, what could persuade you to see your farmlands *change* to urban uses? How might your decision be contributing to a bigger problem?

How can *changes* to land use be *sustainable*?

Without planning, urban growth threatens the ability of *places* to provide effective infrastructure such as transport, water and energy supplies. As well, the quality of their recreational and historical character can diminish. In turn there would be a reduction in the liveability of the *environment* for residents. Uncontrolled outward urban growth – typical of Melbourne but also evident at smaller *scales* in *regional* urban areas – would see further loss of rural land and increasing pressure on roads, public transport and other utilities.

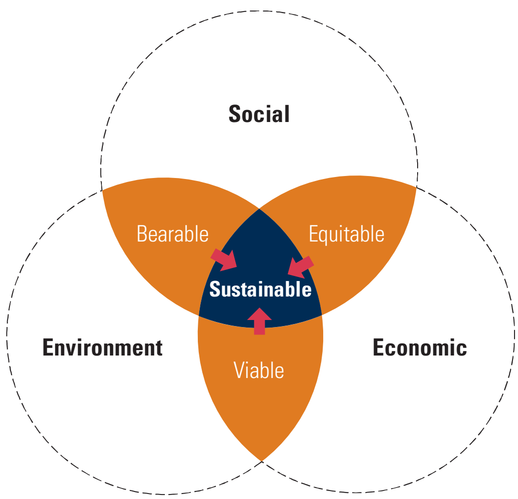
A compromise has now been developed by planners and commercial interests that allows controlled outward expansion and at a slower rate than in previous decades. At the same time higher housing and commercial densities are to be encouraged in new and existing suburbs. The implication for land use *change* is considerable. These planning strategies involve:

- Mixed land uses: a *place* should have multiple functions such as residential, commercial and recreational areas operating day and night and year-round.
- Density: medium- to low-density suburbs, medium- to high-density transport routes together with high-density centres.
- Connectivity: many options to be available for transport and *movement*, with development focusing around transport hubs such as rail interchanges.
- High-quality public realm: safe and active street frontages with sun and weather protection.
- Local character: maintenance of the historic charm of *place*.
- Adaptability: the ability to accept *change* while maintaining functionality.

It is argued that future *sustainable* communities will need to reduce the need for car travel, reduce energy consumption and emissions, use more local materials, support local businesses and create identifiable communities in order to accommodate larger populations and climate *change*.

Some current land use practices conflict with these principles of *sustainable* development. For example, developing peripheral urban, or 'peri-urban', lands into low-density housing contributes to car dependency and urban sprawl. If this type of development does not also provide for jobs and occurs further and further from employment areas, it will result in a housing market that relies on long commutes to and from workplaces. If the price of petrol varies there may be considerable cost borne to the consumer, which threatens their ability to repay their mortgages.

For land use to be *sustainable* it must be socially acceptable, *environmentally* friendly and economically viable (see Figure 2.13). Development of our urban centres is unlikely to be *sustainable* if it largely follows the path of aiming for profits, with minimal regard for the *environment* or society. Examples are the building of housing estates and roads on arable lands or in natural habitats. *Sustainable* development aims to benefit all three categories equally as a way to achieve a healthy future.



▲ **Figure 2.13** The multiple elements of a *sustainable* society

▶ ACTIVITIES

1. Rate your local area in terms of the following six categories: mixed use, density, connectivity, high-quality public realm, local character and adaptability. Justify your ranking in each category with a brief statement and example. What land use *changes* would you recommend to your local planning authority and government to improve the liveability of your area?
2. On a statewide *scale*, how do planners ensure rural areas are not being turned into low-density suburbs, but still retain a healthy-sized population? Use the 'peri-urban futures' website on the internet to collect information on the recommendations for future land use in peri-urban areas.

Climate *change* and land use *change*

Changes in weather and climate characteristics in Australia have significant implications for future land uses: increasing intensity and frequency of hot days and heatwaves, greater severity of droughts, *changing* rainfall *distribution* together with a predicted sea level rise of approximately one metre by the turn of the century due to melting ice and thermal expansion of seawater.

- **Farming *regions***

  The southern half of Australia is recording lower rainfall during the critical growing season of April to October. Lower rainfall can result in poor crop yields for wheat, barley and canola and a reduced ability to raise livestock for meat, milk and wool. Without successful technical adaptations such as new plant types or animal breeds and lower greenhouse gas emissions, farming *regions* may need to *change* their type of cropping and animal raising. Irrigation areas could be increasingly replaced by dryland farms unless new techniques of using less water can be applied.

- **Urban *regions***

  Sea level rises averaging around one metre by the end of the century will occur together with increasing severity of sea-based storms. Low lying coastal suburbs, coastal roads and waterfront land uses including port facilities, beaches, recreational areas (see Figure 2.14) and adjoining property may need protection, reconfiguration or relocation. Planners will need to work for greener and more open spaces to promote cooler and more pleasant living spaces.

- **National *scale***

  Solar and wind farms replacing thermal power stations as energy sources will force land use *change* at selected *places*. Habitats of living creatures will be challenged by climate *change*. For example, saltwater intrusions into freshwater wetlands are likely to occur with rising sea levels. Extensive areas of Kakadu National Park's lowlands are particularly vulnerable to this *process*. The farming areas close to Victoria's Gippsland Lakes are another *region* under threat from *change*. Land clearance of scrub and trees for agriculture purposes contributed about 9 per cent of Australia's greenhouse gas emissions in 2020. Reducing this activity and regreening areas implies significant land use *change*.

▶ ACTIVITIES

1. What is dryland farming? Why might it replace irrigated farmland in many parts of southern and eastern Australia?
2. What costs could be involved for coastal suburbs and towns in coming years? Who should pay for associated developments: residents, or local, state and federal governments?

▲ **Figure 2.14** Bathing boxes at Brighton Beach, Melbourne. Will this recreational land use survive a rise in sea level of one metre or more and increasing intensity of storms?

The future of land use *change*

The patterns of housing *distribution* and the low-density *scale* that Melbourne has at present are not *sustainable*. Much of this development has grown around a monocentric model of employment focused on the central business district. Figure 2.15 (Part A) shows this diagrammatically. These developments can be categorised as:

- Infill: the use of land within a built-up area for further construction.
- Greenfield: land development of undeveloped conservation or agricultural sites.
- Brownfield: land development of industrial or contaminated sites.
- Greyfield: smaller-*scale* cumulative infill development in residential areas where the building stock is near or ending its physical life and land values make redevelopment attractive.
- Urban renewal: land redevelopment and revitalisation of an existing urban area, often in the form of higher density mixed use development.

Each development type brings with it its own costs to society, the *environment* or the economy.

Medium- and high-density infill development and brownfield development can help locate the growing population closer to the CBD and other employment areas and along transport corridors. Substantial *changes* in land use are occurring and are likely to continue to occur. A more dispersed pattern of employment development would mean more employment opportunities around outer Melbourne in a polycentric pattern. This is shown in Figure 2.15 (Part B). With mixed-use centres along public transport corridors, and a retained historic centre to the city, a composite pattern of land use and development will emerge. This is shown in Figure 2.15 (Part C). A growth policy that emphasises this latter model would have significant impact on land uses, including road and public transport networks and population *movements*.

Over the past decade the urgency to refine Melbourne's land use practices has increased. Specific documents that have highlighted this need have been *Melbourne 2030, Transforming Australian Cities* and *Plan Melbourne 2017–2050*. These policy documents make a strong argument for the future direction Melbourne will take and integrate the *scale,* patterns and *spatial association* of *change* that needs to occur in order to keep Melbourne and Victoria liveable.

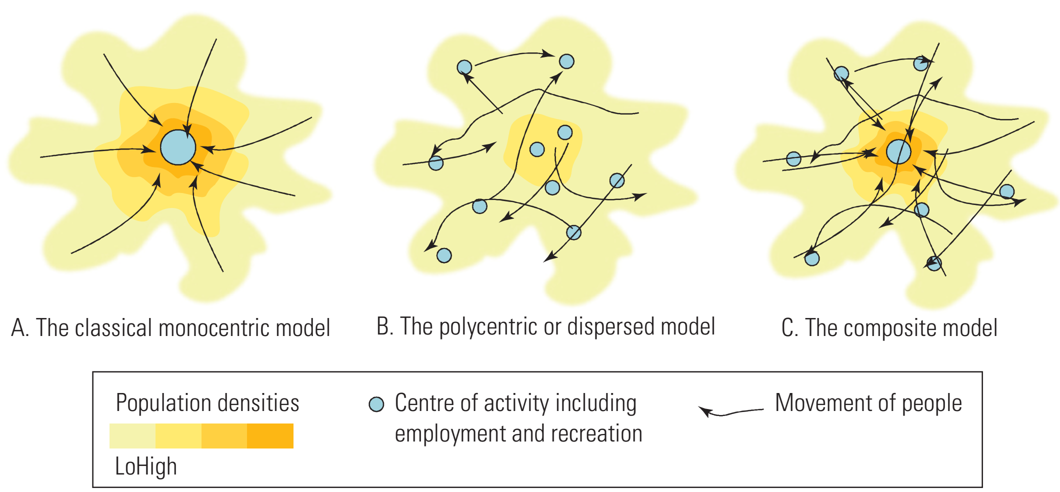
Future patterns of land use development in rural areas in Victoria will need to reflect *changes* in climate (see above), balance land productivity with increasing tourism, housing development and subdivision of large tracts of farmland near existing urban areas. Rural councils already balance the multiple pressures of farming, population growth or decline, tourism and development by designating specific uses of land through policies and strategies.

Both metropolitan and non-metropolitan councils face unique challenges to managing land use *change*. Local planning policy frameworks offer one measure of control which involves the community and industry in permitting growth and *change* in areas. This collaborative planning approach blends geographic thinking with principles of democracy in order to meet fair outcomes for all stakeholders and the *environment*.

ACTIVITIES

1. What geographic characteristics of areas make them desirable *places* for people to live, work and play in? Use specific examples to support your answer.
2. Refer to your local council's planning scheme. What policies are in place to promote *sustainable* growth around specific precincts in your area?
3. Look back to Figure 2.5 (b). Is this an example of infill, greenfield, brownfield, greyfield or urban renewal?

Figure 2.15 Monocentric, polycentric and composite models of urban morphology



Geospatial technologies and land use *change*

Increasingly geographers and planners are using a range of geospatial technologies as effective tools to investigate, collate and assess land use *changes* at a variety of *scales*.

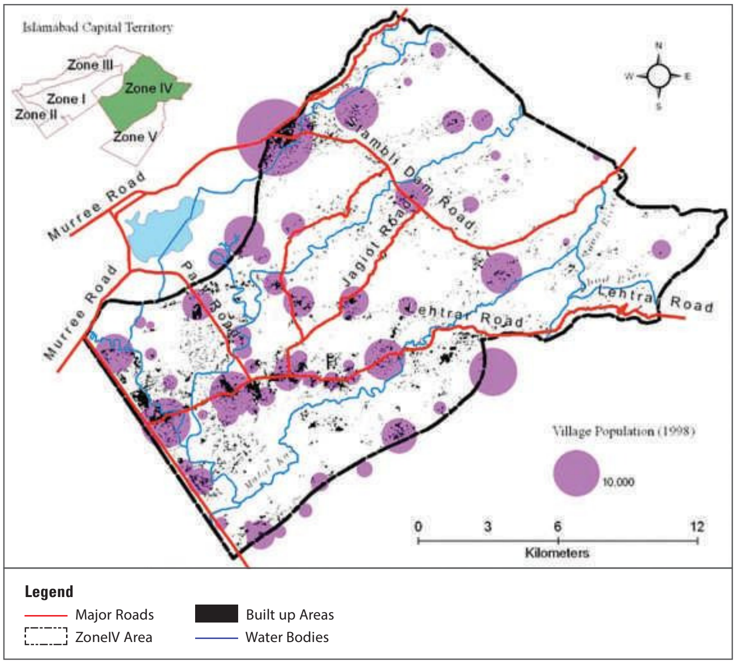
Aerial imagery including ones obtained from satellites (see Figure 2.9), aircraft and drones, allow for rapid large-*scale* collection of data about *changing* land use that would otherwise need to be gained from fieldwork. Satellite imagery has almost total global coverage with many countries operating their own systems or buying relevant data from government agencies such as the United States-based NASA or commercial firms. Data can be collected and produced as images at different times to monitor *changes* that may or may not be occurring.

A Global Positioning System (GPS) is a portable electronic device used to accurately locate positions on or near the Earth's surface. It receives radio signals from multiple GNSS satellites that orbit the Earth to determine and indicate its position. A Geographic Information System (GIS, see Figure 1.21) is a software program allowing any geo-coded information, such as ground acquired or remotely sensed data about land cover, land use, population or climate, to be converted into multiple digital layers displayed in map form.

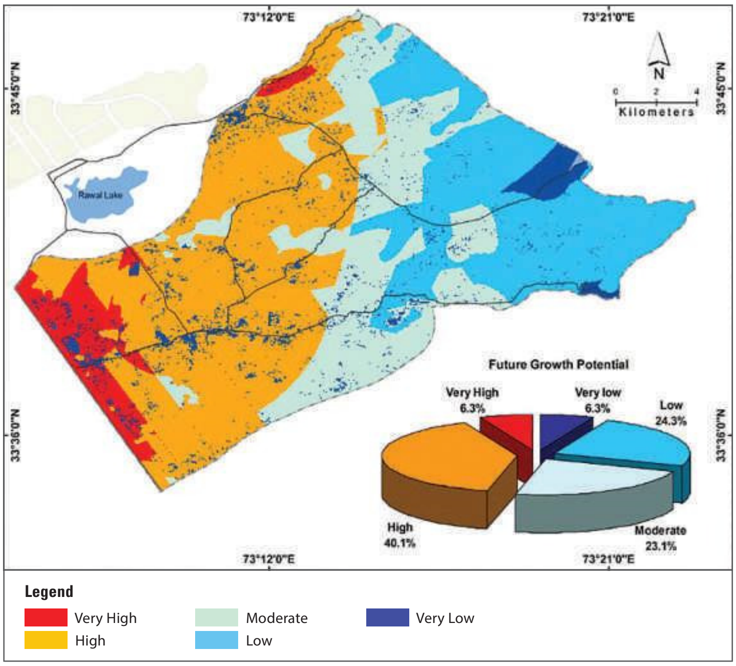
Additional locational data gained from fieldwork surveys and secondary sources can be added to these images, such as that shown in Figures 2.16 (a) and 2.16 (b). Multiple layers of information can be produced from this data often revealing strong *spatial association* between variables such as the location of car showrooms and sale yards with the high density of road traffic in urban areas. Analysis of GIS maps can help determine the best location of a new shopping mall in a large residential *region*, the impact of a hotel resort in a wilderness area and the optimum position for a freeway interchange.

The maps shown in Figures 2.16 (a) and 2.16 (b) show a small part of Islamabad, Pakistan's capital city. They were developed using several overlays of information. The *distribution* and size of village populations together with the existing road network, Figure 2.16 (a), were analysed to help produce Figure 2.16 (b) – areas with future growth potential. These potential growth areas influence planning decisions including the need to get permission from landowners and the opinions of groups directly affected by the urban expansion.

▼ **Figure 2.16 (a)** Village population and road network for part of Islamabad, Pakistan



▼ **Figure 2.16 (b)** Future growth potential for part of Islamabad, Pakistan



▶ ACTIVITIES

1. What advantage will satellite imagery give you in collecting data about land use *change* for a specific site compared to ground surveying. Does it have any disadvantages?
2. Using examples, state what the difference is between GIS and GPS.
3. Suggest what other layers of data could be recorded on Figure 2.16 (a) that might assist the improvement of wellbeing in these and similar villages.

3 Land use change in urban areas

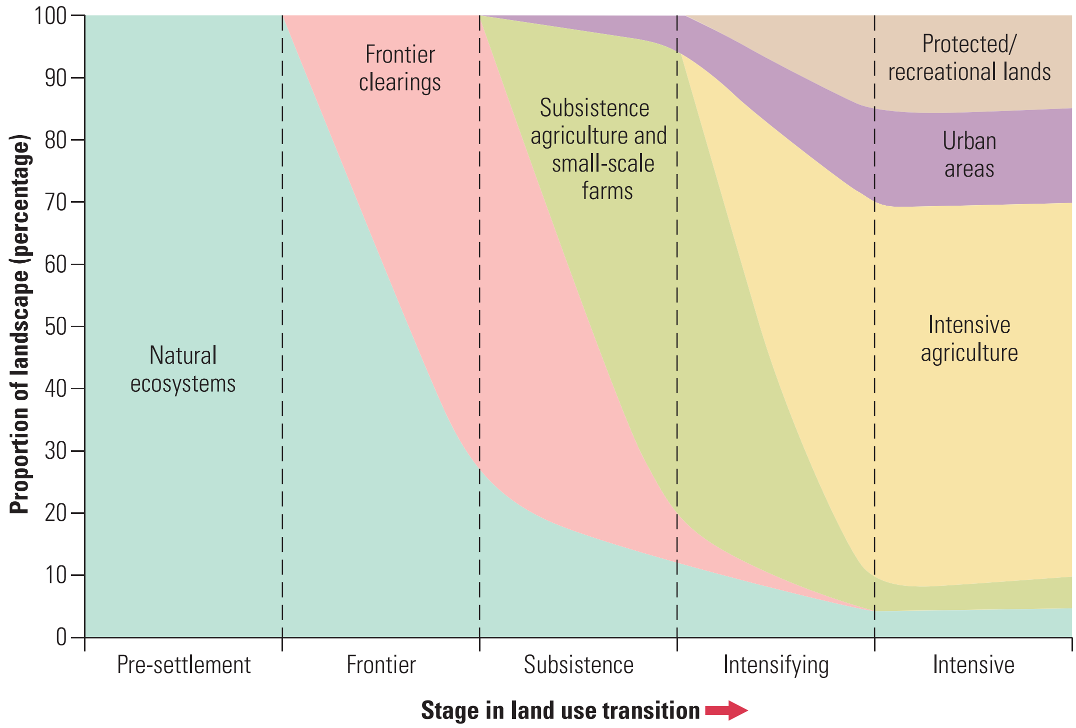
Land use describes the different ways in which people use parts of the Earth's surface. In an urban *environment*, *change* in land use is driven by factors such as population dynamics, the space, resources and infrastructure needed to support the population, and government and commercial decisions dealing with the management and development of the land. These *changes* have impacts on the *environment*, society, liveability and the economy.

Urban development around the world follows a similar sequence of transition stages. In general, the natural landscape is cleared and agriculture continues to expand elsewhere to support an increasing population in growing urban areas. In their study entitled *Global Consequences of Land Use,* Foley et al. (2005) have developed a model representing the transition in land use experienced by a *region* over time (Figure 3.1).

This generalised model represents different stages of development that occur in many *regions* around the world. However, not all *regions* have followed this *process* due to varying social, historical, *environmental*, economic and political conditions.

Transition between stages in this model is based on the need for people to make use of natural resources such as water, soil and forests which can lead to degradation of the natural *environment*. Impacts may include a loss of forest cover, disruption to the water cycle, imbalances in nutrient cycles due to the addition of pesticides and fertilisers, and an overall loss of biodiversity. As populations increase and *regions* develop, these impacts intensify. Land use management seeks a balance between supporting the population while maintaining the function of ecosystems in order to achieve *sustainability*.

▼ **Figure 3.1** Model of land use transition (*Souce:* Foley et al., 2005)



How is land use *changing* in Melbourne?

In recent years, Melbourne has grown at a considerable rate, creating an extensive and expanding urban landscape. The population reached 5.2 million in 2019, an increase of over 2.5 million since 1970. Based on pre-COVID-19 trends, it was expected that population would grow to over eight million requiring an additional 1.6 million dwellings by 2050.

The *regions* experiencing the most rapid *change* in Melbourne are in the peri-urban zone which is also referred to as the rural–urban fringe. This transitional zone is located between urban and rural areas and has accounted for over 40 per cent of growth (Figure 3.2) as housing prices are generally more affordable there than in the inner suburbs. As Melbourne expands, this zone is being pushed further outwards into previously rural areas. The *distribution* of expansion has been uneven, favouring *regions* with easier access to inner zones, attractive natural features and a gentle topography.

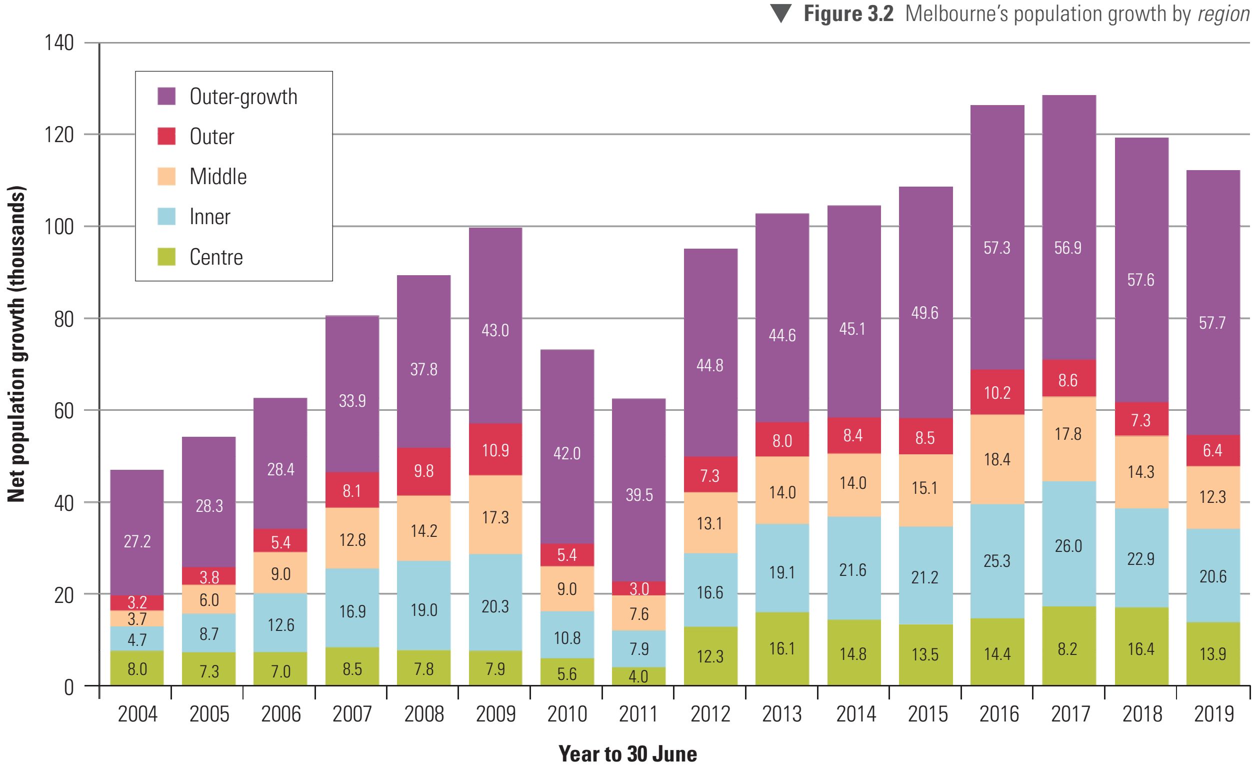
Melbourne's western *region* is growing rapidly, especially in and around Werribee and Wyndham Vale. Nine-hundred hectares of flat and undulating land containing extensive grasslands and major waterways make Werribee an attractive *place* to develop. However, the biodiversity of these *environments* is also threatened by this large-*scale* greenfield development. The Victorian Planning Authority's West Growth Plan projects that this *region* will eventually accommodate over 377,000 residents and provide at least 164,000 jobs. This growth will add significant pressure to existing transport infrastructure as these western communities are already heavily reliant on the Central Business District (CBD) for jobs and services. New transport projects such as the Regional Rail Link and Outer Metropolitan Ring transport corridor will help to reduce this impact and ensure its social *sustainability*.

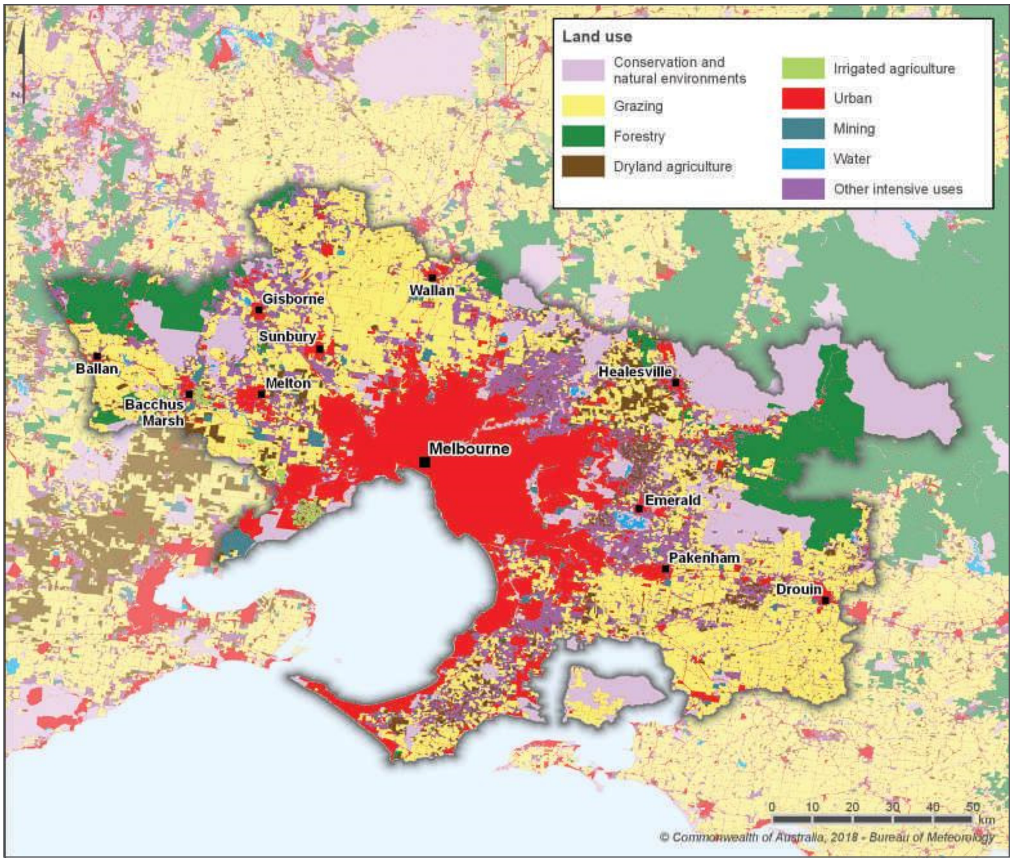
As urban sprawl encroaches on rural and bushland areas, the proportion and *distribution* of land use *changes* significantly. Pressure is placed on rural industries and infrastructure leading to socio-cultural and economic impacts in rural communities such as a loss of jobs. Forested areas are diminishing and becoming fragmented. Similar land use *changes* around the world have led to concern in the scientific community about the future *sustainability* of cities in terms of food production, natural resources and adaptability to the effects of climate *change*.

▶ ACTIVITIES

1. Using Figure 3.1, describe the general *processes* by which urban development transforms the landscape.
2. In what ways could these land use *changes* lead to the degradation of the natural *environment*?
3. Research the history of land use in your local city or *region* and create a timeline of major events. Use it to discuss the extent to which it fits the land use transition model (Figure 3.1).
4. Try to apply the model to Australia's history. Did Australia follow a similar sequence? Compare this model and its application to Australia with a city in a developing country such as Peru or a megacity such as Tokyo.

▼ **Figure 3.2** Melbourne's population growth by *region*





▲ **Figure 3.3** *Distribution* of land use in the Port Phillip and Western Port *regions* (*Source*: Bureau of Meteorology, 2018)

▼ **Figure 3.4** A summary of land use in the Port Phillip and Western Port *regions* (2019)

Land use	Area (hectares)	Area (percentage of total)
Conservation and natural *environments*	196,483	15.38
Grazing	449,423	35.17
Forestry	89,376	6.99
Dryland agriculture	67,540	5.25
Irrigated agriculture	5173	0.4
Urban	275,794	21.58
Rural residential	149,293	11.68
Mining	13,881	1.09
Water	3950	0.31
Other	18,277	2.15
Total	**1,269,190**	**100.00**

ACTIVITIES

1. Referring to Figure 3.2, which *regions* of Melbourne have recently experienced the most growth and why do you think this is the case?
2. Referring to Figures 3.3 and 3.4, describe the *distribution* of two different land uses in Melbourne.
3. a. How do you think the proportion of land use in Melbourne may have *changed* over the last 20 years?
   b. How do you think it will *change* in the next 20 years?
   c. Where do you think these major *changes* will occur?
   d. Suggest reasons to explain your answers.
4. Explore satellite imagery of Melbourne using Google Earth.
   a. Use the historic imagery function to describe *changes* to the geographic characteristics of the south-eastern and western growth corridors over various time *scales.*
   b. Which *regions* have had the most *change* and why?
   c. Compare these *changes* with another city elsewhere in the world such as Las Vegas.
5. 'Population dynamics are the main driving force behind *changes* in land use.' Evaluate this statement and discuss to what extent you agree or disagree.
6. As Melbourne continues to spread into surrounding rural fringe areas, discuss what impact this might have on the *region* in terms of the agricultural industry, the local economy and transportation across Melbourne.
7. Research the West Growth Corridor in more detail and write a summary of the projected growth, major infrastructure projects, the provision of open space and ways in which the Victorian Planning Authority aim to create a *sustainable* community.

What are the *processes* of land use *change* in urban areas?

Land use *change* in urban areas involves a number of physical and administrative *processes*. These *processes* can cause, affect, react to or regulate land use *change*. Physical *processes* are determined largely by the nature of the *change* and can include:

- earthworks to modify a site's topography
- soil tests and the removal of contaminants
- demolition or modification of existing buildings and new construction
- removal and planting of vegetation.

Specific types of land use *change* require additional *processes* such as the filling of quarry pits or upgrades to water, energy, sewerage and transport infrastructure to support residential development. Figures 3.5 (a) and 3.5 (b) show the residential development at the former Eastern Golf Course. This has involved clearing vegetation, earthworks to flatten the sloping topography and the construction of new roads throughout the site.

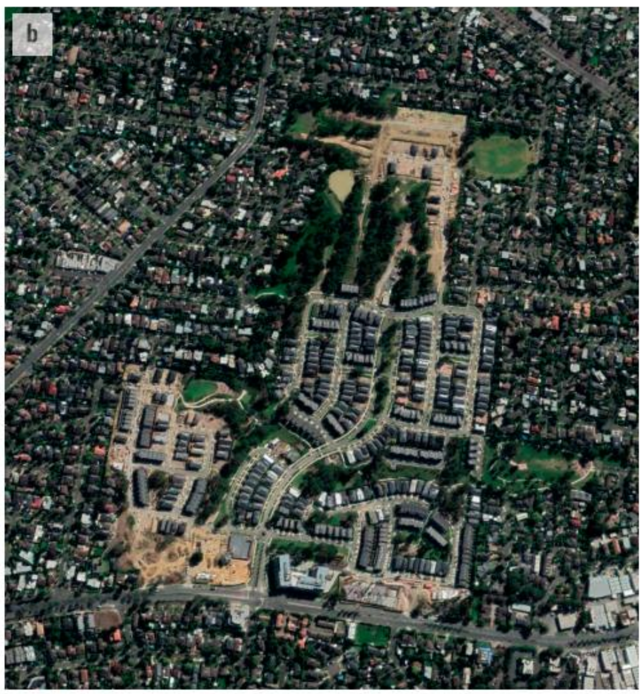
Administrative *processes* are also an essential part of land use *change* as they determine the nature and extent of the physical *changes* that can take place. They involve site assessments and *changes* to planning zones and overlays. Prior to development in Melbourne, a site must undergo a range of assessments depending on the nature of the *change*. These include:

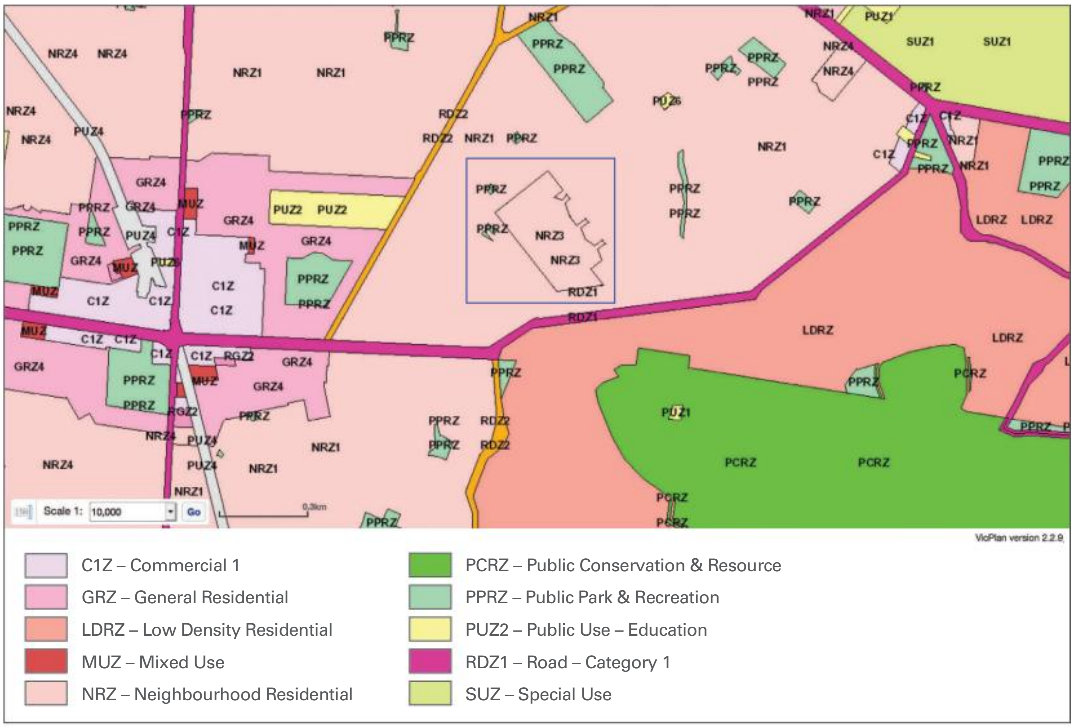
- a transport impact assessment which considers the anticipated traffic and transport implications including car parking, pedestrian and bicycle *movements*
- a site contamination assessment, especially for brownfield development, which assesses the safety of the site based on previous land uses
- a vegetation assessment to determine the extent of vegetation coverage on the site and the ecological quality
- an economic impact assessment, especially for commercial development, which considers the potential trading impacts associated with the site and impacts for the surrounding *region*.

For example, part of the *process* of building the Burwood East Retail Centre at the former Burwood Brickworks site involved a Trading Impact Assessment to ensure that the proposed new commercial land use did not adversely impact existing shopping precincts.

Zones and overlays are planning controls found within a council's planning scheme. They include maps and information to help determine the nature and extent of land use *change* and development that can be undertaken on any property within a municipality. Zones exist to ensure that urban development is appropriate within its *regional* context. For example, zoning prevents industrial development to occur within the General Residential Zone whereas residential development is prohibited within the Public Conservation and Resource Zone. Green Wedge Zones are areas on the fringe of Melbourne's metropolitan areas outside of the Urban Growth Boundary where urban development is prohibited in order to protect the agricultural, *environmental* or historical values of the land and to restrict urban sprawl.

▼ **Figure 3.5** Satellite images taken on **(a)** 15 April 2014 and **(b)** 27 March 2020 show the extent of physical *changes* that have occurred at the former Eastern Golf Course site





▼ **Figure 3.6** A map of land use zones surrounding the former Boronia Heights Secondary College site, located in the centre of the map (inside the blue box) and zoned as Neighbourhood Residential Zone – Schedule 3 (NRZ3)

Overlays provide an additional layer of land use management, requiring developers to meet specific design and building standards when applying for a planning permit. For example, the Heritage Overlay prohibits the modification of historical features without a permit whereas the Vegetation Protection Overlay and Environmental Significance Overlay protect native vegetation and other ecological assets. Not all land has an overlay and some *places* might be affected by multiple overlays.

A preliminary step in larger-*scale* land use *changes* involves applying to the council to *change* the zoning or overlays for a particular site or obtaining a planning permit to overcome restrictions. Boronia Heights Secondary College in Melbourne's east was owned by the Victorian State Government and was zoned Public Use Zone – Education. The school was closed and demolished in 2015 in preparation for a planned residential development. As part of this *process*, the zoning *changed* to Neighbourhood Residential Zone – Schedule 3 (Figure 3.6) and a new development plan overlay was created to determine the density and style of the new development.

▶ ACTIVITIES

1. Using Figures 3.5 (a) and 3.5 (b), describe the extent to which the geographic characteristics of the former Eastern Golf Club have been *changed* as part of the new residential development.
2. Using Figure 3.6, describe the *distribution* of land use zones surrounding the former Boronia Heights Secondary College site.
3. Explain why zones and overlays are essential in ensuring the *sustainability* of land use *changes*.
4. Search for 'Vicplan – Maps and spatial data' and access the interactive map. This interactive map is an example of a Geographic Information System (GIS) because it has several data types organised in layers.
   a. Zoom to the location of your home, school or a *place* you have been studying in class.
   b. Select the Layers tab in the left toolbar. Tick the boxes of the layers you wish to view and adjust the opacity of each layer using the sliders. Clicking on the menu at the top of left toolbar will allow you to display the legend.
   c. Describe the *distribution* of zones or overlays within your selected area.
   d. Select one of the zones or overlays on your map and click on the hyperlink to find out more about the layer. List some of the restrictions within this zone or overlay.
   e. Explain how geospatial technology, such as GIS, can be used to manage land use *change*.
5. Prepare a case study summarising the location, *process* and impacts of land use *change* at the former Eastern Golf Course, Burwood Brickworks or Boronia Heights Secondary College sites.

What are the impacts of land use *change* in urban areas and how can they be managed?

Land use *change* from forested land to agricultural and urban land uses has led to a significant reduction in remnant vegetation. In an urban context, remnant vegetation is defined as bushland that remains as it was prior to development. As well as reducing the size of habitats, the loss of bushland often causes habitat fragmentation as remaining bushland reserves, such as the 100 Acres Reserve (Figure 3.9), are often surrounded by large residential, commercial and industrial landscapes. Habitat fragmentation isolates wildlife populations and reduces their *interconnection* with other locations. This reduces the genetic diversity of animal populations, increases their susceptibility to disease and makes them vulnerable to reductions in food supplies.

Areas containing remnant vegetation within urban *environments* are recognised for their *environmental* and social benefits. Many remnant pockets are protected due to land use zoning. Conservation techniques include fencing off regeneration zones, controlling weeds spread from nearby gardens and revegetating nearby areas with indigenous species. Wildlife corridors, such as the Merri Creek Marran Baba Parklands (see Figure 3.7) in Melbourne's north, are remnant and revegetated bands of habitat. They are used to link fragmented areas of bushland and enable the *movement* of species between populations in different *regions*, reducing many of the impacts associated with isolation.

One of the most significant ways that urban development *changes* the physical landscape is by increasing the proportion of impervious surfaces such as roofs, roads and footpaths covering an area. Urban landscapes severely reduce water infiltration into the soil and instead increase the amount of run-off entering urban waterways via stormwater drains, as demonstrated in Figure 3.8. Untreated run-off entering urban creeks modifies their natural flow regime, causes erosion and degrades water quality by transporting pollutants such as plastic, oil and fertilisers into the system. This has occurred in the Yarraman Creek wich flows hrough various urban land uses in Noble Park(igure 3.10). Urban waterways are often

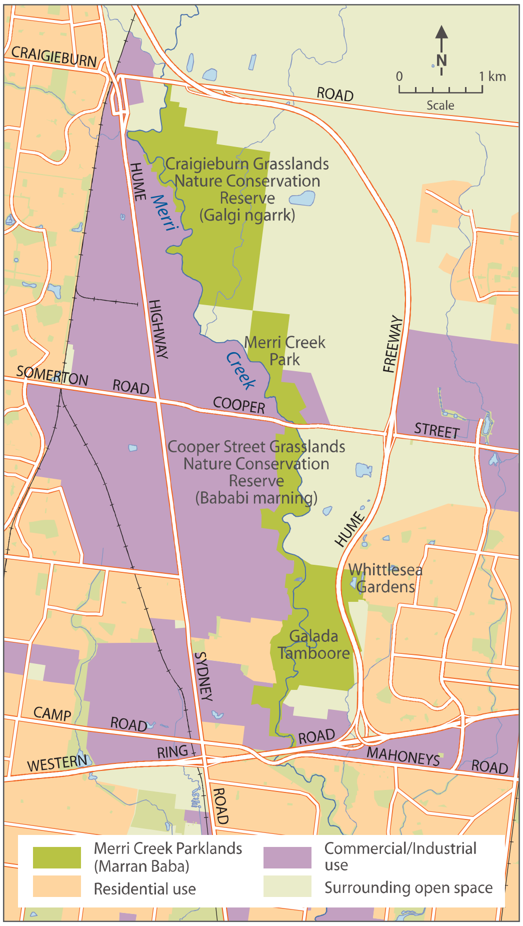
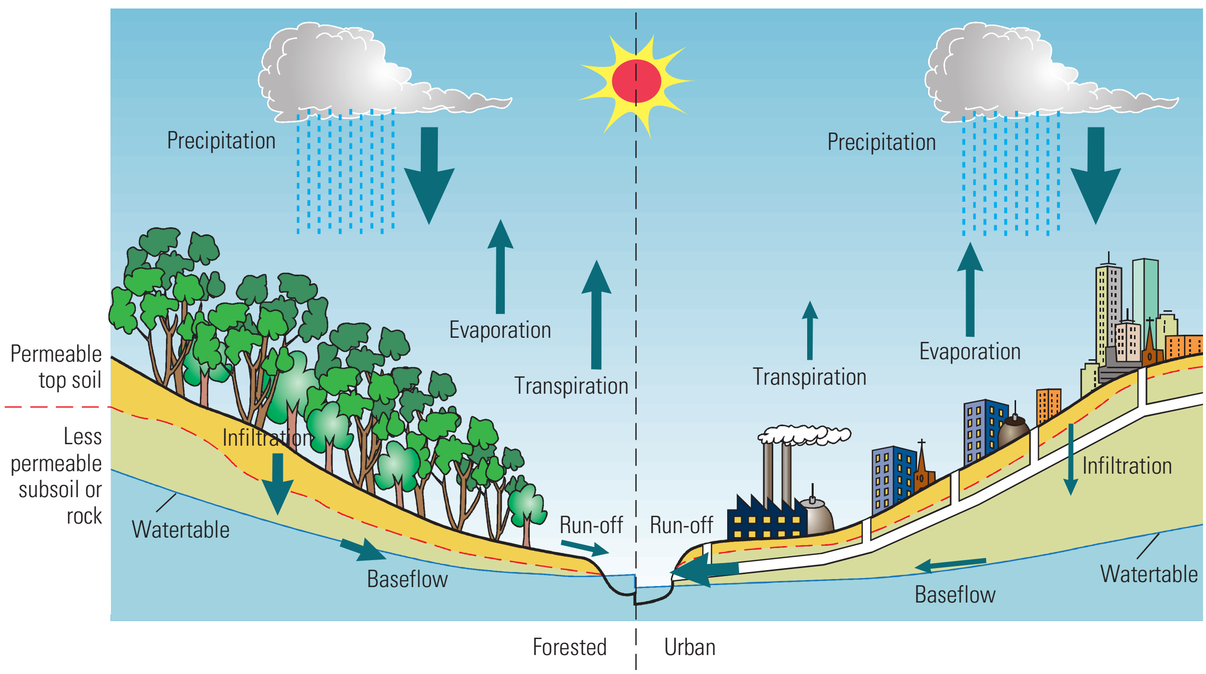


Figure 3.7 Land use surrounding the Merri Creek habitat and recreation corridor

Figure 3.8 Urban development alters the natural balance of the water cycle.



modified to deal with this additional flow by widening and concreting channels. These modifications often increase the risk (as well as intensity and frequency) of downstream flooding, damage riparian vegetation and make urban waterways less aesthetically pleasing.

Water Sensitive Urban Design (WSUD) is a type of stormwater management that seeks to reduce this degradation and restore the health of urban streams. WSUD involves planning urban development to incorporate infrastructure such as raingardens, rainwater tanks and porous pavements to replicate the *processes* of the natural water cycle. This involves a fundamental shift in the management of stormwater as a resource rather than a waste product and drastically reduces the *environmental* impacts of urban land use *change*.

▲ **Figure 3.9** The 100 Acres Reserve in Park Orchards contains an extensive area of remnant woodland providing *enviromental* and social benefits

▲ **Figure 3.10** An example of increased erosion due to land use *change*, Yarraman Creek, Noble Park

In addition to degrading waterways, dense building materials in urban *environments* have an impact on the local climate. The thermal properties of concrete and roads in urban *environments* mean they conduct and store more heat than rural *environments*. Dark roads and roofs also absorb and re-radiate more heat than lighter and more reflective surfaces due to the albedo effect. This combined impact is known as the Urban Heat Island (UHI) effect and it causes urban areas to be warmer than surrounding rural areas. This phenomenon is increased when vegetation is removed and streams are converted to underground drains. In Melbourne, the UHI effect increases average annual surface temperatures by an average of 2–4°C compared to surrounding rural areas. This increase in temperature can contribute to summertime peak energy demands and increase the likelihood of heat-related illness. Urban forests are becoming increasingly important in providing shade and increasing transpiration to reduce the UHI effect while adding benefits such as improved air quality, absorption of stormwater and passive recreation.

The impacts of urban development are compounded as land use *change* increases in the form of urban growth. These impacts are especially noticed in the instances of urban sprawl where low-density outward growth spreads into rural areas. Urban growth areas are often more affordable and therefore attractive to young families. However, these *places* often lack public transport infrastructure leading to car-dependent suburbs that are often not walkable. This creates traffic congestion and is often associated with stress and other health risks. Growth areas are also criticised for lacking basic services such as hospitals, shopping centres, recreational facilities and schools and their low density can lead to social isolation. In an attempt to maintain high levels of liveability in Melbourne, the Victorian State Government developed Plan Melbourne. This policy framework seeks to manage land use *change*, stating that Victoria is committed to focusing on growth in the central city, activity centres, urban renewal areas and urban growth areas and that sprawl will be contained within the Urban Growth Boundary.

▶ ACTIVITIES

1. Using a table, summarise the *environmental*, economic and social impacts of urban land use *change*.
2. Research the Merri Creek wildlife corridor shown in Figure 3.7 including the *regions* it links and benefits it provides. Discuss the contribution that the community can make by planting indigenous vegetation to support this corridor.
3. Refer to Figure 3.8.
   a. Identify three *changes* that can occur to the *processes* of the water cycle due to urban development.
   b. Outline two ways that these *changes* might impact the natural *environment*.
4. Visit Melbourne Water's website to read more about WSUD. In a table, summarise the five different WSUD techniques and explain how one of these could be implemented at your school.
5. Explore the Melbourne Urban Forest – Visual on the City of Melbourne website and use it to discuss the threat to Melbourne's urban forest and the strategies put in place to manage this land use. Discuss the importance of this urban forest in reducing the Urban Heat Island effect.
6. Visit the Plan Melbourne website and read the plan summary. Discuss how the Victorian State Government aims to reduce the negative impacts associated with urban land use *change*.

▶ CASE STUDY The Little Stringybark Creek Project, Mount Evelyn

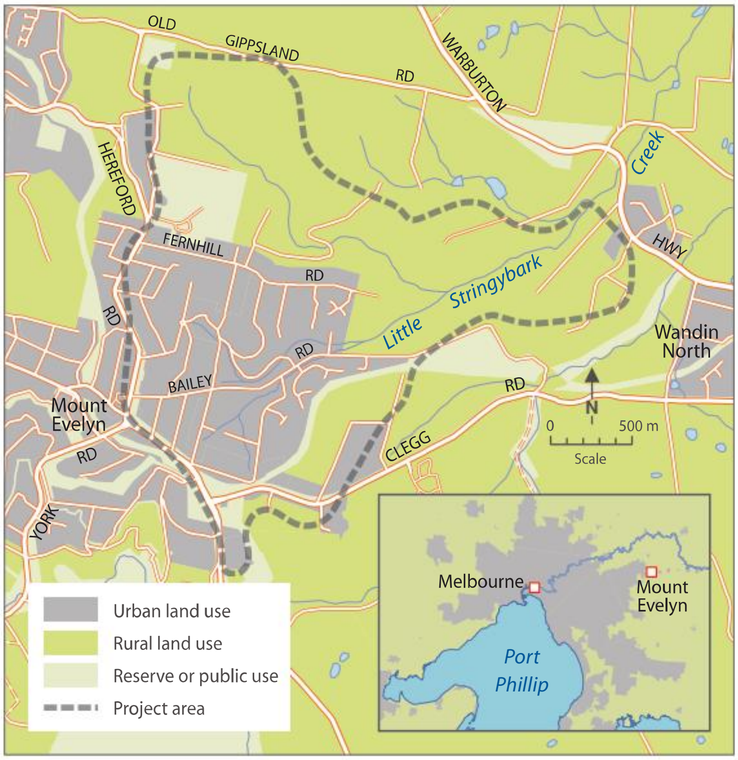
Little Stringybark Creek is a tributary of the Stringybark Creek which flows into the Yarra River and eventually into Port Phillip Bay. Its catchment is located in Mount Evelyn, 37 kilometres east of Melbourne (Figure 3.11). Prior to urban development, Little Stringybark Creek was a healthy stream supporting a pristine riverine ecosystem and forested catchment. Population growth (Figure 3.12) and urban sprawl led to the construction of additional houses, roads and footpaths within the catchment which has degraded the creek and its surrounding *environment*.

How has land use *change* altered the geographic characteristics of this *region*?

The upper reaches of the Little Stringybark Creek catchment, shown in Figure 3.11, covers approximately 300 hectares. During the 1980s, low-priced real estate and attractive natural surroundings led to rapid residential and commercial development in parts of Mt Evelyn that were previously rural. This *process* involved clearing forested and agricultural land and a transition to a dense urban landscape dominated by buildings, roads and other hard, impervious surfaces. One thousand properties currently lie within the catchment with an increase of 7 per cent expected by 2030.

Further downstream, urban development was significantly reduced as part of the Melbourne 2030 green wedge policy. This policy enabled the preservation of many of the rural and natural features of the landscape. Nutrient-poor soil in this *subregion* meant that it was used for grazing instead of intensive agriculture. These factors have enabled the downstream reaches of the creek (see Figure 3.13 (b)) to maintain a relatively natural flow regime, meandering through pockets of remnant vegetation.

▼ **Figure 3.11** The project area in the upper catchment of the Little Stringybark Creek, Mount Evelyn



▼ **Figure 3.12** The growth of the population and number of dwellings in Mount Evelyn (2001–2016)

	2001	2006	2011	2016
Resident Population	9155	9195	9365	9711
Total Dwellings	3144	3223	3371	3533

▼ **Figure 3.13** Satellite photos showing the contrasting land use in the **(a)** upstream and **(b)** downstream *regions* of the catchment

Figure 3.14 A comparison between (a) Little Stringybark Creek and (b) Sassafras Creek

What impact has land use *change* had on the natural *environment*?

Urban development in the Little Stringybark Creek catchment has significantly altered the flow regime of the creek. The addition of impervious surfaces has increased the amount of stormwater run-off and reduced infiltration following rainfall events (see Figure 3.8). This has caused erosion and a widening of the creek's channel and the riverine habitat has been destroyed. The addition of pollutants transported by untreated stormwater into the catchment has also degraded the water quality. These impacts can be observed when comparing Little Stringybark Creek to Sassafras Creek (see Figure 3.14) which is located within a similar peri-urban zone but treats stormwater on site using residential water tanks.

The Little Stringybark Creek Project

The Little Stringybark Creek Project is a study exploring whether a fundamental shift in the management of stormwater can potentially reduce the negative *environmental* impacts of land use *change*. The project combines the expertise of the University of Melbourne and Melbourne Water working closely with the Shire of Yarra Ranges and local residents. The primary goal of the project is to use raingardens (see Figure 3.15), rainwater tanks and other Water Sensitive Urban Design techniques to capture and treat stormwater in an attempt to restore the ecological health of the *region*. By reducing the volume and frequency of run-off entering the creek, the natural flow regime will be restored to what it was prior to urban development which is expected to reverse the degradation caused by this development.

The project used both financial incentives and education to encourage residents and businesses to install rainwater tanks and raingardens on their properties. Payments to participating landholders were determined using a competitive tender *process* based on the properties that could provide the greatest *environmental* benefit for the smallest economic cost.

Has the Little Stringybark Creek Project reduced the *environmental* impacts of land use *change*?

Over the course of the project, rainwater tanks and raingardens have been installed on 240 private properties and 11 larger raingardens and 36 nature strip raingardens have been installed on public land. Although urban growth has continued in the catchment over the course of the project (see Figure 3.12), the amount of run-off draining into the creek has reduced significantly. The final phase of the project involves monitoring the flow and water quality of the creek in order to assess the extent to which its ecological health has improved. The success of the project has led to the application of similar stormwater disconnection programs in other urban catchments, such as Dobsons Creek within Knox City Council.

Figure 3.15 Nature strip raingardens installed to filter run-off from Fernhill Road, Mount Evelyn

ACTIVITIES

1. Use Google Maps to follow the flow of Little Stringybark Creek into Stringybark Creek, Yarra River and Port Phillip Bay. Describe the *interconnection* between upstream and downstream *regions* of the stream network and its implications for land management.
2. Refer to Figure 3.14. Using a table, compare the characteristics of Little Stringyback Creek and Sassafras Creek evident in the photographs.
3. Locate the Little Stringybark Creek catchment by typing one of the street names from Figure 3.11 into Google Maps.
   a. Describe the location of the study area in relation to Melbourne.
   b. Describe the geographic features of the catchment and surrounding *region* using Figure 3.13 or Google's satellite imagery function.
   c. Compare land use in the upper and lower *subregions* of the catchment.
   d. Locate Sassafras Creek and compare the land use of the *region* with the Little Stringybark Creek catchment.
   e. How might the contrasting land uses in these *regions* have influenced the characteristics of the catchments and their ecological health?
4. Refer to Figure 3.8 and use it to summarise the main impacts that development is having on natural *processes* in the Little Stringybark Creek catchment.
5. Watch the *Little Stringybark Creek – Working with the Community* video on the Melbourne Water YouTube channel. Why do you think it was essential to engage with the community to ensure the success of the project?
6. Research Melbourne's green wedges as part of the Melbourne 2030 policy. Discuss the way in which it has affected land use throughout Melbourne.
7. Evaluate whether the Little Stringybark Creek project has demonstrated an ability to improve the *sustainability* of an urban *region* by altering small-*scale* land use.

CAREER PROFILE

Myles Coker

Environmental Engineer (Water Resources)

I am an environmental engineer and my work involves dealing with the ways rainfall and surface run-off interact with landscapes, ecosystems and human activities such as urban development, mining and dam construction. My studies at the University of Melbourne included geomorphology, land and spatial systems and hydrology. I create digital and physical maps of rainfall patterns, land use zones, ecosystems and land cover types. These maps are used to understand how changes to rainfall patterns and surface run-off affect flooding, land erosion, biodiversity and water quality. I work with other geographers, scientists, engineers, planners, architects and others in communities in Australia and overseas. I think of Geography as an essential link in communicating between these diverse professions, interest groups and cultures. I enjoy exploring the environment through the challenge of managing natural resources and by living sustainably.

▶ CASE STUDY Cave Hill Limestone Quarry, Lilydale

> "One of the largest and most significant redevelopment opportunities in the eastern *region* of Melbourne."
>
> Damian Closs, Yarra Ranges Council

Cave Hill Limestone Quarry was a limestone quarry and processing plant located in Lilydale in Melbourne's east. It was established in 1878 and operated for 137 years. Since then, the property has undergone a number of significant *changes* including the establishment of a large-*scale* farm in the late 19th Century, the subdivision of two-thirds of the property for housing estates and the creation of Lillydale Lake in 1990. Due to diminishing limestone supplies, the owners decided that the quarry would not be economically viable in the long term and it was closed in 2015. The site is currently undergoing redevelopment and will become a new residential neighbourhood called Kinley. The project was identified in Plan Melbourne as one of the 20 key redevelopment sites in metropolitan Melbourne.

▲ **Figure 3.16** The location of Cave Hill Limestone Quarry, Lilydale

▲ **Figure 3.17** The quarry pit dominates the landscape of the site

What are the geographic characteristics of the site?

Lilydale is located 35 kilometres east of Melbourne and is part of the Yarra Ranges shire (see Figure 3.16). The Cave Hill Limestone Quarry site is located at 4 Melba Avenue, approximately one kilometre southwest of the Lilydale town centre. The site covers an area of 163 hectares and, in 2020, contained a mixture of open space that was previously farmland, large areas of overburden deposited from mining operations and a quarry pit (see Figure 3.17) which is 120 metres deep and covers an area of approximately 25 hectares. The site also contains a range of original 19th Century industrial and farm buildings, many of which will be preserved for their historical significance. Figure 3.18 shows the mix of land uses surrounding the quarry such as industrial and educational land uses to the northeast and Lillydale Lake and other recreational land uses to the east. Residential land use dominates the rest of the surrounding *region* and the Lilydale metropolitan train line runs through the site from north to south.

What is the reason for land use *change* at this location?

Like most suburbs of Melbourne, the residential population of Lilydale is growing steadily and reached 17,594 in 2019 (see Figure 3.19). Affordable housing and lifestyle choices are driving population growth which is expected to continue with the population projected to reach 30,941 by 2041. This has led to an increase in demand for residential development within Yarra Ranges. As an infill site of this

▲ **Figure 3.18** A satellite image (taken in March, 2018) reveals the suburban land use surrounding the quarry *scale*, the former Cave Hill Limestone Quarry presents an appealing and logical redevelopment opportunity. Future residents will have access to a greater diversity of housing stock, retail and commercial precincts, established neighbourhoods and public transport.

What will be the *process* of land use *change*?

The ongoing development of the Cave Hill Limestone Quarry is an example of urban renewal of a brownfield site. Given that the site was able to remain viable as a quarry for 137 years, it is now one of the largest vacant sites in Melbourne's metropolitan area. The site is expected to eventually accommodate approximately 8000 new residents in 3200 dwellings which will be a mixture of houses, terraces, townhouses and apartments. This will lead to a 60 per cent increase in Lilydale's population. As shown in Figure 3.20, the site will also contain a mix of retail outlets, community facilities, heritage assets, parkland and a proposed train station, subject to government approval. The project will be completed in stages with the entire project expected to take between 15 and 20 years.

Figure 3.19 The past and projected growth of Lilydale's population

Year	Population
1991	9502
2001	13,571
2006	14,477
2011	15,735
2016	16,552
2019	17,594
2021	18,055
2026	20,681
2031	24,403
2036	28,136
2041	30,941

Figure 3.20 The former Lilydale Quarry development plan prepared in 2015 depicts the proposed mix of land uses

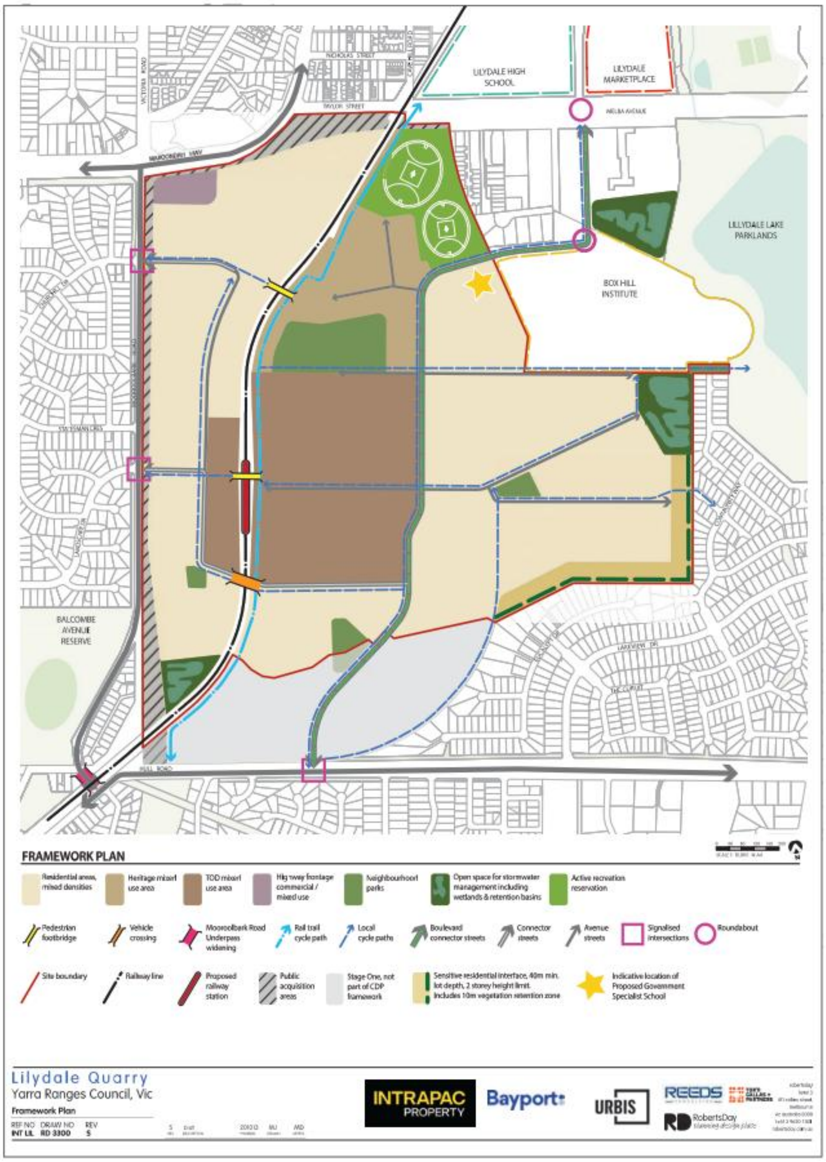
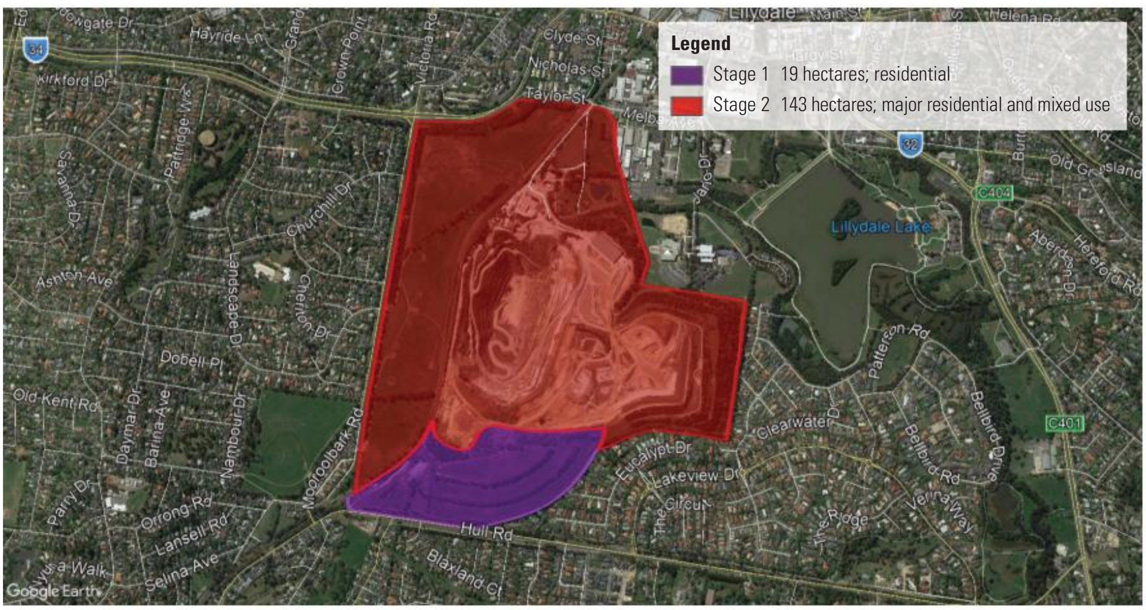


Figure 3.21 The division of the development into two major stages



The *process* of land use *change* began at the quarry in 2012 when reserves of limestone deposits were depleted. The owners, Sibelco, sought to transition the site from industrial to residential and commercial land use and sold the site to Intrapac Property in 2016. The Victorian State Government and Yarra Ranges Council have been involved in the planning *process* to ensure that new development is successfully integrated into the existing urban *environment*. Consultants have undertaken a vegetation assessment that identified 876 mature trees on the site, of which 758 are native to Victoria and 60 are endemic to the Lilydale *region*. An independent traffic assessment has been used to determine where new roads will need to be built and where the capacity of existing roads will need to be upgraded.

The next part of the *process* will involve rezoning the area and applying for permits to begin development. Stage 1, shown in Figure 3.21, is located in the southern part of the quarry and will contain both low and medium density housing (see Figure 3.22) and a new landscaped shared path for cyclists and pedestrians. As shown in Figure 3.23, the zoning for this part of the site has been *changed* from Special Use to General Residential while the remainder of the quarry site is still zoned as Special Use Zone. House and land packages for Stage 1 were presented for sale in 2018, and the first townhomes in 2020.

As part of the land use *change process*, Heritage Council Victoria has sought protection of the significant industrial history of the *region*. In June 2017, 45 hectares of the site were included in the Victorian Heritage Register which does not limit development but helps ensure the preservation of certain structures and elements on the site, ensuring a link is retained to the site's history. The spatial extent of this protection is represented in Figure 3.23 as the shaded orange *region* within the Special Use zone. Features within this protected area include the former quarry pit, historical buildings, processing machinery, remnants of a farm and vegetation. Despite being part of the protected zone, the quarry pit is being filled subject to proper recording of its initial state and protection of surrounding structures. This will involve a significant *change* to the topography of the site as the pit will be backfilled with overburden from the surrounding land. The former pit area is being filled to a geotechnical standard which is expected to allow housing, retail and open space uses across its surface as part of the latter stages of the development. Ten million cubic metres of compacted material will be needed to fill the pit, a *process* which is expected to take six years and cost over $100 million.

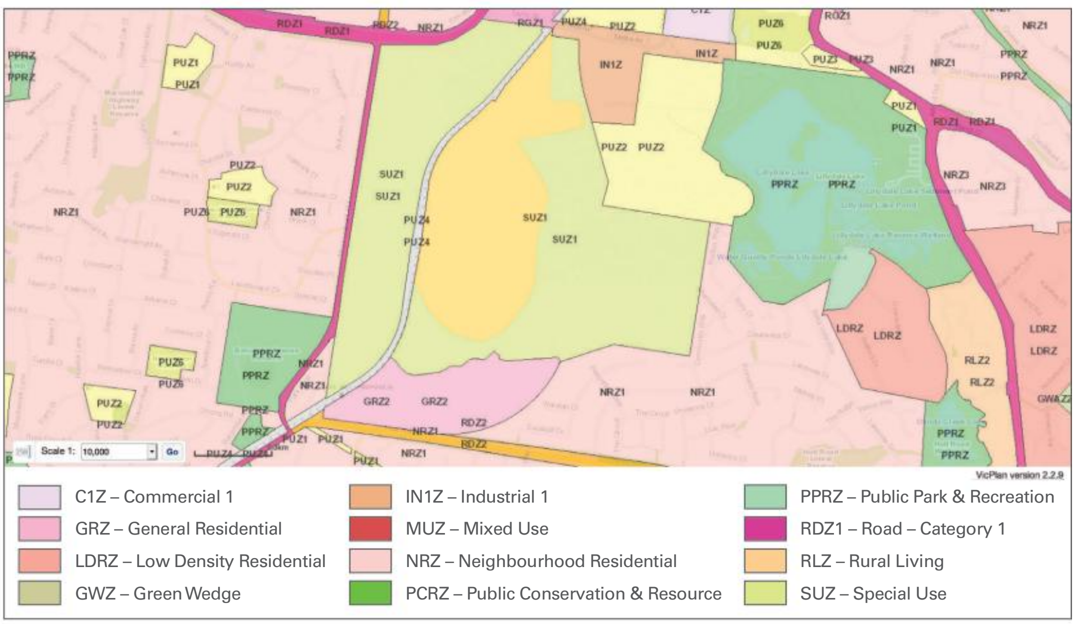
▼ **Figure 3.22** The *distribution* of housing types in Stage 1 of the development

Housing density	Number of lots	Percentage of total (%)
Medium	83	56.4
Low	64	43.6
Total	**147**	**100**

What are the potential impacts of a development of this *scale*?

Infill residential developments often raise concerns within the community over increased traffic congestion, inadequate public transport, lack of community facilities and a loss of open space. The Yarra Ranges Council has managed a planning and community consultation *process* in an attempt to reduce negative impacts throughout the development. Submissions to the Yarra Ranges Council from local residents have included concerns about:

- an increase in local traffic congestion
- a lack of transport infrastructure including cycling provisions, light rail and buses
- limited open space in Stage 1 of the development and no provision for a centre for the community
- an insufficient buffer between roads and housing creating both a traffic hazard and additional noise



▲ **Figure 3.23** A 2020 map showing the zoning of the quarry site and the surrounding *region*. The Victorian Heritage Register overlay is shaded orange within the Special Use zone

- a lack of social housing, especially as there is a lack of affordable housing in the Yarra Ranges Shire
- concerns for the future of local indigenous wildlife such as kookaburras, wedge-tailed eagles, frogs and eastern grey kangaroos
- the height of new housing overshadowing existing residents and creating privacy issues.

On the other hand, positive impacts of this development are likely to include housing diversity, land to facilitate state infrastructure delivery, affordable housing, local jobs and the creation of a vibrant community. The masterplan prepared by Intrapac Property contains over 20 per cent open space, including eight parks, three wetlands, and a network of walking and cycling tracks including a rail trail running the full length of the site parallel to the Lilydale train line which connects into the Warburton Trail. This open space has been designed so that it will be usable by residents for both passive and active recreation. Developers also claim that residents will have access to extraordinary levels of services, amenities and infrastructure to create a lively, attractive and well-serviced neighbourhood.

Figure 3.24 Industrial buildings will be preserved for their historic value

Figure 3.25 A representation of how the quarry's heritage buildings could be restored and repurposed as part of Kinley's new community hub

ACTIVITIES

1. In what ways could the land use *change* at Cave Hill Limestone Quarry be described as both infill and brownfield development?
2. Summarise the *process* of the proposed land use *change* at the former quarry site. Include the nature, *scale* and proposed time sequence of the *change* and both physical and administrative *processes*.
3. a. Using Figures 3.17, 3.18 and 3.23, list some of the geographic characteristics of the quarry site and the surrounding *region*.
   b. Using Figure 3.23, list the land uses surrounding the quarry site.
   c. Using Google Maps, describe the location of the quarry site including its *regional* context.
   d. Using Google Earth, describe how the elevation varies within the quarry site and how this compares with the surrounding *region*.
   e. Using all of the information gathered in parts a to d, discuss how the geographic characteristics of the quarry site and its surrounding *region* are likely to have influenced plans for land use *change* at the quarry.
4. The Yarra Ranges Council predicts that this redevelopment will have major impacts on communities across Lilydale, Chirnside Park and Mooroolbark. Suggest a way in which the quarry site is *interconnected* with these surrounding *regions* and therefore how it might impact them.
5. Referring to Figure 3.20, comment on the *distribution* of the proposed land uses as shown in the development plan. What further information would you require to state that this plan is socially and environmentally *sustainable*?
6. Conduct an internet investigation to find the current plan for this land use area. How much has it *changed* from the proposed plan?
7. Based on the concerns from local residents and the claims from property developers, discuss whether or not you think the land use *change* at the former Cave Hill Limestone Quarry site is likely to be economically, socially and environmentally *sustainable*.
8. Design a field trip to evaluate the potential future impacts of this development for local residents and the surrounding *region*. Include a list of primary and secondary data sources needed and the methods for obtaining this information.

4 Land use change in rural areas

It is common for landscapes and land uses to *change* regularly. These can be driven by factors such as *environmental change*, access to resources, business investment, population growth or government direction. This chapter will focus on the forces that drive land use *change* in rural areas and the consequences of this *change*. It will also investigate how effective management at the local *scale* can mitigate negative consequences of a *change* to land use. An example from within Victoria, Cardinia Shire, will be explored as this area continues to experience rapid land-use *change*. *Changes* to the landscape can be viewed over time by studying old maps and images of an area and by using Geographic Information Systems (GIS).

Why does land use *change* in rural areas?

After its initial establishment in the mid-1830s, Melbourne grew rapidly from being an isolated rural service centre and port to having a diversity of economic activities. Vendors established businesses importing and selling farming equipment, and supporting farming activities. This economic activity meant that by the end of the 19th Century, farms and market gardens on the periphery of the city, in areas such as Camberwell, Collingwood and Prahran, were experiencing land use *change* as farmland became converted to housing for the rapidly expanding city – a *change* that also occurred about 60 years later further out at Chadstone and Box Hill. This phenomenon is common to all of the world's cities and is a *process* known as urban development. Figures 4.1 (a) and 4.1 (b) show an example of how land use has *changed* in Melbourne over time. In 1945, Chadstone was a farming and market gardening *environment* on the fringes of the city, but today is a well-established urban area.

Land use *change* from rural functions to urban can sometimes occur quickly. As the urban area expands, pressure is placed on existing land resources to accommodate more people and activities. Therefore, the land on the peri-urban fringe, which is often rural, comes under pressure from urban activities and becomes more valuable. Landowners, sensing the increased demand for their land and therefore

▲ **Figure 4.1 (a)** Aerial photo of the Chadstone area taken by the RAAF as it was in 1945

▲ **Figure 4.1 (b)** Satellite image of Chadstone Shopping Centre and surrounding suburbs in 2019 its rising economic value, will either sell to developers or continue farming amidst rising council land rates.

Problems arise if urban land use conflicts with rural land use. Sometimes farmers start to neglect their properties, waiting for the land price to increase sufficiently to sell their land. Stock numbers are managed into decline; vegetation may become wild and overgrown with invasive non-native weed species; farm buildings, fences and machinery can fall into disrepair. This *process* is known as 'rural blight' and can actually diminish the value of an area in the short term. The role of State and Local Governments is to manage the transition of this land use *change* to minimise the negative social and *environmental* consequences. This chapter explores how land use *change* proceeds and the role of planning authorities in managing this *process*.

Issues as land uses *change*

Rural and urban land uses can be incompatible in many ways. Intensive agriculture, such as market gardens use raised beds and polyhouses. This requires large amounts of irrigation water, sourced from natural surface drainage or from groundwater. As the land is converted for housing, and there is less vegetation to cover and and transpire soil moisture, more groundwater accumulates and the water table may rise. This may bring toxic soluble soil salts into the upper soil root zone, reducing grass and crop growth and making nearby farming less viable. Even when substantial tree removal occurs in non-irrigrated farmland, 'urban salinisation' and waterlogging in lower lands can still occur. The farming activity may suffer as a result of urbanisation.

Where once farming practices generally went unnoticed, as urban land use creeps closer, other issues can arise. For instance, farmers have reported theft of stock and damage to farm property from residents whose backyards border their properties. Spray droplets from pesticide and herbicide applications on farmland can drift into urban areas on windy days. Although most farmers are careful to prevent this, objections raised by new residents in an area can force traditional agricultural practices to be *changed* or suspended altogether. Conflict also arises with the spread to farms of unregulated weeds and pest animals from neighbouring urban land or even from recently-established small hobby-farms. This has occurred when land is rezoned from its previous use to encompass a mix of land uses, which can at times be incompatible. This problem will be discussed later in this chapter where the role of the Victorian Planning Authority (VPA) is examined. As an example, the use of organic fertiliser such as animal manure within the Cardinia Shire, has caused conflict because of the odour. Many farmers feel it is unreasonable for their operations and practices to *change*, given they have been managing and using the land for a long period of time to provide food for the growing city of Melbourne or for export. New urban residents feel they have a right to live in their new homes, free from the smell of agricultural activity. These examples are typical of conflicts arising from rural land use *change*. Figures 4.2 (a) and 4.2 (b) illustrate the proximity of urban land to rural land in Pakenham located in Cardinia Shire.

Social problems such as feelings of isolation, excessively long car commutes to work and even a sense of reduced community safety for the new urban population can also occur as a result of rapid

▲ **Figure 4.2 (a)** and **(b)** showing proximity of rural to urban land use within Pakenham. (Note the kangaroos in the foreground of Figure 4.2 (a).)

and unplanned urban development – a *process* called urban sprawl. In the 1980s, suburbs of Melbourne such as Mulgrave, Wantirna and Keilor were built rapidly with limited supporting infrastructure to sustain their new urban communities. People living in these areas experienced problems of social isolation, as well as a lack of community services such as schools, health care, sporting facilities, police and appropriate goods and services. These problems were often compounded by poor public transport and inappropriate urban design.

Developers of planned communities are now responsible for building the entire infrastructure in an area such as schools, parks and recreational spaces, shopping and medical services and housing, as shown in Figure 4.3 (b), to prevent and ameliorate social issues. These new communities are thus designed to be more *sustainable* – many have solar panels, use recycled water and have low-use energy fittings throughout for domestic use.

▲ **Figure 4.3 (a)** A recent photo of the Cardinia General Store

▲ **Figure 4.3 (b)** A new urban centre being built on the peri-urban fringe near Cranbourne. When completed, this development will house a shopping centre, library, medical facilities and shared community spaces

▲ **Figure 4.3 (c)** Stock yards, now unused, within a paddock bordering a housing estate on the outskirts of Pakenham. This is an example of rural blight

▲ **Figure 4.3 (d)** New housing estate in Southern Cardinia Shire with farming activity in the foreground

▶ ACTIVITIES

1. Contrast urban and rural *regions*. Show your understanding with examples of land uses typical to each, making clear your understanding of the term *region*.
2. What is the difference between urban sprawl and urban development?
3. What are some of the issues associated with a *change* to land use on the rural–urban fringe? Give examples from an area you may know about.
4. Visit the Melbourne 1945 website and conduct your own investigations into how Melbourne's land use has *changed* over time.

CASE STUDY Cardinia Shire and Pakenham, Victoria

Geographic characteristics of Cardinia Shire

The Cardinia Shire is a large Local Government Area (LGA) located approximately 45 kilometres east of Melbourne and includes the suburb of Pakenham (see Figure 4.4). It is characterised by a mixture of land uses including quarrying, grazing, farming and, since 2010, rapid urban growth and infrastructure development.

Natural characteristics

Cardinia Shire has two significant land *regions*. The north of Pakenham lies on an extensive undulating plateau with heavy clay soils. Cardinia Creek drains the plateau to the south entering at Koo-Wee-Rup swamp where any water will eventually drain into Western Port Bay. Cardinia Reservoir is found in the north-west area of the shire and is a substantial component of Melbourne's freshwater supply. Cardinia Creek forms a natural boundary between the Shire of Cardinia and the Shire of Casey. The other significant land *region* lies to the south of Pakenham and is characterised by having rich and fertile sandy loams on low-lying flat land which eventually gives way to intertidal marshes and floodplains, also draining into Western Port Bay through the Koo-Wee-Rup swamp. This area supports many market gardens which provide specialty herbs and vegetables to Melbourne.

Human characteristics

The area north of Pakenham was once covered in a broadleaf forest. Much of this remnant vegetation still exists within the Bunyip State Park. The first inhabitants of the area were the Kulin people (Woiworung and Bunurong) who occupied the areas between Bunyip Creek, Cardinia Creek and the Koo-Wee-Rup swamp living off the land in a *sustainable* way for over 30,000 years. The first European settlement was recorded around 1837. Europeans quickly brought large-*scale* land use *change* to the *region*, clearing the forest for timber, grazing and and cultivation. A quick tour of the area reveals that much of this land use largely pervades today. Small pockets of remnant native vegetation with wildlife remain within Cardinia Shire. Although these areas are often isolated, they represent an important part of the shire's natural history and require careful management if they are to survive into the future.

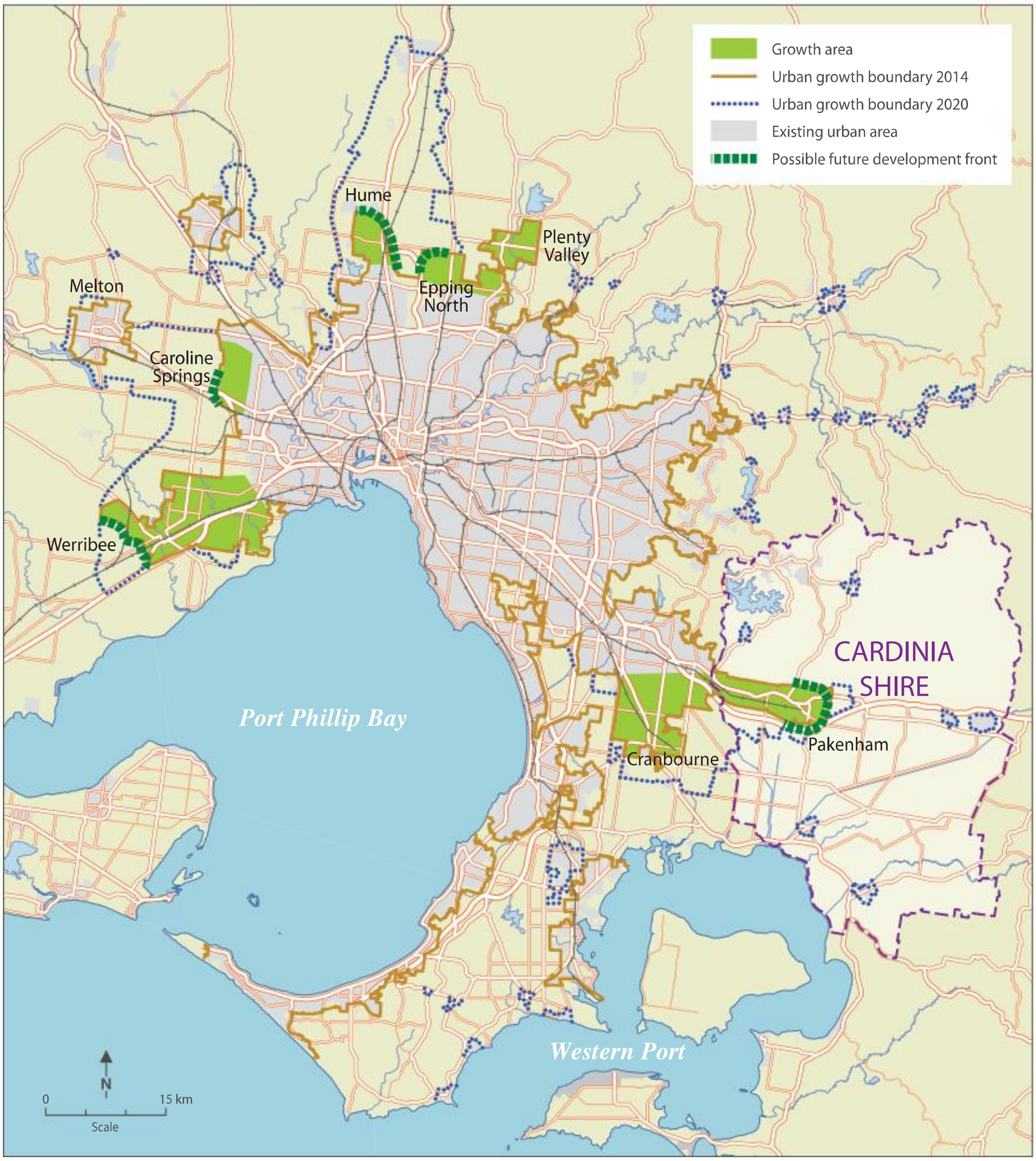


Figure 4.4 Urban growth areas as identified in *Melbourne 2030*

Figure 4.5 **(a)** Population projections until 2041 for several precincts of Pakenham

Precinct name	Population 2020	Population 2041	% change
Pakenham	38,953	51,889	33.2
Pakenham East	110	23,327	21,061.2
Cardinia Road	24,353	29,524	21.2
Officer	12,518	35,074	180.2
Pakenham Balance	1172	1270	8.4
Southern Rural	3232	3719	15.1
Beaconsfield Upper and District	4464	4438	-0.59

Figure 4.5 **(b)** Population precincts within Pakenham

Why is Cardinia Shire *changing*?

Increasing demand is being placed upon the land and infrastructure in order to accommodate an estimated 6 million people by 2050 in Melbourne. With a mostly rural landscape and land use, Cardinia Shire had a population of 120,559 people in 2020. This is expected to double to over 200,000 by 2041. Two *regions* of smaller *scale* have been identified as areas of future growth, the township of Koo-Wee-Rup and Pakenham.

The Department of Transport, Planning and Local Infrastructure has produced *Melbourne 2030 – Planning for sustainable growth*. Aspects of the plan show how specially selected pockets of rural land on the fringes of Melbourne can be converted to urban land use (see Figures 4.5 (a) and 4.5 (b)).

The Cardinia Shire Council has adopted the strategies for development outlined in *Melbourne 2030* to Pakenham. Figure 4.5 (a) is a table showing projected population growth until 2041 for the individual precincts immediately surrounding Pakenham. Figure 4.5 (b) is a map of these growth precincts.

Interconnection within and to *regions*

A *region* is an area that exhibits identifiable and similar characteristics or traits throughout. *Interconnections* occur within and between *regions* when similar land is used by people for the production, and exchange and *movement* of goods, information, transport, utilisation of services and employment. Along with distinctive internal features, these *interconnections* contribute to a *regon's* characteristics.

A simple example of *interconnection* at a *regional scale* occurs around any major airport. A transport network exists to ferry commuters and cargo to and from the airport. Short-stay hotels and carpark facilities form around the periphery of the airport. Transportation and air freight warehouses are also found within this *region*. Finally, flying schools and aeronautical engineering works also occur almost exclusively within this area. There is an exchange of money through investment, goods, people and trade between services within this *region*. The airport itself acts as a transport hub. These *interconnections* result in the area around any major airport sharing such notable characteristics.

The former agricultural land-use of the Cardinia Shire allowed for rural *interconnections* to occur within and between this *region*. Farmers used the Shire's larger town centres such as Pakenham, Koo-Wee-Rup, Gembrook and Lang-Lang to purchase their groceries, use the banks, service their farm machinery, purchase farm equipment and sell their produce in, for example, stock yards. The network of roads allowed farm traffic to move easily about the *region* and to access rural service centres. In this way, it could be said the former land use was strongly *interconnected*.

However, the degree of *interconnection* can *change* with time and circumstances. As new land-uses occur, the *interconnection* between functions can deepen and become more strongly *spatially associated* with each other. For example, as the land use *changes* from rural to urban around Pakenham, the new urban population has many needs such as schools, shopping centres and local transport such as buses and train stations. These are different from the previous rural *interconnections* and may help to establish new *interconnections* and *spatial associations*.

ACTIVITIES

1. Use Figures 4.4 and 4.5 (b), describe the *location* of Cardinia Shire relative to Melbourne. Make sure you refer to the *distance* and direction of Cardinia Shire from Melbourne's CBD in your answer.
2. Using evidence from Figures 4.2 (a) and 4.2 (b), and Figures 4.3 (a), 4.3 (c) and 4.3 (d), describe the past land use of the Cardinia Shire. Consider the services provided by the general store. How long do you think this business will survive in a rapidly expanding urban community?
3. Outline the ways in which the natural and human *environments* are *interconnected* in Cardinia Shire.
4. Examine Figure 4.5 (a) and 4.5 (b). Map the 2020 population data using the base map, Figure 4.7 (d).
5. Produce an overlay of this map using the 2041 data.
6. Describe the *distribution* of the urban growth precincts expected to undergo the greatest *change* for Pakenham.
7. Why do you think there is such variability in predicted *change* to the various precincts over the next few years?

What are the impacts of land use *change* in Pakenham?

Many issues have arisen within Pakenham in the last decade as the community experiences rapid urban growth and land use *change*. These include:

- council transactions in the sale of public land to developers have sometimes been perceived to have been undertaken without transparency and appear to have proceeded quickly, often without community consultation
- some of the best and most viable food-growing farmland is being *changed* to urban development
- too many expansive tracts of native vegetation are being lost despite planned biodiversity corridors
- climate *change* is causing more frequent bush, scrub and grass fires to occur on the outer fringes of Pakenham, posing a threat to residents and livelihoods and putting the local Country Fire Authority (CFA) under increased pressure
- Cardinia Shire has grown, as has the demand on the local roads, kindergarten and schools which are at capacity, with insufficient expenditure on infrastructure
- council rates and charges have continued to rise
- adults in Cardinia Shire are reported to have higher levels of psychological distress, above state average, owing to pressures associated with social isolation, commuter travel times and a lack of a sense of community safety
- gradual loss of the rural *environment* and community is being felt by the residents concerned about the loss of these physical and social attributes.

In 2003, concerned residents in Cardinia shire formed the Cardinia Ratepayers and Residents Association (CRRA) with the aim of improving communication between the community and the council.

While every effort is being made by the Cardinia Shire Council to manage *change* within Cardinia, there exist a range of concerns held by the community.

CAREER PROFILE

Cory Bixler

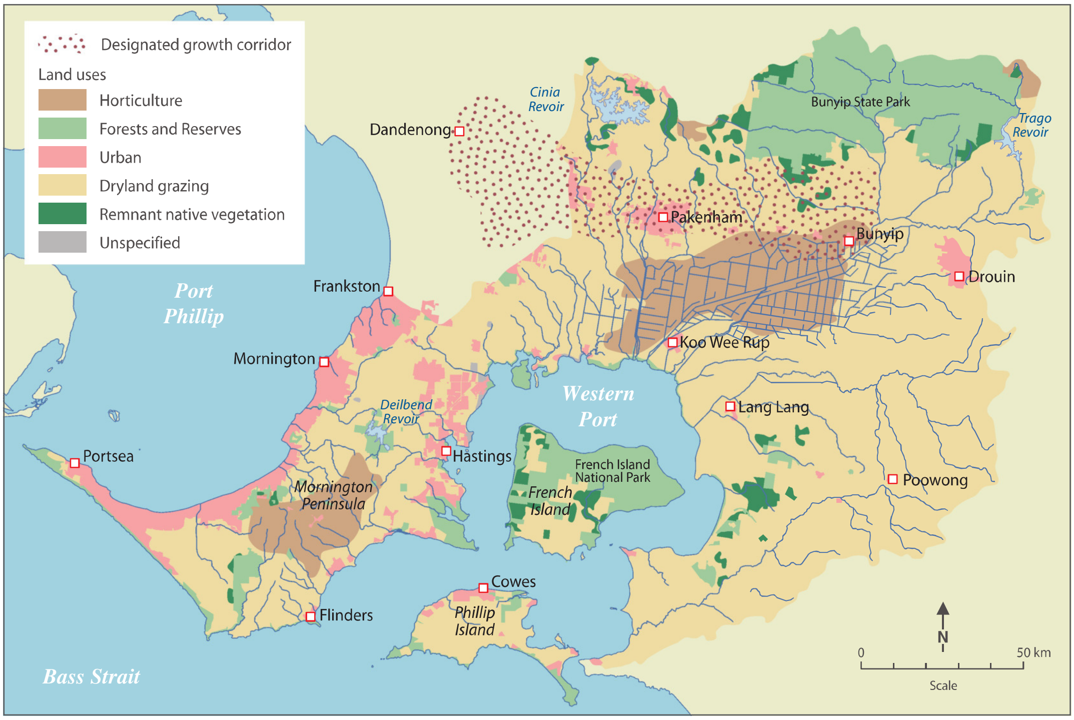
GIS Officer, Cardinia Shire Council

In my job, I am responsible for the development and administration of both hard copy and digital maps for use in reporting, advertising and for the community. My geography and cartography skills come into play when trying to make sense of complex information. This is often best done visually with maps. For example, if we want to see how land use is affecting, or will be affected by, the natural surroundings we can use a GIS (Geographic Information System) to present data from various sources over time. This may include population density, resources, political boundaries and economic activity.

After Year 12, I enlisted with the US Navy where I was an aircraft elevator technician on the USS Nimitz for three years. I travelled the world and discovered two things about myself. One, I didn't want to be a mechanic… EVER. Two, I was fascinated by coastlines and land formation in general and how they varied around the globe. When I left the military I enrolled in university, initially to study computer programming, but found that staring at lines of code all day took much of the fun out of computing for me. Then I was introduced to a course that mixed geography with computers… perfect! I completed a Geography BA at university.

If you study Geography these days you will use GIS. Your prospects as a geographer will be bountiful with many opportunities for GIS professionals in both government and private work. Everyone from the Australian Antarctic Division to McDonalds have GIS professionals working for them. So a degree in Geography with a focus on GIS is a golden ticket to career opportunity and diversity.

▼ **Figure 4.6** Land use in the Cardinia Shire



Some of the concerns include:

- farmers have reported that rubbish from nearby urban neighbourhoods has blown onto their properties, affecting the health of their stock
- new residents, who were attracted to the area by the promised opportunities within the community for employment, have faced extensive commutes back into Melbourne for work
- there has been a lag between the growth of suburban housing and its associated infrastructure to better support community health
- the roads in these peri-urban areas are heavily used by a mixture of slow-moving farm machinery and commuter vehicles; the two uses are incompatible on shared roads and this situation has been described by residents as "*unsustainable*"
- some of Melbourne's best and most productive farmland has been lost forever to urban land use *change*.

Figure 4.6 shows the potential conflict between agricultural land, forests and reserves and urban growth, particularly in the designated urban growth corridor.

How should this *change* be managed?

Under the *Melbourne 2030* plan and the Cardinia Shire's own planning scheme, strong attempts were made to ensure that population growth beyond 2030 is managed to be *sustainable*, fair and ordered. The following list shows the key aspects of planning of these new rural–urban suburbs. As you read the list, think about how consideration has been given to a mixed land use where different uses operate side by side. The Municipal Strategic Statement (MSS) is a better way of understanding the specific intent and expectations of the Local Planning Policy (LPP) for any shire of Victoria.

The development of urban communities in rural areas in Victoria needs to take into account the following:

- ensure a supply of land to meet the needs of a growing population by providing land for housing, industry and infrastructure
- restrict low-density residential sprawl and encourage development in designated growth and enhanced transport corridors
- require new homes to respond to the landscape and heritage of the area
- develop a town centre with opportunities for local employment, and provide education, medical facilities, safe public spaces, goods and services
- encourage high density housing which helps to create a greater sense of community and reduces the number of, and reliance on, car trips by individuals within a neighbourhood
- protect and conserve any pre-existing areas having a high *environmental* (conservation, biodiversity, water), scientific, aesthetic, architectural, historical or cultural value by linking these to other areas through the establishment of wildlife corridors, parks, waterways, walking and cycling tracks
- minimise the impact of natural hazards such as bushfires, floods and mitigating potential climate impacts on the community through careful planning.

▶ ACTIVITIES

1. Refer to Figure 4.7 (b). Using Figure 4.7 (d) as a base, map the *distribution* of land used for housing in Pakenham in 2002. Describe the *distribution* of housing in 2002. Identify and add other land uses onto this map.
2. Use the same base map from question 1 and produce an overlay map using tracing paper to show the *changes* to land use in 2019, again using data from Figure 4.7 (c). Describe the *change* in rural land use in Pakenham from 2002 to 2019.
3. Are there any areas within Pakenham where it appears unplanned land use *change* has occurred? Suggest reasons.
4. Use the internet to search for the specific details regarding the Municipal Strategic Statement (MSS) and Local Planning Policy (LPP) for your chosen fieldwork area.
5. Find out what a '20-minute neighbourhood' is. Describe the *changes* to land use that result from developing these types of neighbourhoods.
6. Download a copy of *Melbourne 2030*. Identify areas on the peri-urban fringe of Melbourne where future urban expansion is being considered. What contingencies are being put in place to assist this land use *change*?

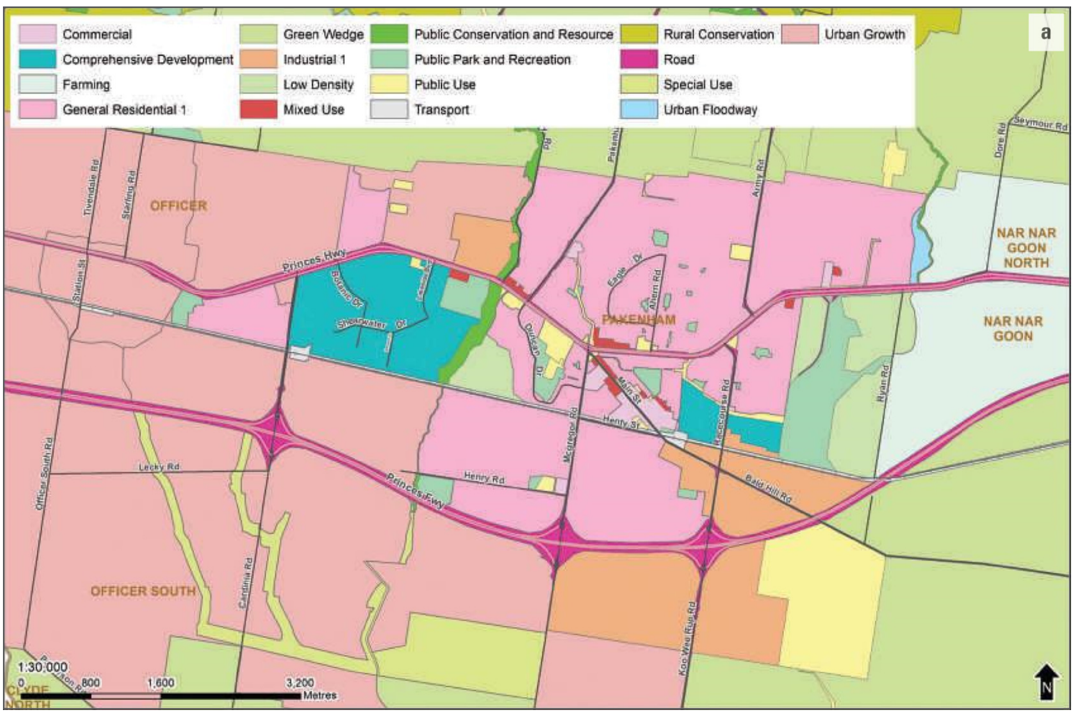
The use of geospatial technologies to analyse, assess and manage land use *change* within Cardinia Shire

In order to manage the consequences of land use *change* within its *region*, the Cardinia Shire employs two teams of strategic planners, the Established Areas Team and the Growth Areas Team, with the aim of assessing and prioritising land use *change*.

At the state level, new growth areas are identified by the Victorian Planning Authority (VPA). This is effectively farmland where the land use is *changed* to urban. This *process* is achieved through the Precinct Structure Planning, or the PSP *process*.

Within Cardinia Shire, the Growth Area Team uses satellite images, such as those in Figures 4.7 (b) and 4.7 (c), to identify suitable sites for new farmland to housing conversion under direction from the VPA. Layers are turned on within the GIS platform to show topography, water courses, remnant vegetation, areas of significant biodiversity or aboriginal cultural heritage – in fact, landscape features that might hinder or enhance a new suburb are considered. Once a parcel of land has been identified which will have the least impact to the area, it is rezoned according to the planning map as shown in Figure 4.7 (a). Another new layer of data is thus established within the GIS platform. The land then becomes available to developers. It is in this way that the various sub-divisions identified in Figures 4.7 (b) and 4.7 (c) were created.

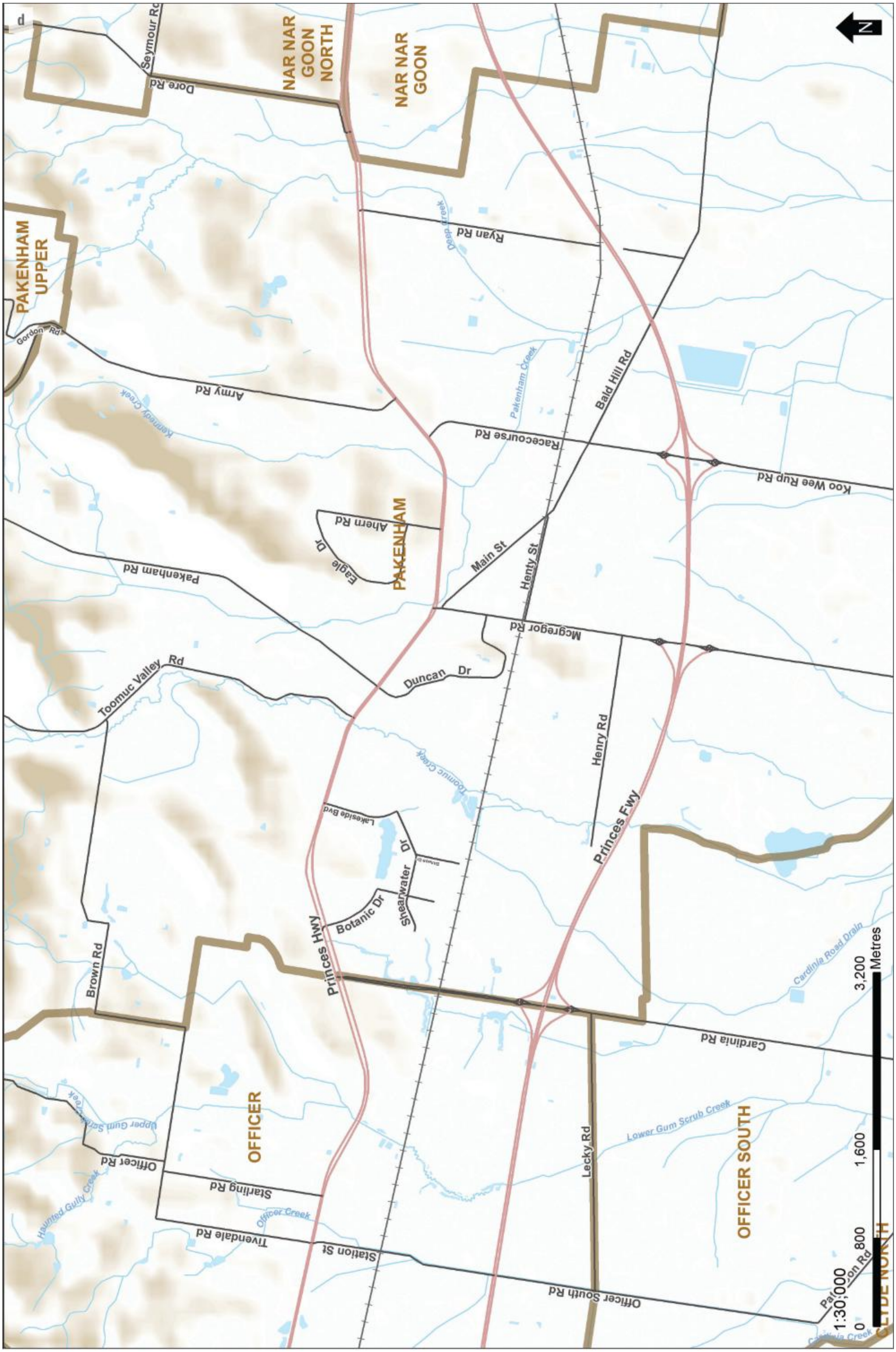
Alo,withinCardinia Shire, the Established Area T eam considers *changes* to current land use where there is already a pre-existing planned land use for an area.



▲ **Figure 4.7 (a)** GIS map of Pakenham in 2020 showing the current Planning Scheme which overlays Pakenham

▲ **Figure 4.7 (b)** GIS map of Pakenham in 2002. The planned housing estates are shown by the yellow lines

▲ **Figure 4.7 (c)** GIS map of Pakenham in 2019 showing the completed housing estates over the planned growth area



▲ **Figure 4.7 (d)** Pakenham study area base map

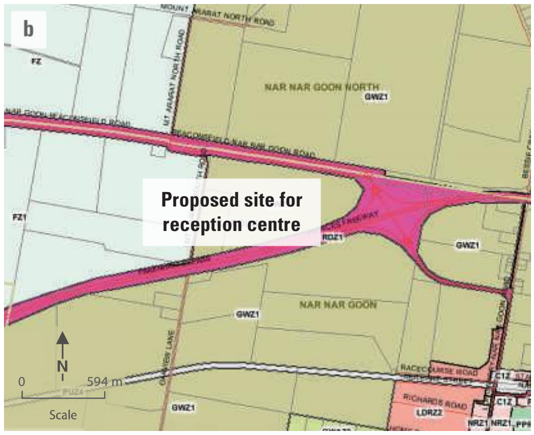
This team seeks to protect existing areas from development which does not fit the character of the immediate *region* but will enhance *interconnections*. They allow for limited *change*, green wedge enhancement and biodiversity protection and to preserve heritage such as significant aboriginal cultural sites and historic buildings. The established area team used *MapshareVic*, a GIS platform to inform future planning decisions. Any individual can use *MapshareVic*. By entering an address on *MapshareVic* for any parcel of land in Victoria, it is possible to produce a Planning Property Report. The report on each parcel highlights to planners, developers and members of the public, who may wish to object to a new development, the current land use zone of the land, as well as other significant data such as prevalence of bushfires, significant biodiversity and natural heritage, Aboriginal heritage and even areas prone to flooding. A planning application permit is produced by the proponent seeking to develop the land, and objections to the development based on a conflict of interest in land use can be presented to the Planning Department. It is their job to make a balanced and fair assessment of future land use.

Sometimes a site visit needs to be made to verify or 'ground truth' the information gathered from the GIS platform. The decisions made are always undertaken with a large degree of community consultation using verified data and are rarely without a degree of public scrutiny and interest.

Figures 4.8 (a) and 4.8 (b) shows an example for a site within the Pakenham Shire, as it undergoes the planning for land-use *change process* from farming to other land uses, in this case a wedding reception centre. The land to the west is designated as a Farming Zone (FZ1) whereas across the road, GWZ1 is classed as a Green Wedge Zone, allowing many activities to occur such as the building of churches, residential properties and even hotels. It is here, where the reception centre is planned. How compatible could these differing land uses be?

Your field work investigation will ultimately investigate the influence of geographical characteristics of the selected area and surrounding *region* as well as the influence of individuals, organisations and planning strategies in order to make your own assessments and evaluations of land-use *change*.

▲ **Figre 4.8 (a)** Planned site for a redevelopment of farming land to a wedding reception



▲ **Figure 4.8 (b)** Planned site of wedding reception centre on planning map

▶ ACTIVITIES

1. Research the role of the Victorian Planning Authority (VPA) and see if you can determine how rural-urban land use *change* is assessed and managed within Victoria. See if you can find what the current plans are for your chosen fieldwork site. Remember, as new projects are completed and provided to developers, they may be removed from the VPA as they are handed over to the local shire council or local planning authority.
2. Examine Figure 4.6 in conjunction with Figures 4.7 (a) and 4.7 (c). Discuss with your class some of the different land use categories and determine what they may mean. (Differentiate between general residential, urban growth, farming and special use). How might this GIS Planning Scheme layer assist in the decision-making *process* for future land redevelopment in and around Pakenham?
3. For the example provided in Figures 4.8 (a) and 4.8 (b), discuss the advantages and disadvantages of having a wedding reception area immediately adjacent to a farming activity. As a class, make your own decision as to whether this development should proceed.
4. Use *MapshareVic* to produce a GIS-based property report for your fieldwork site. Apply the planning approvals *process* to your fieldwork site using the information collected to develop your own arguments for and against the development. Conduct your own site visit and 'ground truth' the area to evaluate the *process* of land use *change*.

5 Investigating land use change: fieldwork

Land use *change* fieldwork investigation of Melbourne's peri-urban growth

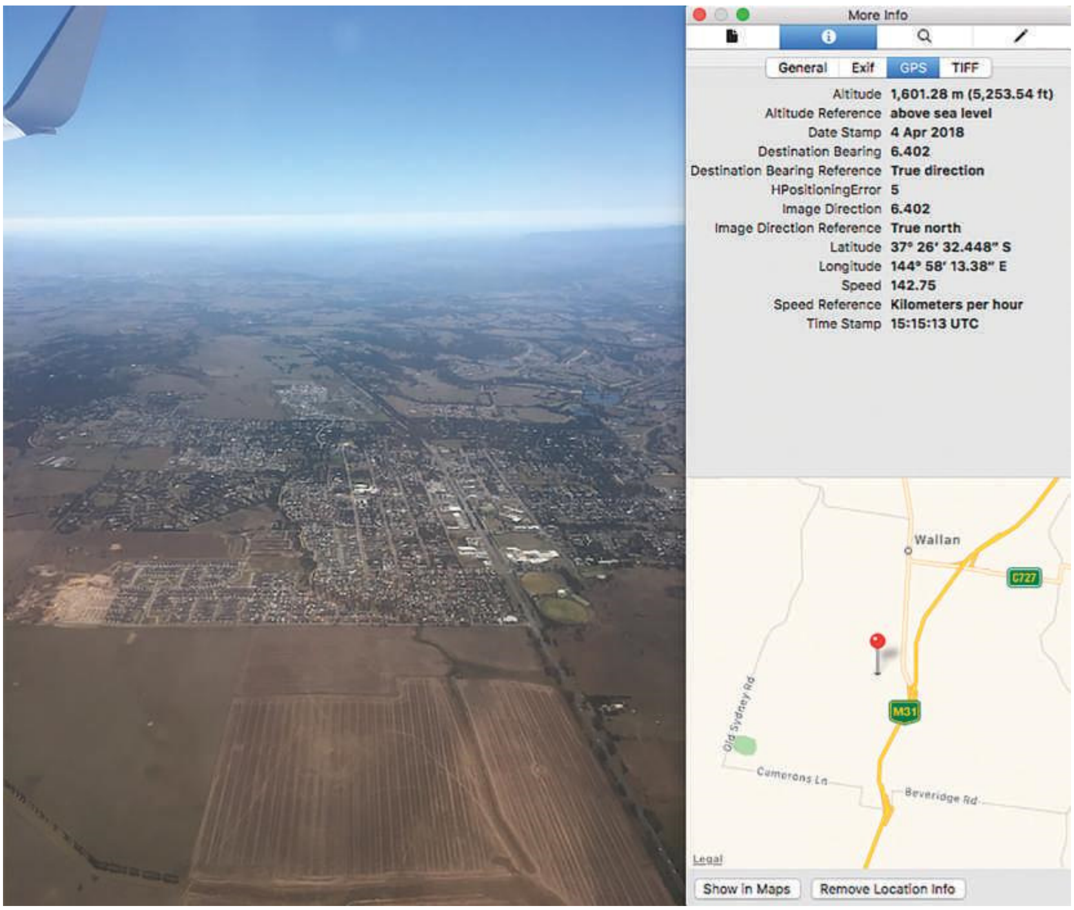
Fieldwork overview

The fieldwork investigation is an opportunity to formulate questions, hypotheses and research techniques in a real-world situation. Working in the field is where many students find their deeper connection to Geography through their interaction with people, the *environment* and the shared experience with their peers. This central component of geographic investigation is explored in this chapter using peri-urban growth areas as a recommended study area. The town of Wallan is used here as a potential study area.

In selecting fieldwork sites, it is important to consider site access, history and where land use *change* has recently occurred. Although the class will likely be using the same study area, each student collects unique evidence to address their primary research question and support their analysis and discussion.

Background on peri-urban growth areas

As urbanisation intensifies worldwide, areas immediately outside urban boundaries are experiencing pressure as *environment*, resources and historical land



▲ **Figure 5.1** Aerial image looking north along the Northern Hwy toward the fast-growing town of Wallan in the Mitchell Shire. Wallan is 45 kilometres north of Melbourne and is one of the furthest extents of the Urban Growth Boundary. The information on the right shows the GPS metadata embedded in the photograph uses undergo *change*, creating complex challenges for governments and communities. The term peri-urban is a conjunction of "peripheral urban", these are the critical *places* where urban and rural land uses overlap and often compete. As discussed in the previous three chapters, large semi-rural areas neighbouring Melbourne's Urban Growth Boundary are experiencing increased development pressure as the population is projected to double by 2050. Melbourne's peri-urban *regions* perform vital functions for Victoria and experience different hazards than urban areas which create unique challenges for planning 'greenfield' residential developments.

Australia has continued to grow its population at one of the highest rates of any of the Organisation for Economic Cooperation and Development (OECD) countries and Melbourne was the fastest growing city in Australia in 2018, adding nearly one million people in 10 years. The population growth rate for *regional* cities and peri-urban areas is estimated to increase by 6 per cent this decade. This growth increases pressure on infrastructure, government services, resources and the natural *environment*. Peri-urban areas are essential to providing food, fibre and resources to support population growth, but also are tasked with absorbing overflow population. Towns such as Wallan, shown in Figure 5.1, are confronted with these challenges as they grow to accommodate a rapidly growing population.

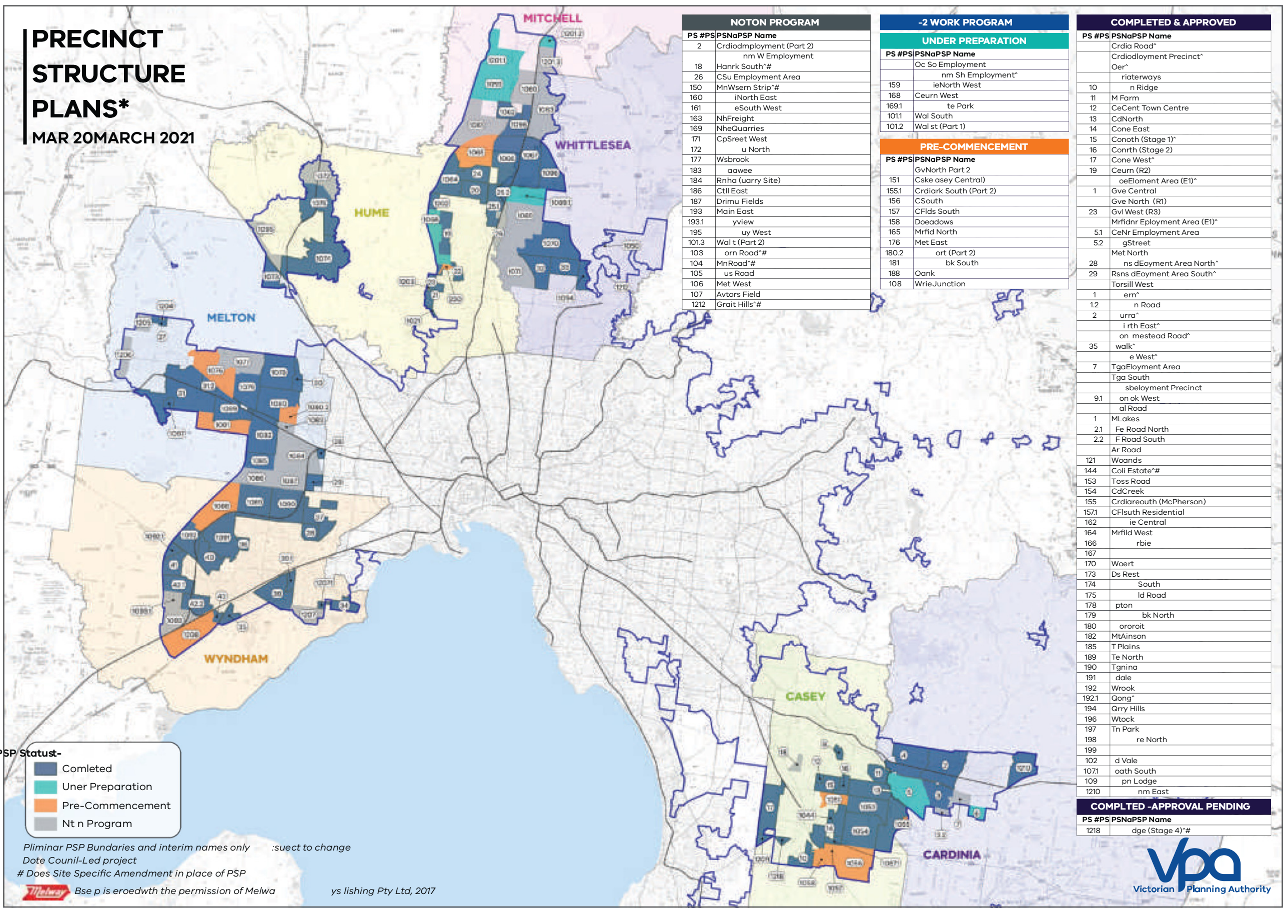
The total area of peri-urban shires is approximately 21,000 square kilometres, or more than double the 2017 area of Greater Melbourne at 8800 square kilometres.

The sparse *distribution* of resources and infrastructure across this *region* results in reduced ability to respond and therefore a higher vulnerability to natural disasters and climate *change*-related risks such as increases in heatwaves, droughts, fires and floods. New communities situated within this context face a different set of challenges than other communities closer to metropolitan Melbourne. The *scale* and complexity of this issue requires in-depth and ongoing research to avoid a cascading failure from inadequate land use practices and offers an exciting area of inquiry for Geography students to investigate.

Investigating growth areas using Precinct Structure Plans

Originally called the Growth Area Authority, the Victorian Planning Authority (VPA) is the statutory body that reports to the planning minister. One of the key tasks it undertakes is planning new precincts in growth areas, many of which are on the Urban Growth Boundary and governed by peri-urban councils. The VPA conducts exhaustive geographic fieldwork, using a variety of data and methods. The result of this work is published as Precinct Structure Plans (PSPs). These documents are the guiding vision for new precincts and are accessible online. Currently there are over 100 PSPs either planned, active or completed in Melbourne as shown in Figure 5.2.

The PSPs are government documents used as blueprints for these precincts and are a rich secondary source of information that can guide the selection of the fieldwork site and inform the research question



▲ **Figure 5.2** A map of the Precinct Structure Plans (PSPs) published by the Victorian Planning Authority in 2021. These are completed, active or proposed future plans. There are over 100 PSPs, which are the detailed visions for Melbourne's growing peri-urban and outer urban communities development. The PSPs represent many years' worth of geographic fieldwork and consultation amongst teams of professionals and exemplify advanced geographic techniques and written communication.

Designing a fieldwork investigation

The following pages discuss the technical aspects of conducting fieldwork and reporting the findings. Conducting fieldwork is a central method geographers use to understand *place*. To better understand the challenges, opportunities and responses in a specific peri-urban location the researcher must design the research investigation using a sequential approach (see Figure 5.3) and prepare for the appropriate fieldwork techniques. The techniques used to gather and create data must be appropriate to the fieldwork site. For example, in human geography interviews, questionnaires and land use mapping are more appropriate techniques than soil profile sketches or measuring water quality.

▼ **Figure 5.3** This flowchart represents the sequential stages of the research *process* for conducting fieldwork

1. Select a site to be investigated
2. Generate main research question(s) and hypotheses
3. Conduct desktop research
4. Seek out potential stakeholders to interview
5. Conduct fieldwork data collection
6. Organise, discuss and analyse the data
7. Format the data into the report
8. Analyse the data with regard to the research question
9. Conclude and evaluate the research *process*
10. Reference all external sources of information

To get started, geographers select and define the area to be investigated, begin writing the research question(s) and then data collection begins at the desktop. The first phase of data collection is called desktop research, the researcher gathers secondary data from a variety of sources including documents, reports, newspaper articles and government and community websites. Geographers and planners further supplement this documentation with remotely sensed secondary data available from satellite imagery, aerial photos, time-lapse animations and historical data such as maps, street level photos, artworks and other archived material.

Once a timeframe for the fieldwork is established key stakeholders are identified and contacted. Stakeholders may include any person with a position of leadership, a vested interest or good knowledge of the area such as a government officer, traders' association member, local business person, librarian, strategic planner, a Country Fire Authority volunteer, local police, indigenous group representative, real estate agent or developer. A meeting with a high-profile community member provides valuable local information and contributes new perspectives to inform the research question.

Writing a research question and developing a hypothesis

High-quality research questions begin with geographers identifying an area of interest that lends itself to investigation and then refining the topic until it is a focused enquiry. For example, land use *changes* occur due to multiple *interconnected* factors, such as the impact rapid population and residential development growth has on peri-urban councils, specifically the relationship between productive land uses and residential zone expansion in a town. Desktop research on local issues provides a foundation for the investigation followed by questions the literature raises, such as "how" and "why" land use *change* is occurring. Out of the questions generated, select a central or primary research question and lesser secondary research questions.

Geographers evaluate and refine their questions over the course of the project. Consider the following evaluation criteria:

- Is the research question geographical in nature? (i.e. does it cover multiple geographic concepts) Is it interesting to you and the broader community?
- Has the question been answered already?
- Is the question too broad, too narrow, or too complex?
- Is the question one that can be answered given the time and resources set aside for the study?
- Will the *process* of data collection produce accurate information?

An example of a primary research question is: "How has the township of Wallan been affected by residential growth in a rural agricultural *region*?" A secondary research question that follows is: "What policies and practices are in place to ensure the character of the township is maintained?"

▼ **Figure 5.4** Overview of geographic fieldwork techniques, applications and notes on presentation

Techniques	Applications	Examples	How to present
Mapping and Surveying	Excellent for documenting position, location storing information on land use, services and amenities for use in comparison later.	Create land use transect maps, service *distribution* maps, sphere of influence maps and coordinate maps of photographs. Draw a map by surveying from a known point on a map.	Use the BOLTSS conventions for presenting mapped data, maps may include annotations or GIS layers.
Sketching and photographing	Sketches are more selective than photos, are a slower *process* than photos which allows for more sensory evidence to be documented. Sketches can be compared with a photograph.	Sketch and photograph scenes from a vantage point and from the street level, photograph examples of zones, public services and land uses, vistas, municipal facilities and the natural *environment*. In some remote or difficult fieldwork sites it may be possible to use a drone to collect aerial photographs or video.	The evidence shown in photos and sketches can be analysed over time to yield information after the fact and should be annotated when presented in the report.
Interviews and questionnaires	Best technique for engaging the public, recording opinions, can lead to information not considered before, may reveal historical and current issues.	Create questions for use in questionnaire and interviews before going in the field. Open ended questions yield qualitative information, closed questions will yield quantitative information and statement questions with a Likert *scale* response can yield both. Seek out local leaders for interviews.	Quantitative responses can be graphed. Qualitative responses can be discussed according to the appropriate themes you are looking for.
Counting and measuring	Provides original data for processing, requires a close examination of local details otherwise looked over, enables temporal analysis of a location.	Counting vehicles and modes of transport from a fixed sampling point over a set period will give frequency data. Measuring *distance* between services or land uses can inform the discussion of accessibility and usefulness.	The results can be put into tables, graphed and mapped.

The hypothesis stems from background reading on the selected area and from synthesising multiple sources of information into a prediction. For example, an informed hypothesis of the research questions may be:

> "If Wallan has experienced growth in new socio-economic areas that have led to *changing* priorities of local government this could lead to decreased productivity of the landscape and contested divisions among the residents. If both the land uses and discord among citizens are real, then an appropriate response from local leaders would be programs and policies to ease this transition, such as by including the existing residents in the decision and planning *process*."

Selecting fieldwork techniques and data

Fieldwork will not employ every technique but includes as many as is feasible. Each technique requires a special skill to refine and possibly equipment such as a smart phone, clipboard, printed questionnaires and a surveyor's wheel. The Figure 5.4 table gives an overview of fieldwork techniques appropriate to investigating land use *change* in a peri-urban location.

Data takes the form of either qualitative or quantitative information. Figure 5.5 has examples of quantitative and qualitative data and specifies when it is classified as primary and secondary data.

Qualitative data will come from observed evidence which is information gathered through the senses, personal communications, written and oral feedback from questionnaires, photographs and videos.

Quantitative data can be measured discretely or continuously, for example number of parking spaces is a discrete number, whereas length of bike paths is a continuous value. Quantitative data usually are classified as frequency numbers, measurements and ratios.

Primary source data is collected for the purposes of the report itself by the researcher. Secondary source data is data that was made for other purposes. This is different to some other fields of social science where a photograph, for example, may be considered primary evidence of an event as it was taken at a particular moment. Geography classifies data as primary data if it was generated for the purposes of the study in question.

▼ **Figure 5.5** Four common types of data that can be gathered or created, with examples

	Primary Source	Secondary Source
Quantitative Data	Extracted GPS metadata from photos taken on a smartphone in the field (as shown in Figure 5.1), frequency counts, numeric survey data, ratios	Census data, numeric data from masterplans or Precinct Structure Plans
Qualitative Data	Empirical evidence gathered from experiencing a *place*, notes from an interview, fieldwork photographs, videos or surveys	Video documentaries, textbooks, other peoples' interviews, other peoples' photographs

There are many types of Geographic Information Systems (GIS) data that can be obtained and created. Remote sensing data is particularly valuable as it can provide insights at a range of *scales*. Satellite imagery, multispectral imaging and infrared sensing are used to identify land uses and *changes* over time. Meteorological conditions such as precipitation, heat and particulate air pollution can be gathered as information sources which use data from multiple satellites, such as the many layers visible in "Earth" by Nullschool (Figure 5.6), which can be temporally adjusted and spatially *scaled*. To produce remotely sensed data in the field, researchers use Unmanned Aerial Vehicle (UAV) drones to capture images, but also use terrestrial remote sensing techniques such as time-lapse photography and 3D scanning and photogrammetry. For each of these ground-based approaches there are many suitable smartphone applications which generate useful images and models.

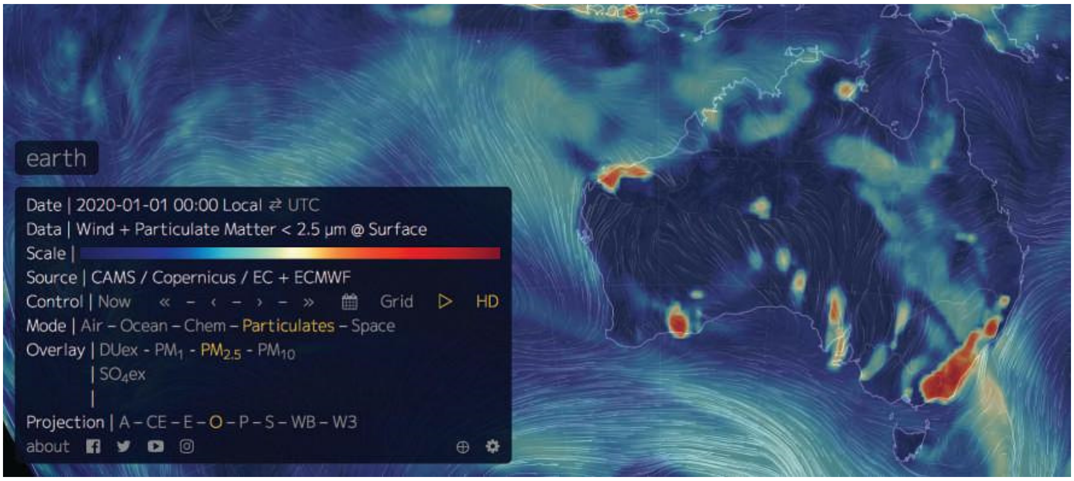


Figure 5.6 This remote sensing image is from multiple satellites and hosted by Nullschool. The date range is set to New Year's Day 2020, showing the significant particulate pollution caused by the severe bushfires which were burning. This data can be viewed at a local *scale* to show how heavily polluted a location was and for how long

ACTIVITIES

Using software to generate GIS placemark layers from photos

An effective way to quickly integrate accurate data into your final report is through metadata. The following sequence is an example of how to extract geolocated GNSS metadata from photos taken on a smartphone and uploaded to a map as a layer. The following instructions require a smart phone, spreadsheet software and Google Maps.

1. After taking multiple images in the field, upload them to a computer and select the images you would like to use.
2. For Mac computers, right click on the image file, under "more info" you can view the lat/long data. To view detailed GNSS information you can open in Preview go to>Tools Menu>Inspector>GPS. For Windows users, right+click on the image go to>Properties>Details>GPS. In both cases the GPS data can be copied directly into a new spread sheet with a column for latitude and a column for latitude.
3. To get the location data into a readable file it needs to be in decimal degrees (-37.416667, 144.983333). If your coordinates are in Degrees/Minutes/Seconds (DMS) format (37°25′0″ S, 144°59′0″ E) you can type the following formula into the spreadsheet table cell as = (Seconds/60+Minutes)/60+Degrees, to convert it to decimal degrees. Latitude in Australia is expressed as a negative number in decimal degrees, which you need to add if you are converting from DMS format.
4. Once your location data is in decimal format you can export the file as a .CSV file to your desktop.
5. Sign into Google Maps online, on the upper left select the menu icon go to>Your Places>Maps> Create. Upload the .CSV file and follow the prompts to designate the location information. The photograph locations will appear on the map.
6. A more advanced step is to export the layer to Google Earth as a .KMZ file by selecting the menu icon near the map title>Export to KML/KMZ. In Google Earth the layer placemarks can be edited, information can be added, or the original photo with text can be included in the placemark window itself.

Presenting and analysing the data

After data is gathered in the field and from secondary sources, it is organised and consolidated according to the research question and used to draw conclusions. For example, mapping conducted in the field can be redrawn for neatness and accuracy, observations and notes can be revised onto one document, photographs can be geolocated as layers on an aerial image using the GIS *process* described in the activities above, sketches and transects can be compared to the masterplans published by local government (see Figure 5.7) and interviews, questionnaires and surveys can be coded into tables.

Once the data is organised the analysis is conducted. A useful technique for analysing qualitative data is the SHEEPT factor analysis. This is a thematic analysis which classifies the data into common factors and helps identify emerging patterns. Figure 5.8 shows the factors and recurring themes that may emerge from the data. Thematic patterns are identified and described in the body of the analysis section by highlighting *interconnection* between the factors, with the research question a central topic throughout.

Figure 5.7 Wallan Masterplan. The map shows areas for improving pedestrian access, increased residential precincts and new bus interchanges

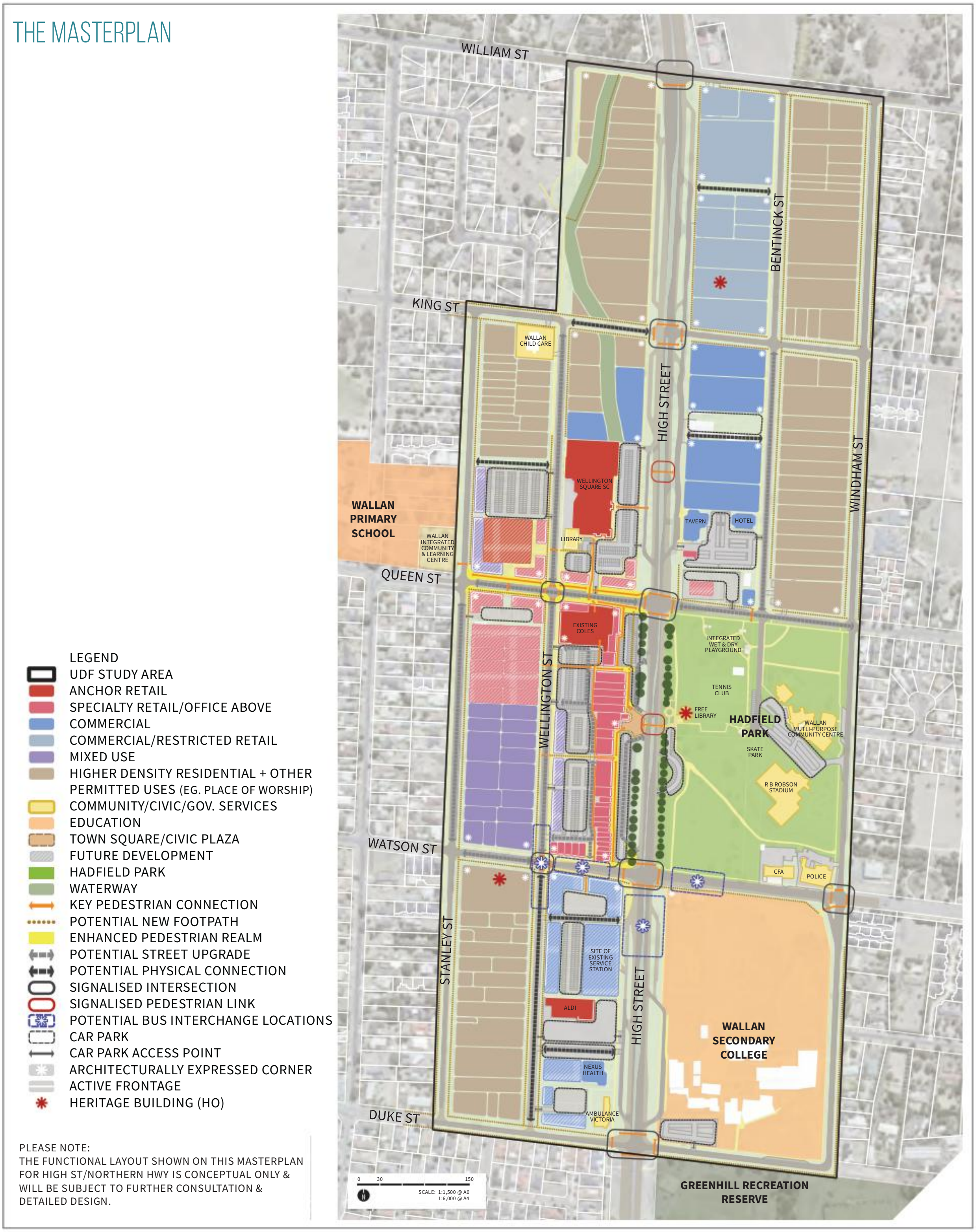


Figure 5.8 The SHEEPT factors and topics that may emerge from a peri-urban fieldwork analysis

SHEEPT factors	Possible topics
Social factors	Culture, population, gender, age, education, lifestyle
Historical factors	Events, land uses, indigenous land use, architecture, decisions
Environmental factors	*Sustainability*, waterways, conservation, climate, resources
Economic factors	Jobs and employment, developer contributions, land value, industry
Political factors	Government interventions, representation, zoning, plans
Technological factors	Transport, renewables, architecture, public amenities, industries, infrastructure

As quantitative data is analysed, geographers look for patterns that emerge and employ a PQE analysis to document these patterns. This acronym stands for Pattern/Quantification/Exception, where the author describes patterns in the data, quantifies characteristics of the data set and then describes any exceptions to the pattern. Primarily used in describing maps, graphs and tables, other components may include temporal patterns, enabling a multi-dimensional analysis.

Finally, field researchers cover as many geographic concepts in the discussion of the findings as is relevant and how it relates them to the primary research question. The discussion includes the *interconnection* between factors, or the possible drivers of the patterns. Central to this is showing an understanding of the *processes* of, and reasons for, land use *change*. Describe how individuals, organisations and markets have influenced the land uses positively and negatively over time and explore the relationship between human settlement and the *environment*.

Concluding

The conclusion is a chance to present an overview of the investigation, summarise thoughts and indicate wider applications of the findings by situating the study within the context of land use planning and geographic enquiry. It shows how the report helps answer questions and relays the significance of the findings and to whom. The conclusion is a place for insights and approaches that helped the fieldwork investigation.

This is the final response to the research question and hypothesis. That is one of the reasons why the evaluation component of your report is important, so that others can learn from your research experience.

Evaluating methods and fieldwork techniques

The final written element of the report is the evaluation. The key areas to reflect on are: the research question, the research design, the fieldwork techniques and the reliability of the data. The evaluation is a self-assessment of the report and how well it answered the research question using valid sources and accurate data. In other words, how could the investigation and reporting be improved if they were done again? The weaknesses and limitations of fieldwork may include: limited resources, errors in data collection, population sampling problems, interference from weather, etc.

Formatting the report

Formatting follows the formal standards of presenting academic information. At VCE Geography level the word limit is approximately 2000 words, has headings that signpost for the reader, pages are numbered, all illustrative material is numbered with a descriptive caption and is integrated into the body text, and finally all outside information is referenced to a standardised format. Geographers use checklists to ensure they have satisfied all the criteria of a report, as in Figure 5.9.

▼ **Figure 5.9** The VCAA checklist to guide the structure and format of the final fieldwork

Report Section	Key Guidelines
Definition of topic	▶ A clear statement of the research question ▶ An outline of the geographic context of the question ▶ A brief hypothesis (expected answer to the research question) and justification of hypothesis
Outline of primary sources and techniques used to collect data	▶ A brief description of the sources and techniques used ▶ A justification of their appropriateness to the research question
Outline of secondary sources	▶ A brief description of the sources and techniques used ▶ A justification of their appropriateness to the research question
Presentation of processed data and information	▶ Use appropriate conventions ▶ Techniques most appropriate to the meaning conveyed by the data and information ▶ Correct sourcing of the data and information
Analysis of processed data and information	▶ Identify key features ▶ Describe patterns identified in the processed data and information ▶ Draw relationships between key features and patterns in the processed data and information ▶ Relate back to the research question and discuss whether or not the data and information has supported the hypothesis
Conclusion	▶ Identify the extent to which the analysis has answered the research question ▶ Note any specific points to be learnt from the investigation
Evaluation	▶ Consider the relative effectiveness (limitations and weaknesses) of the techniques implemented and sources used ▶ Consider future possibilities for any subsequent investigation
Referencing	▶ Bibliography has correct and consistent referencing ▶ Acknowledgment of sources of information and people

CLASS ACTIVITIES

1. In a group, discuss the impact of housing prices on your local neighbourhoods. Where are people moving to accommodate their housing needs? What are the implications of gentrification on the outer suburbs and rural areas?
2. In pairs discuss and present on the consequences of rapid land use *change* on productive agricultural areas that are being turned into masterplanned estates. Can the rural populations afford to live in these suburbs? Can the new residents work in the local areas they inhabit?
3. Write a brief paragraph about the experiences of the youth based on their location. Are rural areas adequately meeting young adults' needs? What are the needs of the youth at various stages in their life and how can cities reflect these needs?
4. Using the Figure 5.7 Wallan Masterplan list the many uses of the town centre. What opportunities for recreation and active travel are there? Where would you spend most of your time if you lived there?
5. Select a fieldwork site as a group and call at the local library, general store or cafe. After explaining the nature of your project, and requesting their permission, ask questions regarding character, culture and lifestyle of the town and whether they see it *changing*.

ONLINE ACTIVITIES

1. Use the Strava heat map function to see the routes that people use most frequently for recreation in your selected location. What patterns of use are present and how would this influence a planner who is designing the precinct?
2. Using the online academic periodical *The Conversation*, search for articles related to Melbourne's population growth and peri-urban development. What are university researchers recommending and are councils heeding this advice?
3. In pairs search for peri-urban shire councils on the profile.id website. Examine and describe the types of industries that currently operate in a council area and which industries have increased and decreased over the last five years.
4. Find and describe four different types of remotely sensed data. Examples may include: LiDAR Digital Elevation Models; UAV based infrared; Multispectral Imaging; RADAR; SONAR; thermal imaging; and altimetry.

Adam Rossimel
Town planner

CAREER PROFILE

Town planning is a profession which seeks to create communities that are liveable, equitable, accessible and financially viable for current and future generations. From things such as transport infrastructure, parks, education centres, the location of jobs and agriculture, to the location and design of every building, house or public space — town planning is ubiquitous and is influential in the way land is used.

The work of a town planner ranges from large-scale projects such as layouts and master planning for new suburbs, to smaller-scale projects such as the design of a new home or cafe, as well as everything in between.

The key principles of Geography underpin almost every aspect of town planning. For every land use, the social, historical, environmental, economic, historical, political and technological implications for an area and its surrounds must be considered. Because every site is unique, the weight given to each of these considerations varies with each project. Studying Geography trains the mind to consider the spatial interactions of land and its surrounds, a major consideration in town planning. To forge long-term plans for locations, key geographical tools include population projections, census data and Geographic Information Systems (GIS).

I have always been interested in Geography and the way in which land is used. When I was younger I was fascinated by different landforms as well the ways in which cities evolved as a response to their environment. Geography provided a way of finding out more, but also raised other questions about the evolving physical and natural world which I wanted to understand further.

▶ CASE STUDY Fishermans Bend Urban Renewal Area

Background

The Wurrundjeri tribe of the Kulin Nation holds the Yarra River in great reverence and believes it to have been formed by Bunjil the creator spirit. The river historically provided Melbourne with rich soils and fresh water. The current mouth of the river at Hobson's Bay is less than 4000 years old, as before then the river emptied into the ocean at Port Philip Heads and the present day bay was a vast hunting ground. Fishermans Bend was an early settlement area from the 1850s for fishermen and dock workers of European descent who lived in makeshift houses near the docks (as shown in Figure 5.10). Its relative isolation from the city made it a popular location in the late-19th Century for the more noxious trades such as abattoirs, boiling-down works, bone mills, fertiliser and glue factories and soap factories, as well as for industry associated with shipbuilding such as shipwrights, candle makers and sail makers. Currently the area is a mixed industrial area where automotive, aeronautics and warehousing businesses comprise most of the industry.

Today this area is the centre of Australia's largest-ever urban renewal project — the Fishermans Bend Urban Renewal Area (FBURA). The majority of the land is within the City of Port Phillip, while the Lorimer Precinct is within the City of Melbourne (as shown in Figures 5.11 and 5.12).

The urban renewal project consists mainly of 'brownfield developments', converting formerly light and heavy industrial land uses to high-density housing and retail. Located from between 800 metres and 3.5 kilometres south-west from the CBD, this 240-hectare area is 20 per cent larger than the CBD's Hoddle Grid. The official 2015 population of 200 people was predicted to increase to at least 80,000 during the 50-year project.

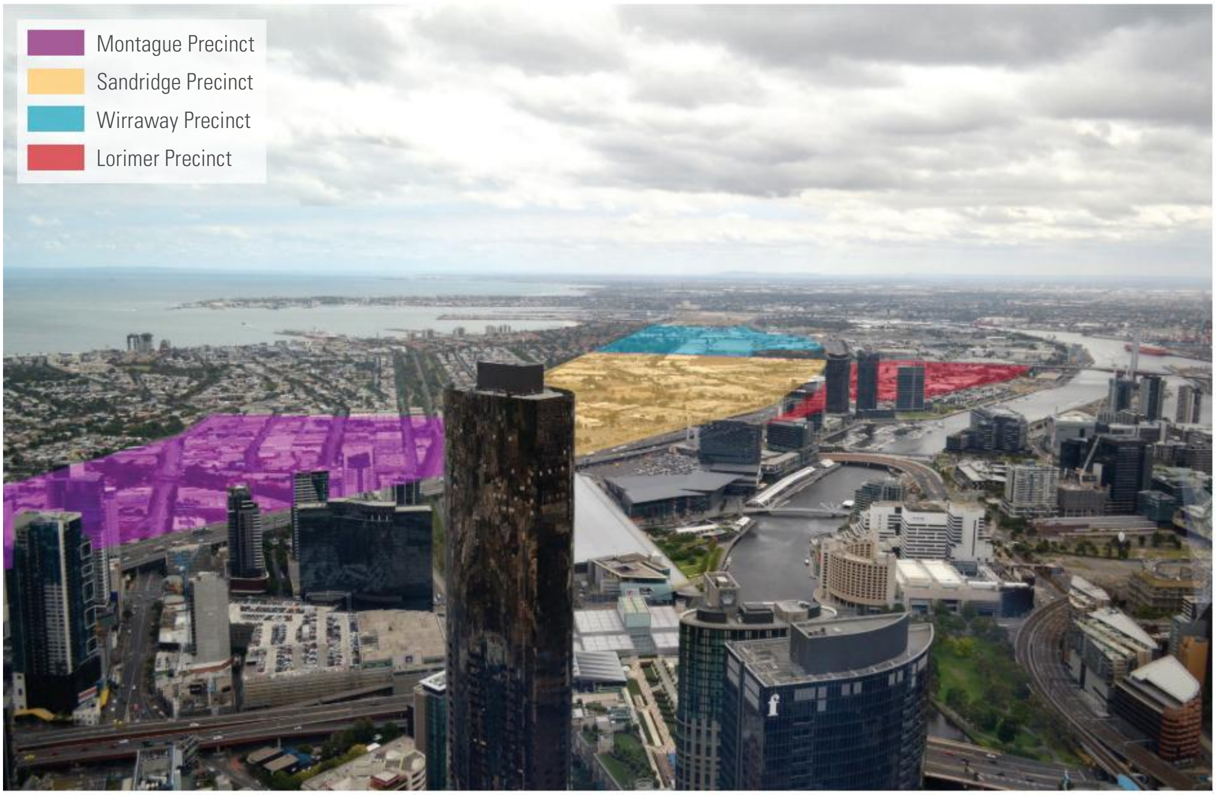
The urban renewal plan was the vision of former Planning Minister Matthew Guy who imagined Melbourne as a 'Manhattan-style' metropolis. In July 2012, he rezoned 240 hectares of Fishermans Bend to 'Capital City Zone' via a Ministerial Amendment to pave the way for the development.

▲ **Figure 5.10** Land use *change* over time **(a)** 'An encampment of Aboriginal Australians on the banks of the Yarra' by John Cotton, circa 1845 (*Souce:* State Library of Victoria); **(b)** 'Fishermans Bend' by Albert Tucker, circa 1939–45 (*Souce:* State Library of Victoria); **(c)** Munro Street, Sandridge Precinct, 2015; **(d)** Thistlewaite Street. Montague Precinct, 2015

The new Capital City Zone (CCZ) had very relaxed height restrictions and had no permit requirements for a number of land uses, such as new residences or restaurants (Figure 5.13). The Minister's Office was criticised for rezoning the area to CCZ with 'discretionary height limits' in place before the release of the strategic framework. This resulted in a windfall to landholders by as much as a 500 per cent increase in land value. For the local councils and the state to provide the infrastructure for the new communities, including sporting facilities, libraries, schools, public transport, parks and service upgrades, land will need to be purchased at current market rates estimated to be hundreds of millions of dollars.

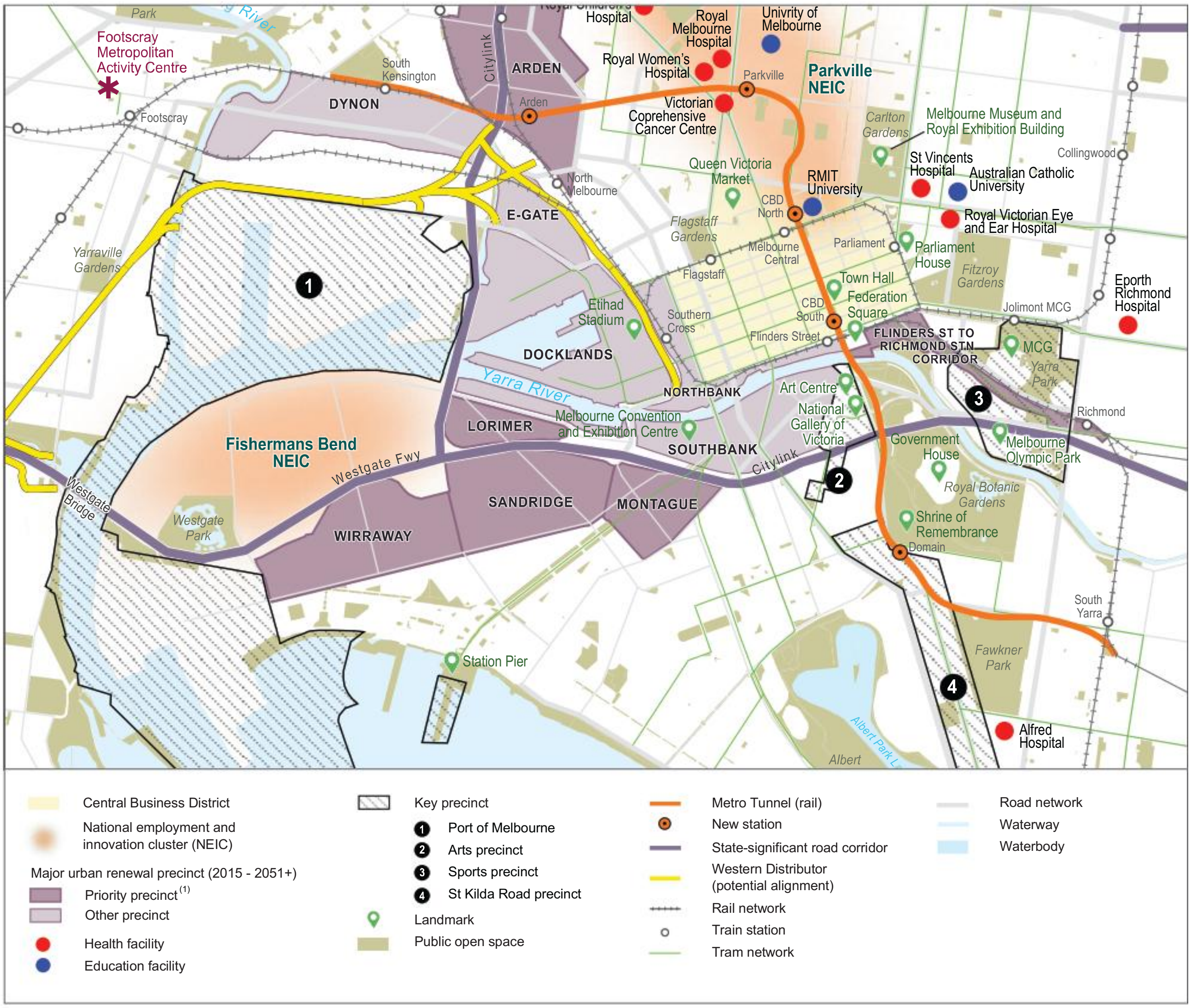
In 2013 the state government released the documents 'Fishermans Bend Draft Vision' and 'Interim Design Guidelines'. The documents outlined the plan for

▼ **Figure 5.11** The view of the FBURA precincts from the Eureka Skydeck with a colour coding overlaid



▼ **Figure 5.12** The precinct plan for the Fishermans Bend Urban Renewal Area (FBURA)

▼ **Figure 5.13** The Central City (Plan Melbourne 2017) for Melbourne 2050 Plan includes the urban renewal at Fishermans Bend



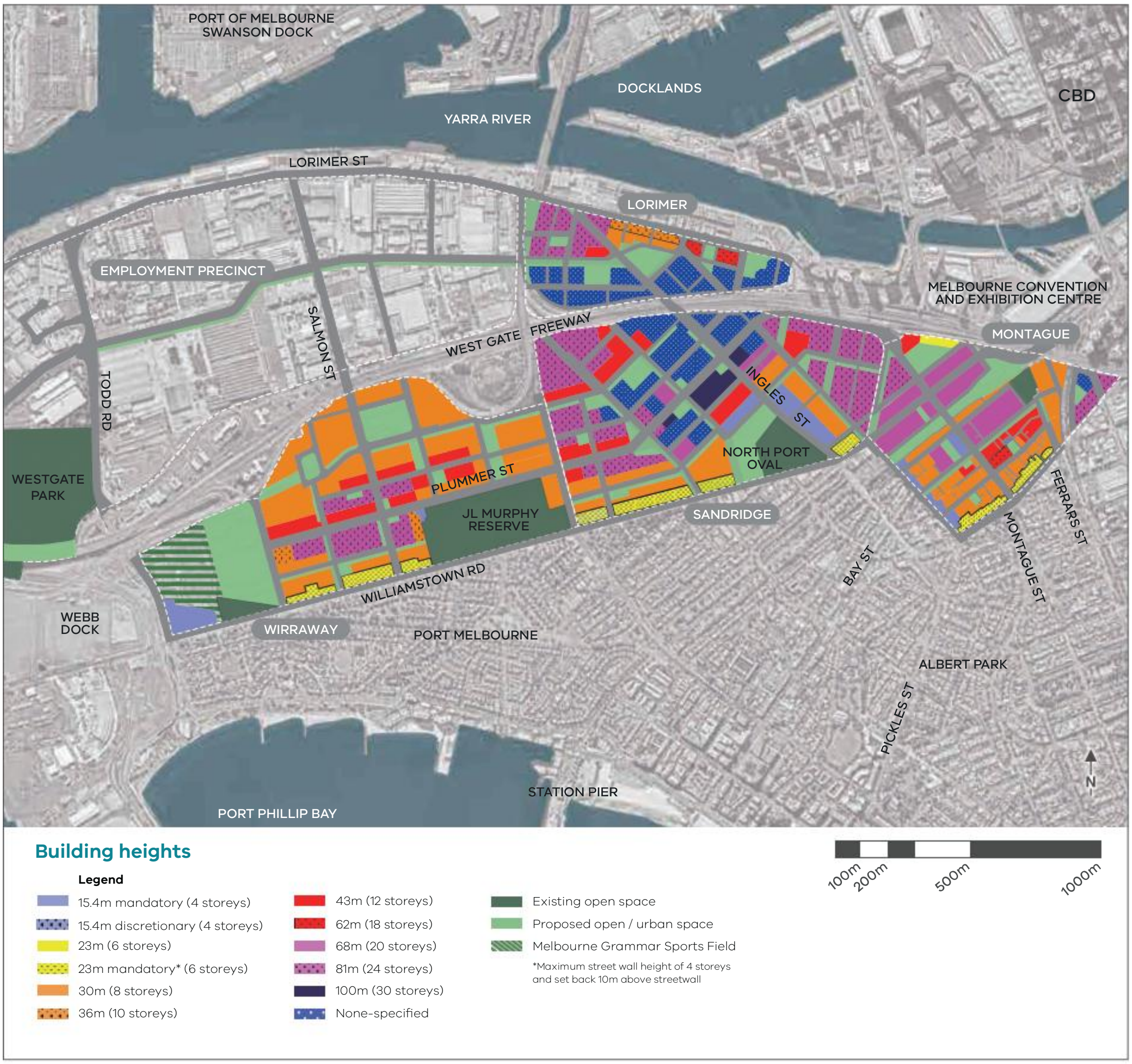
the urban renewal project, with the completion date set for 2050. In July 2014, the 'Fishermans Bend Strategic Framework Plan' was completed, using feedback from the community about the Draft Vision, as well as technical information gathered from many studies commissioned for the project. The agencies involved in the development of this plan included the cities of Port Phillip and Melbourne, Places Victoria, Metropolitan Planning Authority (MPA), and the Planning Minister's Office.

In October 2018, the Fishermans Bend Framework was released by the Andrew's Labor Government. This plan, structured around eight *sustainability* goals details building heights, dwelling ratios and diversity, social and affordable housing, transport and cycling plans, public open space and community infrastructure and requirements for 4- and 5-star Green ratings for all new buildings (Figure 5.14). The aim is to locate jobs, services and dwellings close to each other, resulting in social, *environmental* and economic benefits of a 20-minute neighbourhood. There is also a plan to provide activity centres, community infrastructure and open space within a 10-minute walk – providing a benchmark in improved liveability in Melbourne.

The land use planning for Fishermans Bend has run into physical obstacles. For instance, the significant soil and groundwater contamination resulting from the previous use of the land for noxious industries will require remediation before the land can be used for sensitive uses such as residential or education purposes. The presence of silt in the ground also makes constructing solid foundations for buildings an expensive challenge.

A centrepiece of the plan is a metro rail link that runs west to east through the area. This proposed 30-metre deep tunnel would have to be aligned so that it does not intersect with building foundation pilings or be bored deeper than a depth of 70 metres. The complexities of planning for large *scale* land use *change* over a short period of time are amplified by the regular *change* in state governments. The dramatic land use *changes* planned in the Fishermans Bend Area will play a significant role in managing Melbourne's future population growth.

▼ **Figure 5.14** The mix of building heights at FBURA range from four to thirty storeys which will provide a range of choices in housing size and style



The Fieldwork investigation

Conducting urban fieldwork research is different from research carried out in natural or rural *environments*. Generally, the urban *environment* is more populous, making interviews and observations more feasible. *Movement*, employment, investment, housing, urban design and neighbourhood character all play major roles in the lived experience of the people, and should inform the inquiry at different *scales* in order to identify *processes* that drive land use *change*.

Defining the topic and the research question

Select a research site and conduct background research before writing research questions. The research questions will build off the background readings the researcher gathers from available literature. Once the site is selected, topic is defined and research questions written, the hypothesis can be developed. The hypothesis is a proposed explanation for a phenomenon based on facts and written as a statement, which differs from a prediction that is purely an educated guess.

An example of a research question and hypotheses for an investigation into Fishermans Bend may include:

Research Questions	Hypotheses
What are the main *processes* driving land use *change* in Fishermans Bend?	The geographic *processes* that have had the greatest impact on the *changing* land uses in Fishermans Bend have been global demographic, economic and infrastructure related push-pull factors.
Which areas of Fishermans Bend will be most valuable lots to residents?	Residential developments in Fishermans Bend, public amenities and access to transport infrastructure will be the most valuable developments.
How will Melbourne's existing Capital City Zone be affected by the new precincts in Fishermans Bend?	The opening of Fishermans Bend will drop commercial lease rates in selected CBD areas and diminish real estate growth in similar precincts, such as Docklands and Arden.

Secondary sources of information

After establishing the research question and hypothesis, firstly look for relevant secondary data sources. Australian Bureau of Statistics (ABS), National Archives, council minutes, local planning provisions and interest group newsletters will help frame the questions and guide your primary data collection. Keeping notes and diagrams of *interconnected* relationships will also inform your writing about this data later.

Once a theme emerges, narrow the focus of inquiry and gather more secondary sources to support the theme. Historic photographs might be 'rephotographed' from the same site if you can identify the location, and this is a mixed secondary and primary source technique. This is a powerful method of showing land use *change* as well as *place*, *movement*, *processes* and *change* (as shown in Figure 5.10). Consider the validity of the data source and use academic and official sources as well as newspapers, newsletters and opinion pieces to form a broader view.

The use of secondary data can inform the primary data collection technique. For example, if you were investigating the effects of high-rise buildings on the local urban character, the map shown in Figure 5.14 indicates proposed height limits which provides an opportunity to conduct interviews with employees of local businesses about the impact high-rise buildings may have on them. Such interviews are primary data.

Primary sources and techniques used to collect data

The fieldwork techniques must be appropriate and justifiably linked to the research question. These generally are a combination of qualitative and quantitative techniques. The primary data collected for land use *change* includes face-to-face interviews, photographic evidence of *change*, mapping access points and transect mapping current land uses. Empirical observation of land uses, infrastructure and public amenities will help respond to the research question.

Personal communication with experts and government officials can also provide a rich source of information; it can be collected while in the field or at your desk. Researchers often seek expert opinions from key stakeholders at each step of the research *process*, especially during data collection. Interview questions must always be ethically designed and presented in ways that do not cause harm or discomfort to interviewees, and permission to interview must always be obtained first.

Generating spatial data sets using GNSS and remote sensing for the creation of GIS layers is necessary in fieldwork. In the field, researchers can use smartphone hardware along with applications to generate 3D scanned photogrammetry which can be used for augmented reality or a point cloud modelling which can yield valuable measurements in post-production (see Figure 5.15). Time-lapse footage from a remotely stationed smartphone is a form of terrestrial, or ground-based remote sensing, which can be used to quantify *movement* through the *environment* after the fieldwork.

Presenting the data

Collected data needs to carefully stored, organised and *processed*. Quantitative data should be entered into spreadsheets for graphing, whilst qualitative data needs to be transcribed, annotated and even colour coded for recurring themes. Imagery and maps should be presented as formally as possible, with captions and annotations.

During the data presentation, the quality of the maps, graphs and models contributes to a more coherent analysis later in the report. Using multiple sources of information and technologies to draw relationships between key features and patterns will enhance the quality of the work by making the research findings more reliable and authentic to the audience.

▲ **Figure 5.15** Photogrammetry as a remote sensing tool: A geo-referenced point cloud is generated from a brief video pan; the resulting 3D file is accurate enough to take measurements from on the computer. This file can be converted to use with AR goggles (Image created using KickTheMap app)

Analysing, concluding and evaluating

VCE Fieldwork reports are approximately 2000 words. The analysis and conclusion are designed to be thorough and thought-provoking. The data and captions directly address the hypothesis and primary research question. The analysis uses multiple geographical concepts to illustrate the point from all angles to educate the readers. For example, with the FBURA analysis it would be useful to discuss the successes the City of Port Phillip and City of Melbourne have had in addressing *sustainability* in their existing neighbourhoods. The current FBURA strategic plan addresses *sustainability* briefly but it does not discuss how the plans will address sea level rise or flooding events (as shown in Figure 5.16).

The conclusion addresses whether the data answered the research question and whether it confirmed or refuted the hypothesis.

The evaluation reflects on the quality of the data collected, challenges faced and resolutions to these challenges. Researchers reflect and evaluate how it could be improved if this research was to be done again.

ACTIVITIES

1. Collect historical imagery from recognisable locations in the Fishermans Bend Urban Renewal Area and re-take the images from a similar vantage point for comparison and analysis. Describe and explain the differences in land use you see.
2. Compare differences in the original FBURA Master Plan from 2014 to the current version. What differences are notable? How is *sustainability*, open space and amenity treated in each?
3. Map the current recreational activities that are logged on Strava in Fishermans Bend by viewing Strava Global Heat Maps data to identify running and cycling hotspots.
4. Write three questions regarding land use you could ask retailers or employees in the Lorimer District. Practice writing closed and open questions. What different data types would these responses be?
5. Use the profile.id website to view ABS statistics on the City of Port Phillip. What trends does the data show?
6. Go to the Eureka Skydeck to collect primary evidence of land use *change* taking place. Where are the cranes operating?
7. Download a photogrammetry application, such as KickTheMap, which processes the image remotely and emails it back to the user. Practice rendering a large building or urban area.
8. Write an opinion response to the statement 'If Melbourne becomes a 24-hour metropolis it will benefit the community by attracting more investment'.

▼ **Figure 5.16** Sea level rise inundation mapping showing the Lorimer and Montague precincts under a 1.1-metre flood

6 Land cover change: an overview

Geographers study land cover *change* for many reasons. A study of land cover *change may*:

- provide a global context for *changes* that can help explain local and *regional changes* in land cover and land use
- require an inventory of components such as water, vegetation and rural areas that forms a useful way of describing diverse and dynamic landscapes such as tropical rainforests, grasslands and wetlands
- monitor vegetation cover and subsequently key *environmental* issues such as carbon emissions, and the extent and quality of native species habitat
- enable the identification of areas under pressure in *places* where there are problems such as water shortages and fire dangers. As a result this helps develop strategies to deal with these issues in a *sustainable* way
- help avoid uncontrolled development involving the loss of agricultural land, and destruction of wetlands and forests that lead to deteriorating *environmental* quality and productivity of *regions*
- evaluate the impact of climate *change* on existing and future land cover.

▼ **Figure 6.1** There can be a variety of land cover in a small area

Defining land cover

There are various definitions of land cover. Most have been developed by government authorities in different countries for a range of purposes, such as planning new developments or protecting valued *environments*. A widely accepted definition of land cover comes from the United Nations Food and Agricultural Organization (FAO). It defines it broadly as: 'the observed biophysical cover on the Earth's surface'.

This definition includes what exists on land surfaces – the natural biophysical features of vegetation, water, ice and even bare rock and soil, together with additions made by human activity such as agriculture and urban and industrial landscapes. In reality, land cover can be very complex, even in a small area. Figure 6.1 shows how a variety of land cover can exist in a relatively small area: natural vegetation together with farmed land and even bare rock.

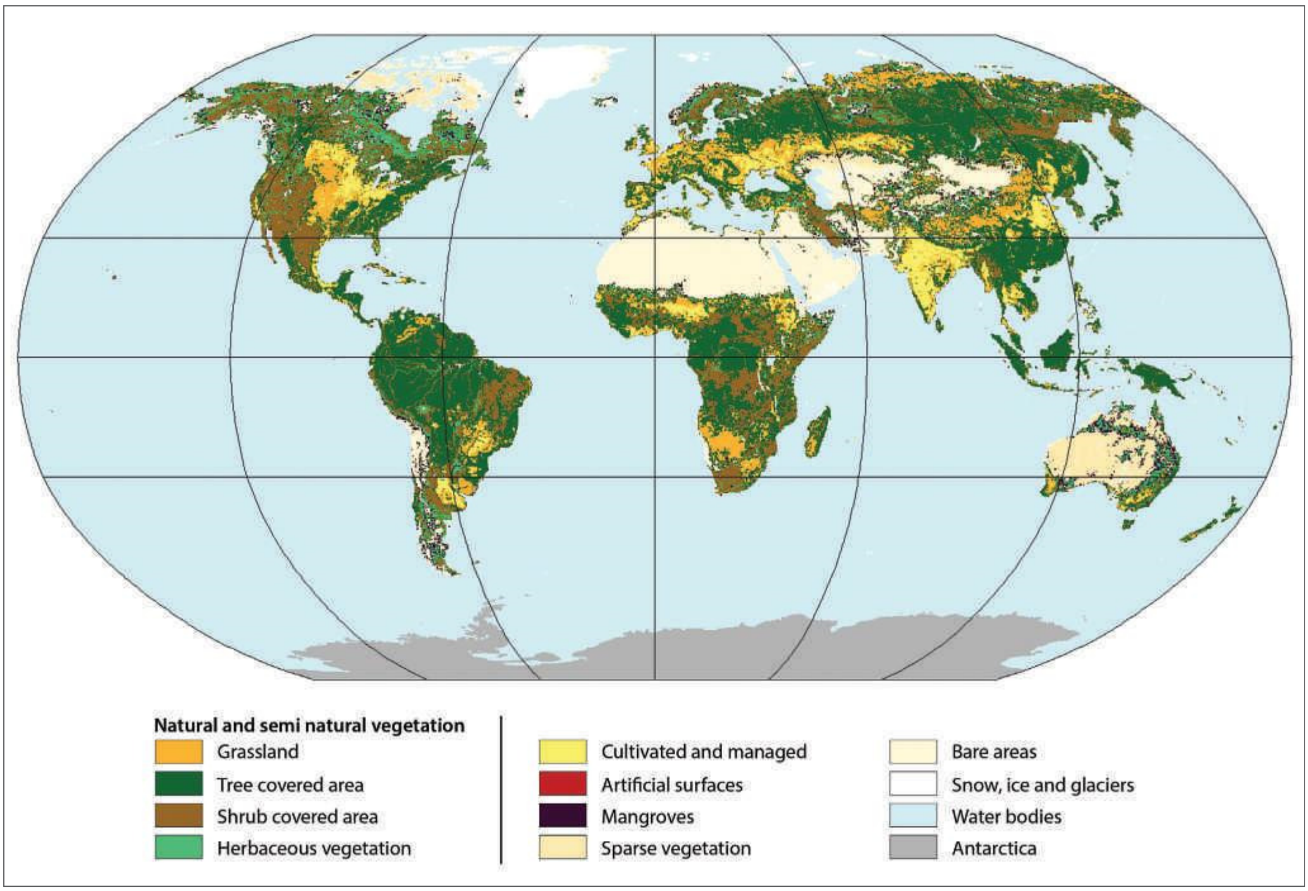
Some academics believe land cover should be defined to include only vegetation and features made by people. Bare rock and bare soil, it could be argued, are not cover but the land itself. Similarly, water and ice surfaces may be seen in that way – not strictly as land cover. However, bare rock and soil together with water and ice surfaces are incorporated in most accounts of land cover in part because of the pervasive influence of human activity even in apparently natural landscapes.

Land cover and land use

There is a strong *interconnection* between land cover and land use. The definitions of these terms overlap to an extent, but there are important differences. Land use is about the use people make of the Earth's varied surfaces. Land cover is often disturbed by human activity and our land uses are often influenced by the availability of particular soils, climate, minerals, vegetation and wildlife that form exploitable natural resources from the land cover. FAO puts it this way: 'land use is characterised by the arrangements, activities and inputs people undertake in a certain land cover type to produce, *change* or maintain it'.

The overlap between definitions can be understood through some examples:

- Grasslands can be considered as a land cover. If human activity on the grasslands is cattle grazing, this is considered as land use.
- Forests can be considered as land cover. Further investigation could show the forests are selectively logged or used for recreational walking or riding. These activities would result in the forest being classified as a particular type of land use.
- A natural lake is land cover but when its use for water sports or for irrigation is discussed, it is also land use.



▲ **Figure 6.2** *Distribution* of dominant land covers (modified from FAO data)

▲ **Figure 6.3** A small-*scale* farming area in southern India

▲ **Figure 6.4** Natural vegetation of coastal northern Queensland

▲ **Figure 6.5** Land cultivated for wet rice in Myanmar

Spatial *distribution* of land cover

FAO's world map of land cover (see Figure 6.2) shows a number of broad categories. At this small map *scale*, small *regional* and local variations in land cover have been absorbed into the broader categories. It is difficult to distinguish small areas such as built-up areas of towns and cities (shown as artificial surfaces) or the vegetation category of mangroves at a global *scale*.

FAO divided land cover into eight broad categories. These categories are further divided according to variations such as intensity (for example, the amount of vegetation cover), vegetation variety (for example, trees or grasslands) and seasonality (for example, regularity of flooding). The following land cover categories include an outline of their main characteristics.

1. Cultivated and managed

For land cover to be categorised as 'cultivated and managed', people must have removed the natural vegetation and replaced it with another type of vegetation. Further human activity is needed to *sustain* this land cover. For example, the land cover in Figure 6.3 is cultivated and managed farmland. At some stage in the past, the lowland has been cleared of trees and scrub. People have planted food crops for their own use. The land needs frequent inputs of human effort, materials and skill to maintain its productive capacity.

Cultivated and managed land cover includes a wide range of land uses such as market gardens, wheat farms and oil palm plantations.

2. Natural and semi-natural vegetation

This form of land cover is made up of both natural vegetation and semi-natural vegetation. Natural vegetation is developed as a result of the *interconnection* between climate, soils, hydrology, landforms, and animal and plant life. In Figure 6.4 the natural vegetation has developed over time in a hot and mostly wet climate, and on fairly fertile alluvial soils that were washed down from mountainous areas. The plants occupying the area now have developed after ongoing competition with other plants for light, space and nutrients.

Semi-natural vegetation is influenced by human activity. Examples include grazing on natural grassland and forests that have been selectively logged. This category also includes vegetation that has grown back after the original vegetation has been cleared, for example secondary forest. You can identify some secondary vegetation in Figure 6.1.

In Figure 6.2 this category of land cover is represented by grassland, shrub-covered areas and herbaceous vegetation.

3. Cultivated aquatic or regularly flooded areas

This land cover is predominantly an aquatic crop, purposely planted, cultivated and harvested. Areas that have been developed for irrigation and require continuous watering in their growing period fall into this category. Extensive areas of wet rice cultivation in

South, South-East and North-East Asia have this type of land cover. Part of the Irrawaddy River Delta of Myanmar is shown in Figure 6.5. Perhaps none of the natural vegetation remains. The *region* has an abundance of water, and gently sloping land covered with alluvial soils built up from seasonal flooding. Temperatures are high all year round. These inputs, together with human labour and skill, have made the *region* a major producer of rice.

Some areas of the world may be regularly flooded, perhaps after heavy rain or as a result of a wet season. The Channel Country of western Queensland is seasonally flooded as a result of summer monsoons and cyclonic rains, but remains largely uncultivated because it is remote, with low fertility soils and short growing seasons.

In Figure 6.2 this category is shown by cultivated and managed, but it is not distinguished from category 1. The large areas of cropland in Asia shown in this figure are mostly wet rice areas and therefore belong to this category of land cover.

4. Natural and semi-natural aquatic land cover or regularly flooded vegetated areas

In this category of land cover, there is a very strong *interconnection* between vegetation and water. Vegetation has adapted to water that is either close to or on the surface of the land. Coastal wetlands supporting mangroves (as in Figure 6.6) and salt marshes are examples. Mangroves grow in sheltered estuaries and bays, lagoons and on tidal mud flats. India's Sundarbans *region* is covered by a large mangrove forest. Wetlands regularly or permanently inundated with fresh water also fit this category. Victoria's Barmah National Park adjoining the Murray River is a wetland forest *environment* fitting into this category.

Land cover in this category is often protected by human activity because of its unique and important habitat for plants and other life forms. The Ramsar Convention on Wetlands is an international agreement aimed at safeguarding the world's wetlands. Australia has 66 wetlands covering 83,421 square kilometres (an area 20 per cent larger than Tasmania) listed under Ramsar.

In Figure 6.2 the *distribution* of this category is not distinguishable because of its small map *scale*.

5. Artificial surfaces and associated areas

Most of us spend a considerable part of our lives using this category of land cover. The natural cover that once covered areas like those shown in Figure 6.7 has been replaced with a variety of constructed surfaces. Apart from buildings, this category also includes transport networks of roads, railways, airports and water port facilities. Waste dumps from urban areas, factories and mines also form part of this category of land cover.

6. Bare areas

Areas with less than 4 per cent vegetation cover are considered by FAO to have a bare land cover. Examples would include hot deserts such as the Simpson Desert in Australia and the Sahara in North Africa (see Figure 6.8), and the climatically cooler deserts of the Atacama *region* in South America and the Gobi of northern Asia. Other bare areas include saltpans, coastlines of bare rock and sand.

▲ **Figure 6.6** Mangroves on the east coast of New Caledonia

▲ **Figure 6.7** Urban areas such as Shanghai are part of the artificial surfaces category

▲ **Figure 6.8** The Hoggar Mountains of Algeria are part of the Sahara Desert

▲ **Figure 6.9** Lake Nasser in Egypt and northern Sudan is an artificial water body

▲ **Figure 6.10** An Antarctic landscape of ice and snow

7. Artificial water bodies, snow and ice

Dams on rivers form reservoirs of water or artificial bodies of water that serve urban, industrial or rural needs. Natural lakes may also be dammed to regulate outflows and thereby expand their surface areas. On a world map such as Figure 6.2 this land cover may appear very insignificant. At local and *regional scales* they can be very important parts of a landscape. Lake Nasser (see Figure 6.9), formed from damming the Nile River at Aswan in Egypt, stretches approximately 550 kilometres in length – about the *distance* from Melbourne to Canberra.

There are two other additions to this category: canals with water, and where snow and ice is manufactured to form or extend the seasonal life of snowfields.

8. Natural water bodies, snow and ice

This very wide-ranging land cover category has developed in response to particular characteristics of the Earth's natural *environments*. Where large volumes of water have accumulated, natural water bodies are formed. Lakes such as the Caspian Sea (Central West Asia) and Lake Victoria (East Africa) as well as the Earth's oceans fit this category. In addition, this land cover category includes areas where the climate is cold enough for land covers of snow, glaciers, ice caps and ice sheets to exist. Extensive areas of Antarctica (see Figure 6.10), Greenland and northern North America are locations for this category. The *changes* in the spatial *distribution* of this land cover is further investigated in Chapter 7.

▶ ACTIVITIES

1. Separate the following features into either land cover or land use. Compare your lists with the lists of at least one other person and be prepared to justify your decisions.

tropical rainforest	waste dump	plantation of oil palm
glacier	housing estate	sea grasses
wet rice farm	mangroves	beach resort

2. a. Refer to Figure 6.3. Identify two (2) inputs of human effort and skill required to manage the land cover.

b. Use Figure 6.2 to name a *region* of a country where this land cover category is present in each of the following continents: Europe, Australia and North America.

3. a. Use Figure 6.2 to decide if the proportion of the Earth's land cover of natural and semi-natural vegetation is approximately 20, 40, 60 or 80 per cent of the area shown.

b. How different is Australia's proportion to that of one other continent?

4. With the aid of an atlas map and Figure 6.2, name three specific areas of Asia that would have a land cover of 'cultivated aquatic or regularly flooded'.

5. Research the way mangroves manage to survive when they are regularly flooded with salty water from incoming tides.

6. Research a specific Ramsar site to determine its *environmental* value and therefore the justification for its protection. Is the *sustainability* of this site threatened in any way?

7. Where are Australia's most extensive artificial surfaces?

8. If a waste dump is revegetated by a local authority, in which category of land cover would you place it?

9. a. Outline the *environmental* conditions contributing to or creating a bare land cover, such as that in Figure 6.8.

b. Name three specific locations in Australia that would fit into this category of land cover.

c. Refer to Figure 6.2. Which *regions* of the world have significant areas of this type of land cover?

d. Compare the *distribution* of this land cover within Australia to that of Africa.

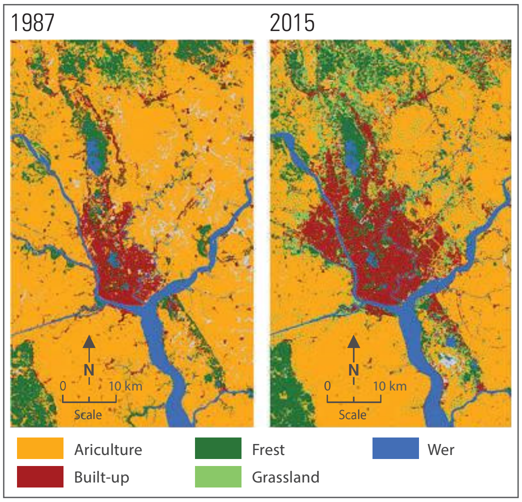
10. Identify at least one location in Victoria that is an example of an artificial water body.

11. a. When, and why, would you find an example of an artificial area of snow in Victoria?

b. Compare the *distribution* pattern of this land cover between the northern and southern hemispheres.

▶ CASE STUDY Yangon, Myanmar

Figure 6.11 shows the *changes* in land cover in the *region* of Myanmar's main city of Yangon. In a very short period, the urban area (described as built-up on the map legend) has rapidly expanded at the expense of other land covers. Such *changes* occur in many *places*.



▲ **Figure 6.11** Land cover, Yangon *region*, Myanmar

▶ ACTIVITIES

1. What is the predominant land use in the *region* for the periods shown on Figure 6.11? Into which of the eight broad land cover categories outlined previously would you place this land use? What additional information, not shown on the map, would you need to confirm your categories?
2. What level of *spatial association* exists between the rivers and the built-up areas in 1987? Does your conclusion still hold for the 2015 situation? Can you locate another example of *spatial association* on the map areas?
3. In which directions have the built-up areas expanded? Which land cover has lost area as a result?
4. Apart from built up areas, what other cover has expanded in area?
5. Expansion of the built-up areas has been limited in the *region* southwest of the main built-up area. What geographical data could you use to determine the reasons for this?

Land cover *changes*

The Earth's land cover has *changed* significantly over many hundreds of thousands of years and for many millions of years before that. Some *changes* have been developing over centuries while others have occurred within a few decades or less. The causes of these *changes* are varied and include ones due to natural *processes* as well as human activity.

Natural *processes changing* land cover

Natural *processes changing* land cover include: (a) climate *change*, (b) geophysical *changes*, (c) plant succession and (d) fires and pests.

a. Climate *change*

Figure 6.12 summarises the Earth's land cover 18,000 years ago. This is a recent time in the Earth's history. Some 10,000 to 15,000 years prior to this time the Earth was experiencing a major ice age. Average annual global surface temperatures fell while snow and ice accumulated to produce enormous ice sheets that covered large areas of North America, Asia and Europe. The drier and cooler conditions saw an expansion of desert and semi-desert conditions in most continental areas. Forest areas shrank.

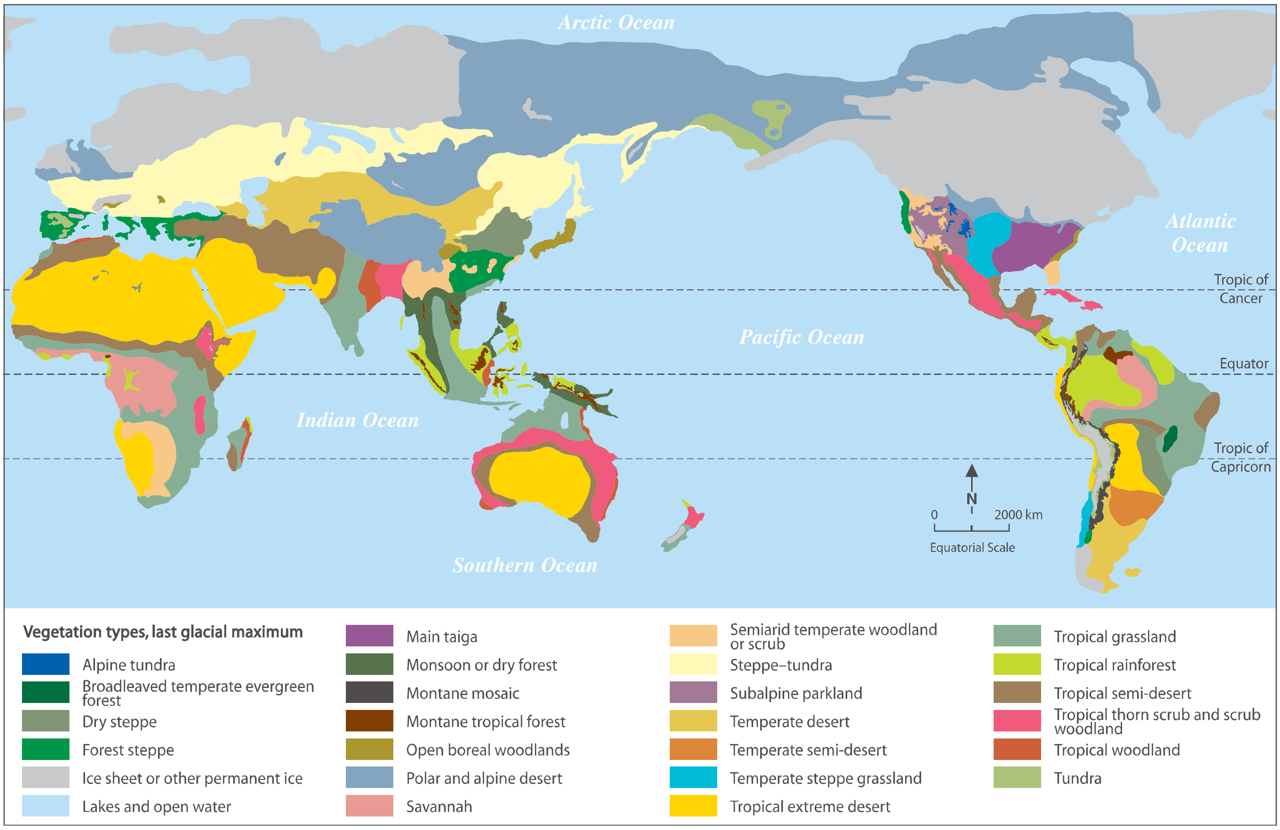
People had already long been living on the Australian continent 30,000 years ago. Its *environment* was greener than today, its lakes fuller and, in the south-east, snow and ice covered the mountains. As the climate cooled and dried during increasing glaciation, forests became more open and grasslands more widespread. The human impact of burning vegetation as a way to hunt animals and produce new vegetation growth to attract animals also contributed to these land cover *changes* in vegetation.

The last of the Earth's many glacial periods – the Last Glacial Maximum – peaked between 17,000 and 21,000 years ago. Global annual average surface temperatures were approximately 6°C cooler than today, although *regional* variation was substantial. Much more of the Earth's liquid water was held as solids, and seawater contracts more at colder temperatures, so that sea levels were up to 125 metres lower than at present. Land bridges between landmasses (can you find them in Figure 6.12?) enabled migration of people into North America from Asia. This period saw Australian desert and semi-desert areas expand as rainfall decreased.

Around 15,000 years ago the Earth began to experience a prolonged warmer and wetter period. This climate *change* produced major *changes* to the Earth's land cover. Ice melted and retreated, and sea levels rose as a result. Forests and grasslands spread. As soils thawed and deepened, and rainfall increased, agriculture involving the clearing of the natural vegetation cover was expanded in west Asia, Europe and the Americas.

Rising sea levels caused Bass Strait to separate Tasmania from the mainland and Torres Strait to separate New Guinea from northern Australia. Gradually, forests and other lush vegetation expanded in the better watered areas of northern, eastern and south-eastern Australia. The ability of ecosystems to adapt to *changes* in climate ensured the survival of many plant and animal species over the following millennia both in Australia and elsewhere in the world.

▼ **Figure 6.12** Land cover about 18,000 BP



Future *changes* in climate appear to be closely *interconnected* to human activities. People are influencing the world's climate through many activities including widespread deforestation as well as the extensive burning of fossil fuels and the subsequent release of greenhouse gases into the Earth's atmosphere. Average annual surface temperatures in the 20th Century rose by around 0.6°C and may rise by another 0.9°C by the end of this century. The warmer temperatures are having a negative impact on the *distribution* of the world's ice and snow cover. In turn these *processes* are altering the temperature of the Earth's oceans and the pattern of *movement* of its currents. *Changes* in climate result in major land cover influences in different *regions*. This includes longer fire seasons, more severe storms, longer drought periods or wetter ones. Climate *changes* also impact the human ability to utilise the *environment* for land use.

Farming areas such as the one in Figure 6.13 will need to adapt to *changes* in climate with *changes* in cropping and intensity of animal grazing. In the last four decades Australia's grain growing areas have tended to locate further south, avoiding the increasingly erratic weather to the north. Desertification involves prolonged loss of productivity and biodiversity, and including the increasingly severe drought conditions of subhumid areas that mostly adjoin the Earth's existing deserts, it could eventually produce several billion climate refugees as the *environment changes*. The United Nations Development Programme estimated two billion of the world's population are at risk from desertification.

▲ **Figure 6.13** A warmer and drier climate in the future will threaten the viability of many farming areas

b. Geophysical *changes*

Land cover *changes* can be brought about by geophysical *changes* such as volcanic activity, earthquakes and landslides. Over millions of years the *distribution* of the Earth's landmasses has slowly *changed* due to tectonic plate *movements*. These rates of *movement* average only a few centimetres a year – about the rate your fingernails can grow each year. Plate *movement* is therefore unlikely to have immediate impacts on existing land cover. Over many thousands of years, vegetation was able to adjust to the climates of different latitudes. These adjustments were in combination with other powerful *processes*: climate *change* (see a. Climate *change*) and the development of plant colonies (see c. Plant succession).

Volcanic activity produces outflows of lava, ash and rock that can smother existing land cover in the areas immediately around eruption points. Vegetated cover can *change* bare surfaces, as in Figure 6.14, once the new surfaces are sufficiently weathered and fertile enough to support new vegetation. Ash deposits combined with rainfall can generate lahars (or mudflows) which can extend beyond eruption zones burying vegetation, cultivated land and artificial surfaces such as roads and villages.

Powerful earthquakes can impact on areas as extensive as 100,000 square kilometres, consequently affecting land cover in either major or minor ways. Over time, earthquakes can elevate or depress landmasses and help form steep slopes. A steeper land surface may result in surfaces unable to support more than sparse vegetation and limit its agricultural or residential potential. In the short term, a major earth *movement* can alter the directional flow of a river. An alteration of drainage patterns can either deprive vegetation of regular or seasonal water supplies or benefit areas otherwise suffering from water shortages.

Bangladesh's Brahmaputra River *changed* course approximately 200 years ago as a result of a major earthquake. The river now flows further westward depriving a major *region* of silt deposits during flood periods. The river's course could *change* again with another major fault *movement*. Some fault *movements* operate much more slowly, such as that which gradually altered the course of the Murray River along the Cadell fault block.

c. Plant succession

Vegetation can adapt to *changing* climate and ground conditions. It also responds to the *interconnection* between specific plants. Plants need water, nutrients, light and space. Some survive and even thrive because of the presence of other plants. Succession involves the colonisation of an area – perhaps weathered volcanic ash, an area burnt out by fire, or sand dunes (see Figure 6.15). The first, or pioneer, plants are eventually replaced by secondary plant species that use the soil, moisture and shade conditions created by the pioneer plants. Over time, further succession occurs with new plants taking over from the secondary species. These secondary species are usually larger and more diverse than the pioneer plants. In this way land cover *changes* from bare cover to vegetated cover. In Figure 6.15 the hardy grasses are the pioneer plants colonising the bare ground. Evolution can also cause variation in vegetation and the animals it supports; generally, much more slowly than succession.

d. Fires and pests

Fires started by lightning storms have had an impact on much of the Earth's land cover. In Australia and elsewhere much of the vegetated land cover had already evolved before human occupation to accommodate the effects of fire. Fires helped prevent large areas of trees growing and consequently promoted the development of fire-dependent grasslands and open woodlands. Today, human activity aims to control or eliminate fires. The 2019–20 fires of southeast Australia largely burned out of control destroying the land cover of 18 million hectares of forest, scrub, farmland and built facilities (Figure 6.16). In some cases, people may burn an area to simulate the natural conditions. This removes ground litter of leaves and branches ('fuel reduction'), encourages seeds to germinate and promotes new growth of plants. These *processes* produce both issues and challenges for a range of people including farmers and conservationists, in areas vulnerable to fires.

▲ **Figure 6.14** Ash erupting from Mount Bromo in east Java can cover extensive areas

▲ **Figure 6.15** Grasses recently colonising coastal dunes on New Zealand's North Island. As in most *places* around the world, the beach and sea level here formed approximately 5000 years ago after the Earth's climate stabilised following 10,000 years of post-glacial warming

▲ **Figure 6.16** Taken on January 4 2020, this satellite image shows the fires and smoke engulfing southeastern Australia

The Earth's millions of species of insects, and thousands of plant diseases, all have an impact on land covers. For example, locust swarms, often involving billions of locusts and covering hundreds of square kilometres, have developed in Africa, Asia, Australia and North America. They are able to consume all leaf and grass vegetation wherever they settle. As a result, the ground can become open to winds and soil erosion, reducing any chance of a return to fuller vegetation cover.

ACTIVITIES

1. Apart from climate *change*, what other factors could account for the increasing desertification of *regions* of the Earth?
2. Summarise the differences in land cover in Australia 30,000 years ago and 18,000 years ago. Discuss how important human activities could have been in *changing* Australia's land cover.
3. Suggest why volcanic activity affected large areas of Victoria's land cover in the relatively recent geological past. Refine your answer by adding reference to relevant locations in western Victoria together with a time *scale* of events.
4. Explain two *environmental* conditions that would make it difficult for the vegetation in Figures 6.14 and 6.15 to thrive.
5. The *region* in Figure 6.13 has been, and is likely to continue, experiencing longer dry periods and hotter summers than in previous decades. How might farmers have to adapt their cultivated and managed land cover to this situation?
6. What *interconnection* do you see between the severity of recent fires in Australia and climate *change*? Discuss the implications of this phenomena for land cover *change* in one *region* of southeast Australia.

Human activity *changing* land cover

Processes, like the ones described in the previous pages, frequently act together with human activity to generate land cover *change*. Several broad areas of human activity can be identified: population dynamics, technology and policies.

a. Population dynamics

The rapid growth of the world's population in the last 300 years has put considerable pressure on land surfaces to become areas of housing, production and, more recently, recreation. Extensive areas of land have been cleared of natural vegetation for cropping and grazing. Because of the *movement* of people from rural to urban areas, between 50 and 55 per cent of the world's population is now living in towns and cities. The space for many of these people has been found at the edge of existing urban areas and often at the expense of cultivated land or natural vegetation. Figure 6.17 is on the south-west fringe of Melbourne's urban area where a land cover of extensively-grazed grassland is being *changed* to artificial surfaces of housing estates.

▲ **Figure 6.17** Urban expansion has meant a *change* in land cover from cultivated and managed land to artificial surfaces

b. Technology

Technology plays a major role in *changing* land cover. It is the means that allows *change* to an *environment* to occur rapidly and at a large *scale*. It can be transferred into areas where it was lacking. It impacts in numerous ways. The building of dams and water diversion schemes is a major example, as Figures 6.18 and 6.19 show. In turn, water application schemes can produce issues related to the diversion of rivers and the flooding of land. *Environmental* challenges such as how to adjust to the *changed* water availability and the loss of natural habitat may be associated with these issues. Technologies that produced toxic or non-biodegradable substances can harm vegetation, wildlife and people.

▼ **Figure 6.18** Some major dam and water diversion schemes

Location	Date	Land cover *change*
Snowy River, Australia	1949–1974	Diversion of Snowy River water into the Murray and Murrumbidgee rivers allowed the expansion of irrigation areas on grazing land in south-east Australia.
Nile River, Egypt	1960s	Damming of the river's floodwaters enabled conversion of 385,000 hectares of desert into farmland (see Figure 6.19).
Euphrates River, Turkey	1970s	Allowed expansion of irrigation areas into previously sparsely grazed areas. Less irrigation water was available for Syria, which led to a reduction of cropping.
Chang River, China	2000–2050	Diversion of 45 billion cubic metres of water a year from south to north China, via three routes, allowed expansion of urban centres and dry season irrigation.

▲ **Figure 6.19** In Egypt's Western Desert at a local *scale*, irrigation water has made possible a land cover conversion from bare areas to cultivated and managed cover

Technology has further applications that can affect land cover:

- machinery and associated infrastructure can clear large areas of forest (see Chapter 8)
- mineral-deficient soils can be made suitable for cropping with the use of trace elements
- hybrid and genetically modified plants can be developed to withstand more hostile *environments* that until recently could not be farmed.

c. Policies

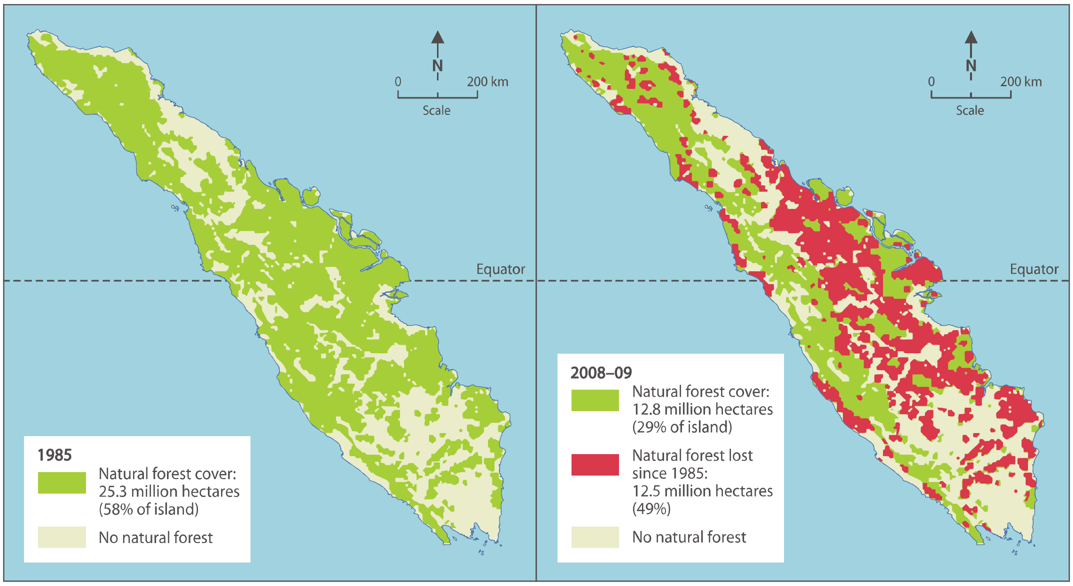
The policies of governments play a key role in land cover *change*. This includes their economic policy such as influencing market prices for domestically produced goods as well as imports and exports and wage and tax level determination. For example, selective logging or clear-felling for commercial timber and clearance of forests for new farming land is often promoted by governments through tax incentives (as a source of revenue, employment and food production), companies (mainly for profits and raw materials) and local landowners (mainly for revenue). Figure 6.20 shows the results of government policy in Sumatra, Indonesia. Even where there have been restrictions on forest clearances, enforcement of the restrictions has often been absent or ineffective. As a result, much of Sumatra's land cover has *changed* from natural vegetation to bare or cultivated land. Technology and the availability of potential markets for goods have allowed this *change* to occur very rapidly.

Chapter 8 examines the role of government policies in forest clearances in some other parts of the world.

Policies can also protect existing land cover. Zoning of land to maintain natural conditions as a wilderness area, marine park or nature park can occur. Australia's iconic national parks of Kakadu, the Great Barrier Reef, Daintree and Wilsons Promontory are zoned for this reason.

In other situations, policies may aim to restore the land cover by eliminating invasive species of animals (for example, feral pigs, buffaloes and cane toads in Kakadu National Park) and plants (for example, blackberries or ragwort from Victoria's coastal parks). In addition, the restoration of water supplies can occur. *Environmental* allocations of water have been made to wetlands such as the Barmah National Park in northern Victoria and the Macquarie Marshes in northern New South Wales to maintain their unique vegetation and *environments*.

▼ **Figure 6.20** Sumatra's *changing* land cover, 1985–2009



ACTIVITIES

1. Name three urban areas of Melbourne or a large Victorian town that have been developed, or are being developed, on former farmland. An atlas or an internet search could help here.
2. For each of the water schemes outlined in Figure 6.18, decide on the *change* in land cover that has taken place or will take place.
3. Refer to Figure 6.20.
   a. Describe the *change* over time of Sumatra's forest land cover from 1985 to 2009. Include estimates of the proportions of Sumatra's natural forest in your answer.
   b. Use an atlas map or Google Maps to discover the relief (topography) characteristics of the main areas cleared of forest. How strong is the *spatial association* between the areas of forest remaining and the type of landscape it covers?
4. What evidence does Figure 6.19 suggest that the original land cover was sandy desert? Justify the broad land cover category you now give this area.

7 Land cover change: melting glaciers and ice sheets

There has been considerable interest and debate about *changes* in the amount of land covered by ice and how the increasing warming of our climate might contribute to this. As well as other scientists, geographers have accumulated data from a range of locations around the globe in an attempt to accurately map these ice cover *changes*, calculate the rates of these *changes* and ultimately predict what these *regions* might look like in the future. Glaciers are regarded as significant climate *change* indicators. The results of these ice-cover predictions have given the global community great cause for concern as many of the impacts will have mainly detrimental effects on people and *environments*. Figure 7.1 shows an image of a plaque in Iceland unveiled in August 2019 to recognise the loss of the Okjokull Glacier and a landscape once covered in ice. This plaque is the first monument of its type to be built and it acknowledges the perilous state of many glaciers on our planet.

▲ **Figure 7.1** Plaque placed to commemorate the loss of Okjokull Glacier

Ice in the cryosphere covers about 20 per cent of the Earth's surface and can fall into six main categories:

- sea ice
- land covered by glaciers
- land covered by ice sheets, including ice shelves
- land such as tundra covered by snow every winter
- land underlain by permafrost
- peri-glacial zones on the margins of ice-bound land.

Of these features, sea ice and peri-glacial zones are subject to most seasonal *change* in ice volume and area with winter advance and summer retreat. Glaciers, ice sheets, and permafrost involve significantly larger volumes of ice and are subject to less seasonal variation, but do vary over time with long-term climate *change*. Globally, an average annual reduction of 87,000 square kilometres of ice occurred between 1979 and 2016.

▶ **Figure 7.2** Aletsch Glacier in Switzerland, the largest glacier in the Alps

▼ **Figure 7.3** The Terminus of Fox Glacier in New Zealand

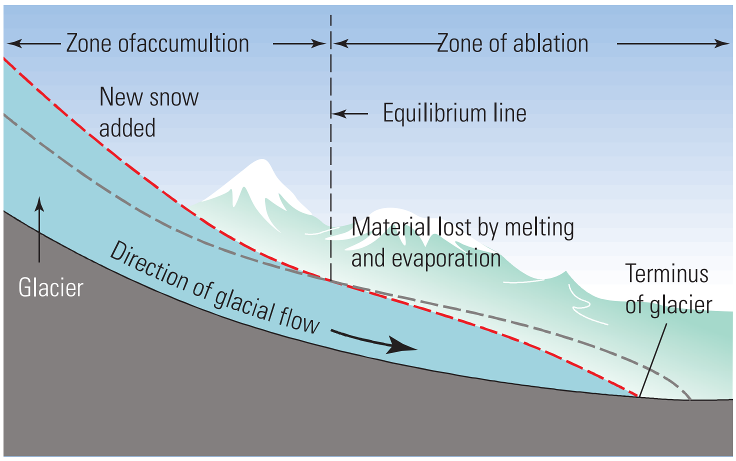
For the purpose of this chapter, only glaciers and ice sheets will be discussed.

A glacier can best be defined as a body of ice formed on land and in motion, confined by terrain, most commonly valleys. There are various types of glaciers but, as seen in Figure 7.2, many glaciers are located in alpine areas where ice can accumulate from many centuries of heavy snowfalls.

Ice and snow accumulates and flows downhill under its own weight and gravity (similar to rivers) to a point called the terminus where ice has melted. Meltwater flows from this point. The terminus of the Fox Glacier in New Zealand can be seen clearly in Figure 7.3.

At a point along the glacier flow, the ice starts melting instead of accumulating and the colour of ice *changes* from bright white to a grey colour. The *process* of melting ice on a glacier is called ablation. Figure 7.4 shows a simple outline of the structure of a glacier. Glacier expanse and volume expands and contracts seasonally and complex measurements taken at various times across the year are used to assess glacier *change*. The mass balance between ice gained versus ice lost over a year allows scientists to work out whether a glacier is advancing or retreating. It is estimated that scientists are currently monitoring the mass balances of 450 glacier's globally. Water equivalent (w.e.) units are generally used to report a glaciers mass balance so that comparisons can be made between different glaciers and different years. Water equivalent (w.e.) represents the volume of water that would be obtained from melting the snow or ice that has been added or lost.

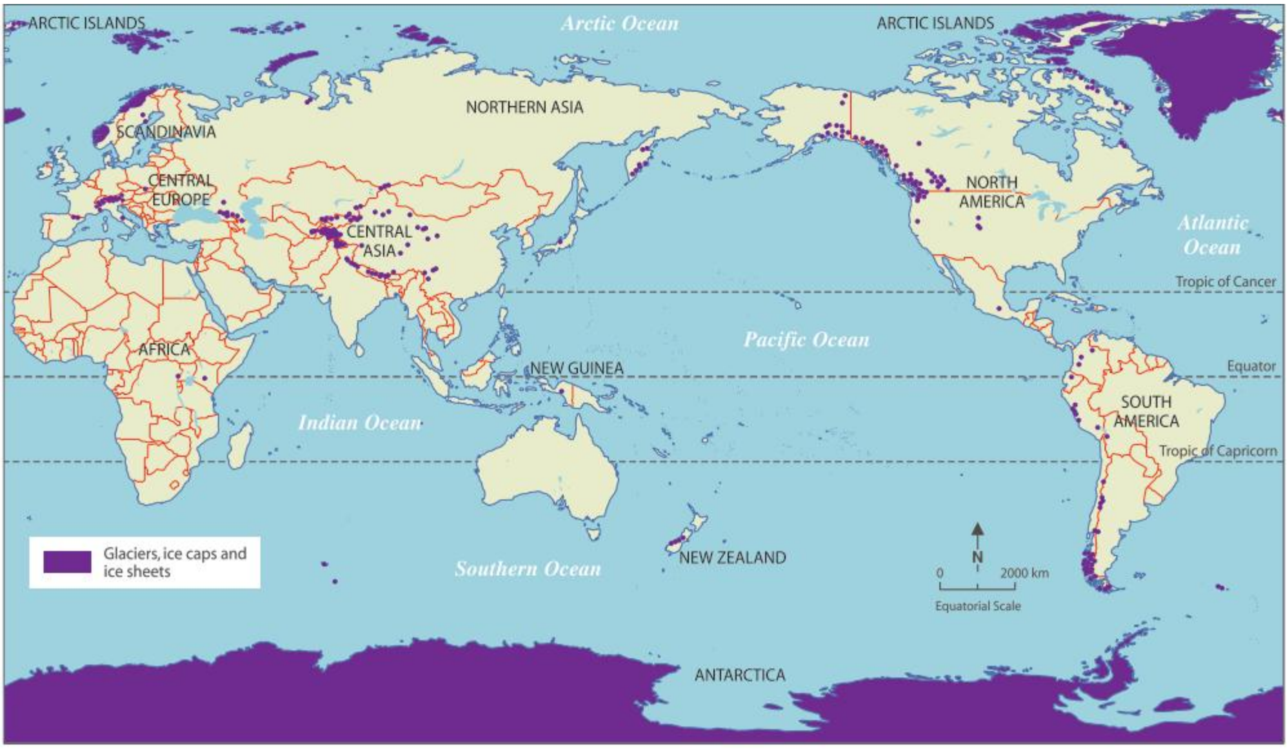
Ice sheets are vast masses of ice that bury tracts of land beneath them and which are not confined to valleys. These sheets of ice are usually domed in shape. They are sometimes referred to as continental glaciers.



▲ **Figure 7.4** Structure of a glacier showing where ice is typically accumulated and lost

The two most significant examples of this type of landform are found in Antarctica and Greenland. Ice sheets typically form in high-latitude *regions* that are characteristically very cold and subject to long harsh winters, short summers and very little intense solar radiation. Ice sheets can move like glaciers radially downwards from the top of the dome. Ice sheets have been present on Earth for millions of years (at least 40 million years in Antarctica) and were last at their peak between 21,000 and 18,000 years ago, at the peak of the last glacial period (Last Glacial Maximum). The Antarctic and Greenland ice sheets contain 99 per cent of the world's freshwater ice, and the Antarctic ice sheet is over four kilometres thick in *places*.

Currently, about 10 per cent of land on Earth is covered by glaciers and ice sheets. This represents about three-quarters of the Earth's freshwater resources.



▲ **Figure 7.5** *Distribution* of land covered by glaciers and ice sheets

What is the current spatial *distribution* of glaciers and ice sheets?

Currently, every continent on Earth contains glaciers except for Australia. The Randolph Glacier Inventory (RGI) has identified 217,175 glaciers covering approximately 726,800 square kilometres of various sizes found in the mountainous *regions* of North America, South America, Europe, Africa, Asia and Antarctica. Figure 7.5 shows the *distribution* of glaciers and ice sheets globally. The *regions* closest to Australia where glaciers are easily observed are New Guinea and New Zealand. The United Nations Environment Programme (UNEP) also created an inventory of the world's glaciers in the 1970s. This inventory has collected data including satellite images and aerial photos on the location, size, length and characteristics of most of the world's glaciers. Figure 7.6 gives an overview of the many groups around the world monitoring glacier *distribution*.

The two major ice sheets are found in the polar *regions* at the opposite ends of the globe. The Antarctic ice sheet is the largest. It covers most of the Antarctic continent and covers an area of 13 million square kilometres – or 9 per cent of the land area on Earth.

▼ **Figure 7.6** Some of the groups monitoring global glacier *distribution*

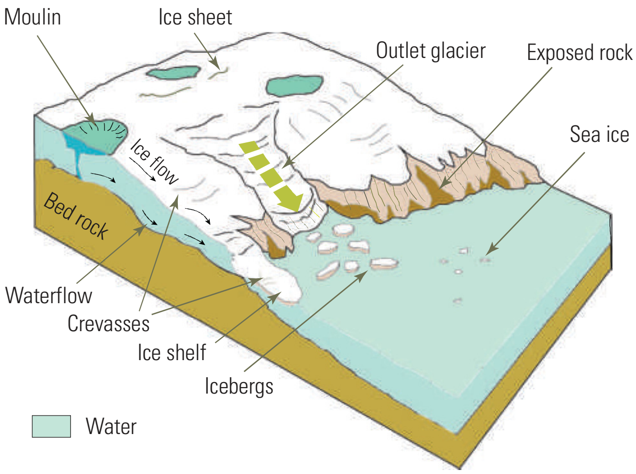
Group	Abbreviation
Global Land Ice Measurements from Space	GLIMS
Intergovernmental Panel on Climate Change	IPCC
National Aeronautics and Space Administration	NASA
National Oceanic and Atmospheric Administration	NOAA
National Snow and Ice Data Center	NSIDC
United Nations Environment Programme	UNEP
United Nations Development Programme	UNDP
United States Geological Survey	USGS
World Glacier Monitoring Service	WGMS
World Bank	WB

What are the natural characteristics of glaciers and ice sheets?

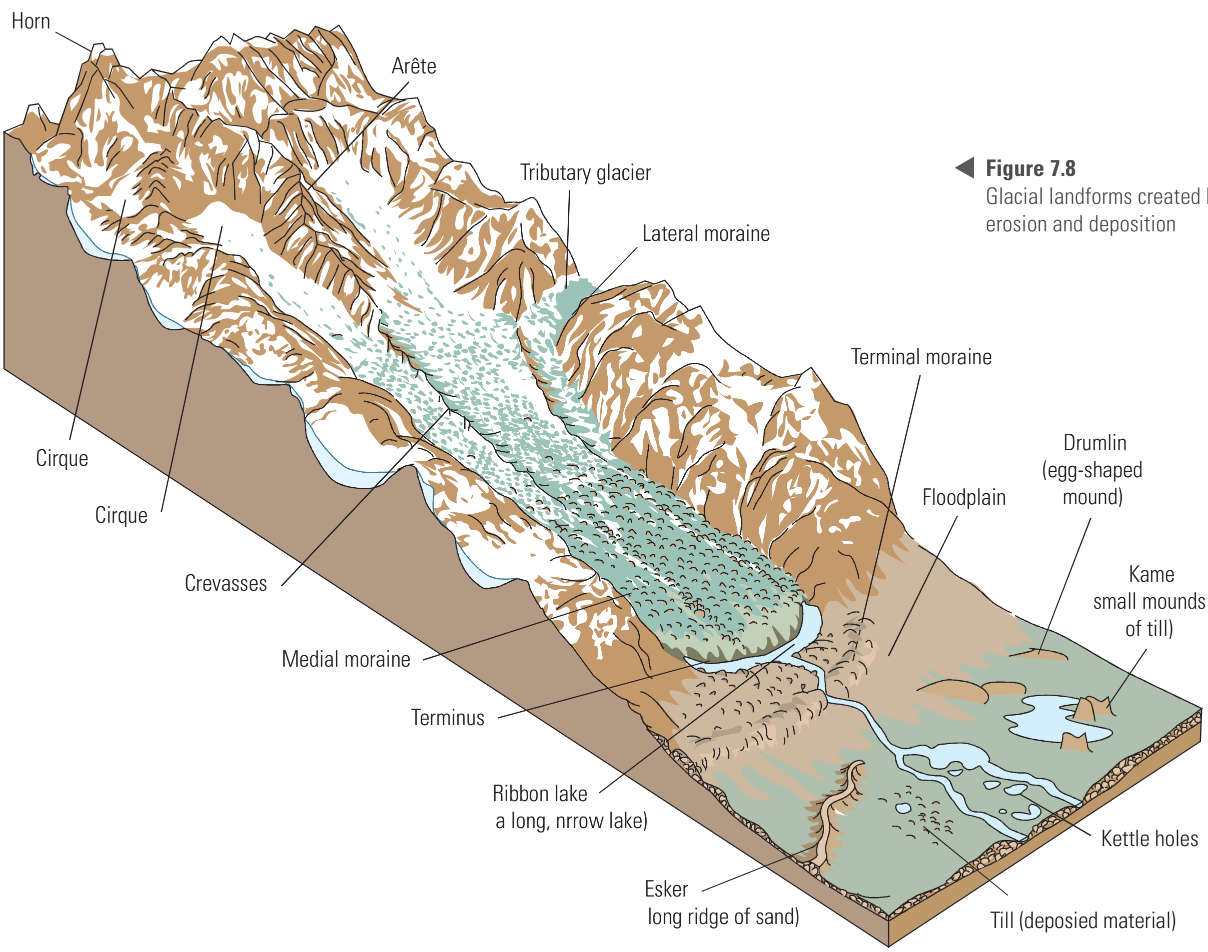
Glacial landscapes are dynamic although, to the untrained eye, it may seem that there is not a lot happening. Like most other landforms, glacial features are created by *processes* such as erosion and deposition, and these natural *processes change* the appearance of glaciers over time. The single biggest factor in explaining the characteristics of glaciers and ice sheets is climate. The typical characteristics of an ice sheet are shown in Figure 7.7. For ice to form, the *region* with ice must be sufficiently cold all year round. Snow is generally deposited in cold/humid periods and does not melt entirely in warm/dry periods. These conditions are common in high latitudes (above 60 degrees north and south of the Equator) and high altitudes. The conditions required for ice to form in alpine areas vary according to latitude, aspect and proximity to the sea. In South America and Africa, glaciers are found in low latitudes and tropical climates over 5000 metres above sea level; in Europe, glaciers can be found in temperate climates in mid-latitude *regions* over 3500 metres above sea level.

Ice can scrape, scour and remove rock as it moves slowly from the valley floor. This erosion creates moraine (material transported by a glacier) that is deposited as till to create depositional landforms at the base (terminal moraine) and sides (lateral moraine) of the glacier. The erosion of rock by ice can create erosional landforms such as cirques, horns and arêtes. Depositional landforms include eskers, drumlins, kame and kettle holes. These landforms can be seen diagrammatically in Figure 7.8.

▼ **Figure 7.7** Characteristics of ice sheets



Only the hardiest of plants and animals inhabit *regions* with ice because, with limited productivity and few ecological niches, biodiversity is low. Animals such as polar bears and reindeer inhabit the ice sheets of the Northern Hemisphere while penguins and seals are the main species seen on Antarctica. In glacial *regions* you might find animals such as goats, leopards, deer and rodents. The most common species of plants in icy areas are algae, lichens and fungi. Limited solar radiation means that ice-bound ecosystems here have short growing seasons, slow metabolism, and cannot recover rapidly from disturbance.



◀ **Figure 7.8**
Glacial landforms created by erosion and deposition

▲ **Figure 7.9** View of the Swiss Alps from the Glacier Express

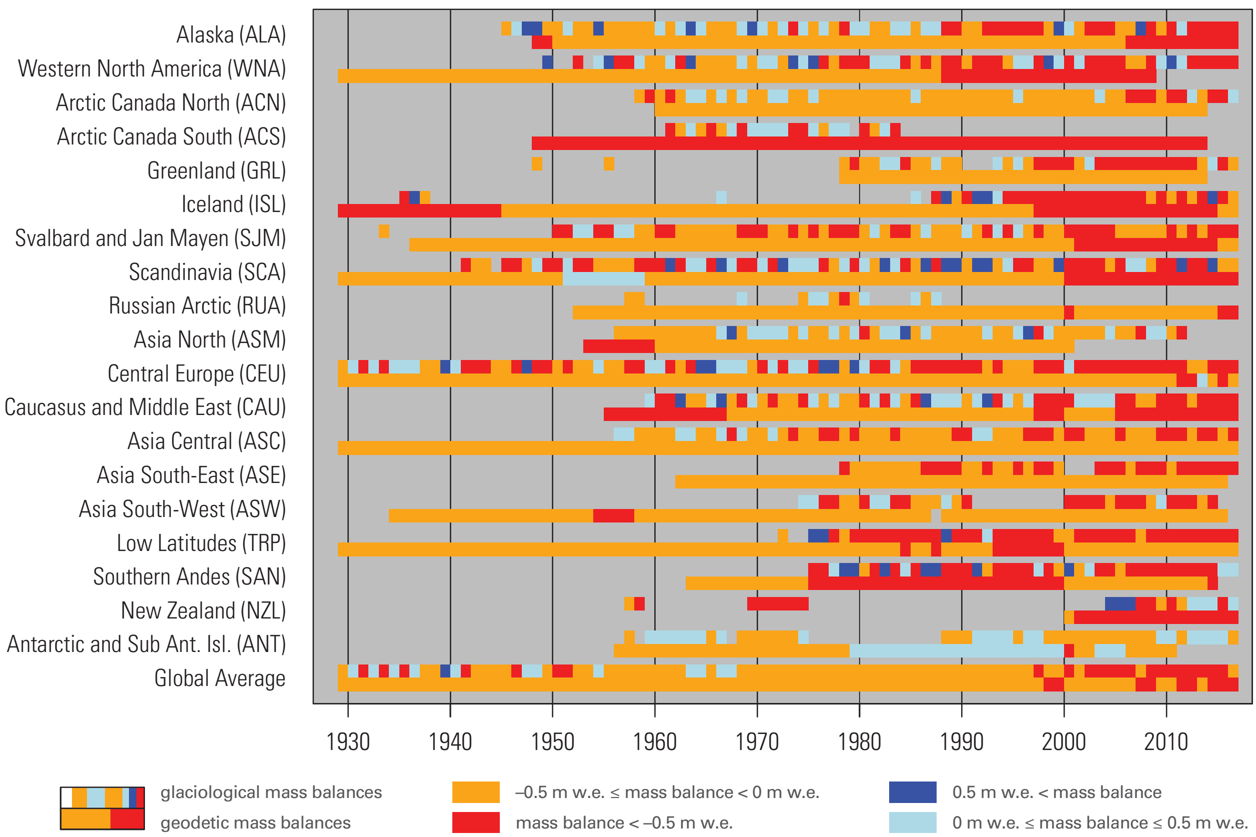
Due to the extreme nature of the climate very few people permanently inhabit *regions* covered with ice, although many people do live along the margins of ice such as in Scandinavia, Nepal, Canada, Russia, Iceland and Greenland. These people are reliant on meltwater for nomadic herding, agriculture, fishing and forestry. In many parts of the world, tourism is causing increased development in alpine *regions* to cater for the increasing popularity of many snow sports, as well as numbers of people attracted to the beauty of glacial landscapes in polar *regions*. One of the most popular train journeys in Europe is the Glacier Express that runs from Zermatt to St Moritz in Switzerland. Each year over 250,000 tourists take this eight-hour trip that allows visitors to see the scenery of more than a dozen glaciers (see Figure 7.9).

Indirectly, thousands of communities are reliant on glaciers and ice sheets as a source of fresh water, food, soil replenishment and climate regulation. Up to 80 per cent of fresh water required for downstream populations and ecosystems emanates from mountain *regions*. People also have to be aware of hazards associated with glaciers and ice sheets such as avalanches and flooding.

How has the spatial *distribution* of glaciers and ice sheets *changed*?

The current *distribution* of glaciers and ice sheets is very different to how these areas used to look even in the relatively recent past. Over the last 100 years, land covered with ice has decreased considerably as the global climate has warmed. Figure 7.10 depicts the average *changes* in glacier mass balance for 19 *regions*, from about 1930 until 2017. Geodetic mass balance measurements are derived from comparing maps, aerial and satellite photographs and elevation data. The data shown in Figure 7.10 is compiled from 450 glaciers and the graph illustrates that the majority of glaciers in the 19 *regions* depicted receded, although notably some

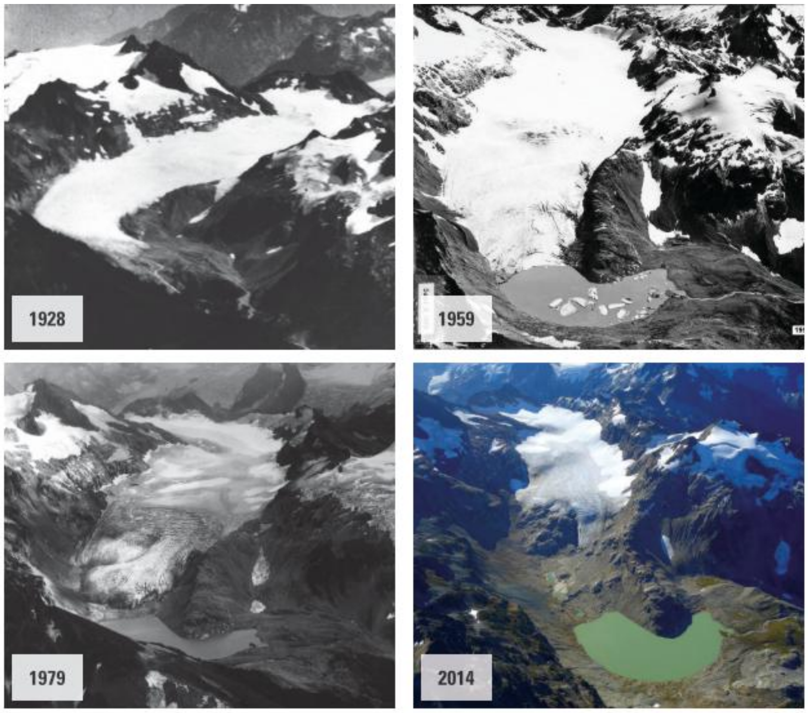
▼ **Figure 7.10** Global *changes* in glacier mass balances between 1930 and 2017. Annual glaciological balances and annual rate of geodetic balance are shown for each region and for the global average. The mass balance is shown as water equivalent units in metres



gained in length in the late 1970s and early 1980s, mostly because warming increased snowfall. There were very few glaciers increasing in length from 2010 to 2015 as these were among the warmest years in recorded history. There is much concern that Africa will soon join Australia as a continent with no glaciers.

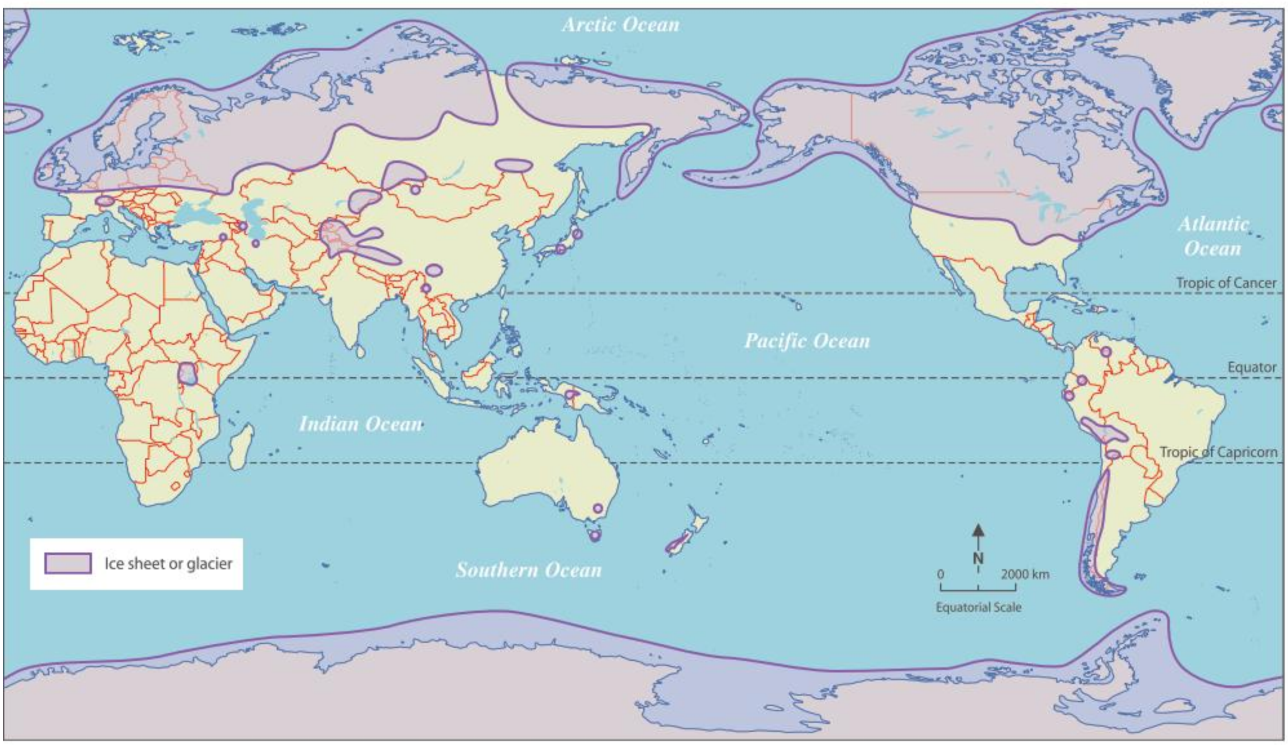
Figure 7.11 shows clear evidence of the decline in the volume of ice from the South Cascade Glacier in the Cascade Ranges in Washington State, USA. This glacier, one of the most watched globally, is estimated to have lost half its volume of ice between 1959 and 2010, with ice loss accelerating markedly in the period 2010 to 2018.

In recent geologic time the trend in ice coverage was not one of recession. After closely examining glacial deposits in many locations, geologists have identified a number of ice ages in the last 200,000 years where ice levels were much higher than today. The most recent of these ice ages peaked between 21,000 and 18,000 years ago in the Australian *region* and it has been estimated that about 30 per cent of the Earth was covered by ice. The average temperature of the Earth was at least seven degrees cooler and sea levels were considerably lower (up to 135 metres) because much more water than today was frozen and seawater contracts at lower temperatures. It is thought that people could have walked on land from the eastern Indonesian-*region* to Tasmania. Figure 7.12 shows the estimated extent of global ice cover around 18,000 years ago. It is important to notice that the amount of ice in the Northern Hemisphere is double that of the Southern Hemisphere (except for Antarctica), and that only relatively small areas of the Australian Alps and Tasmania were covered by ice. These *regions* are better seen in Figure 7.13. At the peak of this ice age it is thought that ice covered 6000 square kilometres of the central plateau of Tasmania to a depth of 700 metres.

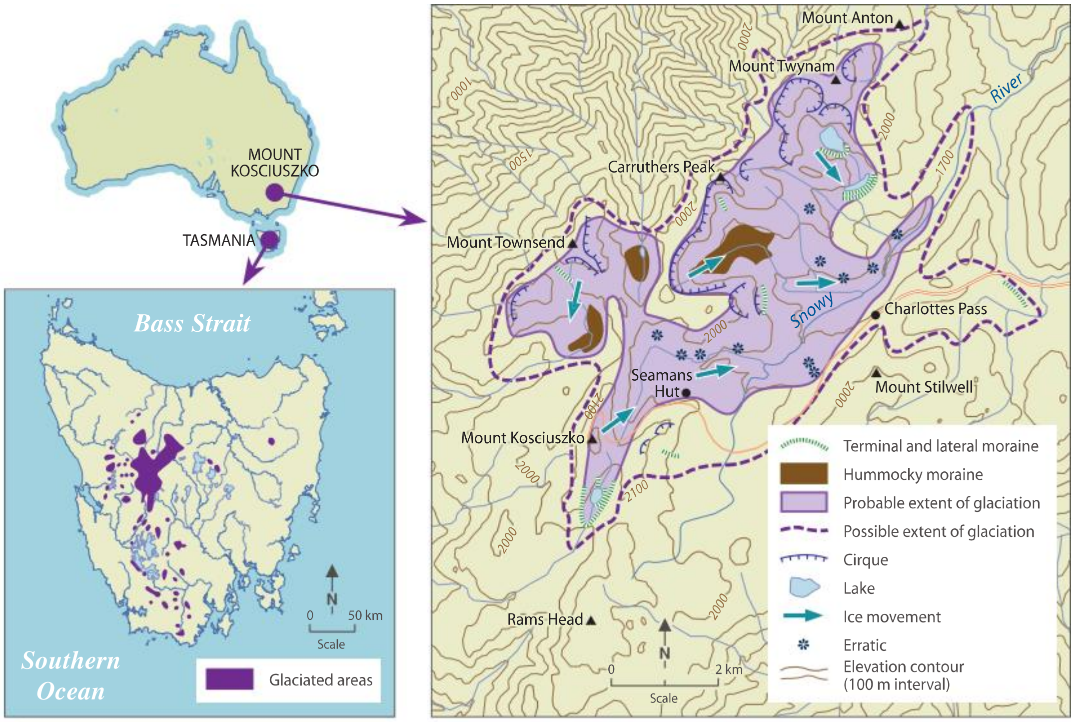


▲ **Figure 7.11** *Change* in the amount of ice on South Cascade Glacier between 1928 and 2014

It is uncertain as to why these ice ages, as symptoms of significant climatic *change*, may have occurred at regular intervals in the Earth's history. Scientists have speculated that this climate *change* could have been influenced by a number of natural causes including astronomical cycle *changes* (Milankovitch cycles), volcanic activity, *changes* in atmospheric gas levels, ocean current *changes* and sun spot activity – and sometimes these forces acted in combination with each other; at other times they operated on their own.



▲ **Figure 7.12** Global glaciation about 18,000 years ago



▲ **Figure 7.13** Extent of glaciation in Australia about 18,000 years ago

ACTIVITIES

1. a. Complete a sketch of Aletsch Glacier, labelling the glacial features you can identify.

b. Complete a sketch of the Fox Glacier labelling the glacial features you can identify.

c. Create a table that contains all the glacial features you identified in questions 1(a) and 1(b). Define whether the feature is formed by mainly erosion or deposition. Select one erosional and one depositional feature and complete an extended description of their formation.

2. Explain how glacier mass balance is calculated. The terms ablation and accumulation must be used in your explanation.

3. Describe the global *distribution* of glaciers and ice sheets as shown in Figure 7.5.

4. The organisations listed in Figure 7.6 are all based in the Northern Hemisphere. Explain why this might be the case.

5. Evaluate the following statement (you will need to refer to an atlas):

'Glaciers are only found in temperate and polar climatic *regions*.'

6. a. Describe the *distribution* of land covered by ice 18,000 years ago.

b. Comparing 18,000 years ago to the present, which *regions* of the world have had the largest decrease in ice cover?

7. Figure 7.10 depicts advancing and retreating glaciers from the 1930s to 2017.

a. Describe the global rates of advance and retreat from 1930.

b. Choose three *regions* that have records for more than 50 years. Describe the rate of advance and retreat of glaciers of each of the *regions* over the given time period.

c. What are the similarities and differences between the *regions* you described?

d. Glaciological mass balances are calculated by scientists in the field whereas geodetic mass balances are taken from photos and other data. Some *regions* shown in Figure 7.10 have data that is conflicting between glaciological and geodetic mass balances. Why might this be the case?

8. Using overlays or a similar technique, plot the *changes* in ice cover of South Cascade Glacier as shown in Figure 7.11.

9. Research a *region* that contains glaciers (apart from South America and Greenland) and create a journal of your research. In your research you should:

a. investigate significant glaciers of the *region* and their characteristics both human and natural

b. collect some diagrams and images that support your description of the human and natural characteristics of the chosen *region*

c. describe the spatial *changes* in ice coverage in your *region* over time

d. describe any activities engaged in by humans in these *regions* and the economic, social and *environmental* impacts associated with these activities

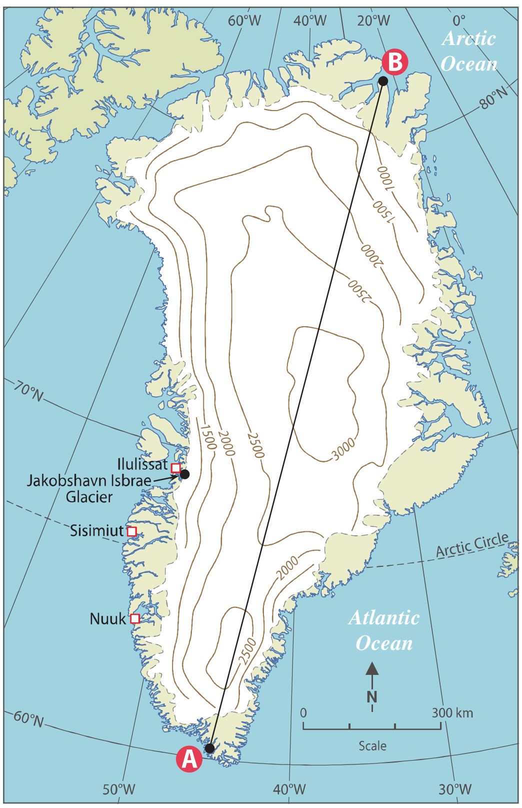
e. provide a statement that looks at what might happen in this *region* in the future if the impacts described in question 9(d) continue.

CASE STUDY Greenland

Greenland is the world's largest island; it is located between the Arctic and Atlantic oceans and found between 60 and 83 degrees latitude north of the Equator. It is a neighbour to Canada, Denmark and Norway, and is considered to be part of the North American continent geologically. Denmark has sovereignty over the island. Greenland has just over 56,000 residents making its population density the lowest in the world. Its residents are mainly Inuit who rely on fishing, fish products and some sheep farming to make a living. Greenlanders live a precarious existence on the rocky fringes between the ice and the sea. There are few roads in Greenland and most people travel between settlements by boat, helicopter or dogsled.

The Greenland ice sheet covers most of the surface of the island. The ice sheet has an area of approximately 1.7 million square kilometres (an area larger than Germany) and is about one-eighth the size of the Antarctic ice sheet. The Greenland ice sheet is dome-like in shape reaching its highest elevation of more than 3000 metres above sea level in the east-central part of the island's interior. It contains about 11 per cent of the Earth's freshwater supply. The contours of the Greenland ice sheet are shown in Figure 7.14. Figure 7.15 shows the Greenland ice sheet in 2011 from NASA satellites using a spectroradiometer.

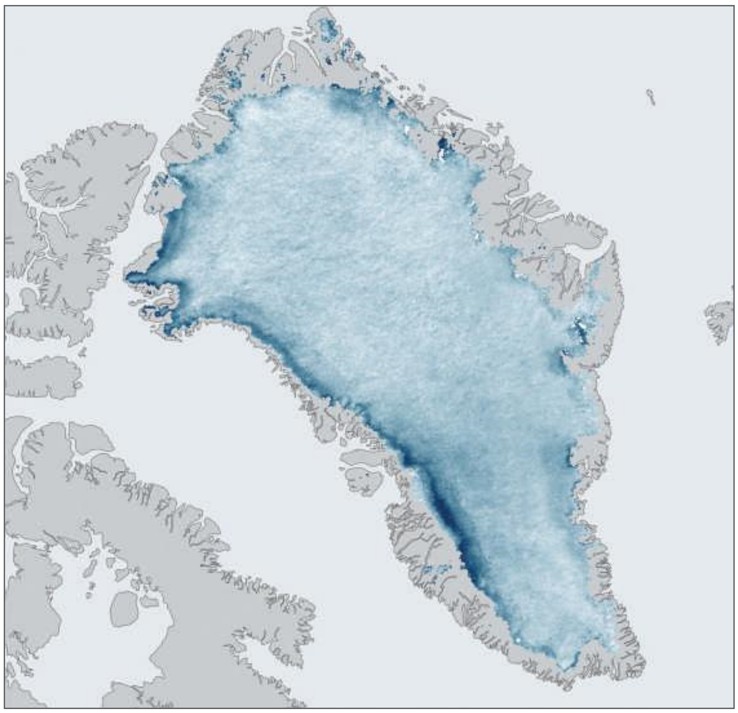
Scientists are particularly interested in monitoring Greenland's ice cap because it is relatively accessible, a good indicator of planetary climate *change* and large enough to pose a global threat from warming. In a four-year project started in 1989, scientists drilled two ice cores over three kilometres deep in the summit of the ice sheet to conduct an extensive ice analys.



▲ **Figure 7.14** Greenland and its ice sheet

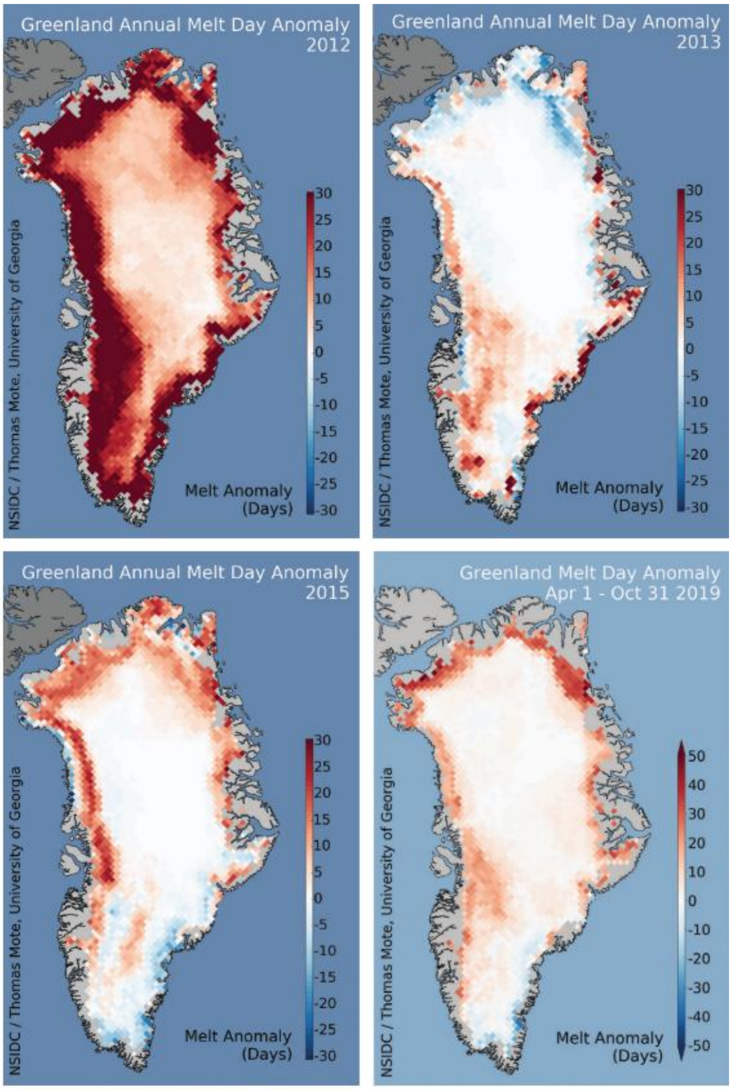
These ice cores were dated back to 110,000 years ago, and chemicals present in the cores provided evidence of volcanic eruptions, temperature *changes* and annual rates of ice accumulation. The cores identified major fluctuations in ice accumulation from year to year highlighting the notion that climates can fluctuate dramatically – even within a few years.

Over the last 30 years there has been an escalating trend in the rate of ice melting at the margins of the ice sheet near the Greenland coast, although there has been some thickening of the ice sheet near the summit. In the period 1992 to 2018 a study completed by NASA and the European Space Agency estimated Greenland has lost 3.8 trillion tons of ice in that period. The rate of ice loss has accelerated from 33 billion tons per year in the 1990s to an average of 234 billion tons towards the end of the study period. The increasing rate of melting is a great concern to researchers as the impact on sea level rise will also accelerate. The loss



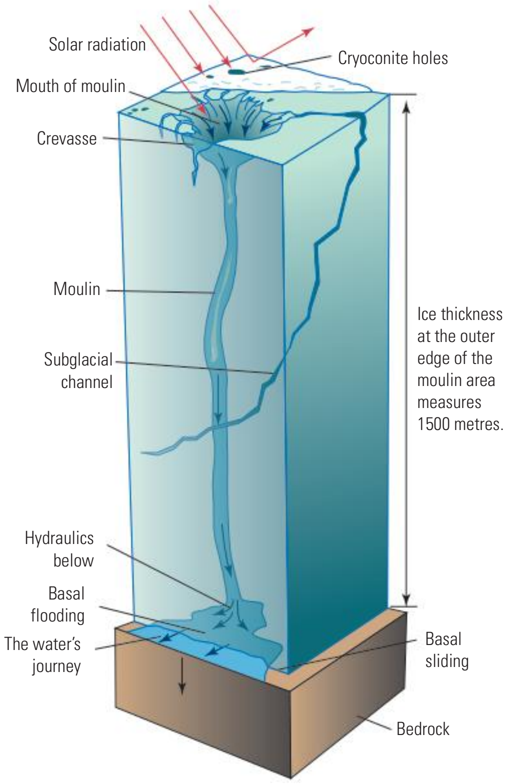
▲ **Figure 7.15** Greenland ice sheet from space

▲ **Figure 7.16** A settlement in Greenland



▲ **Figure 7.17** The number of melt days on Greenland ice sheet in 2012, 2013, 2015 and 2019 in comparison to number of melt days between 1981 and 2010

▶ **Figure 7.18** Cryoconite and the formation of moulins



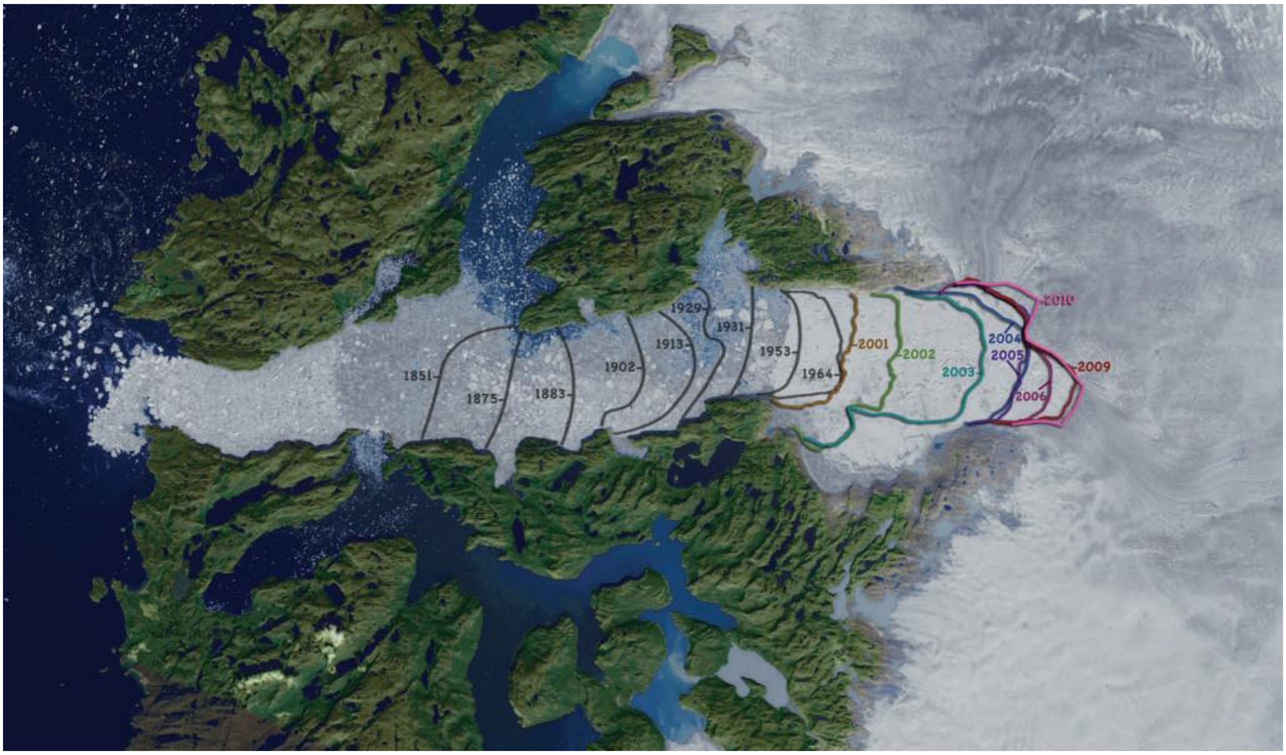
of ice is thought to have been caused by increasingly warmer summers and increasing speeds of moving glaciers. Between 1990 and 2018 meteorologists have recorded a 2.8°C increase in average annual surface temperatures on the Greenland ice sheet. In 2019 the highest point in Greenland, more than 3000 metres above sea level reached temperatures above zero. This has happened only seven times in the past 2000 years.

Figure 7.17 shows the *change* in the number of melt days on the Greenland ice sheet between 2012 and 2019 in comparison to the average number of melt days between 1981 and 2010. These maps clearly show that melting is occurring more quickly in the south-east parts of the ice sheet.

The increased rate of ice melt in Greenland has recently been shown to be caused by increasing surface deposition of airborne particles of the mineral cryoconite. This sediment is a combination of dust blown from central Asian deserts, particulate matter ejected from volcanic eruptions and air pollution from European coal-fired power plants and diesel engines. The dark colour of the cryoconite has decreased the reflectivity (albedo) of the ice, which increases the absorption of heat and in turn increases the rate of melting. Figure 7.18 shows how cryoconite can accelerate ice melting and lead to the formation of moulins that can cause the ice sheet to melt from its base.

It is thought that the annual melting of Greenland ice has been responsible for over 25 per cent of global sea level rise. The sea level is rising about three millimetres per year and about one millimetre of this sea level rise is directly from Greenland's ice sheet melting. Scientists estimate that if in the unlikely event that all of Greenland's ice melted, the global sea level would rise by over seven metres. The Jakobshavn Isbrae Glacier is a glacier that extends between the Greenland ice sheet and the ocean. This glacier was the world's fastest, increasing in velocity from 7 kilometres a year in 1985 to 14 kilometres a year in 2006. Figure 7.19 depicts the retreat of this glacier from the ocean. The glacier has retreated over 40 kilometres since 1851. In 2016 scientists reported that ocean currents had become a lot colder near Jakobshavn Isbrae Glacier and NASA reported in 2019 that the glacier had stopped retreating. Scientists are trying to work out what is happening with Jakobshavn Isbrae Glacier as all other glaciers in Greenland are retreating at increasing rates.

The decline in ice cover and increasing temperatures has resulted in many other *changes* with significant social, economic and *environmental* consequences for people in Greenland. Traditional ways of life are being challenged. Hunters are giving up dog teams to hunt reindeer as there are decreased opportunities to hunt on sea ice. In 2018 sea ice was forming two months later and melting one month earlier. The hunters are *changing* to fishing as fish species not seen before are migrating north as the water warms. Mackerel, herring, cod and tuna are being caught in increasing quantities. Ninety per cent of Greenland's export income is derived from fishing but the move from hunting to fishing is very expensive as equipment needs to be purchased, infrastructure built, and people trained in new jobs.



▲ **Figure 7.19** Landsat image of Jakobshavn Isbrae Glacier showing its retreat from 1851. The landsat images begin in 2001. Dates prior to 2001 have been estimated from other photos and data

As the ice contracts a wealth of mineral resources have been exposed. Zinc, uranium, gold, copper, sapphires and rare earth minerals have been found and the first mine extracting lead and zinc was controversially given permission to start operations in January 2017.

The contraction of ice has also seen land available for farming increase. Soil has been imported and sheep are being grazed and crops grown. Greenlanders can now buy local lamb, potatoes, cabbages and turnips in the shops. Since the 1990s the growing season has expanded by three weeks as the climate has warmed. Although providing new opportunities for farming, this warming has also contributed to droughts in 2015 and 2016 and wildfires in 2017.

With the increased media attention related to ice melting, tourism to Greenland has increased significantly. In 2017 the highest number of people on record visited Greenland with nearly 267,000 visitors. This can be compared to 1994 when tourism data was first published when there were just over 114,000 visitors.

▶ ACTIVITIES

1. Using an atlas, describe the location of Greenland. Make sure you use latitude and longitude to define its location and also describe surrounding water bodies and countries.

2. a. Make a photocopy of Figure 7.14. Plot a cross-section of the Greenland ice sheet between points A and B marked on the map. Make sure you label the sea, land and ice.

b. Describe the profile of the Greenland ice sheet. Why is the ice sheet thickest in the middle of the island?

3. Look at Figure 7.15. Why might the edge of the ice sheet be a different colour to the colour of ice in the middle of Greenland?

4. Life for those residing in Greenland is not easy. Refer to Figure 7.16 to explain why this is the case.

5. Refer to Figure 7.17.

a. Describe the patterns evident in the number of melt days occurring in Greenland between 2012 and 2019.

b. The *distribution* of melt days in Greenland in 2013 has some differences to the melt patterns of 2019. Outline and explain these differences.

c. Which part of Greenland do you think is melting the slowest? Justify your answer.

6. Refer to Figure 7.18.

a. Describe how cryoconite speeds up the rate of ice melt.

b. Describe how a moulin forms.

7. Refer to Figure 7.19.

a. Create a graph that shows the rate of decline of Jakobshavn Isbrae Glacier, in kilometres, from 1851 to 2010.

b. When were the fastest and slowest rates of decline? Quantify your answer.

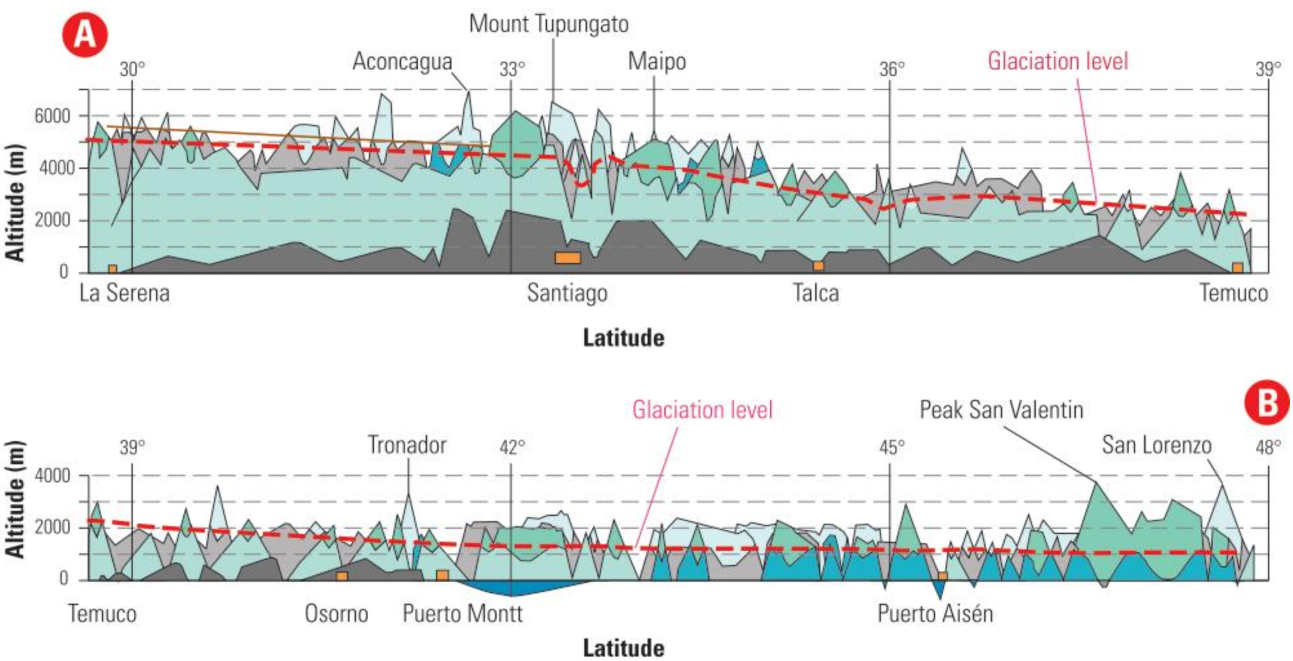
8. As the climate warms and more land is exposed, Greenlanders are keen to expand their uses of this new land. Predict the likely economic, *environmental* and social consequences of these *changing* land uses on Greenland.

9. Deposits of cryoconite found in Greenland are created from activities in other parts of Europe and Asia. Imagine you have been employed as a geographer in the European Union (EU) with the responsibility for creating a plan to reduce cryoconite. What actions might you implement?

CASE STUDY South American glaciers

All of the glaciers in South America are located within the Andes mountains. The volume of ice found in the Andes is the second-largest amount of ice cover in the Southern Hemisphere (behind Antarctica) and constitutes about 7 per cent of the world's glaciers. The Andes are the longest continental mountain range in the world, extending over 7000 kilometres and spanning seven countries. The Andes spans three clear climatic zones – the tropics, between 11 and 23 degrees latitude; the dry, between 23 and 35 degrees latitude (the Atacama, sits between the Andes and the Pacific Ocean at this point); and the wet, found between 35 and 55 degrees latitude. Glaciers are found in each of these climatic zones although the snow line is considerably different in each. The snow-line altitude varies across all glaciers in the Andes depending on latitude, proximity to the sea, aspect and altitude. In the tropics, glaciers are found at over 4500 metres above sea level; in the dry areas they are located at over 5000 metres above sea level. Most glaciers are found in the wet climates, generally in the Patagonian *region* where glaciers start at only 300 metres above sea level in the highest latitudes; they range to about 4000 metres above sea level at the northernmost point of this climate zone. In 2010 the World Glacier Monitoring Service (WGMS), a branch of the United Nations Environment Programme (UNEP), estimated that there were approximately 25,492 square kilometres of glaciated areas in South America. Chile and Argentina (which includes Patagonia) have most of the glaciated *regions* with just over 23,000 square kilometres or 90 per cent of glacier coverage. Peru has 7 per cent, Bolivia 2 per cent, with the other countries sharing the remainder. Figure 7.20 shows the *distribution* of glaciated *regions* in South America.

▲ **Figure 7.20** *Distribution* of glaciers in South America



▲ **Figure 7.21** Cross-section of the Southern Andes

Figure 7.22 The Terminus of Perito Moreno Glacier in Argentina (note the people at the bottom left)

Some of the most spectacular and recognisable glaciers in the world are located in South America. Perito Moreno Glacier found in the Southern Patagonian *region* of Argentina is perhaps the most famous of these, with a terminus that is five kilometres wide and approximately 60 metres high. It is 30 kilometres long and covers 250 square kilometres. Perito Moreno is the third-largest reserve of fresh water on earth. This glacier forms part of Los Glaciares National Park. There are 47 large glaciers within the park, which was declared a World Heritage site in 1981. It is estimated that in the six months each year when the park is open, it averages over 200,000 tourists.

South American glaciers have been monitored closely over the past 30 years as they are critical sources of water for people, agriculture, industry and domestic use. Over 80 per cent of water used by Peruvians emanates from glaciers including all water for the capital city, Lima. Seventy per cent of electricity generated in Peru and Bolivia comes from hydropower. Most glaciers on the South American continent are declining considerably (the rates of decline are different in each climate zone) and this has led to hazardous conditions particularly in the form of floods and avalanches. Ice avalanches in Peru have killed thousands of people and caused millions of dollars in damage while melting glaciers have caused glacial lakes at the terminus of glaciers to break their banks and flood villages downstream, all causing significant financial costs. This type of flood is called a glacial lake outburst flood (GLOF). Five glacial lake outburst floods occurred in one area of Chile in an 18-month period in 2008 and 2009.

Another reason why South American glaciers have been monitored closely is because 99 per cent of the world's tropical glaciers are located here. Seventy-one per cent of these are in Peru and 20 per cent in Bolivia. These tropical glaciers are receding at an accelerated rate and it is predicted many will not exist beyond 2021 if the current rate of melting continues. In the last 35 years these tropical glaciers have lost between 25 and 50 per cent of their ice volume, and volume reductions often accelerate ice melt (because the surface area relative to total ice mass increases). Glaciers at lower altitudes are retreating the fastest. At 5421 metres above sea level, Chacaltaya Glacier in Bolivia (Figure 7.23) was once the world's highest ski resort and a source of 30 per cent of the water supply for La Paz (the capital city), as well as a source of water for the highest navigable lake in the world, Lake Titicaca.

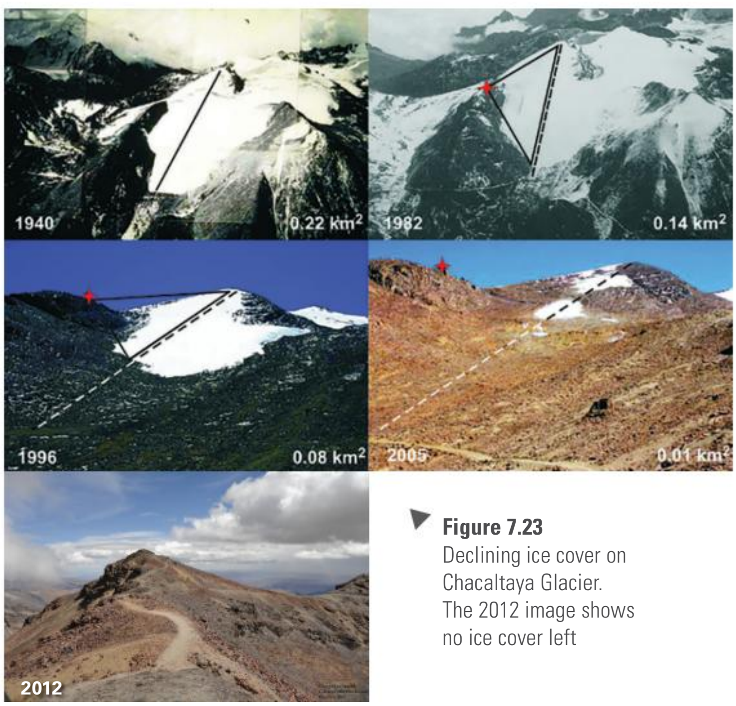


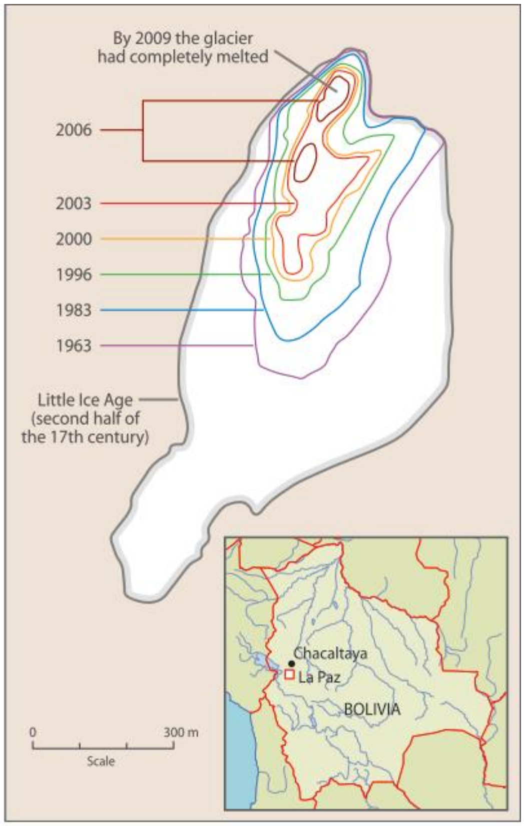
Figure 7.23 Declining ice cover on Chacaltaya Glacier. The 2012 image shows no ice cover left

Lake Titicaca has an average depth of 134 metres and is fed by five river systems that get their water from glaciers. Since 2000, the melting glaciers in the *region* have caused water levels to drop in Lake Titicaca by nearly 80 centimetres per year. Chacaltaya Glacier was thought to be around 18,000 years old and initially scientists predicted that the rate of melting would mean the glacier would cease to exist in 2015. Chacaltaya melted faster than expected and, by 2009, there was no ice left (see Figures 7.23 and 7.24).

With the loss of Chacaltaya Glacier and the decline of other glaciers nearby, the Bolivian government has recognised that many areas will undergo severe water stress. As a response, the government enforced severe water restrictions in 2016 on the capital La Paz and surrounding highland *regions*, affecting nearly 2.3 million people. This decision was taken as the three reservoirs serving La Paz all fell below 10 per cent capacity. The biggest dam, Ajuan Kota (see Figure 7.25), was at only 1 per cent of total water capacity when this photo was taken. La Paz residents are subject to daily water rationing and are allowed to fill two containers every three to four days from water tankers (see Figure 7.26). The lack of water has also led to considerable civil unrest in the Bolivian capital as competition to access water for a variety of purposes has led to conflict. Demand for drinking water is increasing as La Paz's population is increasing annually. Farmers have had reduced access to water to grow food crops leading to food shortages and, in some cases, the farmers have lost their livelihoods completely. Recreational facilities have not been maintained and are decaying. Electricity production has declined as between 30 and 40 per cent of electricity in Bolivia is produced from hydropower.

In an attempt to increase precipitation to increase water levels in reservoirs, the Bolivian government, with the assistance of the Venezuelan government, introduced a cloud seeding program injecting silver iodide into the atmosphere to artificially condense atmospheric water vapour to form clouds and encourage rain. At the time of writing, this endeavour had experienced limited success.

Other solutions to Bolivia's water crisis have involved funding from Brazil and China to secure water and electricity supplies with the proposed construction of multiple mega dams.



▲ **Figure 7.24** The demise of Chacaltaya Glacier

▲ **Figure 7.25** The nearly empty Ajuan Kota reservoir in 2017

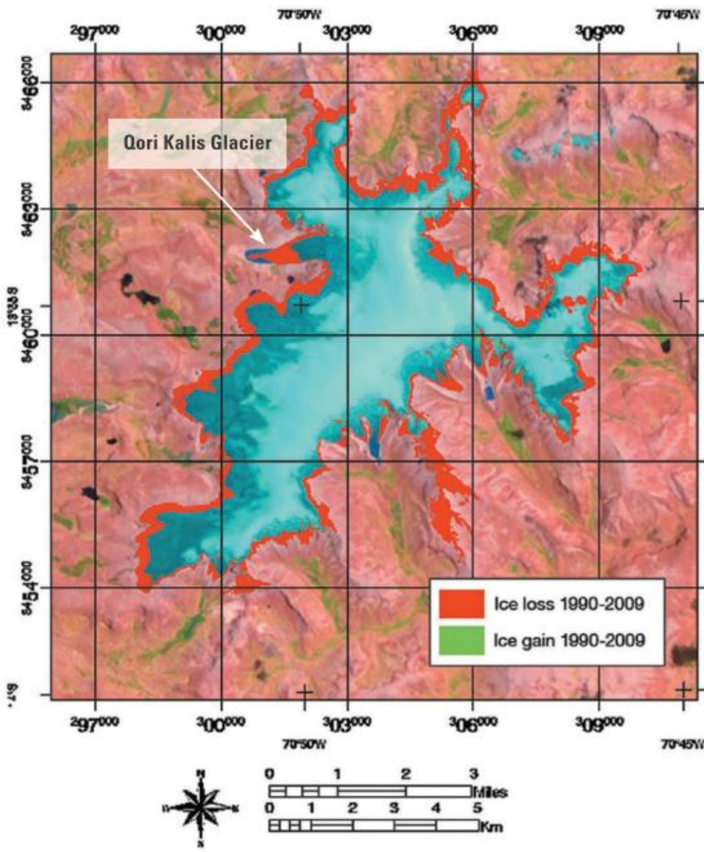
▲ **Figure 7.26** La Paz residents getting their water rations

▲ **Figure 7.27** Photographs of La Raya, Peru

Press releases in 2017 and 2018 have indicated these dams may go ahead in areas owned by indigenous people or in *regions* previously classified as national parks. More than 17 indigenous groups and numerous *environmental* groups are actively opposing these proposals.

Peru and Bolivia are two of the poorest countries in South America and they rely heavily on tourism as income. Tourists are made aware of glacial retreat in the *region* and there are a number of tours that bring visitors close to the retreating glaciers. In countries where infrastructure is poor, one way to see tropical glaciers is to catch the Andean Explorer, a train that runs between the ancient Inca capital of Cuzco in Peru and Puno on the Peru–Bolivia border, on the edge of Lake Titicaca. The train ascends the Andes reaching a height of 4319 metres above sea level at the town of La Raya where it stops for views of glaciers emanating from the Quelccaya Ice Cap. Figure 7.27 shows the town of La Raya and the views of the glaciers at this point.

Among other rapidly retreating glaciers that are being monitored very closely is Yanamarey Glacier in Peru. Satellite tracking of this glacier has shown that 85 per cent of its volume has been lost and the glacier is expected to dry up before 2021. Another Peruvian glacier predicted to vanish in the next 2 years is the Qori Kalis Glacier. This glacier emanates from the Quelccaya Ice Cap and has been steadily retreating over the last 30 years, but melting rates have accelerated in recent years. The Quelccaya Glacier is the largest tropical glacier in the world and has been closely monitored using a range of geospatial technologies to assess rates of ice loss and gain. Figure 7.28 depicts 20 years of remotely sensed data collected from aerial photography, satellite imagery and laser radiation detection systems. As Qori Kalis has melted, a large lake has formed at its terminus. In March 2013 a large chunk of ice broke off the glacier, tumbled downhill and splashed into the lake causing a wall of water to flood the valley below.



▲ **Figure 7.28** Ice loss and gain on Quelccaya Ice Cap between 1990 and 2009

ACTIVITIES

1. On a base map of South America and using information in this chapter, annotate each country showing the percentage of glaciers found there.
2. Refer to Figure 7.20 and, using the map you have constructed in question 1, describe the *distribution* of glaciers in South America.
3. Figure 7.21 depicts a cross-section of Andean glaciers. What *spatial associations* can you identify from this diagram? Think about the location of glaciers and their respective latitudes and altitude.
4. Complete a photo sketch of the Perito Moreno Glacier labelling glacial features that can be identified.
5. Explain why the social, economic and *environmental* impacts of glacial retreat might be more severe on those in developing countries like Peru and Bolivia in comparison to developed countries.
6. Chacaltaya Glacier's demise was watched by many groups across the world.
   a. Use Figure 7.24 to construct a graph that illustrates the decline in ice cover from 1963.
   b. Could the rate of decline shown be evidence that the climate in this *region* is warming?
   c. Over 30 per cent of La Paz's water supply disappeared with the loss of Chacaltaya Glacier and the impacts of this are really starting to be felt. Create a table that summarises the social, economic and *environmental* impacts of the loss of this glacier.
7. Figure 7.27 depicts images of La Raya, located in Peru at over 4000 metres above sea level. Explain why you think there are no trees visible in any of the photographs.
8. a. Explain how the use of geospatial technologies, such as satellite photography, can help predict *changes* in ice cover.
   b. How might the use of geospatial technologies assist the Bolivian and Peruvian governments to prepare for *changes* in ice cover?
9. The loss of water as glaciers retreat is of great concern to South American governments. Predict the impacts on people and *environments* of further glacier loss if the current global warming continues.
10. People living in Peru and Bolivia in the Central Andes *region* of South America are reliant on many crops grown locally as food sources. Crops include potatoes, corn, quinoa and beans. Explain the social and economic impacts that could result from decreasing water supplies.

Professor Andrew Mackintosh

Professor and Head, School of Earth, Atmosphere and Environment, Monash University

CAREER PROFILE

I am the Head of the School of Earth, Atmosphere and Environment at Monash University, and also a Professor. It is my task to shape the future of the School, which is at the forefront of climate and environmental research, to lead a research group of doctoral students and post docs, and to teach undergraduate students.

My research group (https://www.icesheet.org) aims to understand how glaciers and ice sheets respond to climate change, to improve predictions of sea level rise and other impacts. As part of my job I have had the privilege of briefing governments and being a lead author for the Intergovernmental Panel on Climate Change (IPCC).

Prior to Monash, I was the Director of the Antarctic Research Centre at Victoria University of Wellington in New Zealand. I have also worked in The Netherlands and the USA. I grew up in Melbourne but left in the mid-1990s to pursue a PhD at University of Edinburgh in the UK. My current job at Monash is the first time that I have worked in Australia other than being a sales assistant or kitchen hand!

I love my job because I work on a topic that really matters – understanding climate change – in remote and beautiful locations in the world's major mountain ranges and polar regions. For me, nothing beats flying into a remote field camp in Antarctica, encouraging a promising young scientist into a PhD programme, or offering an academic job to the next superstar of STEM.

What are the causes of melting glaciers and ice sheets?

In the previous pages of this chapter it has been established that there is a clear trend emerging from monitoring of the cryosphere by a range of groups across the world. These groups include UNEP, NASA, WGMS, NSIDC and the World Bank. All recent studies have concluded that the area of ice found in glaciers and ice sheets is declining with almost no exceptions. This decline has a number of clear causes with the most significant being the steady and consistent warming of the Earth's climate.

NASA and the NOAA, both based in the USA, stated that 2016 was the hottest year and 2019 the second hottest year in the Earth's recorded history and that the 10 hottest years on this planet have occurred since 1997. The average annual surface temperature in 2016 was 0.9°C warmer than 20th Century average temperatures. Figure 7.29 shows that since the mid 1970s, Earth's global average annual surface temperatures have risen consistently.

It is estimated that since accurate records have been collected in 1880, the Earth's annual average surface temperature has increased by 0.94°C. Since the mid 1970s this has correlated with a decline in the *distribution* of ice in the Arctic from latitudes 72 degrees north to 75 degrees north of the Equator. Scientists think this represents losing about 40 per cent of the ice that was present in the Arctic.

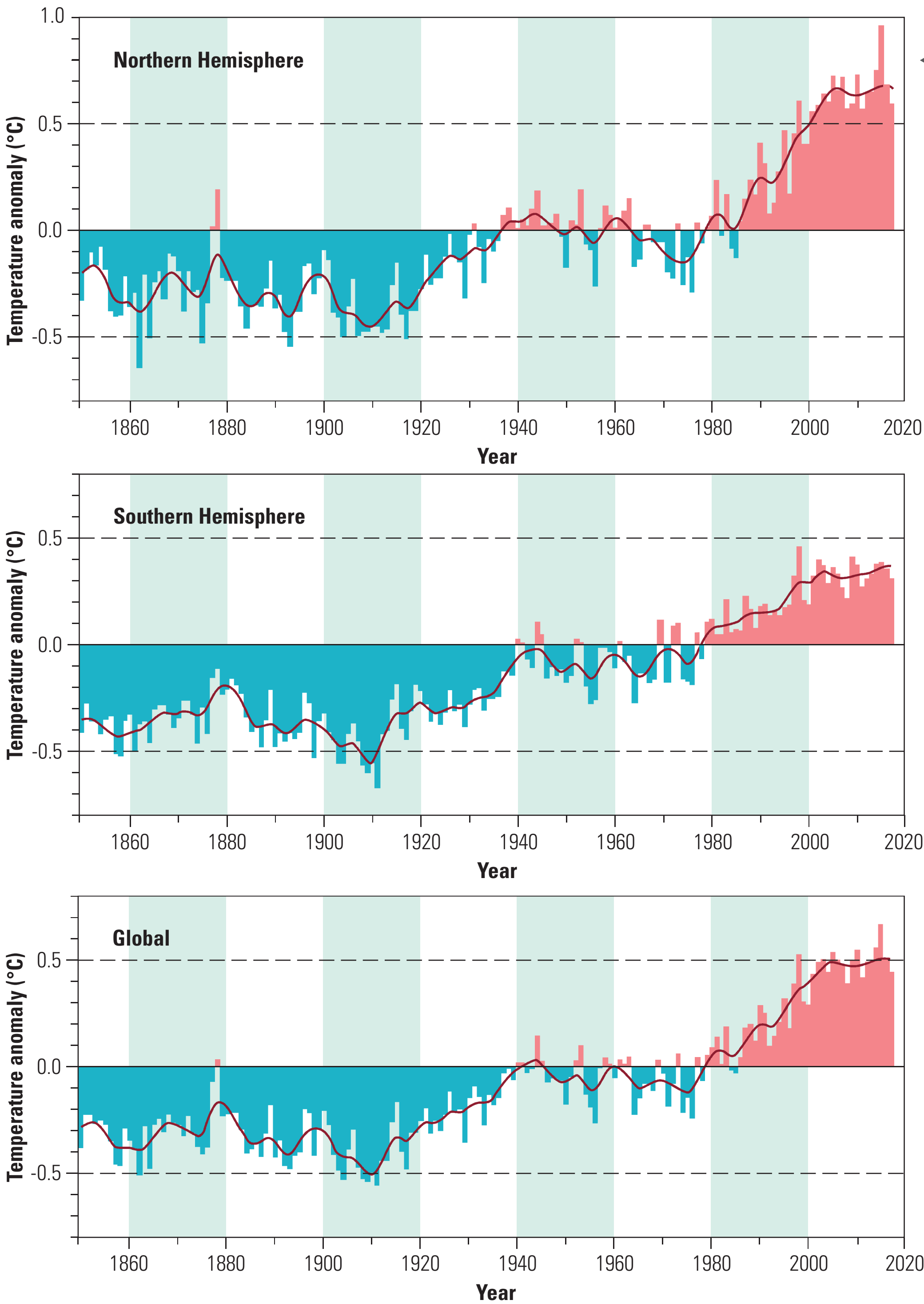
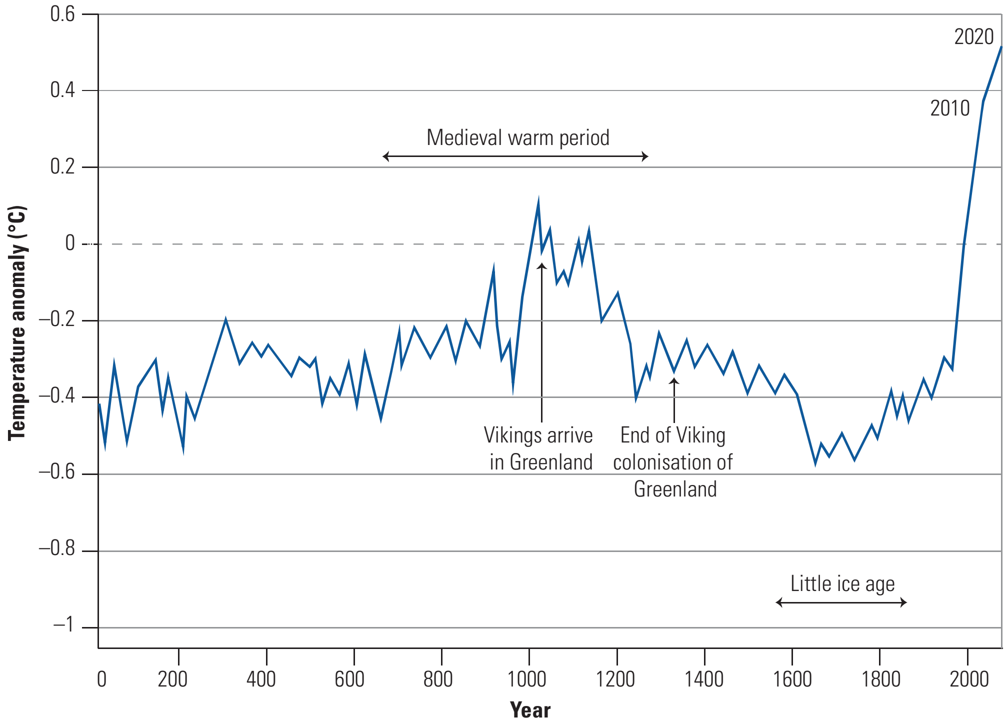


Figure 7.29
Global temperature trends, 1850–2018

Figure 7.30 Anomalies in the Earth's temperature over the last 2020 years



The Earth's atmosphere has warmed considerably since the Last Glacial Maximum, and is doing so now. This is known from a range of indirect (or 'proxy') evidence collected across the world including ice cores, annual sediment layers (known as 'varves'), fossil records, microscopic pollen evidence, tree ring analysis, carbon dating and direct evidence in the form of documented weather observations for hundreds of years. There was a warmer period experienced about 1000 years ago and a little ice age experienced 400 years ago. The *change* in the Earth's climate for the last 2000 years can be seen in Figure 7.30.

The Hadley Centre, a climate research group in the United Kingdom, has monitored records of global temperatures since the mid-19th Century when industrialisation and the burning of fossil fuels became commonplace. Their research has noted increases in surface air temperature, humidity, ocean heat, sea surface temperature, temperatures over oceans, temperatures over land and sea levels, with associated declines in snow cover, Arctic ice cover and glacier mass balance. The anomalies or difference between long-term averages seem to have accelerated since the 1970s.

The IPCC released its 5th Assessment Report in 2013–14 that combined the research of 831 experts in climate science and was peer reviewed by 800 other climate experts who made over 142,000 comments. It stated that the accelerated rates of global warming since the middle of the 20th Century were most likely (more than 90 per cent likely) due to human activities causing a combination of elevated levels of greenhouse gas emissions (so-called source effects such as air pollution) and decreased rates of natural greenhouse gas uptake (so-called sink effects such as deforestation reducing carbon sequestration).

Natural *processes* causing melting glaciers and ice sheets

There are a number of natural causes of melting glaciers and ice sheets (warming) and some of the points listed below can also lead to the cooling of *places* in some cases or localised impacts.

a. **Variations in solar energy:** the solar energy received by the Earth is not constant. Regular long-term variations to levels of solar radiation reaching Earth were hypothesised between the 1920s and 1940s by scientist Milutin Milankovitch. He argued that the elliptical orbit of the Earth is subject to three independent cycles of *change* that alter the *distance* between the Earth and Sun every 26,000, 41,000 and 100,000 years thereby producing our planet's periodic natural climatic cycles of global glaciation and warming. From the 1970s, the analysis of the gas content of ancient atmospheric air bubbles now trapped deep in Antarctic ice have confirmed the Milankovitch Cycles.

b. **Oceanic circulation *changes*:** the direction of ocean currents has *changed* regularly in recent geological times and many continents have experienced *changed* climates as a result. *Changed* ocean currents have an impact on the exchange of heat between oceans and the atmosphere. An example of this in the Pacific *region* affecting our weather patterns has been the impact of El Niño and La Niña on Australia's climate. Both El Niño and La Niña relate to *changes* in sea surface temperatures caused by ocean currents *changing*. El Niño relates to colder ocean temperatures and drier climates for the east coast of Australia while the west coast of South America receives wetter conditions (La Niña). When ocean currents *change* the reverse can happen with La Niña bringing unstable and wetter weather to Australia. At the planetary *scale*, thermohaline (part of oceanic) circulation transfers heat throughout the oceans, and past *changes* to these currents have caused major shifts in global climate. Ocean waters are also warming near the surface as mixing with cool deep water is declining.

c. **Volcanic activity:** this can cause significant amounts of dust and gases to be injected into the atmosphere. This in turn can lead to both warming and cooling events for the climate, depending on the matter being injected although the impacts tend to usually be short term. Masses of volcanic dust can lead to cooling when atmospheric dust intercepts or reflects incoming solar radiation, and the ejection of greenhouse gases from volcanoes can lead to very minor atmospheric warming. The Mount Agung volcanic eruption in Bali in 1963 produced enormous quantities of air-borne ash thereby blocking out sufficient incoming solar radiation to reduce global average temperatures by 0.5°C in the two years after the eruption. The last major eruption to have an impact on climate was the Mt Pinatubo eruption in the Philippines in 1991, which had a similar impact on global temperatures to the 1963 Mt Agung eruption. NASA has estimated that the five biggest eruptions this century have reduced global temperatures by only 0.2°C.

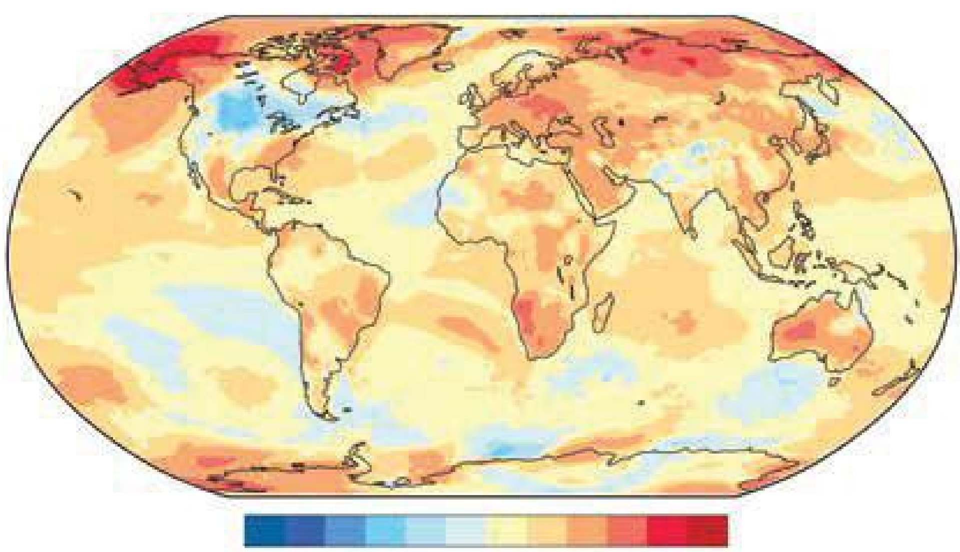
d. **Plate tectonics:** the *redistribution* of landmasses has long been caused by plate tectonics. This has led to long-term impacts on the climate as the *movement* of continents *change* oceanic and atmospheric circulation patterns. Landmasses have slowly drifted into different latitudes over millions of years, colliding with other landmasses. This has led to the formation of volcanoes and fold mountains such as the Himalayas that are growing at a rate of one centimetre per year. The Australian continent is moving north seven centimetres per year. The impacts of plate tectonics on climate tend to occur over long periods of time and vary considerably with location. Recent research in this area is investigating relationships between moving continents, *changing* ocean depths and ocean currents.

What are the human activities causing melting glaciers and ice sheets?

Since the beginning of the Industrial Revolution, people have significantly *changed* the appearance of the Earth's surface. Cities have incorporated factories, skyscrapers and increased numbers of residences; populations have increased rapidly; consumption of resources has increased; agriculture expanded; forests have been cleared; eco-systems *changed*; and travel opportunities broadened with the advent of rail and air travel. These and other *changes* have contributed to an accelerated warming of the Earth in the last 150 years and led to the coining of the term 'global warming'. Global warming implies that the trend over a period of time and over the entire planet is that of warming. This does not mean all *places* have warmed or that the rate of warming is equal. The Southern Ocean has recorded relatively little warming although heat absorption by the oceans has generally been significant and has delayed warming of land surfaces. The greatest rates of temperature increase have been recorded in the heavily industrialised countries of the Northern Hemisphere. Figure 7.31 shows the rate of temperature *change* on Earth in 2019 in comparison to the average temperatures between 1981 and 2010.

There are three main ways that people can contribute to the warming of climates.

1. **Alteration of the composition of gases in the atmosphere:** this factor is considered by scientists to be the greatest cause of global warming. Industrialisation has meant the increased injection of greenhouse gases such as carbon dioxide, methane, fluorocarbons, nitrous oxides and ozone into the atmosphere. Figure 7.32 shows the estimated *changes* in the concentrations of three selected greenhouse gases from pre-industrial times to 2018. It is interesting to note that the United Nations has estimated that 60 per cent of greenhouse gas emissions are from cities, yet cities only cover about 2 per cent of the Earth's surface. The destruction or degradation of natural systems, such as forests or swamps, that normally



Figre 7.31 Global temperature anomalies comparing 2019 to the 1981–2010 average

▼ **Figure 7.32** Atmospheric concentrations of greenhouse gases

Gas	Estimated preindustrial concentration*	2010 concentration	2018 concentration	Main human activity source
Carbon dioxide	288 ppm**	391 ppm	408 ppm	Fossil fuels, cement production, land use *change*
Methane	848 ppb***	1800 ppb	1869 ppb	Fossil fuels, rice paddies, waste dumps, livestock
Nitrous oxide	285 ppb	323 ppb	331 ppb	Fertilizers, combustion engines, industries

*The preindustrial value is for the 17th and 18th Centuries. There have been significant variations, as, for example, over the course of the ice ages.

**ppm = parts per million

***ppb = parts per billion

Source: Carbon Dioxide Information Analysis Center, Environmental Sciences Division, Oak Ridge National Laboratory (historical estimates), NOAA Annual Greenhouse Gas Index (2010 data), NOAA and WMA (2018 data).

trap and reduce (sequester) greenhouse gases such as carbon dioxide and methane also *changes* atmospheric composition and contributes to global warming. Methane release from vast areas of thawing sub-Arctic permafrost and from lake-bottom sediments is becoming a major issue and challenge.

2. **Alteration of landscapes:** this factor is considered to be the second most important in causing global warming. Considerable *changes* in solar radiation absorption (albedo) are created by the construction of hard surfaces in cities, the clearance of forests for agriculture and many other modifications to the landscape. These landscape *changes* lead to the retention of heat near the Earth's surface, enhancing the greenhouse effect. Urbanisation *changes* soil moisture balances as impervious surfaces replace porous ones causing heat islands to develop. Removing forests for crops reduces evapotranspiration and *changes* the dynamics of radiation created by forest canopies. This *change* in albedo leads to additional heat being retained which causes *changes* in moisture levels in the atmosphere and thus wind patterns, and heat and moisture transport across continents.

3. **Direct addition of heat to the atmosphere:** many of the activities associated with everyday life directly add heat to the atmosphere. Burning fossil fuels for electricity production, transportation (planes, cars, ships etc.), heating and cooling of residences and workplaces, and ovens and household appliances are good examples of this. This addition of heat can have localised impacts but is not thought to be a major influence on global climatic warming.

Burning fossil fuels such as coal, oil and natural gas, and the clearing and burning of forests contributes to most of the estimated increase in carbon dioxide. The burning of forests is somewhat of a double impact. Burning adds carbon to the atmosphere as well as removing the forests that naturally remove ('sequester') carbon from the atmosphere via photosynthesis and store the carbon in the roots or trunks of trees. As greenhouse gases absorb outgoing infrared radiation higher greenhouse gas concentrations lead to the warming of the lower atmosphere. This leads to an enhanced greenhouse effect. Ironically, carbon dioxide increases plant growth and this can lower land surface albedo by increasing plant cover, thereby increasing heat retention.

The recent 2019 and 2020 Australian bushfires demonstrated how bushfires can impacts on glaciers. Significant amounts of ash and dust from these fires were blown across the Tasman Sea and deposited on the New Zealand's more than 300 glaciers. Glaciologists believe that this may have sped up melting by 20 to 30 per cent in the 2019–2020 summer.

There is an increasing body of evidence to show that other human activities have contributed to declining volumes of ice. The layers of cryoconite being found in Greenland have already been mentioned (see pages 89–91) while in many other *places* around the world links have been made with other activities.

In Switzerland, for example, declining glacier sizes have been linked with the increase in tourism to the Alps from the 1860s. Wealthy tourists wanting to get close to the slopes for snow sports encouraged the building of resorts and railways, and the burning of coal caused soot and particulates to be deposited on the ice increasing the rate of melting.

Tourism is also estimated to be responsible for 5 per cent of global greenhouse gas emissions. Research from both Norwegian and Swiss scientists has identified that as ice cover recedes in the European Alps, winter sport enthusiasts are tending to move further afield to pursue snow sports and other snow- and ice-based recreational opportunities. This is creating more demand for flights and increased flying times, placing increased pressures on ski resorts to increase and improve infrastructure. All of these activities increase greenhouse gas emissions.

The melting of glaciers and ice sheets has also led to increases in a new sector of the tourism market, that of climate *change* tourism. Tourists are flocking to destinations that have been identified to be in danger of disappearing in the future. Visits to Antarctica are increasing at about 6 per cent per year, tourism to Iceland and Greenland has soared and each year there are more visits to Mt Kilimanjaro in Tanzania where 85 per cent of its glacial ice has been lost since 1912. Other *places* where tourism numbers have increased significantly are Patagonia and Alaska.

In other parts of the world other human activities such as land clearing and farming have led to particulate matter such as soil and dust being taken by air currents and deposited on snow areas accelerating melting.

Globally, increased long-*distance* dust deposition from accelerated desertification is a major cause of reduced albedo on ice surfaces and therefore increasing ice melt. For example, dust deposits from the Sahara Desert accumulate on some central European glaciers and feed microscopic algae which in turn reduces ice albedo and increases ice melt.

ACTIVITIES

1. With reference to the natural causes of climate *change*, evaluate each of these causes and how they might influence the advance or retreat of ice and snow locally and *regionally*.
2. Refer to Figure 7.29.
   a. Compare the rate of warming between the Northern Hemisphere and Southern Hemisphere. What similarities and differences did you notice?
   b. How can you account for the differences between both hemispheres?
3. Describe the trend apparent in Figure 7.30.
4. Refer to Figure 7.31.
   a. The rates of temperature *change* across the world in 2019 are not uniform. Identify and describe the areas that are warming the most and areas that are showing very little *change*.
   b. What explanations could explain the patterns you described in question 4(a)?
   c. Antarctica's ice cover is receding even though this figure shows parts of Antarctica are getting colder. Why might this be the case?
5. a. The concentration of methane in the atmosphere has increased at a far greater rate than other greenhouse gases as shown in Figure 7.32. Why might this be the case?
   b. Which of the human activities listed in the Figure 7.32 table that lead to increased greenhouse gas emission would be from urban areas?
6. Look at the natural and human causes of climate *change*. Do some research to find real-world examples of these causes other than those mentioned in this chapter.
7. Numbers of people participating in climate *change* tourism have increased dramatically. How might this increase in tourism numbers contribute to the depletion of glaciers and ice sheets?

What are the impacts of melting glaciers and ice sheets?

Images of *changing* ice cover on ice sheets and stories of melting ice have dominated the media for many years. The decline in ice cover on ice sheets and glaciers can have many impacts on the social and economic wellbeing of the population as well as the *environment*. As with climate *change*, the current impacts of declining ice cover vary in scope according to location, as do the predicted impacts. The most obvious *change* with declining ice cover is a *change* in the *distribution* of water.

Declining ice cover can lead to a range of impacts including sea level rise, people *movement*, agricultural output *change*, *changes* in freshwater *distribution*, *change* to plant and animal communities, disease and natural disasters.

1. **Sea level rise:** it is estimated that during the 20th Century sea levels rose by about 20 centimetres (or 0.2 metres). Predictions from scientists have estimations of sea levels rising by another 20 to 60 centimetres by the year 2100. Much of the rise can be attributed to thermal expansion. Water, like many other substances, expands as it warms. As the climate continues to warm this expansion will continue at greater rates in the future. As glaciers retreat and ice sheets melt, there is also a *change* in the rates of heat absorption as ice is more reflective than water. A good example of a *change* in the *distribution* of ice is in the Glacier National Park in the state of Montana in the USA, where there were 150 glaciers in 1850. There are currently 25 left with the rest predicted to melt in the next 15 years. Greenland is losing approximately 249 cubic kilometres of ice directly into the sea per year.

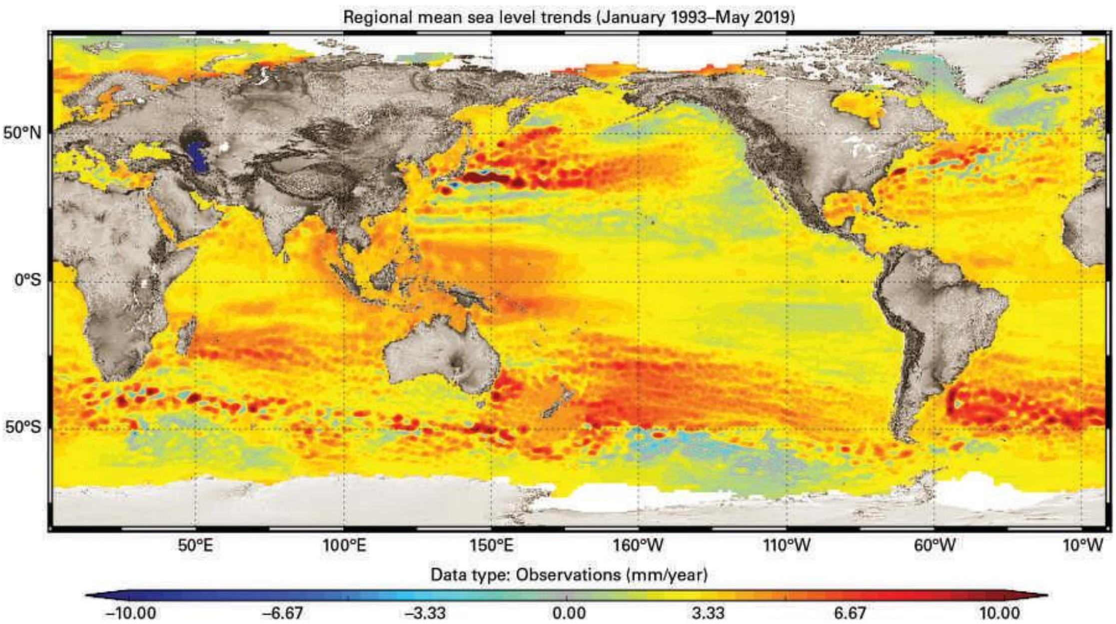
   All meltwater eventually ends up in the oceans contributing to a direct rise in sea level.

   The rising sea level is making many coastal *environments* vulnerable to storm surges and other impacts of rising sea water. It is thought that two-thirds of all cities with a population of over five million people are at risk from sea level rise and the Organisation for Economic Co-operation and Development (OECD) has listed the 20 most vulnerable cities across the world to coastal flooding (see Figure 7.33). Figure 7.34 shows a visualisation created by NASA that summarises global sea level *changes* over a 26-year period between 1993 and 2019. Sea level *changes* are varied with the highest sea level rise recorded in the Western Pacific *region*.

   The Bureau of Meteorology in Australia is currently monitoring sea levels in the South Pacific *region* to generate data related to rising sea levels. They have supplied tide gauges to 12 South Pacific countries to monitor and predict tidal ranges. These gauges are linked to geodetic monitoring stations

▼ **Figure 7.33** Top 20 cities at risk from coastal flooding

Rank	Country	Urban agglomeration	Exposed population (2007)	Exposed population (2070)
1	India	Kolkata (Calcutta)	1,929,000	14,014,000
2	India	Mumbai (Bombay)	2,787,000	11,418,000
3	Bangladesh	Dhaka	844,000	11,135,000
4	China	Guangzhou	2,718,000	10,333,000
5	Vietnam	Ho Chi Minh City	1,931,000	9,216,000
6	China	Shanghai	2,353,000	5,451,000
7	Thailand	Bangkok	907,000	5,138,000
8	Myanmar	Rangoon	510,000	4,965,000
9	USA	Miami	2,003,000	4,795,000
10	Vietnam	Hai Phòng	794,000	4,711,000
11	Egypt	Alexandria	1,330,000	4,375,000
12	China	Tianjin	956,000	3,790,000
13	Bangladesh	Khulna	441,000	3,641,000
14	China	Ningbo	299,000	3,305,000
15	Nigeria	Lagos	357,000	3,229,000
16	Côte d'Ivoire	Abidjan	519,000	3,110,000
17	USA	New York–Newark	1,540,000	2,931,000
18	Bangladesh	Chittagong	255,000	2,866,000
19	Japan	Tokyo	1,110,000	2,521,000
20	Indonesia	Jakarta	513,000	2,248,000



▶ **Figure 7.34** Global sea level *changes* as detected by satellites between 1993 and 2019

run by Geoscience Australia that use GNSS (Global Navigation Satellite Systems) to collect absolute measurements of vertical tide height. Some scientists have estimated that if sea levels rose one metre, then 15 per cent of Pacific Islands will be inundated.

Rising sea levels will reduce the amount of land where a rapidly increasing population can reside. This has implications on the size of settlements, the amount of land that can grow food and on natural *environments*.

2. **People *movement*:** declining ice cover will also have an impact on peoples who rely on glaciers and ice sheets for their livelihoods and those affected by rising sea water. This includes indigenous peoples such as the Inuit in Alaska and Canada, residents of towns reliant on activities in these areas, Pacific Islanders and many others.

In Nunavut territory in Canada, Inuit hunters have seen reduced numbers of species that form the basis of their diets such as the ringed seal, polar bear and narwhal. There has also been a *change* in the migration patterns of some species, which has seen traditional species moving away or being out-competed for food. Research by Yale University showed that, traditionally, Inuit kill around 60 narwhals each year for food. In 2012, Inuit killed only three narwhals. They observed killer whales (usually not found in the area) kill many narwhals or scare narwhals away. As food sources are becoming insecure many Inuit are being forced to move to settlements and live in non-traditional ways. This has had many negative impacts on Inuit culture and lifestyle.

In the South Pacific, residents of the island of Tuvalu have become 'climate refugees' and have had to be evacuated because of coastal flooding. Many of these people have now had to leave their country and reside somewhere else.

3. **Agricultural output:** the retreat of ice sheets and glaciers has a major impact on food supplies and the food security of many communities. Water resources become unreliable and crop failures increase. In Peru, Bolivia and Ecuador, many of their combined population of 53 million people are reliant on food grown by water supplied by glaciers in the Andes. Figure 7.35 shows a fertile valley in the high Andes that is fed by water from glaciers.

   The United Nations Development Programme (UNDP) has estimated that crop yields will decline by 30 per cent by 2050. This situation is replicated in Central Asia where many countries are reliant on water from glaciers in the *region*. In addition to this, many of the world's most productive food bowls are on river deltas that are the most susceptible areas to sea level rise causing soil salinisation and inundation. River deltas in Asia such as the Mekong and Ganges grow 90 per cent of the world's rice.

4. **Freshwater resources:** the *change* in the *distribution* of fresh water is complex. Glaciers store about 75 per cent of the world's fresh water and act like natural reservoirs, storing water in winter and releasing water in summer. Warming climates are *changing* levels of run-off with associated *changes* in water temperature and peak stream flow. This leads to *changing* water *distributions*, and communities reliant on water are having to adapt to unreliable amounts of water. Increased melting can lead to enlarged glacial lakes and outburst flooding, as rising water levels cause lake banks to burst. Much of the water from melting glaciers generally ends up in the sea, becoming salty, and is lost as a freshwater source. As time goes by and glaciers continue to retreat, this situation can accelerate and water supplies can become scarce, meaning communities reliant on water will have to move or *change* their ways of living. This cycle has already happened in many *regions* of the world including the Himalayas. Once the glacier is gone that water source is lost, at least for thousands of years until the water cycle allows evaporation and sublimation from the ocean to return fresh water to the land.

5. **Plant and animal communities:** there are many species of plants and animals that depend on glaciers and ice sheets for their survival. These animals lose their habitat as ice retreats. The loss of ice and *changes* in temperature can lead to migration pattern *change*, altitude *changes* and reproduction *changes*. Each of these *changes* can have wide-ranging implications on food chains. As water temperatures are rising around Antarctica, krill numbers have declined markedly. Along with massively increased fishing by humans, this has caused Adélie penguins to die of starvation and many other species reliant on krill to decline in numbers. Scientists are particularly worried about species loss and extinction, and a loss of biodiversity as mountain ecosystems, polar ecosystems and tundra *change*. As climates warm these ecosystems are declining in area, and bordering ecosystems can expand into areas previously characterised by colder climates and higher altitudes. The warming of the climate and sea level rise are also causing great concern about coastal ecosystems and coral reefs.

6. **Disease:** as temperatures warm, there is a concern that many diseases and disease carriers such as mosquitoes and ticks will expand their spread and range. This could have devastating impacts on people and animals living in cold *places* where the cold has prevented these diseases from spreading. Malaria is one disease predicted to expand its range as climates warm.

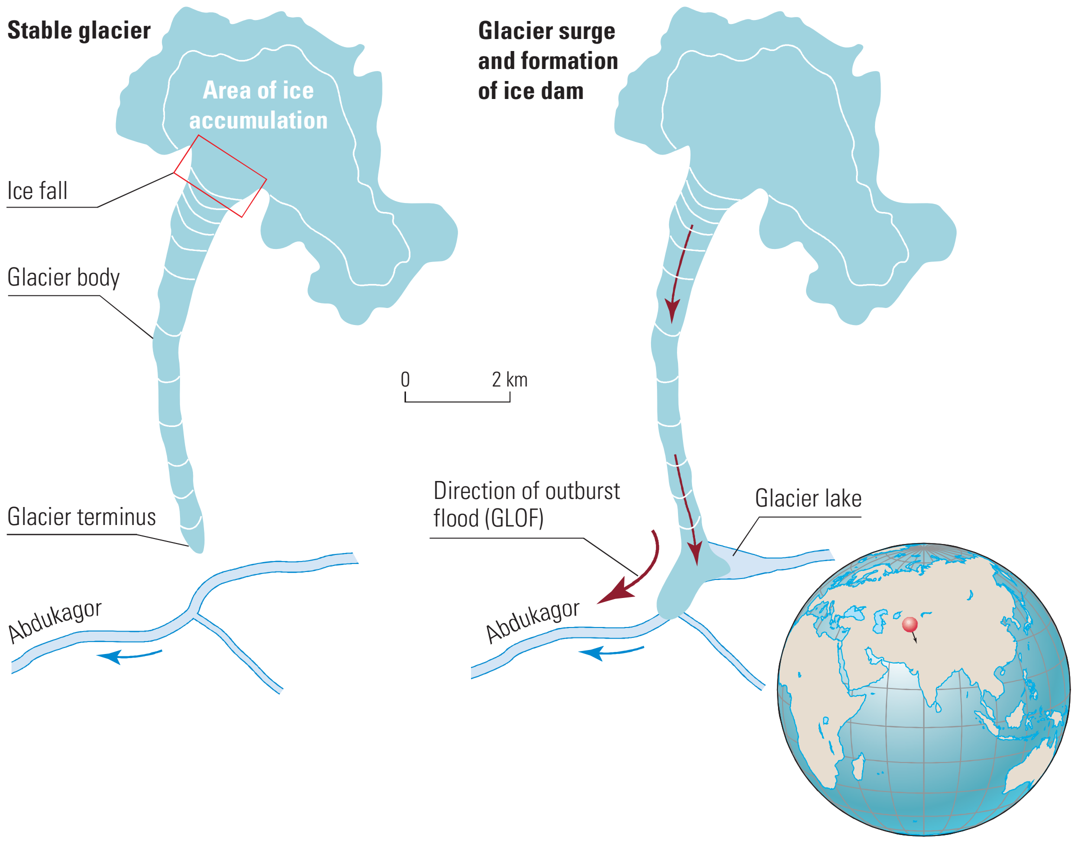
Figure 7.35 Corn growing in the high mountain valleys of Peru over 3000 metres above sea level

7. **Natural disasters:** the melting of ice sheets and glaciers is leading to many more natural disasters, particularly flooding, as GLOFs (glacial lake outburst flood) increase in frequency across the globe. This has devastating impacts on villages downstream from glaciers. Expanding populations and deforestation have made the impacts of these floods worse particularly in Himalayan *regions*. Flooding can *change* ecosystems considerably as it can lead to *changes* in a river's course and sediment deposition, while pollutants stored in glaciers and ice sheets over many years can be released. Figure 7.36 depicts how a GLOF occurred at Medvezhiy Glacier in Tajikistan, and Figure 7.37 shows the increase in GLOF frequency in High Mountain Asia.

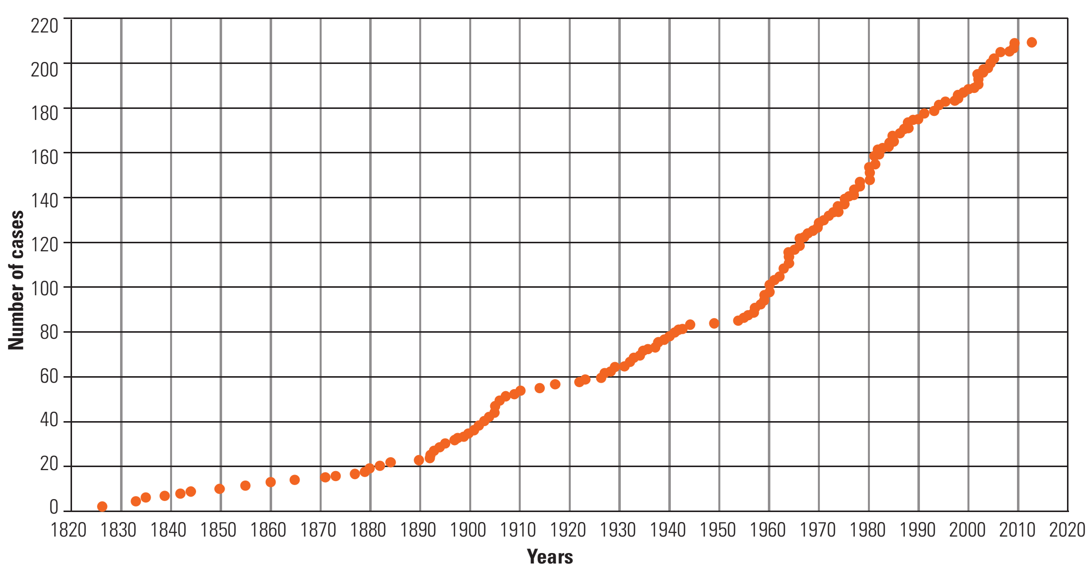
In developing countries, the impacts of GLOFs have been even more pronounced as infrastructure such as roads, bridges, hydroelectricity power stations and residences are destroyed.

It is also thought that the huge weight of glaciers suppresses earthquakes. A cubic metre of ice weighs about one tonne and NASA suggests that the melting of ice causes pressure to be reduced on the tectonic plates making them freer to move and possibly generate earthquakes.

▶ **Figure 7.36** Glacial outburst flood at Medvezhiy glacier



▼ **Figure 7.37** Occurrence of glacial lake outburst flood (GLOFs) in High Mountain Asia 1826–2011



▶ ACTIVITIES

1. There are seven major categories that summarise the consequences of melting ice sheets and glaciers. Create a table that summarises each of the seven categories, the impact of each and how the impact is currently being monitored.
2. a. Using an atlas, locate each of the cities listed in Figure 7.33. What similarities and differences can you identify between their respective locations?
   b. Describe the patterns evident in sea level *change* in Figure 7.34.
   c. Predict which urban areas in Figure 7.33 might be at greatest risk given the patterns you described in question 2(b).
3. Food and water security are major challenges in the 21st Century as populations increase, and *environments* and climates *change*. Create a before/after diagram that explains how melting glaciers are leading to food and water issues for many people.
4. Climate *change* is causing many *changes* to the migration patterns of birds and animals across the planet. Conduct some research to find other examples of migratory *changes* other than those covered in this chapter.
5. Explain the term 'climate refugees.' Predict the impacts of increasing numbers of climate refugees from *places* such as Bangladesh, Maldives and Pacific Islands.
6. Referring to Figure 7.37, describe the trends in GLOFs in High Mountain Asia.

The use of geospatial technologies to assess melting glaciers and ice sheets

Historically, the assessment of glacier advance and retreat has been quite difficult as areas where glaciers are found are often difficult to access, have extreme climatic variations and little, if any, permanent human settlements. Until the late 20th Century the most common way to assess glacier *change* and assess whether the glacier was retreating or advancing was to examine the glacier at its terminus and observe *changes* in colour and debris cover. *Changes* in colour and debris cover could indicate different pattern of ice accumulation or ablation, especially because darker ice surfaces absorb more heat and therefore melt faster.

If more technical measurements were required, such as *changes* in speed, width or depth, scientists would have to complete sets of measurements that usually involved digging ice pits and placing marker poles on accessible parts of the glacier then using surveying techniques over time and complex mathematical calculations to monitor *change*. Consequently, there is more historical data available for glaciers that were easier to access in Switzerland, USA and Iceland rather than glaciers in the Himalayas, Antarctica and the Andes where historical data is scarce or even non-existent.

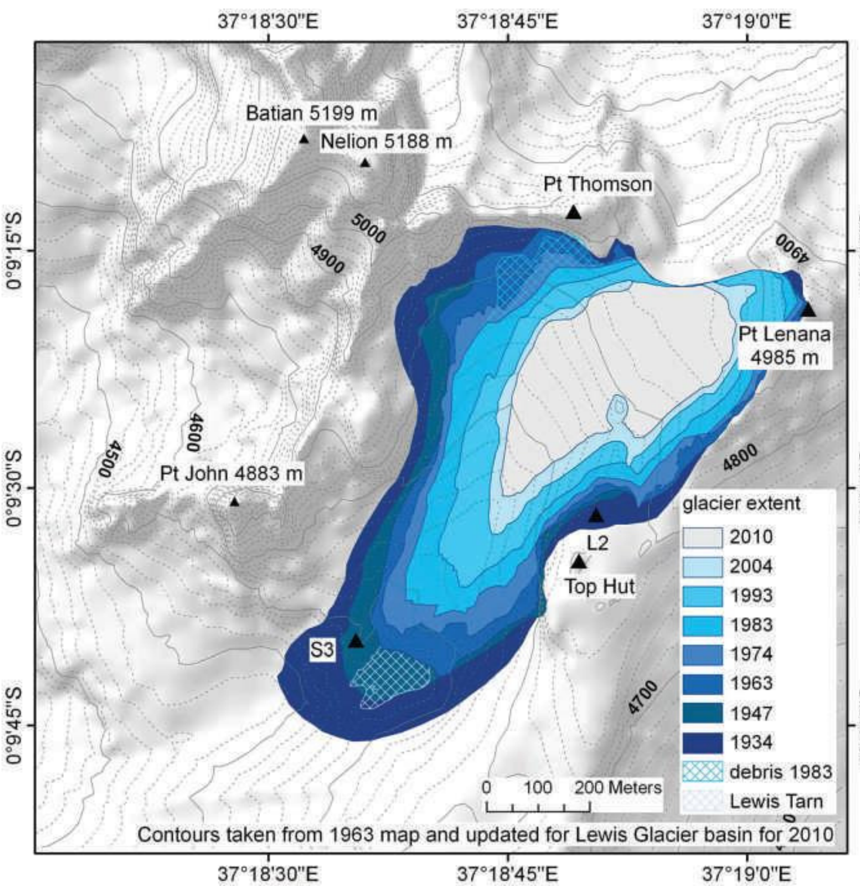


Figure 7.38
This map of ice cover *change* on Lewis Glacier, between 1934 and 2010 was constructed using a combination of historical and recent methods

The development of new geospatial technologies and an understanding of how to interpret this data is allowing scientists to monitor glacier *changes* more easily. These technologies are also creating large data sets that are giving scientists a better understanding of the complex relationships that impact on *changes* in ice *distribution*.

Geospatial technologies being utilised include:

- Remote sensing where information collected from a range of satellites is interpreted. The information collected includes digital elevations, satellite images and topographical data. This data allowed for the construction of Figure 7.28 showing the *changes* in ice cover of Qori Kalis Glacier.
- The ICESat-2 satellite launched by NASA in 2018 that measures polar ice height on Antarctica and Greenland to a couple of centimetres (the width of a pencil) using the latest laser altimeter technology.
- The use of GIS to map data sets. Digital data held in the Global Land Ice Measurements from Space (GLIMs) data sets and National Snow and Ice Data Center (NSIDC) are compatible with GIS to enable improved interpretation.
- Optical sensors that measure levels of solar radiation and surface reflectivity (called albedo) can be useful for thermal readings to predict ice freezing and melting.
- GPS tracking and tracking software can be accurately used to map images taken of glacier retreat so that accurate representations can be constructed. Figure 7.38 shows a map constructed from historical mapping methods, aerial photographs and satellite images of Lewis Glacier in Kenya from information collected from 1934 to 2010.
- Use of GNSS to provide highly accurate data on glacier *movement* and sea level rise. Sensors can be permanently placed in various locations and tracked via use of GNSS antennae to provide real time data. Icelandic glaciers are mainly monitored this way and this technology provides significant cost saving benefits.
- Climate models are built from satellite data at NASA's centre for climate simulation and a supercomputer built by the Japan Meteorological network uses climate data collected from a range of sources to predict patterns of glacial melting. These models and predictions can be used by a range of NGO's and governments to plan future actions.

How have people responded to melting glaciers and ice sheets?

Reduction in the area and volume of ice sheets and glaciers has long been the most visible indicator that climates are warming. Consequently, many of the responses to glacier and ice sheet retreat are *interconnected* with other responses to reduce human contributions to global warming.

Immense amounts of data are being collected and analysed from a range of sources and perspectives by many groups around the globe including UNEP, IPCC, NSIDC, NOAA and numerous universities. Sometimes, offshoots of other groups are created to concentrate approaches to particular aspects of an issue – such as the World Glacier Monitoring Service (WGMS), a branch of UNEP, or action groups such as Stop Global Warming Now. The responses to glacier and ice sheet decline are using ever-increasing levels of geospatial technologies that integrate remotely sensed data and direct field observations as discussed in the previous section.

Although there have been irrefutable trends in climate warming and reams of other evidence related to glacial melting available for over a decade, many governments around the world have been reluctant to act on this evidence for a variety of reasons. The USA and Australia are among many countries that initially refused to ratify the Kyoto Protocol, and Canada withdrew after not being able to meet its carbon targets.

Apart from monitoring glaciers, Figure 7.39 shows a brief selection of hundreds of responses to glacier and ice sheet retreat.

ACTIVITIES

1. Some glaciers in the Himalayas only have data available about their respective ice cover from fairly recent times. Explain why this is the case.

2. a. Using Figure 7.38 showing ice recession at the Lewis Glacier in Kenya, complete sketches of the glacier's extent in 1934, 1983 and 2010 (try and keep the diagrams to *scale*).

b. Comparing the sketches you have made and using Figure 7.38, calculate the approximate rate of decline of Lewis glacier.

c. Lewis Glacier is located on Mt Kenya, the second highest mountain in Africa and is the last glacier left on this mountain. Given the rate of *change* you calculated in question 2(b), predict when Lewis Glacier will cease to exist.

3. How can the use of geospatial technologies increase knowledge about glacier characteristics?

4. In your Geography class, divide into groups and research the nine categories in Figure 7.39 in more depth. Each group needs to explain to the rest of the class why their category will be the most effective in reducing global warming.

5. After listening to the opinions of your classmates, which of the nine categories of responses listed in Figure 7.39 do you think will be the most effective? Explain your reasoning.

6. What criteria could you establish to help evaluate the effectiveness of each of the responses listed here?

7. You have just been employed to implement actions to reduce the melting of the world's glaciers. What are the things you would do immediately to reduce ice melting?

8. Why do you think many countries have been slow to act in relation to reducing the causes of global warming?

9. Evaluate the following statement:

'The only way to reduce the rate of glacier and ice sheet melting is to reduce the amount of carbon being added into the atmosphere.'

Figure 7.39 Responses to ice sheet and glacier retreat

Response	*Scale* of response	Groups responding	Nature of the response	Examples
Climate action groups	Mainly global and often promoted extensively with social media	Greenpeace Australian Conservation Foundation World Wildlife Fund (WWF)	Creating publicity and providing information about how to reduce global warming	Groups advocating for carbon neutral housing, promote awareness of food miles, alternative energies and use of public transport
		Union of Concerned Scientists		A group of scientists based in USA who promote scientific solutions to global issues
		Let's create a climate for change		A group that links all climate *change* groups in Australia together to inform climate debate. It also raises funds to train facilitators to spread the latest research about climate *change*
		School Strike for climate		Greta Thunberg used social media to encourage students to protest about climate *change*. This movement starting in Sweden, has gone global with rallies all over the world in September 2019
International collaborations	Global	United Nations Interest groups, countries	Open discussions leading to action and policies about carbon emissions	The Kyoto Protocol was created after the United Nations Framework Convention on Climate Change (UNFCCC) was ratified in 1997, setting carbon emission goals. 184 countries have signed the protocol The Marrakesh Accord in 2001 developed the protocols further. There have been many climate summits eg: the Lima Climate Summit of 2014, Paris Agreement in 2015, UN Climate Summit 2019 in New York, COP 25 in Madrid 2019, and UN Climate Action Summit 2020
		IPCC (Intergovernmental Panel on Climate Change)	A body created by merging branches of WMO (World Meteorological office) and UNEP (United Nations Environment Programme). The IPCC is comprised of researchers who collect and analyse data and write reports about how to best respond to the social, economic and *environmental* impacts being created by anthropogenic climate *change*	IPCC's assessment report monitoring current research is published regularly. IPCC 5 was published in 2015 and IPCC 6 is due in 2022 Special Report on Global Warming 2018 Special Report on the Ocean and Cryosphere in a Changing Climate 2019
Emission trading schemes and congestion tax	*Regional*	European Union	An economic solution to put a price on carbon so that companies have to offset carbon or pay for their emissions	The EU Greenhouse Gas Emission Trading Scheme is a binding agreement across all EU countries so that Kyoto targets can be met. A 2020 study on this reported that the scheme in Europe reduced carbon dioxide emissions An Australian version of this scheme "the carbon tax" was repealed by the Abbot government in 2014
		South Korea	National trading emissions scheme	The second largest trading scheme in the world behind the EU
		UK, Sweden, Singapore, Italian Governments (and many others)	A tax placed on cars using congested roads to try and reduce traffic and air pollution and encourage more people to use public transport	London Tax is approx. A$20 per day Milan Tax approx. A$10 per day Electric vehicles are exempt in many *places* Most European countries subsidise the purchase of electric vehicles

▼ **Figure 7.39** *continued*

Response	*Scale* of response	Groups responding	Nature of the response	Examples
Public awareness and publications including newspapers, videos, magazines	Global	Variety of authors and groups	Avenues to make people and groups aware of current issues and opinions	Former US vice president Al Gore released the movie "An Inconvenient Truth" to make people aware of climate trends and issues. This was followed up with "An Inconvenient Sequel" in 2017. In 2020 the ABC released a three-part series "Fight for Planet A: Our Climate Challenge"
Clean and green energy solutions	Often national with international collaborations	Clean Energy council, Conservation groups	Advocate for energy sources that do not burn fossil fuels and don't release carbon such as wind, solar, hydro and nuclear	Massive solar projects are being constructed in India, Mexico, Japan and Australia that will power industry without emitting carbon products into the atmosphere Mega wind farm projects have become popular in USA, China, India and UK. Australia has 47 wind farms (2020). The biggest is the Stockyard Hill Wind Farm in Victoria that generates 530 megawatts
Monitoring of glaciers and ice sheets	Global	UNEP, NOAA, NASA,	Collaborative networks like the Global Terrestrial Network for Glaciers (GTN-G). This network links the WGMS and NSIDC and is made up of scientists globally collecting and share data about specific glaciers and ice sheets. They use Global Ice Measurements from Space (GLIMS) as well as data collected in the field. This improves knowledge and understanding about glacial *change* that can be shared with other groups and organisations	The European Space agency has had a number of *environmental* satellites orbiting around the Earth since the 1990's. examples are Satellites ERS-1 and ERS-2 which are remote sensing satellites and are responsible for collecting information about land, water, ice and atmosphere. NASA's Ice, Cloud and land Elevation Satellite-2 (ICESat-2) launched in 2018, measures the average annual elevation *change* of land ice covering Greenland and Antarctica to within the width of a pencil, capturing 60,000 measurements every second
Addressing water security issues	Local and *regional*	Governments, action groups, townspeople, NGO's	Finding solutions to decreasing water supplies caused by reduced water flows as glaciers reduce in size	Farmers in South America and Himalayan countries are being assisted by various NGO's to grow crops that require less water such as grapes, cotton and nuts. In Nepal measures are being implemented to reduce water consumption and improve efficiency as water flows are expected to decrease by 20 to 30 per cent by the middle of this century
Disaster management	Local, *regional*, international	Governments, action groups, townspeople, NGO's UNEP, European Commission, Red Cross and Red Crescent	Creating solutions and management plans to deal with increasing disasters related to the decline in ice coverage such as GLOFs, mudslides and avalanches	In Pakistan, Nepal, India, Tibet and Bhutan GLOFs have increased in frequency causing huge damage. More than 75 glacial lakes have been identified as being potentially dangerous in these countries and measures are being taken to reduce water volume in lakes and install early warning systems. Community based approaches have been implemented in India and Pakistan where communities are educated about the risks of GLOFs and monitor lake stability
Reafforestation schemes	*Regional*	Emission traders, conservationists, UNDP, NGO's	Forests have been planted in many *places* to sequester carbon, hold slopes together, *change* land surface albedo, conserve soil, protect animal habitats and reduce air temperatures	Examples of these schemes can be found in Japan, Canada, UK, Australia, Italy, Nepal, Peru and Norway. In Tibet a project is about to begin that will afforest land at the headwaters of 6 rivers. The project is estimated to cost US$4.8 billion

CASE STUDY Kyrgyzstan

The Himalayas orogenic belt formed from the collision of the Eurasian and Indian tectonic plates and created mountain ranges that are home to approximately 56,000 glaciers. These glaciers act as water storage for approximately 1.9 billion people. Using photographs from Cold War spy satellites owned by the US government, scientists have created a more than 50-year picture of glacial retreat using the largest 650 glaciers in this *region* as a reference. These glaciers are retreating at an average of 0.43 metres annually over the 50 years and this is putting significant pressure on many people living in these *regions*.

The Tien Shan Mountains are part of the Northern Himalayas and run for 2900 kilometres mainly straddling the border between Kyrgyzstan and China. Kyrgyzstan, a land-locked country with a population of 6.3 million people and a former part of the Soviet Union, has 80 per cent of its land area dominated by the Tien Shan Mountains that can reach over 7000 metres above sea level making it a country with one of the highest average elevations in the world. Kyrgyzstan has more than 7000 glaciers that cover over 30 per cent of the land area of the country. Figure 7.40 shows some of the geographic features of the country. Kyrgyzstan was one of the subjects of the US spy satellite photos from the 1960's. The importance of these photos cannot be underestimated as due to political strife associated with the collapse of the Soviet Union very little monitoring of glaciers took place. Political stability in Kyrgyzstan was only recently achieved in 2011. This *region* is also of special interest to scientists as some of the fastest retreating glaciers on the planet are found here and the success of responses made here will be instrumental in informing policies related to global glacier retreat. Added to this is the fact that six major river systems that provide water to other Central Asian countries have their source in Kyrgyzstan. These countries: Kazakhstan, Uzbekistan and Tajikistan are becoming increasingly concerned about the stability of their water supply.

The people of Kyrgyzstan, who are mainly from the Kyrgyz ethnic group, are highly reliant on the water emanating from the more than 7000 glaciers located here. Kyrgyzstan is one of the poorest country's in Central Asia with an estimated 25 per cent of the population living below the poverty line. Water from glaciers supplies 85 per cent of the countries drinking water as well as supporting a diverse range of agricultural produce that is harvested from significant tracts of irrigated crops and pastures. Figures 7.41 and 7.42 show the yurts of nomadic sheep and goat herders in the foothills of the Northern Tien Shan Mountains and agricultural areas fed by water from glacier melt in the Central Tien Shan Mountains. Agriculture employs half the country's population as well as comprising 36 per cent of Kyrgyzstan's GDP (Gross Domestic Product). Hydroelectricity is Kyrgyzstan's main source of electricity with 75 per cent of the country's power coming from seven hydroelectricity plants, many of them fed by glacial meltwater. Exporting energy from these hydroelectric plants is the country's biggest export earner with revenue from mining generating

▼ **Figure 7.40** Glaciers, rivers and lakes of Kyrgyzstan

▲ **Figure 7.41** The yurts of nomadic herders in Kyrgyzstan

▲ **Figure 7.42** Aerial photograph of irrigated cropland in Kyrygyzstan

the next greatest source of revenue for the country. Kyrgyzstan has large deposits of gold, uranium, mercury and rare earth minerals. As Kyrgyzstan does not have any of its own oil or gas, the cost of importing these fossil fuels is prohibitive. This negates the revenue earned from exporting electricity and minerals. Consequently, the Kyrgyzstan government is looking to expand mining operations.

The longest glacier in Kyrgyzstan is Engilchek Glacier which is 60 kilometres in length and there are eight glaciers that have been extensively monitored since 2010 in the Tien Shan Mountains. Seven of the eight glaciers are located within Kyrgyzstan and one glacier is found just over the border in Kazakhstan. Each of these glaciers' *changes* in mass balance have been widely published by researchers who are connected with a range of global glacier research networks. In the period between 2016 and 2019 seven of the eight glaciers being monitored showed a decrease in average glacier length of approximately 0.6 metres per annum. Another glacier in the Central Tien Shan Mountains, Bordu Glacier, which only started being monitored recently has shown an even greater ice loss with a retreat of just over 4 metres in the 4 years to

2020. The average decline of a glacier in the Himalayas over this 4-year period has been 0.5 metres per year.

Comparing the current *distribution* of glaciers to the photos from 50 years ago, it is estimated that the extent of Kyrgyzstan glaciers has decreased by between 30 to 35 per cent. Over the last decade, the impacts of melting glaciers have been causing increasing concern for the people of Kyrgyzstan. The Kyrgz Academy of Science has identified 199 glacial lakes that have the potential to turn into GLOFs (glacier lake outburst flood) with increased melting.

The frequency of GLOFs has been increasing with floods and debris flows becoming an increased hazard for many. There have been 22 GLOFs since 1952 and the size of these events has shown a marked increase. UNICEF has identified Kyrgyzstan as one of the 36 countries globally that will be most impacted by water stress in the next decade. In the last 20 years it is estimated that the average annual surface temperature has increased by 1.2°C in this *region* and the country's dependence on melt water for energy and agriculture make it highly vulnerable to further warming of the climate. In the last eight years there have also been two major droughts that have led to significant food supply issues and increased worries about future food security as crop yields have declined. A study published in 2016 showed that a combination of increasing landslides and floods, as well as land degradation and water availability issues are initiating *environmentally* induced migration within Kyrgyzstan. The people moving are mainly involved in agriculture and animal husbandry and this is leading to significant pressures being placed on other fertile farming *regions* in the country.

Warming temperatures have also led to *changes* in infectious and vector borne disease patterns. Scientists are concerned about increasing mosquito and tick habitat as well as a rise in diseases attributed to poor water quality and inadequate sanitation such as cholera, typhoid, hepatitis, and noroviruses.

The shrinking of ice area and volume has also led to considerable interest in exploring exposed slopes by mining companies who are particularly interested in rare earth mineral deposits due to the increasing use of these minerals in mobile phones and computers. Scientists are worried that mining activities might accelerate the rate of glacial melting. The biggest mine in Kyrgyzstan, the Kumtor open cut gold mine, is over 4000 metres above sea level. Blasting, gold processing and the operation of equipment at this mine has led to dust, ash and particulates depositing on the ice as well as contamination of water. Two glaciers nearby to this mine no longer have any ice.

In 2018 the United Nations Environment Project (UNEP) launched the Vanishing Treasures project designed to protect vulnerable mountain species, and conserve mountain ecosystems and their biodiversity. The project recognised that Kyrgyzstan ecosystems were experiencing drastic *changes* in snow cover and glacier extent and that a keystone species of the mountainous *regions*, the Snow Leopard, is having its habitat severely eroded by *changing* climate and human activities. Figure 7.43 shows a snow leopard pictured at more than 5000 metres above sea level. Many other animal species are also threatened in this *region* including the Dhole, Tien Shan Squirrel and Menzbiers Marmot. In the last decade, numerous organisations have become established across the country to respond to issues and challenges associated with Kyrgyzstan's melting glaciers.

One of the few glaciers that has been extensively studied in Kyrgyzstan is the Golubin Glacier (see Figures 7.40 and 7.44), located in the Northern Tien Shan Mountains. The glacier is found 3400 metres above sea level and it covers an area of 5.45 square kilometres (2017). This glacier has been researched since 1958 and mass balances reported from 1969 to 1994. A pause in the monitoring of this glacier occurred as Kyrgyzstan gained its independence from the Soviet Union, with measurements of the Golubin Glacier restarting in 2010. Monitoring

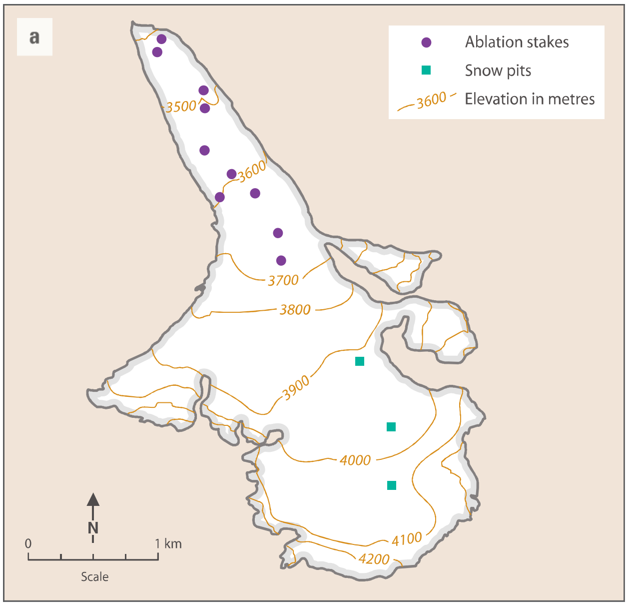
▲ **Figure 7.43** Snow leopard in high mountain Kyrgyzstan

▲ **Figure 7.44** Golubin Glacier, Kyrgyzstan

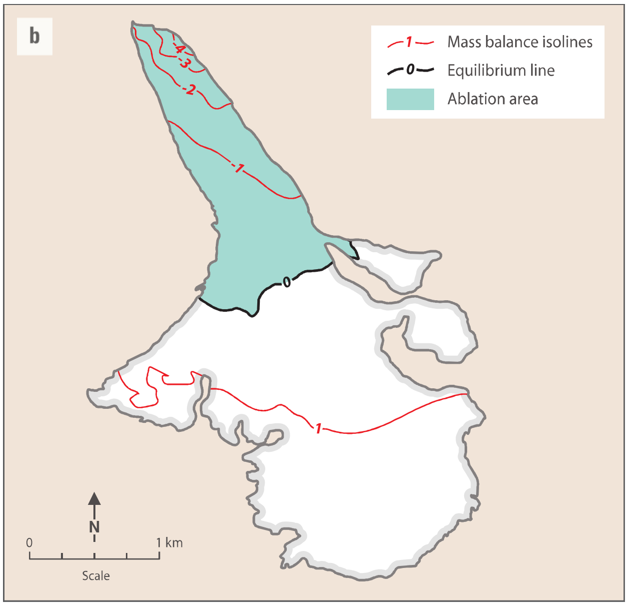
is managed and funded by a consortium of six organisations that are located in Kyrgyzstan, Switzerland and Germany. Data collected and other observations are sent to the Global Terrestrial Network for Glaciers (GTN-G). This organisation is jointly run by three operational bodies: the WGMS, the NSIDC and GLIMS. GTN-G was set up after the 1990 Climate Change conference in Geneva Switzerland.

Figure 7.45 (a) shows the topography of Golubin Glacier with two of the methods used to observe glacier *changes*: ablation stakes and snow pits. There are 10 ablation stakes that are used to record the freezing and melting of ice at that point whilst the snow pits are trenches dug into the ice to observe the snow layers and any *changes* that might be taking place over time. Aerial photos are also used for comparison purposes across the years. Figures 7.45 (b) and 7.45 (c) show mass balance *changes* for the Golubin Glacier in 2015/2016 and 2016/2017. The consortium monitoring this glacier are using the same techniques at four of the other seven glaciers in Kyrgyzstan that are being extensively monitored to see if the patterns observed at Golubin Glacier using these techniques are similar to observations made at the other monitored glaciers. To address some of the impacts caused by melting glaciers, the following projects are some of the responses that are being implemented in Kyrgyzstan (costings are in US dollars):

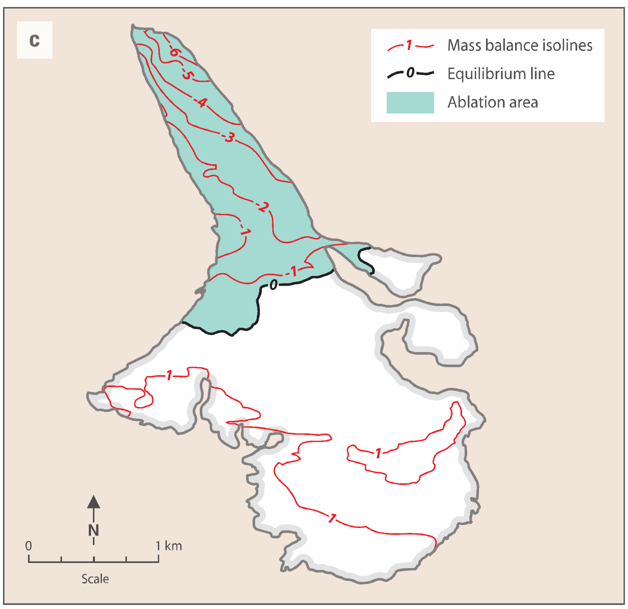
- The World Bank has given US$46 million to create a *sustainable* water supply for farmers and improve sanitation. This project is due to finish in 2025.
- USAID has given US$10 million to teach farmers how to grow crops using less water and with less wastage. This project is due for completion in 2021.
- The UNDP has allocated US$47 million to create better resource management practices with a view to minimising the impacts of GLOFs, mudslides and landslides. This project finishes in 2022.
- Red Crescent, an NGO, has been funded to create and communicate disaster management plans to all Kyrgyzstan residents.
- The Kyrgz Academy of Science in collaboration with the Norwegian government and UNDP have been trialling reafforestation of slopes cleared over generations for grazing and fuel wood to reduce air temperature, take up CO_2 and improve water quality. Only 5.6 per cent of Kyrgyzstan is currently forested.
- An agreement to build infrastructure to collect melt water and build modern hydroelectric infrastructure in the Naryn Valley has been recently signed. The Kyrgyz government has partnered with a private Czech company to build two new dams worth US$3 billion.
- The Asian Development Bank (ADB) and the Asian Development Fund (ADF) have allocated US$36 million in grants and loans to modernise irrigation methods, improve land management, and improved telecommunications in the Ferghana Valley. This is due for completion in 2022.



▲ **Figure 7.45 (a)** Topography and monitoring sites on Golubin Glacier



▲ **Figure 7.45 (b)** Ice measurements on Golubin Glacier in 2015/16



▲ **Figure 7.45 (c)** Ice measurements on Golubin Glacier in 2016/17

▶ ACTIVITIES

1. Kyrgyzstan is a country that many people in Australia may not have heard of. Using information described in this chapter, outline the geographic characteristics of the country.
2. The glaciers being monitored in Kyrgyzstan are shown in Figure 7.40 have an unusual *distribution*. Explain why this might be the case.
3. Figure 7.45 shows the topography and *changes* in mass balance of Golubin Glacier over a year.
   a. Explain the location of the ablation stakes and snow pits in relation to the equilibrium line of Golubin Glacier.
   b. Describe the *changes* in mass balance between 2015/16 and 2016/17.
   c. What causes could explain the *changes* you have described?
   d. The Golubin Glacier is still being monitored manually by scientists who visit the stakes and snow pits at regular occasions during the year. What might be the advantages and disadvantages of using sensors linked to GNSS to remotely monitor the stakes and snow pits from the laboratory?
4. Apart from the monitoring of glaciers, there are many other projects underway in Kyrgyzstan that are responding to the impacts of melting glaciers.
   a. Create a table, similar to the one in Figure 7.39, that summarises each of the responses related to melting glaciers in Kyrgyzstan (include the monitoring of glaciers).
   b. Which organisations involved in these responses could be considered global?
   c. Which of the projects do you think would have the most beneficial impact on Kyrgyz people? Why?
   d. Which of the projects do you think would have the most beneficial impact on mountain *environments*? Why?
   e. Imagine that you were appointed by a global auditing group to assess the effectiveness of the responses underway in Kyrgyzstan to reduce the impact of melting glaciers. What criteria would you introduce to assess the effectiveness of these responses?
   f. If you were the water and *environment* minister in the Kyrgyz government, what responses might you introduce to reduce the impacts of melting glaciers?
5. Kyrgyzstan is one of the lowest carbon emitters per head of population on Earth yet is suffering some of the greatest impacts associated with warming climates. This is a so-called 'trans-boundary' issue because the pollution mainly comes from elsewhere and crosses the national border to affect Kyrgyzstan. Evaluate the following statement: 'Wealthy high carbon emitting countries should fund responses to deal with trans-boundary issues created by warming climates in less wealthy low carbon emitting countries.'

8 Land cover change: deforestation

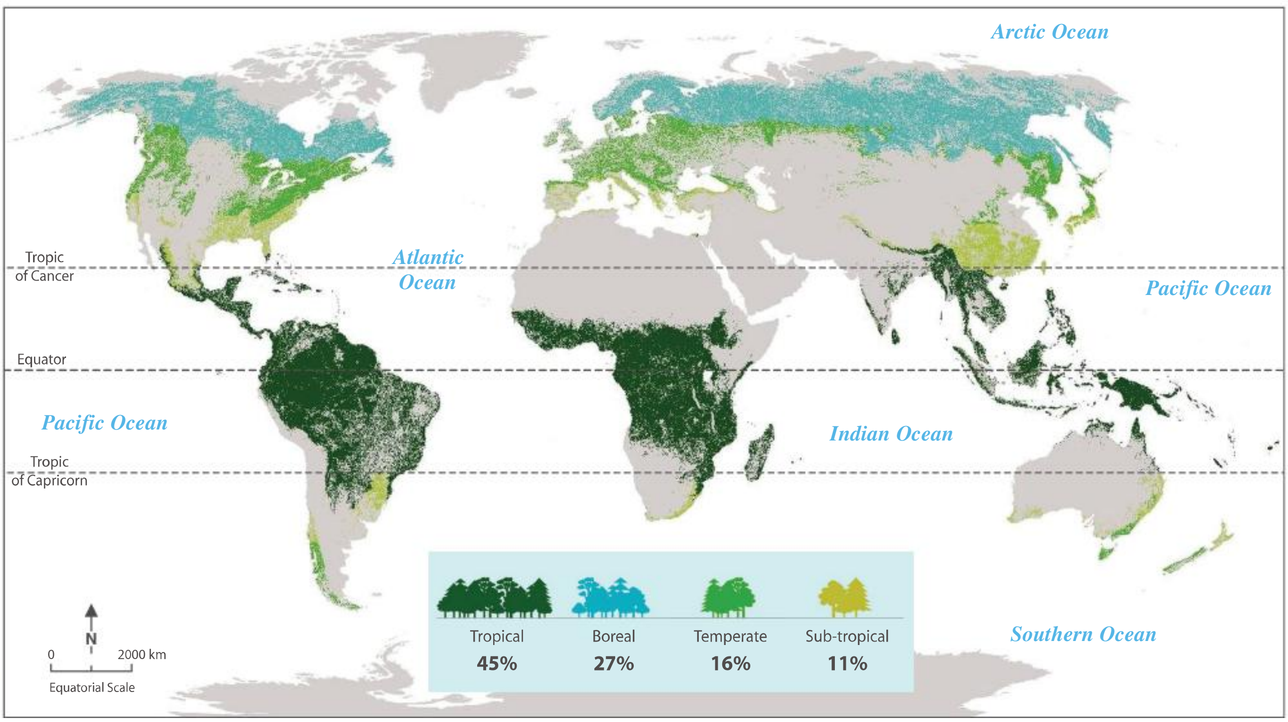
The *distribution* of forest land cover across the world has *changed* in response to *interconnecting* natural *processes* and human activities. Today, forests collectively cover approximately 31 per cent of the world's total land area and contain most of the world's terrestrial biodiversity. But the world's forests are diminishing in extent and quality. Deforestation has resulted in an annual loss of 10 million hectares of forest over recent years, and while the rate of deforestation has slowed overall, and the regrowth of forests in some *regions* has offset some of this loss, many forests are experiencing rapid rates of decline.

While large tracts of the world's remaining forest are contained within national parks and other conservation reserves, most forest land cover exists outside these protected areas and is important for sustaining livelihoods. The World Bank estimates about 350 million people live within or close to forests across the globe and one third of humanity depend on them to varying degrees for their subsistence and income. Forests also provide important 'ecosystem services' to human communities, such as erosion and flood control, maintaining water resources, climate regulation, habitat for pollinators and seed dispersers, and for sustaining soil health. Deforestation therefore creates a number of social, *environmental* and economic issues and challenges.

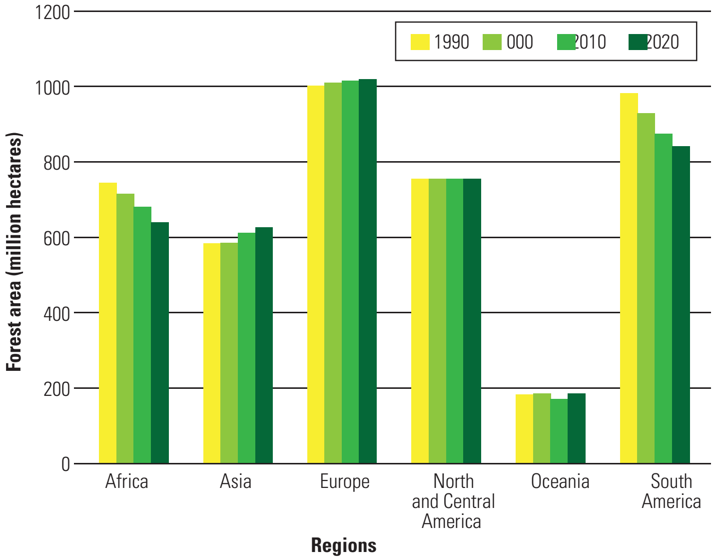
What is the current spatial *distribution* of forests?

The world's forests are widely *distributed*, occurring on all continents except Antarctica, and total just over four billion hectares worldwide. Figure 8.1 shows the global *distribution* of forests today, while Figures 8.2 and 8.3 contain statistical data on forest land cover. As can be seen in Figure 8.3, ten countries make up over half of all global forests.

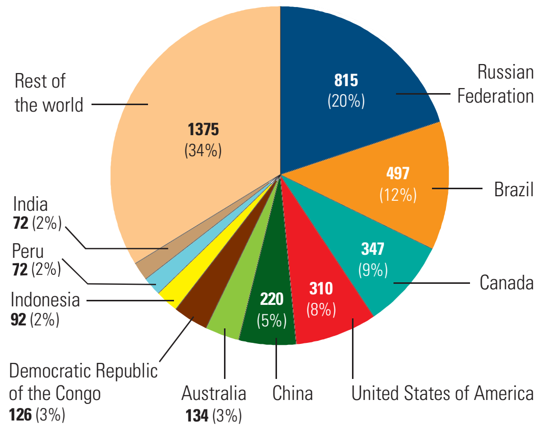
▼ **Figure 8.1** The world's forest biomes



▼ **Figure 8.2** Forest area, by *region*, 1990–2020



▼ **Figure 8.3** The relative *distribution* of the world's forests by country, 2020 (million hectares and percentage of world's forests)



What are the natural characteristics of forests?

Forests are dynamic *environments* which *change* through time and space. The *interconnection* of biophysical conditions such as climate, soil, aspect, elevation and fire history creates a mosaic of forest types. Forests also *change* their characteristics over time, including the species present and their density and height, in response to the dynamics of plant succession, as they develop and mature into a 'climax community'; and longer term through evolution.

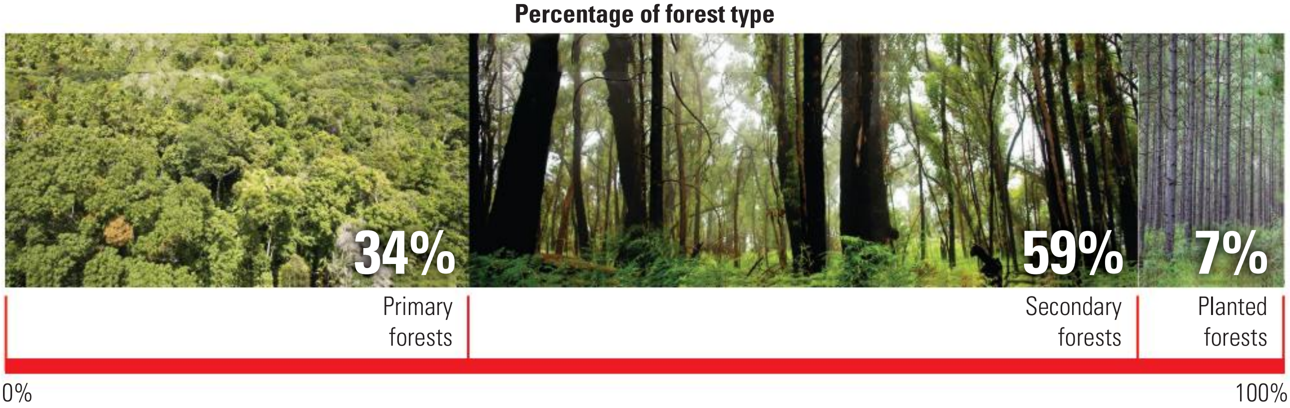
Because climate is one of the major determinants of the type of forest that forms, forests are commonly classified according to this factor: tropical and subtropical rainforests, temperate forest and boreal forests. Slightly more than half are located in the tropics and the remainder are in temperate or sub-arctic *regions*.

The Food and Agriculture Organization (FAO) of the United Nations collates information about the world's forests and regularly releases this information in the form of Global Forest Resources Assessment (FRA) reports. These inventories are collated through the use of remote sensing and geospatial technologies as well as on-ground surveys, conducted and submitted by each country. They are used widely to assess forests and to develop management strategies for dealing with deforestation.

Forests are biomes dominated by trees, where the foliage of the trees forms a canopy. The FAO defines forests as "land spanning more than 0.5 hectares with trees higher than five metres and a canopy cover of more than 10 per cent, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use". Figure 8.4 shows some of the types of forests found in Australia, classified according to their natural characteristics related to their structure. These forests can be classified as 'closed forests' or 'open forests' according to the density and height of the tree canopy. Woodlands are also a type of forest biome in which the trees are smaller in height and girth, and are more widely spaced, forming a discontinuous canopy.

▲ **Figure 8.4** Types of forest: **(a)** Closed forest – Denmark River in the town of Denmark, Western Australia); **(b)** Open forest – Eucalyptus forest in the High Country, Victoria; **(c)** Woodland – Salmon gum, near Kalgoorlie in the Goldfields Region, Western Australia

Figure 8.5 Characteristics of the world's forests



Forests can also be categorised by the level of human activity involved in their development:

- primary forests, or 'intact' or 'old growth' forests have remained relatively undisturbed for centuries, and are still dominated by natural *processes*
- secondary forests, or 'regrowth' or 'regenerated forests', consist of native species but they have been relatively recently disturbed by human activities and have been allowed to regenerate naturally, or humans have intervened in their development, such as through replanting or seeding. They will eventually develop into a climax community which may be indistinguishable from a primary forest, though this may take hundreds of years
- plantations are a 'monoculture' of native or non-native trees planted for the commercial production of a particular species (excluding tree food crops) or for *environmental* services such as erosion control (excluding tree food crops).

The FAO differentiates between planted forests, which includes plantations as well as forests regrown by planting or deliberate seeding, and natural forests, that is, primary forests and secondary forests which have naturally regenerated post deforestation or degradation. The relative contribution of each categories to global forests is shown in Figure 8.5.

David Lindenmayer

Professor of Ecology and Conservation Science, Australian Research Council Laureate Fellow, Research Director of the Threatened Species Research Hub

I studied Geography to Year 12, majored in Geography as part of my Diploma of Education at University of Adelaide in 1986, and taught and lectured in Landscape Ecology in the Department of Geography at The Australian National University.

I have worked as a forest ecologist since 1983, on an almost continuous basis since then. I have written more than 940 scientific articles on forests, woodlands and biodiversity in Australia and overseas, including 38 books.

I use Geography skills a lot in learning how to 'read' a forest or woodland landscape – determining what factors influence where animals and plants occur and why they occur where they do. I also work with other geographers especially those that use Geographic Information Systems (GIS) and computer-based mapping to help explain the population dynamics of animals as well as the landscape dynamics of forests and woodlands and the biodiversity they support.

I was inspired to study Geography many years ago – my parents used to go on epic car drives to far-off places in eastern and northern Australia when there were no DVD players, CD players, or even radios. I used to look at the Australian landscapes and wonder about how they came to be the way they are. Then I had excellent and inspiring teachers at school and created a passion for the kind of work I do now.

There are huge opportunities for geographers in careers through computer-based mapping and connecting such skills to how resources and biodiversity exist in landscapes, even more so with satellite imagery and related kinds of data and spatial coverage.

How has the spatial *distribution* of forests *changed* since the last Glacial Maximum?

Forest land cover existed hundreds of millions of years before human evolution began. Over geologic time forests have evolved and *changed* in *distribution* in response to natural *processes*, particularly the swings between glacial periods and relatively warm interglacial periods (see Chapter 7).

As can be seen in Figure 8.6, during the height of the last glacial period, when the earth was colder and more arid and sea levels were at least 100 metres lower than present, the *distribution* of forests was much less extensive than today, and biomes including grasslands, desert, and tundra were more widely *distributed*. This glacial period commenced approximately 30,000 years ago, with the Glacial Maximum in the Australian *region* occurring between 21,000 and 18,000 years ago (although the beginning, end and duration varied in different *regions* across the Earth).

The colder and drier conditions and the presence of extensive ice sheets over parts of North America and northern Europe meant forests were less extensive, though the biomes and species they contained were similar to those of today. Open forest and woodlands were more widely *distributed* than today and closed forests were very limited in *distribution* to pockets of moist *environments* near the Equator. Latitudinally, forests were located closer to the Equator and did not extend as high in terms of elevation as they do today. The forests of the Amazon and the Atlantic forests of South America were much less extensive, while equatorial Africa had relatively little forest due to the much drier conditions. There was very little forest in northern Europe due to the prevalence of ice and desert, and southern Europe was mainly grassland with scattered patches of trees in moist areas. North America was dominated by forest, but a more open version dominated by species tolerant of the colder conditions. Much of northern and central Asia was desert-like, but there were scattered trees in the uplands and in southern China. Japan was dominated by open woodland and South-East Asia by open grassland and dry forest. The deserts of Australia's mainland were much more extensive and forest cover was greatly diminished. During the Ice Age, plant succession resulted in the slow colonisation of the exposed continental shelves throughout the world.

As the world moved into the present interglacial period, sea levels rose and warmer, wetter conditions prevailed allowing the recolonisation of land abandoned by retreating glaciers and ice. Forests expanded and retreated pole-ward and into higher altitudes, and were flooded in coastal *regions* inundated by rising seas. The current *distribution* of vegetation is thought to have more or less stabilised approximately 6000 years ago, following the Holocene Climatic Optimum. Forests eventually covered approximately 47 per cent of the world's land cover, and the world's human population reached about 5 million, living a Palaeolithic lifestyle, though the very first agrarian societies were developing.

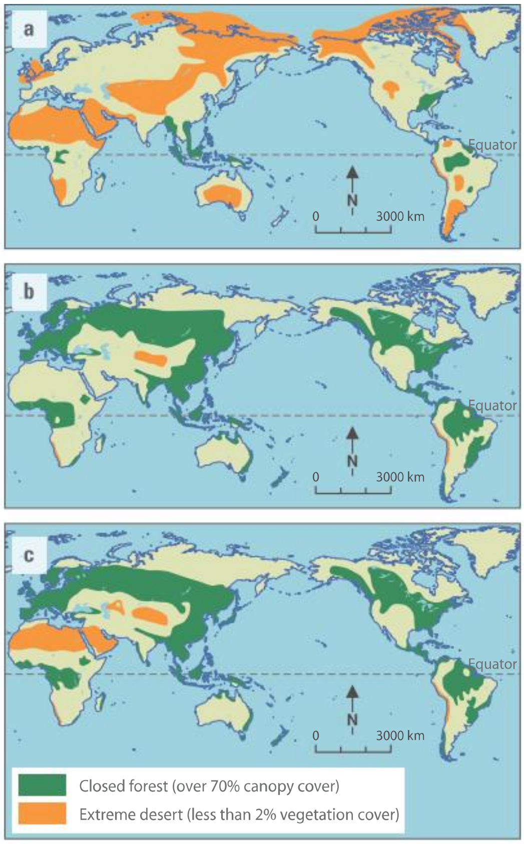


Figure 8.6
The *distribution* of vegetation land cover during **(a)** the Last Glacial Maximum, **(b)** the Holocene Climatic Optimum, and **(c)** the potential land cover today showing the *distribution* of biomes if clearing did not occur

The first Agricultural Revolution was dawning and the impact of human activities on the world's forests was just beginning.

While there have been other, less dramatic fluctuations in climate resulting from natural *processes* over the last 6000 years, the climate remained relatively stable until the recent rise in global temperatures due to the enhanced greenhouse effect. Human activities are now having an increasingly significant influence over the *distribution* and nature of the world's forests.

ACTIVITIES

1. Refer to Figures 8.1, 8.2 and 8.3.
   a. Describe the global *distribution* of forest land cover in the world today.
   b. Analyse the *interconnection* between natural *processes* and human activities in the formation of secondary forests and plantation forests.
2. Investigate and describe the natural characteristics of the different types of forest biome shown in Figure 8.1.
3. Compare the *distribution* of forests between the Last Glacial Maximum, the Holocene Climatic Optimum and today, commenting on the *distance* forests were located from the Equator and the proportion of forest land cover on each continent relative to the present.
4. Consider the Global Forest Resources Assessment (FRA) reports regularly released by the Food and Agriculture Organization (FAO) of the United Nations. Discuss the importance of the attempts by the FAO to regularly collate information on forests.

What is deforestation?

Forests are cleared and modified as a source of wood and non-timber forest products; to *change* the land cover to accommodate other land use such as the establishment of settlements, farms, dams and mines; or as a result of natural disasters such as drought, fire and landslides. The *process* of deforestation and the degree of damage or loss varies according to how it is cleared or modified.

Where the land is cleared for conversion to another land use, vegetation is usually removed physically or through the use of fire. Where the forest is logged for its timber reserves, the forestry method employed varies and can have a significant impact on the quality and quantity of *change* in land cover, as can be seen in Figure 8.7.

Forests subjected to modification through human activities such as selective logging, replanting, shifting cultivation and woodfuel collection are not classified as deforested, but are deemed to have experienced forest degradation. The FAO defines 'deforestation' as the long-term reduction of tree canopy cover to below 10–30 per cent (depending on the type of forest) and 'forest degradation' when deforestation results in more than 10–30 per cent of forest cover remaining through *processes* such as selective logging or the development of secondary forest.

A more protracted form of deforestation results from fragmentation. This typically occurs where there is some clearing of pockets of forested land, most commonly for the construction of roads, leaving a series of fragments of intact forest. Over time the periphery of each remnant becomes degraded and may become too small to support viable forest ecosystems and too isolated from other fragments, thereby preventing the *movement* of plants and animals along natural forested corridors. Figure 8.8 shows how this occurred in South-East Asia during the *regon's* peak of deforestation between 1970 and 1990.

People also play a role in increasing the *distribution* of forests through afforestation, where trees are planted on land that was not previously forested. Forestry activities may also involve post-logging reforestation of land through seeding or replanting, or through allowing a forest to regenerate naturally. While some countries continue to sustain high levels of net forest loss, many have recorded an overall gain in forest land cover due to afforestation and reforestation.

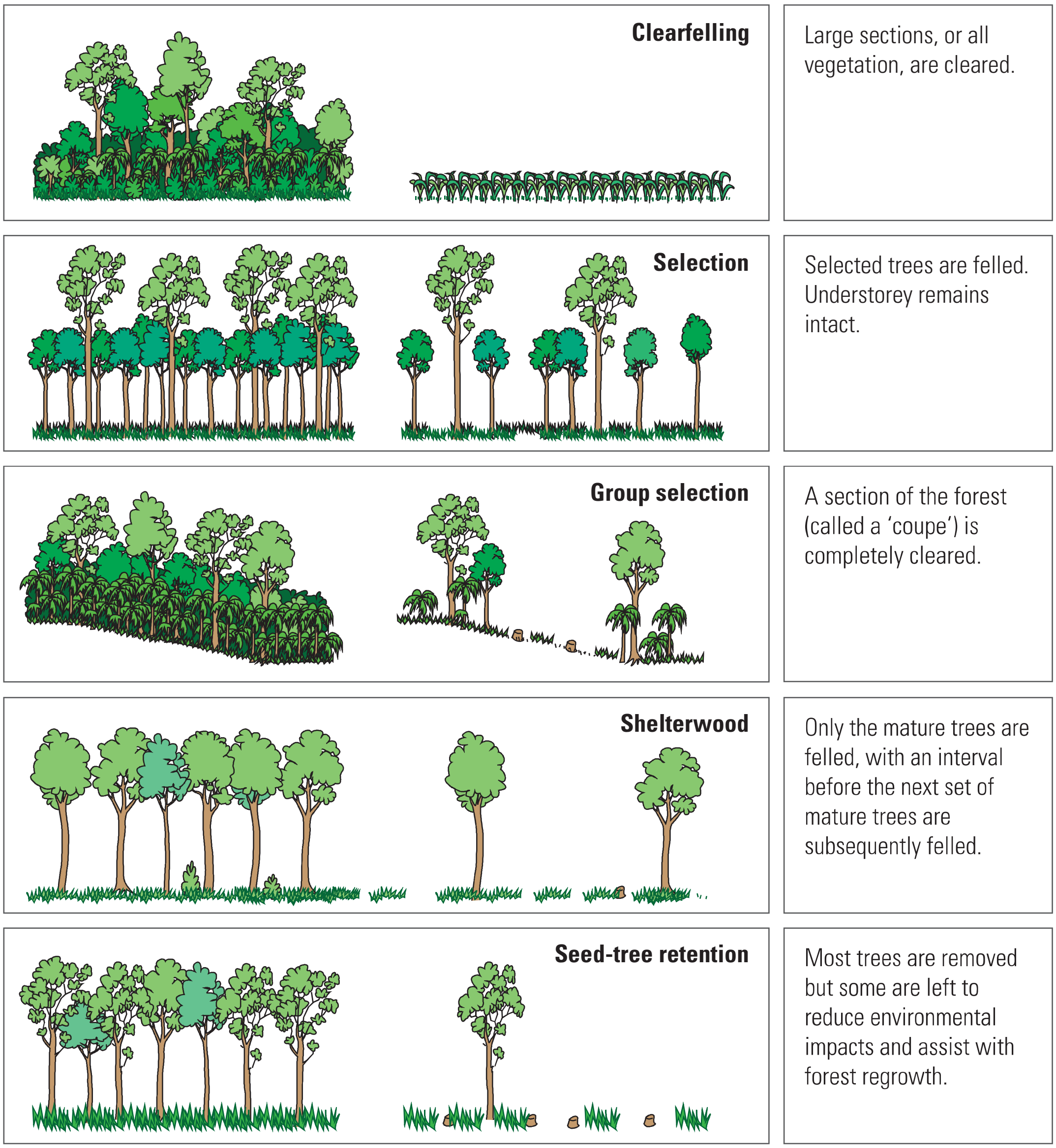


Figure 8.7 Systems of forest management used in forestry

The FAO differentiates between deforestation and net forest *change*. Deforestation is the conversion of forest to other land use, while net forest *change* is calculated from the difference between deforested land and forest gains, over a given period. Net forest *change* can therefore be positive, where forest rehabilitation, reforestation and afforestation exceeds deforestation and results in forest expansion, or negative when forest loss is greater.

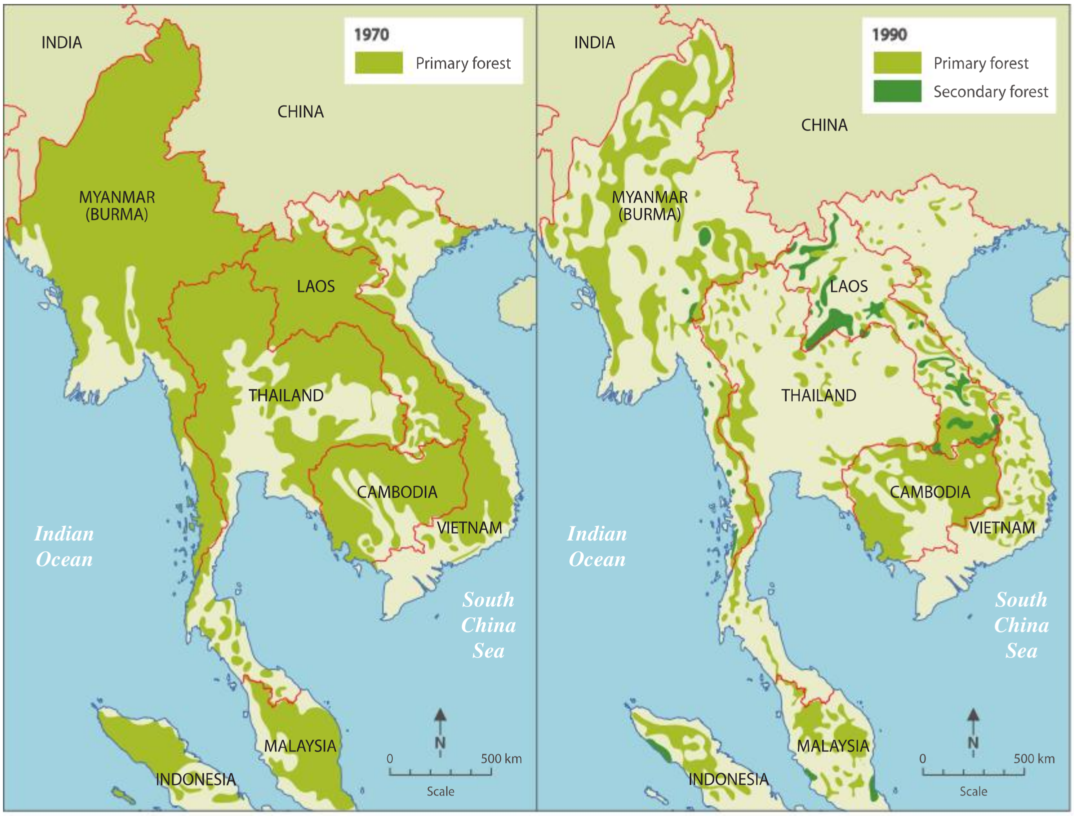


Figure 8.8 *Change* in land cover in South-East Asia, 1970–1990, resulting from the fragmentation of its forest

What is the global *distribution* of the *process* of deforestation?

Today forests cover about 31 per cent of the land's surface, but it is believed they covered 47 per cent of the world before the advent of agriculture. The transformation of the world's biomes into farmland is possibly the most significant and visible mark people have made upon the Earth. It has been estimated that over the last 5000 years, as an increasing demand for food, fibre and fuel has accelerated the conversion of land to agriculture, human activities have been responsible for the deforestation of a total of approximately 1.9 billion hectares. Cultivated land now constitutes approximately one-quarter of the Earth's terrestrial surface.

Over recent decades, a number of nations have slowed forest loss or even increased their net forest cover, but many of the *regions* of the world grappling with extreme poverty continue to experience high rates of deforestation. Figure 8.9 shows the worldwide *distribution* of deforestation.

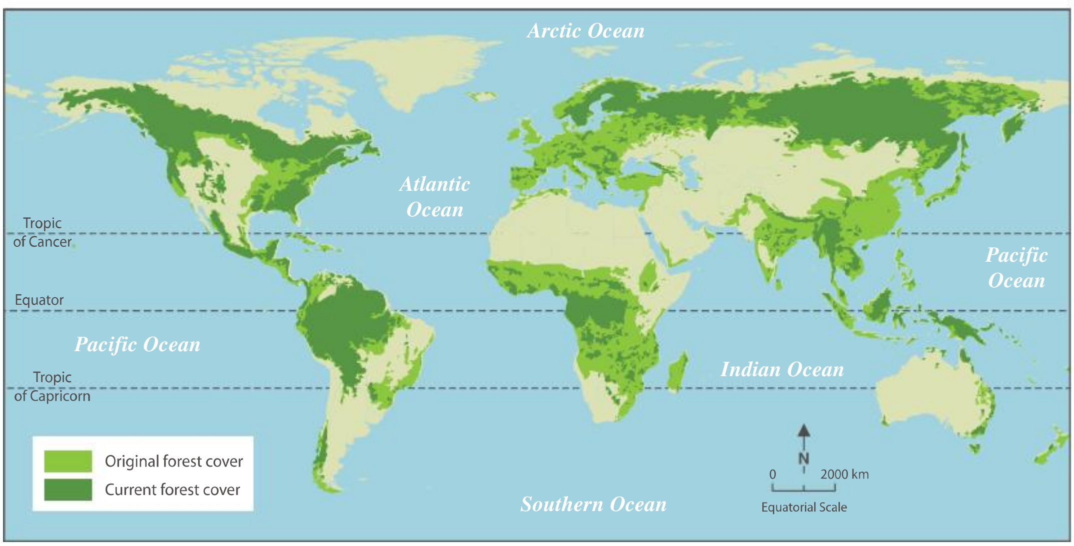
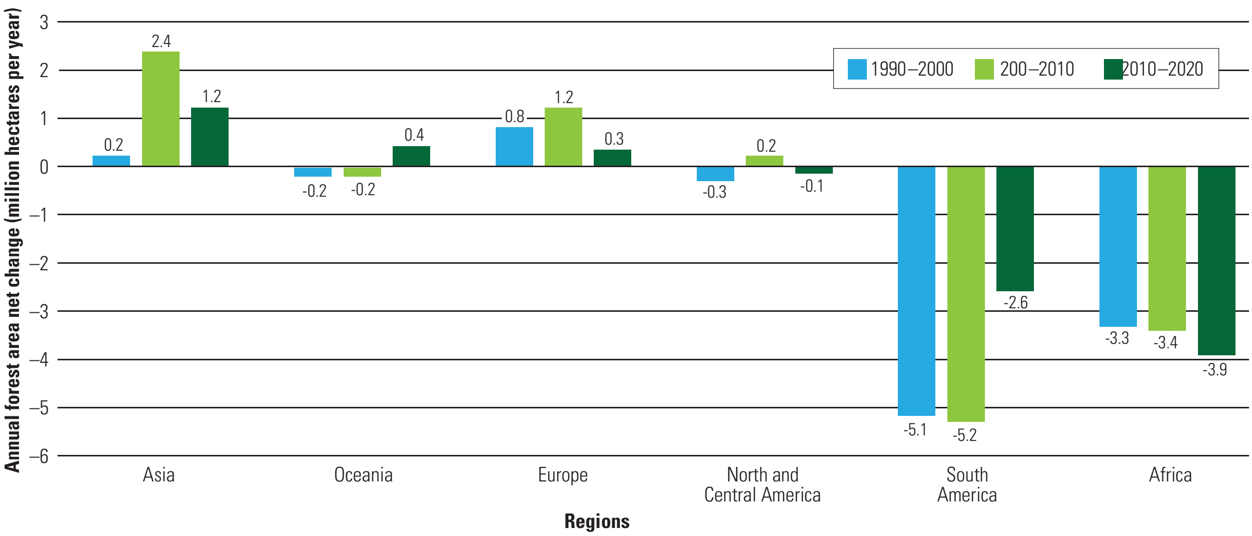


Figure 8.9 Global forests and deforestation

Until the mid-20th Century, the main location of deforestation was the temperate forest of the world. Four thousand years ago forests made up 60 per cent of China's land cover, but by the time the People's Republic of China was declared in 1949, forest cover was at its smallest area, covering less than 10 per cent of its land area. Much of Europe's forests were already lost during the Industrial Revolution, which accounts for the fact this continent has the least primary forests remaining today. Croplands expanded rapidly in Europe after 1700, and in North America, Australia and northern Asia after the mid-19th Century. Roughly 70 per cent of all the original temperate forests, including the Mediterranean woodlands, had been lost by 1950. The large-*scale* loss of forests that did occur in the tropics was often initiated by the colonising nations of Europe, such as the plundering of many of India's forests by their British colonisers between 1850 and 1920. While agriculture was the main factor driving this deforestation, *unsustainable* rates of timber harvesting, especially for export, also contributed.

By the middle of the 20th Century, deforestation in the temperate *regions* of the world slowed and the tropical forests entered into a phase of accelerating loss. Globally, deforestation peaked between the last two decades of the 20th Century due to rampant deforestation in the developing world, especially in South-East Asia which lost more than 30 per cent of its forests, and in Africa and Latin America which lost 18 per cent of their total forest area.

▼ **Figure 8.10** Net annual *change* in forest area by *region*, 1990–2020



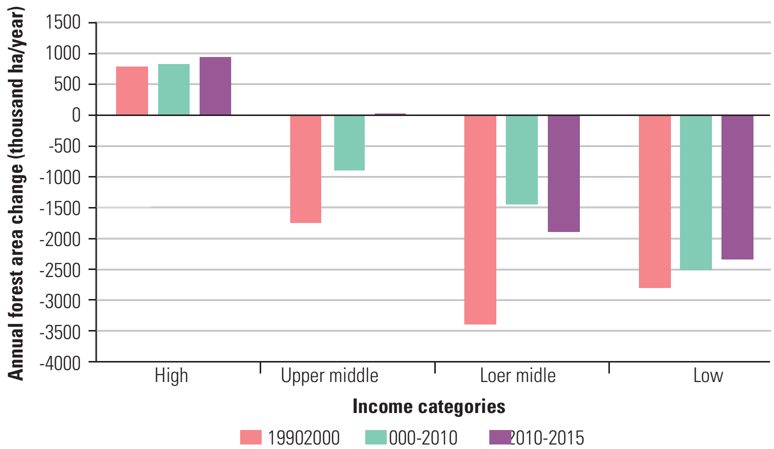
▼ **Figure 8.11** Deforestation rates, by *region* and subregion, 1990–2020

***Region*/subregion**	**Deforestation (1000 ha/yr)**			
	1990–2000	**2000–2010**	**2010–2015**	**2015–2020**
Eastern and Southern Africa	1781	2240	2116	2199
Northern Africa	461	442	330	316
Western and Central Africa	1854	1631	1998	1899
Total Africa	**4096**	**4314**	**4444**	**4414**
East Asia	399	353	369	170
South and Southeast Asia	3689	2232	2460	1958
Western and Central Asia	82	99	96	107
Total Asia	**4170**	**2684**	**2925**	**2235**
Total Europe	**88**	**92**	**201**	**69**
Caribbean	3	2	23	5
Central America	228	222	142	168
North America	740	475	253	263
Total North and Central America	**972**	**699**	**418**	**436**
Total Oceania	**655**	**662**	**458**	**42**
Total South America	**5837**	**6667**	**3354**	**2953**
WORLD	**15,818**	**15,117**	**11,801**	**10,150**

Over the last three decades, the rate of deforestation has slowed substantially, and many countries have offset their forest losses through afforestation and reforestation, resulting in a 40 per cent decline in the rate of net forest loss since 1990. While these figures give cause for some celebration, they also mask the *regional* variations in the degree of forest *change*, with most forest loss occurring in Sub-Saharan Africa, South America and South-East Asia, often involving the expansion of plantations and the reduction in natural forests in the tropics. Furthermore, the total area of forest has continued to decline, with a current net loss of 4.7 million hectares each year, and setting aside global forest gains, 10 million hectares of forest worldwide continue to be cleared each year.

Globally, temperate forests have increased since 1990, while boreal and subtropical forests recorded no significant net *change*. This is due to reduced rates of deforestation and also through afforestation, with a net average increase of three million hectares per year. China, for example, planted over 60 billion trees in the last 40 years. However, there has been a net loss in tropical forests over this period, mainly in the developing world, averaging 5.5 million hectares of forest loss per year over 1990–2020. Forest area declined within Central and South America, South-East Asia and Sub-Saharan Africa but expanded in Europe, North America, the Caribbean, East Asia and Western-Central Asia. For the decade 2010–2020, deforestation in the tropics accounted for 90 per cent of all global deforestation, with land clearing for agriculture being the overwhelming cause.

▼ **Figure 8.12** The trend in forest *change*, 1990–2015, by income category. The income categories are defined by Gross National Income (US$) per capita per year: low (US$1045 or less), lower-middle (US$1046–$4125), upper-middle (US$4126–$12,745) and high (US$12,746 or more) (based on World Bank data, 2013)



There has also been a *change* in the quality of forests worldwide over the last 30 years, with the expansion of planted forest (reforested, afforested and plantation forests), which increased by 123 million hectares since 1990, while natural forests (primary and naturally regenerated forest) declined in area and quality over this period. And although natural forests still overwhelmingly dominate global forest cover, making up 93 per cent of the total, less than a third of these forests are now classified as primary forest. Furthermore, 9 per cent of the remaining primary forests of the world exists as fragmented remnants lacking connectivity, putting their long-term *sustainability* at risk.

▶ ACTIVITIES

1. Explain the difference between 'deforestation', 'forest degradation' and 'fragmentation'.
2. Refer to the information provided in the text and Figure 8.5.
   a. Describe the major trends in the quality of the world's forests over the last three decades.
   b. Comment on the implications of this *change* for the *environment*.
3. Refer to the methods used in commercial logging of forests shown in Figure 8.7. Compare the significance in *change* in forest cover likely to result from the various methods shown.
4. Refer to Figure 8.8. Describe the *change* in the spatial *distribution* of forests in South-East Asia.
5. The FAO in its Global Forest Resources Assessment report (FRA 2020) estimates the current rate of global *deforestation* to be over 10 million hectares per year, yet the same report states net forest *change* is the loss of 4.7 million hectares of forest per year.
   a. Explain the term 'net forest *change*', how it differs from deforestation, and how it is calculated.
   b. To put this data in context, estimate how many of your school's 'area equivalents' are currently lost each year due to deforestation.
   c. Based on the data in Figure 8.10, calculate the net change in global forest area for the three periods shown.
6. Use the data in Figures 8.10 and 8.11 and information in the text to describe in detail the current *regional* trends in forest loss using examples and quantification.
7. Access the Global Forest Resources Assessment (FRA 2020). Identify the countries that currently have high rates of forest loss (in excess of 0.5 per cent). Using a copy of the map shown in Figure 8.9, create a map with annotations for each such country, including their rate of forest loss.
8. Some commentators have stated that the deforestation occurring today is an issue of the tropical rainforests of the developing world. Explain why they have reached this conclusion, referring to information provided in the above text, Figure 8.1 and Figure 8.11.
9. Refer to Figure 8.12. Describe the *spatial association* between levels of economic development and the proportion of land area lost to deforestation apparent in this graph.

What are the causes of deforestation globally?

Human activities overwhelmingly account for the loss and degradation of forest land cover, but natural *processes* also contribute. Australia, for example, recorded the second highest rate of forest loss of all the nations in the world over the period 2000–2010, largely as a consequence of its decade-long drought and the widespread bushfires this fuelled over the first decade of the 21st Century. The 'Black Summer' bushfires of 2019–2020 once again caused large-*scale* forest loss in Australia, with over 18 million hectares burnt, mostly in forested areas. Yet in the period 2011–2016, Australia recorded a net increase of 3.9 million hectares of forest, through above average rainfall, curbing deforestation and the expansion of planted forests. This data highlights the *interconnection* between human activities, such as forest rehabilitation and rising greenhouse emissions, with natural *processes* related to climate variability and natural disasters, on our nation's forest growth.

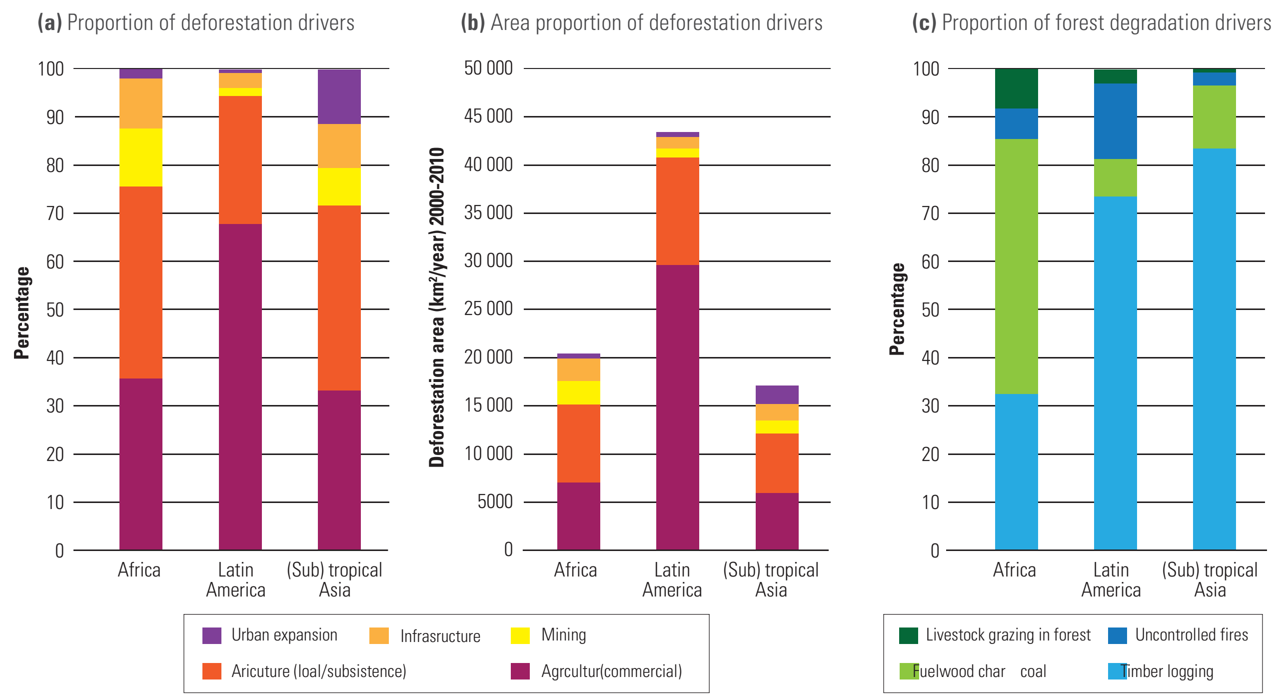
Human activities causing deforestation

Currently, there are several *interconnected* direct and indirect causes of forest loss and degradation, and their relative importance varies across time and space; however, the greatest cause of deforestation worldwide is agricultural expansion. Agriculture is estimated to be responsible for approximately 73 per cent of global deforestation, while logging contributes approximately 19 per cent and woodfuel collection about 6 per cent, and the rest due to infrastructure development. While subsistence farming was the main driver of deforestation prior to the 20th Century, its role has diminished since the 1950s and currently accounts for less than one third of land use *change* to agriculture. There are significant *regional* variations in the causes of deforestation and forest degradation, as is shown in Figure 8.13.

While agriculture and logging are the main direct causes of deforestation, a number of social, political and economic factors are indirect 'drivers' of deforestation:

- Projects to improve infrastructure, such as mines, dams, transport and rural settlement facilities, may lead to forest loss. The development of roads and rural settlements, in particular, increases accessibility to forested areas, frequently triggering deforestation. The construction of the Trans-Amazonia highway in Brazil and the large-*scale* transmigration programs in Indonesia, in retrospect, both paved the way for the large-*scale* deforestation that ensued in these two countries since the 1960s.
- The agriculture sector is often supported by government subsidies in an effort to promote food security. However, this may enhance the economic benefits of farming relative to the income derived from intact forests, fuelling deforestation.
- The enforcement of forest protection laws and forestry management regulations is typically difficult in forested areas because of their remote and isolated locations, and requires considerable financial and workforce resources. The lack of such 'capacity' often leads to illegal logging, and illegal trade in timber and forest products.
- Many developing and emerging economies with large areas devoted to forests have been susceptible to poor forest management because they lack the workforce capacity to enforce existing laws, and corruption because forest products provide high financial rewards relative to average incomes. Logging licences, or 'concessions', have often encouraged the rapid and wasteful exploitation of forests for short-term financial

▼ **Figure 8.13** The main causes of forest loss and degradation in *regions* of the tropical world



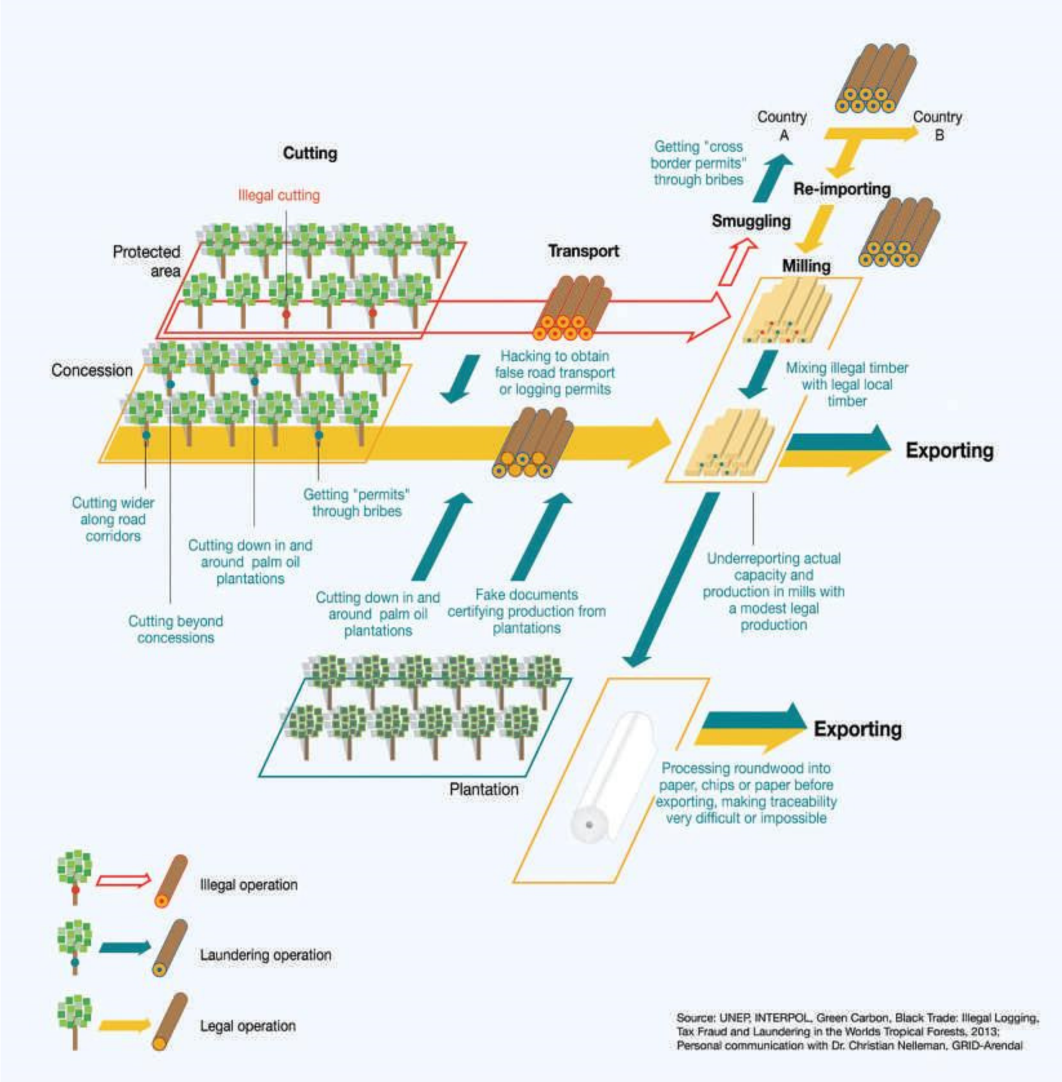
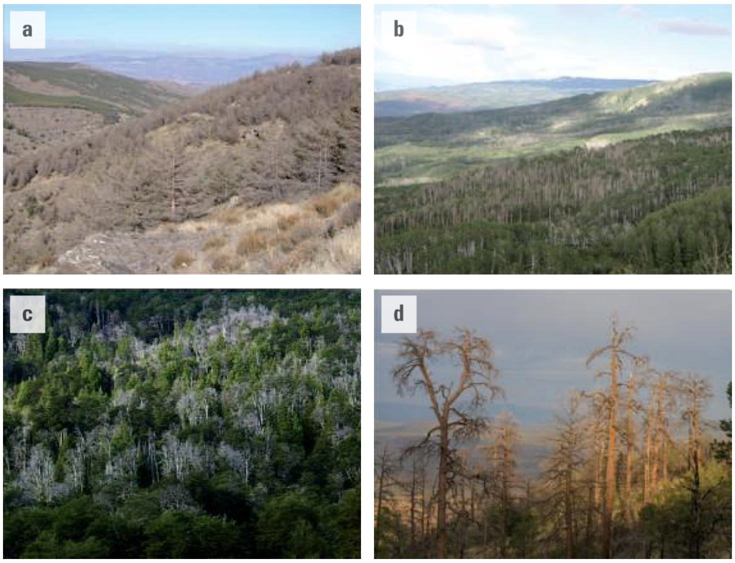


Figure 8.14 Illegal and corrupt practices in the forestry industry

gain with insufficient attention to the broader and long-term benefits of intact forests. Currently, the International Criminal Police Organisation (INTERPOL) has estimated forestry crimes, including illegal logging and unlawful clearing for agriculture, total US$51 billion–US$152 billion per year, with three quarters of this activity emanating from Indonesia and Brazil. Figure 8.14 outlines many of the avenues for illegal and corrupt practices in the forest industry.

- Issues regarding land rights and forest ownership hamper effective forest management, particularly among Indigenous minorities and forest-dependent rural communities. The system of land tenure determines who can use the land and access its natural resources, who can make decisions regarding its management, and who actually owns the forest and its resources. But land tenure conditions are unclear in many forested areas of the developing world. This can lead to the manipulation of vulnerable forest communities. For many Indigenous forest communities, the idea of possession and selling land or its products is a foreign concept, which too often has resulted in the lack of recognition of their inalienable right to land which they have settled over many generations and with which they have developed a strong spiritual bond.
- Wars and civil disruption, throughout history, have also had devastating effects on forests. One example is the civil disruption in Rwanda in the early 1990s, which led to the mass migration of more than 750,000 refugees to a camp near the Virunga National Park in the neighbouring Democratic Republic of the Congo, where a large area of protected mountain gorilla habitat was deforested.
- The pursuit of economic development is often the underlying driver of deforestation. Developing countries use the land and products of their forests as a means of alleviating poverty, as in such *regions* the imperative of providing food security and a basic income may take precedence over the obligation of protecting forests. Typically, as countries develop economically, deforestation occurs at a rapid rate. As they transition into an emerging economy, their increased wealth provides the income to more actively address deforestation, and reduces their dependence on logging forests. At this stage, countries usually curb their deforestation and, eventually, often increase their forest area through the protection of remaining native forests and through reforestation and afforestation. This *process* is evident in Figure 8.12.



▲ **Figure 8.15** Images of climate *change*-induced forest dieback from around the world: **(a)** Spain, **(b)** Colorado, **(c)** New Mexico and **(d)** Argentina

While not classified as deforestation but as a form of forest degradation, the current global warming resulting from human activities that increase greenhouse gas concentrations in the atmosphere, has caused measurable *changes* to the natural characteristics and the *distribution* of forests in some *regions*, and is predicted to continue to do so in the future. Such predictions have been explored through computer modelling, which involves entering data about the *environmental* needs of different plant species, and the predicted *changes* in precipitation and temperature, into purpose-developed computer programs to gain insights into how land cover may *change* as a result of global warming. But some forests have already manifested such *change*. This includes the *change* in the geographic range and species composition of forests, with forests 'migrating' in response to *changing* climate patterns, and extensive climate *change*-induced tree mortalities in some *regions*. An increase in the frequency and severity of extreme weather events resulting from global warming, such as tropical storms, floods, droughts and forest fires, are also predicted to eventually affect aspects of forest land cover.

The *interconnection* between global warming and forests is very complex, as there are variations in the susceptibility of forests to climate *change* according to their latitude, the type of forest, its structure and age, and other biophysical aspects. Furthermore, some forests can benefit from elevated greenhouse gas concentrations and the consequent warming. An increase in carbon dioxide in the atmosphere has a 'fertilization effect' on some species, causing them to photosynthesise more rapidly, while increased temperatures has resulted in a longer growing season, benefitting others. However, increased temperatures also exacerbates drought, water and heat stress, and pest and pathogen infestations in forests. A number of *regions* have already experienced extensive tree mortalities, termed 'forest dieback events' when more than 10 per cent of the dominant canopy species is lost due to higher temperatures and lower water availability, and increasing infestations induced by a warmer climate. These events, shown in Figure 8.15, have been most pronounced in forests that naturally occur in drier *regions*, but forest dieback has been documented on every vegetated continent in every type of forest over the past three decades, and computer modelling predicts this will become more widespread over this century. In some forests, the *changing* climate appears to have *changed* the natural characteristics of the land cover, with some species coping better than others, or *movement* in the *distribution* of plant species, or *change* in the density and height of the forest layers. In Queensland, for example, increasing drought has triggered a higher mortality of the tree species *Eucalyptus crebra* within some tropical and subtropical forests, while other smaller tree species were relatively unaffected, altering the forest's species composition and its structure. In other areas, there have been reports of a gradual transition from forest into woodland or savanna.

Natural *processes* causing deforestation

Natural *processes* affecting forests include 'biotic disturbances' such as pest invasions and disease outbreaks, and 'abiotic disturbances' created by forest fires, climatic events such as hurricanes, cyclones, typhoons, storms, floods and drought, and tectonic events such as landslides, earthquakes, volcanic eruptions and tsunami. While these natural disturbances can have a devastating impact on forests, this usually occurs on a local or *regional scale*, and the impact tends to be forest degradation rather than loss. With appropriate management, forests usually recover and regenerate from such disturbances, as they have over millennia. Furthermore, on a global *scale*, the combined impacts of these factors is currently dwarfed by the human activities directly causing deforestation, and many factors classified as natural *processes* may be exacerbated or caused by human activities. Annually, these disturbances affect less than 2 per cent of global forest land cover, although on a local or *regional scale* they can be very disruptive. Natural climate *change* over many thousands or millions of years also causes deforestation especially when temperature, evaporation or precipitation extremes reduce forest growing seasons, or when wildfire becomes more common.

Some of the more significant natural *processes* affecting forest land cover include:

- Insect pests and diseases affect less than 2 per cent of forest worldwide annually, though the damage they cause in some *regions* is significant, primarily in the temperate and boreal zones. The recent invasion by the native North American beetle, the mountain pine beetle, *Dendroctonus ponderoseae*, has devastated more than 11 million hectares in Canada and western USA since the late 1990s and is spreading well beyond its normal range, partially due to milder winters.
- Wildfires affect about 3 per cent of global forest area each year, primarily in dry temperate and tropical *regions*. The forest fires that burned within various countries in Sub-Saharan Africa, Indonesia, Greece, Russia, Portugal, Brazil, Chile, Canada, the USA and Australia at various times

over 2001–2020, for example, have had a great impact in those *regions*. While some forest biomes naturally regenerate after wildfires, or even depend on fire for their regrowth (including much of Australia's temperate forests), some forests are very sensitive to fire and can be devastated by them, particularly when forest fires are more frequent or more intense than would occur under purely natural conditions.

- Irregular ocean circulation patterns, including El Niño Southern Oscillation and the Indian Ocean Dipole, and their influence on extreme weather events such as drought, tropical storms and flooding affect less than 0.5 per cent of global forest areas annually.

Understanding the complex *interconnection* of the various natural *processes* and human activities that cause deforestation and forest degradation at any given location is vital to developing appropriate responses. The initial impetus for forest clearing, for example, may be provided by high global timber prices that motivate logging operations and the construction of access roads by government authorities, which may then be followed by agricultural expansion in the deforested areas, as occurred in South-East Asia until the 1980s (see Figure 8.8). And what appears to be natural causes of deforestation may be induced by human activities, such as more frequent and intense fires and more frequent extreme weather events resulting from global warming (see Figure 8.15).

ACTIVITIES

1. Outline the natural *processes* and human activities that affect the *change* in spatial *distribution* of forests across the world. Analyse the relative importance of these two factors over:
   a. geologic time *scales*
   b. the last 5000 years.
2. Explain why averaging the data across each continent and across the world can give a misleading picture of the state of forests. Refer to the data in the tables of the appendix of the Global Forest Resources Assessment (FRA 2020) to support your explanation.
3. Refer to the information shown in the proportional column graphs in Figure 8.13. Working in groups and using the matrix below, shade the cell for each major world *region* for each factor currently contributing to deforestation of the tropical rainforests in their *region*, using different colours to denote different degrees of contribution: significant, moderate or minor.

	Subsistence agriculture	Commercial agriculture	Logging	Urban expansion	Mining	Infrastructure	Livestock grazing in forests	Uncontrolled fires	Woodfuel and charcoal
Latin America (South America and Central America)									
Subtropical and tropical Asia									
Africa									

Significant cause of deforestation
Moderate cause of deforestation
Minor cause of deforestation

(adapted from: www.geography.org.uk and www.panda.org)

4. Refer to Figure 8.14. Identify the stages within the supply chain of timber that are prone to illegal and corrupt activities.
5. Refer to Figure 8.8. Cambodia's geographic characteristics is largely shared by its neighbouring countries, yet both of the time lapse maps show the level of deforestation was less for Cambodia than for the surrounding countries. Suggest why this may have been the case, classifying your reasons as social, economic, political or technological.
6. Examine how the current global warming is leading to a *change* in forest land cover. Analyse and describe the *interconnection* between human activities and natural *processes* in causing this forest degradation.
7. Predict the *region* you think is most likely to experience the highest rate of deforestation over the next decade, providing justification for your prediction.

What are the impacts of deforestation?

The XIV World Forestry Congress was held in Durban, South Africa in 2015 to develop a vision for how forests could contribute to the achievement of the 2030 Agenda for Sustainable Development. The Congress set out its vision in its Durban Declaration:

> "Forests are more than trees and are fundamental for food security and improved livelihoods. The forests of the future will increase the resilience of communities by: providing food, wood energy, shelter, fodder and fibre; generating income and employment to allow communities and societies to prosper; and harbouring biodiversity. They will support *sustainable* agriculture and human well-being by stabilizing soils and climate, and regulating water flows."
>
> Durban Declaration, FAO, 2015

This Declaration recognises that the benefits of forests to people goes beyond their utility as a source of timber and land. This includes the services they provide, such as water filtration and regulation, carbon sequestration and climate stability, erosion control and the preservation of soil quality and habitat for flora and fauna, in addition to the many social and economic benefits they offer to people, including a vast array of non-timber forest products. It also acknowledges the non-commercial significance of forests, as well as their commercial benefits. These benefits, summarised in Figure 8.17, tend to remain 'invisible' in economic evaluations of forests and are therefore underappreciated. In West Africa, for example, over four million women earn about 80 per cent of their income from the collection, *processing* and marketing of oil-rich nuts collected from shea trees that occur naturally in the forests, but because this enterprise is an 'informal' enterprise (work not done under legal contract) in the local economy it may not be given due consideration when decisions are made about the use and management of such forests.

A number of studies have concluded that the total economic value associated with maintaining intact forest ecosystems is often higher than the value derived from logging or conversion to farmland. Many of their benefits, however, would be difficult or impossible to replace if they were lost.

The world's population has doubled over the last 50 years and the global economy has increased fourfold. To meet this increased demand, the production of food and timber, and the construction of infrastructure, have also grown, and will continue to be the major drivers of forest loss in the future.

Deforestation has had considerable impacts:

- the many ecosystem services forests provide are being degraded faster than they can recover, and collectively forest biomes have suffered the greatest *environmental* impact of all terrestrial biomes
- the number of species on the planet continues to decline, partially due to deforestation, and over the past few hundred years humans have increased the species extinction rate by as much as 1000 times background rates typical over the planet's history; some 10–30 per cent of mammal, bird and amphibian species are currently threatened with extinction
- water quality is declining, and flood frequency and magnitude is increasing, as a consequence of forest cover loss
- once forests are lost or degraded, most of their social benefits and many economic benefits, particularly of the non-timber forest product sector, may be lost
- forests modulate land-atmosphere fluxes of heat energy and water, so their loss can have a local warming and drying effect
- the forestry industry, together with the loss of the capacity of forests to absorb greenhouse gases caused by deforestation, accounts for significant greenhouse gas emissions.

Deforestation has a significant impact on global climates due to its influence on global carbon emissions. Decaying forest debris generated during logging *processes* releases greenhouse gases, as do fires used to clear forest land cover, hence deforestation is estimated to contribute about 10 per cent to global greenhouse emissions. The loss of forests also diminishes an important store of carbon. All plants store carbon absorbed through photosynthesis, but forests are the most significant carbon 'sink' on land due to the amount of biomass they hold. Globally, forests store 54 per cent of the

▼ **Figure 8.16** **(a)** Women in Mali collect firewood and **(b)** forest mushrooms and berries for sale at the Annecy Food Market, France

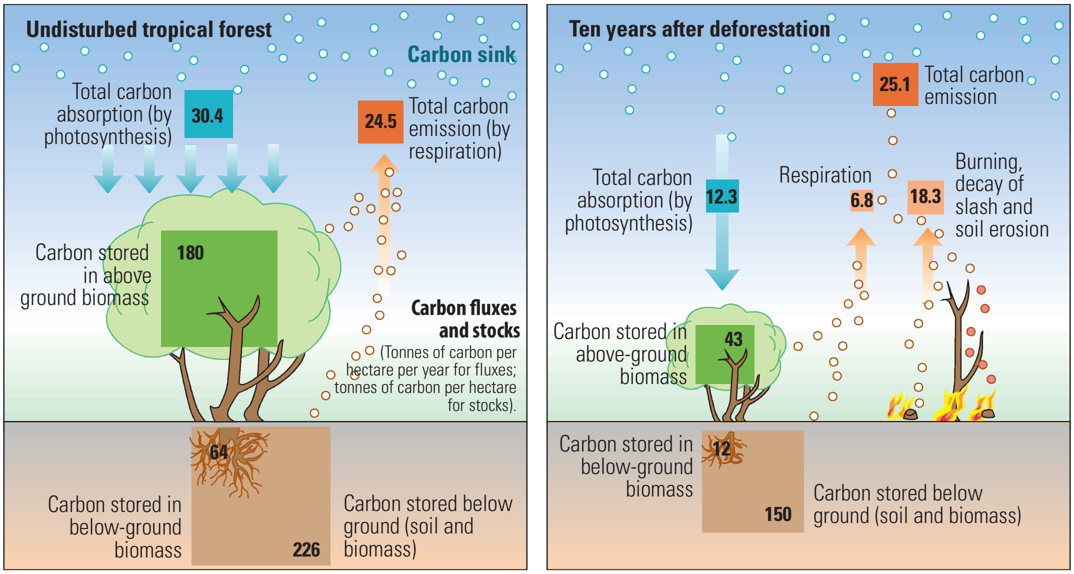
Figure 8.17 The benefits of intact forests on the *environment*, economic activity and social conditions

Environment	Because forests collectively contain approximately 80% of all land-dwelling species on Earth, they are an important store of genetic diversity.
	Forests filter and regulate run-off, and thus improve water quality and help control water flow. By reducing erosion, they lessen turbidity and improve water quality locally and downstream. Three quarters of the world's accessible fresh water comes from forested watersheds.
	Forests protect against floods, landslides, and soil erosion. By regulating run-off they moderate floods and reduce the physical force of water. They reduce the risk of erosion and landslides as they provide a buffer to erosion.
	Because they absorb much groundwater through their roots, forests keep the watertable low in the soil profile and reduce the risk of soil salinity.
	Coastal forests such as mangroves protect coastal *regions* from the impact of tsunamis, waves and storms.
	Locally, forests influence climate by providing a source of atmospheric moisture, shade and shelter from wind.
	Forests have a significant impact on global climates through their sequestration of carbon, rendering them an important carbon sink.
	The maintenance of forest can help adapt to climate *change* by providing a refuge for wildlife, and facilitate the migration of animal and plant species latitudinally and altitudinally.
Economic activity	The formal forestry sector employs 45 million people globally, and wood and manufactured forest products add more than US$580 billion to the world market economy each year.
	Over 41 million people are employed in the informal forestry sector worldwide, which includes the commercial collection of fuelwood and the production of charcoal.
	Forests provide many non-timber forest products (NTFP) which generate US$124 billion in revenue per year. Income from natural forest products often provides a 'safety net' for rural poor and forest-dependent people, filling in the gaps between seasonal harvests and affording rural poor communities with low-cost business enterprises.
	Forest species of insects and birds provide essential services to agriculture, such as seed dispersal and pollination that can be worth billions of dollars annually.
	Forest tourism can have a positive effect on the incomes of the poorest households. The ecotourism market has grown three times faster than the tourism industry as a whole, earning over US$60 billion.
Social conditions	About 350 million people live inside or close to forests worldwide and are largely dependent on these areas for their subsistence, and 1.6 billion people worldwide depend to varying degrees on forests for their livelihoods.
	Around 1 billion people depend substantially on forests for their nutritional needs and food security, including many living in extreme poverty. Forests provide fruits, nuts, honey, leaves, fungi and bushmeat. Forests provide many products apart from food, including livestock fodder, fibres and building materials, and medical and pharmaceutical products.
	About 2.4 billion people worldwide, but particularly in Africa and South Asia, use wood or charcoal for cooking and boiling water. Woodfuel energy is often the only energy source in rural areas of less developed countries.
	Many medical products are sourced from forests, and pharmaceutical companies are constantly engaged in searching forests for ingredients for new drugs and other medical innovations. Less than 1% of known plants have been fully analysed for their potential pharmacologic composition.
	About 60 million Indigenous people are wholly dependent on forests, including a number of hunter–gatherer societies and low-intensity subsistence farming communities, who maintain a spiritual connection with their land.
	Forest-protected areas such as national parks are visited annually by millions of people for a vast range of recreational and tourist pursuits. Approximately 3.7% of the world's forests are designated for the provision of recreation, tourism, education, or conservation of cultural and spiritual heritage.

total carbon pool in all terrestrial ecosystems, and more carbon than the entire atmosphere. Figure 8.18 shows how forests sequester carbon and release it back to the atmosphere when deforestation occurs. The amount of carbon sequestered by forests varies according to forest extent and density, the species, growth conditions and their age within successional dynamics; actively growing trees absorb more carbon dioxide than mature trees. This issue presents a challenge for forest management: whether to develop younger, rapidly-growing forests and plantations which may absorb more carbon as they grow, or maintain and protect older, natural forests. However, planted forests are unlikely to offer suitable habitat for many forest-dwelling species, nor provide the level of ecosystem services, social benefits or non-timber forest products of older, natural forests.

The United Nations Department of Economic and Social Affairs has calculated that reducing forest loss is the most cost-effective means of addressing rising greenhouse emissions. A study of tropical rainforests estimated that if deforestation worldwide can be slowed by 50 per cent by 2050, and total rainforest loss limited to 50 per cent of its current extent, this would save the emission of 50 billion tonnes of carbon into the atmosphere. In recognition of this important role of forests, the signatories of the

Figure 8.18 Tropical forests as carbon sinks and sources



Ne: 'Carbon fluxes' are the exchange of carbon between the atmosphere, biosphere and hydrosphere while 'carbon stocks' are the natural systems which store (sequester) carbon such as biomass (organisms) on or below the ground. Flux values are reported as a 10-year average.

ACTIVITIES

1. Refer to the positive impacts of forests listed in Figure 8.17.
   a. Categorise the *scale* each impact operates on; i.e. the local, *regional* or global *scale*.
   b. Explain why many of the benefits of intact forests are under-valued in economic evaluations.
2. Access the YouTube video *Convenient Truth (Part 1)* produced by the FAO explaining how forests store carbon but can also become a source of greenhouse gas emissions through deforestation. Use this and the information in Figure 8.18 to explain how keeping forests intact can reduce the severity of climate *change* as well as assist in mitigating its impacts.
3. Create a concept map that outlines the major impacts of deforestation in and around a location. Consider its positive and negative impacts on social conditions and economic activity as well as its impact on the *environment*.

2015 Paris Agreement on climate change pledged to conserve forests as a global carbon sink.

Well-managed forest ecosystems can also help in the adaption to the impacts of climate *change*. They can provide a refuge for wildlife, and maintaining large areas of forest will allow animal and plant species to migrate latitudinally and altitudinally in response to global warming. Forests also offer protection from increasing hazards and can protect ecosystem services and social benefits which may be under threat from a *changing* climate. For example, mangroves protect coastal areas against storms, forest products provide local communities with a safety net when climate variations harm farm productivity, and intact forests regulate water quality and river flows in catchments affected by *changing* patterns of rainfall and snowmelt.

How have people responded to deforestation?

Forests are usually managed at a local and *regional scale*, with national governments establishing policies and laws to guide their management, and developing long term management plans for individual forests. But with over 90 per cent of the current destruction occurring in tropical forests in the developing world, there is an urgent need for the global community to assist in arresting the deforestation of this biome. The range of strategies available to deal with deforestation is shown in Figure 8.19.

While the protection of forests in reserves such as national parks and wildlife parks can be a very effective way of dealing with deforestation, the reality is that much of the world's remaining forest has a *spatial association* with the poorest parts of the world, and the use of wood and non-timber forest products is critical to stave off hunger and abject poverty in these *regions*. Hence the *sustainable* use of forests through forest conservation, rather than forest preservation, has been identified by the United Nations as one of the key strategies to alleviating world poverty set out in the Sustainable Development Goals.

Most countries have forest management guidelines aimed at achieving *sustainable* forest use, but implementing these measures has been beset with challenges. These difficulties include:

- illegal harvesting of forest products and the challenge of monitoring large tracts of land in often quite remote and isolated locations
- the high cost of enforcing forest protection
- susceptibility of the forest sector to corruption and poor management, particularly in developing nations where the monetary inducement for forest commodities is great relative to standard wages
- difficulty in measuring the true value of the informal forest sector, as well as the ecosystem services and social benefits intact forests provide, so that these values are undervalued in the decision-making *process*.

The use of geospatial technologies to address deforestation

Technological innovations involving remote sensing and other geospatial technologies such as Global Navigation Satellite System (GNSS) and Geographic Information System (GIS), together with technological means of sharing data, have greatly assisted with the monitoring of forests. The various ways it is used to manage forests and address deforestation is shown in Figure 8.20. The use of aerial images means large and remote areas of forest can be surveyed economically and accurately. Complementing this with samples of data collected on-site at ground level to verify the remote sensed data, termed 'ground truthing', provides more reliable data.

Remote sensing through aerial photographs, satellite, radar, laser scanners or unmanned aerial vehicles (UAV), including drones, allows for the production of aerial images of land cover. These have been used extensively to classify forest cover and monitor its extent and detect *change*, and there are applications and software developed specifically for the use in the forestry sector. The electronic images derived from remote sensing and GNSS can be used to produce maps or models using GIS for the analysis and recording of data. As of 2020, the FAO, in their Global Forest Resources Assessment inventories, has moved towards using *OpenForis*, an open-source geospatial platform to collect, analyse and publish data about the world's forests.

While the use of remote sensing and other geospatial technologies can assist with *change* detection, there can be challenges associated with the use of this technology:

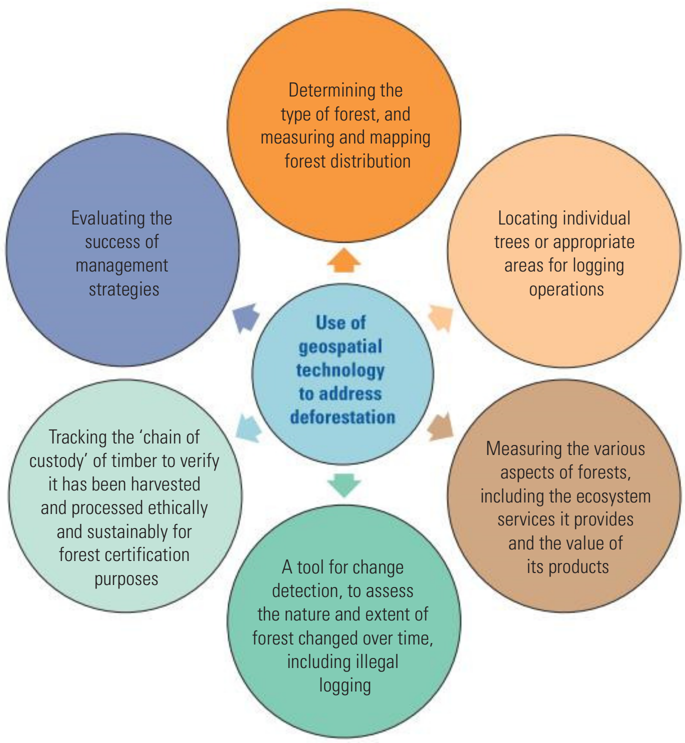
- cloud cover can hamper the analysis of some aerial images, and some remote sensing tools lack sufficient sensitivity to reliably detect and measure aspects of forests. This is particularly problematic for rainforests, which have so much moisture in the air above this type of land cover
- estimates of forest cover or the type or condition of forests can vary with different sources due to the use of different measurement techniques, technology and forest definitions, hampering comparison and analysis of *change*. Some sensors cannot distinguish between dense woody shrubland and forest, for example. Estimating the contribution of deforestation to carbon emissions is particularly challenging, due to the variation in carbon sequestration with the type of forest as well as many other physical factors (resulting in wildly varying figures produced for this ecosystem service).
- some geospatial technology cannot detect small *scale* deforestation
- high-resolution images and the various technologies used to collect, collate, record and disseminate spatial data are very costly and mostly rely on the provision of reasonably advanced and expensive computing infrastructure networks. This challenge is evident in the fact the FAO, in its forest inventories, has relied on satellite imagery covering a 10 per cent sample to supplement information on tropical rainforest deforestation
- Unless the data collected from remote sensing is verified with ground truthing, the reliability of the data may be in doubt.

The use of satellite images by the Brazilian Space Agency and Global Forest Watch for *change* detection provides two examples of how geospatial technologies have been used strategically to address deforestation.

Figure 8.19 Strategies available to address deforestation

Strategies to respond to deforestation
Implementing *sustainable* forest harvesting practices, such as selective logging, lengthening harvesting rotations, and post-harvesting restorative replanting and natural regeneration
Monitoring forests to enable accurate reporting on the location and extent of forest loss and strengthen enforcement of existing regulations
Sourcing timber from plantations instead of native forest through afforestation
Protecting forests in reserves for scientific, recreational and tourist purposes only
Forest certification programmes that certify sustainably and ethically produced timber, so consumers can select forest products based on this aspect
Establishing policies and laws which forbid the importation of illegally logged timber (eg: the *Lacey Act* in the United States and the *Forest Law Enforcement, Governance and Trade Action Plan* of the European Union and Australia's *Illegal Logging Prohibition Act 2012*)
Providing communities in the developing world with alternative sources of fuel for domestic cooking and heating
Accurately assessing the economic value of the informal forestry sector products so that the use as intact ecosystems is compared equitably with other less *sustainable* uses of forest lands, such as agriculture
Assigning a monetary value for the ecosystem services and social benefits of forests to guide authorities in their decisions by taking into consideration the true cost of deforestation
Payment for ecosystem services, where the price for a defined ecosystem service is assigned to a particular area and local landowners are paid to maintain this forested area in place of the income they would earn from its deforestation
Reassessing land tenure laws and government subsidies provided to the forestry and agriculture sectors so that *sustainable* forest use is fostered by government
Implementing community-based natural resource management, so that the financial benefits of forests are directed to local and national communities.

Figure 8.20 The use of geospatial technology to manage forests and address deforestation

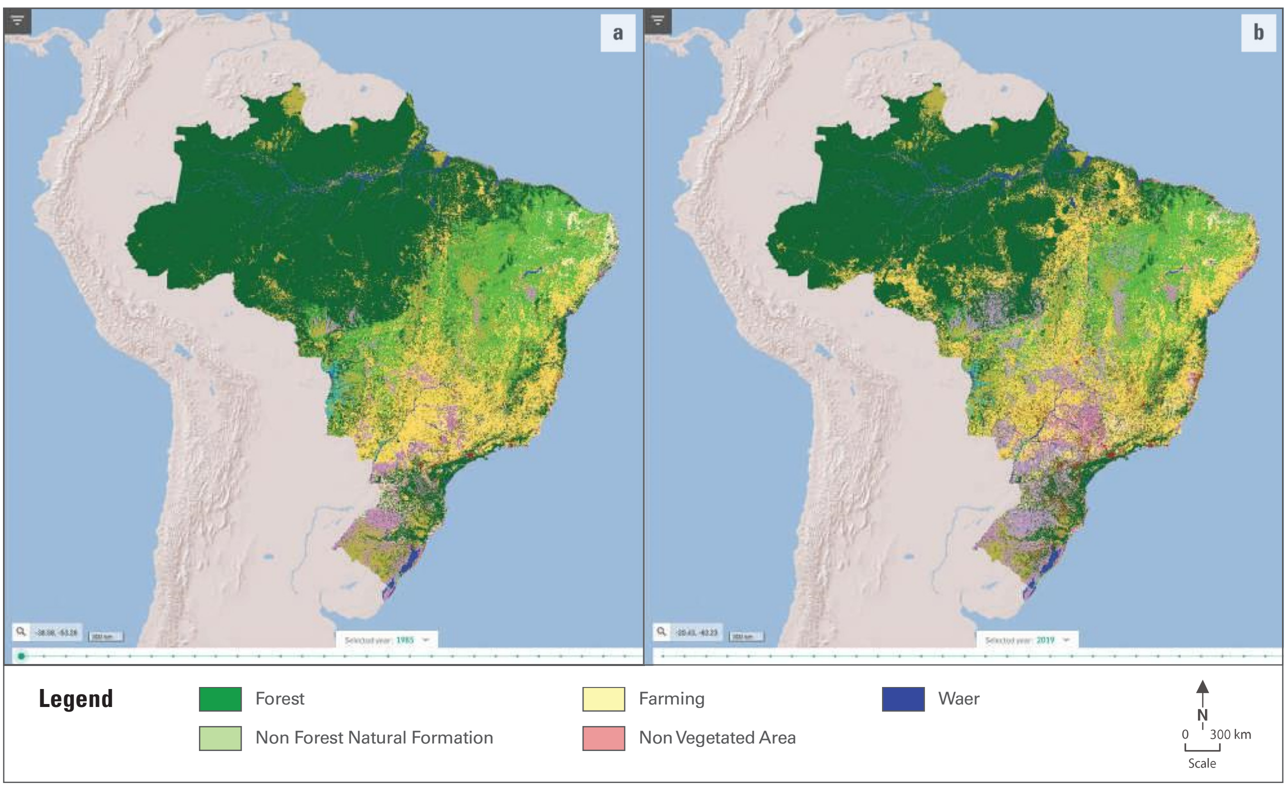


CASE STUDY The use of geospatial technology to manage deforestation in Brazil

The tropical forests of Brazil have sustained some of the highest levels of deforestation over the last 50 years, losing approximately 17 per cent of its forest over this time (see Figures 8.21, 8.22 (a) and 8.22 (b)). This has been largely due to the expansion of large-*scale* agriculture which led to the rapid fragmentation of the primary forests of the Amazon. The use of geospatial technology revealed the Brazilian Amazon to be a hot spot for this land cover *change* as it became one of the world's top agricultural producers, particularly of soy beans and beef cattle. Areas deep within the Amazon rainforest were extremely isolated until railways and roads connected it with the outside world in the second half of the 20th Century. Large-*scale* deforestation began in the Brazilian Amazon in the 1970s and accelerated in the 1990s when soy plantations and cattle ranches grew rapidly in response to the booming global demand for their commodities.

To manage deforestation, Brazil has implemented some of the most technically advanced forest monitoring programs in the world. Since the 1980s, the Brazilian National Space Agency (INPE) and NASA have assisted with the production and interpretation of satellite images of the *region*. These images form the world's longest, most consistent record of *change* in the Amazon. Meanwhile the Brazilian Agricultural Research Corporation simultaneously collected ground-referenced data by interviewing farmers to develop accurate and detailed land cover histories for land across the *region* for the period 2005–2013. This information was used to monitor land cover *change* and enforce the *environmental* laws and the licensing system for rural properties that was introduced in 1999 to curb illegal logging. In addition, the Brazilian Government introduced a moratorium on the export of soy beans sourced from farms established on deforested land, while a consortium of the country's largest beef producers placed a self-imposed ban on sourcing cattle from newly-cleared forestlands. In 2004, the government also established a policy increasing the network of national and state parks, including protected territories for Indigenous groups, and strengthened *environmental* enforcement agencies. More efficient farming methods, in addition to these policies, reduced the rate of forest loss, while maintaining the country's lucrative soy and beef industries. While these strategies allowed authorities to decrease the rate of deforestation in the Brazilian Amazon, as can be seen in Figure 8.22, deforestation has nevertheless continued, with the loss of almost 100 million hectares of forest in Brazil since 1985. This issue has been exacerbated by the weakening of *environmental* laws in 2012 and a reduction in the funding for their enforcement, in addition to widespread forest fires such as those witnessed over the summer of 2019–2020.

▼ **Figure 8.21** MapBiomas time lapse satellite images of Brazil's forests in **(a)** 1985 and **(b)** 2019



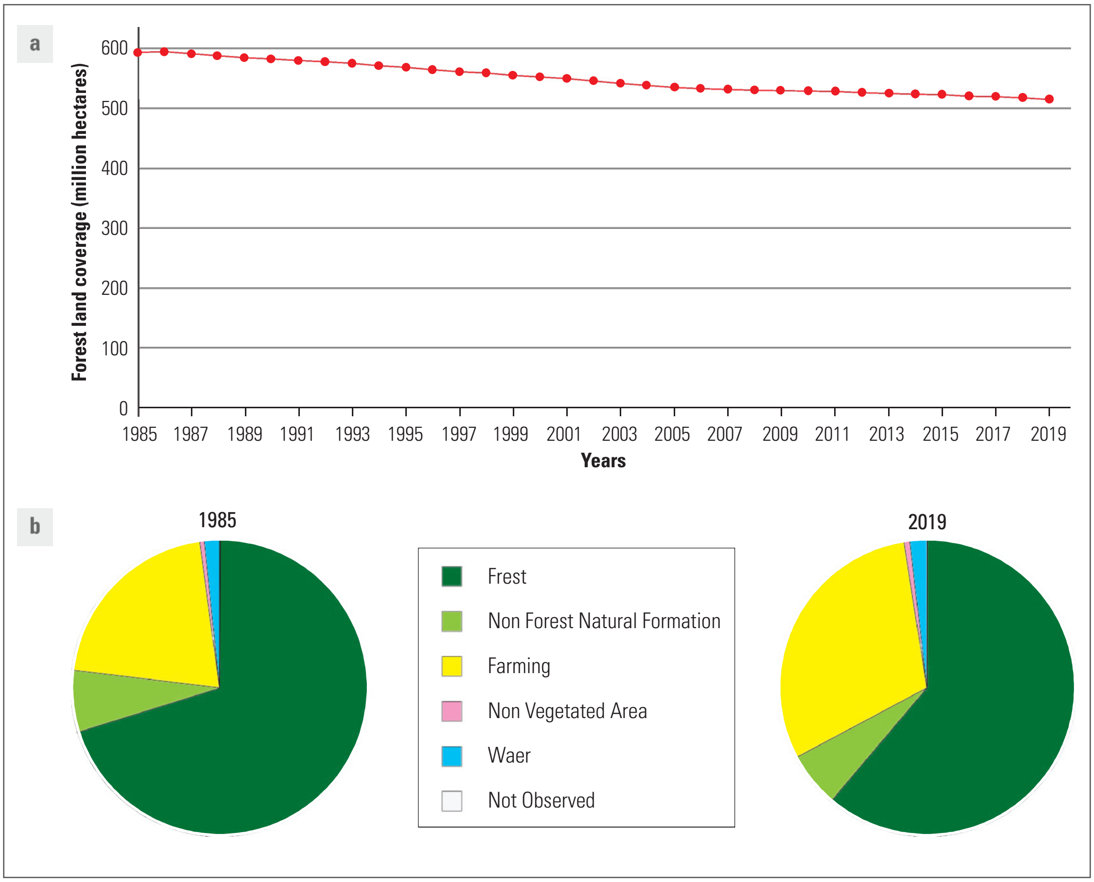


Figure 8.22 Forest land cover *change* in Brazil: **(a)** The trend in Brazil's area of forest land cover 1985–2019 **(b)** The relative contribution of different land cover in Brazil in 1985 and 2019

ACTIVITIES

1. Explain the difference between forest conservation and forest preservation, and identify which is more closely aligned with the concept of *sustainable* development.
2. Consider the strategies listed in Figure 8.19 to address deforestation. Analyse the practicality and likely effectiveness of each of these strategies, and identify any negative aspects each is likely to have.
3. Investigate the *Lacey Act* in the United States, the *Forest Law nforcement, Governance and Trade Action Plan* of the European Union, the *Clean Wood Act* in Japan, or Australia's *Illegal Logging Prohibition Act* and describe how these regulations address deforestation.
4. Some of the geospatial technologies commonly used to collect remotely sensed data on forests include satellite images (including Landsat), LiDAR (light imaging, detection, and ranging), terrestrial photogrammetry and UAV/drones. Explore the use of this technology to monitor and manage forests:
   a. Describe how one of these technologies is used to collect data about forest land cover.
   b. Explain how the three-dimensional aspects of *places* are determined using GNSS.
   c. Explain how GIS is used to manage forests.
   d. Outline the positive and negative aspects of using remote sensing to monitor forests.
   e. Explain how 'ground truthing' can overcome some of the weaknesses of using information derived from remote sensing.
5. Refer to the satellite images showing deforestation in Brazil, shown in Figure 8.21.
   a. Describe the trend and *change* in the *distribution* of forest for the period shown, including quantification.
   b. Describe the *change* in the *distribution* of forest in Brazil over the period shown.
6. Visit one of the following sites that provide access to interactive maps of Brazil and its land cover and deforestation:
   - Plataforma Mapbiomas
   - Terra Brasilis
   - NASA's Earth Observatory site
   - University of Maryland Global Forest Change
   - Global Forest Watch

   Use the geographic media at these sites to create an annotated visual display on deforestation for Brazil or a location within this country. Identify the geospatial technology used to collect and collate the data shown.
7. Analyse why forest management is more problematic in developing *regions* than in countries that have attained a high level of economic development.
8. Explain why deforestation must be addressed on a global *scale*. Consider:
   - forests are a 'global common' in terms of their *environmental* benefits
   - *regions* which are the current site of the most intensive deforestation
   - products of cleared forestlands are globally traded commodities.

Global responses to deforestation

United Nations Forum on Forests' *Strategic Plan for Forests 2017–2030*

The United Nations Conference on Environment and Development (the 'Rio Earth Summit') of 1992 was a seminal point defining how humanity should interact with the Earth throughout the 21st Century. Deforestation was among the most controversial issues discussed at the conference, as the developing nations requested an increase in foreign aid to fund the creation of reserves for forest protection within their borders. While the summit failed to produce a binding international agreement on deforestation, it did reaffirm the concept of *sustainable* development and acknowledged that 'locking up' forests in protected reserves was not a feasible solution in many parts of the world where many people relied on forests for their livelihood.

The issue of deforestation has been relevant to a number of international agreements and conventions. However, it was not until the 21st Century that there was a United Nations–backed instrument specifically designated to address forest conservation on a global *scale* – the United Nations Forum on Forests (UNFF).

The UNFF was established in 2000 and is composed of all the United Nations member states. The subsequent Forest Instrument (the *Non-legally Binding Instrument on All Types of Forests*) was drafted in 2007 and was considered a milestone, as it was the first truly international plan of action for *sustainable* forest management.

The objectives of the UNFF emphasise balancing the *environmental* priorities of forest protection with the use of forest resources as a means of subsistence and *sustainable* income, particularly for Indigenous peoples and rural poor communities whose livelihoods depend on forests. In 2017, the UN Forum for Forests adopted its *Strategic Plan for Forests 2017–2030* (UNSPF). This plan presents six Global Forest Goals which provided a framework for *sustainable* management of forests, as well as for halting deforestation and forest degradation:

1. Reverse the loss of forest cover worldwide through *sustainable* forest management, including protection, restoration, afforestation and reforestation, and increase efforts to prevent forest degradation and contribute to the global effort of addressing climate *change*. To this end, the UNSPF set a target to expand global forest area by 3 per cent above the 2015 level by 2030, an area of 120 million hectares. This would also reduce atmospheric carbon dioxide by around 15 gigatonnes per year, which could potentially be enough to limit warming to less than 2°C, the target set by the international community in the Paris Agreement in 2015.
2. Enhance forest-based economic, social and *environmental* benefits, including by improving the livelihoods of forest dependent people.
3. Increase significantly the area of protected forests worldwide and other areas of sustainably managed forests, as well as the proportion of forest products from sustainably managed forests.
4. Significantly increase financial resources for the implementation.
5. Promote governance frameworks to implement *sustainable* forest management, including through the UN Forest Instrument, and enhance the contribution of forests to the 2030 Agenda.
6. Enhance cooperation, coordination, coherence and synergies on forest-related issues at all levels, including within the UN and member organizations, as well as across sectors and relevant stakeholders.

The Forum on Forests releases regular reports on the UNSPF, evaluating progress on the forest-related indicators of the Sustainable Development Goals, as well as progress towards the targets for the Biodiversity Convention and the Paris Agreement on Climate Change, based on data from the Global Forest Resources Assessment (FRA). The criteria used include indicators of forest condition and socioeconomic aspects of forest use, and aim to provide a valid and comprehensive assessment of the value of intact forests.

The report released in 2020 determined that, on the current trajectory, the world is not on track to meet the UNSPF target of achieving a 3 per cent net increase in forest land cover (over its 2015 level) by 2030. And the fact 420 million hectares of forest land cover has been converted into other land uses since 1990, when coordinated global efforts to reduce deforestation began in earnest, brings into question the effectiveness of such responses to deforestation. Yet some progress has been made. Deforestation has been lowered from 12 million hectares each year to 10 million hectares per year over the last decade, and the rate of net forest loss has slowed, declining from 7.8 million hectares per year in 1990–2000 to 5.2 million hectares per year over 2000–2010 and 4.7 million hectares per year in 2010–2020. Forests protected within national parks and other conservation reserves have also increased, and now total 18 per cent of all forest land cover, exceeding the Biodiversity Convention target of protecting at least 17 per cent of terrestrial ecosystems. Furthermore, over half the world's forests used for their forest products now have a long term management plan for their *sustainable* development.

A 2019 review of the progress of the UNSPF identified greater financial support for developing countries was required. This would enable them to implement *sustainable* forest-management practices by building capacity within the workforce of the forestry and wildlife management sector to enforce existing regulations regarding illegal logging and forest use, and assist with their domestic forestry institutions. The review also identified that, while many countries announced their individual plans and joint strategies to meet the goals, most failed to articulate the practical actions they planned to take to reach these goals.

Global Forest Watch 2.0

In the past, one of the challenges associated with managing forests has been that authorities have not detected illegal deforestation until months or years afterwards. This problem can be partially overcome by the use of remote sensing. One innovation that has facilitated the online reporting of forest extent, as well as the enforcement of existing forest management regulations, is Global Forest Watch 2.0. This is an online platform, launched in 2014, providing aerial images of the global *distribution* of forests in near real-time for public viewing. This enables all stakeholders, including forestry and conservation authorities, *environmental* lobby groups and members of the public, to monitor forests and post alerts if they detect there has been illegal activity; it also facilitates responsive action.

The platform brings together data derived from satellites with internet technologies, to access and collect data about forests in a transparent manner and on a global *scale*. Cloud computing and open source software is used to rapidly *process*, interpret and send large volumes of satellite data, using GNSS coordinates, by utilising clusters of servers scattered around the world. Smartphones can be used to download maps and satellite images, as well as upload GNSS locations and photographs from the ground. Global Forest Watch was developed by the World Resources Institute and a number of partners, including Google, the University of Maryland and the United Nations Environment Programme (UNEP). This technology will also assist forest certification organisations to track the chain of custody of timber and authenticate its origin.

Forest Certification

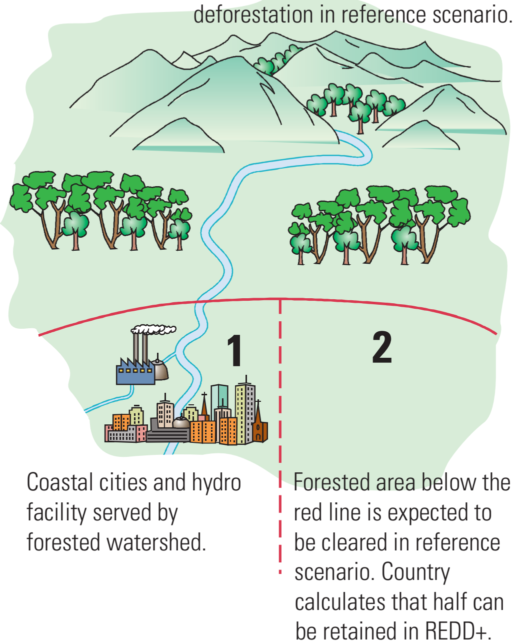
Forest Certification (GFC) is a system established to allow consumers to make informed choices about their purchases of timber and non-timber forest products. It is aimed at promoting *environmentally* appropriate, socially beneficial and economically viable management of the world's forests. This is achieved by producers of timber and NTFP (non-timber forest products) seeking certification for their product, with certification awarded on the basis of a number of criteria related to the legal, ethical and *sustainable* sourcing and production of their product. The assessment is carried out by a certification agency, such as the Forest Stewardship Council (FSC) or the Programme for the Endorsement of Forest Certification, and considers all stages of the commodity's 'chain of custody', from forest to consumer. The producer can then advertise their accreditation. Global forest area certified under the two non-government organisations has grown steadily and totalled 426 million hectares in 2019.

Reducing Emissions from Deforestation and forest Degradation (REDD)

Reducing Emissions from Deforestation and Forest Degradation (REDD) is a program where industrialised countries fund local and *regional* projects within developing countries, which assists them to improve the management of their forests or implement afforestation projects as a means of arresting greenhouse emissions. It is based on the understanding that curbing deforestation both reduces a major source of carbon emissions and maintains one of its important sinks, as shown in Figure 8.18. It also acknowledges that the monetary value of the ecosystem service of intact forests, including carbon storage, is not reflected in the decision-making involved in the exploitation of forests. By creating a financial value for the carbon stored in trees, REDD aims to make forests more valuable standing than they would be cut down. The program also ensures the actions taken to address deforestation conserve natural forests and their biodiversity, and respect the knowledge and rights of local Indigenous and forest-dependent communities.

The program was initiated in 2005 when the governments of Costa Rica and Papua New Guinea, in a submission on behalf of the Coalition for Rainforest Nations at a conference of the United Nations Framework Convention on Climate Change, called on the industrialised member states to take action to reduce emissions from deforestation in developing countries. The idea evolved into the broader REDD+ mechanism when a large number of industrialised countries confirmed their support and pledged funding for projects to arrest deforestation. The scenario in Figure 8.23 shows an example of how a REDD+ project can lead to better *environmental* outcomes while providing for the needs of people.

▼ **Figure 8.23** An example of a REDD+ project to protect catchment forests



▼ **Figure 8.24** Examples of projects that REDD+ funds and guidelines which safeguard their effectiveness

Initiatives	Safeguards
Examples of initiatives that REDD+ funds includes projects which: ▶ involve the *sustainable* production of wood and non-timber forest commodities ▶ provide payment to Indigenous or forest-dependant residents to maintain ecosystem services of forests by leaving them intact ▶ promote forest-based ecotourism ▶ help address the drivers of deforestation by encouraging more intensified agricultural output on land already under cultivation ▶ rehabilitate previously degraded lands by converting them into farms or plantations ▶ replace the use of fuelwood and charcoal in households with renewable energy sources or improve the efficiency of stoves and heaters.	Safeguards REDD+ projects must include: ▶ identification of the key drivers of deforestation for the project's *region*, as well as the 'national circumstance' which may impact on these drivers such as population pressure or land tenure laws, and designs projects which address these causes ▶ explanation of how the project effectively protects forests and biodiversity in the long term ▶ measurement and documentation of the benefits of the project ▶ involvement of the traditional custodians of the forest at all stages of the project's design and implementation ▶ assurances the benefits from the project reach the intended communities and are *distributed* equitably ▶ the formulation of national action plans to deal with carbon emissions by the host nation.

In 2008, FAO joined forces with the United Nations Development Programme (UNDP) and the UNEP to form UN-REDD to assist developing countries prepare and implement national REDD+ strategies. The program has expanded steadily since and now has over 60 official Partner Countries spanning Africa, Asia-Pacific and Latin America-Caribbean. The sorts of projects REDD+ funds and the safeguards it has put in place to ensure projects are carried out effectively and ethically are shown in Figure 8.24.

The effectiveness of REDD+ in reducing deforestation hinges on the compliance with the safeguards and its capacity to fund projects. It also depends on its capacity to guard against 'leakage', where the protection of ecosystem services or social benefits in one *region* merely results in the *movement* of *unsustainable* and inequitable practices to forests elsewhere. A study concluded the REDD program provides a unique opportunity to achieve large-*scale* emissions reductions at comparatively low cost, and determines a monetary value of the ecosystem services and social benefits of forests so their true value is taken into consideration. This allows intact forests to compete with other land uses, such as logging and agriculture, which have historically caused their destruction. By 2020, 30 countries in Africa, Asia and Latin America had developed national REDD strategies, with nine of these countries reporting a reduction in emissions through curbing deforestation.

▶ ACTIVITIES

1. Search for and examine the indicators established for each of the goals of the UN Strategic Plan for Forests 2017–2030 (UNSPF) by the UN Forum on Forests. Critically analyse whether the indicators allow for a thorough and balanced assessment of progress on the social, economic and *environmental* dimensions of *sustainable* forest management and use.
2. Examine the most current information on UN Forum on Forests. This will require accessing the most recent progress report on UNSPF 2017–2030, but also the Global Forest Resources Assessment (FRA 2020). Write an essay evaluating this global response to deforestation, discussing its strengths and weaknesses, and providing evidence for your viewpoint.
3. Refer to the information on Global Forest Watch in this chapter and visit their website:
   a. Consider the positive and negative aspects of Global Forest Watch program.
   b. Develop criteria to evaluate its effectiveness in achieving *sustainable* forest management.
   c. Evaluate its effectiveness against these criteria.
4. Comment on the importance of tracking the chain of custody of forest products seeking forest certification.
5. Visit the REDD+ website and investigate some of the programs it has engaged in within the developing world.
   a. Create an annotated map showing the *distribution* of partner countries and some of the projects that are being implemented, at a local *scale*, within the host countries.
   b. Evaluate the global program under the following headings:
      - economic costs and benefits
      - equity and fairness to people living in and near the forest
      - benefits for the *environment*
      - its effectiveness in achieving its targets.
   c. Research and examine one local example from this program.

CASE STUDY A national response to deforestation: Cameroon

With more than 20 million hectares of forest – slightly less than half the nation's land area – the forests of Cameroon contribute significantly to its economy as well as providing non-timber forest products for its people and important *environmental* services. The forests of Cameroon also provide valuable habitat for native species: over 800 of its flowering plants have been classified as threatened species and 26 of its mammals as endangered or critically endangered. Much of the southern half of the country is dominated by dense tropical rainforest which forms part of the Congo Basin of Central Africa (see Figure 8.25). The Congo Basin is the second largest rainforest in the world and contains one fifth of the world's remaining closed canopy tropical rainforest, and is therefore of *regional* and global significance. The *region* also sustains the livelihoods for 80 million people living across the basin. But deforestation and forest degradation rates in the Congo Basin have increased significantly over recent decades, and the *region* currently has one of the highest rates of forest loss in the world.

Forests play a critical role in providing income and meeting the day-to-day needs of the people of Cameroon:

- Timber is an important commodity, with the formal timber sector contributing about 15 per cent of Cameroon's total exports and 7 per cent of its GDP.
- Fuelwood and charcoal are the most important energy source for cooking in a typical rural Cameroonian household.
- Forest foods including fruits, nuts, seeds and bushmeat supplement the diet of many Cameroonians, particularly the poor and forest dwellers, and especially during lean times.
- Non-timber forest products contribute nearly 44 per cent of household incomes, including extracts from the bark of a number of native trees used locally and sold on the global market for their pharmaceutical properties.
- The forests of Cameroon are also home to approximately four million forest-dependent people, including approximately 50,000 Indigenous people, the nomadic Baka, Bagyeli, Bedzang and Bakola and the sedentary Bantu, who rely, to varying degrees, on hunting and gathering activities to subsidise their livelihood.

Over recent decades Cameroon has recorded very high rates of deforestation, with agriculture and logging the main direct causes of this forest loss. Historically, 'slash and burn' subsistence agriculture and small-*scale* commercial farming of cash crops including cocoa and coffee have been the main cause of deforestation. However, since the 1980s the large-*scale*, commercial monoculture plantations of rubber, palm oil, tea, sugar cane and bananas have increased as contributing factors. Logging has also played a significant role in undermining Cameroon's forests. Small-*scale* logging has been traditionally carried out in the forestlands near large towns in Cameroon to meet the timber needs

▲ **Figure 8.25** The forests of the Congo Basin, showing the location of Cameroon's forests within the *region*. This map shows the most densely forested areas as of 2010

▲ **Figure 8.26** A logging truck travelling east to the port of Douala in Cameroon

of local people, including the substantial market for domestic woodfuel and charcoal. However, large-*scale* commercial logging has become a major contributor to deforestation in Cameroon over recent decades. It is mainly carried out by foreign multinational companies for timber destined for the export market. Timber is now Cameroon's second most important export commodity, after petroleum, and the nation has become Africa's leading timber exporter and the largest exporter of tropical hardwood to the European Union. Logging concession allocations and consequent deforestation have grown steadily. Since 1986, forest land cover has been lost at a rapid rate, as the income from the forestry sector soared.

Over time, there has been a complex *interconnection* between the direct causes of deforestation, agriculture and logging, with indirect drivers including population growth, global market conditions and government policies. Some examples of factors having a significant impact on Cameroon's deforestation include:

- The extension of the Trans-Cameroon railway in the early 1970s contributed to the *movement* of logging operations from the centre and south-west of the country deeper into the forestlands in the east. The subsequent construction of roads opened up these remote *regions*, turning the eastern *region* into the nation's biggest timber producer, but also a deforestation 'hot spot', supplying 60 per cent of the nation's timber by 1992. These logging roads subsequently increased access to isolated forests, opening up these areas for other land use.

- Corrupt practices are endemic in Cameroon's forestry sector. One of the most highly criticised past practices was the allocation of logging permits under negotiated terms. This led to collusion between government authorities allocating the concessions and permit-holders, and the over-allocation of logging concessions. Illegal practices have also occurred 'downstream', in timber transport and export (see Figure 8.14). The impact has been a diversion of revenue away from local populations and the Cameroonian economy, and the lack of adequate enforcement of forestry regulations and *environmental* standards, and this problem persists today.
- The lack of technical expertise and workforce capacity has hampered effective forest management. One example that exemplifies this lack of capacity was reported by the World Resources Institute: in the Eastern Province, 116 agents were engaged to monitor more than 20 million hectares with the support of one single vehicle and a few motorbikes, and these agents had resorted to accepting transport from the very companies they were required to monitor.
- Government policies and management have often influenced deforestation through pricing policies to encourage cash cropping, providing infrastructure in and to remote forest areas, and failing to adequately protect the rights of local forest-dependent communities.

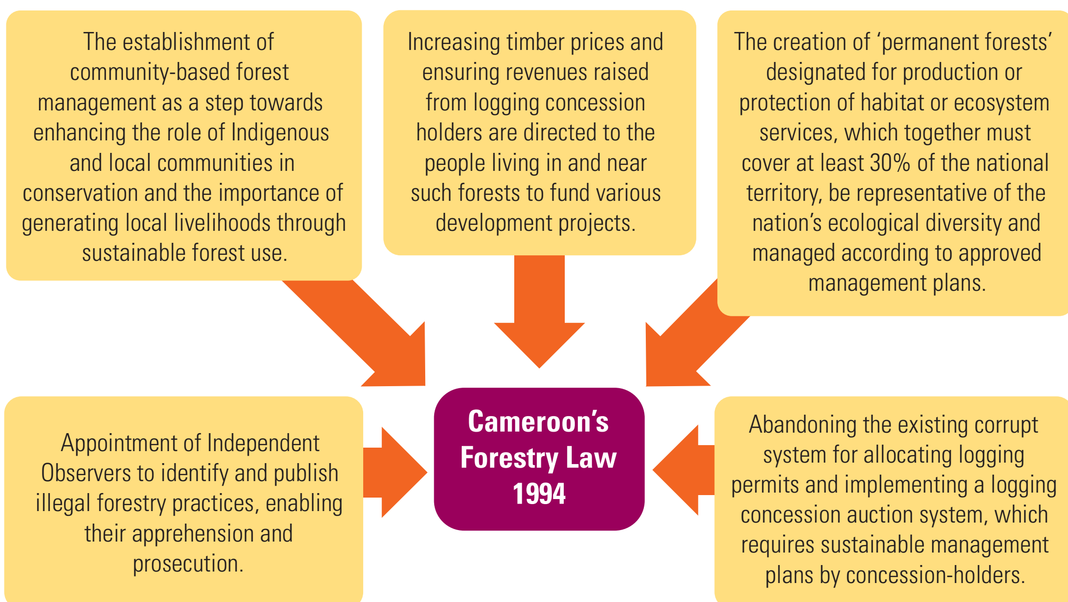
Concern over the rapid rate of forest loss triggered the introduction of the forestry reforms of the Forestry Law in 1994, the first country in the *region* to do so, and involved inviting independent observers to oversee the implementation of the reforms. Some of the key aspects of the reforms are shown in Figure 8.27.

Cameroon's forest management has seen some improvements to its forest governance since the reforms:

- While 40 per cent of forest cover was set aside for timber extraction, over half was devoted to reserves for nature conservation and tourism; the remainder is for rural residents, with many practicing shifting cultivation.
- land allocated to protected areas increased by 8 per cent, largely driven by the creation of new national parks, though many resulted from the reclassification of existing forest reserves, and some have been designated as hunting reserves
- aided in part by a simplification of the application and allocation *process*, community forests increased significantly, with over 300 such sites
- illegal forest activity declined and was estimated to account for less than 10 per cent of timber production, due partly to the work of independent observers
- forest management plans were documented for much of the forest area designated for logging or community use
- exports have favoured processed timber, with restrictions placed on the export of raw logs, resulting in increased employment and income.

Despite these successes, there have been some failures in Cameroon's efforts to address deforestation: the reforms of the 1994 Forestry Law have been hampered by insufficient focus on the traditional uses of its forests, a lack of workforce capacity for monitoring and enforcing forest activities, and entrenched corruption.

Illegal logging continues to be a major concern. While the work of independent observers has led to the prosecution of some of the perpetrators of illegal forest activities, the financial penalties are too low and too few violations are reported or prosecuted. The Yale Centre for Environmental Law and Policy awarded the country an Environmental Performance Index of 22.75 (out of 100) in 2018.



▲ **Figure 8.27** Key aspects of Cameroon's Forestry Law of 1994 (and related legislation)

The 1994 reforms also failed to adequately protect the *interconnected* social and economic rights of the people living in and near Cameroon's forests. While there are now over 300 community forests set aside for their use, and their combined area totals nearly one million hectares, each reserve is limited by law to fewer than 5000 hectares, a size widely considered to be too small to develop into viable enterprises, and collectively community forests total less than 5 per cent of all forestlands. A 2019 study of these community forests also concluded that the vast majority did not meet standards for accountability, equity and performance. Furthermore, Indigenous and forest-dependent communities in Cameroon still often have no legal tenure over their traditional forest lands, which remain formally owned by the state, and the customary land uses of these disenfranchised peoples are vulnerable to allocation for other uses.

Despite the forest reforms and a slight slowing in the rate of net forest loss since 2010, the country continues to experience high rates of deforestation, losing over two million hectares of forest since 1990, mostly within its primary forests, and increasing forest degradation. And while some of the losses due to deforestation have been offset by reforestation, the forest lost has been exclusively replaced by plantations.

Some recent development projects have contributed to this rainforest loss:

- 73,000 hectares of forest was allocated for oil palm plantation in a biodiverse forest area in the southwest *region* of the country.
- A dam constructed on the Lom River and opened in 2018 at Lom Pangar to produce hydroelectric power and to regulate water flows along the Sanaga River in the east of the country, flooded 32,000 hectares of forest.
- The development of a rubber plantation adjacent to the Dja Faunal Reserve UNESCO World Heritage Site in the country's south-eastern *region* since 2011 resulted in the clearing of more than 10,000 hectares of dense tropical rainforest, with a logging concession allowing for an additional 35,000 hectares to be cleared (see Figure 8.28). The reserve is home to the Indigenous Baka people, and provides habitat for a number of endangered species, including western lowland gorillas, chimpanzees and African forest elephants.

▲ **Figure 8.29** Local communities have been enlisted to use smartphone apps to assist with detecting and reporting suspicious forest activity in Cameroon

▲ **Figure 8.28** Aerial image of the Sudcam rubber plantation in development in Cameroon's south-eastern *region*

The Cameroon government has announced further reforms to the Forest Law of 1994, including improved participation, transparency, and land tenure reform, though this *process* has been slow in its implementation. Meanwhile, there have been a number of other promising advances in *sustainable* forest management in Cameroon:

- In 2017, the government committed US$935,000 annually towards plans to restore 12 million hectares of deforested land to redress the challenges of dwindling forests and to conserve indigenous forestlands, as part of the Bonn Challenge initiated by the International Union for Conservation of Nature. The government has also taken a tougher approach to illegal logging: in 2016, the licenses of four logging companies were suspended while 35 other companies were issued with warning notices, and fines totalling over US$88,000 were enforced for illegal forest activities.
- Cameroon's readiness preparation for REDD+ programs (see page 133) was endorsed by the World Bank in 2013. However, critics argue that there has been inadequate consultation with rural and Indigenous forest communities in this planning *process*, which is one of the requirements of the REDD+ program.
- Cameroon now has several Forest Stewardship Council certified forest operations (see page 133).
- In 2011 Cameroon entered a Voluntary Partnership Agreement with the European Union through its Forest Law Enforcement, Governance and Trade (FLEGT) programme to improve forest governance and ensure timber exports to the European Union were sustainably sourced.

There have also been some recent initiatives in Cameroon involving the application of geospatial technologies to empower local communities to help reduce deforestation:

- Some forest *regions* have introduced a project that cross references information from "eyes on the ground" provided by local people with the "eyes in the sky" provided by Global Forest Watch (see page 133). This information sharing has been used to improve the accuracy of international monitoring instruments by 'ground truthing' information on forest condition and activities with remote sensing data. The spatial information for the *region* is transformed into a format that communities can access and *process* themselves using Participatory 3-Dimensional Modelling (P3DM), an interactive visual tool that converts spatial information into a physical, three-dimensional model. It can be used to display and disseminate data about tree cover loss and other relevant information on a smart phone. One example of a local application of satellite imagery of deforestation in Cameroon by Global Forest Watch was evident in the development of the rubber plantation adjacent to the Dja Faunal Reserve (see page 137). Global Forest Watch detected this land cover *change*, with the assistance of local people on the ground, and the issue then received media coverage and resulted in pressure on the company involved, Sudcam, to cease logging operations in the area. The company subsequently developed a Sustainable Natural Rubber Supply Chain Policy and created an independent Sustainability Council. Subsequent satellite imagery from Global Forest Watch indicate no further clearing has happened since the deforestation ban was issued in December 2018.

- There is an initiative to enlist local people to geo-tag images of freshly cut stumps and send them to authorities to monitor suspicious logging activities. More than 100 people have been trained as community 'forest defenders' in the eastern *region* of the country and other areas where illegal logging has been prevalent. The training has been organised in collaboration with Forest and Rural Development, a Cameroonian group that works with communities to monitor forest activities, combat corruption and improve governance of forests.
- The extension of the Trans-African Highway, connecting Central Africa from east to west as of 2013, facilitated transport and trade across the *region* as well as the development of villages along its route, but it has also enabled logging activities and farm development in forested areas that were previously too isolated and remote. The African Conservation Foundation and the Environment and Rural Development Foundation developed a program using geospatial technology, provided by Global Forest Watch (see page 133) to identify and protect the forests of southwest Cameroon. The program involved the creation of tree cover loss maps from satellite images for each year from 2001 to 2014 to identify the *changes* in the forests in the *region*. The visual images established a strong *spatial association* between the rapid loss of tree cover and the construction of the road from 2008, when the road construction commenced. On-ground observations confirmed this was due to increased illegal logging and conversion of forest to agricultural land and plantations, facilitated by the improved accessibility into the *region* due to the Trans-African Highway, and were able to determine the perpetrators of the deforestation in a number of cases.
- The Wildlife Conservation Society of Cameroon, with the support of the European Union's FLEGT programme, developed a monitoring tool, which allows forestry operators to meet their regulatory requirement of monitoring wildlife within their forest concession, through the use of a matrix to record the species present and their abundance. In 2019, the Cameroonian government passed a law making the use of this web and mobile based application compulsory for all forest concession-holders, to regularly record and evaluate the impact of their operations on native wildlife.

The government of Cameroon has the long-term aim of becoming an emerging economy by 2035. A 2015 study calculated that this development will result in the loss of a further two million hectares of the country's forest cover. The challenge for Cameroon will be to achieve the *sustainable* development of its precious forest resources.

ACTIVITIES

1. Access the most recent data on deforestation on Cameroon from the Global Forest Watch website and the Global Forest Resources Assessment (FRA 2020). Using this data and the information provided above, summarise for Cameroon:
   - its location and land cover, including a location map and a sketch map of its forests
   - its location within the global *distribution* of forest land cover, including the *region* of forest it lies within
   - *changes* in the *distribution* of its forests over time
   - reasons for the *change* in the *distribution*
   - the impact of deforestation on the *environment*, economic activities and social conditions
   - responses to deforestation at this location at local and national *scales*
   - the use of geospatial technologies to assess and manage deforestation.

   Conclude with an evaluation of the efforts to manage deforestation in Cameroon, including a set of criteria which can be used to guide your assessment, and quantified data.
2. Use the internet to investigate an example of a REDD+ local initiative within Cameroon designed to address the impacts of deforestation such as:
   - the REDD+ program at Mount Cameroon, south-west *region* of Cameroon
   - or its 'Payment for Services' program in the south and east of Cameroon

   Develop a summary of this initiative, including an evaluation of the program.
3. Visit the University of Maryland's Global Forest Change website. Zoom in on Cameroon on the GIS map provided and access the GIS layer that provides the most recent data on the forest loss. Describe the location of Cameroon within the global *distribution* of forest loss.

▶ CASE STUDY The forests of the Central Highlands of Victoria

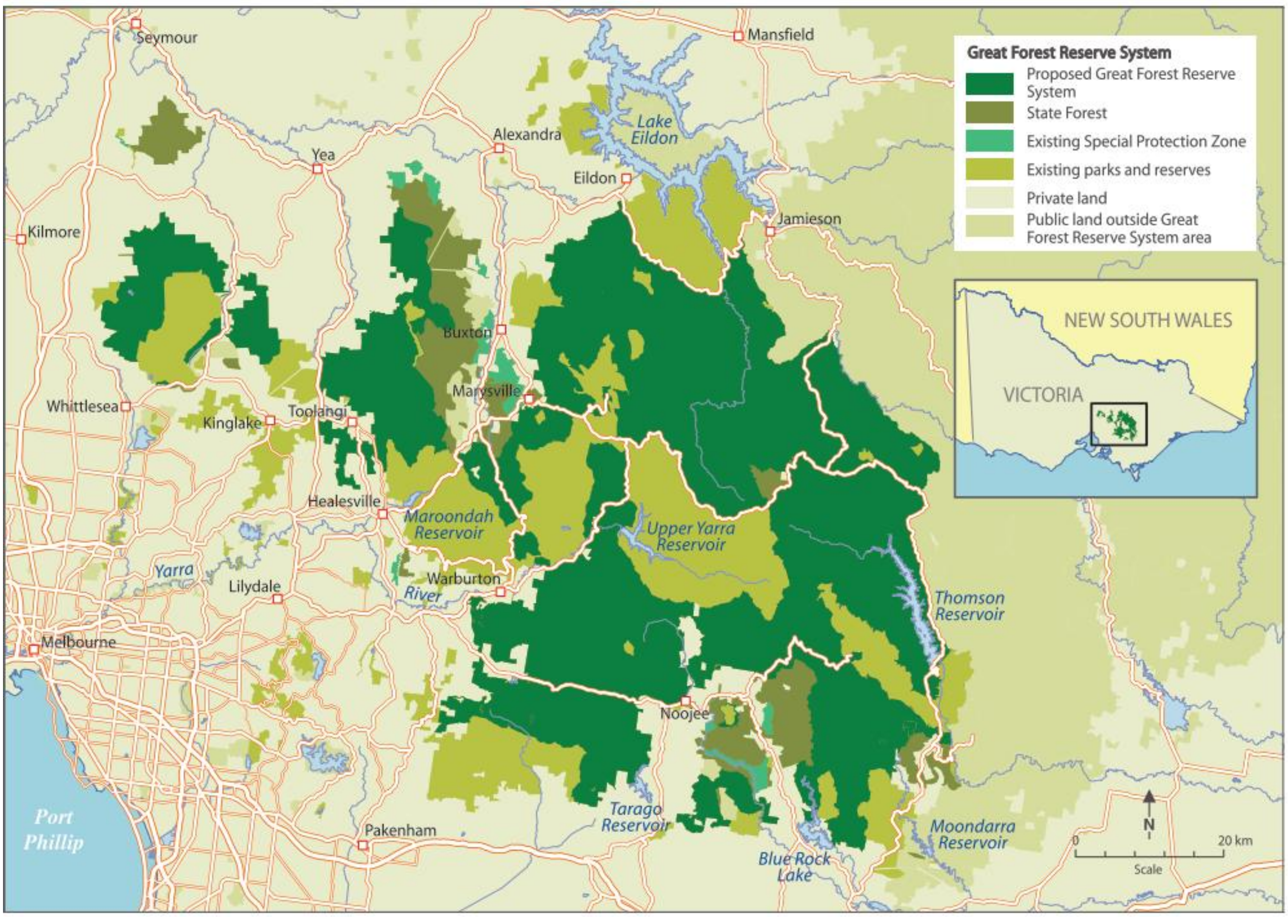
The Central Highlands of Victoria contain large areas of temperate forest dominated by mountain ash, *Eucalyptus regnans,* the world's tallest flowering tree. At present, nearly half the *region* of a little over one million hectares is forest, of which a third is held in a series of protected reserves and the remainder in state forest, some of which are vital as water catchments. The forests of the *region* are very fragmented and include 1886 hectares of old growth forest spread across 147 different patches. It is one of only a few locations of the highly endangered Leadbeater's Possum, Victoria's faunal emblem. The forests of the Central Highlands are threatened by large-*scale* coupe clearfelling within the state forests, in addition to fires including the Black Saturday fires of 2009 which nearly wiped out the last remaining populations of Leadbeater's Possum. Forestry, timber cutting and sawmilling have been major industries in the *region* since the late-19th Century and expanded to supply post-war housing demand after 1945. The logging now occurs under a Regional Forest Agreement, established in 1998. In 2018 VicForests, the managers of forestry operations in the Central Highlands, was unsuccessful in its bid to gain Forest Stewardship Council (FSC) certification as it failed to conform with established FSC standards.

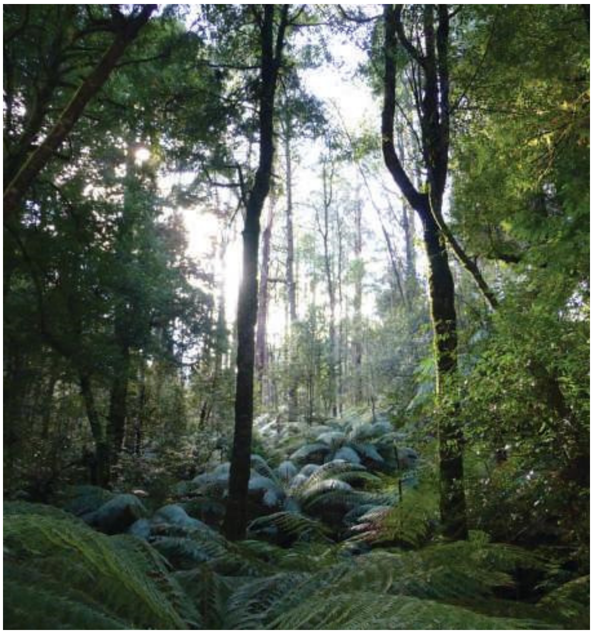
A consortium of the Australian Conservation Foundation, the Wilderness Society, the Victorian National Parks Association and the Royal Society of Victoria has put forward a proposal for a new national park in the *region*, the Great Forest National Park. The park would add 355,000 hectares to the existing 170,000 hectares of parks and protected areas in the Central Highlands of Victoria, connecting the existing forests of the *region* and step up the level of protection afforded to the remaining old growth forests (see Figure 8.30).

The key reasons the proponents have put forward the proposal are to:

- conserve the flora and fauna of the *region*, including endangered species
- protect the water catchments of Melbourne, LaTrobe and the Goulburn Murray systems
- assist with Australia's greenhouse gas emission obligations
- enhance tourism in the *region*
- protect *places* of spiritual nourishment.

▼ **Figure 8.30** The proposed Great Forest National Park, Central Highlands of Victoria





▲ **Figure 8.31** Temperate rainforest, Toolangi, within the proposed Great Forest National Park

▶ ACTIVITIES

1. Create a report on the case study of the forests of the Central Highlands of Victoria as an example of deforestation on a *regional* and local *scale*. Visit the Great Forest National Park website and access the maps in the *Great Forest National Park Report* to supplement the information provided within this chapter. Create a report on the proposed Great Forest National Park, including:

a. an outline of the *regon's* land cover and biophysical *environment*

b. the land use in the *region*, the authorities involved in its management, and how it has been managed over time

c. the benefits of the forests of the *region* to people and the *environment*, including the social conditions and economic activities of people outside the *region*

d. the details of the proposed new national park, including maps

e. criteria which can be used to evaluate the proposal and your evaluation of whether the proposal would lead to the *sustainable* development of the forests of this *region*

f. outline some key reasons why some people might oppose the suggested new park.

▶ CASE STUDY A local response to deforestation: Monte Alto Forest Reserve, Hojancha, Costa Rica

The inhabitants of the small town of Hojancha in the central highlands of the Nicoya Peninsula in the Guanacaste province of northwestern Costa Rica have responded to the challenge of deforestation. The land surrounding the headwaters of the Nosara River, which flows from these highlands into the Pacific Ocean, suffered deforestation under a past government policy that encouraged large-*scale* land clearing for agriculture. Much of the original rainforest of the wider *region* was cleared for cattle ranching, but also for commercial timber logging, intensive grain cultivation, and coffee and sugarcane plantations, which eventually reduced forest cover to 12 per cent of its original *distribution*. The Nosara River is a source of drinking water for the inhabitants of Hojancha, a town of about 250 families, and this land cover *change* had resulted in the degradation of the forests located in the river's headwaters, and a consequent deterioration of water resources. Long and erratic droughts in the dry season were followed by extreme flooding in the rainy season, causing both soil erosion and water scarcity. It is estimated that between 1968 and 1992, the flow of the Nosara River was reduced by 90 per cent, leading to an acute water shortage and subsequently the out-migration of more than 50 per cent of the population of Hojancha.

The local farmers came together in 1993–1994 to form the Foundation for Monte Alto Forest Reserve, with the goal of restoring the forest of the headwaters of the Nosara River and developing *sustainable* livelihoods. The foundation purchased parcels of degraded land, one hectare at a time, along the steepest slopes within the headwaters where freshwater springs originate. After a quarter of a century of rehabilitation works, the foundation has overseen the recovery of an important watershed, including restored water levels, an increase in forest cover to 56 per cent, improved biodiversity, and a reversal of out-migration of local inhabitants. A number of species have returned to the area: before the restoration, there were hardly any sightings of agoutis, peccaries, white-faced monkeys or ocelots in the area, but these species are now often seen.

▲ **Figure 8.32** The location of Hojancha, Guanacaste province of north-western Costa Rica

Botanists have also identified two rare and endemic species in the reserve, which had previously been considered extinct.

The restoration involved the formation of a 924 hectare protected zone, the Monte Alto Reserve, as well as areas reforested with high value timber species, such as teak, for *sustainable* wood production, and for agroforestry plantations for coffee bean production. This *process* required the purchase of land for natural regeneration and reforestation, and an agreement with the Costa Rican Ministry of Environment facilitated local participation in the area's management decisions and the provision of technical assistance. Income generated by ecotourism within the area helped to reduce the community's reliance on forest clearing for cultivation and provided the funds to purchase land from willing farmers for forest restoration. Since the restoration of the forest, ecotourism has been promoted to accommodate visitors and create jobs while enabling the foundation to purchase more land to expand and continue restoration (see Figure 8.33). Local school children are also invited to learn about the foundation's work and to take part in educational activities on the importance of functioning ecosystems and healthy forests to community wellbeing. These activities culminate in an annual tree-planting drive, where local children plant native tree species in degraded areas.

Stakeholders are now looking at improving connectivity between the remaining remnants of natural forest. By adopting a flexible and inclusive approach that started out small and then built in *scale*, Monte Alto Forest Reserve Foundation has shown the development of functional and productive forests is achievable.

The work of the Hojancha community has been supported by a shift in the national government's approach to its forests. In the 1950s–1960s, government policies encouraged forest clearing in Costa Rica to make way for agriculture, which included imposing a tax on forests as 'unproductive land'. By 1980, the country was losing 4 per cent of its forest every year, mainly to land use *change* to pasture. However, since the 1980s, a *change* in government policies and the introduction of a series of forest laws have greatly reduced deforestation in Costa Rica. In 1994, the government declared *sustainable* development to be a national objective. It scrapped its military, and diverted these funds into 'Dividends from Peace', investing instead in education, health care, communications, and natural resources. In collaboration with the World Bank, it calculated a monetary value for the ecosystem services provided by its forests and factored this into its planning, and introduced a tax on fossil fuels to fund *environmental* improvements. A network of conservation areas was created and there was a shift towards promoting reforestation, ecotourism and good forest management. Today, over half of the country sustains forest land cover, compared to 21 per cent in 1987, and over a quarter of its land is under protection in either national parks or private reserves.

▲ **Figure 8.33** The Monte Alto Forest Reserve, Hojancha, Costa Rica

ACTIVITIES

1. Access the GIS map on the Global Forest Watch website and the data tables from the Global Forest Resources Assessment (FRA 2020). Using both sources, contrast the *distribution* of forest loss in Costa Rica with the rest of the world and with the other countries in the Central America *region*.

2. Access an online, three dimensional image of Hojancha (search for 'Hojancha Costa Rica 3D map'):

a. State the relative location (from Costa Rica's capital, San Hosé) and the absolute location of Hojancha.

b. Describe the *distribution* of forest land cover in the *region* surrounding Hojancha.

c. Search online for an 'elevation map' of Hojancha. Referring to this map and using the tools it provides:

- measure the *distance* from the town centre to the source of the Nosara River (Rio Nosara), to its south
- state the direction the river flows from its source towards the Pacific Ocean
- determine the elevation of Hojancha and that of the source of the river
- create a topographic map of the town, the Nosara River and its surrounding *region*, including a *scale*
- create a cross section from the northern edge of the town to the valley to the south of the source of the river
- measure the gradient of the river from its source to the town.

d. Analyse how physical *environmental* factors, namely the topography of the site, may have contributed to the adverse impacts on the *regon's* water quality, post deforestation.

3. Referring to the text, analyse the impacts of deforestation at this site on the *environment* and on economic and social conditions of Hojancha.

4. Analyse the work of the Foundation for Monte Alto Forest Reserve in reducing the impacts of deforestation at this local *scale*. Include data in your analysis to support your contentions, and identify the aspects of this local response which have been key to its success.

5. Suggest how geospatial technologies may have been employed to assist with assessing and managing deforestation at this site.

Glossary

abiotic: non-living items and *processes* in the natural world; relating to the physical world

ablation: the loss of snow and ice on a glacier by melting, sublimation and evaporation

accumulation: the addition of snow and ice to a glacier or ice sheet; the opposite of ablation

ad hoc development: improvised, unplanned or one-off development; not suitable for application elsewhere

afforestation: the establishment of a forest in a *region* that has not previously been forested

agrarian societies: communities that have farming as the economic base of their relationships with their *environment*

Agricultural Revolution: a mid-18th Century period of technological change that increased agricultural productivity by mechanising farming and enlarging field sizes often resulting in much reduced numbers of farmers and agricultural labourers. Can also refer to other periods of major agricultural *change*.

agroforestry: a system of farming that integrates the growing of trees, crops and/or livestock

albedo: the amount of electromagnetic radiation that is reflected from a surface compared to the amount that is absorbed; refers to the reflectivity of a surface, and the higher the albedo the less heat is absorbed on that particular surface

amenity: a desirable, attractive or useful feature of a *place*; may refer to a facility in a *place*

arid: severe dry conditions that significantly limit plant growth; arid zones are climatic *regions* perennially lacking water (i.e. not just seasonally or during drought); typically evapotranspiration is greater than precipitation. Aridity increases with a prolonged reduction in precipitation including during ice ages.

biodiversity: the variety of living organisms (plants and animals including microorganisms) in a particular *region*. It comprises the variety of species, the genetic variety within species, and the variety of different habitats and ecosystems within a *region*. Biodiversity loss is a major problem that impoverishes *environments* and is due to natural or human processes or a combination of both.

biome: a type of natural *environment*, encompassing its biotic components of plants and animals as well as the physical landscape they inhabit, especially covering large areas. Forests, woodlands, savannah, grasslands, coral reefs, desert and tundra are all examples of different biomes, and each may contain a range of ecosystems and habitats.

biophysical *(environment)*: various aspects of the natural world, including its biotic (or living) components, such as plants and animals, as well as its abiotic (or non-living) components, such as the soil, water and air, that make up the surroundings

bioregion: a bioregion is an ecologically and geographically defined area that is smaller than an ecozone, but larger than an ecoregion and an ecosystem

biotic: comprising living organisms; relating to the living world

boreal forest: a forest biome dominated by coniferous trees, located within subarctic (boreal) *regions* of the Northern Hemisphere; covers the largest area of any forest-type on Earth, and is also known as Taiga. Has enormous numbers, but relatively few species, of trees.

brownfield: land development of industrial or contaminated sites

bushmeat: meat procured from wild animals

carbon sequestration: the absorption and subsequent storage of carbon dioxide from the atmosphere, such as by plants through photosynthesis that subsequently store carbon in woody tissue or in the soil

carbon sink: a carbon sink is a natural or artificial reservoir that accumulates and stores some carbon-containing chemical compound for an indefinite period; may result from short-term *processes* such as sequestration or human action (e.g. plantations, or injection into porous rock), or long-term ones such as geological deposition; all natural greenhouses gases have their own particular sink *processes* and storages

carbon source: activities or *processes* that release gaseous carbon emissions into the atmosphere

carrying capacity: the maximum population size of a species that can be *sustained* by the *environment* in terms of food, water and habitat; varies according to factors such as technology used or the consumption per person (so that the same number of people in different *places* can have markedly different carrying capacities); in agriculture refers to livestock carrying capacity which can be increased by land use intensification

clear felling: the complete clearance of trees in a *region* for timber harvesting or to make land available for infrastructure or agriculture

climate *change*: Climate *change* occurs when the regular, predictable pattern of lower-atmospheric conditions alters. This may be due to regular natural episodes of *change* to the *processes* that influence our climate – astronomical variables such as the orbital relationship between our planet and the Sun (Milankovitch cycles) that affect the amount of incoming solar radiation that drives the climate system, or planetary variables such as terrestrial or atmospheric factors here on Earth. *Change* may be naturally slow (taking tens of, or hundreds of, thousands of years, evident for example in many glacial cycles over millions of years) or more abrupt (possibly only millennia, centuries or less). Climate *change* can also be caused by human actions such as those activities that increase greenhouse-gas 'sources' or reduce their 'sinks' thereby contributing to our disturbance of the Natural Greenhouse Effect. Note that natural climate variability should not be confused with long term *change*, and the Natural Greenhouse Effect should not be confused with the Enhanced Greenhouse Effect or the 'Global Warming' the latter contributes to.

climate variability: over many years, *regional* climates typically experience periodic variations within the natural, normal and predictable range of their prevailing climatic conditions (e.g. patterns of precipitation, temperature, wind, humidity, etc) with some varying more or less than others. Much of this natural variability is due to various dynamic influences such as episodic changes in nearby ocean current circulation patterns including the El Nino Southern Oscillation (ENSO) that influences climates in many *regions* bordering the Pacific Ocean. Observers will note that climates are subject to periodic, and possibly cyclical, *change* perhaps over a few decades before returning to what they were – but these are normal and natural patterns that have prevailed for thousands of years. This variability should not be confused with longer term climate *change* such as that related to long term glacial cycles or current global warming.

climax community or forest: *see* plant succession; a relatively stable end-stage of succession after which there is little *change* in that plant community as long as its environment remains undisturbed

closed forest: *see* forest canopy cover

commercial farm (or plantation): farming for profit through trade in crops or livestock, as opposed to farming for sustenance of the household (the latter is called subsistence)

commodities: products that are commonly sold on global markets; typically, products intended to trade for cash sale rather than subsistence use

conservation: careful (i.e. conservative or *sustainable*) management and use of resources so that resource depletion will be reduced over time and/or renewable resources will be the focus of use

continental shelf: the seabed that extends from a continent at a relatively moderate slope and beyond which there is deep ocean; covered by relatively shallow water during interglacial periods but often exposed during glacial periods

control: used in an experiment as a constant, baseline or standard that is unchanged for comparison with results; important as a reference point in monitoring *change*

coppice: trees that if cut down or heavily pruned are capable of producing new growth from their trunks, stumps or roots; a *sustainable* method to create new woody stems

coupe clear felling: a method of felling the forest in sections called logging coupes; the coupes are cleared of all or most trees, often prior to re-seeding or re-planting as a tree plantation (as opposed to selective logging where mainly commercial tree species are logged and removed)

cryoconite: a grey to black coloured mineral composed of windblown sediments that comprise a combination of small rock particles, soot, dust and microbes. Cryconite is one of many material deposits (e.g. soot, dust, soil, algae or other dark minerals) that may reduce albedo thereby retaining more heat and accelerating surface ice melt.

cryosphere: a term referring to all the snow, ice and permafrost on and beneath the surface of the Earth and ocean

deforestation: the long-term reduction of tree canopy cover to below 10–30 per cent of its original cover (depending on the type of forest)

desertification: results wherever a reduction in natural growing season and/or an increase in land degradation causes a prolonged and substantial loss of ecological productivity; long term desertification may result from glaciation and is typical of ice ages because of the formation of very cold arid climatic conditions over large *regions*

desktop research: the collection of secondary data or that which has already been collected; to most people it suggests important sources such as published reports, maps and statistics

drylands: areas of the world that have a growing season of 1–179 days. These are *regions* classified climatically as arid, semiarid and dry subhumid because of their limited precipitation and/or high evaporation.

ecological productivity: a measurement of plant production or increase in growth of vegetation over one year. Often used as a measure of the organic fertility of a given area (and portrayed as Net Primary Productivity); varies according to factors such as the availability of sunlight, water and nutrients.

ecosystem services: the direct and indirect contributions ecosystems make to human wellbeing (and the rest of Nature) such as water filtration and regulation, carbon sequestration and climate stability, nutrient cycling, erosion control and the preservation of soil quality. It can also embrace the economic and social benefits to people, such as their recreational, aesthetic and cultural values, as well as the biological resources they provide. The loss of ecosystem services is one of the costs of environmental destruction and degradation; and retaining or improving ecosystem services is one goal of *sustainable* development.

ecosystem: a community of biotic or living organisms, including plants, animals and microorganisms, in conjunction with the abiotic, or non-living, components of their environment (including air, water and mineral soil), interacting as a system

elevation: height of a land surface above mean (average) sea level

Enhanced Greenhouse Effect: is a process that modifies the natural Greenhouse Effect by enhancing (increasing) the amount of heat stored in the lower atmosphere, thereby increasing annual average surface temperatures. Since the late 19th Century, for example, there has been about 1.1°C average increase; with higher increases on land but less over the oceans. Two major forms of human activities are responsible: those that increase the emissions (or sources) of greenhouse gases and those that decrease the *processes* whereby greenhouse gases are absorbed and stored (sinks). The sources have been diversified to include non-natural greenhouse gases including those designed to retain heat in refrigeration. Human activity has also forced an enormous increase in emissions of natural greenhouse gases e.g. carbon dioxide released as a by-product from fossil fuel combustion or methane emissions from swamp drainage or permafrost melt. The sinks have been reduced by factors such as soil disturbance or reduced photosynthesis – the latter including from deforestation as well as phytoplankton loss from marine pollution and warming sea water. The resulting worldwide temperature rise is often referred to as Global Warming but its geographical *distribution* varies considerably, being greater for example in polar *regions*. The interrelated process involves natural feedback effects that may increase heating (positive feedback, such as warming causing permafrost melt releasing methane and carbon dioxide that causes more warming) or decrease it (negative feedback, such as carbon dioxide emissions increasing plant growth that cause increased sequestration thereby reducing carbon dioxide).

environment: the living (biotic) and non-living (abiotic) surroundings around individual organisms and communities; varies in *scale* but includes at least those component *processes* and resources upon which life is dependent; a distinction is often made between the 'human' and 'natural' components – but the complex *interconnections* between the two is also important, as is the increasing presence of natural components and *processes* heavily influenced by human action

emerging economies: human communities which have progressed economically and reached a certain level of economic development, but are not yet considered an industrialised society; also known as 'developing economies'

fieldwork technique: activities undertaken in the field to collect data, evidence and information to resolve a research question or problem; depending on the subject of the research, the fieldwork may take place in natural landscapes such as forests or coasts or highly-modified landscapes such as farms or cities

flow regime: the variability of the flow of a river throughout a year; river flow volumes, rates and timing are often affected by various human-induced disturbances to river catchments, but changes also occur naturally

forest: natural land cover covering at least half a hectare dominated by trees having a height of at least five metres and a crown cover of at least 10 per cent. It includes regenerating forests and plantations but excludes orchards and food crops.

forest canopy cover: the uppermost forest layer that is formed by the foliage of the highest trees within a forest biome. Where the canopy forms over 70 per cent cover it is defined as a closed forest, and where it is less than this it is deemed to be an open forest. Where the foliage does not form a continuous canopy and the trees have characteristically short trunks, the biome is defined as a woodland.

forest certification: a system where the timber and other forest products are inspected and tracked by an independent authority to verify it has been sourced from *sustainable* and ethically managed forests, in accordance with established guidelines. It is a means of providing consumers with the information they need in selecting their forest product purchases if they are seeking to buy goods that have been harvested and produced while conserving the long-term health of the forest and also protecting the social and economic wellbeing of workers and local forest communities. The certification *process* begins in the forest and continues through the entire 'chain of custody' of the product including its processing, transport and sale.

forest degradation: various *processes* whereby forests are subjected to substantial modification through human activities such as fire, the introduction of invasive species, selective logging, replanting and fuelwood collection, with forest loss of up to 30 per cent

forest fragmentation: the deterioration of a forest resulting from the clearing of pockets of forest leaving a series of separate fragments of intact forest. Over time the periphery of each remnant becomes degraded and may become too small to support viable forest ecosystems and too isolated from other fragments, leading eventually to deforestation. Each fragment may deteriorate from excess sunlight, invasion by pest species and desiccation due to wind penetration. Habitat fragmentation in all ecosystems is a general problem especially when populations become isolated because no wildlife corridors are left to allow *movement* of wild animals.

forest protected areas: reserves designated specifically for forest protection, such as national parks forest or reserved forest

forest rehabilitation: the restoration or rehabilitation of a degraded forest through various methods including replanting tree and other plant species endemic to that forest, restoring natural water regimes, or reducing environmental threats such as logging, hunting, and exotic weeds and pathogens

fuelwood collection: the collection of twigs, branches, logs and bark as a source of fuel. This, along with the processing of wood to create charcoal, is the most common source of fuel for household cooking and heating for much of the developing world.

genetic diversity: the variety in the gene pool of a species

Geographic Information Systems (GIS): a computer-based system used to collate, analyse, produce and present digital data in a spatial form. It includes, but is much more than, a highly-sophisticated way of quickly, cheaply and accurately conducting research into *spatial associations*, and of mapping.

geologic time: long time *scales*, covering periods of hundreds of thousands or many millions of years during which the geology of a region or the entire planet is formed; the periods predating human evolution may be referred to as 'deep time'

geospatial technology: a range of integrated systems and their components (GNSS, GPS, GIS, etc) that use digital geographical data to collect, analyse, compare and display information; also known as spatial technology

geo-tag: a *process* of providing information on the exact location (usually through GPS) and date/time for a particular image

glacial lake outburst flood (GLOF): glacial lakes appear in natural landscape depressions downstream of the terminus of some glaciers if sufficient terminal moraine is deposited to dam the outlet stream. Huge increases in the rate of flow and volume of meltwater occasionally cause the lake to breach the dam and cause a sudden flood further downstream, sometimes causing considerable damage; a natural *process*, glofs may become more common as global warming increases the rate of glacial retreat from ice melt

glacial maximum: each glaciation has a period during which the global extent of permanent ice (generally in the form of ice-sheets and sea-ice) is at its maximum extent. The maximum generally peaks when the average annual surface temperature on the Earth is at its minimum. Characteristically, glacial maxima are associated with relatively low sea-level, comparatively large continental land masses and extensive areas of arid-lands especially deserts. Glacial maxima are shorter periods than the broader glaciation of which they are a part. More specifically the term 'Last Glacial Maximum' refers to the last in a long series of glacial maxima due to natural cyclical climate *change*: the one that occurred globally about 22,000 to 18,000 years ago (but with *regional* variations in the timing).

glacier: a mass of land ice flowing downhill from its source above the snowline where it is cold enough for permanent ice to form; glaciers are usually contained high in an alpine valley but may occur at lower elevations in polar *regions*

glacial retreat: glaciers retreat when the rate of ablation of glacial ice from various processes (including melting, sublimation and evaporation) exceeds the rate of accumulation. The length and profile (cross section) of the glacier *changes* – the terminus (lower end) of the glacier appears to retreat uphill, the edges retreat inward and the surface lowers making the glacier shorter, narrower, flatter and less bulky (reduced 'mass balance'). In the short term, meltwater flows may increase, but longer term the reduction in ice volume will reduce this flow substantially.

Global Navigation Satellite System (GNSS): systems of multiple satellites providing global coverage that transmit position and time data to Earth-bound GNSS receivers for use in navigation and the analysis of geographic data. The GNSS's individual networks include Galileo, BeiDou, NAVSTAR, and GLONASS.

Global Positioning System (GPS): a computer-based system that allows accurate positioning (usually in latitude and longitude) of a receiver anywhere on, or near, the surface of the Earth. It uses a range of satellite-based receivers for triangulation of electronic signals transmitted from a GPS-unit. It does this by automatically calculating the time differences that the signal reaches the two or more different satellites of known location and returning that information to the receiver. Initially developed with high accuracy, great privacy and stability for military operations in the 1970s, it has been expanded to civilian applications for governments, businesses and private citizens. Cost, accuracy, and ease of use have all dramatically improved. It can be used for many applications wherever precise knowledge of real-time geographical location is valuable including navigation, mapping, environmental monitoring and management, remotely-operating mobile machinery, and inventory-tracking.

global warming: an increase in the average (mean) annual global surface temperature due to the Enhanced Greenhouse Effect

government subsidies: financial assistance provided by government to promote or encourage particular activities or sectors. The support may be provided through such incentives to producers as cash grants, interest-free loans, or tax breaks and these might be used to lower prices to encourage demand for particular goods or services.

grasslands: a natural ecosystem where grasses are the dominant vegetation type (including savannah and prairie, pampas and veldt). Trees are scarce and scattered in these *regions*.

greenfield development: converting natural or rural lands into a built *environment*

Greenhouse Effect: is a natural atmospheric process existing for millions of years by which particular, so-called, greenhouse gases retain some of the heat re-radiated as long-wave infra-red radiation from the Earth's surface out toward space. Initially, land cover on the Earth's surface is warmed each day after it absorbs incoming short-wave solar radiation that has passed through the atmosphere without heating it. Naturally-occurring atmospheric greenhouse gases such as carbon dioxide, water vapour and methane can store and release heat. The volume of these gases is basically determined by two natural *processes* including the feedback mechanisms that regulate them: emissions such as from animals, wildfires or volcanoes (sources), and storage (sinks) such as sequestration by plants, and absorption by soils, swamps and oceans. By influencing the net availability of energy in the atmosphere and stabilising its level of heat (i.e. the temperature) the Greenhouse Effect has long been an important influence on climate, weather, ocean currents and land cover. Vital to the evolution and continued existence of life on Earth, the natural Greenhouse Effect has kept annual average surface temperature stable at about a mild 14°C rather than an icy –18°C (although longer term, temperature fluctuations depend on a different process: the Milankovitch cycles that influence the total amount of incoming solar radiation and cause natural climate *changes* such as periodic ice ages).

greyfield development: conversion of large unused tracts of retail (shopping) strips, often surrounded by asphalt

ground truthing: use of ground level observations for comparisons to assist with the interpretation, calibration and analysis of remotely sensed data. For example, aerial images may render the differentiation between primary and secondary forest difficult to discern, but the collection and use of ground level observations may clarify such data so that aerial images can be modified to record the two types of vegetation, instead of classifying them as the same grade of forest.

growing season: the period of time in a year when temperatures and rainfall allow for the growth of plants; growing seasons are typically influenced by aridity (such as in deserts), low temperatures (such as in alpine or polar *regions*), or a lack of sunlight (such as in boreal and especially polar *regions* in winter).

Holocene Climatic Optimum (HCO): During the de-glaciation following the Last Glacial Maximum (i.e. during the Holocene epoch of the last 11,700 years), there was a period between about 9000 and 5000 years ago when global annual average surface temperatures were warmer than today by a few degrees and consequently the climate was wetter, sea-level higher and coasts further inland. The extra warmth and humidity extended growing seasons thereby promoting the growth of forests and the contraction of deserts. It also contributed to the dispersal and growth of human populations, and in some societies the development of agriculture in the deeper, more fertile soils. But the warming was far from uniform: some high latitude *regions* experienced up to 4 degrees Celsius warmer than today; in other *regions* temperature difference were of only 1 or 2 degrees, and in yet other *regions* temperatures were about the same as today. While the effects of the warming are broadly similar to Global Warming, and the range of limitations and opportunities typical of environmental *change* presented itself, the causes of atmospheric *change* were somewhat different and the climate *distributions* much more varied. Therefore, we should be wary in using the HCO as a general model for current or predicted climate *change*.

ice core: some scientists routinely drill down (coring) into accumulated sediments to recover fossil evidence and preserved geological deposits so that they can reconstruct and date what past environments were like. Ice cores are especially valuable for climate research as tiny air bubbles from what was once the then prevailing atmosphere at the surface of that site may have been trapped in the snow before it was compressed into ice, and these can be analysed for their gas composition, for example to record greenhouse gas levels and estimate temperatures (the latter from isotope ratios). Some ice cores preserve many hundreds of thousands of years of information crucial to interpreting past climate *change* and this information can then be used to assist climate *change* prediction.

ice sheet: a mass of land ice covering an enormous area (typically of more than 50,000 square kilometres) that is, or was, sufficiently deep to cover the land surface (topography) beneath it; also known as 'continental glaciers' largely because of the ice sheets that previously covered northern *regions* of the European and North American continents during the Last Glacial Maximum. The ice *moves* downhill at its edges under the influence of gravity and where it encounters the ocean may protrude as an ice shelf which is typically where icebergs break off and float away in a process called 'calving' and which may be increasing because of global warming.

illegal logging: occurs when there is an absence of government permission to log forest areas through logging concessions or licenses (see logging concession); permission may not have been sought by loggers or their applications rejected or are outdated or not relevant to that site, species or tree size. It is illegal to log forests when trees are felled without such permission.

indigenous vegetation: plant species that occur naturally in a specific *region*

Industrial Revolution: a late-18th Century period of rapid technological and social change whereby mainly-agricultural economies were changed to those dominated by mechanisation, manufacturing and dependence on industrial commodities such as minerals and non-animal power sources such as water and fossil-fuels.

industrial societies: human communities which have reached a high level of economic development through the implementation of advanced technologies and rely on secondary or tertiary industrial sectors for a large proportion of their economic activity

infill development: the rededication of land in an urban environment, usually open space, to new construction; often involves land use intensification from higher density building and population influx

informal forestry sector: small-*scale* enterprises which harvest forest products for sale other than the formal timber industry, such as collection for wood and non-wood products for food, fibre and fuel

infrastructure: includes built facilities that provide services such as transport and communication networks, energy frameworks, systems for water supply as well as waste disposal and treatment

intensive land use: land used to generate a high output by the intensive application of inputs of the factors of production (including capital investment, labour and resources such as irrigation-water, biocides and fertilisers); these higher levels and rates of inputs give a much higher yield per unit of area e.g. of crops or livestock than that obtained by more extensive land uses. Contrasts with 'extensive land uses' that use fewer inputs of resources to obtain a given output e.g. grazing in drylands or non-irrigated crop farming.

key geographical concepts: a collection of concepts significant to a geographic perspective and often routinely used by geographers for analysis and description; twelve are used in the current VCE Geography course (*change, distance, distribution, environment, interconnection, movement, place, process, region, scale, spatial association,* and *sustainability*) each with their own specific meaning and some *interconnected* to or overlapping with others.

land cover: the physical material covering the surface of the Earth; various land cover classifications, each with sets of specific land cover categories indicating the prevailing surface features in particular zones, are routinely used by researchers, land managers and government agencies – these are often in map form and may be used for various governance (regulation), conservation or development purposes

land degradation: a *change* to the condition or quality of land, vegetation cover, soil and water resources that reduces its quality or productivity. It may result from either natural or human processes but is generally due to human action including as a result of over-exploitation or unsustainable use.

land management practice: the approach taken to achieve a land use outcome

land tenure: the laws that determine who owns, or is the custodian of, a particular area of land. Many indigenous communities around the world have been the custodians of particular areas over hundreds of generations but lack formal and documented legal ownership of their ancestral lands.

land use: the use people make of the Earth's surface and its resources. More than a simple physical expression of particular methods or technologies, land uses typically involve complex social interactions between communities and their environment often developed over long periods of time.

land use classification: a consistent system for collecting and presenting land information that uses common criteria to differentiate land uses of different types for the purpose of improving land management; each region may have multiple land uses, but the dominant one is used for that region's classification

land use intensification: the more intensive use of land or sea to generate higher outputs such as agricultural intensification, housing people at higher densities, or coping with more traffic in a given space

Local Government Area (LGA): a specific unit of government territory used for administrative purposes

liveability: the sum of the material and non-material factors that add up to a community's quality of life; not to be confused with *sustainability* because increasing liveability may be unsustainable e.g. through high consumption of energy and non-biodegradable resources

local character: the qualities that make one local area (*place*) distinct from another; encompasses a range of physical components of both the natural and built environment

logging concession (or licence): a licence or permit, dispensed by a government authority, allowing the holder to harvest a particular area of forest. The concession may specify the area, rate, period and logging system permitted, as well as the age, species, dimensions and characteristics of the trees to be harvested. It is a method of controlling logging activities and also generating income from timber.

marginal land: land that is generally of poor quality, low productivity and low value for human land use

masterplan: a dynamic long-term planning document that provides a conceptual layout to guide future growth and development; provides spatial data in the form of various map overlays, detailed reports and relevant legislation or regulations

meltwater: the flow (*movement*) of melted water from ice from glaciers, icesheets and icebergs; typically flows on or from ice surfaces, but may also flow within or beneath large ice masses

metadata: data providing information about one or more aspects of other data

methane: a natural greenhouse gas less abundant than carbon as an atmospheric gas, but more effective in trapping heat; methane sinks occur in permafrost, tundra swamps, arctic lake sediments, and as carbonates in some deep ocean sediments. Global warming may trigger the release of much greater volumes of methane from the melting of frozen material (a 'positive feedback effect').

monocentric city: a city that comprises a single centre or nucleus of activity (such as a Central Business District)

monoculture: the cultivation, or existence, of a single crop on a farm or within a *region*

moraine: eroded material transported and deposited by a glacier; typically containing pulverized rock or larger pieces, such as boulders, evident on the sides (lateral moraine) or tongue of the glacier (terminal moraine)

moulin: a vertical cylindrical shaft in the ice by which surface meltwater flows down from the surface to the base of a glacier

native species: species which have evolved within a particular biophysical environment over many thousands of generations; note that species may be generally native to a particular *region* (such as Australia, or the Wimmera) but might not be endemic to (originate from) a particular location or habitat within it – so even native species may be exotic if introduced to some *places distant* from where it evolved

native vegetation: plant species that are indigenous (or 'endemic') to a particular *region*

net forest *change*: the total *change* in area of land under forest cover when both loss of forest through deforestation and the regrowth resulting from afforestation and reforestation are taken into account

non-government organisation (NGO): an organisation that is independent of government and is usually set up by volunteer groups and run on a not-for-profit basis to focus on a particular issue or provide a service

non-timber forest products (NTFP): forest products other than timber. Can include fruits, seeds and nuts; vegetables and vegetative matter; herbaceous plants, grasses, palms, ferns and fungi; fish, birds and wild mammals (bush meat or game); medicinal and pharmaceutical plants; gums, resins and essences; and barks and fibres. Water is another major NTFP because many forests are catchment zones in which are located the headwaters of river systems.

old growth forest: a relatively undisturbed forest in which natural processes prevail; *see* primary forest

open forest: *see* forest canopy cover; includes both woodlands and areas of trees with taller trunks classified as open forests

perennial: lasting or existing for longer than a year; enduring or continually recurring

peri-glacial: remnant glacial landform features evident in the landscape such as moraine deposited by glaciers or ice sheets, or more currently, deep layers of permanently frozen soil (permafrost) and special forms of disturbed surface patterns in cold-climate *regions* experiencing intense frost (freezing and thawing) such as in sub-arctic and some alpine *regions* of North America (Canada and Alaska), Asia (Russia) and Europe (Scandinavia)

peri-urban: the areas that typically surround cities and exhibit some of both rural and urban features. Because of their proximity to the city, this 'rural-urban fringe' may be commercially significant for water catchments, forestry, mineral and stone extraction, tourism and recreation, hobby and productive farming (including fruit orchards and market-gardening of vegetables); issues and challenges often arise here where land uses are incompatible.

planning overlay: an overlay is a state-standard provision which addresses a single issue or related set of issues (such as heritage, bushfire or flooding). Planning scheme maps identify land affected by spatial overlays, often with the region classified into zones within which land use is regulated.

plant succession: the non-seasonal, incremental *change* in the composition and relative abundance of plant species within an ecosystem as it develops towards its 'climax community' or recovers from a disturbance; occurs over a much shorter period than does vegetation *change* due to evolution

plantation: a forest of trees entirely created through planting, typically in rows, to form a monoculture of native or non-native trees. The trees are planted for the commercial production of a particular species or for environmental services such as erosion control or carbon sequestration. Typically, more productive, efficient and profitable of a particular commodity or service, but involves environmental trade-offs. It generally excludes tree food crops.

polycentric city: a city with multiple centres or nuclei of activity, possibly with each centre having different specialist activities beyond the basic services. Polycentric cities typically have less congestion and associated pollution and energy use because not all activity and *movement* (travel) converge on a single central point. Careful planning is needed to ensure this decentralisation is not a disadvantage if there is insufficient trade or culture to support business or community activity in any one of the nuclei, or if infrastructure is merely duplicated in separate centres.

Precinct Structure Plan (PSP): these are high level master plans for whole communities that layout roads, shopping centres, schools, parks, housing, employment, connections to transport. Through better planning, these are generally directed at resolving the complex issues of biodiversity, cultural heritage and infrastructure provision.

primary data: primary research consists of a collection of original primary data collected by a researcher. It is often undertaken after the researcher has gained some insight into the issue by reviewing secondary research.

primary forest: a forest which remains in its natural state, virtually untouched, containing the full array of native species which have evolved over thousands of years and subject to predominantly or exclusively natural *processes* and systems; also called 'intact' or 'old growth' or 'climax' forest. Primary forests are rapidly disappearing around the world due mainly to clearing or degradation.

primary industry: an industry, such as mining, agriculture, or forestry, that is concerned with obtaining or providing natural raw materials (such as fish, livestock, crops, minerals, or fibre) for later conversion into commodities and products for the consumer

primary research question: the central issue to be understood and resolved in the study; should be posed as a single question and one that can be reasonably answered given the scope of the study and time and resources available

qualitative data: usually so subjective that it cannot be expressed as a number, or is potentially misleading when quantified. Data that represent nominal *scales* such as gender, socioeconomic status, religious preference are usually considered to be qualitative data.

quantitative data: any observable phenomena that can be accurately or precisely expressed as a number, or quantified

reference: a permanent benchmark with, or from, which the results of an experiment are compared

reforestation: the reestablishment of a forest cover that had been removed either naturally or through human actions; also known as reafforestation

remnant vegetation: areas of bushland that remain as they were prior to development or other disturbance

remote sensing: involves data-gathering distant from the human observer including in remote, inaccessible or inhospitable *regions* or in areas too large for affordable ground-based investigation; the production of images gathered from aerial photographs, satellites, radar, laser scanners (LiDAR) or drones. Increasingly, but not exclusively, the data is presented in a digital form that can be analysed by computer e.g. in data layers for mapping or to investigate *spatial association.*

riparian zone: the land and ecosystems located along, or immediately adjacent to, the banks of a river

run-off: water that flows over the surface of the land

rural areas: *regions* in which the majority of the population are employed in primary activities such as agriculture, fishing, forestry and mining

rural blight: the gradual winding down of farm operations and agricultural infrastructure resulting in an idle and derelict farming landscape of diminished visual and agricultural value

satellite imagery: images created by computer and generated from remotely sensed digital data procured by a series of earth-observing satellites. The images are generated from different wavelengths (spectral bands) to selectively enhance particular land cover features (water, forests, topography, crops, etc.) and although they may look like photographs are not. The Landsat satellites have, from 1972, collectively provided the longest series of earth-observing satellite data and are valuable to monitor *change*, but dozens of other companies have developed specialist or competitor satellite series at varying resolutions, geographical coverage, and thematic focus (e.g. natural feature monitoring including weather, ice, or sea-surface height). Huge improvements are being made in the use of more affordable and more numerous micro-satellites, in the computer-power to process and analyse the information and in the affordability and ease of access to the data the satellites provide.

sea level rise: the average height of the surface layer of seas and oceans fluctuates (rises and falls) over thousands of years due principally to climate change, and in the longer term of millions of years from geological *changes* such as continental drift and sedimentation of ocean basins. Sea levels naturally fall as climates *change* into an ice age (as more water is held globally as ice rather than liquid water) and they rise whenever deglaciation occurs such as when the Earth shifts from an ice age into an inter-glacial phase (sea levels rising by 120 metres between the Last Glacial Maximum about 18,000 years ago and the present). More recently, sea levels have risen (by about 20 centimetres in the past century) because of global warming in part due to icesheet melt but also because of thermal expansion. The rate of rise is increasing, posing a range of problems for coastal regions including periodic flooding, permanent inundation, erosion and salinisation.

secondary data: the data that have been already collected by, and may be readily available, from other sources

secondary forest: a forest of native species that has been modified in some way by human activities, such as through selective logging, or assisted restoration through replanting or reseeding with native species; also referred to as 'regrowth' or 'regenerated forests'. Without more disturbance these forests may eventually develop into a climax community which may be indistinguishable from a primary forest.

secondary research question: ancillary or supporting question to be answered using the same data and the findings of the primary research question; it is a logical query that assists the researcher clarify or resolve some part of their primary research question

selective logging: long-practiced forestry method of selecting specific trees for felling within a forest; can reduce the cost of timber-getting and reduce wastage in timber milling and processing. More *sustainable* in terms of preserving biodiversity than clear felling, but long term viability depends on not exceeding the forest's *sustainable* yield; contributes to forest degradation by changing tree species mix and age-profile.

slash and burn: a type of farming practised by communities with comparatively low levels of technology, which involves the cutting and burning of the existing vegetation of forests or woodlands to create fields and is usually a part of a mobile and *sustainable* agricultural land use as long as there is sufficient time and fertile land. It is a type of subsistence agriculture.

social housing: housing provided by government agencies or not-for-profit organisations for people on low incomes or with particular needs

spatial technology: *see* geospatial technology

speculation: the practice of engaging in risky financial transactions in an attempt to profit from fluctuations in the market value of a tradable good such as land (buying when the commodity price is low with the intention of selling in the future at a higher price); tends to inflate prices for lower-income consumers.

subsistence agriculture: agriculture predominantly for the sustenance of the farming household

***sustainability*:** the condition that arises when an activity, structure, pattern or *process* continues unaltered over a lengthy period of time without the depletion of the resources upon which its existence depends; typically, it refers to environmental *sustainability* (and for example depends on *sustainable* economic, social, and environmental conditions); but geographers also use the term to refer to *sustainable* cities, populations, or economies

***sustainable* development:** a *process* that enables a desirable future state for human societies in which living conditions and resource-use continue to meet human needs without undermining the integrity, stability, productivity and continuity of natural biotic systems

terrestrial: refers to landscapes, land cover, or environments and their component parts, *processes* and systems related to the land (and by definition not the sea or atmosphere)

thermohaline circulation: global currents within and between ocean basins *move* vertically and horizontally across huge *distances*; these are driven by and in turn redistribute heat and are influenced by the salinity levels of the water (generally saltier, colder and denser sinks to and pools in the ocean depths). This 'thermo' (heat) 'haline' (salt) circulation is a major influence on global climate patterns as well as the chemistry and biology of the oceans. Accelerated polar ice melt may disturb this circulation by reducing ocean salinity and surface water density (a possible 'positive feedback effect').

top-down / bottom-up approach: a top-down development approach usually means that a government or NGO organises and manages an aid project without much consultation with those affected; a bottom-up approach starts with the people affected who manage their own aid projects with possibly some assistance (often referred to as starting at the 'grass-roots level'). Development by hybrid approaches using the best of both methods is more typical today.

transboundary issue: exists when a problematic event or *process* occurs across a political boundary or border. For example, an activity upstream of rivers in one state or country that flows down through another might impact negatively on *regions* or nations downstream. The same is the case with transboundary air pollution, or with hunting and fishing of migratory species. The difficulty is that the cause of, and responsibility for, the problem is physically, economically and legally *distant* from where the damage is done.

transmigration programs: large-*scale* migration programs designed to redistribute population and resettle people (e.g. from congested cities to under-populated rural areas, often across great *distances*); associated with decentralisation policies that reduce congestion in source *regions* and create opportunities in the destination *places*, but has contributed significantly to deforestation in some regions of Indonesia and in Amazonia

urban areas: centres of higher-density population often living and working in high-rise buildings where the majority of the workforce is employed in non-primary occupations. These include secondary industries such as processing and manufacturing of raw goods and tertiary services such as finance, education, design, health and entertainment. Definitions of urban vary, but can include village as well as town and city.

urban growth boundary: the legal extent of a metropolitan area where certain types of development and subdivision are allowable, and beyond which they are excluded or highly-regulated

urbanisation: the *process* whereby there is an increase in the percentage of a region's population living in urban areas; typically, a result of internal and international migration into a city and by natural increase of the urban population. Urbanisation is not to be confused with merely an increase in the number of inhabitants in (residents of) an urban population – urbanisation can occur with no change or even a decline in an urban population if neighbouring rural populations grow at a slower rate regardless of their size.

urban renewal: program of land redevelopment seeking to revitalise urban areas often through the provision of new public infrastructure and incentives for the improvement of private housing and industry

urban sprawl: the uncontrolled spatial expansion of urban areas especially when there is a lack of supporting infrastructure such as transport, education or medical facilities (often because new residents on the expanding city edge become physically too *distant* from, or cannot afford to access, existing facilities). Not to be confused with well-planned urban expansion that may involve urban growth where communities are not 'blighted' by a lack of access to facilities.

water sensitive urban design (WSUD): a planning strategy aimed at the *sustainable* use of water in cities; literally planning that is sensitive to the need to conserve water. This is achieved by implementing physical designs in the built environment to reduce water wastage and improve access for both human water users and natural consumption (environmental flows) as well as economic, political and social policies aimed at more *sustainable* water consumption and production (supply).

wildfires: typically referred to in Australia as 'bushfires', but wildfires elsewhere

zones: the planned separation of land uses into exclusive areas in a *region* – e.g. residential, industrial, heritage or environmental conservation zones; enforced through legislative controls by state and local governments

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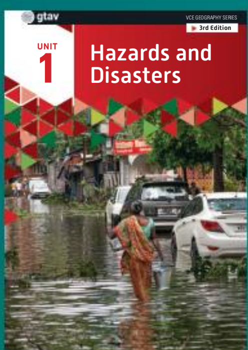
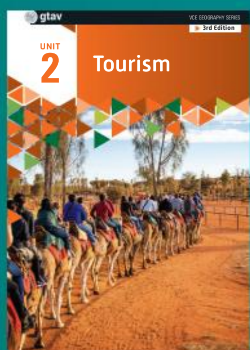
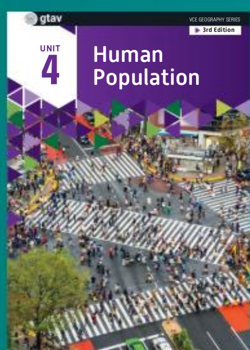
The textbook includes two investigations of geographical change: change to land cover and change to land use. The investigation of land use change involves the selection of a local area land use as a field investigation. The study of land cover change involves an investigation of deforestation and melting glaciers and ice sheets.

Written by experienced VCE Geography teachers, this third edition textbook incorporates updated text, case studies, geospatial technologies, fieldwork and rich data as well as activities to assist students to develop an understanding of the content and skills of Geography, and prepare them for success in their VCE assessments.







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