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VCE GEOGRAPHY

UNIT

3

Changing the Land



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1 Geographical concepts and questions

Introduction

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. Concepts are the big, organising ideas which, together, uniquely belong to Geography as a field of study.

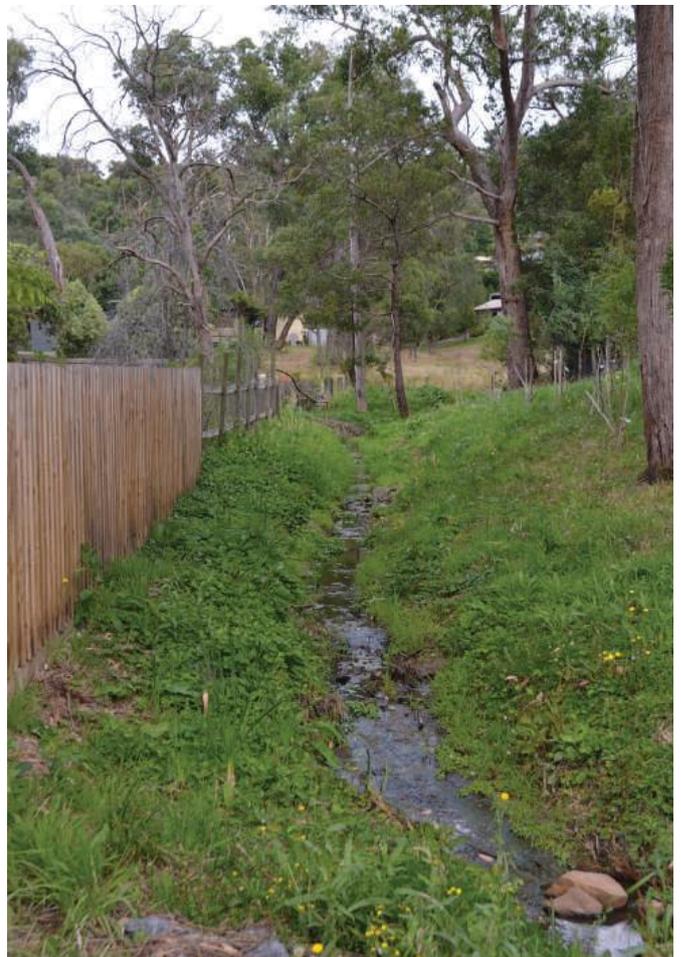
VCE Geography is underpinned by ten interrelated key geographical concepts. These should form part of your vocabulary and guide you in your thinking, description, analysis, synthesis and communication in Geography. The concepts are used in conjunction with skills, and are applied to topics of study to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

In VCE Geography, the ten key geographical concepts are: *place, scale, distance, distribution, 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 of importance 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.



▲ **Figure 1.1** Sassafras Creek, Sassafras



▲ **Figure 1.2** Stringybark Creek, Mt Evelyn

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, as specific as a street address, or (with the aid of a smartphone) even a latitude and longitude. The latter two 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, Sassafras Creek flows through the town of Sassafras in Melbourne's Dandenong Ranges. The latitude and longitude of Sassafras is 37° 52' S latitude, 145° 21' E longitude. Stringybark Creek flows through Mt Evelyn which is located at 38° 78' S latitude, 145° 38' E longitude. Until these are seen on a map or visited in the field, there is very little information about their respective locations. Both creeks run through very different rural–urban areas, with figures 1.1 and 1.2 providing more information on each *place* to enable you to infer more about each location.

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*.

Understanding a *place* relates to the perception of, and meaning people attach to a location and its immediate surroundings; this creates their 'sense of *place*'. Though people may recognise the significance of the *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, but for a natural landscape, the *place* is valued on the basis of other, less

tangible qualities such as aesthetic beauty, untouched remoteness or, for some people, a spiritual significance and attachment to *place* going back many generations.

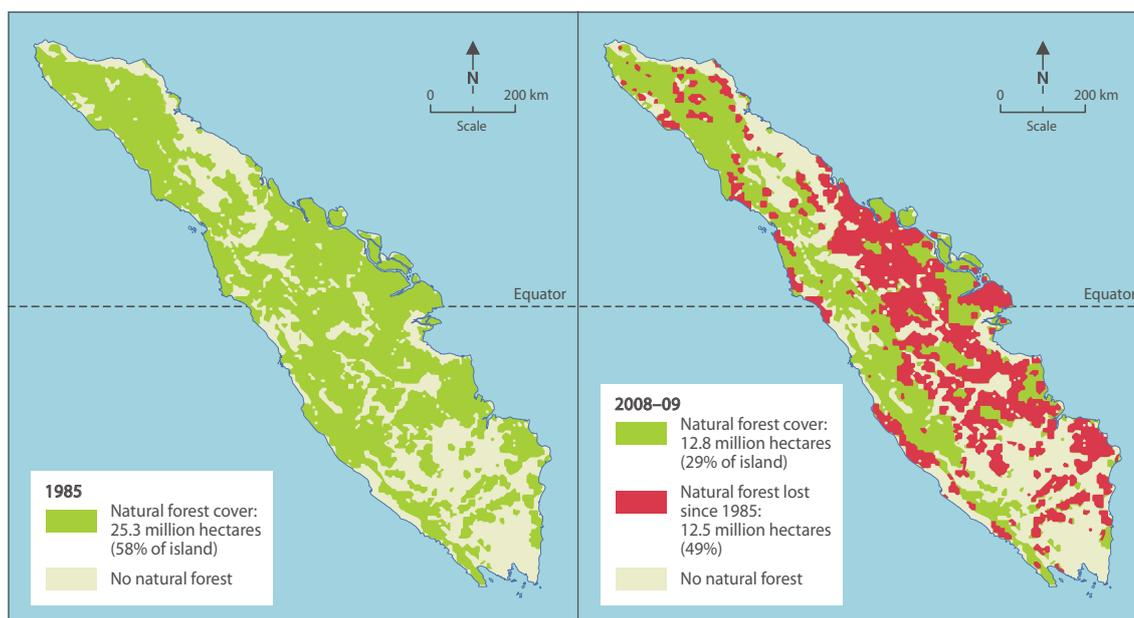
Place is important when considering land use *change*. *Places* on rural–urban fringes are constantly under pressure of development particularly in large, growing urban areas. Perceptions about *change* in some *places* will be affected depending on the impact on the environment (as shown in figures 1.1 and 1.2) and their significance to others. For example, is the *change* close to a national park or sites of Indigenous significance?

There are also significant *places* undergoing land cover *change*. For example, the extent of forest removal in Sumatra 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 Sumatra compared to geographers and biologists studying the same forests for biodiversity and water quality.

Scale

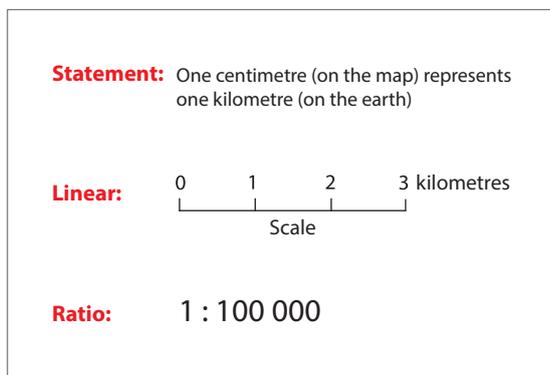
Scale refers to the size of something compared with something else and is used in one of two practical ways in Geography.

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



▲ **Figure 1.3** Sumatra's *changing* land cover, 1985–2009

► **Figure 1.4**
The *scale* of a sandstorm event in China in 2010 as a result of increasing dryland areas in Mongolia



▲ **Figure 1.5** Map *scale* can be expressed as a statement, a ratio or in linear format.

a topographic map may be 1:25 000. Figure 1.4 shows the extent — that is, *scale* — of a sandstorm over China. By reading the *scale* on the map, observations and conclusions can be made about the impact of this *process* and its links to land use *change* in Mongolia. *Scale* on a map can be expressed in various ways, as shown in figure 1.5.

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 1.6.

▼ **Figure 1.6** 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
<i>Regional</i>	Flexibly defined, varies in size and nature (see <i>Region</i>)

Increasing scale

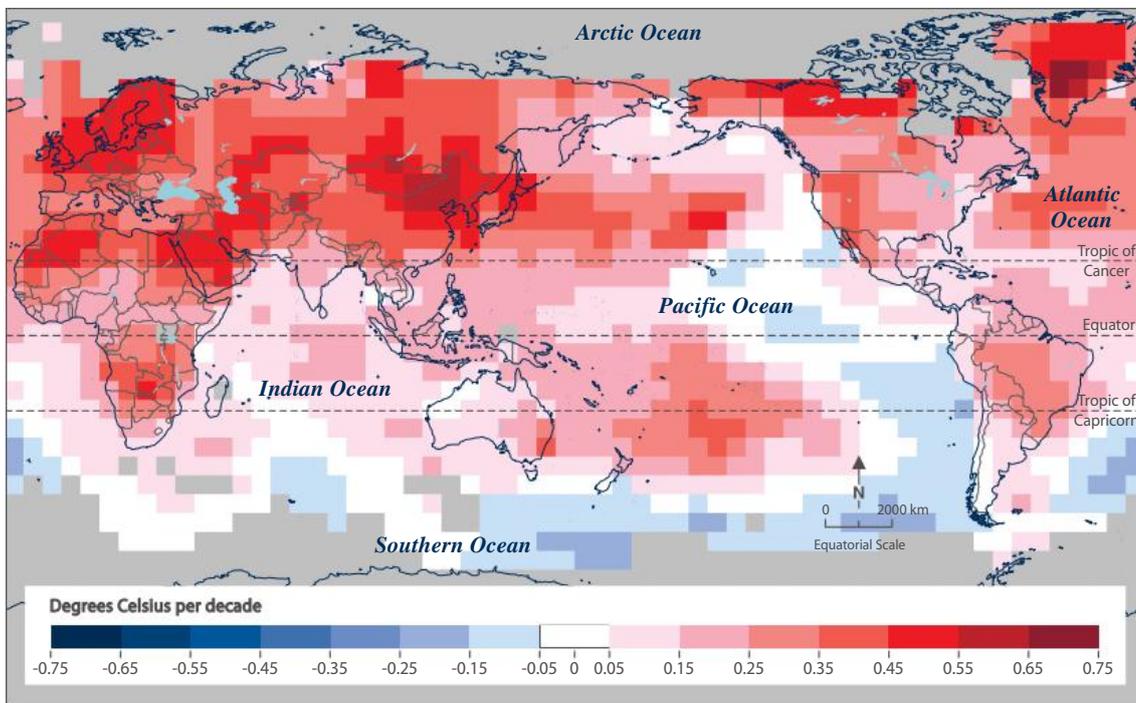
Land cover *changes* resulting from deforestation, desertification, melting sea ice and sea level *change* vary in their *scale of distribution* and impact. At times these events are observed and measured at a local or national *scale*. A number of case studies in this textbook are provided at a range of *scales*. The example of loss of forest cover in Sumatra is a *regional scale* (see figure 1.3, page 3). Sometimes the *change* can be observed at a global *scale* such as surface temperature *changes* shown in figure 1.7.

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.

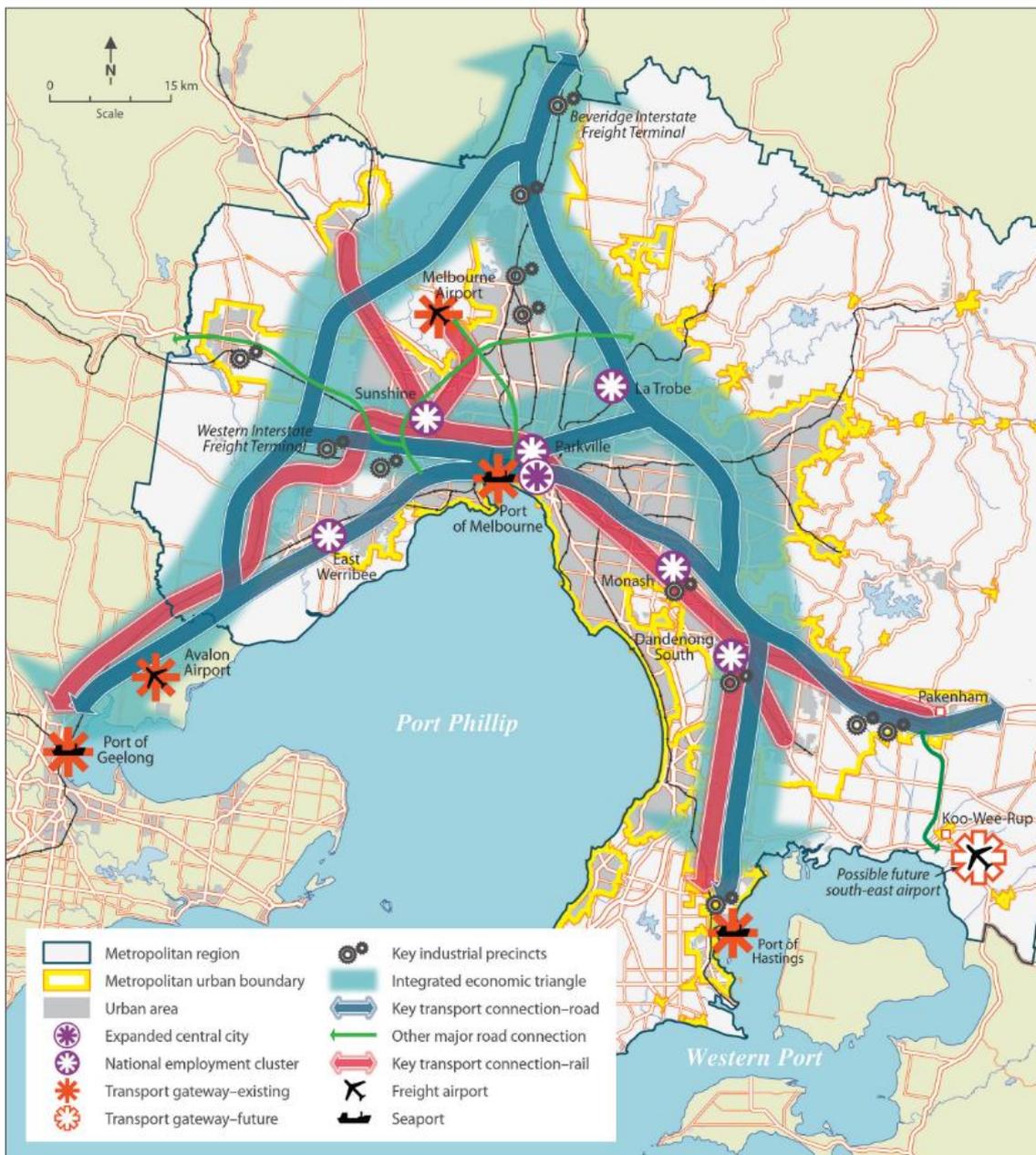
Distance

Distance is measured in a number of ways. In its simplest form, it is the space between two different locations and can be determined using an absolute measure such as kilometres. *Distance* is used to assist with defining where things are in space, often also using direction. As an example, Orbest is 375 kilometres east of Melbourne.

Distance is clearly used as an indication of proximity, which itself often relates to the existence of relationships between things. Greatly distant phenomena are less likely to influence one another.



▲ **Figure 1.7** Global surface temperature changes between 1979 and 2005



▲ **Figure 1.8** Plan Melbourne showing the predicted corridors of urban growth for Melbourne until 2050

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'), or the cost of travelling a certain *distance* (e.g. it's expensive to fly to South America), are examples 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. 'I thought the trip to Mildura would be much faster by train').

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 1.8 shows the relevance of *distance* when considering Melbourne's future growth.

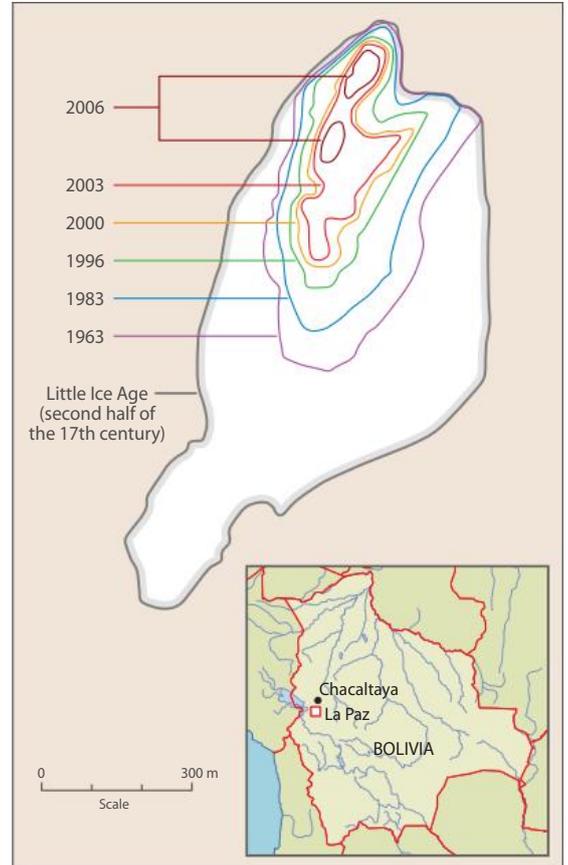
Distribution

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 1.9 shows the global *distribution* of glaciers, ice caps and ice sheets.

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*.

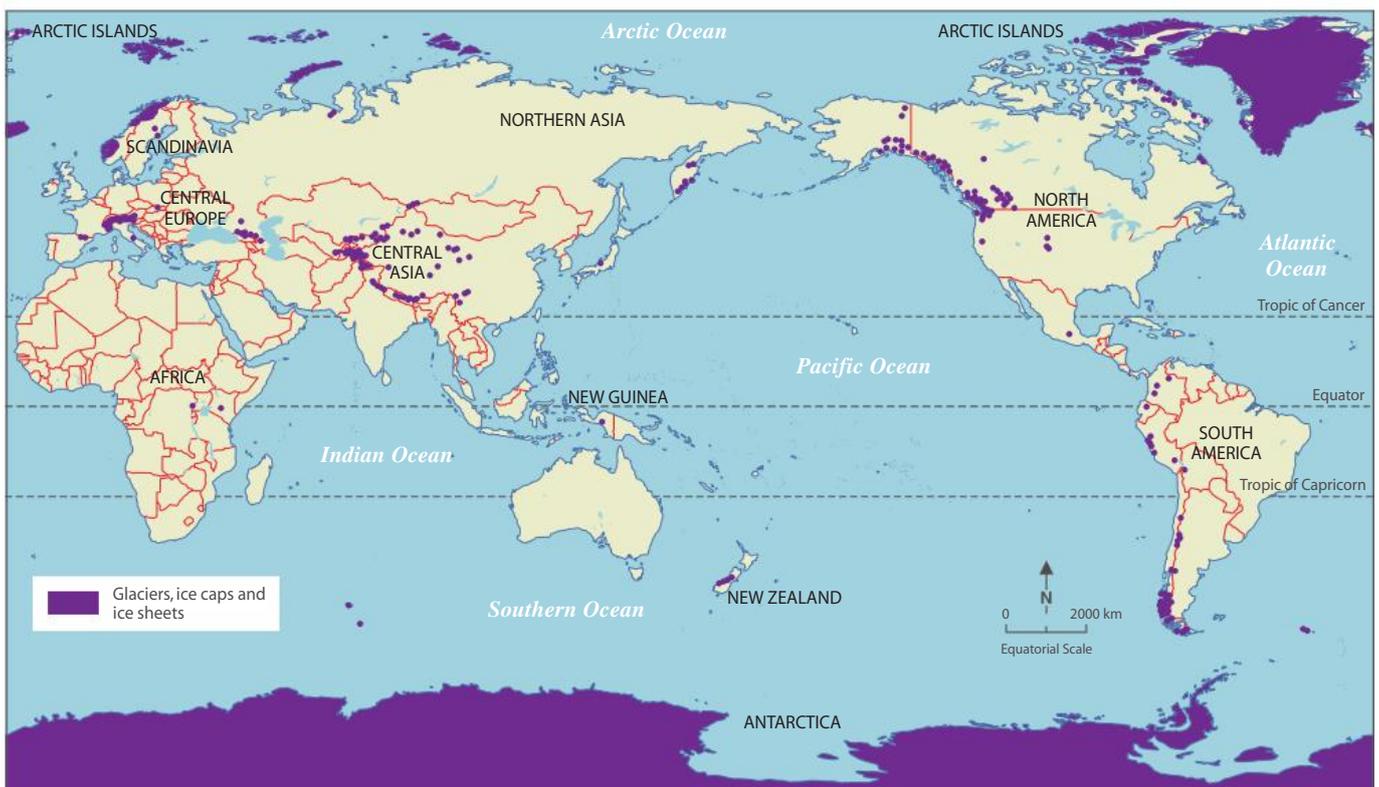
Movement

Movement involves a *change* in location of phenomena such as people, goods and ideas through travel or flow. The development of transport infrastructure and mode 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.



▲ **Figure 1.10** Movement of ice in the Chacaltaya Glacier, Bolivia

▼ **Figure 1.9** The global *distribution* of glaciers, ice caps and ice sheets



Movement is an important consideration in land cover change. Consider *regions* that are increasingly affected by desertification. The impact of this *process* can be the *movement* of people from rural to urban areas; or the *movement* of sand and soil no longer held in *place* by vegetation resulting in dust and sand storm events. Figure 1.10 shows an example of the *movement* of ice in the Chacaltaya Glacier, Bolivia, over time. The concepts of *movement*, *change* and *distribution* are involved 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*.

Region

A *region* is a definable area containing one or more characteristics that distinguish it from surrounding areas. *Regions* can be defined at a range of *scales* by physical characteristics such as mountain ranges and drainage basins, politically by official decisions about boundaries and names, and by common usage or for a given purpose by selecting a particular characteristic 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 1.11 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

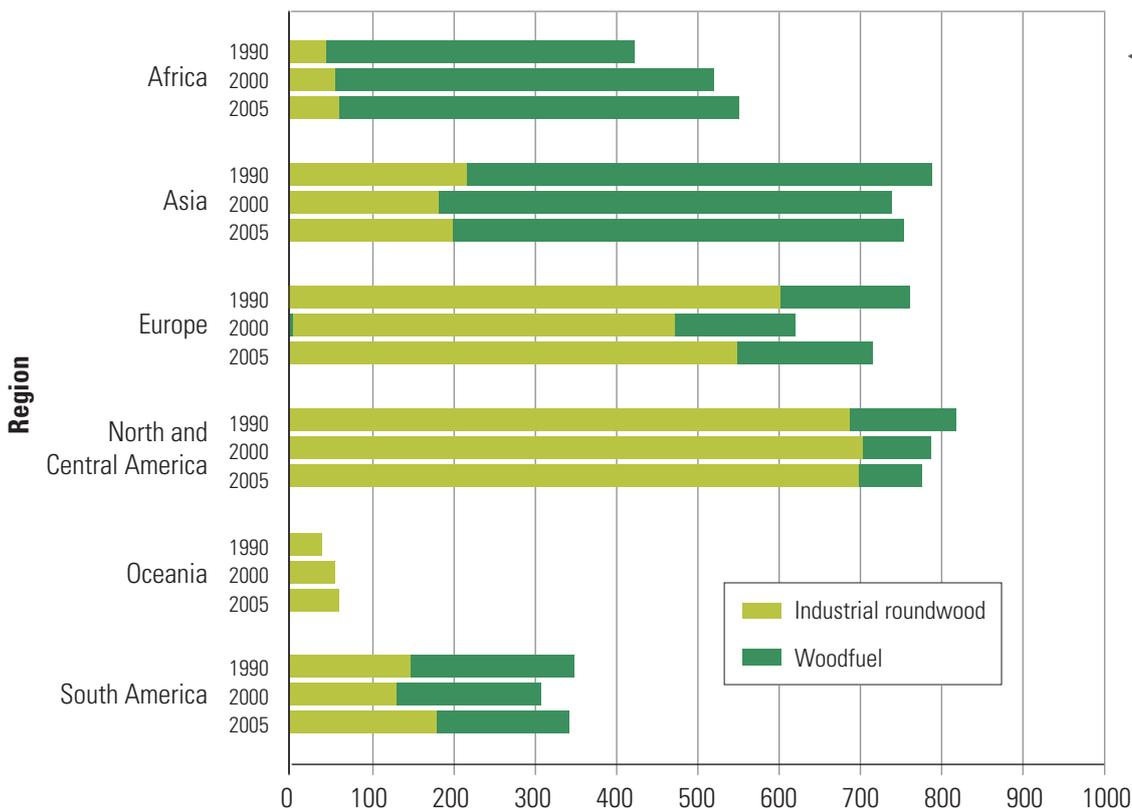
▼ **Figure 1.11** Examples of *regions* at different *scales* and how they are defined

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

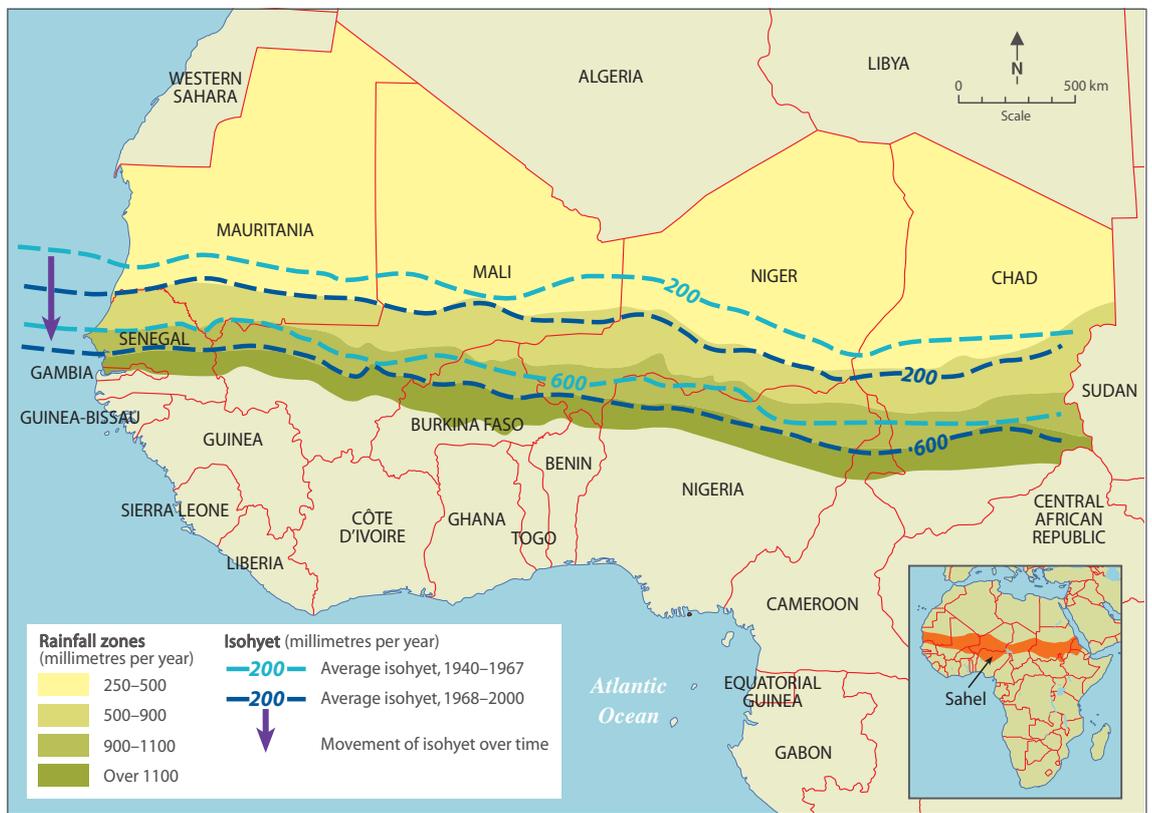
the differences can be associated with the amount of forest cover in each *region*, the policies in *place* to manage forests, socioeconomic pressures in each *region*, the use made of the wood and the type of land use replacing the forest. Figure 1.12 provides some information on the trees removed for industrial use and woodfuel, and shows patterns across *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*, and this often relates to *sustainability*.



◀ **Figure 1.12** Trends in wood removals, 1990–2005 (million square metres) by *region*



▲ **Figure 1.13** *Changing climate patterns in the Sahel, Africa*

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 Sumatra shown in figure 1.3 (see page 3).

Rates 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 1.13 shows the physical *change* in rainfall pattern in the Sahel. The data allows a consideration of the rate of *change* that has occurred in this *region*.

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 a variety of *scales*. For example, planning *processes* such as the decision to build a freeway in an urban area can result in *changed* patterns of *movement* of people and have an impact on population densities. Examples of this can be seen in figure 1.14.

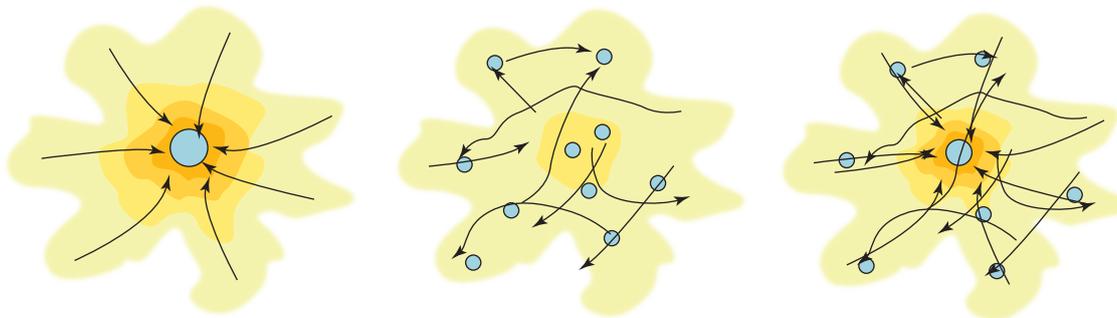
Complex interrelationships between different *processes* can have an impact on one another. The water cycle is a complex *process* which involves the *movement* of water in different physical states in the environment. Figure 1.15 shows the impact

of urban *change* on the water cycle. *Changes* in land use can alter this *process* quite dramatically. The impact of increasing atmospheric carbon has resulted in measurable *changes* to the climate across the Earth. There are complex interrelationships between the *processes* of deforestation and climate *change*. Climate *change* has an impact on the rate of desertification, sea level rise and melting of glaciers and sea ice. The result of *changes* to complex *processes* has far-reaching impacts on both the environment and people. Chapters 2–9 investigate these *processes* further.

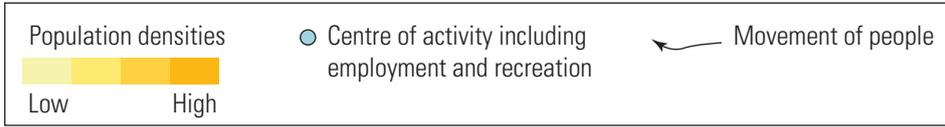
Spatial association

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 a strong *spatial association* between areas of the Earth with low rainfall and low population density. 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 low *spatial association* between urban areas and the *distribution* of native animals in Australia. 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 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 1.9 (see page 6) shows the

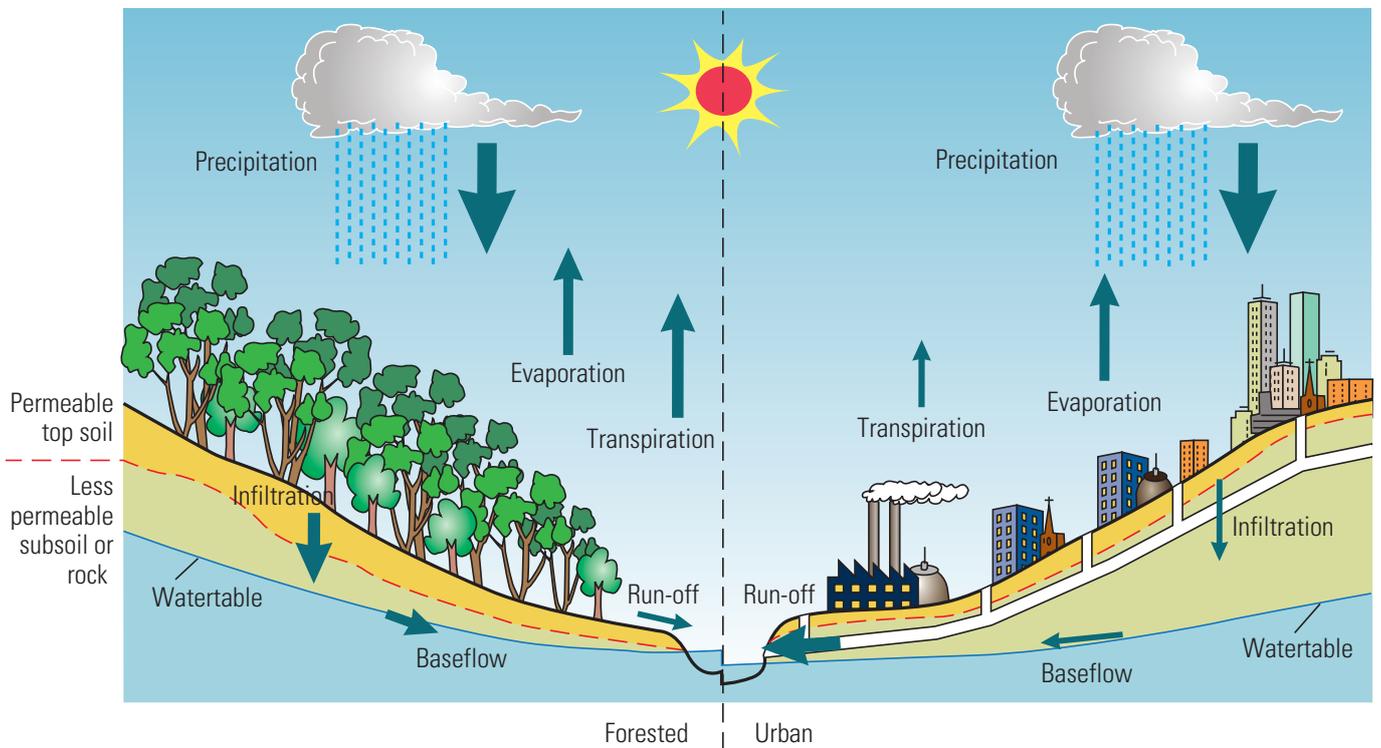


A. The classical monocentric model B. The polycentric or dispersed model C. The composite model



◀ **Figure 1.14**
Processes involved in models of urban morphology

▼ **Figure 1.15** The impact of urban development on the water cycle



distribution of glaciers, ice caps and ice sheets. The study of topographic and temperature maps in an atlas will show a high degree of *spatial association* between the location of ice areas and the *distribution* of average temperatures and high elevation areas.

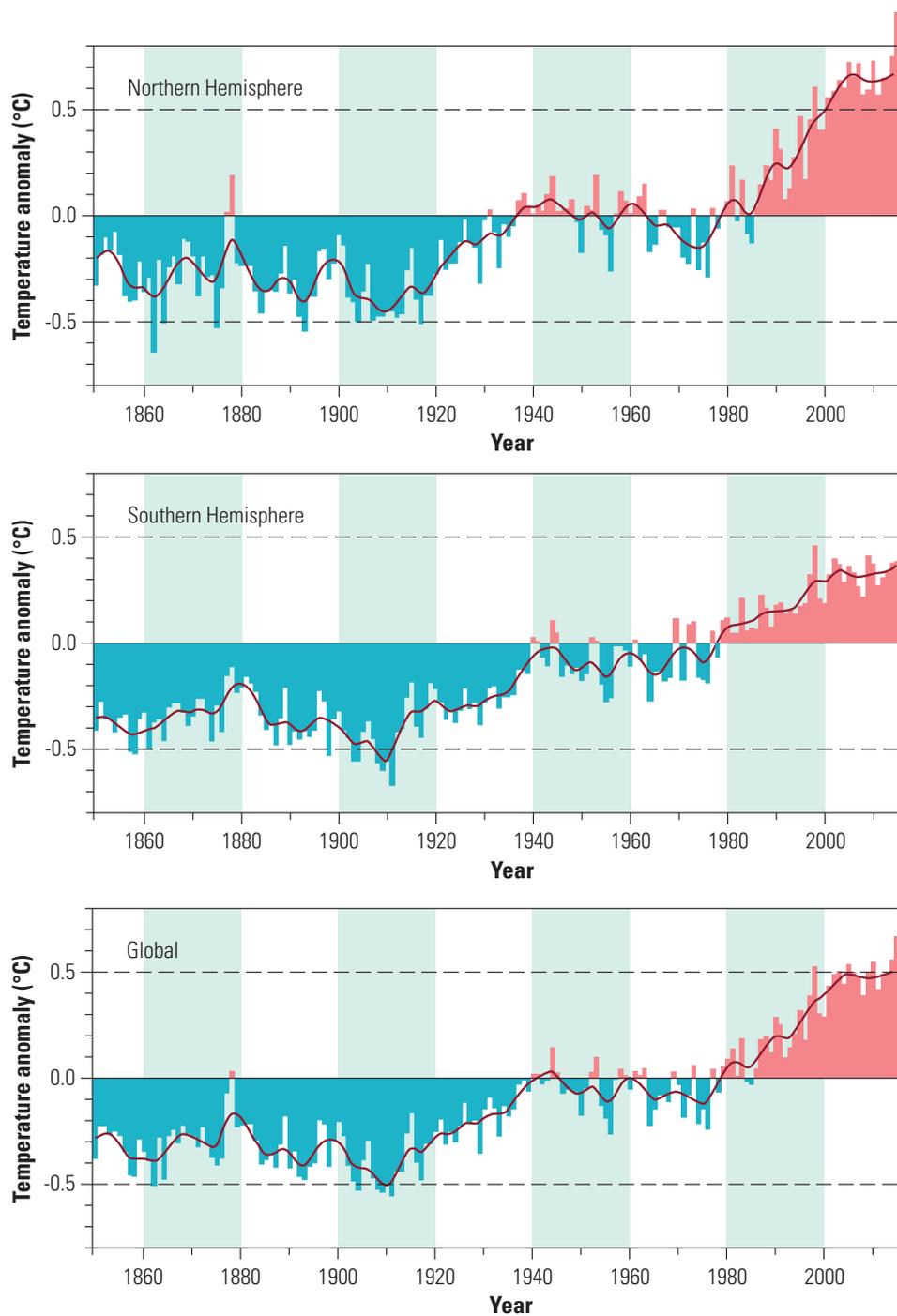
Sustainability

Sustainability is a different concept from the others and it encourages the formation of evaluations or judgements about current situations and their potential *change* into the future. *Sustainability* is the capacity of the environment and social systems to support people and other living things now and into the future. It involves environmental, social, economic and political considerations. There is a strong relationship between *changing* land cover and climate *change*. Chapter 8 examines how *changing* land cover contributes to climate *change* and impacts negatively on the *sustainability* of forest areas. At a global *scale*

temperature trends, as shown in figure 1.16, indicate the dramatic *changes* in global temperature over time.

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 (see figures 1.1 and 1.2, page 2). *Changing* land use from rural productivity to urban housing can have an impact on agricultural production and soil health. Careful planning must be included in any land use decisions for the best *sustainable* outcomes to be achieved from the *change*.

► **Figure 1.16**
Global temperature trends,
1850–2011



► ACTIVITIES

Place

1. What is the difference between an absolute and a relative location? Give an example of each.
2.
 - a. Using Google Earth or a smartphone GPS receiver, determine the absolute location of the following in latitude and longitude: the MCG; Melbourne Airport carpark; Lake Hattah in Hattah-Kulkyne National Park, Victoria.
 - b. Describe your perceptions of these three *places*. How might this sense of *place* differ for other people?
 - c. Using Google Earth, determine the relative location of each of these *places* from your home and your school.
3. Identify the land use for each *place*. How could each land use affect the sense of *place* of each? Discuss in small groups.
4. Examine figures 1.1 and 1.2 (see page 2).
 - a. Contrast these *places* in terms of their probable surrounding land use.
 - b. Explain how the *process* of urbanisation could cause a *change* in the natural stream habitat in Stringybark Creek.
5. Examine figure 1.3 (see page 3). Survey your family and friends about their perception of Sumatra in relation to the extent of forest lost. What are these perceptions based on? How might these perceptions differ for people living in Sumatra?

▶ ACTIVITIES *continued*

Scale

- Write two summary statements with the following starting stems:
 - ▶ Small-scale maps tend to show ...
 - ▶ Large-scale maps tend to show ...
- Express the *scale* in figure 1.4 (see page 4) as a ratio and a statement.
- Use the map *scale* in figure 1.4 (see page 4) to calculate the largest area of heavy dust storm in China. What is the furthest *distance* that dusty areas have moved from Mongolia and in which direction?
- Study figure 1.7 (see page 5). Write a short paragraph that describes the changes in surface temperatures between 1979 and 2005 at a global *scale*. What impact might these *changes* have on the extent of desertification and sea ice and glacier melting in specific *regions*?
- Allocate an observational *scale* for the following land use and land cover *changes* (you may have to research the event): melting Greenland ice sheet; removal of Malaysian rainforests for palm oil plantations; thawing permafrost in the Arctic Circle; expanding desertification in the Sahel in Africa; glacial retreat in the European Alps; expanding urbanisation on Melbourne's rural–urban fringe; redevelopment of inner urban areas to residential uses.

Distance

- Using figure 1.8 (see page 5) and/or Google Earth's *distance* measuring tool, calculate the approximate *distance* of the following in the predicted 2050 urban growth corridor:
 - the Port of Hastings to the Port of Melbourne by rail
 - the western interstate freight terminal to the Port of Geelong by road
 - proposed south-east airport to Melbourne CBD by straight line.
- Use Google Earth or an atlas to measure the *distance* between where you live and the location of Sassafras Creek (figure 1.1, page 2) and Stringybark Creek (figure 1.2, page 2).

Distribution

- Refer to figure 1.9 and describe the *distribution* of glaciers, ice caps and ice sheets. Use an atlas to include specific place names in your description.
- Choose one of the *regions* with glaciers and use Google Earth to zoom in to the area. Provide another description of the *distribution* of the glaciers at this different *scale*.

Movement

- Study figure 1.10 (see page 6). How has *movement* been depicted in this map?
- Use the *scale* of the map to measure the extent of glacial retreat in the Chacaltaya Glacier in Bolivia.
- Study figure 1.4 (see page 4). Use the *scale* and *distance* to describe the *movement* of sand and dust from Mongolia.

Region

- Study figure 1.12 (see page 7) and answer the following (use data from the graph in your answers):
 - Which *region* has produced the greatest amount of industrial roundwood over time? Which has produced the least?
 - Name the two *regions* that rely most heavily on removing wood for fuel?
 - Which *region* has shown the greatest change in industrial roundwood production?
- Create a table similar to figure 1.11 (see page 7) and provide three more examples for each *region* shown in relation to land use and/or land cover *change*.

Change

- Conduct some research to provide two examples that can reflect each the following geographical *changes* specifically related to land use/land cover *change*: *movement*, *size*, *distribution* and *density*. For each example, provide a location and its rate of *change*.
- Use figure 1.13 (see page 8) to describe the *change* that has occurred to the average rainfall (isohyet line) in the Sahel. Describe the rate at which this *change* has taken place.
- Compare the rates of *change* for desertification occurring in the Sahel and the rate of *change* in an earthquake disaster.
- State the rate of *change* shown in figure 1.3 (see page 3).

Process

- Refer to figure 1.14 (see page 9). Describe how each planning model could result in different land use *change*, population density and people *movement*.
- Using the information provided in figure 1.15 (see page 9), outline how the water cycle *process* has altered as a result of urban *change*.

Spatial association

- Use atlas maps which show world temperatures and elevation. Use these maps and figure 1.9 to describe the degree of *spatial association* between the location and *distribution* of glaciers, ice caps and ice sheets, and elevation and temperature.

Sustainability

- Outline the pattern of temperature *change* that has occurred in the Northern Hemisphere and Southern Hemisphere, as well as globally, between 1850 and 2011 in figure 1.16.
- Sustained increased global temperatures are having an impact on land cover, especially by increasing areas of desertification and melting sea ice and glaciers. Use two examples to outline how temperature *changes* are affecting the *sustainability* of environments and economies.

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 and enhance geographical understanding.

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

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', above.
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.
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 <i>process</i> 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 <i>scale</i> .
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'.



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*
- ▶ being able to monitor *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), 2.2 (b), 2.2 (c)** Some land uses in Victoria



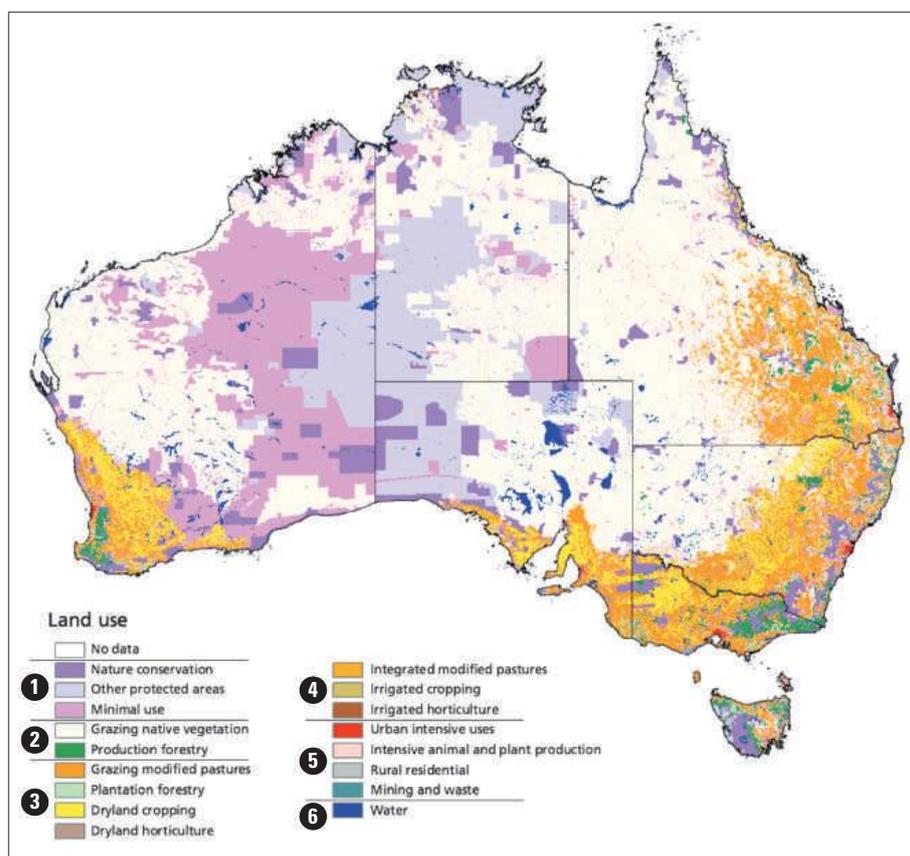
Land use is the purpose to which the land cover is committed. Land use occurs through various human interventions, which alter or modify the land cover or an existing use. Think of where you are at present: has it always been this land use? Some land cover may be in its original state, such as a national park or coastal *region*, but is used for recreation or preserved because of its environmental or ecological value.

Different land uses depend on the existing land cover and the history of land use in an area.

Typical categories 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 Mt Buller
- ▶ transport routes, such as the Hume Highway
- ▶ dwellings, such as the suburbs of Boronia in Melbourne or Eaglehawk in Bendigo
- ▶ industrial use, such as milk processing at Warrnambool.

Figures 2.1 and 2.2 show a range of land uses in Victoria. Clearly, in a small area land uses can vary considerably. In figure 2.3, 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.



▲ **Figure 2.3** (a) The *distribution* of Australian Land Use Mapping (ALUM) classifications

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

LAND USE		AREA (square kilometres)	PERCENTAGE
Land use category ①			
	Nature conservation	569 240	7.41
	Other protected areas	1 015 359	13.21
	Minimal use	1 242 715	16.17
Land use category ②			
	Grazing, native vegetation	3 558 785	46.30
	Production forestry	114 314	1.49
Land use category ③			
	Grazing modified pastures	720 182	9.37
	Plantation forestry	23 929	0.31
	Dryland cropping	255 524	3.32
	Dryland horticulture	1 092	0.01
Land use category ④			
	Integrated modified pastures	10 011	0.13
	Irrigated cropping	12 863	0.17
	Irrigated horticulture	3 954	0.05
Land use category ⑤			
	Urban intensive uses	16 822	0.22
	Intensive animal and plant production	3 329	0.04
	Rural residential	9 491	0.12
	Mining and waste	1 676	0.02
Land use category ⑥			
	Water	125 618	1.63
	No data	2 243	0.03
Total		7 687 147	100.00

▶ 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?
 - 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.



▲ **Figure 2.4** (a) Lake Condah in western Victoria is the site of numerous eel traps constructed and used by Indigenous communities before and after European settlement of the *region*. The land use was *changed* then and more recently has *changed* to become a heritage site.



▲ **Figure 2.4** (b) The Pyramid of the Moon, Teotihuacan, Mexico. This massive pyramid was constructed between 200 and 450 AD and is now a UNESCO listed World Heritage site and the most visited archaeological site in Mexico. Its land use has therefore *changed* from religious to recreational.



▲ **Figure 2.4** (c) The Yorkshire Brewery site in Collingwood, inner Melbourne, had an industrial land use from 1880 until the 1950s and remained unused until its conversion into apartments in 2015. The brewery tower is a registered heritage building.

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. And in turn these new land uses *changed* as human needs increased or altered.

Land use *change* occurs at varying *scales*, rates of *change* and degrees of intensity. For example, ancient stone technologies, such as those around Lake Condah shown in figure 2.4 (a), had relatively low impact on the environment but left evidence of land use practices. Larger-*scale* developments such as the one shown in figure 2.4 (c) generated major *changes* to the environment including the clearing of forests and redirection of water. Today these sites, like thousands of others throughout the world, have been developed for recreational purposes. Many modern land use *changes*, such as the Yorkshire Brewery site in figure 2.4 (c), are very intensive and may involve complex systems of industrial agriculture, waste disposal or road paving. Intensive land use means involving large amounts of inputs of resources and energy at a site, thus having a large impact on the landscape. Specific rules govern the ways lands can be used in order to safeguard against ad hoc, or makeshift development, by using policies, planning zones and overlays to regulate the uses allowed.

▶ ACTIVITIES

1. Compare figures 2.4 (a) and 2.4 (b). Which construction would have made the larger impact on the landscape? Be sure to justify your decision. What other information would you need to have to be sure of your decision?
2. The features of figure 2.4 (a) and figure 2.4 (b) are now parts of important heritage sites. What supporting land uses are likely to develop as a consequence?
3. What is the land use *change* in figure 2.4 (c)? What factors might have led to the most recent *change*?

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 may be more important than others. As the *change process* develops it is possible the relative importance of factors will alter. For instance, environmental or heritage issues may begin to emerge once 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, 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 these ambitions could be realised and Australia's cities grew outwards at rapid rates.

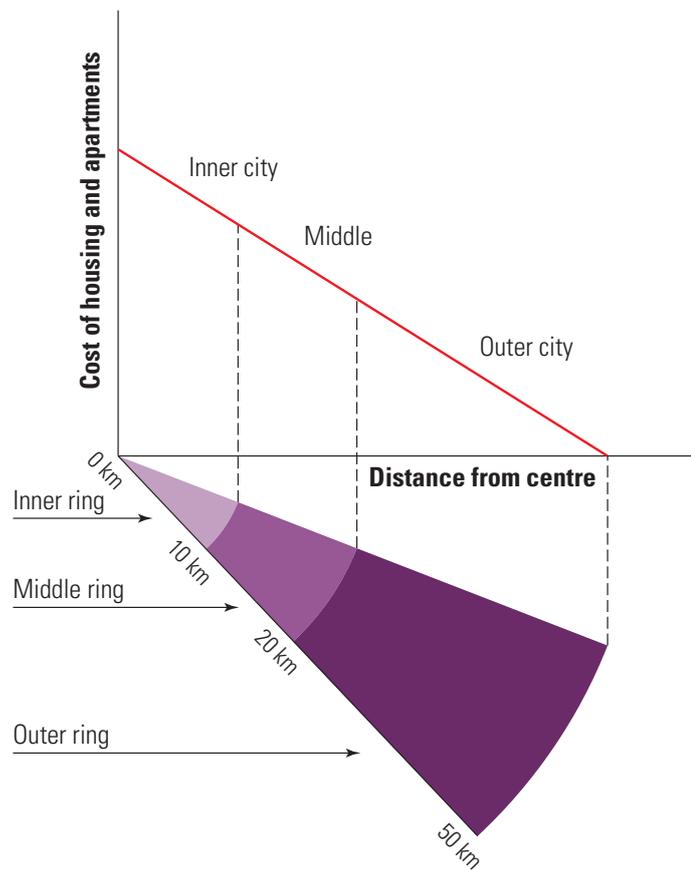
Historic factors

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. 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 population's heritage. As a result land use becomes conserved but altered to accommodate interested visitors — like the sites in figures 2.4 (a) and 2.4 (b).

Economic factors

Economic factors are the activities linked to the creation of wealth 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 2.5), 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 commercial uses closest to the centre, followed by residential and commuter zones further away from the centre. 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 road infrastructure, have allowed outward urban growth



▲ **Figure 2.5** Alonso's Bid Rent theory of land value

to occur. Current and future patterns of growth need to consider other important variables such as the role of government planning, environmental needs (see below) as well as social factors (see above).

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, drainage, soils, indigenous vegetation and climate. Environmental factors have major influences on land use. The nature of a *region's* environment may prohibit some land uses such as developing arable farming on steep slopes or in arid climates. 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 (see overleaf). The likelihood of negative effects of land use *change* on biodiversity, downstream users of water, community wellbeing and the character of a *region* are now major considerations in determining the *scale* and functioning of land use *change*. 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 longer *distances* food will need to travel? Will residential development that only provides new housing — and not new employment opportunities — have an impact on community wellbeing because residents have to spend a long time travelling to and from work?



▲ **Figure 2.6** The Kalgoorlie Super Pit is the product of modern technology.

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 a 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. This land use *change* may also have an impact on land use along the route both negative, such as additional traffic noise and or the need to remove trees, and 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*.

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 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 speed travel time and information technology enables some people to work from home allowing residential development to occur further away from workplaces. Mining companies can achieve profit from developments in hostile environments such as the Pilbara or Kalgoorlie regions of Western Australia because of large-scale infrastructure and mining operations, as in figure 2.6.

▶ ACTIVITIES

1. Discuss in a group which are the main factors that would play a role in the following proposed land use *changes*. Try to establish and justify a rank order for these factors:
 - ▶ 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.
2. On the internet, 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 direction that land use *change* is occurring in your community. Write a suggestion about how land could be used better.
3. Identify an area of *change*, or proposed *change*, in your school or home area. What factors do you think might be dominant here?
4.
 - a. What physical factors would have been considered before the large open-cut mine shown in figure 2.6 could have been developed?
 - b. In what ways could economic factors combine with technological factors to produce a land use *change* like that in figure 2.6?

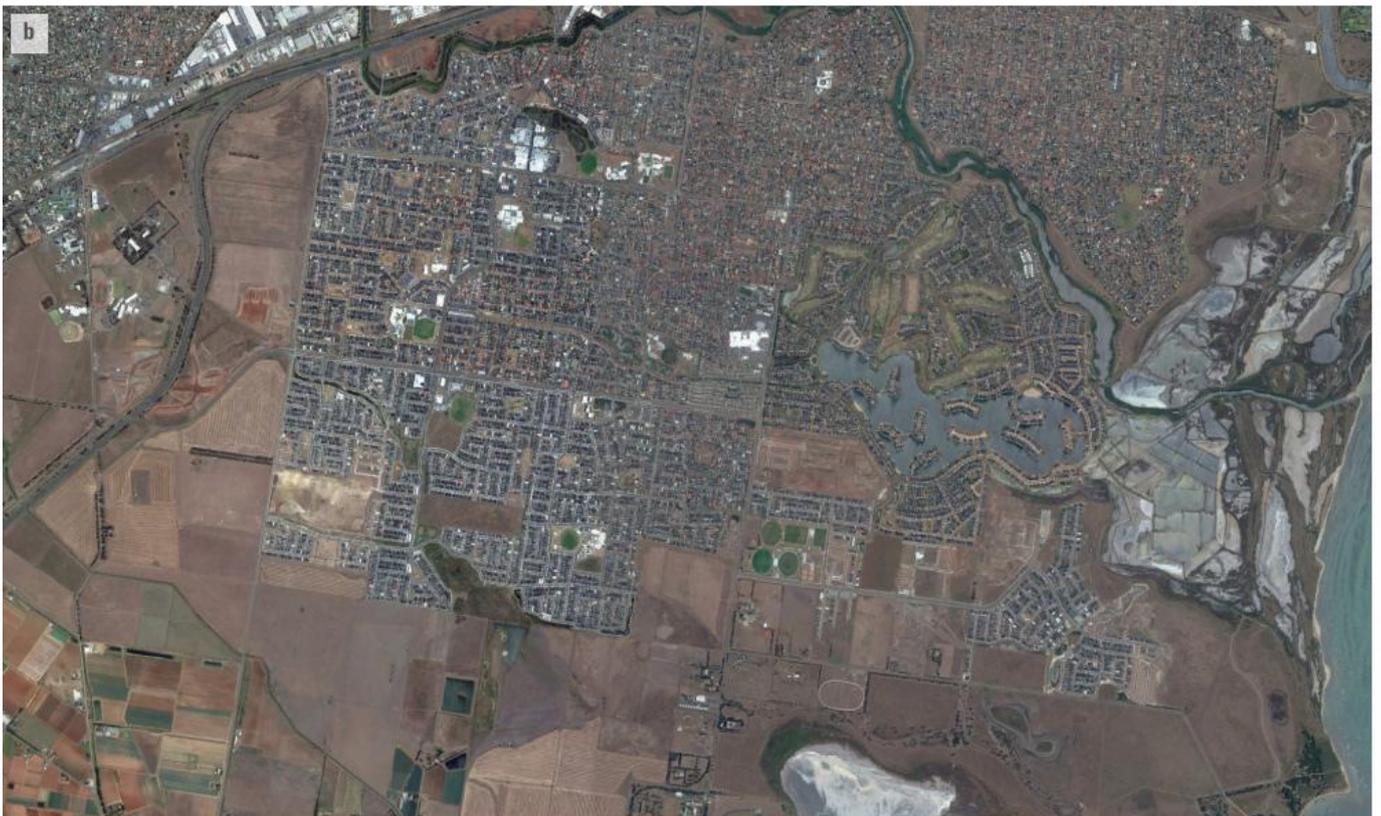
Impacts of land use *change*

Land use *change* can have far-reaching and long-term impacts. Population growth and *movement* can cause land use *change*, 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. Land use intensification can occur when converting prime

agricultural land into suburban housing developments, as in figures 2.7 (a) and (b). This is a long-term land use *change* that affects an area's ability to produce agricultural products, but allows for other forms of community development. High impact land uses like industrial parks can leave contaminants in the soil and watertable which need to be remedied before other land uses can occur there.



▲ **Figure 2.7** (a) Point Cook, Victoria, 2002



▲ **Figure 2.7** (b) Point Cook, Victoria, 2015

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 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.

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* in Western Victoria which had severe impacts was the clearing of the Mallee scrub. Before European settlement in the nineteenth century, the ecosystem was *sustainable* and dominated by the 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 were dryland and

irrigation salinity (refer to figure 2.8), soil erosion, high-level weed invasion on both crops and pasture land, and some of the worst rabbit and mouse plagues in the state's history. The Mallee now has low fertility in comparison to the more fertile and higher rainfall areas to the south. Major tree-planting campaigns are being introduced to help stabilise the soils and habitat.

Land use generates *movements* of people and goods. People need somewhere to live, shop, play, learn and work. A *change* in land use can lead to more people moving in 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 Point Cook area between 2002 and 2015 are an example of these *changes*.



▲ **Figure 2.8** 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 2.7 (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 in 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 2.7 (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 2015.
 - 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?
 - f. Why might habitat fragmentation not be an issue in this area of land use *change*?

Processes for land use change

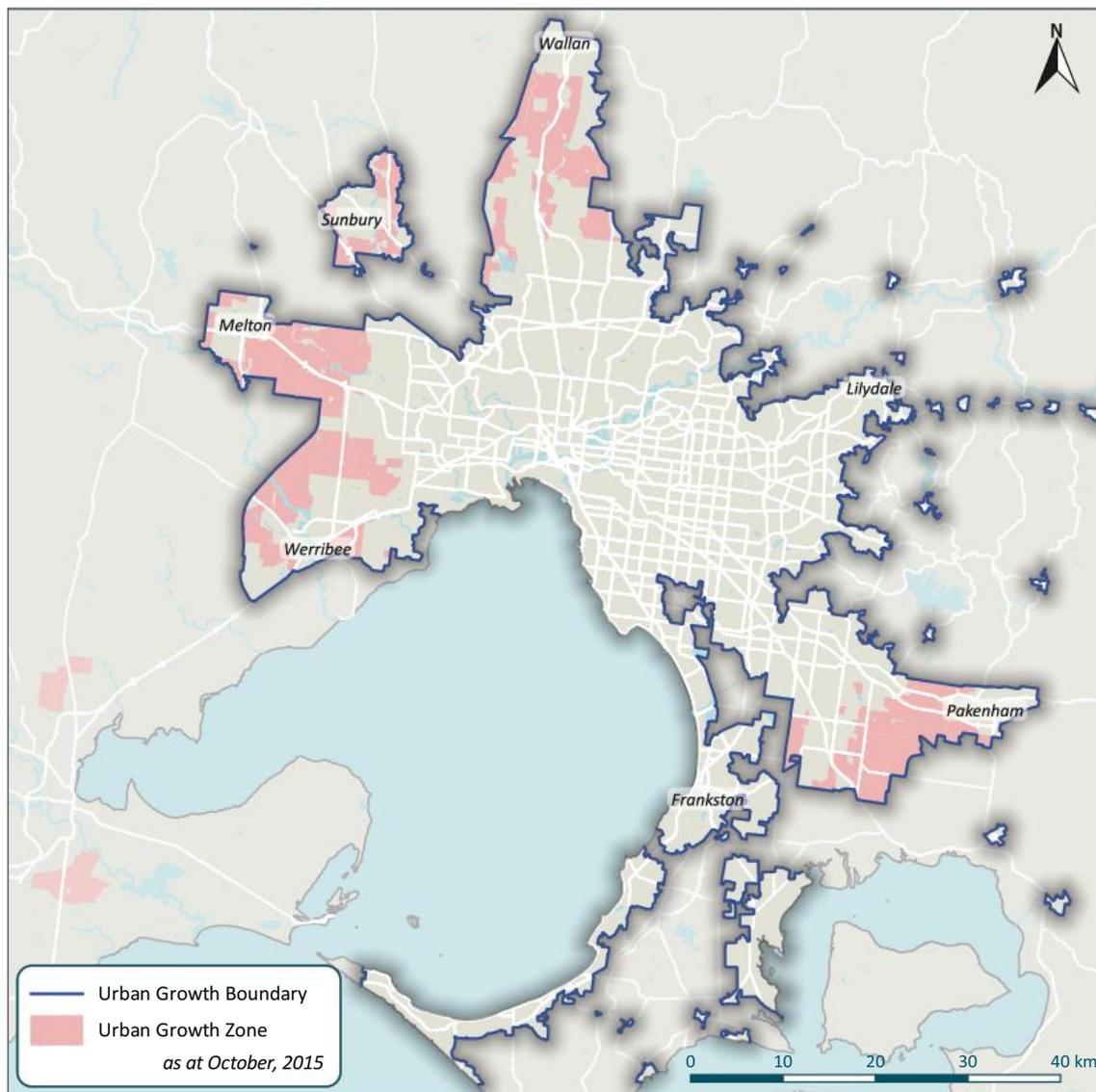
Australia has 561 local governments, of which 79 are in Victoria. These local governments are the responsible authorities in charge of the land use and management in their area. Official *changes* to land use generally need planning permits. Victoria has a State Planning Policy Framework (SPPF) and each 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 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 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.

A major challenge Victoria faces is how to manage its future land use *change*. If historic patterns of *change* continue there may be an increase in the severity of impacts including urban sprawl, loss of agricultural lands, increased car dependency, and habitat fragmentation. With the Victorian and Melbourne populations projected to effectively double by 2060, managing this growth will require strategic planning and collaboration with communities to ensure the maintenance of the local character, amenities and quality of life. Some instruments planners use to do this are 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 2.9). This boundary separates urban land uses from the rural farms, conservation areas and green wedges where different policies and rules apply.

▼ **Figure 2.9** Melbourne's Metropolitan area bounded by the Urban Growth Boundary



▶ ACTIVITIES

1. How does a proposal to *change* land use in an urban area of Victoria differ from one in a rural area?
2. Suggest why the following land uses are often restricted in urban areas: abattoir, waste treatment, power generation.
3. '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.
4. 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 or contraction.

How can *changes* to land use be sustainable?

The challenges of climate *change* and population growth will continue to put pressure on land and other resources such as water and vegetation. One strategy to maintain healthy rural and *regional* land uses, growth and infrastructure development is to confine development within existing areas of cities and towns. Strategies to achieve liveability and *sustainability* within boundaries need to comprise key ingredients of existing successful cities. The following elements have been jointly promoted by Victoria's and Melbourne's planners as a way to manage urban land use intensification while maintaining a high standard of liveability:

- ▶ 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*.

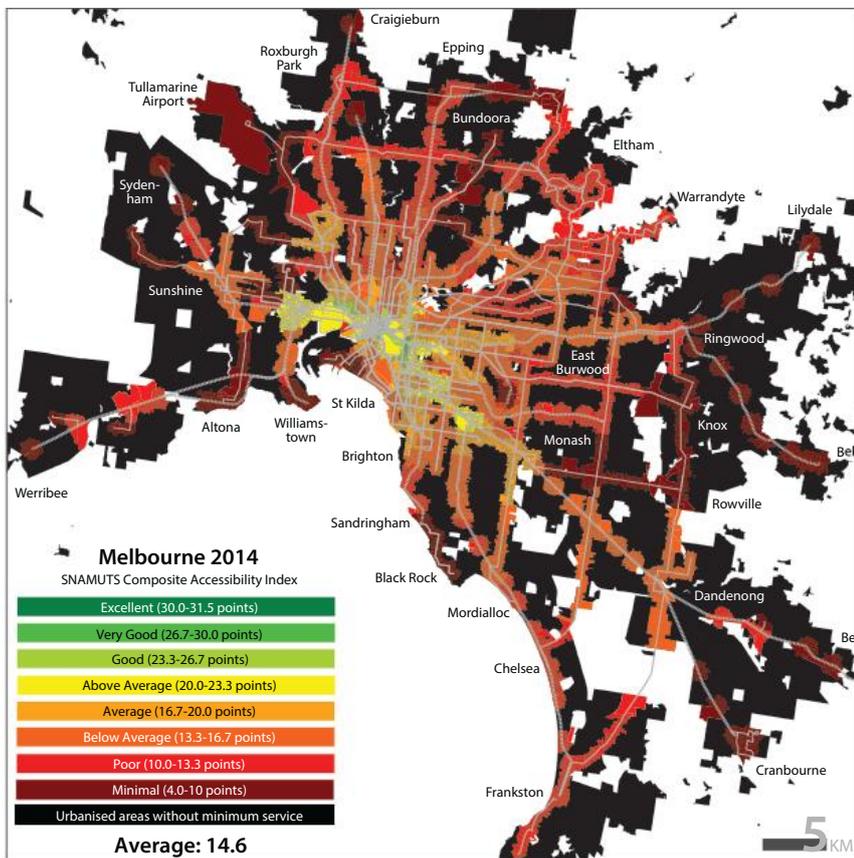
Some current land use practices conflict with these principles of *sustainable* development. For example, developing peripheral urban, or 'peri-urban', lands into low-density housing contributes to car dependency and urban sprawl. If this type of development does not also provide for jobs and occurs 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.

This association between commuter dependence on petroleum and the capacity to pay off the mortgage is an example of unsustainable land use patterns. Elsewhere in the world, higher density areas have reduced car dependency, like Manhattan where only 25 per cent of people own cars and even fewer use them to commute to work. The average population density of Manhattan is 27 670 people per square kilometre and swells to 65 580 people per square kilometre on business days. The advantages of living close to or within denser transport corridors are shown in figure 2.10. Development located within these corridors has multiple modes of transportation and access to activity centres.

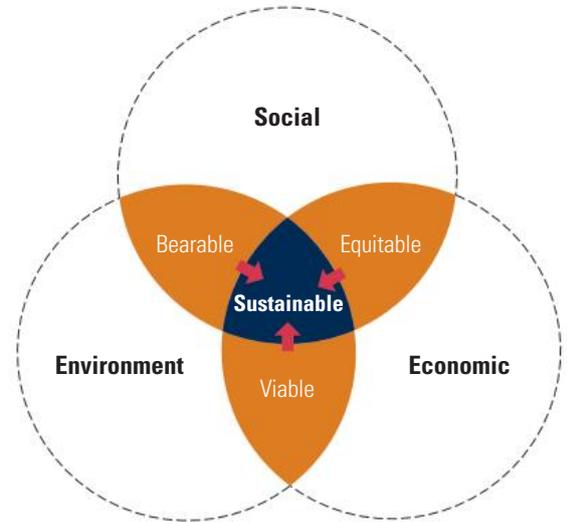
For land use to be *sustainable* it must be socially acceptable, environmentally friendly and economically viable (see figure 2.11). Development of our urban centres is unlikely to be *sustainable* if it largely follows the path of aiming for profits, with minimal regard for the environment or society. Examples are the building of housing estates and roads on arable lands or in important habitats. *Sustainable* development aims to benefit all three categories equally as a way to achieve a healthy future.

▶ 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.
3. Identify areas in figure 2.10 that need new transportation options to support the community. What infrastructure upgrades do you recommend?



▲ **Figure 2.10** Melbourne's public transportation accessibility composite map. The average score of 15.3 is out of 32.3 points possible.



▲ **Figure 2.11** The multiple elements of a *sustainable* society

Con Charalambou Geospatial analyst

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*



CAREER PROFILE

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/customeriser.

The future of land use *change*

Melbourne has a land area of 9990.5 square kilometres with an average population density of 430 per square kilometre. Current projections indicate that the population will grow by 3.3 million people in the next 35 years. Maintaining the same population density would require an additional 7600 square kilometres of land to be added to the urban growth boundary.

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 2.12 (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 particular 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 2.12 (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 2.12 (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*.

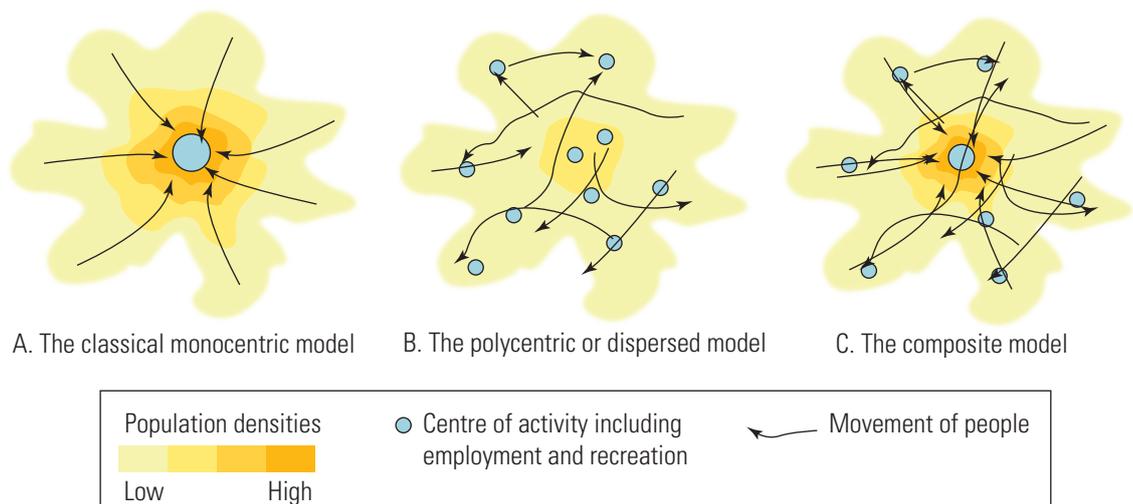
Over the past decade the urgency to refine Melbourne's land use practices has increased. Specific documents that have highlighted this need have been *Melbourne 2030*, *Transforming Australian Cities* and *Plan Melbourne*. These policy documents make a strong argument for the future direction Melbourne 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 development in rural areas in Victoria will need to balance land productivity with increasing tourism, housing development and subdivision of large tracts of farm land. 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.

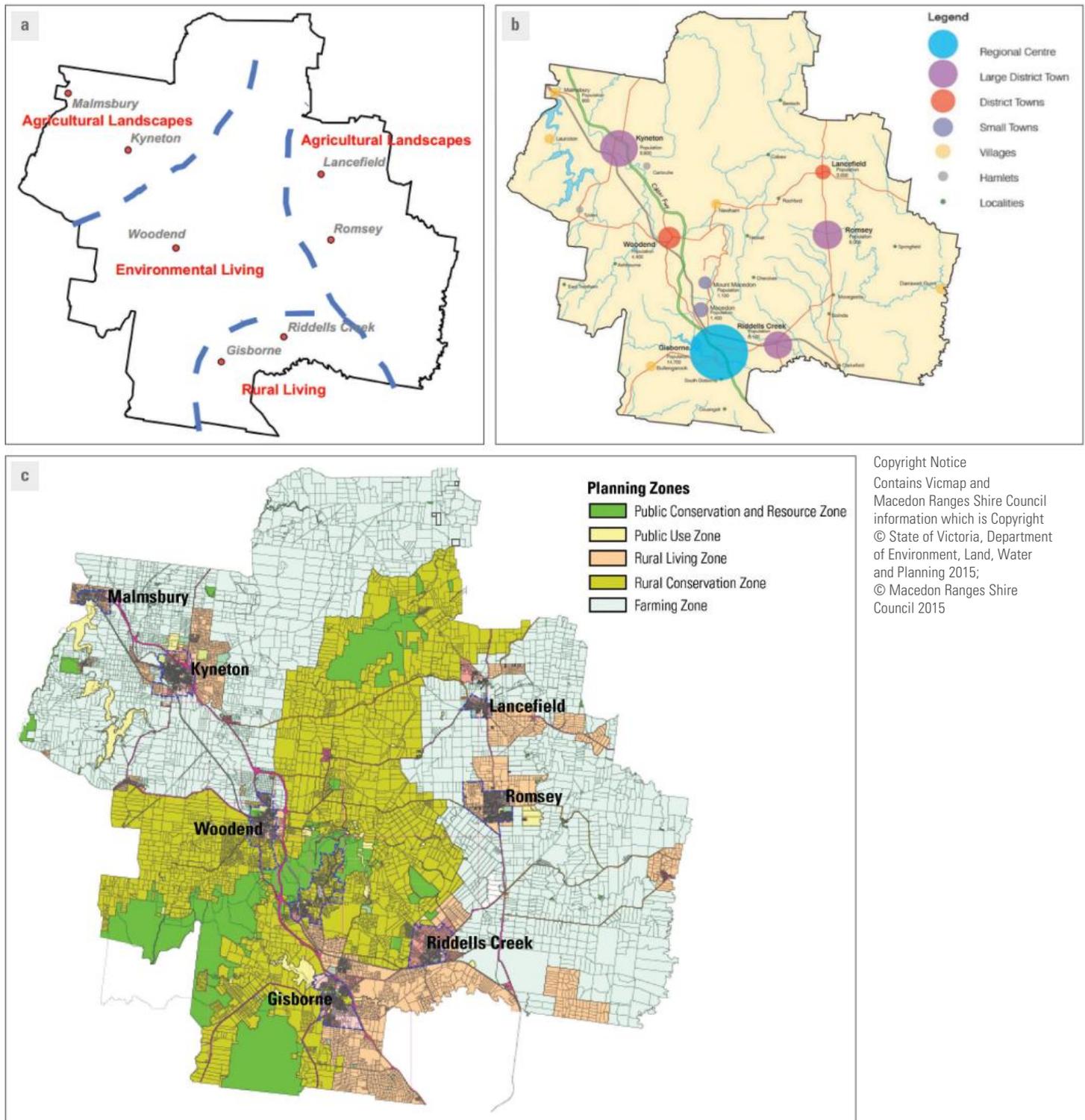
Macedon Ranges Shire Council is a peri-urban council, with Gisborne a 30-minute drive from Melbourne's centre. The shire's main growth projections are along the Calder Freeway corridor (shown in figure 2.13). Designating certain areas for rural living, environmental living and agricultural landscapes allows for controlled land use *change* across the shire.

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.

▼ **Figure 2.12** Monocentric, polycentric and composite models of urban morphology



▼ **Figure 2.13** Macedon Ranges Shire Council (a) Rural land uses (b) Recommended future growth areas (c) Planning zones



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▶ ACTIVITIES

1. What geographic characteristics of peri-urban areas make them desirable *places* for people to live? How has this affected the farming communities in those areas? Use Wyndham or Macedon Ranges or your own example.
2. Refer to the Macedon Ranges Shire Council planning scheme on the internet. Read Clause 22.15: Rural Living; Clause 22.17: Living Forests; and Clause 22.20: Agricultural Landscapes. What policies are in place which will allow or prohibit land use *change* over time? How effective do you think these strategies will be?
3. Refer to your local council's planning scheme. Using section 22, what policies are in place to promote sustainable growth around specific precincts in your area?
4. A farmer south-west of Romsey (figure 2.13) is keen to sell his land for housing development. What problems do you envisage for the farmer and the wider community? Who might be supporting the farmer in his ambition?
5. Look back to figure 2.4 (c). Is this an example of infill, greenfield, brownfield, greyfield or urban renewal?

3

Land use change in urban areas

Introduction

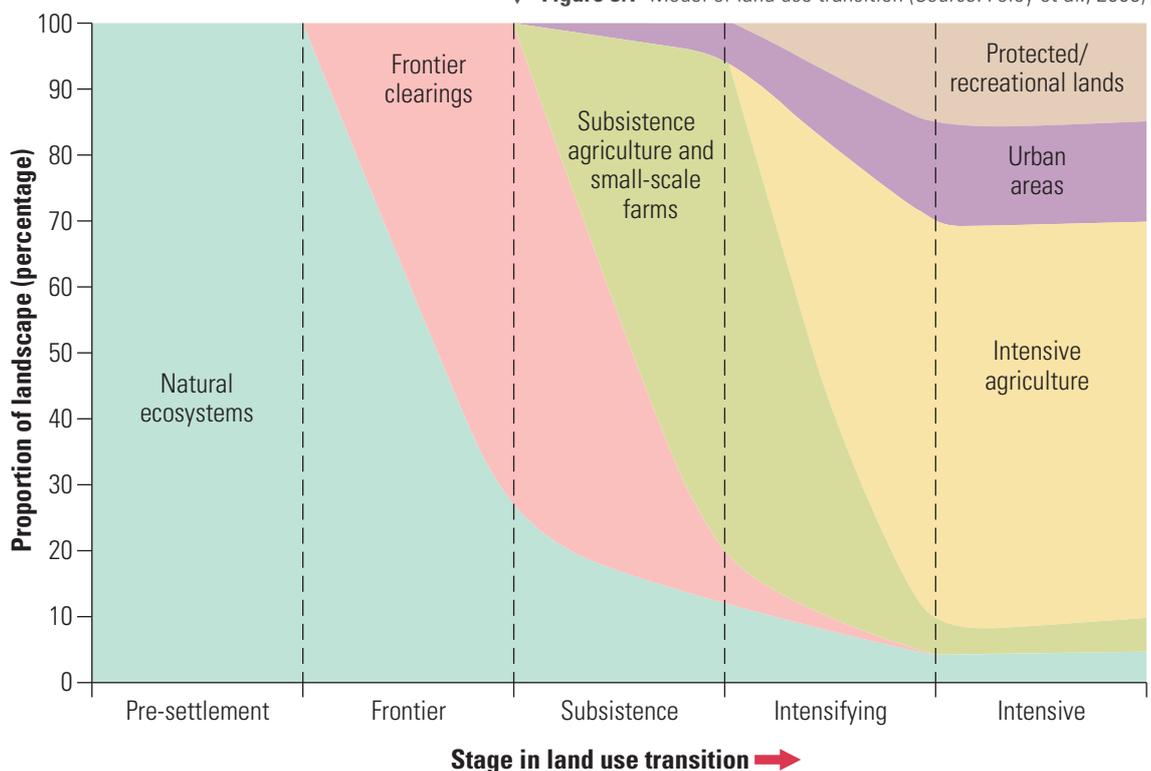
Land use describes the different ways in which people use parts of the Earth's surface. In an urban environment, *change* in land use is driven by population dynamics, the space, resources and infrastructure needed to support the population, and government and commercial decisions dealing with the management 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 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. Different *regions* are in different stages depending on their history and social and economic conditions but the sequence of development and outcome is similar.

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 (Source: Foley et al., 2005)



What is land used for in Melbourne?

In recent years, Melbourne has grown at a considerable rate, creating an extensive and expanding urban landscape. The population reached 4.3 million in 2013, an increase of nearly 1.7 million since 1973. If trends continue, it is expected to reach over seven million by 2050. Up to 1.6 million new dwellings will be required to support this growing population.

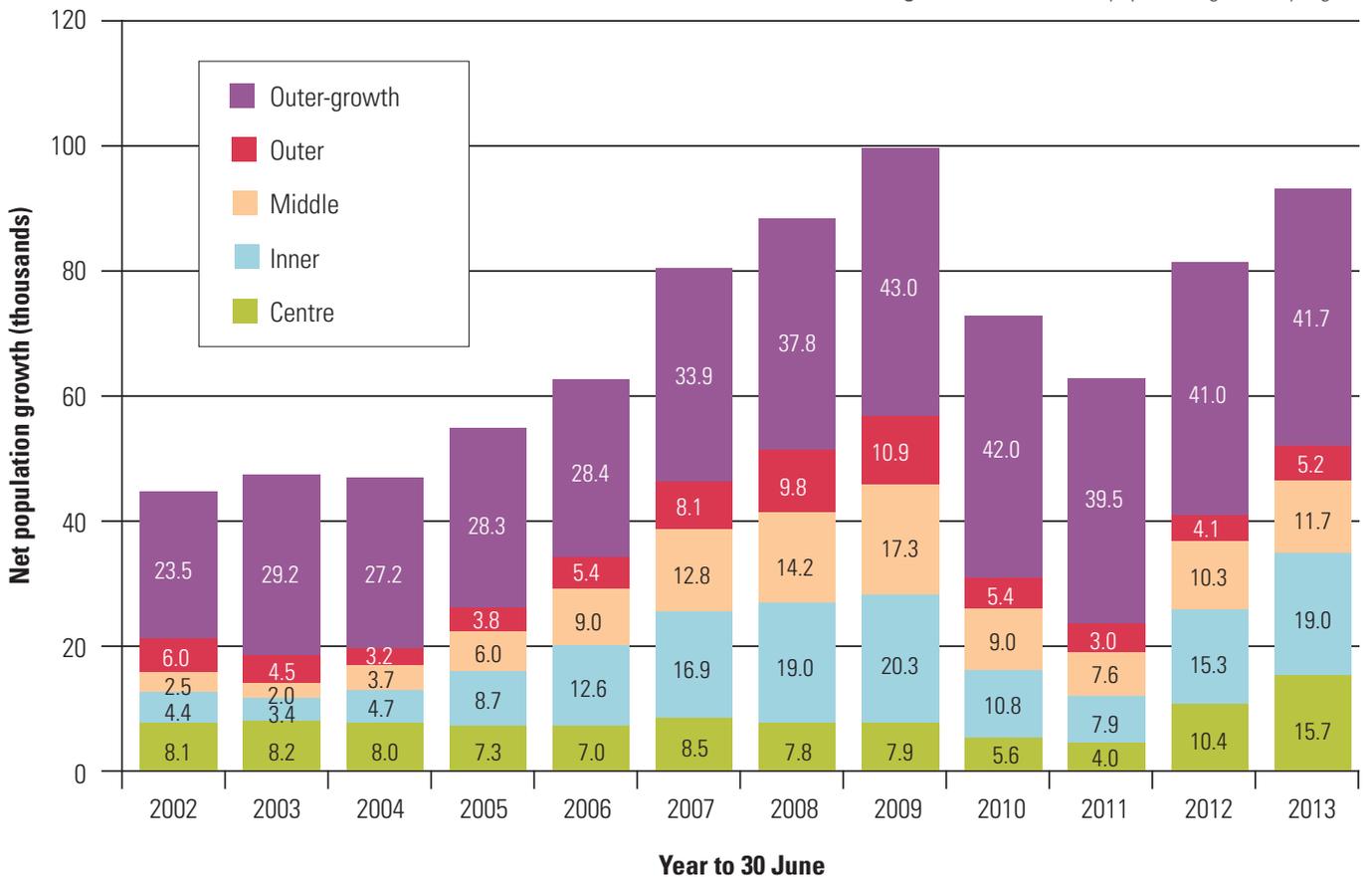
The *regions* experiencing the most rapid *change* in Melbourne are in the peri-urban zone which is also referred to as the rural–urban fringe. This transitional zone is located between urban and rural areas and has accounted for over 40 per cent of growth (figure 3.2). As Melbourne expands, this zone 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.

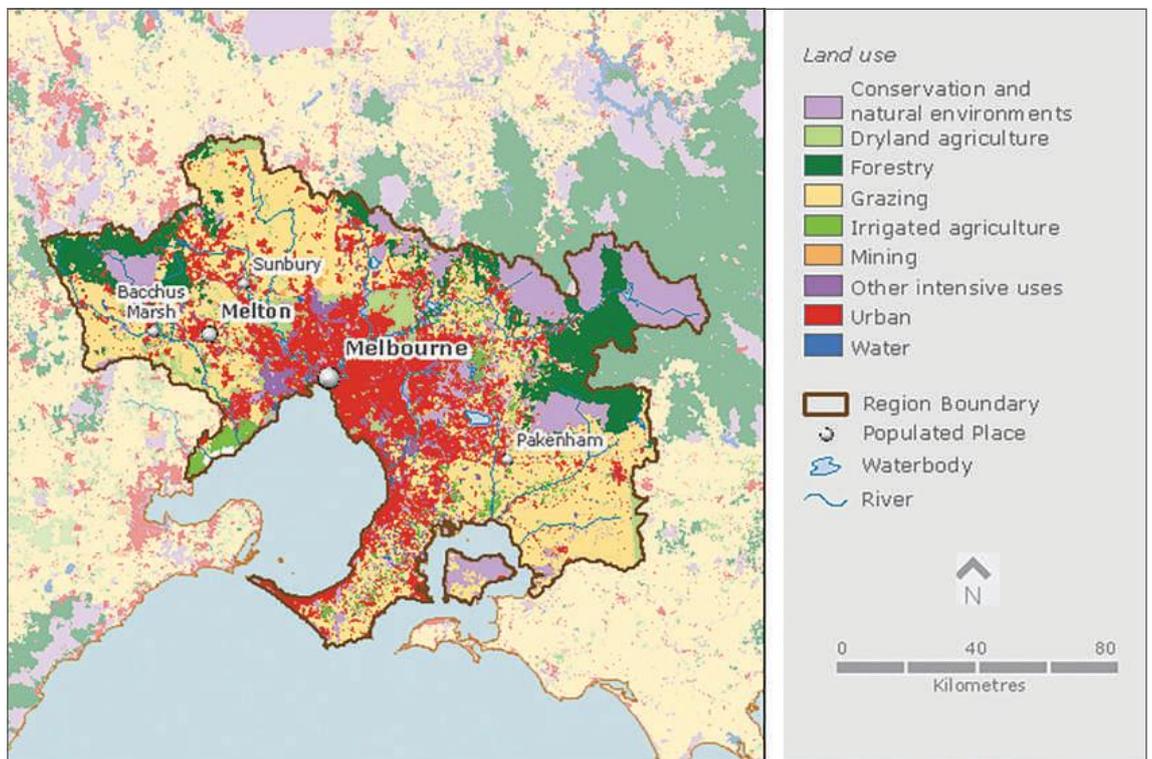
As urban sprawl encroaches on rural and bushland areas, the proportion and *distribution* of land use *changes* significantly. Pressure is placed on rural industries and infrastructure leading to socio-cultural and economic impacts in rural communities such as a loss of jobs. Forested areas are diminishing 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 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 Melbourne region (Source: Bureau of Meteorology, 2010)

▼ **Figure 3.4** Land use in the Melbourne region (Source: Bureau of Meteorology)

LAND USE	AREA (square kilometres)	AREA (percentage of total)
Grazing	4196	36
Urban	2801	24
Conservation of natural environments	1941	17
Forestry	1302	11
Dryland agriculture	513	4
Other intensive uses	362	3
Irrigated agriculture	350	3
Water	187	1
Mining	71	1
Total	11 723	100

▶ ACTIVITIES

- Referring to figure 3.2 (page 27), which *regions* of Melbourne have experienced the most growth and why do you think this is the case?
- Referring to figures 3.3 and 3.4, describe both the *distribution* and proportion of two different land uses in Melbourne.
- How do you think the proportion of land use in Melbourne may have *changed* over the last 20 years?
 - How do you think it will *change* in the next 20 years?
 - Where do you think these major *changes* will occur?
 - Suggest reasons to explain your answers.
- Describe the *changes* in the geographic characteristics of your local area over a short time *scale* and research long-term land use *changes*.
- Explore satellite imagery of Melbourne using Google Earth.
 - Use the historic imagery function to describe *changes* to the geographic characteristics of the south-eastern and western growth corridors over various time *scales*.
 - Which *regions* have had the most *change* and why?
 - Compare these *changes* with another city such as Los Angeles.
- 'Population dynamics are the main driving force behind *changes* in land use.' Evaluate this statement and discuss to what extent you agree or disagree.
- 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.
- Find an example of a city in the United States which has tried to reduce the impacts of urban sprawl by transitioning to a more *sustainable* city. What strategies have been implemented in order to achieve this?

What are the impacts of large-scale changes to land use?

A steady increase in urban density and sprawl has been a major factor leading to a *change* in land use in cities around the world. The 'pre-developed' landscape has been altered significantly to meet the demands of a growing population. This has had a significant impact on the natural environment, leading to additional social and economic issues. These *changes* are interconnected.

▼ **Figure 3.5** Environmental impacts of *changes* to land use in an urban area

CHANGE	CAUSE	IMPACT
Cleared land	Urban and agricultural development	Loss of habitat, reduction in bushland and a loss of biodiversity
Pest and weed infestation	Deliberate and accidental introduction of foreign species such as rabbits and blackberries	Competition with indigenous species for habitat
Additional water and pollutants entering waterways	An increase in untreated stormwater run-off due to roofs, roads and other impervious surfaces	Erosion, channel widening, poor water quality, flooding and alterations to the natural flow regime of streams
Fragmentation of remnant bushland	Urban sprawl and its associated infrastructure	Lack of genetic diversity within populations and susceptibility to disease
Loss of forest and increase in reflective surfaces	Increasing urban density leading to more hard surfaces such as roofs and roads	Urban Heat Island effect leading to increased temperatures

► ACTIVITIES

In small groups, choose one of the impacts of land use *change* (see figure 3.5) to research in more detail at a specific location. Consider:

- the type, *scale* and *process* of the land use *change* that led to the impact and the time period over which it took place
- the reasons for the *change* including the influence of individuals, organisations, government department planning strategies and the geographic characteristics of the surrounding *region*

- details of the positive and negative impacts of the *change* on the environmental, economic and social conditions of the selected area
- potential solutions to reducing any negative impacts or ways to enhance positive impacts.

Present and share this information to your class as a case study. Include a flowchart summarising the *changes* and their impacts as a sequence of events.

How can small-scale land use changes reduce environmental degradation?

Environmental degradation of ecosystems due to land use *change* can often lead to social and economic impacts. For example, population growth has caused coastal urban land use *changes* in Tanzania. A drastic reduction in the size of the Pugu and Kazimzumbwi forest reserves has led to impacts such as increased salinity and a reduction in water quality, threatening the livelihood of communities that depend of the forest's ecosystems. Small-scale land use *change* through effective urban planning and management aims to reduce these impacts in a cost-effective way while providing social benefits to the community, thereby achieving economic, social and environmental *sustainability*.



Figure 3.6 Two different *regions* of The 100 Acres Reserve in Park Orchards, Victoria. The first image (a) is a landscape dominated by pine trees (an introduced species) while the second (b) shows an extensive area of remnant woodland as part of the Anderson's Creek wildlife corridor.

1. Conserving remnant vegetation

In an urban context, remnant vegetation is defined as bushland that remains as it was prior to development (see figure 3.7). Preservation of remnant vegetation is essential in providing habitat for native animals, maintaining clean water supplies, carbon storage, improved aesthetics and an opportunity for low-impact recreation. Conservation techniques include fencing off regeneration zones, weed control and revegetating nearby areas.

2. Planting indigenous vegetation

In order to combat the loss of habitat and reduction of biodiversity in urban areas, there has been a recent trend towards planting indigenous species in gardens and landscapes as a cheap and low-maintenance alternative to traditional gardening. 'Indigenous' refers to species that occur naturally in a specific *region* whereas native refers to species that come from anywhere in Australia. Although indigenous plantings alone cannot replace the *processes* and biodiversity of remnant bushland, they are important links with existing bushland. Benefits include:

- ▶ enhancing local biodiversity and improving the ecological balance of an ecosystem
- ▶ fostering genetic diversity between *regions*
- ▶ thriving without the use of fertilisers due to their adaptation to the local climate, soil type and terrain
- ▶ preserving the ecological history, culture and identity of a *region*.

3. Establishing wildlife corridors

Residential and commercial development in Melbourne has led to habitat fragmentation in which wildlife populations are separated. Wildlife corridors, such as the Merri Creek *Marran Baba* Parklands (figure 3.8) in Melbourne's north, are remnant and revegetated bands of habitat used to link isolated areas of bushland. They enable the *movement* of species between populations in different *regions*. This enables populations to increase their genetic diversity and reduce their susceptibility to disease while making them less vulnerable to alterations in food or water supplies.

4. Water-sensitive urban design

Urban development in previously forested catchments is a land use *change* that leads to a degradation of local waterways. A rise in impervious area from additional roofs, roads and footpaths increases the amount of stormwater run-off and alters the *processes* of the water cycle (see figure 3.10). Untreated run-off entering urban creeks modifies the natural flow regime and degrades water quality by transporting pollutants such as plastic, oil and fertilisers into the system. Water-sensitive urban design (WSUD) is a planning and design approach which integrates a range of measures to minimise the impact of urbanisation

on local waterways (see figure 3.9). By managing stormwater effectively, urban environments are able to replicate the *processes* in the natural water cycle. This involves a fundamental shift in the management of stormwater as a resource rather than a waste product. Additional benefits include recharging of groundwater supplies, reducing the demand on potable water and creating a more aesthetically pleasing landscape.

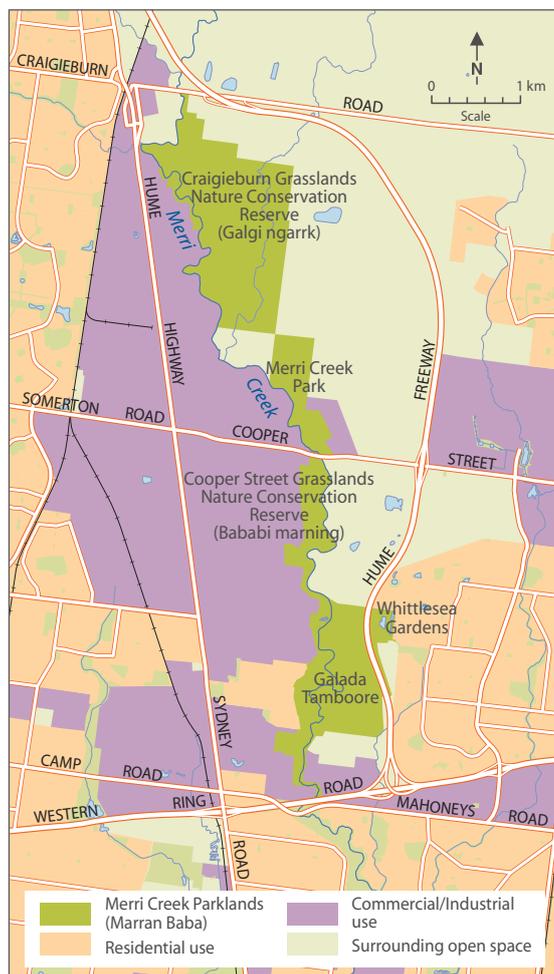
5. Urban Heat Island effect

Land use *change* that results in the addition of dense building materials, removal of vegetation and the rapid removal of water through urban drainage systems captures and retains more heat. This is known as the Urban Heat Island (UHI) effect and it causes urban areas to be warmer than surrounding rural areas. In Melbourne the UHI effect increases temperatures by an average of 2–4 °C compared to surrounding rural areas. Slowing the drainage of water using WSUD methods reduces the effect by increasing evaporation and transpiration. This is particularly effective when stormwater is used to irrigate the urban forest. Maintaining a healthy urban forest reduces the UHI effect by providing shade. Added benefits of an urban forest include improvements in air quality, absorption of stormwater and recreation.



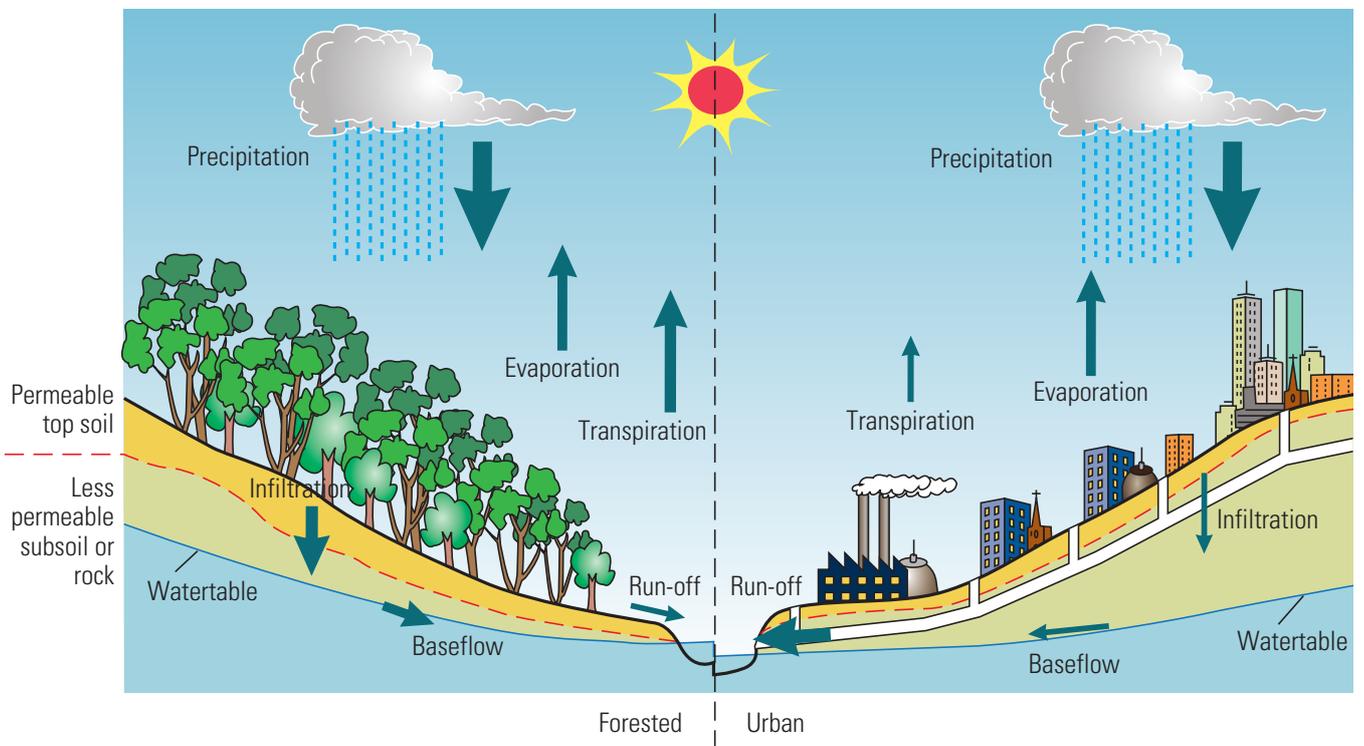
▲ **Figure 3.7** Indigenous planting (left) supporting four hectares of remnant vegetation (right) in Loughies Bushland, Ringwood North

▼ **Figure 3.8** Land use surrounding the Merri Creek habitat and recreation corridor



▼ **Figure 3.9** WSUD management techniques can be integrated into land use through a variety of treatments as an alternative to large-scale drainage infrastructure.

TREATMENT	FUNCTION
Rainwater tanks	Store roof run-off, reduce stormwater, save potable water.
Wetlands	Naturally treat run-off and slowly infiltrate it into the soil.
Swales	Slow and spread stormwater, by creating linear depressions that allow it to infiltrate.
Raingardens	Collect stormwater and use biofiltration to treat it as it passes through several porous layers.
Porous paving	Reduce run-off by allowing water to infiltrate into the soil beneath.
Pollutant traps	Physically trap solids such as litter and coarse sediment before entering creeks.



▲ **Figure 3.10** Urban development alters the natural balance of the water cycle.

► ACTIVITIES

1. Compare the geographic characteristics of the different *regions* of The 100 Acres Reserve shown in figure 3.6 (page 30) and list the social and environmental benefits of each.
2. Research the Merri Creek wildlife corridor (see figure 3.8, page 31) 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 3.10.
 - a. Identify three *changes* that have occurred to the *processes* of the water cycle due to urban development.
 - b. Select one of these *changes* and describe the impact that it may have on the natural environment.
4. Research one of the WSUD treatment methods (see figure 3.9, page 31) in more detail and explain how one or more of them could be implemented in your school. How would you convince your school community that it is a good idea?
5. Research Melbourne Water's 10 000 Raingardens Program. Explain its role in raising awareness within the community and improving the health of local waterways.
6. 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 an urban forest in reducing the Urban Heat Island effect.
7. Explain how *small-scale* land uses can have multiple benefits for the natural environment, community and economy, and influence the *sustainability* of large-scale urban developments. Provide specific examples.

What effect does urban development have on the health of urban waterways?

Studies at the University of Melbourne have identified incremental urban development as the major threat to the health of urban streams in Melbourne. An increase in the density of urban development and urban sprawl into rural and forested areas is leading to further clearing of remnant bushland and an increase in

impervious coverage. This is affecting the natural *processes* and the health of urban creeks (see figure 3.10). As the population increases, the *scale* of this land use *change* increases and the associated impacts are compounded.

▼ **Figure 3.11** An example of increased erosion due to land use change, Yarraman Creek, Noble Park



▼ **Figure 3.12** Impacts of land use *change* on urban waterways

CHANGES	IMPACTS
Increased coverage of impervious surfaces in the catchment due to additional roofs, sealed roads and footpaths	Less infiltration, more run-off and an increase in volume of stormwater flowing into creeks
Increase in the volume of stormwater run-off entering creeks and drainage systems following rain events	Erosion and channel enlargement and an alteration of natural flow regime (see figure 3.11)
An increase in the frequency of run-off events due to unnatural drainage systems	Alteration of seasonal conditions and influence on stream <i>processes</i>
Increase of unfiltered pollutants entering the system from cars, litter and chemicals	Poor water quality affecting ecological balance; increased algal growth and a loss of biodiversity
Loss of vegetation in the riparian zone	Loss of habitat and less transpiration
Less aesthetically pleasing	Social impacts on residents

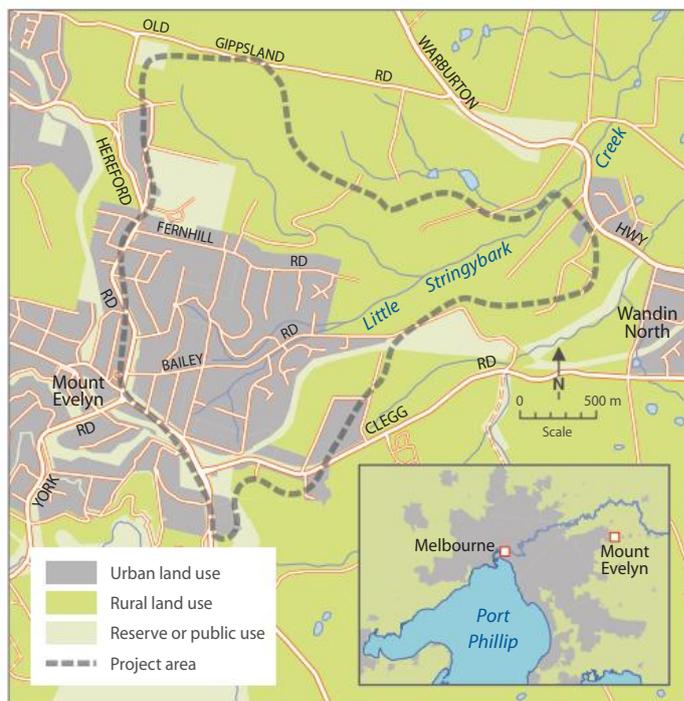
► ACTIVITIES

1. Research stream bank erosion and list three effects it has on the health of a river system. How can erosion be managed in urban waterways?
2. Choose three impacts and effects of land use *change* on urban waterways (see figure 3.12) and discuss how they are interconnected.
3. Visit the website of the Healthy Waterways Waterwatch program or Melbourne Water's Waterways Local Updates website to find out information about the health of your local waterway, the causes of this health and recent management projects.

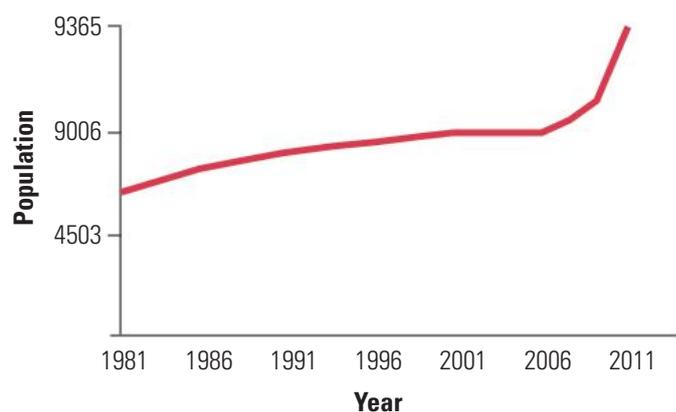
Case study: The Little Stringybark Creek project, Mount Evelyn



▲ **Figure 3.13** Comparison between Sassafras Creek (a) and Little Stringybark Creek (b)



▲ **Figure 3.14** Project area in the upper catchment of the Little Stringybark Creek, Mount Evelyn



The Little Stringybark Creek project is a pilot study exploring how a fundamental *change* in the use of stormwater can potentially improve the health of an urban creek and catchment. Prior to development, Little Stringybark Creek, Mount Evelyn, was a healthy stream supporting a pristine riverine ecosystem and forested catchment. The addition of pollutants transported by untreated stormwater into Little Stringybark Creek has degraded the water quality. It has also altered the flow regime of the stream leading to increased erosion and channel modification. These impacts can be observed when comparing Little Stringybark Creek with Sassafras Creek (see figure 3.13) which is located within a similar peri-urban zone but treats stormwater on site using residential water tanks. A combined project involving the University of Melbourne, Monash University, Melbourne Water and the Shire of Yarra Ranges has attempted to restore the health of Little Stringybark Creek by reducing the volume of untreated stormwater entering the stream.

Study area: catchment characteristics

The Little Stringybark Creek catchment is located 37 kilometres east of Melbourne. The catchment area at its source is approximately 300 hectares and the total catchment is 800 hectares. One thousand properties lie within the catchment area, 740 of which were selected as potential participants in the program. Little Stringybark Creek is a tributary of the larger Stringybark Creek which flows into the Yarra River and eventually into Port Phillip bay. It was chosen as the *location* for this project due to its size, condition and influence on downstream water courses.

◀ **Figure 3.15** The growth of Mount Evelyn (1981–2011) is the main factor causing land use *change* leading to a clearing of vegetation and an increase in impervious surface area.

The region

The characteristics of the Little Stringybark Creek catchment vary according to the land use in two main subregions. The upper reaches — the focus of the study — are particularly degraded due to an overabundance of run-off from the suburb of Mount Evelyn. Cheap real estate prices and attractive natural surroundings led to rapid development during the 1980s. Over the past ten years, growth has steadied (see figure 3.15) and is forecast to drop by two per cent (190 residents) by 2031. However, a decline in the size of households is predicted to bring a seven per cent increase in the number of households during this period.

Residential and commercial development in Mount Evelyn has led to clearing of bushland and a transition from rural to urban land use. Additional roofs, roads and other impervious surfaces have meant that the natural *processes* of the catchment have not been able to function. Alterations to the flow regime have caused erosion and a widening of the channel while habitat has been destroyed in the previously forested catchment.

Further downstream, urban development in the catchment has been 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 the area meant that it was used for grazing instead of intensive agriculture. A more natural flow regime in this subregion enables the creek to meander naturally through pockets of remnant vegetation.

▶ ACTIVITIES

1. Refer to figure 3.13. Using a table, compare the characteristics of Sassafras Creek and Little Stringybark Creek evident in the photographs.
2. Locate the Little Stringybark Creek catchment by typing one of the street names from figure 3.14 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 3.16 or Google's Satellite Imagery function.
 - c. Compare land use in the upper and lower subregions of the catchment.
 - d. Estimate the percentage of impervious area from roofs and roads.
 - e. Locate Sassafras Creek and compare the land use of the *region* with the Little Stringybark Creek catchment.
 - f. How might the contrasting land uses in these *region* have influenced the characteristics of the catchments and their ecological health?
3. Refer back to figure 3.10 (page 32) and use it to summarise the main impacts that development is having on natural *processes* in the Little Stringybark Creek catchment.
4. Watch the *Working with the Community* YouTube video on the Little Stringybark Creek project website. Identify the land use changes discussed by the community and the impact that these changes have had on the *region*.
5. Use the online Melway map to follow the flow of water from 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.
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.

▼ **Figure 3.16** Satellite photos (taken in December, 2014) showing the contrasting land use in the upstream (a) and downstream (b) *regions* of the catchment



Project aims and details

The overall aim of the Little Stringybark Creek project is to restore the ecological health and natural flow regime of the creek to a level consistent with a natural stream. Natural *processes* that existed prior to development will be replicated by:

- ▶ increasing the amount of stormwater that is captured and treated before entering the creek
- ▶ reducing the volume and frequency of run-off entering the creek.

The project is hoping to achieve several additional benefits that will be applicable to other sites and projects including:

- ▶ serving as a pilot study for innovative catchment-wide approaches to creek management
- ▶ raising the awareness of the negative impacts of stormwater on the health of urban creeks and promoting and demonstrating cost-effective WSUD techniques
- ▶ trialling approaches to engage and involve the local community
- ▶ reducing the reliance on potable water sources by recycling stormwater.



▲ **Figure 3.17** Nature strip raingardens installed to filter run-off from Fernhill Road, Mount Evelyn

The project uses both financial incentives and education to encourage residents and businesses to install rainwater tanks and raingardens on their properties. Payments to participating landholders are made via a competitive tender process which included four rounds from 2008 to 2015. Successful properties are chosen based on the opportunity for the greatest environmental benefit with the smallest economic cost.

The Little Stringybark Creek project is known as a Before–After Control Reference Intervention experiment. Extensive monitoring of Little Stringybark Creek is compared with three control and three reference streams. The three control streams are located amidst similar urban land use in which an unnatural catchment has led to similar degradation.

The control sites will not be altered. The three reference streams are in good ecological health (see Sassafras Creek, figure 3.13, page 34), located in relatively pristine *regions* that lack urban development, or already prevent run-off entering the stream using residential water tanks.

▶ ACTIVITIES

1. Why are reference and control sites essential in this type of project?
2. Visit the homepage of the Little Stringybark Creek project. Watch the *Keeping the Stormwater in the Catchment* YouTube video and write down what the project is trying to achieve and some of the techniques that are used to achieve these goals.

Achievements

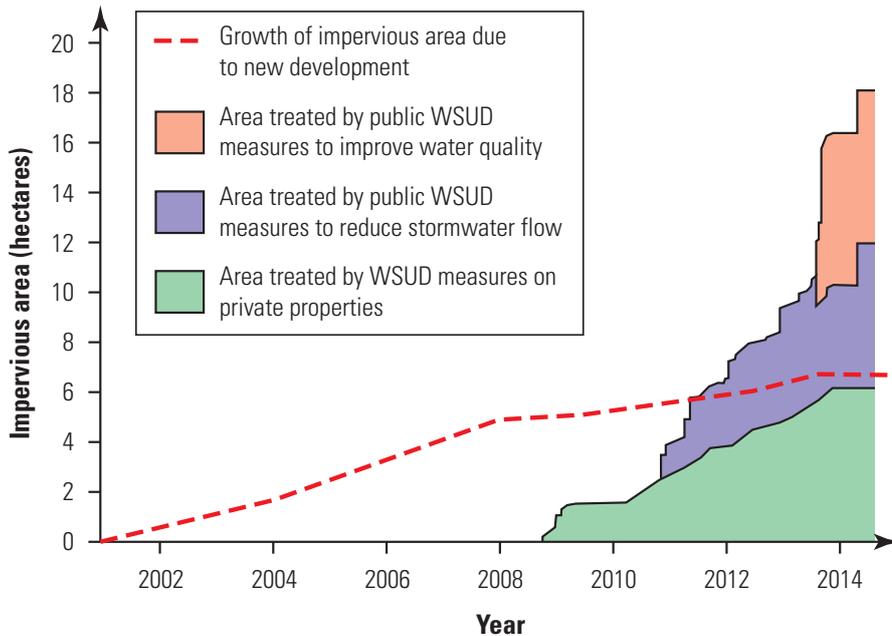
The Little Stringybark Creek project has already managed to achieve many of its aims:

- ▶ The local community have been educated and involved in small-*scale* management of their local creek.
- ▶ Water tanks and raingardens on private and public land have increased the amount of infiltration which has restored baseflow, reduced run-off and saved potable water by recycling rainwater (see figures 3.17 and 3.18).
- ▶ The Yarra Ranges Council has introduced an Environmental Significance Overlay making it mandatory for all new development over 10 square metres that would increase the hard surface area to treat and infiltrate a percentage of their stormwater on site.
- ▶ Although new developments have increased the percentage of impervious area, the amount of area actually draining to the creek has been reduced significantly (see figure 3.19).
- ▶ There has been a fundamental shift in the management of stormwater, seeing it as a resource rather than a waste product.

The final phase of the Little Stringybark Creek project will be monitoring the study area in order to assess the extent to which the health of the creek has improved. The flow, water quality and ecological indicators are being studied regularly to see whether the creek has become less like the control streams and more like the reference streams. If the project is rated a success, there is potential to apply similar programs in other degraded urban streams. Overall, the project has shown that although large-*scale* land use *change* in the form of urban development has adversely affected the natural environment, small-*scale* land use *changes* have reduced this impact while providing economic and social benefits to the community.

▼ **Figure 3.18** A summary of the achievements of the program (as of January 2015)

ACTION	AREA OF IMPERVIOUSNESS TREATED (hectares)	AMOUNT OF INFILTRATION (millilitres per year)	POTABLE WATER SAVED (millilitres per year)
230 private properties retrofitted with water tanks and raingardens	5.4	7.7	16.8
11 large-scale public raingardens	10	26.9	14.6
36 nature strip raingardens to treat road run-off	1.2	3.6	N/A



◀ **Figure 3.19** Despite growth in the amount of impervious area due to new development, implementing Water Sensitive Urban Design (WSUD) measures on both private and public properties since 2009 has greatly increased the area in which stormwater is treated. Treatment methods have reduced stormwater flow and improved water quality.

Note: WSUD refers to Water Sensitive Urban Design.

► ACTIVITIES

- In what ways has the project already been successful (despite not knowing whether or not it has altered the ecological health of the catchment)?
- Why do you think it was essential to engage with the community to ensure the success of the project?
- What might be some of the positive and negative impacts of installing rainwater tanks and raingardens on residential properties?
- Refer to figure 3.19.
 - Describe the growth in impervious area due to new developments. Why is this important to consider when evaluating the success of the project?
 - What is the total area within the catchment that has been treated using WSUD techniques?
 - What proportion of the treated area is on private land compared to public land?
 - Do you think that the total area treated is significant when compared with the total size of the catchment?
- Explain how researchers will be able to evaluate whether or not the project has improved the health of the creek in terms of the reference and control sites.
- Using the Melbourne Water website, find some examples of additional urban catchments that might benefit from a similar project.
- Overall, do you think that the Little Stringybark Creek project demonstrated an ability to improve the *sustainability* of an urban *region* by altering small-scale land use?

Suggested fieldwork activities

Effects of land use *change* on the health of an urban river system

1. Choose a creek or river that flows through a variety of landscapes such as forest, agricultural, peri-urban or dense urban.
2. Observe, identify and measure the geographic characteristics, water quality, riparian vegetation and volume of discharge along various upstream and downstream transects.
3. Use this data and your observations to explore the ways in which surrounding urban land use is affecting the health of the waterway and the extent of the degradation.

Possible sites include:

- ▶ Yarra River, the transition from the upper Yarra Valley to Melbourne
- ▶ Dandenong Creek
- ▶ Merri Creek
- ▶ Maribyrnong River
- ▶ Larger rivers passing through *regions* of different rural and urban land uses (e.g. Goulburn River, Ovens River).

▼ **Figure 3.20** The geographic characteristics of the Yarra River *change* as it flows downstream through Warrandyte State Park (a) and Birrarung Marr, Melbourne (b).



Examples of using Water Sensitive Urban Design (WSUD) to reduce the environmental impacts of urban land use *changes*

1. Visit a site that is applying WSUD techniques or larger-*scale* catchment management techniques.
2. Explore the water management *processes* and how they are incorporated into the urban land use.
3. Research the surrounding catchment to assess the potential benefits of this management on local waterways.
4. Explore the additional benefits of the urban land use including aesthetics, recreation, Urban Heat Island effect and potential long-term economic benefits.
5. Survey locals about their knowledge of water management projects and their impact on local waterways.

Possible sites include:

- ▶ Wetlands at Afton Street Conservation Park, Essendon West
- ▶ Vegetated swales at Lynbrook Estate
- ▶ Raingardens at Docklands Park, Federation Square, and Lambert Street, Richmond
- ▶ A large-*scale* rural wetland or catchment management project (e.g. Yea wetlands).

Remnant vegetation

1. Visit a local site of remnant vegetation, regeneration or a wildlife corridor within an urban context.
2. Research the reasons why remnant vegetation remains or why the area was chosen for regeneration.
3. Devise a method to assess the biodiversity of the area.
4. Identify and explore land use *changes* that have impacted the landscape.
5. Explore the work councils are doing to maintain the area.
6. Contact a local Friends group to find out how the community is involved in maintaining the site.
7. Discuss the way *changes* to the management of the *region* have or could potentially provide environmental, social and economic benefits to the community.



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.



4 Land use change in rural areas



▲ **Figure 4.1** (a) Rural land use *change*: hay bales cut and rolled, with new housing in the background at Point Cook, Victoria. (Melbourne is just visible in the distance.)



▲ **Figure 4.1** (b) A functioning vineyard on the banks of the Yarra River near Young Street in Kew. The land has remained agricultural since the 1890s and is one of two functioning vineyards on the Yarra River within the inner city, the other being on Coppin Grove.



▲ **Figure 4.1** (c) Rural blight in Pakenham

It is common for landscapes and land use to *change* regularly. These *changes* are driven mainly by environmental *change*, access to resources, population growth or government direction. This chapter will focus on the forces that drive land use *change* in rural areas. Examples from within Victoria — Cardinia Shire, Pakenham and Koo-Wee-Rup — will be explored as these areas will experience rapid land-use *change* within the next 15 years. *Changes* to the landscape can be viewed over time by studying old maps and images of an area, and with GIS.

A history of land use *change*

If you walk around Melbourne, you will find many examples of land use *change* in these settlements. Figures 4.1 (a), (b) and (c) show examples of the rural past of many Melbourne suburbs.

Melbourne grew rapidly around the grid of streets and long-running avenues established by Robert Hoddle in 1837. It quickly went from being an isolated rural service centre 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 nineteenth century, farms and market gardens on the periphery of the city, in areas such as Camberwell, Collingwood and Malvern, were experiencing land use *change* as farmland became housing for the rapidly expanding city. This phenomenon is common to all of the world's cities and is a *process* known as urban development.

Land use *change* from rural functions to urban ones can sometimes occur quickly. As the urban area grows, pressure is placed on existing land resources to accommodate more people and activities. Therefore, the land on the urban fringe, which is often rural, comes under pressure from urban activities and becomes more valuable. Land owners, sensing the increased demand for their land, will either sell to developers or continue farming amidst rising land rates.

There are still small pockets of old farming landscape in Melbourne — on the edge of Melbourne near Point Cook, figure 4.1 (a); an active vineyard on the banks of the Yarra River in Kew, figure 4.1 (b); and, in Pakenham, an example of rural blight. This land will shortly be developed for housing.

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 starts to 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.

Conflicts over *changing* land use

Rural and urban land uses can be incompatible in many ways. Intensive agriculture, such as market gardens using raised beds and polyhouses, often requires large amounts of irrigation water, sourced from natural surface drainage or from groundwater. When the land is used for housing, and there is less vegetation to cover and soak up surface moisture, the watertable has risen. This has brought salt into the groundwater, making farming less viable. The farming activity suffers 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, complaints and concerns are received by the farmer and the local council. Finally, the use of organic fertiliser, such as animal manure, has caused conflict because of the smell. 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. 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 use to rural land use in Pakenham.



▲ **Figure 4.2** (a) Rural and urban land use within close proximity in North Pakenham



▲ **Figure 4.2** (b) Urban development in North Pakenham along a farm boundary

Social problems for the emerging urban population also occur as a result of rapid and unplanned urban development, sometimes 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 such as schools, parks and recreational spaces, shopping and medical services and housing, as shown in figure 4.3 (a). Homes are designed to be more *sustainable* — many have solar panels, use recycled water and have low-use energy fittings throughout.



▲ **Figure 4.3** (a) Built community open space at Caroline Springs, western Melbourne



▲ **Figure 4.3** (b) Urban lots ready for sale in Pakenham. Note the proximity of new planned housing to the pre-existing rural land-use.

▶ ACTIVITIES

1. Contrast urban environments with rural environments and show your understanding with examples of land uses typical of each.
2. What is the difference between urban growth and urban development?
3. What are some of the issues associated with land use on the rural–urban fringe? Give examples from an area you may know of.
4. Why do you think the Victorian government has allowed ‘planned community developments’ to occur in so many of the growth areas of the state?

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 (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.

Cardinia Shire has two significant land *regions*. The north of Pakenham lies in 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 corner 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 which eventually give way to intertidal marshes and floodplains, also draining into Western Port Bay through the Koo-Wee-Rup swamp. This area supports a high number of market gardens which provide specialty herbs and vegetables to Melbourne.

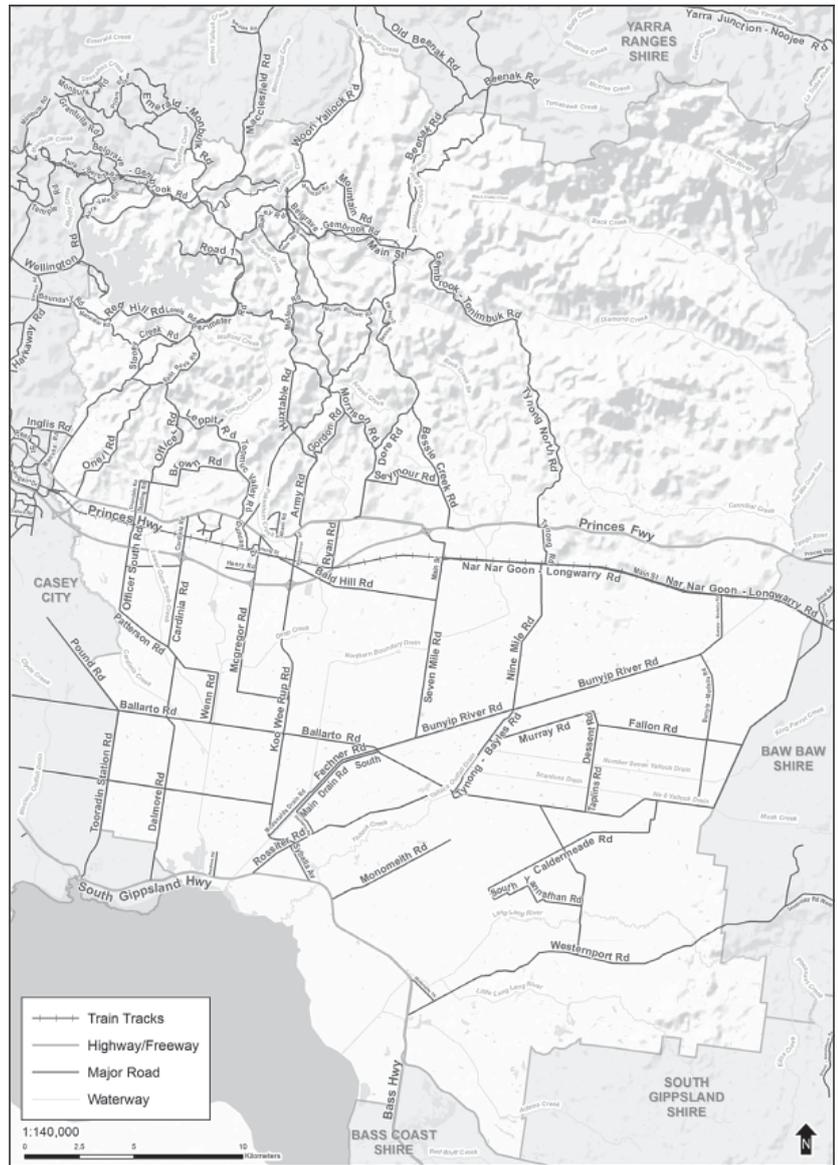
The area north of Pakenham was once covered in a broadleaf forest. Much of this remnant vegetation still exists within the Bunyip State Park. The first inhabitants of the area were the Kulin people who roamed the areas between Bunyip Creek, Cardinia Creek and the Koo-Wee-Rup swamp living off the land 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 pastoral activities. A quick tour of the area reveals that this land use largely pervades today. Small pockets of remnant vegetation with animals 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 are to survive into the future.

Why has Cardinia Shire changed?

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 90 566 people in 2015. This is expected to double to over 180 000 by 2036. 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 *Plan Melbourne*. 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 figure 4.5 overleaf).

The Cardinia Shire Council has adopted the strategies for development outlined in *Plan Melbourne* to Pakenham. Figure 4.6 (a) on the following page is a table showing projected population growth until 2036 for the individual precincts immediately surrounding Pakenham. Figure 4.6 (b) on page 45 is a map of these growth precincts.

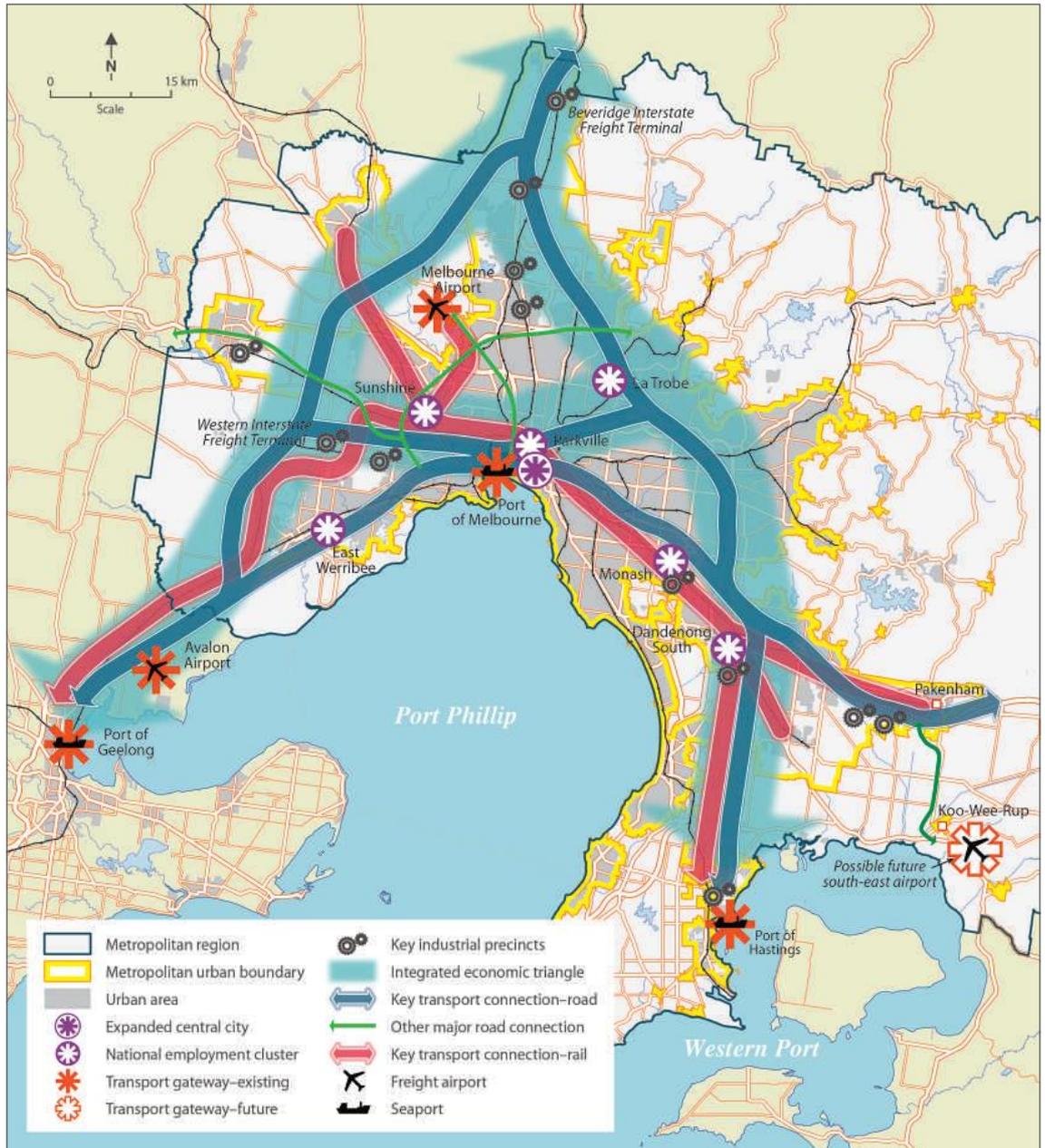


▲ Figure 4.4 Map of Cardinia Shire

▶ ACTIVITIES

1. Describe the *location* of Cardinia Shire.
2. Using evidence from figures 4.2 (a) and (b), describe the past land use of the Cardinia Shire.
3. Outline the ways in which the natural and human environments are interconnected in Cardinia Shire.
4. Describe the site and situation of Pakenham and Koo-Wee-Rup. In what ways do these environments differ?

▼ **Figure 4.5** *Plan Melbourne* shows the predicted corridors of urban growth for Melbourne until 2050.



▼ **Figure 4.6** (a) Population projections until 2036 for several precincts of Pakenham

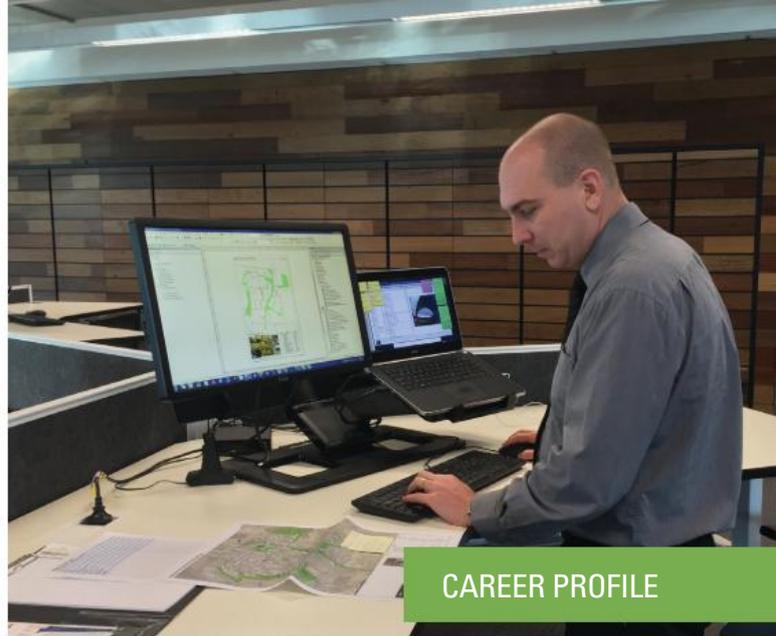
PRECINCT NAME	POPULATION 2015	POPULATION 2036	% CHANGE
Pakenham	32140	39963	24.34
Pakenham East	74	17780	23927.45
Cardinia Road	15683	27587	75.91
Officer	2286	33321	1357.53
Pakenham Balance North and South	1085	1190	9.73
Southern Rural	3174	15411	385.56
Beaconsfield Upper and District	4326	4554	5.27

▼ **Figure 4.6** (b) Population precincts within Pakenham



► ACTIVITIES

1. Map the 2015 population data. Figure 4.11 may help you.
2. Produce an overlay of this map using the 2036 data.
3. Describe the *distribution* of the urban growth precincts expected to undergo the greatest *change* for Pakenham.
4. Why do you think there is such variability in predicted *change* to the various precincts over the next few years?
5. What other rural areas of Melbourne are predicted to experience land use *change* under *Plan Melbourne*?



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.

Planning for land use *change*

Under *Plan Melbourne* and the Cardinia Shire's own planning scheme, every attempt is being made to ensure that population growth into 2036 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 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
- ▶ 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.



▲ **Figure 4.7** (a) Planned housing and community development west of Pakenham



▲ **Figure 4.7** (b) North Pakenham, allotments ready to be sold

▶ ACTIVITIES

1. What evidence can you see of rural land use in figures 4.7 (a) and (b)?
2. What evidence can you see of urban 'planning' in these new emerging suburbs?
3. Refer to figure 4.8 (a). Using figure 4.11 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.
4. Use the same map from question 3 above and produce an overlay map using tracing paper to show the *changes* to land use in 2014. Describe the *change* in rural land use in Pakenham from 2002 to 2014.
5. Are there any areas within Pakenham where it appears unplanned land use *change* has occurred? Suggest reasons.

Impacts of land use *change* in Pakenham

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

- ▶ development has proceeded quickly in the shire, often without community consultation
- ▶ council transactions in the sale of public land to developers have been perceived to have been undertaken without transparency
- ▶ some of the best and most viable food-growing farmland is being given over to urban development
- ▶ too many expansive tracts of native vegetation are being lost despite planned biodiversity corridors
- ▶ gradual loss of the rural environment and community is being felt by the residents concerned about the loss of these physical and social attributes
- ▶ 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.

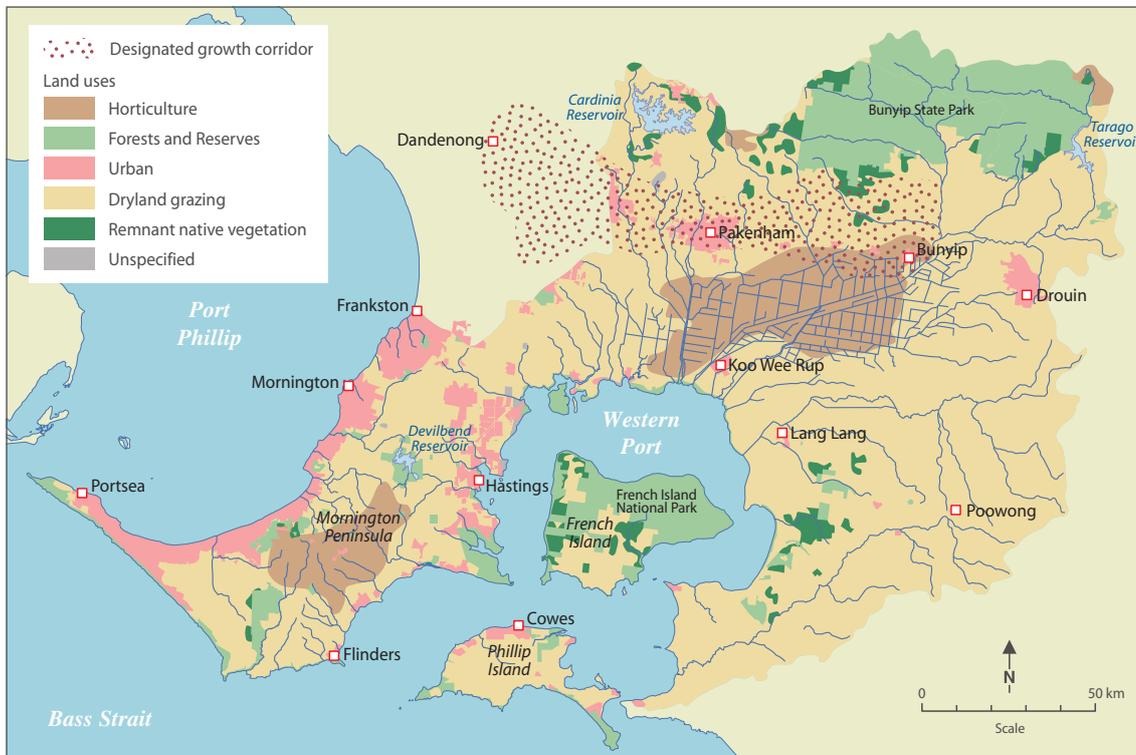
In 2003, concerned residents in Cardinia shire formed the Cardinia Ratepayers and Residents Association (CRRA) with the aim of improving communication between the community and the council.

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

Some of the concerns include:

- ▶ farmers have reported that rubbish from nearby 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
- ▶ 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
- ▶ some of Melbourne's best and most productive farmland has been lost forever to urban land use *change*.

Figure 4.9 shows the potential conflict between agricultural land, forests and reserves and urban growth, particularly in the designated urban growth corridor.



▲ **Figure 4.9** Land use in the Cardinia Shire including the horticultural region in the Koo-Wee-Rup area



▲ **Figure 4.8** (a) GIS map of Pakenham in 2002. The planned housing estates are shown by the grey lines.



▲ **Figure 4.8** (b) GIS map of Pakenham in 2014 showing the completed housing estates over the planned growth area

Case Study: Asparagus growing in Koo-Wee-Rup

The Koo-Wee-Rup swamp is characterised by peaty loam soils, deposited from the upland areas of Cardinia Shire, making it perfect for the growth of asparagus. This soil allows for deep roots to penetrate. Peat exists in only a small *region* 60 kilometres south-east of Melbourne (see figure 4.9 on page 47). The asparagus produced in Koo-Wee-Rup accounts for more than 93 per cent of Australia's total crop. Green asparagus is the dominant variety grown, with some white asparagus and a very limited amount of purple asparagus.

Continued urban growth and land use *change* means that many asparagus growers are finding it difficult to continue farming. The challenges faced include:

- ▶ incompatible road use between farm machinery and private vehicles
- ▶ loss of production due to rising salinity levels owing to increased run-off from urban areas (see figure 4.10 (b))
- ▶ fears of spray-drift from farming operations going into urban areas
- ▶ concerns by new residents over pumping of irrigation water in drought periods.

These concerns have forced many farmers to forego their water entitlement, resulting in a *change* of farming practices from asparagus to less thirsty but also less valuable crops. This has caused a decline in the income of farmers and is responsible for many having to sell their farms and relocate their operations.



▲ **Figure 4.10** (a) A mural representing the rural history of Koo-Wee-Rup



▲ **Figure 4.10** (b) New houses built in close proximity to farmland and drainage features on the northern border of Koo-Wee-Rup

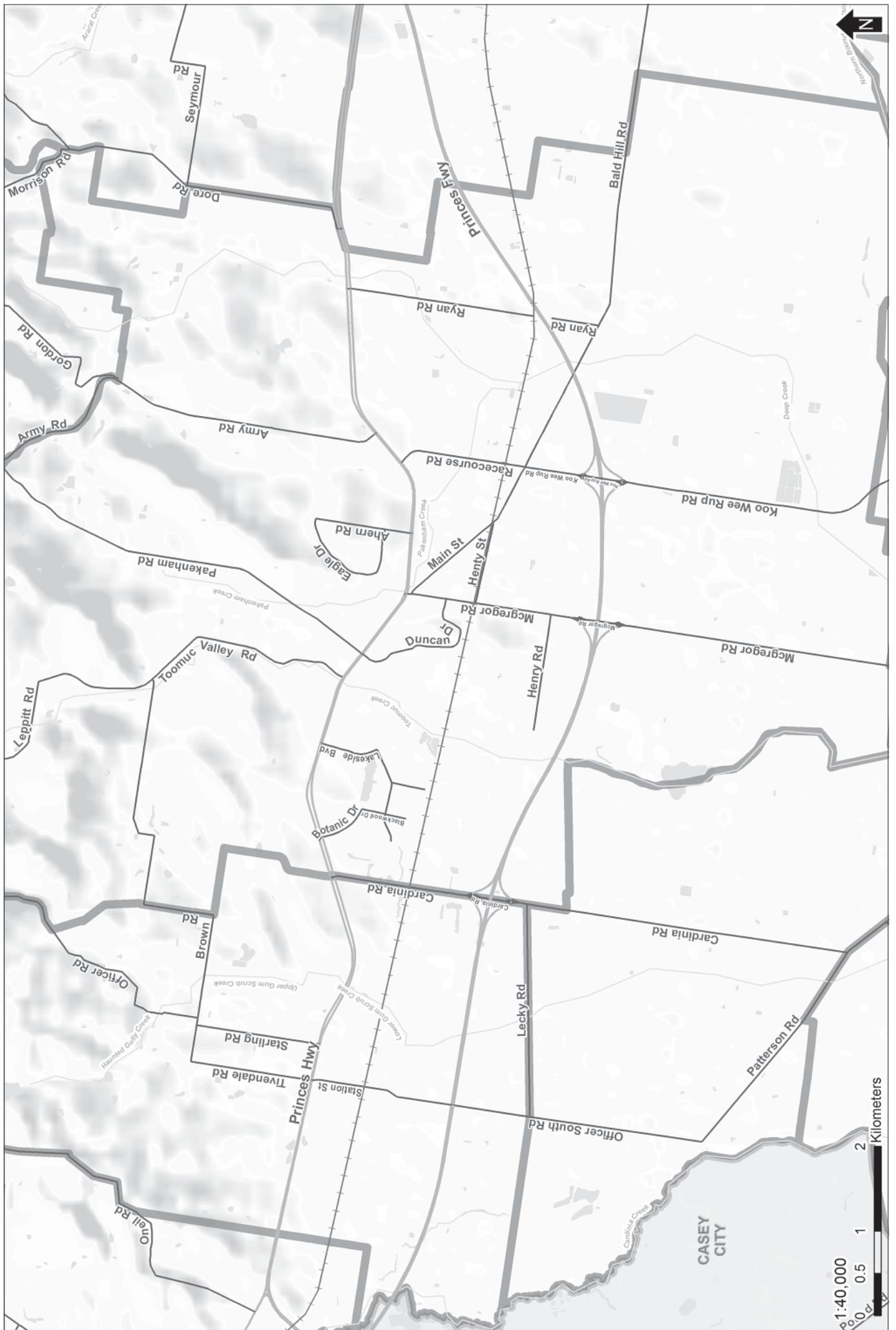
▶ ACTIVITIES

1. What are some of the environmental, social and economic challenges that towns such as Pakenham and Koo-Wee-Rup are facing?
2. Who is responsible for managing these challenges?
3. What suggestions can you make for managing rural land use *change* in the years ahead?
4. 'Minimising rural land use *change* would best be served by encouraging urban growth upwards not outwards.' This topic could be used for a formal debate or for classroom discussion.

Suggested fieldwork activities

Visit any of Melbourne's peripheral growth areas: for example, Koo-Wee-Rup, the Mornington Peninsula, Bacchus Marsh, Gisborne, Craigieburn, Greenvale, Werribee South or *regional* centres such as Waurn Ponds or Wandana Heights in Geelong, Mitchell Park or Yorkdale in Ballarat, Dennington Estate in Warrnambool or Traralgon East, Traralgon.

- ▶ Take photos of the old and new land uses. Obtain old maps and photos of an area and compare these with Google Earth images today.
- ▶ Interview the local historical society to discuss land-use *change*.
- ▶ Obtain the planning policies for future growth in your selected shire and evaluate these.
- ▶ Interview the local planner about policies related to rural *change* within the *region*.
- ▶ Survey long-term residents and farmers about their concerns regarding land use *change* and new residents to the area about their views of their suburb. What do they like/dislike about it? Are they happy with the transition taking place?



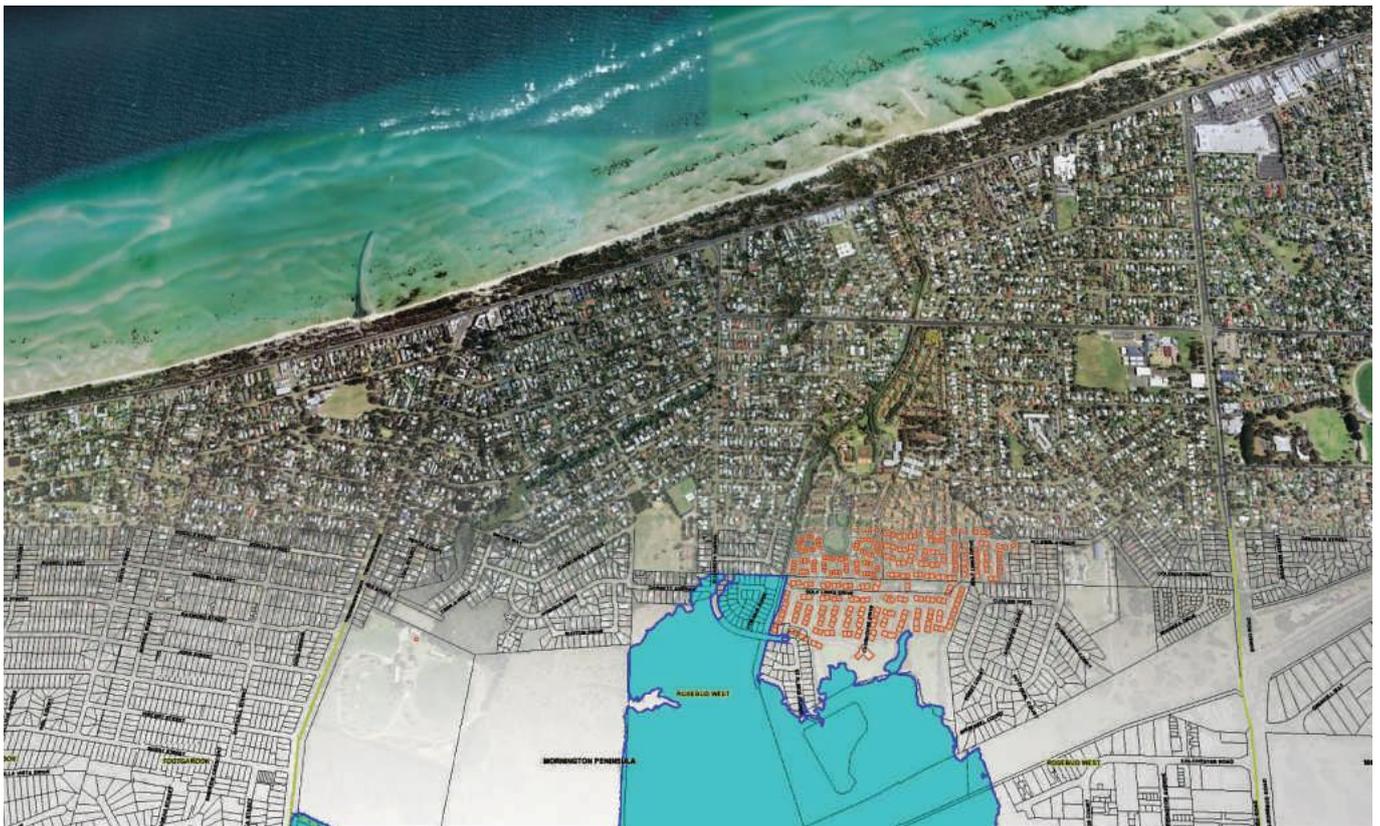
▲ Figure 4.11 Pakenham study area base map



5 Investigating land use change: fieldwork

The fieldwork investigation is an opportunity to formulate hypotheses, questions and research methods 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 natural environments and the shared experience with their peers. This central component of geographic investigation is explored in this chapter using two examples near Melbourne, one rural and one urban.

▼ **Figure 5.1** Aerial image of Rosebud West with a planning map overlay showing Tootgarook Swamp in close proximity to property parcels and holiday destinations. The existing wetlands area is indicated by the blue outline of land subject to inundation. Planning overlays are used to make decisions about the natural and built environments.



Land use *change* case study one: Tootgarook Swamp

In selecting a fieldwork site it is important to consider site access, history and where land use has recently occurred. Areas of interest to consider are bushland reserves or wetland reserves around the area such as Betty Clift, Gardens Road, Goolgowie, Old Cape Schanck Road, Peninsula Gardens, Sanctuary Park, Sylvan, Tootgarook Swamp, Tootgarook Wetlands and Waterfall Gully. Each student should be collecting unique evidence to address their central research question and support their analysis and evaluation.

Where is Tootgarook Swamp located?

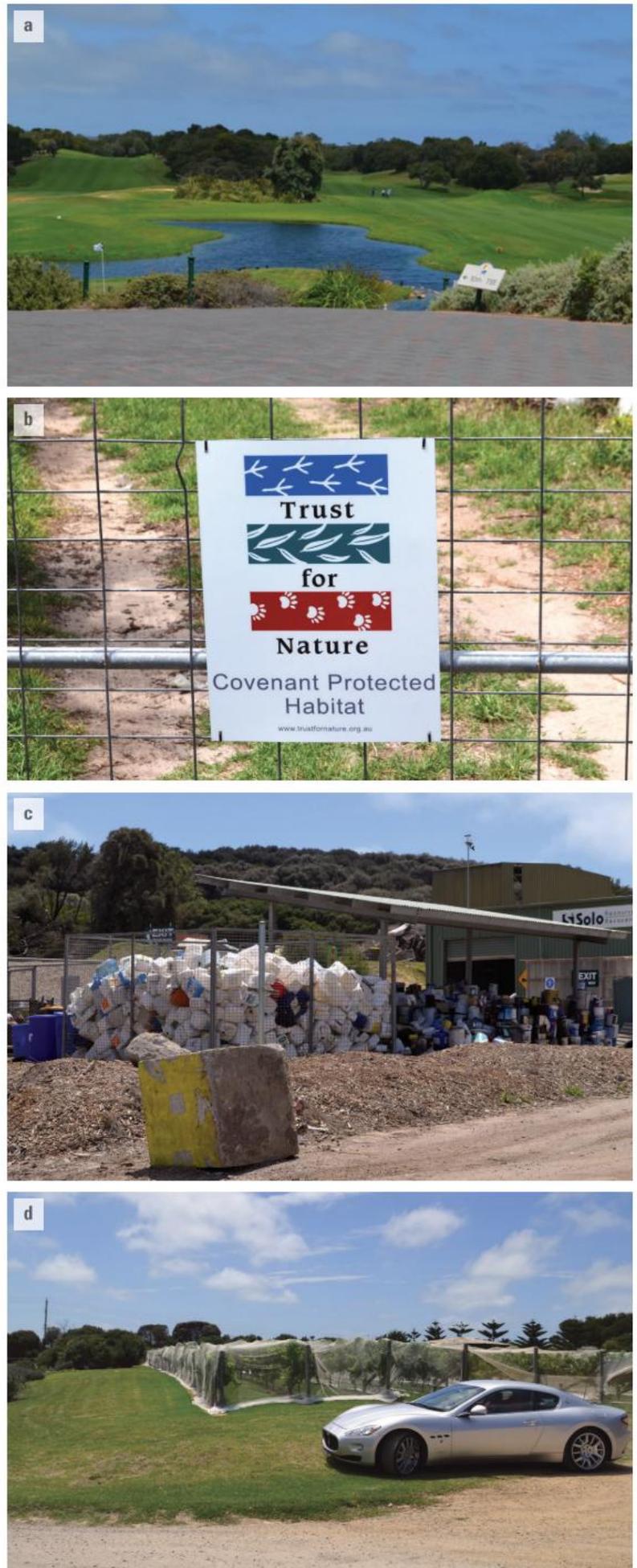
Tootgarook Swamp is a wetlands located on the Mornington Peninsula approximately 65 kilometres south of Melbourne's CBD. The Tootgarook wetlands formation is nearly 380 hectares and is considered an endangered bioregion of the Gippsland Plain. It is surrounded by the rural localities of Fingal and Boneo, and the suburbs of Tootgarook, Rosebud West and McCrae. This *region* of the southern Mornington Peninsula offers opportunities to collect and synthesise information on land use *change* and investigate the associated conflicts over land use. The wetlands historically stretched from Port Phillip to the ocean. Today, a further 25 per cent of the wetlands is the subject of property development applications.

Until the 1970s, Australian environmental policies encouraged the draining of wetlands to expand agricultural potential. Recent ecological and geographic investigations undertaken by interest groups, Department of Environment, Land, Water and Planning, and international conservation groups have indicated that the wetlands are more significant than previously thought, due to their rich biodiversity. As the case for protecting wetlands gains momentum, so too does the pressure to *change* the land to accommodate urban expansion, recreational activity and increased real estate values.

Historical background

The wetlands hold high cultural significance for the Bunurong (or Boonerwong) people of the Kulin Nation. There are many archaeological sites containing shell middens surrounding the wetlands. These are listed on government databases such as Planning Maps Online, 'Areas of Aboriginal Cultural Heritage Sensitivity Overlay'. When settlers arrived in the 1800s they sought to drain the swamp for cattle and cropping. By the 1920s the area was still subject to inundation due to the low slope of the land to the bay. The peat from the swamp was a high-value fertiliser, and for a time was harvested for export. A 1995 study found that that the wetlands were valuable for their floodwater storage ('Draft Chinaman Creek Catchment Strategy, Pat Condina & Associates, February 1997'). Subsequent investigations have determined that the existing remnant vegetation is rare and endangered, forming part of a larger chain of habitats for Victoria and for migratory birds that travel from the northern hemisphere to use wetlands as nesting sites.

▼ **Figure 5.2** Competing demands on land use in the Tootgarook swamp area include (a) recreation, (b) conservation, (c) waste disposal and (d) agriculture



Currently, the condition of the wetlands is threatened by changing land uses. Mornington Shire maintains a central tip next to the wetland; there are several golf courses; and vineyards abut conservation areas. Currently, 77 hectares are awaiting permit applications for development.

Evidence of land use change

The suburb of Tootgarook experienced the highest increase in median house prices on the Mornington Peninsula between 2013 and 2014. The extension of the Mornington Peninsula Freeway all the way to the Tootgarook Swamp area improves access to the popular beach destinations on the peninsula. Although some developments in the endangered bioregion have been rejected by the shire, it continues to receive development applications, as shown in figure 5.3.

Other areas of activity include considerable conservation efforts from organisations such as Save Tootgarook Swamp Incorporated and The Southern Peninsula Indigenous Flora and Fauna Association (SPIFFA). Work conducted by ecologists from these organisations has resulted in the shire creating a

formal Tootgarook Wetlands Working Party to seek advice on the nomination of the wetlands for Ramsar listing and protection. The Port Phillip and Western Port Catchment Management Authority (PPWPCMA) supports the listing of the wetlands as a direct result of the conservation efforts.

Tootgarook Swamp is a perennial home of many bird species listed under international migratory bird agreements with Japan (JAMBA), China (CAMBA) and Republic of Korea (ROKAMBA). The presence of these birds strengthens the nomination of the site for Ramsar listing.

The wetlands are at a critical junction of land use (see figure 5.4). Increasing pressure for land development is driven by the scarcity of land and growing population of Melbourne. Simultaneously the value of the endangered remnant habitat is increasingly significant at local, *regional* and international *scales*. As a carbon sink, the peat mire captures more carbon than a mature forest. The economic valuing of ecosystem services is an area of academic research which is contested and not well understood.



▲ **Figure 5.3** Land sales and development applications in the wetlands are driven by increases in the market value of land.

The fieldwork investigation

Geography is a unique discipline whereby students have the opportunity not just to collect information but to create knowledge around land use *change*. The fieldwork investigates how *change* in land uses is occurring at the local *scale* and what *processes* are involved in making *change*.

Defining the topic and the research question

The definition of the topic can be developed before commencing the fieldwork data collection. After conducting desktop research, develop a research question that answers your hypothesis. The research question may be supported by further sub-questions which aim to answer the hypothesis. In this example, a primary research question might be:

'Which land uses are the most threatening to the continuity of the Tootgarook wetlands habitat?'

Supporting questions might be:

'What evidence is there of changing land uses around the wetlands?'

'What policies can be implemented to manage the growth around the wetlands?'

'How have stakeholders been active in protecting the natural resource?'

When defining the topic, research questions and a hypothesis, it is important to outline the geographic context of the area being studied by incorporating many of the key geographical concepts: *change, distance, distribution, movement, place, process, region, scale, spatial association, sustainability*.

Before carrying out fieldwork, a hypothesis needs to be developed. For example, 'The current land use *changes* around the Tootgarook wetlands may contribute to further habitat collapse and species loss.' The fieldwork data collection will, hopefully, answer the research questions regarding where the land use *change* is taking place and why. The quality of work starts with the initial research and the applicability of the research questions to the site.

Primary sources and techniques used to collect data

Primary data is information that has been collected first hand in the field. In gathering the data there are many sources of information that should be considered. Primary data comes in the form of quantitative and qualitative data. Both forms of data are equally valuable in understanding complex issues in Geography.

Quantitative primary data consists of counts, measurements and estimates. Quantitative data should be presented in various graphic representations, to support the themes and respond to the research question — for example, as graphs, tables and timelines.

Qualitative data may include interviews and surveys which should be recorded and transcribed. The re-reading of this data can provide recurring themes for the final report. Photography, GIS marking and field sketching also make up primary qualitative data which can further support recurring themes in the analysis.

Secondary sources

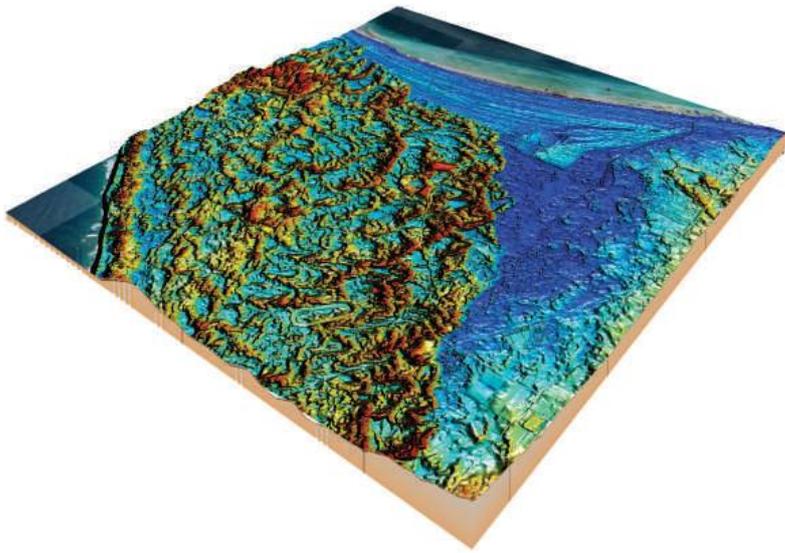
Secondary data can be collected from the Australian Bureau of Statistics (ABS), National Library of Australia, developer groups, council minutes, news archives, documentaries and grey literature such as technical reports, statistical reports and market research reports. Academic literature should also be consulted, with the aim to use as high a quality of research data as possible. Access to multiple sources of secondary data offers exposure to conventions and themes in research and writing practices. Excellent sources of secondary data include: Department of Environment, Land, Water and Planning (DELWP), interactive maps, Trove, the National Library of Australia and conservation groups like SPIFFA and Save Tootgarook Swamp.



▲ **Figure 5.4** Aerial photograph looking west over Tootgarook Swamp under 3.2 metres of flood



▲ **Figure 5.5** Watercolour of the southern Mornington Peninsula from Arthurs Seat, by A.C. Cooke, c. 1890



▲ **Figure 5.6** This block diagram of Tootgarook Swamp was constructed using Google Earth elevation profiles, Digital Elevation Model imagery and Adobe software.

This topic investigates land use *change*. Data collected should indicate how geographic concepts like *process*, *scale* and *region* have affected the nature of land uses. Using historical imagery or maps can illustrate this. A comparison of figure 5.5 with figure 5.4 shows how development has *changed* the land.

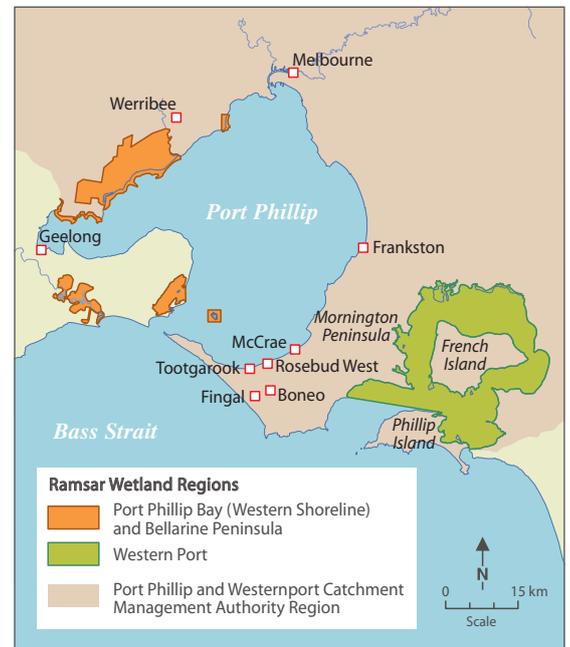
Presentation of *processed* data and information

Once desktop research and fieldwork research have been carried out, the data needs to be categorised to show emerging themes. Photographs, maps and other visual imagery need to have conventional attributes such as the border, outline, legend, title, *scale*, source, neatness and accuracy (BOLTSSNA), and clear captions. To be relevant, any figure or table used in a report needs to be mentioned in the text.

Web and desktop applications like Google Earth, Avenza, Planning Maps Online or ArcGIS should be used to graphically represent the data collected. Original data can be layered into these applications as needed; for example, Google Maps online can import your CSV file addresses into place markers automatically. More advanced presentations of work will integrate multiple applications and software, as shown in figure 5.6.

Analysing, concluding and evaluating

The research questions should be addressed and answered throughout each section. When the themes are identified in the data they will guide the analysis and conclusion. Referring to patterns of *distribution*, *movement*, *processes* and *scale* associated with the issue will make the analysis meaningful and relevant. The key geographical concepts (listed earlier in chapter 1) should be emphasised in the analysis and conclusion. Addressing each concept in the research question and data will improve the quality of the report.



▲ **Figure 5.7** Map of Port Phillip Western Port Catchment Management Authority (PPWCMA) Ramsar Wetlands.

By including findings from secondary data collection with the primary data, a more complete report will emerge. In the example of Tootgarook Swamp, an examination of the regional context of nearby Ramsar sites on the western shore of Port Phillip and the Bellarine Peninsula, and all of Western Port shows gaps in land protection on the peninsula. (This can be seen in figure 5.7.) This is further evidence that *movement*, *processes* and *region* may play a significant role in the function of the Tootgarook wetlands area.

The evaluation stage is a chance to discuss errors, negative results or modifications that are required to improve the research. This reflection is an analysis of the procedures used and the *process* of application of key skills and knowledge.

Referencing

The most important component of the research is the referencing, without which the work cannot be considered original. Although it comes last in the report, it needs to be conducted at each step in the research process. The social sciences generally use the Harvard system where the key elements are listed in order of Author, Date, Title and Publisher. In-text citations indicate the source of data and text. Without in-text citations the work becomes an example of plagiarism. Referencing your sources is essential as it serves as evidence of the thoroughness of your investigation and is an archive to support other researchers. This example uses a previous GTAV textbook:

End of text citation: Pask, R. (ed.), 2006, *New Perspectives: VCE Geography Units 1–4*, GTAV, Melbourne, pp. 250–1.

In-text citation: (Pask 2006).

▶ ACTIVITIES

1. Referring to figure 5.2, discuss the four images and how the various land uses come into conflict. Suggest what forces drive the *change* that they indicate.
2. Generate a hypothesis and research question you could apply to a local fieldwork analysis of your own choosing.
3. Create a database of ten online sources of authentic secondary data for use in your fieldwork research. (Suggestion: try Trove and Google Scholar for starters.)
4. After creating a primary research question on land use *change*, generate five survey questions to ask people face-to-face or over the phone which may help answer your research question.
5. Create a diagram of the relevant stakeholders in an area experiencing land use *change*.
6. Write a template for a brief email or letter explaining your research topic and requesting a small amount of information. Seek out experts and stakeholders relevant to your topic. Obtain their email addresses so you can send them your letter. (This information can be referenced in-text as personal communication.)
7. Create elevation profiles using the Google Earth 'Path tool'. This elevation profile can be used to determine slope and *distance*, or as a base for a transect or a block diagram.
8. Locate the relevant Planning Scheme for your Local Government Authority. Search the Municipal Strategic Statement from Clause 20 onward of the Local Planning Provisions. Identify policies, objectives and strategies that relate to your land use *change* investigation and discuss how these relate to your themes.
9. Locate historical imagery from National Library of Australia archives of your fieldwork area. Compare any photographs, illustrations or paintings you discover with imagery of the current area. Write a statement on the land use *change* over time that has occurred.
10. Use the Department of Environment, Land, Water and Planning's interactive map to create original maps of your area's EVCs (Ecological Vegetation Classes), zones and overlays. Analyse these maps and data to develop descriptions and explanations.
11. Explain and assess positive and negative impacts of land use *changes* on the Tootgarook Swamp area and the surrounding *region*.

Adam Rossimel Town planner

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 geographical information systems (GIS).

CAREER PROFILE



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.

Land use *change* case study two: Fishermans Bend Urban Renewal Area

Background

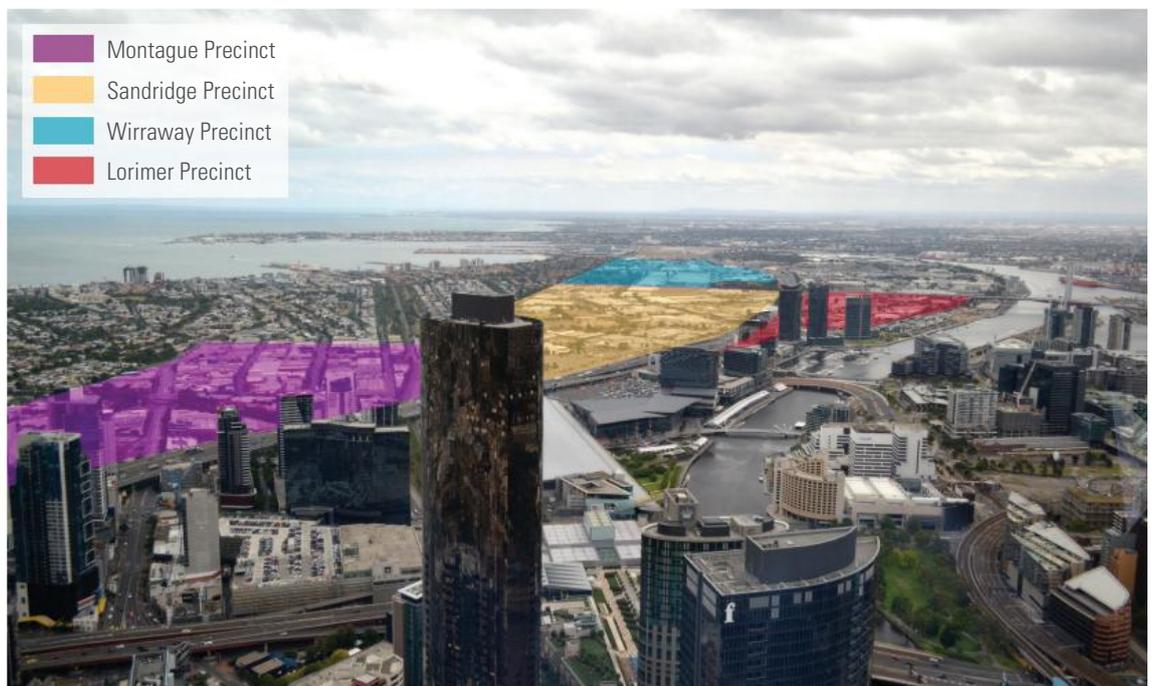
The Yarra River holds great significance for the Wurrundjeri tribe of the Kulin Nation, believed to be formed by Bunjil the creator spirit. The river historically provided Melbourne with rich soils and fresh water. The mouth of the Yarra at Fishermans Bend was an early settlement area for dock workers 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 for the more noxious trades such as abattoirs, boiling-down works, bone

mills, manure 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). A majority of the land is within the City of Port Phillip, while the Lorimer Precinct is within the City of Melbourne.



▲ **Figure 5.8** The precinct plan for the Fishermans Bend Urban Renewal Area (FBURA)



▲ **Figure 5.9** The view of the FBURA precincts from the Eureka Skydeck



▲ **Figure 5.10** Land use *change* over time: (a) L. Buvelot painting 'Huts on the South Wharf', c. 1860; (b) A. Tucker 'Fishermans Bend' gelatine print c. 1939; (c) Munro Street, Sandridge Precinct, 2015; (d) Thistlewaite Street, Montague Precinct, 2015.

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 current official 2015 population of 200 people is set to increase to at least 80 000 during the 50-year project.

Evidence of land use *change*

The urban renewal plan is the vision of former Planning Minister Matthew Guy who imagined Melbourne as a 'Manhattan-style' metropolis. In July 2012, Minister Guy rezoned 240 hectares of Fishermans Bend to 'Capital City Zone' via a Ministerial Amendment to pave the way for the development. The new Capital City Zone (CCZ) has very relaxed height restrictions and has no permit requirements for a number of land uses, such as new residences or restaurants. 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 values. This value uplift will be captured through 'development contributions' which will be used to fund infrastructure for the new community, including sporting facilities, libraries, street upgrades, public transport, new parks and service infrastructure upgrades.

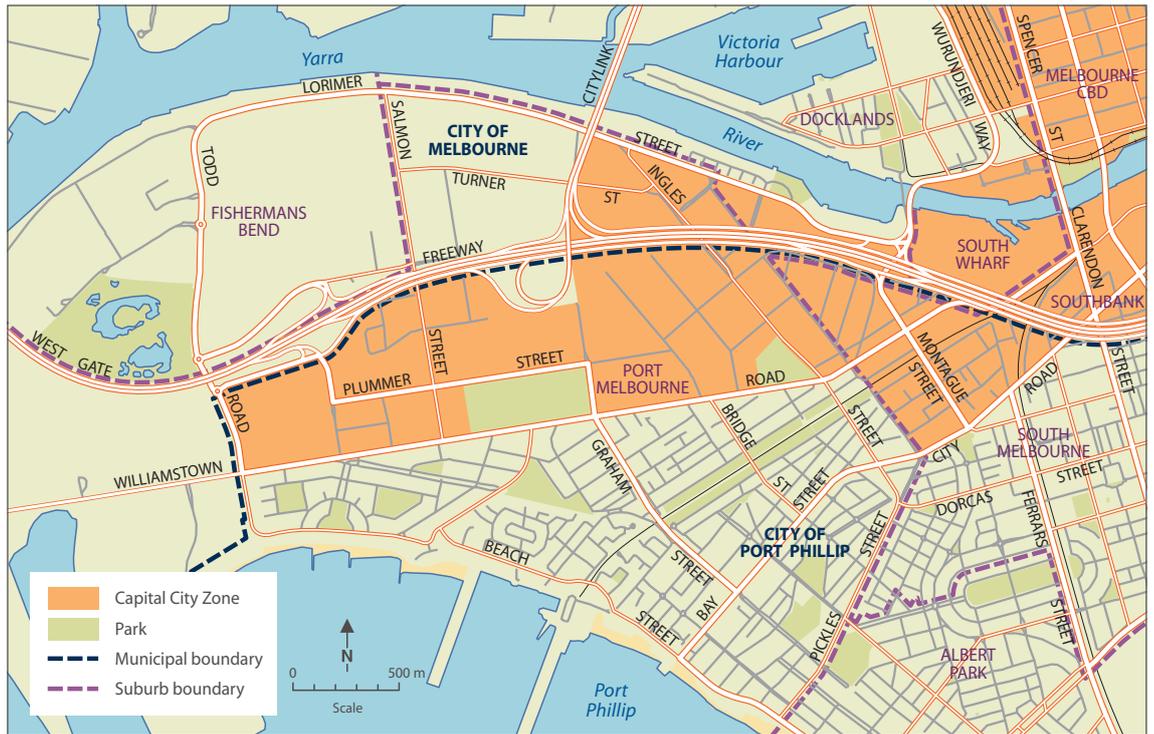
In 2013 the state government released the documents 'Fishermans Bend Draft Vision' and 'Interim Design Guidelines'. The documents outlined the plan for the urban renewal project, with the completion date set for 2050. In July 2014, the 'Fishermans Bend Strategic Framework Plan' was completed, using feedback from the community about the Draft Vision, as well as technical information gathered from many studies commissioned for the project. Many agencies were involved in the development of this plan including the cities of Port Phillip and Melbourne, Places Victoria, Metropolitan Planning Authority (MPA), and State Government departments. These stakeholders will continue to be involved in implementing the Fishermans Bend Strategic Framework Plan, with differing levels of investment and authority. For example, the councils will be responsible for assessing some types of planning permit applications, while the Minister for Planning will be the 'responsible authority' for other types of planning permit applications (usually bigger buildings or developments with high values). These thresholds are set out in the CCZ schedule.

In order to make the new neighbourhoods liveable, investment in new roads, public transport, schools, affordable housing, parks and shops is necessary. One criticism levied has been that infrastructure was not adequately addressed in the master planning phase. Land use planning has also 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. The presence of Coode Island silt and Fishermans Bend silt in the ground also make constructing solid foundations for buildings an expensive challenge. Changes in government have also affected the plan: the new state government (elected in November 2014) has removed the Melbourne Rail Link shown in the Fishermans Bend Strategic Framework Plan as running through Fishermans Bend, and is now pursuing the Metro Rail project from Arden to South Yarra.

The government is continuing the planning work for Fishermans Bend. The Employment Precinct was included in the Urban Renewal Area in April 2015, expanding Fishermans Bend to 455 hectares in total. The next phase is to introduce detailed Neighborhood Precinct Plans for each of the precincts, and devise innovative planning solutions to the challenges of the project. The dramatic land use *changes* planned in the Fishermans Bend Area will play a significant role in managing Melbourne's future population growth.

▼ **Figure 5.11** The new CCZ zone extension into Fishermans Bend



▼ **Figure 5.12** Still from the 3D fly-through of the Metropolitan Planning Authority's vision for Fishermans Bend showing the vast array of possible high rise residences



The fieldwork investigation

Conducting urban fieldwork research is different from research carried out in natural 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 be the subject of inquiry at different *scales* in order to understand land use *change*. Due to the expanded role of economics in urban areas, patterns of *distribution*, *spatial association* and *processes* tied to the economy can also be included in a fieldwork investigation.

Defining the topic and the research question

Demand creates competition for resources. In this case it is land values versus land uses. In defining the topic one needs to do preliminary research, and formulate a hypothesis and a research question.

An example of a hypothesis for the FBURA is: 'Urban renewal of Fishermans Bend was inevitable as it is located a short *distance* to the city.' The research question and supporting questions should take into account the multiple stakeholders and groups vying for control of the land. Questioning the social, economic and environmental factors involved in land use *change* is a comprehensive initial approach to this research topic.

Examples of research questions include:

'To what degree was the urban renewal plan driven by local interests?'

'Which areas of Fishermans Bend will be most desirable to residents?'

'Did locals anticipate a major renewal project of this *scale*?'

Secondary sources of information

After establishing the hypothesis and research question, 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 direct your primary data collection. Keeping notes and diagrams of different 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 can be 'retaken' if you can identify the location. 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 steer (or inform) the primary data collection. For example, if you were investigating the effect of high-rise buildings on the local urban character, a map such as figure 5.13 showing proposed height limits (a secondary source) would provide the opportunity to conduct interviews with employees of local businesses about the effect high-rise buildings will have on them. Such interviews are primary data.

▼ **Figure 5.13** The discretionary heights of the planned developments from the Melbourne Planning Authority



Primary sources and techniques used to collect data

The primary data collected for land use *change* includes face-to-face interviews to gauge the opinions of shopkeepers or tradespeople, residents, workers and other users of the area, photographic evidence of *change*, mapping of pedestrian access points toward the CBD and traffic counting. Observations of behaviours, *movement* patterns, and *distribution* of amenities such as shops, community facilities and open space can yield valuable results to help build the response to the research questions.

Personal communication with experts and government officials can also provide a valuable source of information; it can be collected while in the field or at your desk. Researchers are encouraged to seek expert opinions and advice at each step of the research *process*, especially during data collection.

Collecting and presenting the data

All data collected should relate to the research question and hypothesis. During the collection phase effort should be made to collect information with peers, address people on the street and spend enough time in an area to witness patterns of *movement* and *processes*.

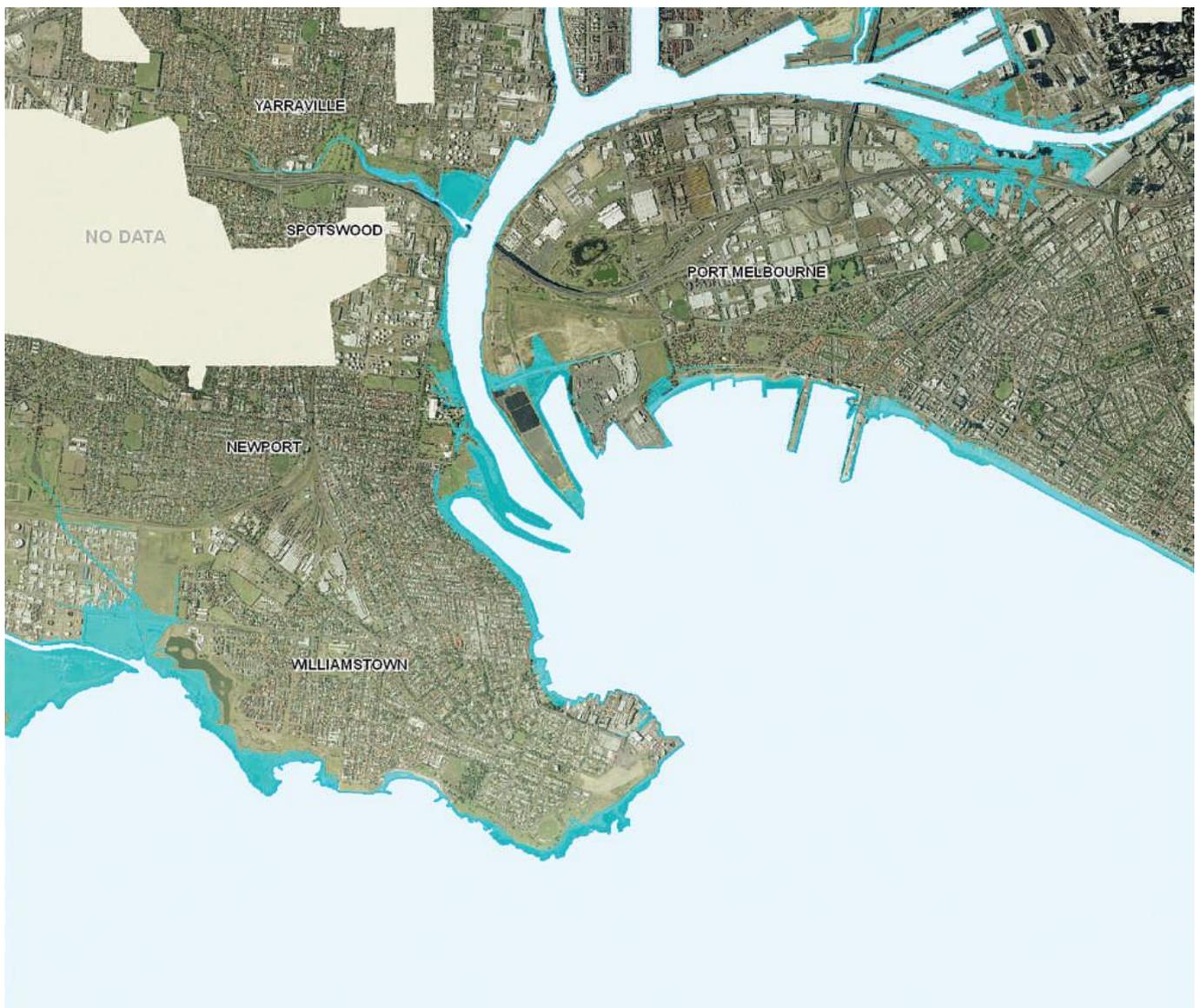
The aim is to identify the geographical characteristics of land use *changes* and to explore these in the context of the surrounding *region*. The nature of primary research often turns up sensitive information. The ethical response is to keep sensitive information in confidence and record data accurately.

During the data presentation phase, interpretation of maps, graphs and models is necessary for a coherent analysis. Use multiple sources of information and technologies to draw relationships between key features and patterns in the processed data. This will enhance the quality of the work and make it easier to communicate to your audience.

Analysing, concluding and evaluating

As the word length is limited to 2000 words, the analysis and conclusion should be succinct and thought provoking. The data and captions should reflect the hypothesis and central research question. The analysis directly addresses the research question by applying data collected and multiple geographical concepts to illustrate your point from many angles. 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

▼ **Figure 5.14** Sea level rise inundation mapping showing the Lorimer and Montague precincts under a 1.1-metre flood



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 5.14).

Although land values are positively affected by development plans, they are negatively affected by the risk of flooding. The conclusion should address whether the data helped to answer the research question or not and what future land use strategies can be used in your study area.

Referencing

Most educators agree that the style of reference is not important, as long as all the references are formatted the same. In the social sciences, the standard format is Author, Date, Title, Publisher (see page 56). Much of the data that is collected is from online sources.

PDFs and academic journal articles can be referenced like hard texts but information from websites, archives and newspapers needs to adhere to the same conventions as other web resources, citing the author, title, date accessed and the URL. Personal communications do not need to be referenced at the end of the report, but need to be referenced in-text. Keeping track of your references and creating a comprehensive bibliography before you begin writing can save time in the last stages of the report process.

▶ 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. Download the strategic frameworks and precinct plans for the FBURA. Compare the discussions of *sustainability* with the current 'Plan Melbourne' discussion of *sustainability*.
3. Create an image overlay in Google Earth using a historic map of Fishermans Bend. Turn the transparency down to accurately superimpose the image and compare the *changes* in land uses. Can you identify land uses from maps and aerial images alone?
4. Create an online photo hosting account, upload your own photos from the fieldwork, create *place* markers in Google Earth where the images were taken, and add the photo's URL HTML to the dialogue window of the *place* marker. Export the *place* marker and email it to a classmate or teacher. The resulting file will open the photograph plus any additional written content you added when it is opened.
5. Write three questions regarding land use you could ask residents, retailers or employees in the Lorimer District Precinct. Be sure to create open-ended questions and use language that is objective and non-leading.
6. Use Profile ID to view ABS statistics on the City of Port Phillip. What trends does the data show?
7. Go to the Eureka Skydeck to collect primary evidence of land use *change* taking place. Where are the cranes operating?
8. Write a set of research questions that address geographic concepts through social, economic and cultural investigation; for example, how does *distance* from the city affect property values? How has the significance of Fishermans Bend as a *place changed* to those who work there?
9. Design a master plan for the same area of Fishermans Bend. How would you ensure it was fit for living, *sustainable* but also able to accommodate 80 000 people?
10. Write an opinion response to the statement 'If Melbourne becomes a 24-hour metropolis it will attract more investment'.

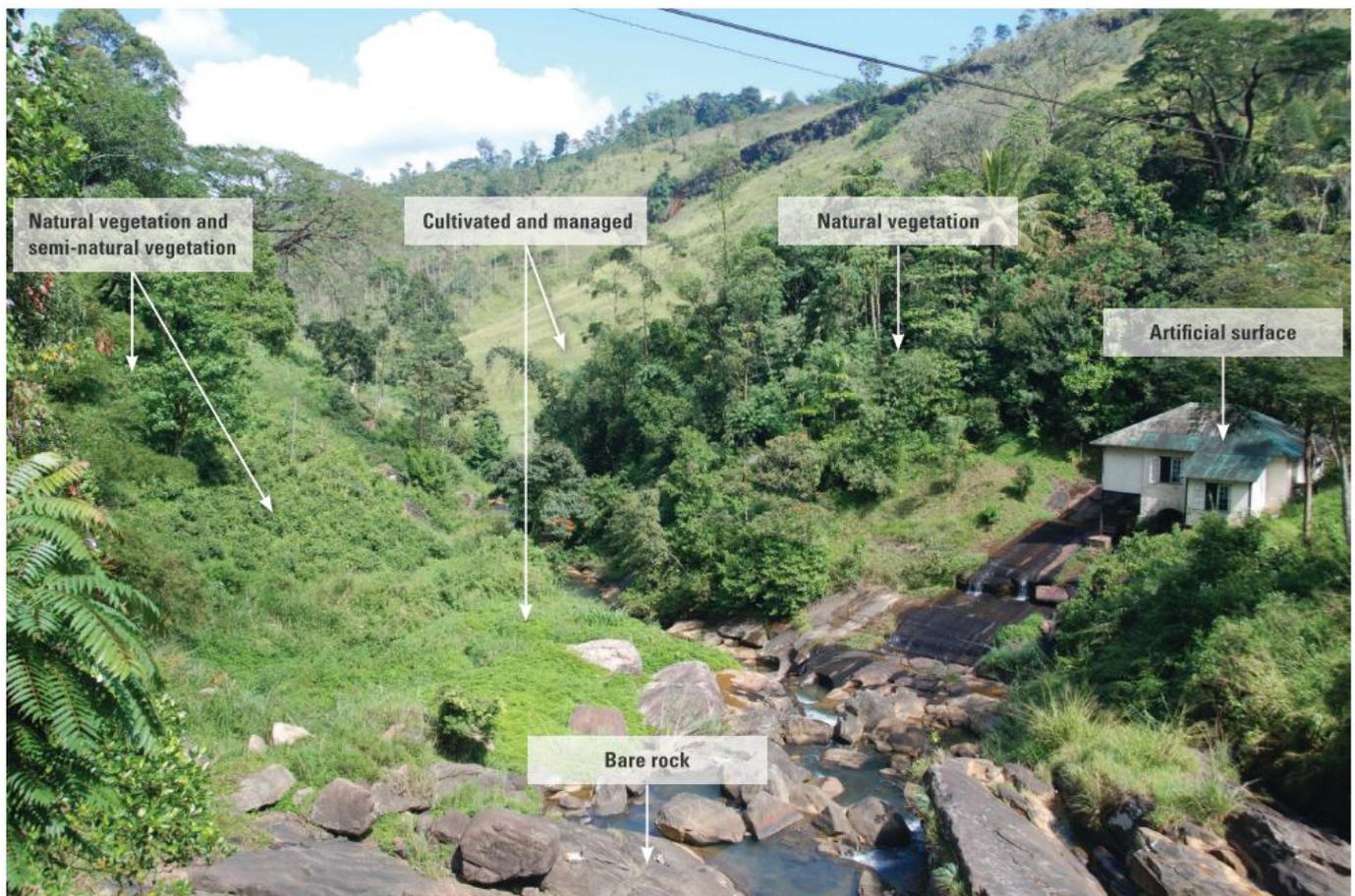
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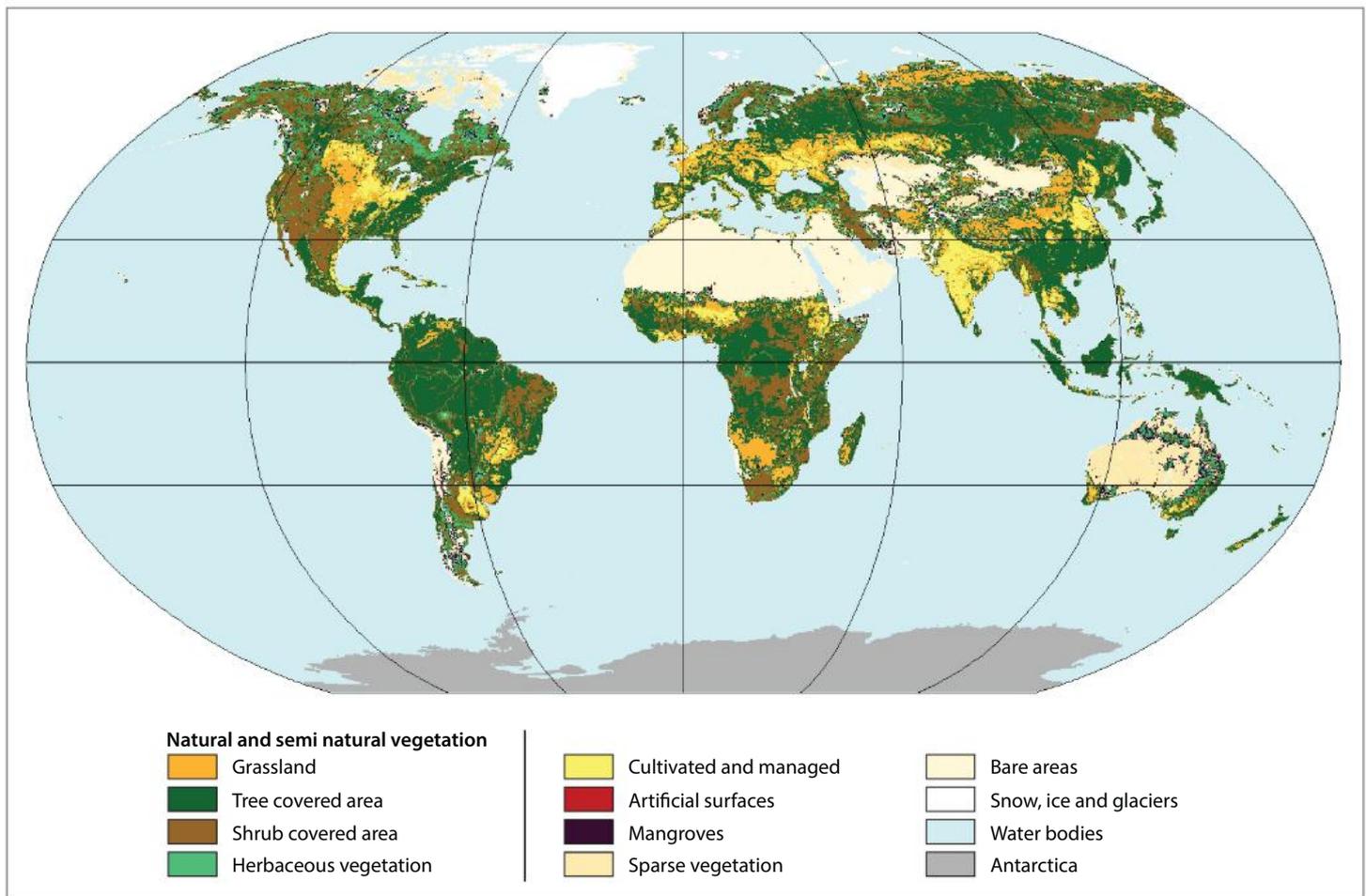
Land cover change: an overview

Geographers study land cover *change* for many reasons. Land cover *change*:

- ▶ provides a global context for *changes* that can help explain local *changes* in land cover and land use
- ▶ requires an inventory of components such as water, vegetation and built-up areas that form a useful way of describing the diverse landscapes such as tropical rainforests, grasslands and wetlands
- ▶ monitors vegetation cover and subsequently key environmental issues such as carbon emissions, and the extent and quality of native species habitats
- ▶ enables 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*
- ▶ helps 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*.

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





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

Defining land cover

There are various definitions of land cover. Most have been developed by government authorities in different countries for different 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 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.

Land cover and land use

There is a strong connection 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 surfaces. 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 latter uses would see the activities classify the forest as land use.
- ▶ A natural lake is land cover but when its use for water sports or for irrigation is discussed, it is land use.



▲ **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 Burma

Distribution of land cover

FAO's world map of land cover (see figure 6.2) shows a number of broad categories. At this *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), and the vegetation category of mangroves at a global *scale*.

FAO divided land cover into eight 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 farm land. 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 and skill to maintain its productive capacity.

Cultivated and managed land cover includes a wide range of land uses including market gardens, wheat farms and 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, 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. 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 Burma 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.

In figure 6.2 this category is shown by cropland 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 *spatial association* 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 develop in sheltered estuaries and bays, lagoons and on tidal mud flats. 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 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 65 wetlands covering 83 000 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 *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 form part of this category of land cover.

6. Bare areas

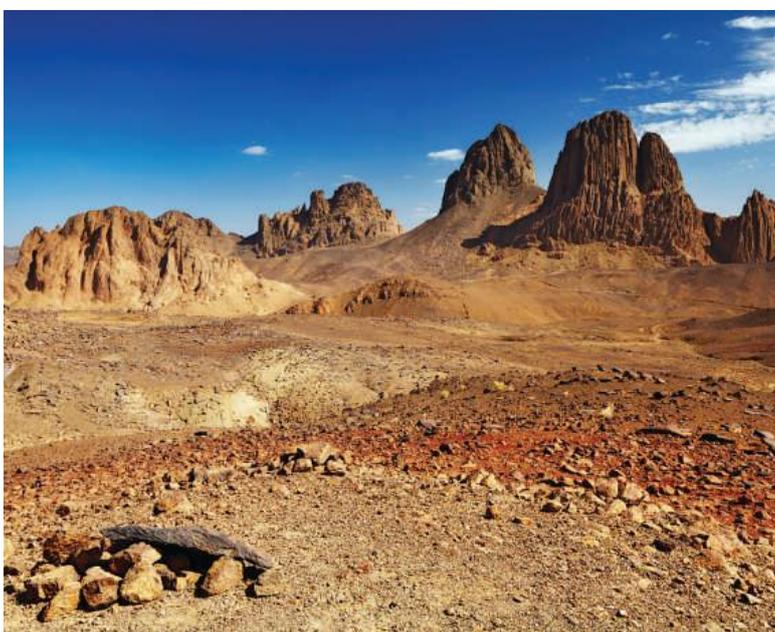
Areas with less than four per cent vegetation cover are considered by FAO to have a bare land cover. Examples would include deserts such as the Sahara in North Africa (see figure 6.8), the Gobi of northern Asia, the Simpson of Australia and the Atacama of South America. Other bare areas include salt pans, 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 this category.



▲ Figure 6.8 The Hogar 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 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 about 550 kilometres in length — the equivalent *distance* of 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 land cover 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 and Lake Victoria 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.

▶ ACTIVITIES

- 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
- Identify two inputs of human effort and skill required to manage the land cover in figure 6.3.
- 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.
- 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.
 - How different is Australia's proportion to that of one other continent?
- 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'.
 - Research the way mangroves manage to survive when they are regularly flooded with salty water from incoming tides.
 - 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?
 - Where are Australia's most extensive artificial surfaces?
 - If a waste dump is revegetated by a local authority, in which category of land cover would you place it?
 - Outline the environmental conditions contributing to or creating a bare land cover, such as that in figure 6.8.
 - Name three specific locations in Australia that would fit into this category of land cover.
 - Refer to figure 6.2. Which *regions* of the world have significant areas of this type of land cover?
 - Compare the *distribution* of this land cover within Australia to that of Africa.
 - Identify at least one location in Victoria that is an example of an artificial water body.
 - When and why would you find an example of an artificial area of snow in Victoria?
 - Compare the *distribution* pattern of this land cover between the northern and southern hemispheres.

Land cover changes

The Earth's land cover has *changed* significantly over many thousands of years. 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 are (a) climate *change*, (b) geophysical *processes*, (c) plant succession and (d) fires and pests.

a. Climate change

Figure 6.11 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 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 were already 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, 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 world's last glacial period peaked between 17 000 and 21 000 years ago. Global temperatures were approximately 4 °C cooler than today. Ice held so much water as solids that sea levels were up to 125 metres lower than at present. Land bridges between landmasses (can you find them in figure 6.11?) enabled migration of people into North America from Asia. This period saw Australian desert and semi-desert areas expand as rainfall decreased.

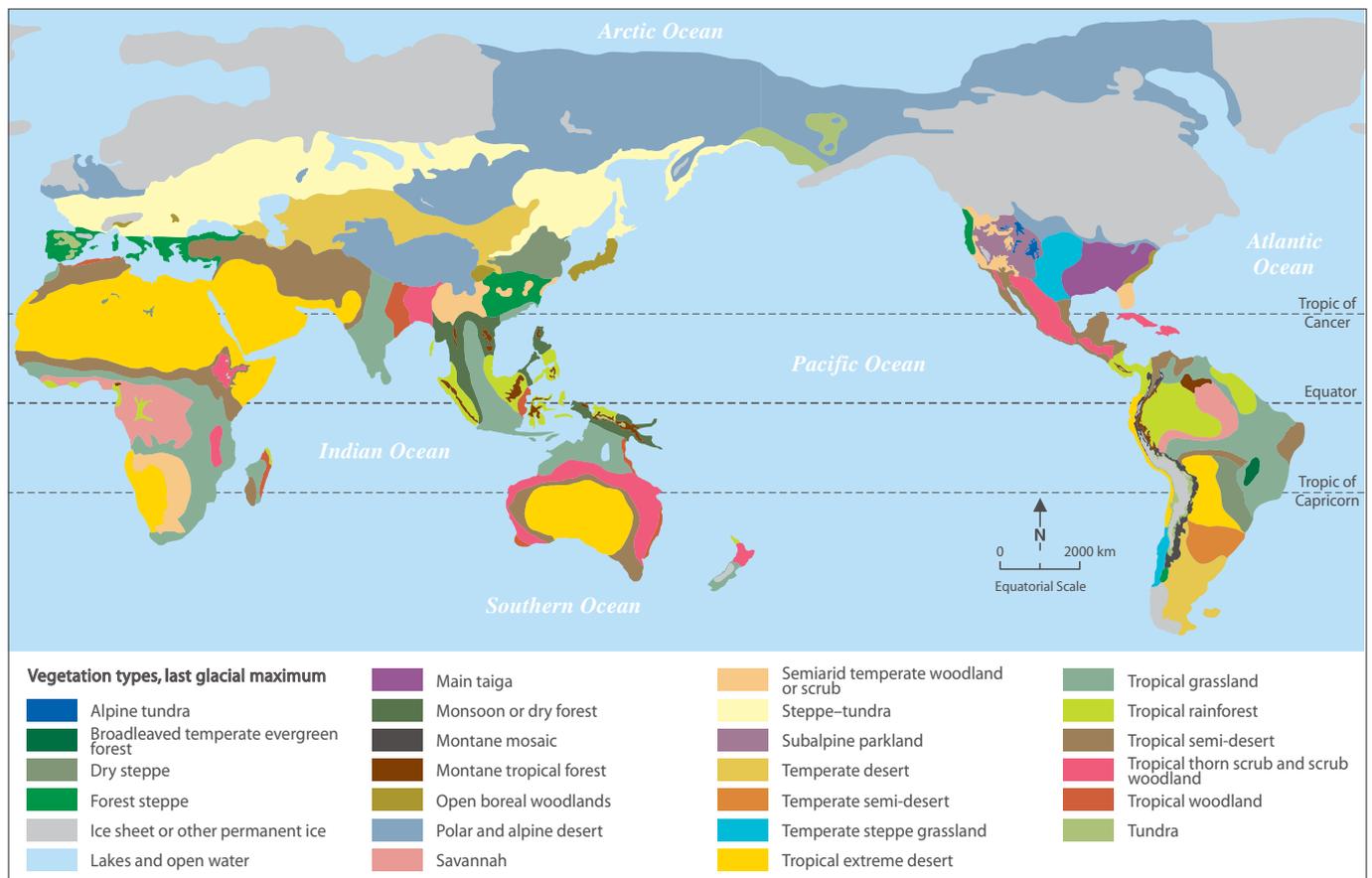
Around 15 000 years ago the Earth experienced a warmer and wetter period. This climate *change* produced major *changes* to the Earth's land cover. Ice melted and retreated, and sea levels rose as a result. Forests and grasslands spread. Agriculture involving the clearing of the natural vegetation cover was expanding in west Asia, Europe and the Americas.

In Australia, rising sea levels saw Tasmania become separated from the mainland and Torres Strait appear (between northern Australia and New Guinea). Gradually vegetation expanded in the better watered areas of northern, eastern and south-eastern Australia.

Future *changes* in climate appear to be closely related to human activities. People are influencing the world's climate through the burning of fossil fuels and the release of greenhouse gases into the Earth's atmosphere. Average temperatures in the twentieth century rose by around 0.6 °C. The warmer temperatures are already having a negative impact on the *distribution* of the world's ice and snow cover. Chapter 7 looks at this phenomenon in greater detail.

Climate *change* is one of the factors affecting rates of desertification by increasing the intensity of drought in semi arid and subhumid *regions* of the world.

▼ **Figure 6.11** Land cover about 18 000 BP



Farming areas such as the one in figure 6.12 will need to adapt to *changes* in climate with *changes* in cropping and intensity of animal grazing. The United Nations Development Programme estimated two billion of the world's population are at risk from desertification. Chapter 9 has more information on this *process*.

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 plate movements. As a result land covers were able to adjust to the climates of different latitudes. These adjustments were in combination with other powerful *processes*: climate *change* (see above)

and the development of plant colonies (see 'Plant succession' on the following page).

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 6.13, once the new surfaces are sufficiently weathered and can 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



▲ **Figure 6.12** A warmer and drier climate in the future will threaten the viability of many farming areas.



▲ **Figure 6.13** Ash erupting from Mount Bromo in east Java can cover extensive areas.



▲ **Figure 6.14** Grasses colonising coastal dunes on New Zealand's North Island

landmasses and help form steep slopes. A steeper land surface may result in surfaces unable to support more than sparse vegetation. 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*.

c. Plant succession

Vegetation can adapt to *changing* weather, climate and ground conditions. It also responds to the interconnection between specific plants. Plants need water, 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 6.14). 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 6.14 the hardy grasses are the pioneer plants colonising the bare ground.

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 grasslands. Today human activity aims to control or eliminate fires. In some cases people may fire an area to simulate the natural conditions. This removes ground litter of leaves and branches, encourages seeds to germinate and promotes new growth of plants.

The Earth's thousands of species of insects, and plant diseases, all have an impact on land covers. 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 warming, 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 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 grasses in figure 6.14 to thrive.
5. Consider the following sequence of events that might impact on a land cover of open eucalypt trees and grasses. Produce a series of sketches with appropriate labels to explain their impact.

fire heavy rain regrowth locust swarm heavy rain

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 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 6.15 is on the south-west fringe of Melbourne's urban area where a land cover of grazing land is *changing* to artificial surfaces of housing estates.

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 figure 6.16 shows.

Technology has further applications that can affect land cover:

- ▶ machinery and associated infrastructure can clear large areas of forest (see below and page 100)
- ▶ 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.

▼ **Figure 6.15** Urban expansion has meant a *change* in land cover from cultivated and managed land to artificial surfaces.



▼ **Figure 6.16** 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 6.17).
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.

c. Policies

The policies of governments and the influence of market prices for goods play a key role in land cover *change*. Selective logging for commercial timber and clearance of forests for new farming land is promoted by governments (as a source of revenue, employment and food production), companies (mainly for raw materials) and local landowners (mainly for revenue). Figure 6.18 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 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 markets for goods have allowed this *change* to occur very rapidly.

Chapter 8 looks at the role of government policies and forest clearances in 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.

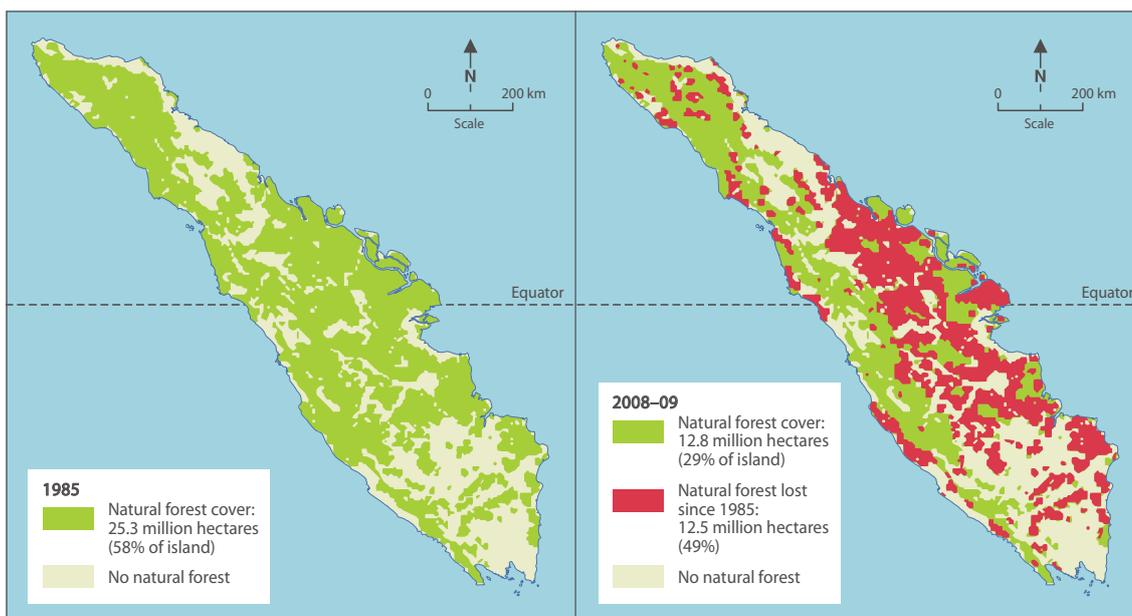
In other situations policies may aim to restore the land cover by aiming to eliminate invading species of animals (for example, feral pigs, buffaloes and cane toads in Kakadu National Park) and plants (for example, blackberries from Victoria's coastal parks). In addition the restoration of water supplies 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 6.17** An Egyptian onion grower (just discernible at the right of this image): at a local *scale*, irrigation water has made possible a land cover conversion from bare areas to cultivated and managed cover.

▶ 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 6.16, decide on the *change* in land cover that has taken place or will take place.
3. Refer to figure 6.18.
 - 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?



▲ **Figure 6.18** Sumatra's changing land cover, 1985–2009



7

Land cover change: melting glaciers and ice sheets

Introduction

There has been considerable interest and debate about *changes* in the amount of land covered by ice and how the ever-increasing warming of our planet might contribute to this. Scientists and 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 one impact of this in Alaska as walrus seek refuge on ever-decreasing amounts of ice.



▲ **Figure 7.1** Walrus competing for land in Alaska

Land covered by ice in the cryosphere can fall into four main categories:

- ▶ land covered by glaciers
- ▶ land covered by ice sheets (permanent ice that can increase and decrease seasonally)
- ▶ ice in the sea
- ▶ land covered by ice only seasonally such as tundra and land subject to permafrost.

These types of land are categorised as peri-glacial environments and cover approximately 20 per cent of the Earth's surface.

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 many types of glaciers but glaciers generally begin in alpine *regions*, as seen in figure 7.2.

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 Arapaho Glacier in the Rocky Mountains 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 can expand and contract seasonally. Glacial volume is measured on the mass balance between ice gained versus ice lost over a year. This mass balance assists scientists in working out whether a glacier is advancing or retreating.



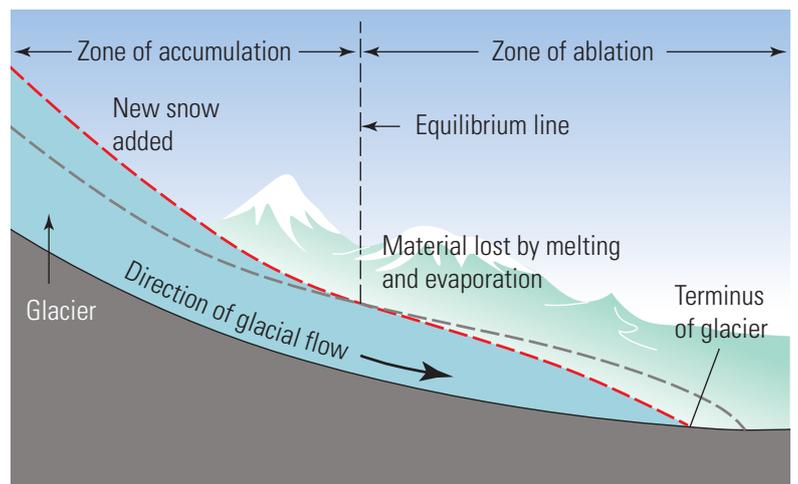
▲ **Figure 7.2** Aletsch Glacier in Switzerland, the largest glacier in the Alps



▲ **Figure 7.3** The terminus of Arapaho Glacier

Ice sheets are masses of ice not confined to valleys that bury large tracts of land beneath them. Sometimes ice sheets are also called continental glaciers and the two 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 and short summers. Ice sheets can move like glaciers and also expand and contract seasonally. Ice sheets have been present on Earth for millions of years (at least 40 million years in Antarctica) and were at their peak between 21 000 and 18 000 years ago, at the peak of the last glacial period. The Antarctica 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.



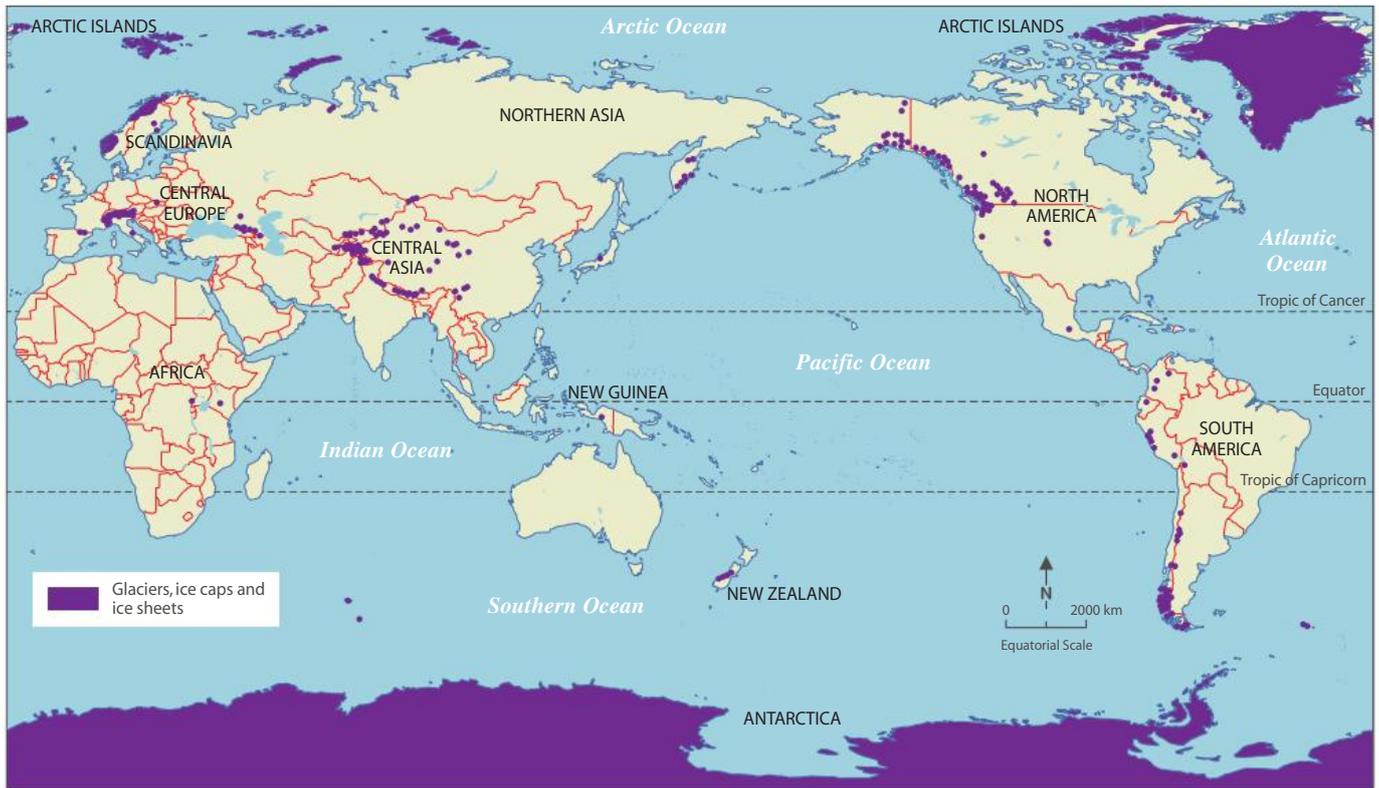
▲ **Figure 7.4** Typical structure of a glacier

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

Currently, every continent on Earth contains glaciers except for Australia. It is estimated that there are over 130 000 glaciers 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 seen are New Guinea and New Zealand. The United Nations Environment Program (UNEP) 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 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 nine per cent of the land area on Earth.



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

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

GROUP	ABBREVIATION
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 Program	UNEP
United Nations Development Program	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 constantly changing and 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. 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 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 kettleholes. These landforms can be seen diagrammatically in figure 7.7.

Only the hardiest of plants and animals inhabit *regions* with ice, so 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.

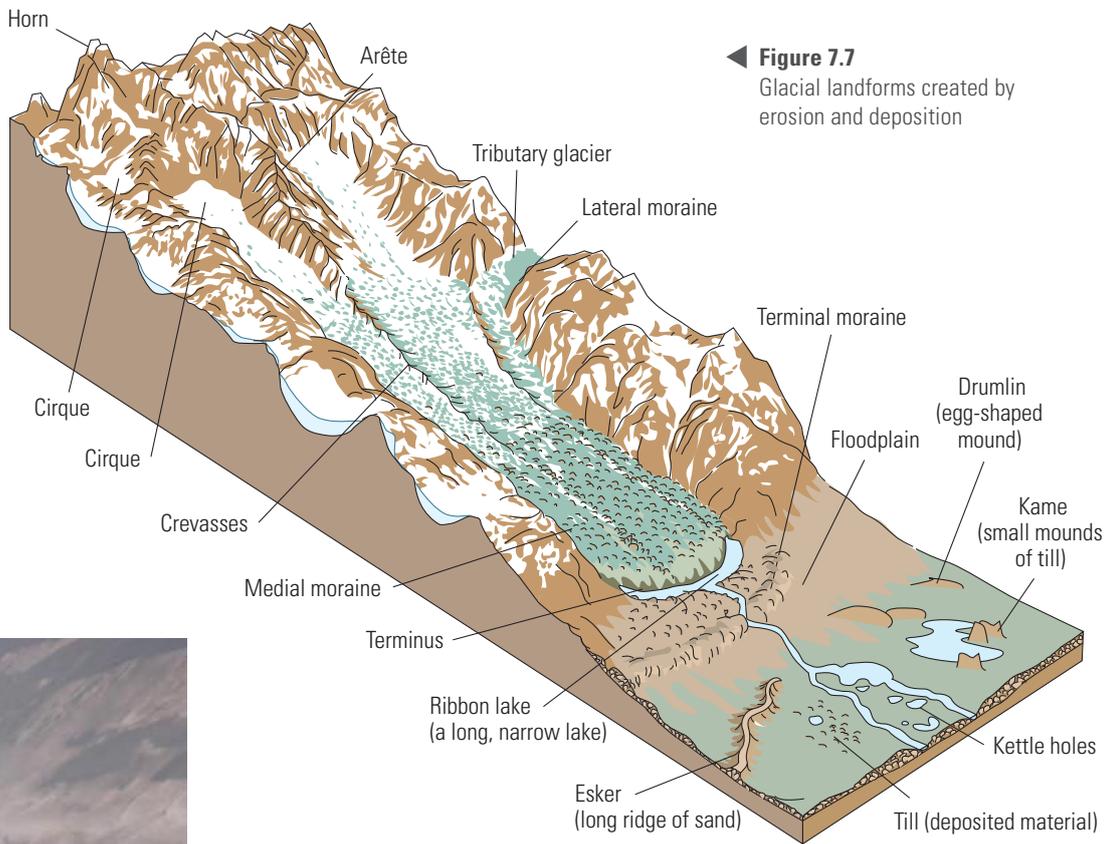


Figure 7.7
Glacial landforms created by erosion and deposition



Figure 7.8
View of the Swiss Alps from the Glacier Express

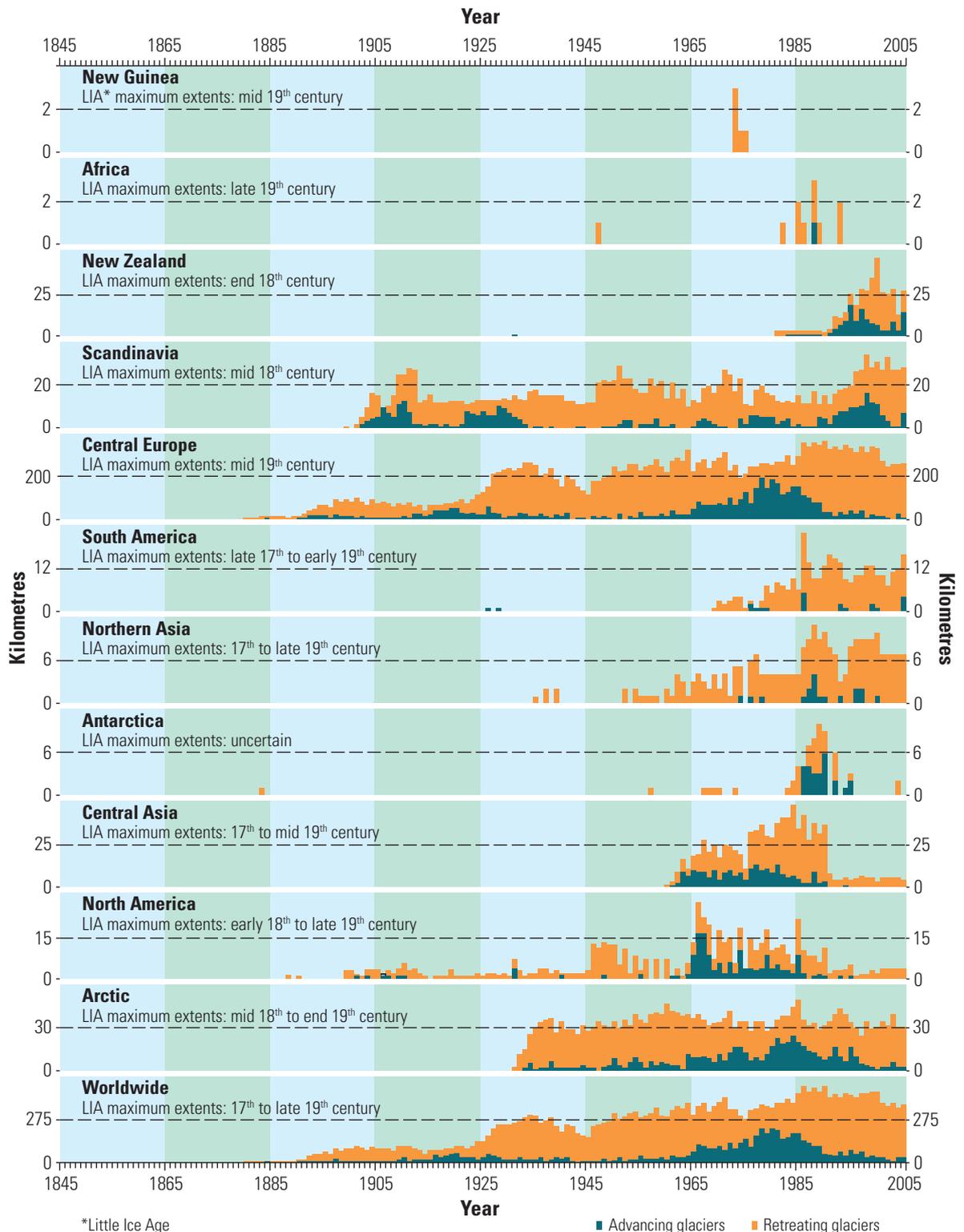
What are the human characteristics of glaciers and ice sheets?

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 areas in countries such as in Nepal, Canada and Scandinavia. These people are reliant on meltwaters for 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 environments. 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 7.8 on page 77).

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.

► **Figure 7.9**
Glacier length changes, 1845–2005. Blue indicates advancing glaciers while tan indicates retreating glaciers.

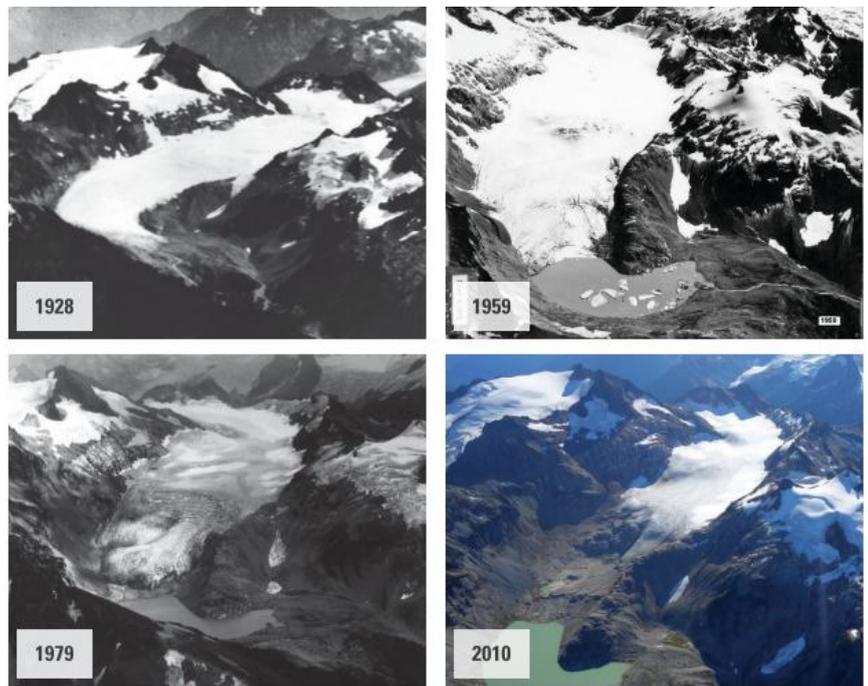


How has the *distribution* of glaciers and ice sheets changed?

The current *distribution* of glaciers and ice sheets is very different to how these areas used to look in the past. Over the last 100 years land covered with ice has decreased considerably as the global climate has warmed. Figure 7.9 depicts *changes* in glacier length for all *regions*, from about 1880 until 2005. This data, from 420 glaciers, illustrates that the majority of glaciers receded, although noticeably some gained in length in the late 1970s and early 1980s. There were very few glaciers increasing in length from 2010 to 2014 as these were among the warmest in recorded history. There is much concern that Africa will soon join Australia as a continent with no glaciers.

Figure 7.10 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 is estimated to have lost half its volume of ice between 1959 and 2010.

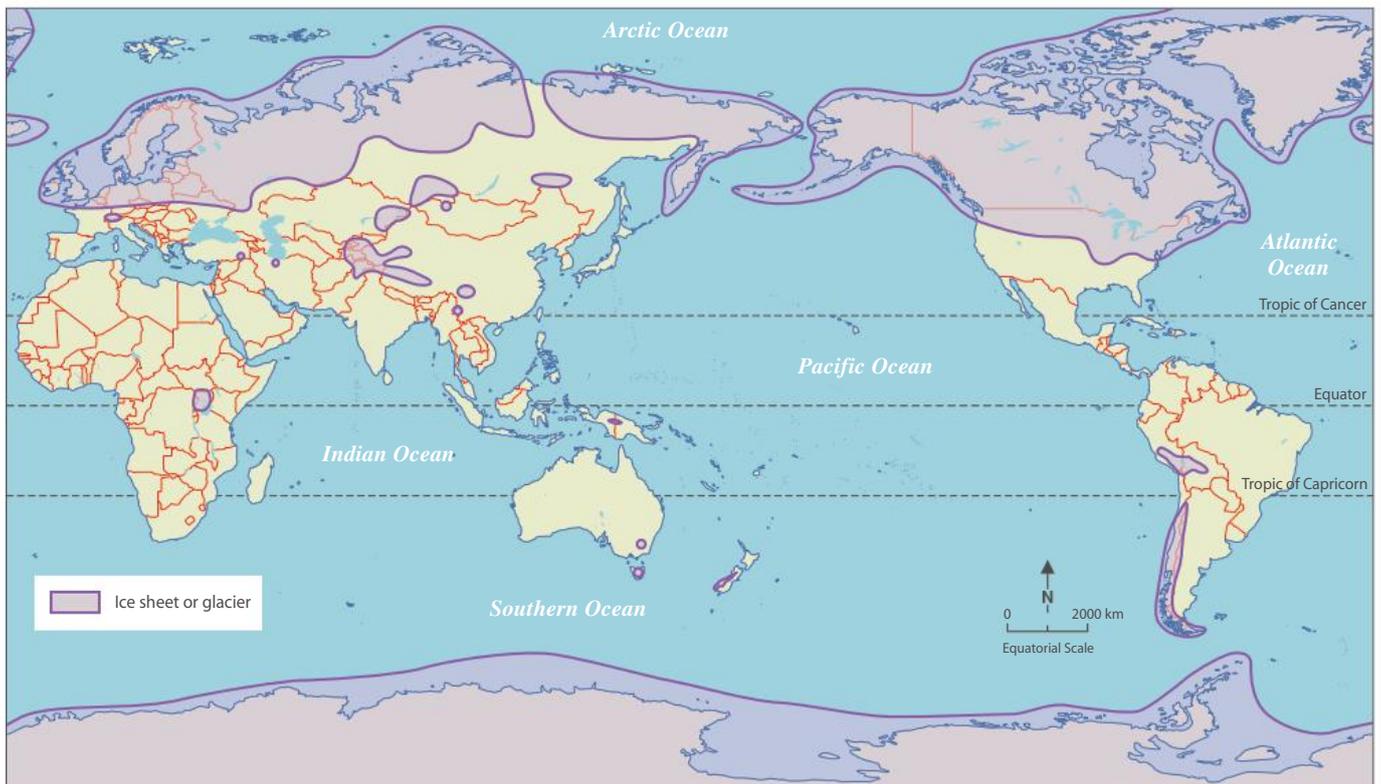
In recent geologic time the trend in ice coverage was not one of recession. After closely examining glacial deposits in many locations, geologists have identified a number of ice ages in the last 200 000 years where ice levels were much higher than today. The most recent of these ice ages occurred between 21 000 and 18 000 years ago 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 (as much as 100 metres) as water was frozen. It is thought that people could have walked on land from present-day Indonesia to Tasmania. Figure 7.11 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, and that only relatively small areas of the Australian Alps and Tasmania were covered by ice.



▲ **Figure 7.10** Change in the amount of ice on South Cascade Glacier between 1928 and 2010

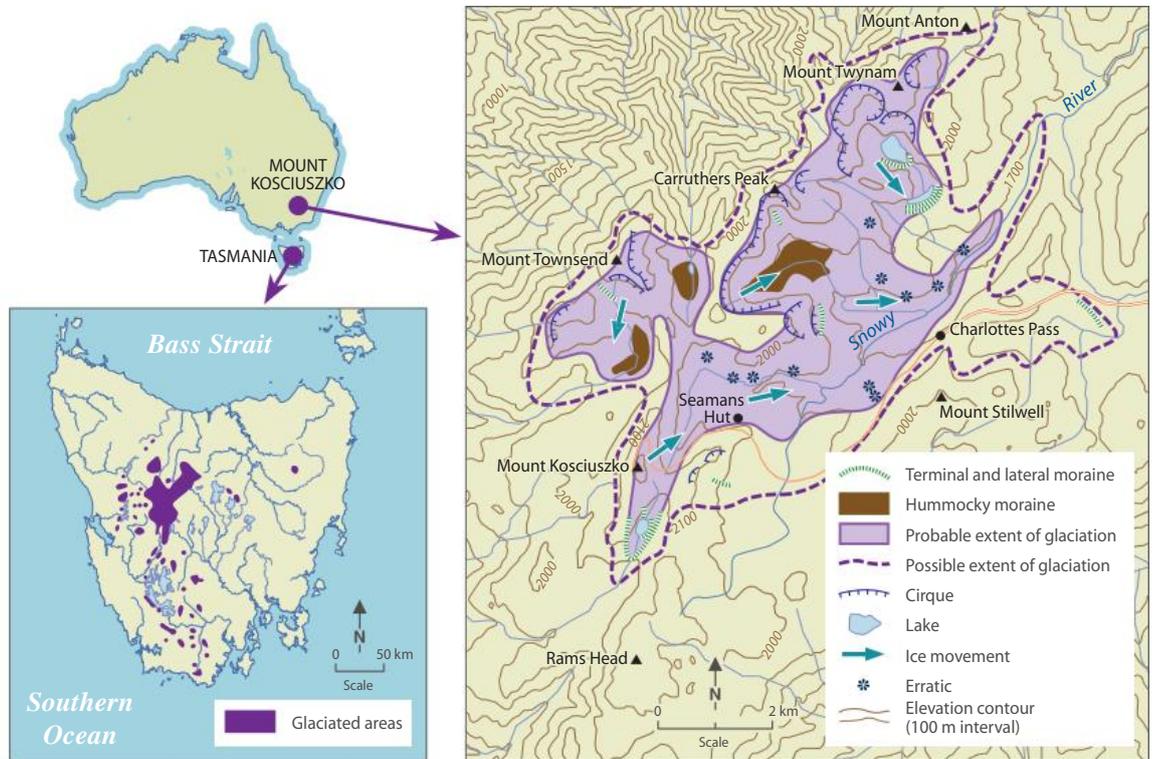
These *regions* are better seen in figure 7.12 overleaf. At the peak of this ice age it is thought that ice covered 6000 square kilometres of the central plateau of Tasmania to a depth of 700 metres.

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 celestial cycle *changes*, volcanic activity, *changes* in atmospheric gas levels, ocean current *changes* and sun spot activity.



▲ **Figure 7.11** Global glaciation about 18 000 years ago

► **Figure 7.12**
Extent of glaciation in
Australia about 18 000
years ago



► ACTIVITIES

- Complete a sketch of Aletsch Glacier, labelling the glacial features you can identify.
 - Complete a sketch of the Arapaho Glacier labelling the glacial features you can identify.
 - 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.
- Explain how glacier mass balance is calculated. The terms ablation and accumulation must be used in your explanation.
- Describe the global *distribution* of glaciers and ice sheets as shown in figure 7.5.
- The organisations listed in figure 7.6 are all based in the Northern Hemisphere. Explain why this might be the case.
- Evaluate the following statement (you will need to refer to an atlas):
'Glaciers are only found in temperate and polar climatic *regions*.'
- Describe the *distribution* of land covered by ice 18 000 years ago.
 - Comparing 18 000 years ago to the present, which *regions* of the world have had the largest decrease in ice cover?
- Figure 7.9 depicts advancing and retreating glaciers from the 1800s to the present.
 - Describe the global rates of advance and retreat from 1885.
 - 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.
 - What are the similarities and differences between the *regions* you described?
- Using overlays or a similar technique, plot the *changes* in ice cover of Cascade Glacier as shown in figure 7.10.
- Research a *region* that contains glaciers (apart from South America and Greenland) and create a journal of your research. In your research you should:
 - investigate significant glaciers of the *region* and their characteristics both human and natural
 - collect some diagrams and images that support your description of the human and natural characteristics of the chosen *region*
 - describe the spatial *changes* in ice coverage in your *region* over time
 - describe any activities engaged in by humans in these *regions* and the economic, social and environmental impacts associated with these activities
 - provide a statement that looks at what might happen in this *region* in the future if the impacts described in question 9 (d) continue.

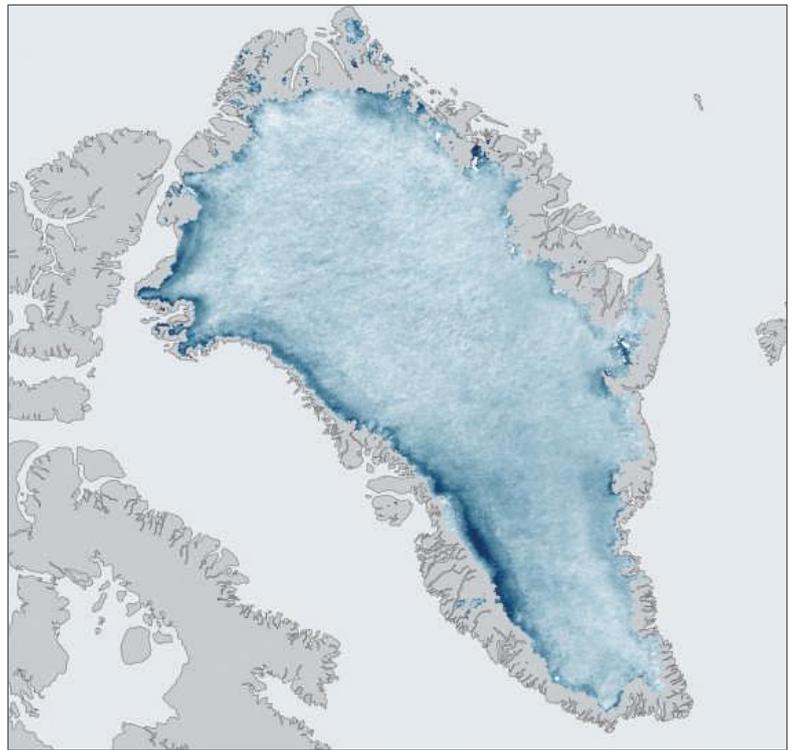
Case study: Greenland

Greenland is the world's largest island 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. Denmark has sovereignty over the island. Greenland has only about 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 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. It contains about 11 per cent of the Earth's freshwater supply. The contours of the Greenland ice sheet are shown in figure 7.13.

The ice sheet shows various colours when seen from space. Figure 7.14 shows the Greenland ice sheet in 2011 from NASA satellites using a spectroradiometer.

The island of Greenland has been of great interest to scientists as the warming of the global climate has meant that ice in Greenland is melting. 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 analysis. These ice cores were dated back to 110 000 years ago, and



▲ **Figure 7.14** Greenland ice sheet from space

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 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 1993 to 1998 it is estimated the rate of ice loss was 7.3 cubic kilometres per year. This increased to 44 cubic kilometres in 2002 and increased substantially to 249 cubic kilometres per year in 2006. The loss of ice is thought to have been caused by increasingly warmer summers and increasing speeds of moving glaciers. Swiss researchers recorded a six-degree increase in temperature between 1991 and 2004.



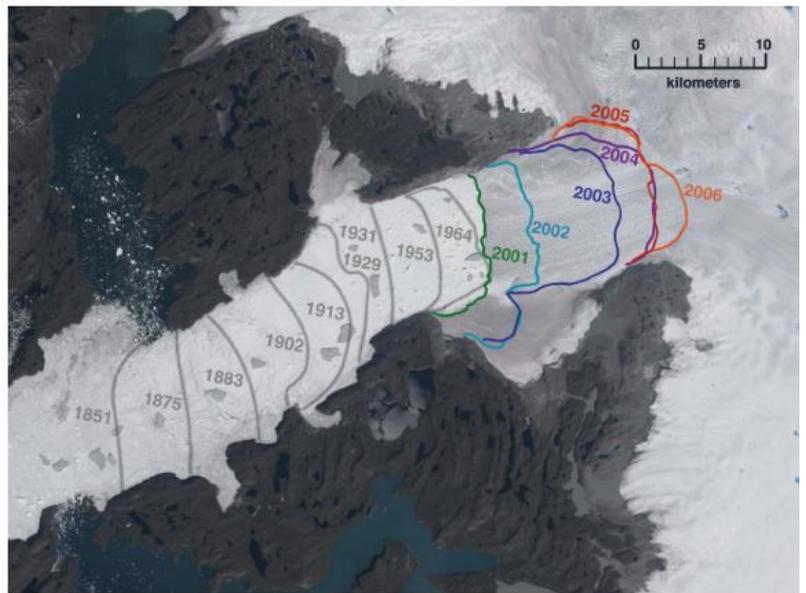
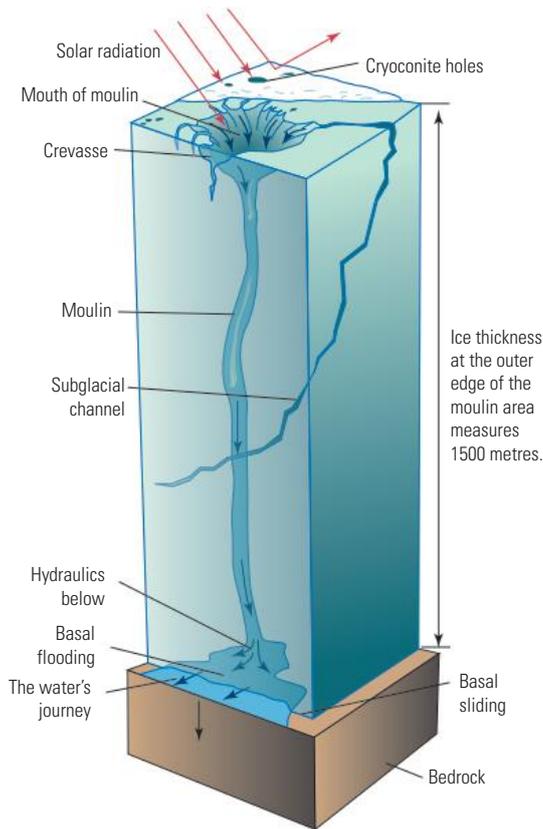
▲ **Figure 7.13** Greenland and its ice sheet



▲ **Figure 7.15** A settlement in Greenland

The melting of ice in Greenland has been exacerbated by the discovery of increasing levels of the mineral cryoconite. This mineral begins as airborne sediment spread over ice by wind. The airborne sediment is a combination of dust from central Asian deserts, particulate matter from volcanoes, and particles from European coal-fired power plants and diesel engines. The colour of the cryoconite has decreased the albedo or reflectivity of the ice, which increases the absorption of heat and in turn increases the rate of melting. Figure 7.16 shows how cryoconite can accelerate ice melting and lead to the formation of moulin that can cause the ice sheet to melt from its base.

It is thought that the annual melting of Greenland ice has caused sea levels to rise globally by 0.5 millimetres per year over the last 30 years. Scientists estimate that if 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, the world's fastest, increased in velocity from 7 kilometres a year in 1985 to 14 kilometres a year in 2006. Figure 7.17 depicts the retreat of this glacier from the ocean. The glacier has retreated over 40 kilometres since 1851.



▲ **Figure 7.17** 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.

▲ **Figure 7.16** Cryoconite and the formation of moulin

▶ ACTIVITIES

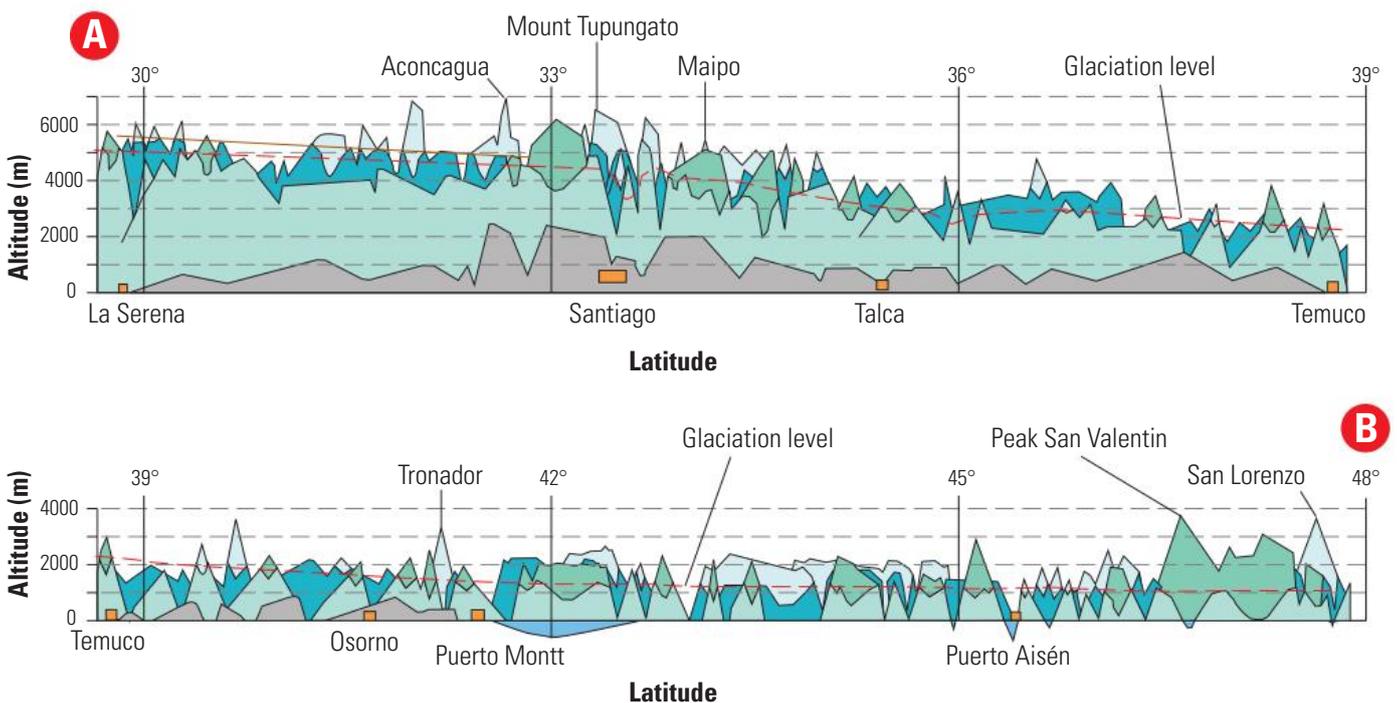
- Using an atlas, describe the location of Greenland. Make sure you use latitude and longitude to define its location and also describe surrounding water bodies and countries.
- Make a photocopy of figure 7.13. Plot a cross-section of the Greenland ice sheet between points A and B marked on the diagram. Make sure you label the sea, land and ice.
 - Describe the profile of the Greenland ice sheet. Why is the ice sheet thickest in the middle of the island?
- Look at figure 7.14. Why might the edge of the ice sheet be a different colour to the colour of ice in the middle of Greenland?
- Life for those residing in Greenland is not easy. Refer to figure 7.15 to explain why this is the case.
- Refer to figure 7.16.
 - Describe how cryoconite speeds up the rate of ice melt.
 - Describe how a moulin forms.
- Refer to figure 7.17.
 - Create a graph that shows the rate of decline of Jakobshavn Isbrae Glacier, in kilometres, from 1851 to 2006.
 - When were the fastest and slowest rates of decline? Quantify your answer.
- As the climate warms and more land is exposed Greenlanders are keen to expand their uses of this new land. Soil is being brought in to grow pasture and vegetables such as cabbages, sheep herds are being expanded and, most recently, the government is encouraging natural resources exploration such as oil and gas. Predict the likely economic, environmental and social consequences of these changing land uses on Greenland.
- 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 seven 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 world's driest desert, 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, mostly 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 Program (UNEP), estimated that there were approximately 25 492 square kilometres of glaciated areas in South America. Chile and Argentina (which includes Patagonia) have the most of the glaciated regions with just over 23 000 square kilometres or 90 per cent of glacier coverage. Peru has seven per cent, Bolivia two per cent, with the other countries sharing the rest. Figure 7.18 shows the distribution of glaciated regions in South America.



▲ **Figure 7.18** Distribution of glaciers in South America



▲ **Figure 7.19** Cross-section of the Southern Andes



▲ **Figure 7.20** Perito Moreno Glacier of Argentina

Some of the most spectacular and recognisable glaciers in the world are located in South America. Perito Merino glacier found in the Southern Patagonian *region* of Argentina is perhaps the most famous, with a terminus that is five kilometres wide and approximately 60 metres high. It is 30 kilometres long and covers 250 square kilometres. Perito Merino 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.

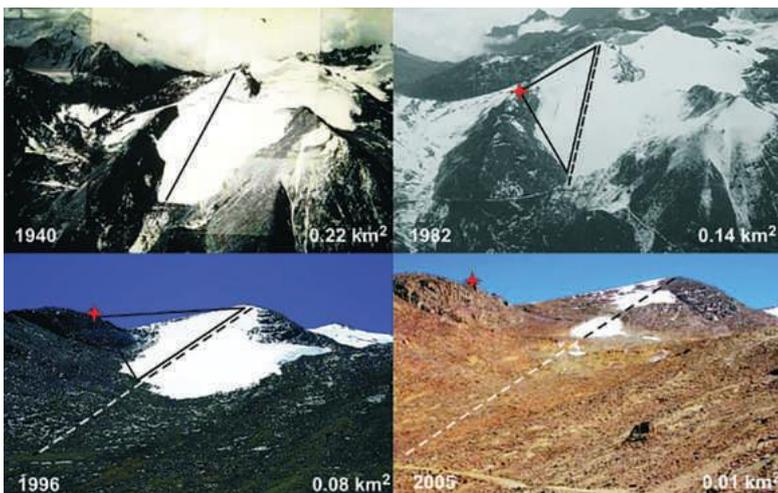
South American glaciers have been monitored closely over the past 30 years as they are critical sources of water for people, agriculture, industry and domestic use. Over 80 per cent of water used by Peruvians emanates from glaciers including all water for the capital city, Lima. Seventy per cent of electricity 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 damages 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.

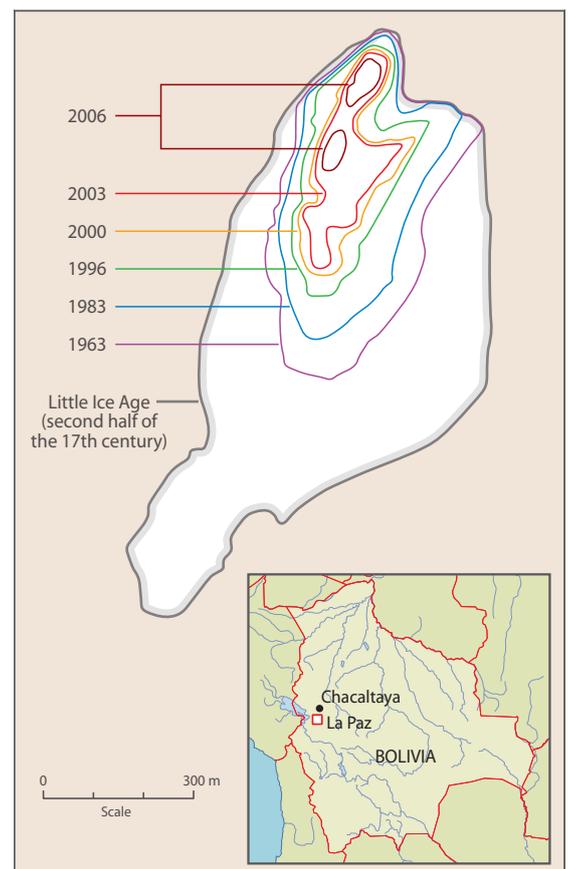
Another reason why South American glaciers have been monitored closely is because 99 per cent of the world's tropical glaciers are located here. Seventy-one per cent of these are in Peru and 20 per cent in Bolivia. These tropical glaciers are receding at an accelerated rate and it is predicted many will not exist beyond 2020 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. Glaciers at lower altitudes are retreating the fastest. Chacaltaya Glacier in Bolivia 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. 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. In 2009 Chacaltaya lost all its ice and ceased to exist. Figure 7.21 shows the decline in ice coverage between 1940 and 2007.

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

▼ **Figure 7.21** Declining ice cover on Chacaltaya glacier



▼ **Figure 7.22** The demise of Chacaltaya Glacier



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 7.23 show the town of La Raya and the views of the glaciers at this point.

Among other rapidly retreating glaciers that are being watched very closely by geographers and scientists is Yanamaray 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 2020. Another Peruvian glacier predicted to vanish before 2020 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. 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 7.23** Photographs of La Raya, Peru

▶ ACTIVITIES

- On a base map of South America and using information in this chapter, annotate each country showing the percentage of glaciers found there.
- Refer to figure 7.18 and, using the map you have constructed in question 1, describe the *distribution* of glaciers in South America.
- Figure 7.19 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.
- Complete a photo sketch of the Perito Moreno glacier labelling glacial features that can be identified.
- 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.
- Chacaltaya glacier's demise was watched by many groups across the world.
 - Use figure 7.22 to construct a graph that illustrates the decline in ice cover from 1963.
 - Could the rate of decline shown be evidence that the climate in this *region* is warming?
- Figure 7.23 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.
- 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.
- 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. With declining water supplies, explain the social and economic impacts that could result from decreasing water supplies.

Factors causing *changes* in ice sheet and glacier extent

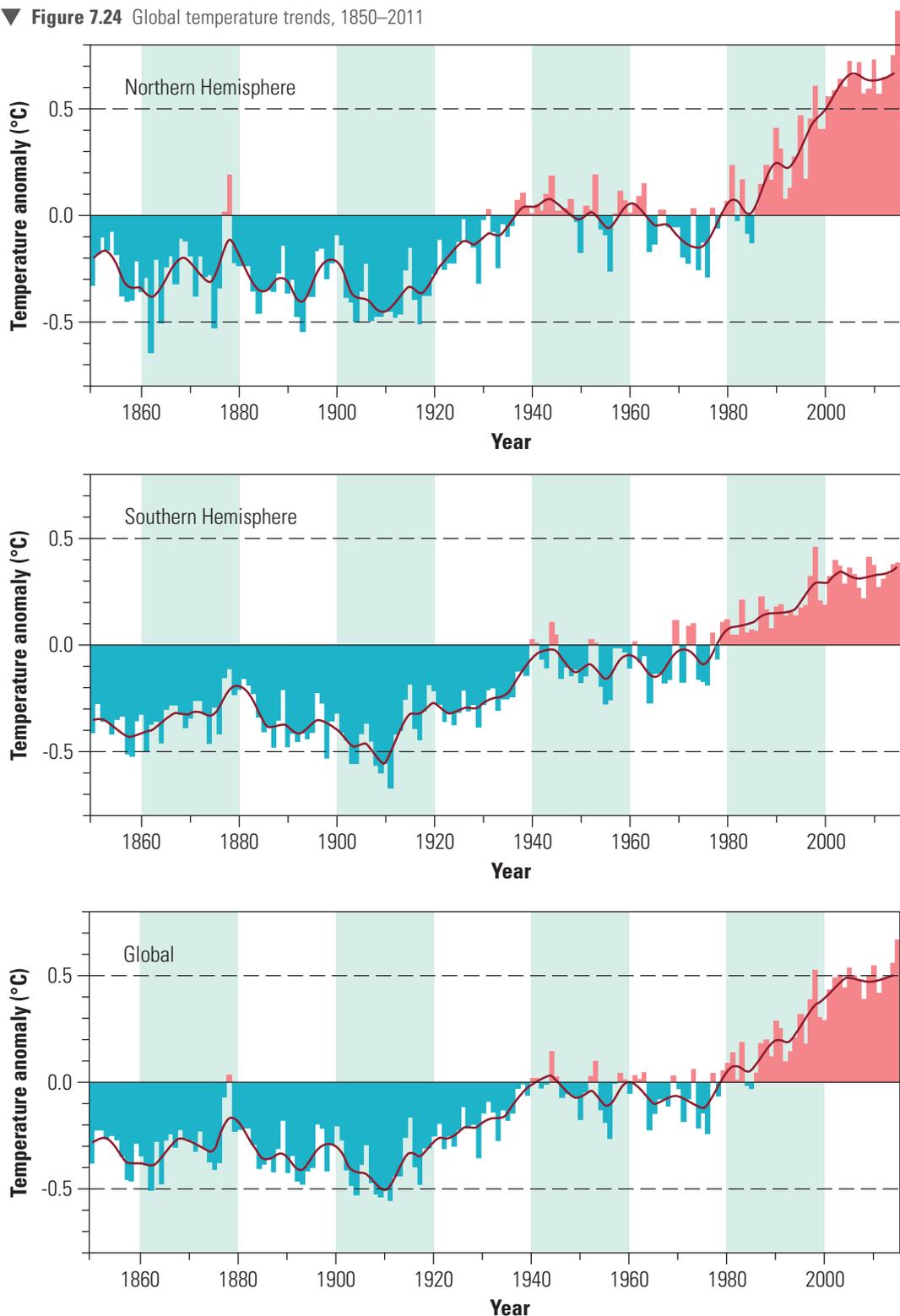
In the previous pages of this chapter it has been established that there is a clear trend emerging from monitoring of the cryosphere by a range of groups across the world. These groups include UNEP, NASA, WGMS, NSIDC and the World Bank. In all recent studies it has been concluded that the area of ice found in glaciers and ice sheets is declining with nearly 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 2014 was the hottest year in the Earth's history and that the 10 hottest years on this planet have

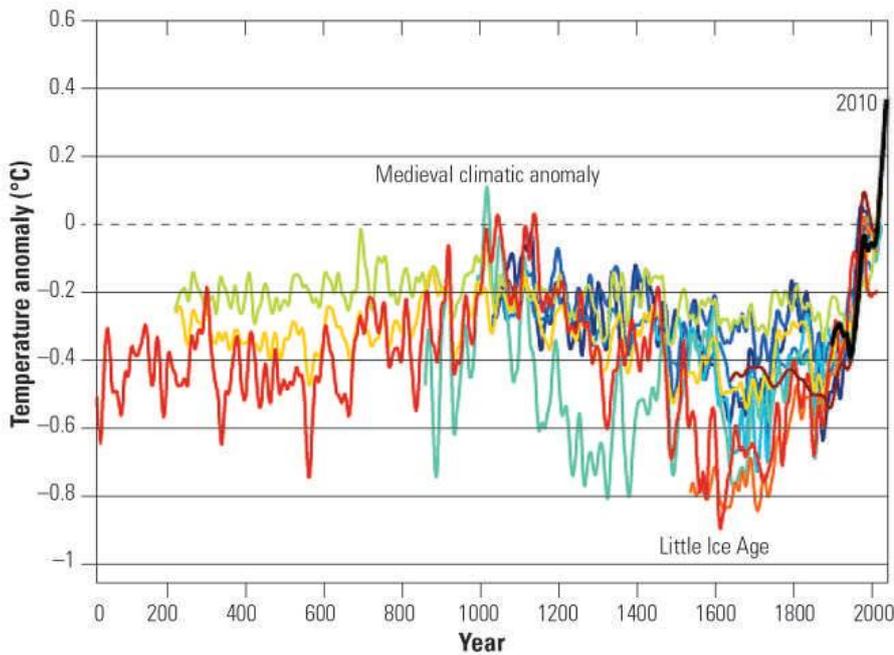
occurred since 1997. The average temperature in 2014 was 0.7 degrees Celsius warmer than twentieth-century average temperatures. Figure 7.24 shows that since the mid 1970s, Earth's temperatures have risen consistently.

It is estimated that since accurate records have been collected in 1880, the Earth's average temperature has increased by 0.85 degrees Celsius. 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 7.24** Global temperature trends, 1850–2011



▼ **Figure 7.25** Anomalies in the Earth's temperature over the last 2000 years

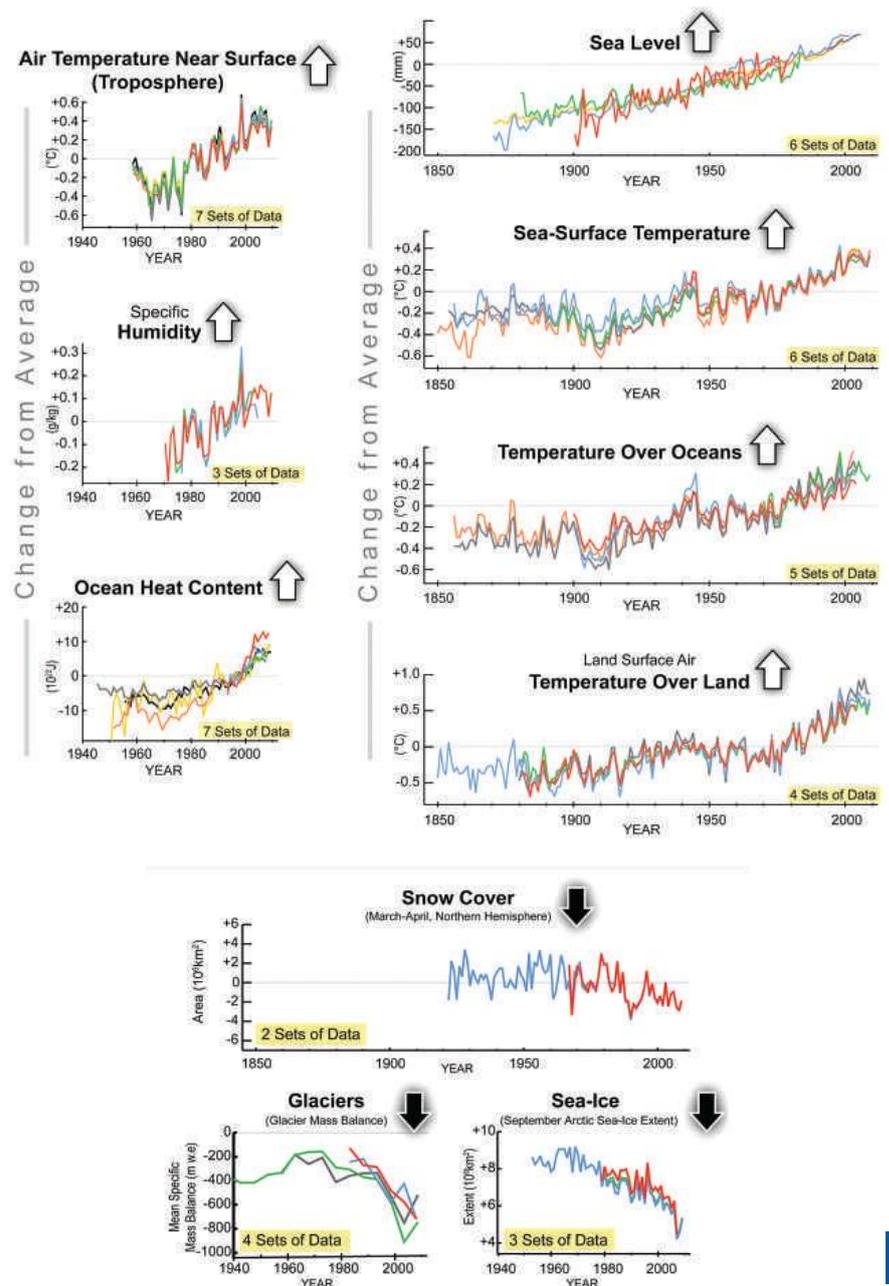


The Earth is warming and has done so for the last 12 000 years. This is known from a range of evidence collected across the world including ice cores, sediments from varves, fossil records, pollen evidence, tree ring analysis, carbon dating and records of weather observations for hundreds of years. There 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 7.25.

The Hadley Centre, a climate research group in the United Kingdom, has monitored global temperatures since the mid-nineteenth century when industrialisation and the burning of fossil fuels became commonplace. Their research has noted rises 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. Figure 7.26 shows a variety of climate data collected by the Hadley centre.

The IPCC released a report in 2007 that combined the research of 150 experts in climate science and was peer reviewed by 600 other climate experts. It stated that the accelerated rates of global warming since the middle of the twentieth century were most likely (more than 90 per cent likely) due to elevated levels of greenhouse gas emissions resulting from human activities.

▼ **Figure 7.26** Climate data collected by the Hadley Centre since 1850. Arrows represent trend direction.



Natural causes of climate change

There are many natural causes of climate *change* 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*: recent research has shown that the solar energy received by Earth is not constant. Sun-spot activity correlates with higher annual temperatures on Earth.
- b. *Oceanic circulation changes*: the direction of ocean currents has *changed* regularly in recent 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 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.
- 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 be short term. Masses of dust can lead to cooling, for example, Mount Krakatoa, while the injection of greenhouse gases can lead to warming.
- d. *Plate tectonics*: the *redistribution* of landmasses has long been caused by plate tectonics. This has led to long-term impacts on the climate. Landmasses have drifted into different latitudes and landmasses colliding with other landmasses has led to the formation of 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.

What are the human causes of climate change?

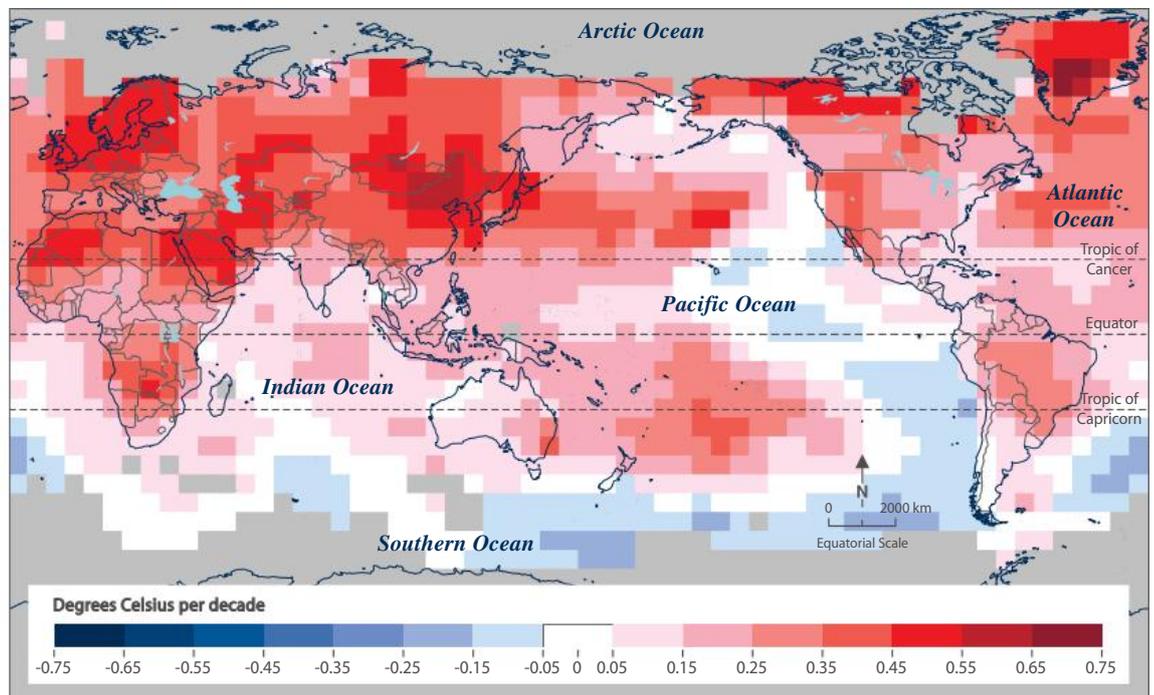
Since the beginning of the Industrial Revolution, people have significantly *changed* the appearance of the globe. Cities have incorporated factories, skyscrapers and increased numbers of residences; populations have exploded; consumption of resources has increased; agriculture expanded; forests cleared; eco-systems *changed*; and travel opportunities broadened with the advent of air travel. These *changes* have led 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 very little warming and the greatest rates of temperature increase have been recorded in the heavily industrialised countries of the Northern Hemisphere. Figure 7.27 shows the rate of temperature *change* on Earth between 1979 and 2005.

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

1. *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 some local impacts but is not thought to be a major cause of global climatic warming.
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. Urbanisation *changes* soil moisture balances as impervious surfaces replace porous

► **Figure 7.27**

Global temperature change between 1979 and 2005



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 *changes* in moisture levels in the atmosphere and thus wind patterns, and heat and moisture transport across continents.

3. *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 increased ozone into the atmosphere. Figure 28 shows the estimated *changes* in the concentrations of five selected greenhouse gases from pre-industrial times to 2010.

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 remove carbon from the atmosphere via photosynthesis and store the carbon in the roots or trunks of trees.

As greenhouse gases absorb the sun's radiation, higher greenhouse gas concentrations lead to the warming of the lower atmosphere. This leads to an enhanced greenhouse effect.

Other causes of ice sheet and glacier depletion

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 page 82) 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. 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. This has happened in the United States and South America.

▼ **Figure 7.28** Atmospheric concentrations of greenhouse gases

GAS	ESTIMATED PREINDUSTRIAL CONCENTRATION*	2010 CONCENTRATION
Carbon dioxide	288 ppm**	391 ppm
Methane	848 ppb***	1800 ppb
Nitrous oxide	285 ppb	323 ppb
Chlorofluorocarbon-12	0 ppt****	530 ppt
Chlorofluorocarbon-11	0 ppt	245 ppt

*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

****ppt = parts per trillion

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

▶ 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 7.24.
 - 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 trends apparent in figure 7.25.
4. Refer to figure 7.26.
 - a. Look closely at the data collected by the Hadley Centre. Are the trends depicted consistent for all sets of data collected?
 - b. What important relationships can be identified when comparing data sets together?
 - c. Glacier mass balance in the Northern Hemisphere has decreased steeply in recent times. Which set of data best explains this trend? Why?
5. Refer to figure 7.27.
 - a. The rates of temperature *change* across the world 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 5(a)?
 - c. The west coast of South America is getting colder yet glaciers are retreating. Why might this be the case?
6. The concentration of methane in the atmosphere has increased at a far greater rate than other greenhouse gases as shown in figure 7.28. Why might this be the case?
7. 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.

What are the impacts of declining ice cover?

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, and disease and natural disasters.

1. *Sea level rise*: it is estimated that during the twentieth 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 37 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 OECD (Organisation for Economic Co-operation and Development) has listed the 20 most vulnerable cities across the world to coastal flooding. See figure 7.29.

The Bureau of Meteorology in Australia is currently monitoring sea levels in the South Pacific 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 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.

▼ **Figure 7.29** 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 7.30** Corn growing in the high mountain valleys of Peru over 3000 metres above sea level

Rising sea levels will reduce the amount of land where an ever-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, their combined population of 53 million people are reliant on food grown by water supplied by glaciers in the Andes. Figure 7.30 shows a fertile valley in

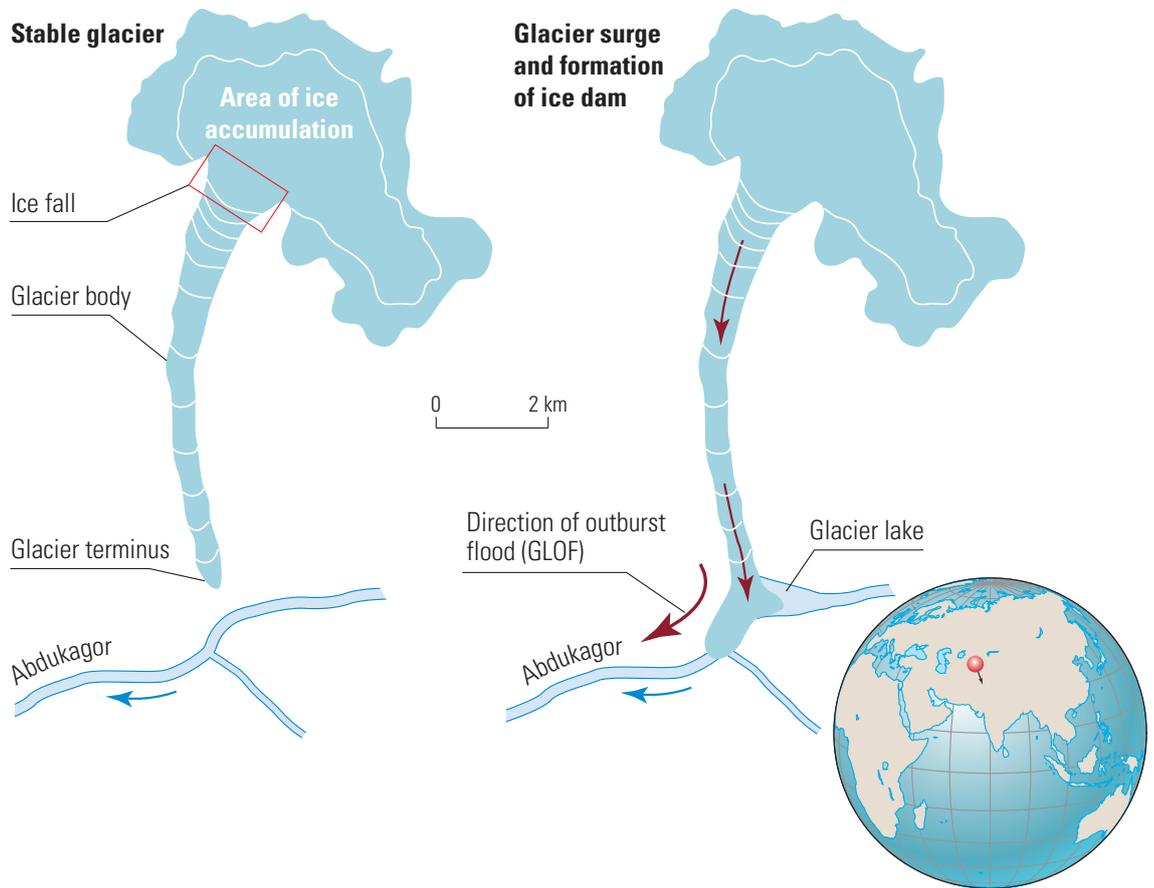
the high Andes that is fed by water from glaciers.

The 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. 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.

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. This has

▼ **Figure 7.31** Glacial Outburst flood at Medvezhiy glacier



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 for coastal ecosystems and coral reefs.

6. *Disease*: as temperatures warm, there is a concern that many diseases and disease carriers such as mosquitoes 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.

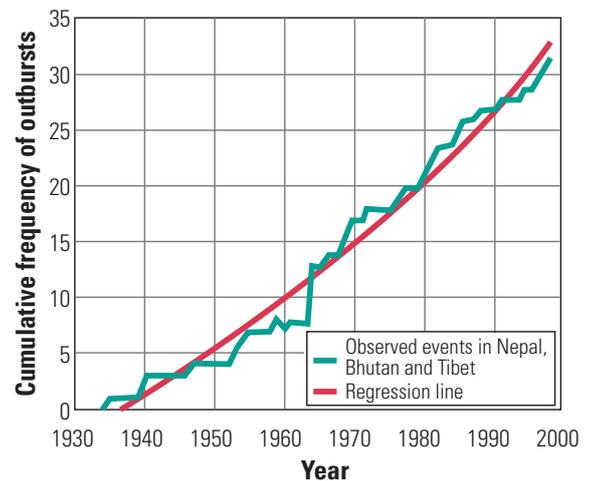
It is thought that the warming of climates may reduce the spread of respiratory diseases.

7. *Natural disasters*: the melting of ice sheets and glaciers is leading to many more natural disasters, particularly flooding, as GLOFs (Glacial Lake Outburst Floods) 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 7.31 depicts how a GLOF occurred at Medvezhiy glacier in Tajikistan, and figure 7.32 shows the increase in GLOF frequency in Nepal, Tibet and Bhutan.

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 7.32** GLOFs over time in Nepal, Bhutan and Tibet

▶ 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. Using an atlas, locate each of the cities listed in figure 7.29. What similarities and differences can you identify between their respective locations?
3. Food and water security are major challenges in the twenty-first century as populations rise, 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 7.32 describe the trends in GLOFs in Tibet, Bhutan and Nepal.

Responses to glacier and ice sheet retreat

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 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, 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 technology — including satellite imagery, GNSS, aerial photography, scientific probes and GIS — to monitor and obtain the most recent information about trends and to help scientists understand the reasons behind ice cover reduction.

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.

A brief selection of the hundreds of responses to glacier and ice sheet retreat is shown in figure 7.33 overleaf.

▶ ACTIVITIES

1. In your geography class, divide into groups and research the nine categories in figure 7.33 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.
2. After listening to the opinions of your classmates, which of the nine categories of responses listed in figure 7.33 do you think will be the most effective? Explain your reasoning.
3. What criteria could you establish that could help evaluate the effectiveness of each of the responses listed here?
4. 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?
5. Why do you think many countries have been slow to act in relation to reducing the causes of global warming?
6. 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 7.33** Responses to ice sheet and glacier retreat

RESPONSE	SCALE OF RESPONSE	GROUPS RESPONDING	NATURE OF THE RESPONSE
Climate action groups	Mainly global and often promoted extensively with social media	Greenpeace Stopglobalwarming.org Australian Conservation Foundation World Wildlife Fund (WWF)	Creating publicity and providing information about how to reduce global warming
International treaties	Global	United Nations, interest groups, countries	Open discussions leading to action and policies about carbon emissions
Emission trading schemes	<i>Regional</i>	European Union	An economic solution to put a price on carbon so that companies have to offset carbon or pay for their emissions.
Public awareness, education and publications including newspapers, videos, magazines	Global	Variety of authors and groups	Avenues to make people and groups aware of current issues and opinions
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.
Monitoring of glaciers and ice sheets	Global	UNEP, NOAA, NASA,	Collaborative networks like the WGMS (World Glacier Monitoring Service) made up of scientists around the globe collect and share data about specific glaciers and ice sheets. They use GLIMS, (Global Land Ice Measurements from Space) as well as data collected in the field. This improves knowledge and understanding about glacial <i>change</i> that can be shared with other groups and organisations.
Addressing water security issues	Local and <i>regional</i>	Governments, action groups, townspeople, NGOs	Finding solutions to decreasing water supplies caused by reduced water flows as glaciers reduce in size
Disaster management	Local, <i>regional</i> , international	Governments, action groups, townspeople, NGOs, UNEP	Creating solutions to increasing disasters related to the decline in ice coverage such as GLOFs, and avalanches
Reafforestation schemes	<i>Regional</i>	Emissions traders, conservationists	Forests have been planted in many <i>places</i> to sequester carbon, hold slopes together, <i>change</i> land surface albedo, conserve soil and protect animal habitats.

EXAMPLES

Stopglobalwarming.org has created a Global Warming Virtual March to petition world leaders.
Other groups advocate carbon neutral housing, food miles to reduce transport fuel consumption.

The Kyoto Protocol was created after the United Nations framework convention on climate *change* (UNFCCC) was ratified in 1997, setting carbon emission goals. The protocol has been signed by 184 countries. The Marrakesh Accord in 2001 developed the protocols further. There have been many climate summits; e.g. the Lima climate summit of 2014.

The EU Greenhouse Gas Emission Trading Scheme is a binding agreement across all EU countries so that Kyoto targets can be met.
An Australian version of this scheme was 'the carbon tax'; it was repealed by the Abbott government in 2014.

Former US vice president Al Gore released the movie *An inconvenient truth* to make people aware of climate trends and issues.

Massive solar projects are being constructed in India, Mexico, Japan and Australia that will power industry without emitting carbon products into the atmosphere

The European Space Agency has had a number of environmental satellites orbiting the Earth since the 1990s. 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.

Farmers in South America and Himalayan countries are being assisted by various NGOs 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.

In Bhutan, GLOFs have increased in frequency causing huge damage; 25 glacial lakes have been identified as being potentially dangerous and measures have been 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.

Examples of these schemes can be found in Japan, Canada, UK, Australia, Italy and Norway.
In Tibet, a project is about to begin that will afforest land at the headwaters of six rivers. The project is estimated to cost US\$ 4.8 billion.

Professor Chris Wilson

Geoscientist and glaciologist, School of Earth, Atmosphere and Environment, Monash University

I trained as a structural geologist and for more than 30 years have been studying the deformation of ice and ice mixtures, to interpret and predict the past and future behaviours of polar and glacial ice. With climates changing, this research is essential in developing reliable climate models that can assess the reduction of ice cover over time. Simulating ice behaviour under different conditions of temperature, pressure and flow can help researchers explain how ice crystals form and ice structures develop in glaciers and ice sheets. I have conducted research in the field in Antarctica on eight occasions as well as fieldwork in the mountains of Tibet on ten occasions.



In my academic work, I have held positions at several universities, most recently at Monash University. Much of my research has been in collaboration with a range of geoscientists from many parts of the world. This type of career provides opportunities to travel the world, conduct fieldwork in sometimes remote and hard to reach *places*, and collaborate globally with interesting people from many locations.

There are many skills required to be successful in this field, many of which are developed in Geography as well as Science. I have to be collaborative, a strong communicator, able to collect and interpret evidence collected in the field, be open to new ideas, feedback and research, and be able to create and read a variety of maps.

In recent times there has been a decline in funding for Antarctic research and there are not any opportunities to study glaciers in Australia. Overseas this situation is very different as there is much concern in glaciated areas about ice decline. In Australia there are many career opportunities in climate science, geophysics, physical geography and geology.

8

Land cover change: deforestation

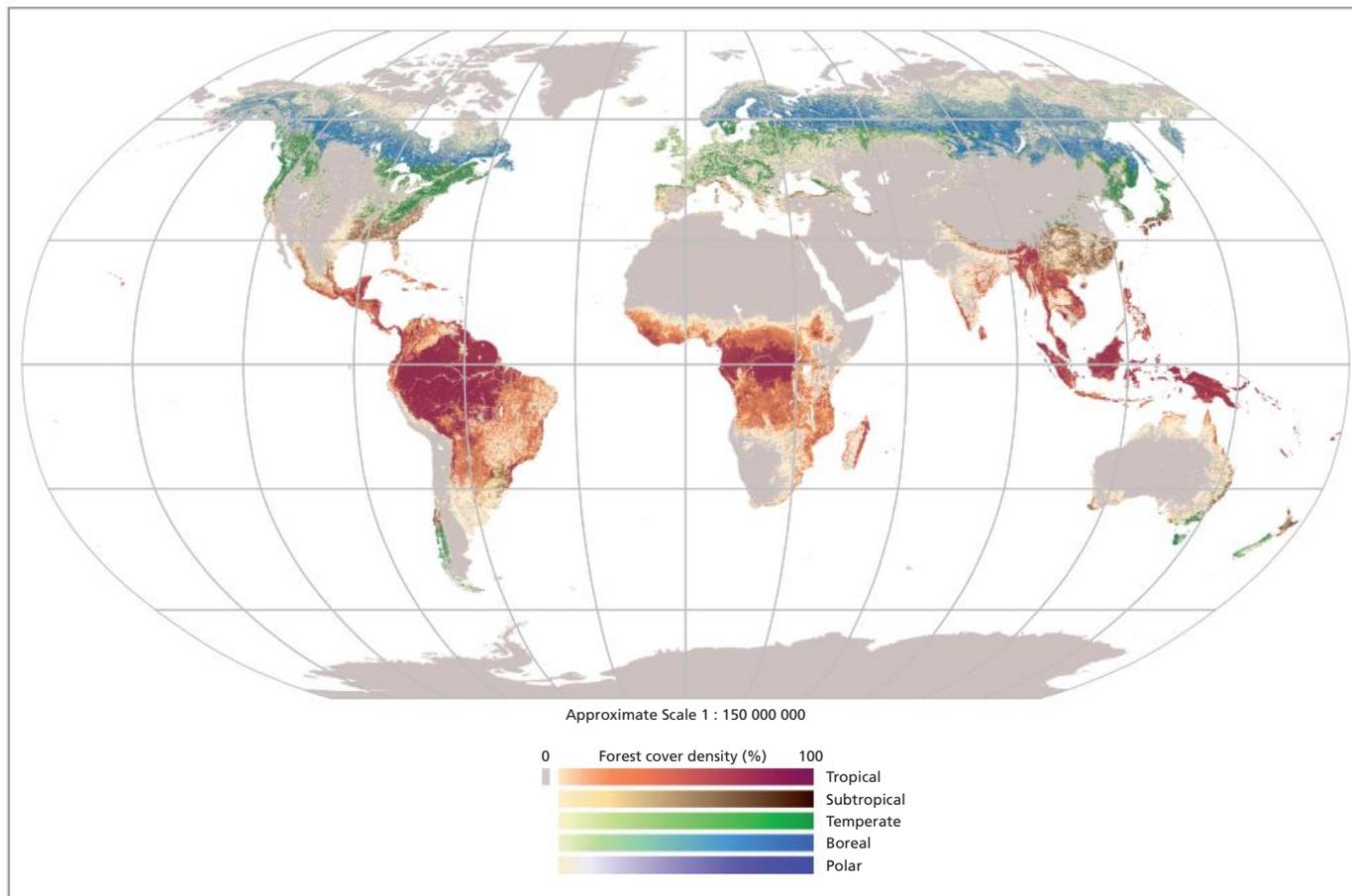
The *distribution* of forest land cover across the world has *changed* in response to interconnecting natural *processes* and human activities. Today, forests collectively cover nearly a third of the world's total land area and contain most of the world's terrestrial biodiversity. But the world's forests are diminishing in extent and quality. Deforestation has resulted in an annual loss of 13 million hectares of forest over recent years, and while the rate of deforestation has overall slowed and the regrowth of forests in some *regions* has offset some of this loss, many forests are experiencing rapid rates of decline.

The nature and spatial *distribution* of forests

The world's forested area totals 4 billion hectares worldwide. Because climate is one of the major determinants of the type of forest that forms, forests are commonly classified according to this factor. Slightly more than half are found in the tropics and the rest are in temperate *regions*. The *distribution* of the world's forests is shown in figures 8.1, 8.2 and 8.3.

Forests are dynamic biomes which *change* over 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* over time in response to the dynamics of plant succession as they develop and mature.

▼ **Figure 8.1** The World's forest biomes, 2010



▼ **Figure 8.2** The *distribution of forests by region, 2010*

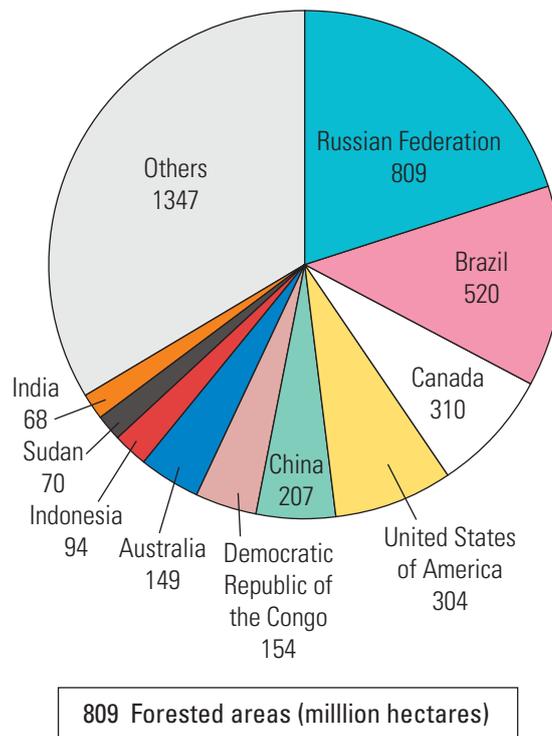
Region/subregion	Forest area	
	Thousand hectares	Percentage of total forest area
Eastern and Southern Africa	267 517	7
Northern Africa	78 814	2
Western and Central Africa	328 088	8
TOTAL Africa	674 419	17
East Asia	254 626	6
South and South-East Asia	294 373	7
Western and Central Asia	43 513	1
TOTAL Asia	592 512	15
Russian Federation	809 090	20
Europe (excluding Russian Federation)	195 911	5
TOTAL Europe	1 005 001	25
Caribbean	6 933	0
Central America	19 499	0
North America	678 961	17
TOTAL North and Central America	705 393	17
TOTAL Oceania	191 384	5
TOTAL South America	864 351	21
WORLD	4 033 060	100

The Food and Agriculture Organization (FAO) of the United Nations (UN) collates information about the world's forests and regularly releases this information in the form of Global Forest Resource Assessment reports. These inventories are collated through the use of remote sensing and spatial technologies, conducted and submitted by each country. They are used widely to assess forests and to develop management strategies for dealing with deforestation. Figure 8.4 overleaf shows some of the types of forests found in Australia, classified according to the density of the forest canopy cover.

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

- ▶ primary forests, or 'intact' or 'old growth' forests, are forests that remain in virtually pristine condition, containing the full array of native species
- ▶ secondary forests, or 'regrowth' or 'regenerated forests', consist of native species but they have been disturbed by human activities, or humans have intervened in their development, such as through replanting. They will eventually develop into a climax community which may be indistinguishable from a primary forest, though this may take hundreds of years (refer to figure 8.5 overleaf)
- ▶ plantations are a 'monoculture' of native or non-native trees planted for the commercial production of a particular species or for environmental services such as erosion control (excluding tree food crops).

The relative contribution of each of these three categories to global forests is shown in figure 8.5.

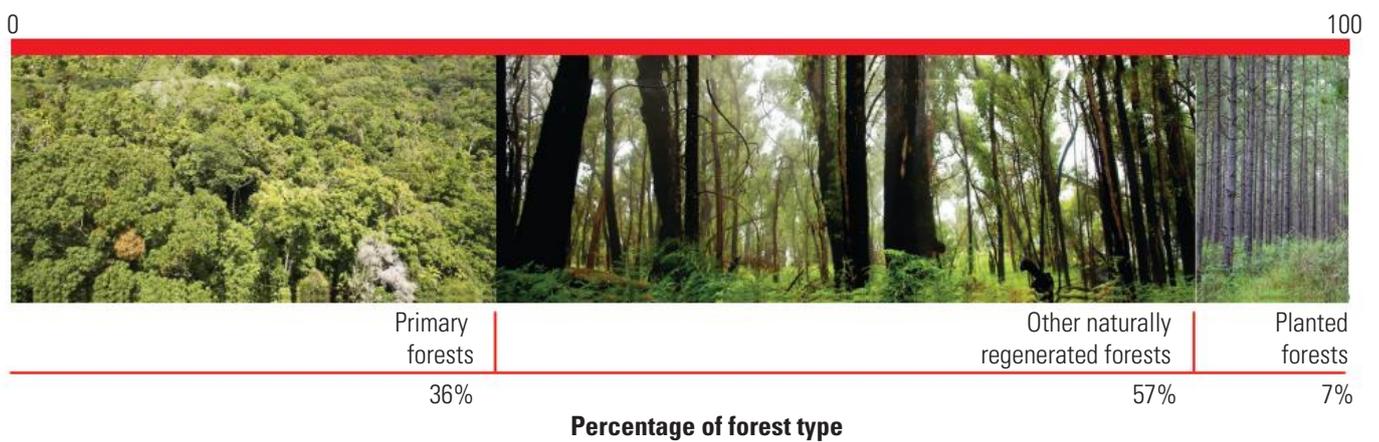


▲ **Figure 8.3** Countries with the largest forest area, 2010



▲ **Figure 8.4** Types of forest: (a) Closed forest (The Denmark River, in the town of Denmark, Western Australia); (b) Open forest (Salmon gums, near Kalgoorlie, Goldfields Region, Western Australia); (c) Woodland (Olgas or Kata Tjuta, Northern Territory)

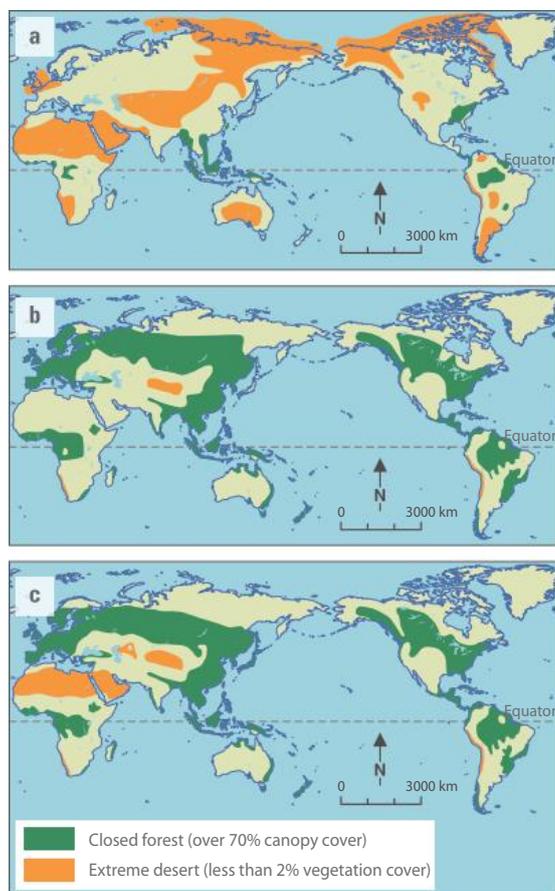
▼ **Figure 8.5** Characteristics of the world's forests, 2010



Change in the spatial distribution of forests over geologic time scales

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 occurring between 21 000 and 18 000 years ago.



▲ **Figure 8.6** The *distribution* of vegetation land cover during the last glacial maximum (a), during the Holocene climatic optimum (b), and (c) the potential land cover today showing the *distribution* of biomes if clearing did not occur.

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 far up altitudinally. 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 an 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. 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 migrated 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 8000 years ago, in the Holocene climatic optimum, when forests eventually covered approximately 47 per cent of its land area. The world's human population was about 5 million at this time and were living a Paleolithic lifestyle, though the very first agrarian societies were developing. The 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 8000 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. Describe the global *distribution* of forest land cover in the world today.
2. Investigate and describe the different types of forest biome shown in figure 8.1.
3. Describe the major differences in *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 Resource Assessment reports regularly released by the FAO (Food and Agriculture Organization) of the United Nations:
 - a. Discuss the importance of the attempts by the FAO to regularly collate information on forests.
 - b. Analyse the reliability of this data, taking into consideration the methods used in its collection and the sources of the data the FAO collates.

Deforestation

Forests are cleared and modified as a source of wood and non-wood 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 completely 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 degree of *change* in land cover, as can be seen in figure 8.7.

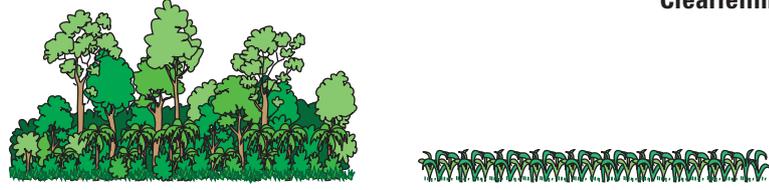
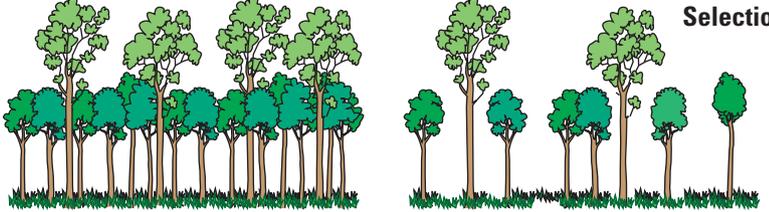
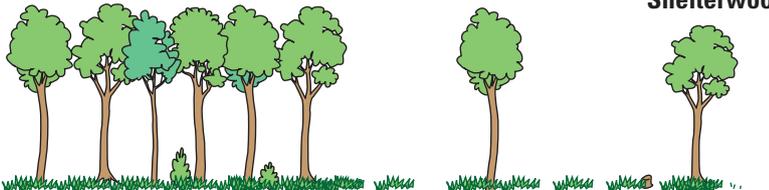
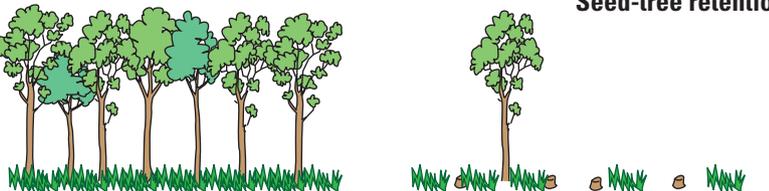
Forests subjected to modification through human activities such as selective logging, replanting and fuelwood collection are not classified as deforested, but are deemed to have experienced *forest degradation*. The FAO defines 'deforestation' as the long-term reduction of tree canopy cover to below 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

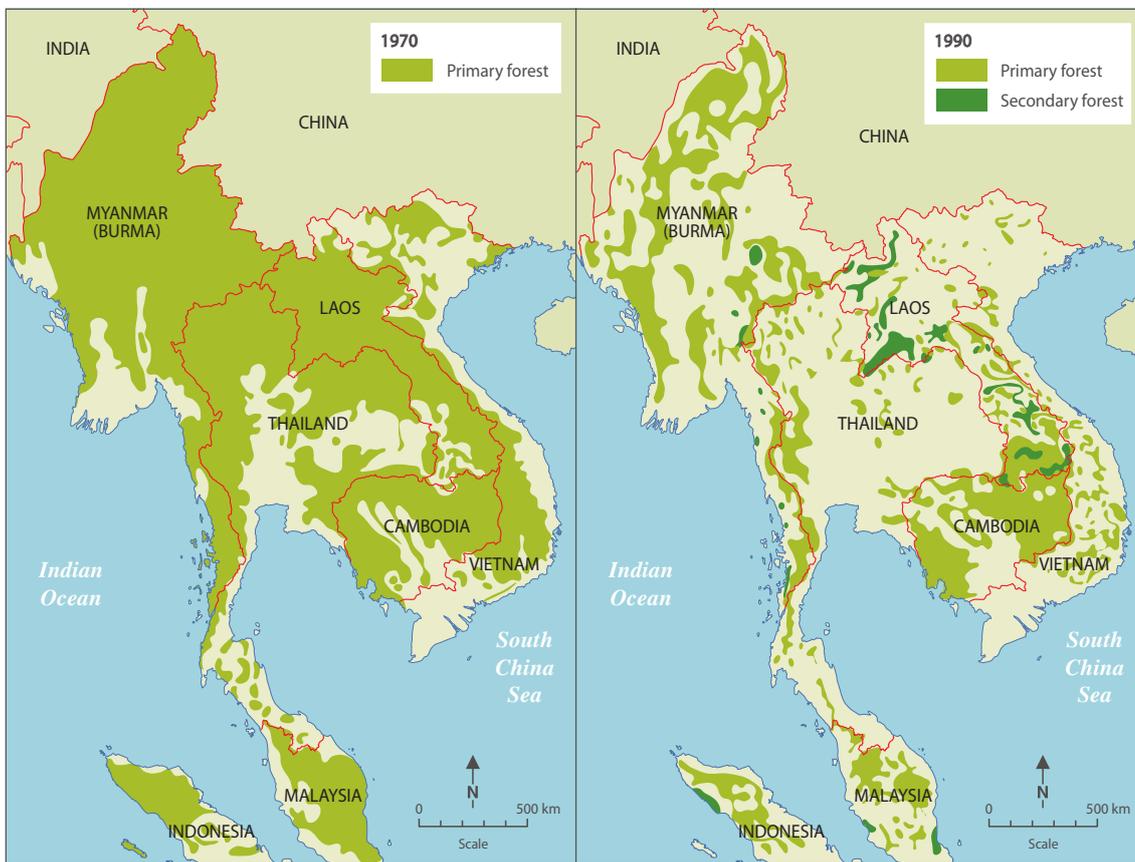
through *processes* such as selective logging or the development of secondary forest.

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, leading eventually to deforestation. Figure 8.8 shows how this occurred in South-East Asia during the *region'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. Net *change* in the extent of forest is calculated from the difference between deforested land and forest gain from afforestation. 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. Forestry activities may also involve post-logging *reforestation* of land through seeding or replanting.

► **Figure 8.7**
Systems of forest management used in forestry

 <p style="text-align: right;">Clearfelling</p>	<p>Large sections, or all vegetation, are cleared.</p>
 <p style="text-align: right;">Selection</p>	<p>Selected trees are felled. Understorey remains intact.</p>
 <p style="text-align: right;">Group selection</p>	<p>A section of the forest (called a 'coupe') is completely cleared.</p>
 <p style="text-align: right;">Shelterwood</p>	<p>Only the mature trees are felled, with an interval before the next set of mature trees are subsequently felled.</p>
 <p style="text-align: right;">Seed-tree retention</p>	<p>Most trees are removed but some are left to reduce environmental impacts and assist with forest regrowth.</p>



▲ **Figure 8.8** Change in land cover in South-East Asia, 1970–1990, resulting from the fragmentation of its forest

The distribution 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 agricultural revolution. 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 1.8 billion hectares. Cultivated land now constitutes approximately one-quarter of the Earth's terrestrial surface.

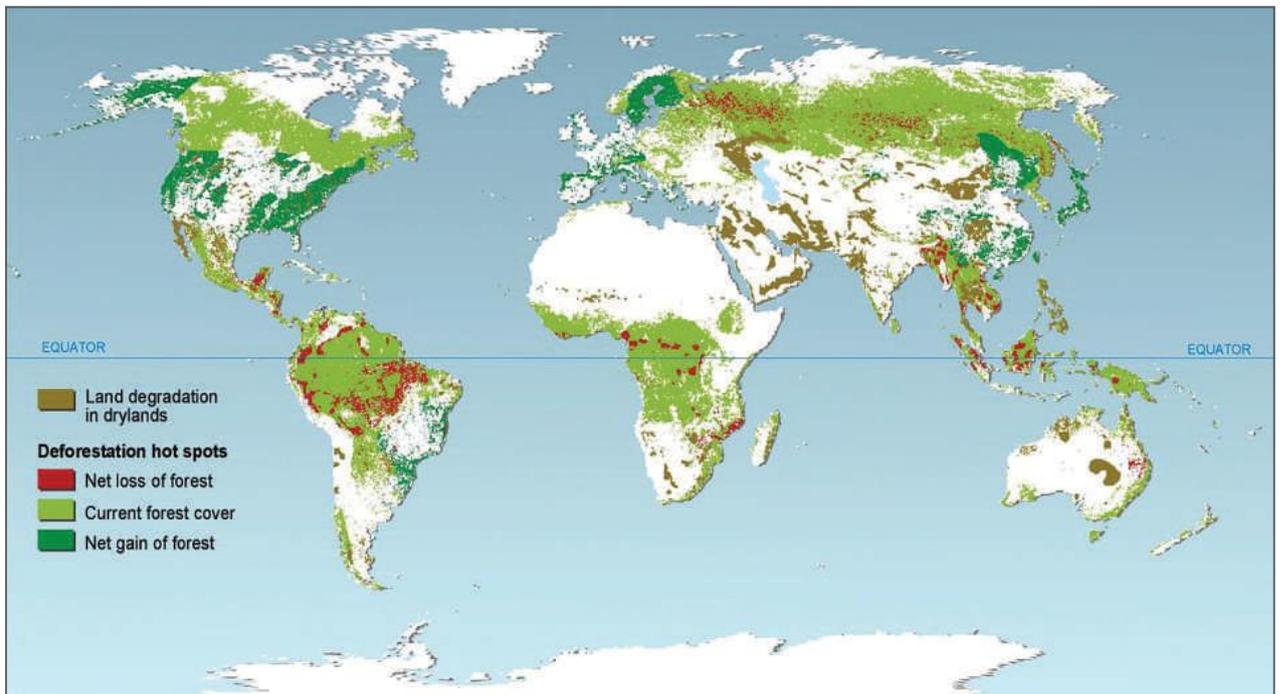
Over the last decade a number of nations have actually increased their net forest cover through either afforestation or arresting deforestation, or a combination of both. But many of the *regions* of the world grappling with extreme poverty are now witnessing accelerating rates of deforestation. Figure 8.9 (overleaf) shows the worldwide *distribution* of deforestation.

Until the mid-twentieth 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 lowest point, covering less than 10 per cent of its land area. Much of Europe's forests were already lost by the time of the Industrial Revolution, which accounts for the fact this continent has the least number of primary forests remaining today. Croplands expanded rapidly in Europe after 1700, and in North America, Australia and northern Asia

after the mid-nineteenth 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 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 also contributed.

By the middle of the twentieth 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 twentieth century due to the 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 (page 103) shows this pattern of forest loss.

As can be seen in figures 8.11 and 8.12 on page 103, there are currently huge *regional* variations in the degree of deforestation and net forest *change*. The FAO estimates 13 million hectares of forest were lost each year around the world in the period 2000–10, a reduction in forest loss from the 16 million hectares per year recorded during the 1990s. Taking into account afforestation figures, the net deforestation during 2000–10 was 5.2 million hectares per year, a 37 per cent reduction on the 8.3 hectares per year of the previous decade. But net forest loss in tropical forests of the developing world averaged over 12 million hectares per year over the past two decades. About 30 countries currently have annual rates of deforestation in excess of 0.5 per cent, and unless measures are taken to arrest



▲ **Figure 8.9** Global forests and deforestation

this deforestation these countries are set to lose most, if not all their forests by the end of this century.

Meanwhile, most countries with temperate and boreal forest ecosystems are experiencing stable or increasing forest land cover. This includes most of the industrialised parts of the world and some emerging economies in Asia including China, India and Vietnam. This increase is generally due to reduced rates of deforestation and through afforestation, with a net average increase of 3 million hectares per year. China, for example, has planted approximately 80 million hectares of trees over the last 60 years.

There has also been a *change* in the quality of forests worldwide, with one of the most significant trends

being the reduction in primary forests. Each year since 1990, 6 million hectares of primary forest are lost or modified through downgrading to secondary forest, and about 2.8 million hectares of plantation forests are added to global forest stocks.

Human activities overwhelmingly account for these *changes* in land cover, but natural *processes* are also at play. Australia recorded the second highest rate of forest loss of all the nations in the world over the period 2000–10 largely as a consequence of its decade-long drought and the widespread bushfires this fuelled over the first decade of the twenty-first century.

▶ ACTIVITIES

1. Explain the difference between 'deforestation' and 'forest degradation'.
2. Investigate the deforestation of Easter Island and explain how the unsustainable use of forests is thought to have contributed to the demise of its first Polynesian settlers.
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 estimates 13 million hectares of forest across the world have been lost each year over recent years, with a net loss of 5.2 million hectares per year when afforestation is taken into account.
 - a. Explain the term 'net forest *change*' and how it is calculated.
 - b. Calculate the area of your school or suburb in hectares to put these figures into context. Estimate how many of your school's or suburb's 'equivalents' are lost each year, in terms of area, due to deforestation.
6. Use the data in figures 8.11 and 8.12 to describe in detail the current *regional* trends in deforestation, using examples and quantification.
7. Refer to the information provided in the text and figure 8.12.
 - a. Describe the major trend in the relative contribution of primary, secondary and plantation forests to the world's total forest land cover.
 - b. Comment on the implications of this *change* for the environment.
8. Access the most recent edition of the FAO's Global Forest Resources Assessment Report. Identify the countries that currently have high rates of deforestation, in excess of 0.5 per cent, and create annotations for each such country, including their rate of deforestation. Using a copy of the map shown in figure 8.9, label this map with the prepared annotations.
9. 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 and figures 8.10 to 8.12 as well as the map in figure 8.1.

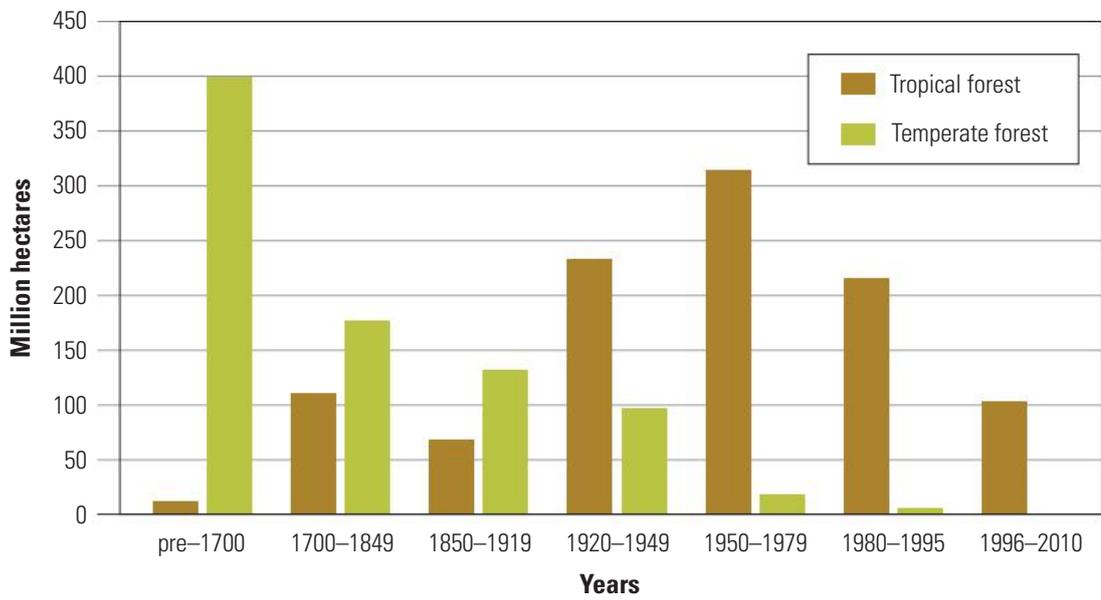


Figure 8.10
Estimated deforestation by type of forest and time period, 1700–2010

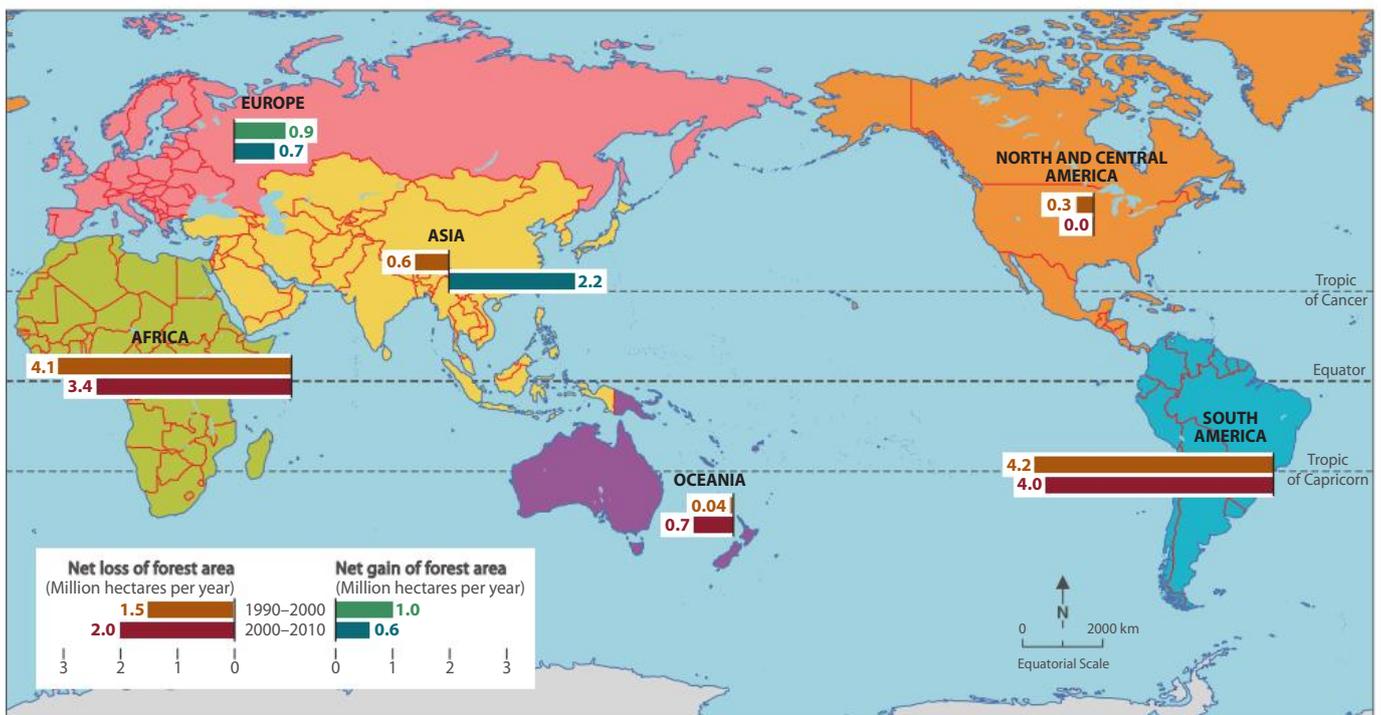


Figure 8.11 Annual change in forest area by region, 1990–2010

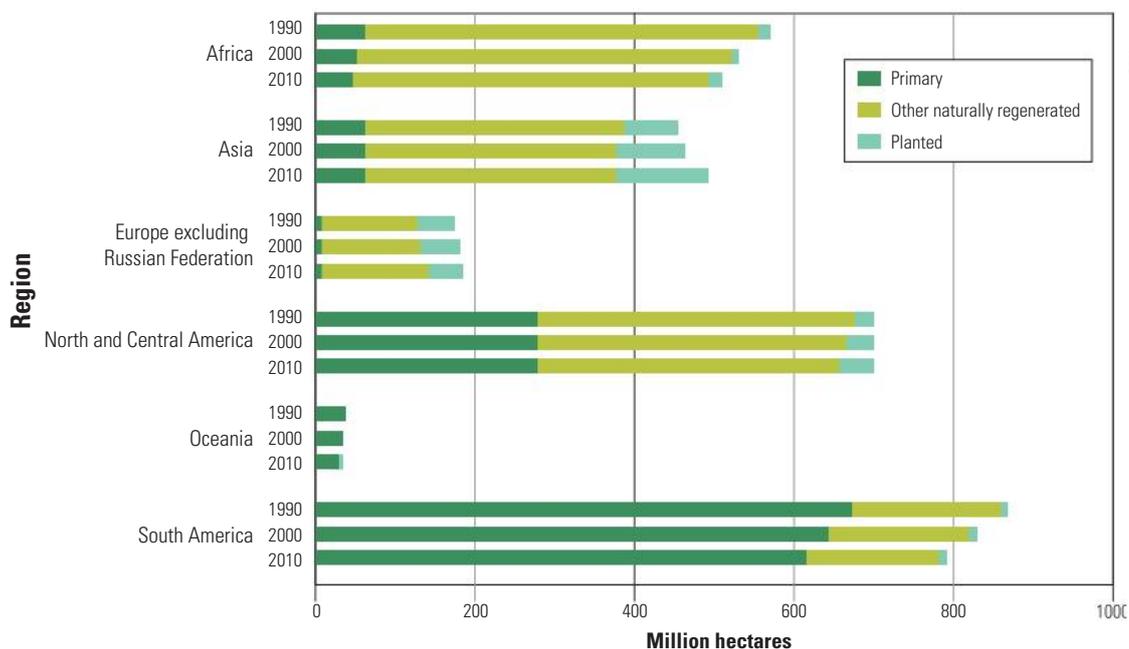


Figure 8.12
Trends in forest characteristics by region and subregion, 1990–2010

The causes of deforestation

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 probably responsible for approximately 74 per cent of global deforestation, while logging contributes approximately 19 per cent and fuelwood collection about 6 per cent. While subsistence farming has been the main driver of deforestation prior to the twentieth century, its role has diminished since the 1950s. There are significant variations in the causes of deforestation, as is shown in figures 8.13 and 8.14.

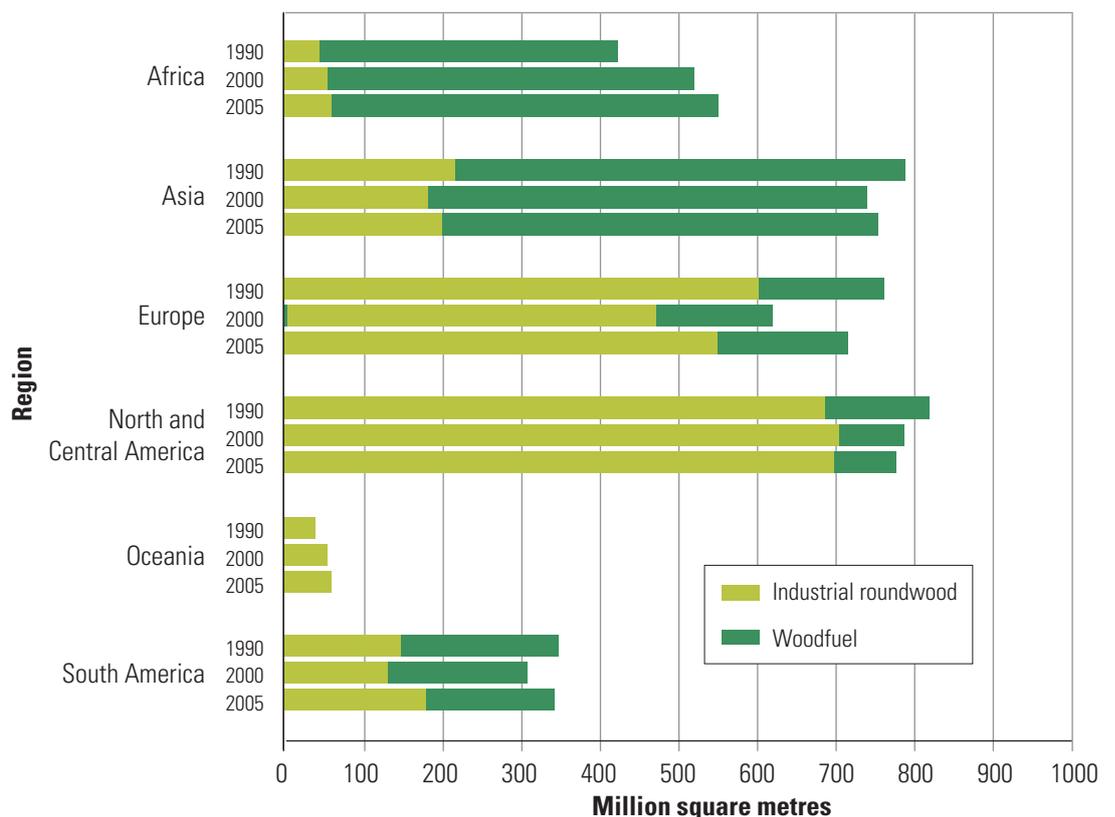
While logging and agriculture are the main direct causes of deforestation, a number of social, political and economic factors are indirect 'drivers' of deforestation:

- ▶ 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' inevitably leads to illegal logging, and illegal trade in timber and forest products.
- ▶ As can be seen in figure 8.15, many countries with large areas devoted to forests have been susceptible to corruption and poor forest management 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 gain with insufficient attention to the broader and long-term benefits of intact forests. Currently an estimated US\$30–100 billion per year is generated by illegal logging, often fuelling regional conflict in addition to environmental losses.

▼ **Figure 8.13** The main causes of deforestation in *regions* of the tropical world

	MAIN CAUSE OF DEFORESTATION
South America	Timber logging and agriculture, particularly cattle ranching, and soy and sugar plantations
Central America	The conversion of forest to small farms for pasture and cropping
South-East Asia	Logging for timber and large-scale plantations for palm oil, coconut, teak and rubber
Africa	Small-scale activities such as subsistence agriculture, fuelwood collection and charcoal; a growing presence of foreign timber countries

▼ **Figure 8.14** Trends in wood removals, 1990–2005 (million m³)



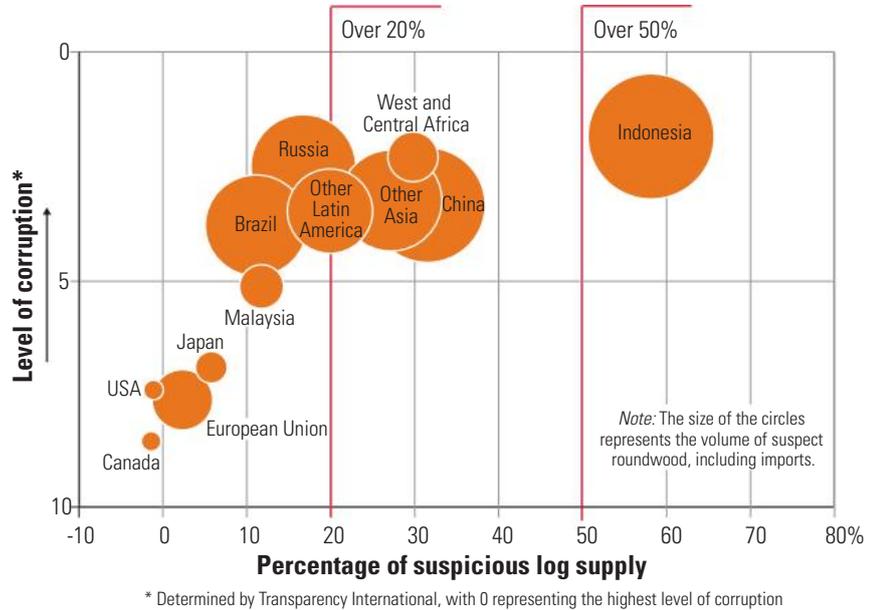
► Issues regarding land rights and forest ownership hamper effective forest management, particularly among indigenous minorities and forest-dependent rural communities. The system of land tenure determines who can use the land and access its natural resources, who can make decisions regarding its management, 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 forest. One example is the civil disruption in Rwanda 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 the protected of the mountain gorilla was deforested.
- Economic growth is the underlying driver of deforestation and forest degradation. 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.

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 tsunamis. 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 are dwarfed by the human activities directly causing deforestation, and many factors classified as natural *processes* may be exacerbated or caused by human activities. Annually, each type of disturbance affects less than 2 per cent of global forest land cover, although on a local or *regional scale* they can be very disruptive. Storms and blizzards experienced in January 2008 in eight provinces in China, for example, caused great damage to 18.6 million hectares of forest.

Some of the more significant natural *processes* affecting forest land cover include:



▲ **Figure 8.15** Logging and corruption

- Insect pests and diseases affect less than 2 per cent of forest worldwide, 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 ponderosae*, 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 1 per cent of all forests worldwide. 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. The replacement of vast areas of tropical rainforest with impoverished weedy grasslands has been observed in parts of Indonesia and the Amazon Basin subsequent to widespread burning in the 1980s and 1990s.
- It is anticipated that climate *change* and El Niño events will influence forest cover — due to their impact on temperature and available moisture, as well as their influence on drought, forest fires, sea level, tropical storms and flooding. Some impacts of global warming include the *change* in the geographic range and species composition of forests, with forests 'migrating' in response to changing weather patterns, and climate-induced dieback, where forests lose health and die due to heat stress and aridity.

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, page 101).

▶ ACTIVITIES

- 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:
 - geologic time *scales*
 - the last 5000 years.
- Describe and explain the causes of deforestation and identify which cause you consider to have had the greatest impact for each continent over the last two centuries, justifying your choices.
- Refer to the graph showing the relationship between logging and corruption in figure 8.15. Describe the *spatial association* apparent in this graph, including any anomalies to this pattern.
- Predict the *region* you think is most likely to experience the highest rate of deforestation over the next decade, providing justification for your prediction.
- 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 most recent FAO Global Forest Resources Assessment report to support your explanation.

▼ **Figure 8.16** The benefits of intact forests on the environment, economic activity and social conditions

Environmental	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.
	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 <i>regions</i> 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.
Economic activity	The formal forestry sector employs over 13.7 million people across the world, and wood and manufactured forest products add more than US\$450 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 commercial products which generate US\$14 billion in international trade. 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 about US\$60 billion in 2009.
Social conditions	About 1250 million people live inside forests worldwide and are largely dependent on these areas for their subsistence, and just under 20% of the global population depend to varying degrees on forests for their livelihoods.
	As many as 300 million people worldwide depend substantially on forests for their nutritional needs, in the form of 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 40% of the developing world cook with fuelwood or charcoal, and many boil their water with wood. Wood 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.	

Impacts of deforestation

Forests provide a wealth of resources and services to people and are crucial to the sustenance of so many natural *processes* on which life depends. On International Day of Forests on 21 March 2014, the UN Secretary-General Ban Ki-moon delivered an address. The following is an extract:

Forests are the lungs of our planet. They cover one third of all land area and are home to 80 per cent of terrestrial biodiversity. They are crucial for addressing a multitude of sustainable development imperatives, from poverty eradication to food security, from mitigating and adapting to climate *change* to reducing disaster risk.

The Secretary-General's address emphasises the importance of forests to people not only for the numerous resources and income they generate, but also their benefits that go far beyond their utility as a source of timber and land. This includes the ecosystem services they provide, such as water filtration and regulation, carbon sequestration and climate stability, nutrient cycling, erosion control and the preservation of soil quality, in addition to the many social benefits they offer to people, such as their recreational, aesthetic and cultural values. Many of these benefits, summarised in figure 8.16, tend to remain 'invisible' in economic evaluations of forests and are therefore underappreciated. In West Africa, for example, over 4 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' aspect of 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.

Between 1960 and 2000 the world population doubled and the global economy increased more than sixfold. To meet this increased demand, food production increased by roughly two-and-a half times, installed

hydropower capacity doubled, wood harvests for pulp and paper production tripled and timber production increased by more than half. All these human activities have been major drivers of deforestation.

Deforestation has considerable impacts:

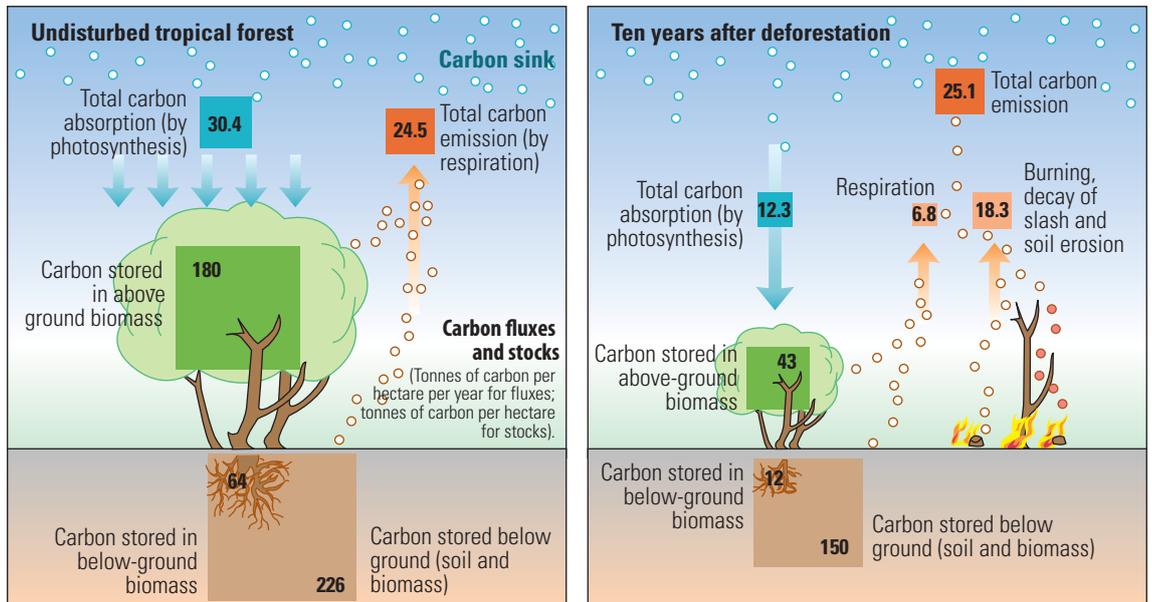
- ▶ the many ecosystem services forests provide are being degraded faster than they can recover, and collectively forest biomes have suffered the greatest environmental impact of all terrestrial biomes
- ▶ the number of species on the planet continues to decline, partially due to deforestation, and over 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
- ▶ deforestation accounts for around 10 per cent of the world's total carbon emissions, with the loss of tropical rainforests contributing nearly 20 per cent
- ▶ once forests are lost or degraded, most of their social benefits and many economic benefits, particularly of the informal forestry sector, may be lost.

Deforestation has a significant impact on global climates due to its influence on global carbon emissions. All plants store carbon absorbed over their lifetime 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 total carbon pool in all terrestrial ecosystems. The amount of carbon sequestered by forests varies according to the species, growth conditions and their age within successional dynamics; actively growing trees absorb more carbon dioxide than mature trees. But forests are also a source of atmospheric carbon when trees die and decay or are burnt, and the 'land use *change* and forestry' sector contributes 10 per cent to greenhouse emissions worldwide. Overall, however, forests provide a net gain in carbon storage. A 2007 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

▼ **Figure 8.17** (a) A man in Adarawa, Niger, collects fuelwood and (b) forest mushrooms and berries for sale at the Ancey Food Market, France



▼ **Figure 8.18** Tropical forests as carbon sinks and sources



would save the emission of 50 billion tonnes of carbon into the atmosphere. Figure 8.18 shows how forests sequester carbon and release it back to the atmosphere when deforestation occurs.

Well-managed forest ecosystems can also help in the adaptation 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.

Responses to deforestation

Forests are usually managed at a local and regional scale, with national governments establishing policies and laws to guide their management. But with 96 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-wood 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 Millennium Development Goals.

Most countries have forest management guidelines aimed at achieving sustainable forest use, but implementing these measures has been problematic. 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.

ACTIVITIES

1. Refer to the positive impacts of forests listed in figure 8.16. Categorise the scale each impact operates on; i.e. the local, regional or global scale.
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 help prevent climate change as well as assist in mitigating its impacts.
3. Create a concept map that outlines all the impacts of deforestation. Consider its positive and negative impact on social conditions and economic activity as well as its impact on the environment.

The use of spatial technology to address deforestation

Technological innovations involving remote sensing, spatial technologies such as Global Positioning System (GPS) 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. Complementing on-ground data collection with the use of aerial imaging means large areas of forest can be surveyed economically and accurately.

Remote sensing through aerial photographs, satellite, radar, laser scanners or 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 GPS can be used to produce maps or models using GIS for the analysis and recording of data.

While the use of remote sensing and spatial technologies can assist with *change* detection, there can be challenges associated with the use of this technology:

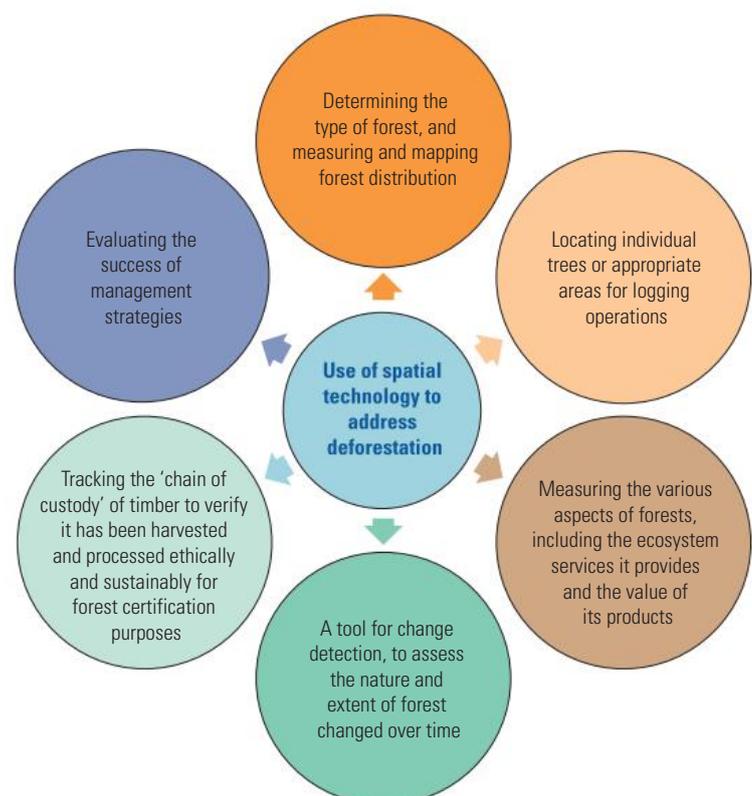
- ▶ cloud cover can hamper the analysis of aerial images and some remote sensing tools lack sufficient sensitivity to reliably measure aspects of forest
- ▶ estimates of forest cover or the type of forest can vary with different sources due to the use of different measurement techniques, technology and forest definitions, hampering comparison and analysis of *change*. 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)
- ▶ the difficulty in accessing spatial data from private forest holdings has been an obstacle to comprehensive forest monitoring in some *regions*
- ▶ 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 cloud-computing infrastructure networks.

The use of Landsat satellite images by the Brazilian Space Agency (for *change* detection) and Global Forest Watch provides two examples of how spatial 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 but reducing reforestation
▶ 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 <i>Lacey Act</i> in the United States and the <i>Forest Law Enforcement, Governance and Trade Action Plan</i> of the European Union)
▶ Providing communities in the developing world with alternative sources of fuel for domestic cooking and heating
▶ Accurately assessing the economic value of the non-formal 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 spatial technology to manage forests and address deforestation

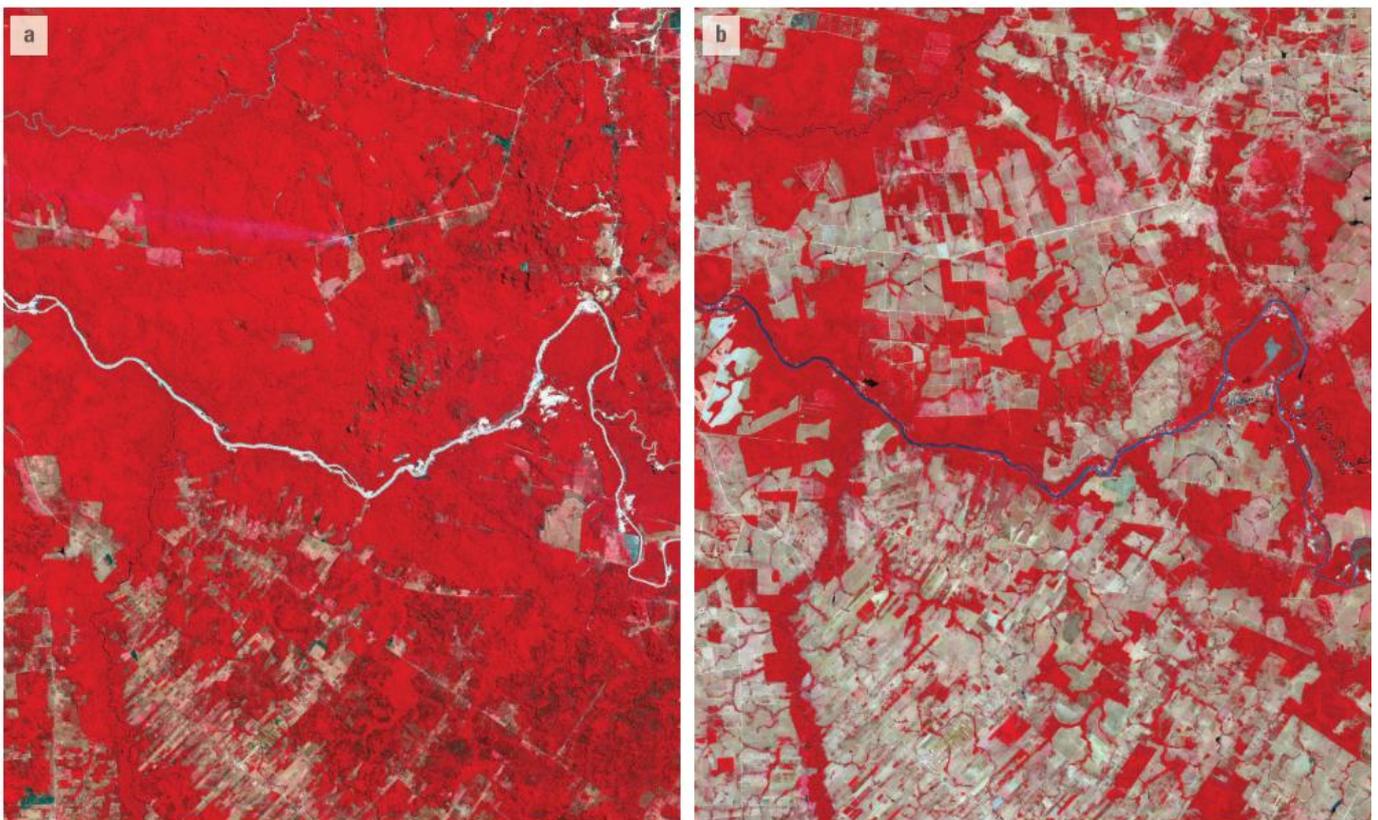


Case study: the use of spatial technology to manage the forests of Mato Grosso State, Brazil

The tropical forests of Latin America have sustained some of the highest levels of deforestation over the last 30 years, largely due to the expansion of large-scale agriculture in Brazil, which led to the rapid fragmentation of what was mostly primary forests of the Amazon. The use of spatial technology revealed the Brazilian state of Mato Grosso to be a hot spot for this land cover change. As an inland state deep within the Amazon rainforest, Mato Grosso was extremely isolated until railways and roads connected it with the outside world in the second half of the twentieth century. Large-scale deforestation began in the state in the 1970s due to the rapid expansion of soy plantations and accelerated in the 1990s when the number of cattle ranches more than doubled in the region. The satellite images in figure 8.21 show the systematic expansion of these large-scale farms, which consumed more than 540 000 hectares in the state between 2001 and 2004.

Brazil has one of the most technically advanced forest monitoring programs in the world and has taken significant steps to address this deforestation. Since the 1980s the Brazilian Space Agency has assisted with the production and interpretation of Landsat satellite images of the region, and this information has been used to enforce the environmental licensing system for rural properties that was introduced in 1999 to curb illegal logging. In addition, the Brazilian government introduced a moratorium on the expansion of all soy farms, and a consortium of the country's largest beef producers placed a ban on sourcing cattle from cleared forestlands. These strategies have allowed authorities to decrease deforestation in Mato Grosso by 93 per cent between 2004 and 2010, from 11 814 square kilometres to 828 square kilometres. This has been achieved while maintaining Brazil's lucrative soy and beef industries.

▼ **Figure 8.21** Landsat images of deforestation in Mato Grosso State, Brazil, in (a) 1992 and (b) in 2006. The red areas denote forest.



▶ 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 entail.
3. Investigate the *Lacey Act* in the United States and the *Forest Law Enforcement, Governance and Trade Action Plan* of the European Union, and describe how these regulations address deforestation.
4. Access YouTube video clips to find out more about the use of spatial technologies in forest management. Explore the use of technology to monitor and manage forests.
 - a. Describe how remote sensing is used to collect data about forest land cover.
 - b. Explain how the three-dimensional aspects of *places* are determined using GPS.
 - c. Explain how GIS is used to manage forest.
 - d. Outline the positive and negative aspects of using remote sensing to monitor forests.

▶ ACTIVITIES *continued*

5. Refer to the Landsat images of Mato Grosso in Brazil shown in figure 8.21.
 - a. Create an overlay map of the *region* for the two dates shown.
 - b. Label the following features: Rio Peixoto de Azevedo and the MT419 highway.
 - c. Use the *scale* to estimate the size of the area of forest loss between 1992 and 2004.
 - d. Referring to the key geographic concepts of *distribution* and *spatial association*, describe the *change* evident from these images, including quantification.
 - e. Discuss the similarities between your map and the use of GIS in forest management.
6. 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
 - ▶ global inequalities in wealth
 - ▶ products of cleared forestlands are globally traded commodities.

Global responses to deforestation

United Nations Forum on Forests

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 twenty-first 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. This has continued to be the focus of international efforts to address deforestation since.

The issue of deforestation has been relevant to a number of international agreements and conventions. However, it was not until the twenty-first 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 UNFF agreed on four shared Global Objectives on Forests:

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.
2. Enhance forest-based economic, social and environmental benefits by improving the livelihoods of forest-dependent people.
3. Increase significantly the area of sustainably managed forests, including protected forests, and increase the proportion of forest products derived from sustainably managed forests.
4. Increase financial assistance for sustainable forest management.

The objectives 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. The UNFF has established a *process* for the reporting on progress in *sustainable* forest management from the global level down to the forest management unit level, and has developed a set of indicators of forest condition and socioeconomic aspects. The *process* was introduced to improve the assessment of the true ecological and socioeconomic value of intact forests.

While the UNFF is still in its infancy, a 2005 review of its progress identified a number of areas in need of improvement:

- ▶ greater financial support for developing countries. This would enable them to implement sustainable forest-management practices; 'build 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
- ▶ introduction of mechanisms to measure the value of non-market forest products and uses. This would enable the true value of intact forests to be taken into consideration in decisions regarding forest use
- ▶ addressing the lack of a legally binding, international agreement on forests.



▲ **Figure 8.22** The Global Forest Watch website, showing an example of how the site can provide current information on the status of forests around the world

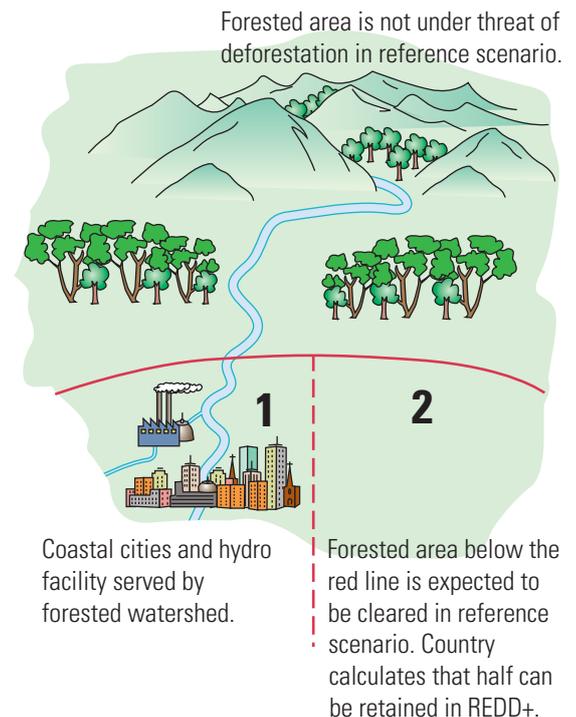
Global Forest Watch 2.0

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 (see figure 8.22). 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 worldwide *scale*. Cloud computing and open source software is used to rapidly *process*, interpret and send large volumes of satellite data, using GPS coordinates, by utilising clusters of servers scattered around the world. Smartphones can be used to download maps and satellite images, as well as upload GPS 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 UN Environment Program (UNEP). This technology will also assist forest certification organisations to track the chain of custody of timber and authenticate its origin.

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 on page 108. 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.



▲ **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

<p>Examples of initiatives that REDD+ funds includes projects which:</p> <ul style="list-style-type: none"> ▶ involve the sustainable production of wood and non-wood 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 degrade land 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. 	<p>Safeguards REDD+ projects must include:</p> <ul style="list-style-type: none"> ▶ identification of the key drivers of deforestation for the project's <i>region</i>, 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.
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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.

In 2008, FAO joined forces with the UN Development Program and the UN Environment Program to form UN-REDD to assist developing countries prepare and implement national REDD+ strategies. The program has US\$118 million funding committed for its projects, sourced from private and public funding. It is hoped REDD+ will halve deforestation by 2020, but this has

been estimated to require approximately US\$38 billion per year. 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 will hinge on the compliance with the safeguards and its capacity to fund projects. It will also depend 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 2012 study concluded the REDD program provides a unique opportunity to achieve large-*scale* emissions reductions at comparatively low costs, 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.

▶ ACTIVITIES

1. Investigate some of the international agreements and organisations involved with the conservation of the world's forests apart from UNFF. Describe their aims.
2. Write an essay evaluating the UNFF, discussing its strengths and weaknesses, and providing evidence for your viewpoint.
3. 'Good governance of the world's forests has to be more than just redrawing the lines on a map.' Discuss this comment and how it may pertain to the management of forests.
4. Refer to the information on Global Forest Watch in this chapter and visit their website:
 - a. Consider the strengths and weaknesses of Global Forest Watch program.
 - b. Develop criteria to evaluate its effectiveness in achieving *sustainable* forest management.
 - c. Evaluate its effectiveness against these criteria.
5. Visit the REDD website and investigate some of the programs it has engaged in within the developing world. Then carry out the tasks below.
 - 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.

Case study: Cameroon

With more than 20 million hectares of forest — slightly less than half the nation's land area — the forest sector of Cameroon contributes significantly to its economy as well as forest resources and important environmental services. Much of the southern half of the country is dominated by dense tropical rainforest which forms part of the Lower Guinean forest of Central Africa, one of the continent's biodiversity 'hot spots' renowned for its high number of endemic species.

Forests play a critical role in providing income and meeting the day-to-day needs of the people of Cameroon. Some examples are listed below.

- ▶ Timber is an important commodity for the domestic and export market, with the formal timber sector contributing US\$695 million to the Cameroon economy in 2011, which is 2.82 per cent of its GDP and significantly higher than the global average of 0.9 per cent. Timber also generates thousands of jobs in the formal and informal sector.
- ▶ Fuelwood is the most important energy source in the Cameroonian household, supplying 68 per cent of fuel for cooking.
- ▶ 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-wood 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 a small number of indigenous pygmy communities who still lead a traditional, hunter-gatherer existence.

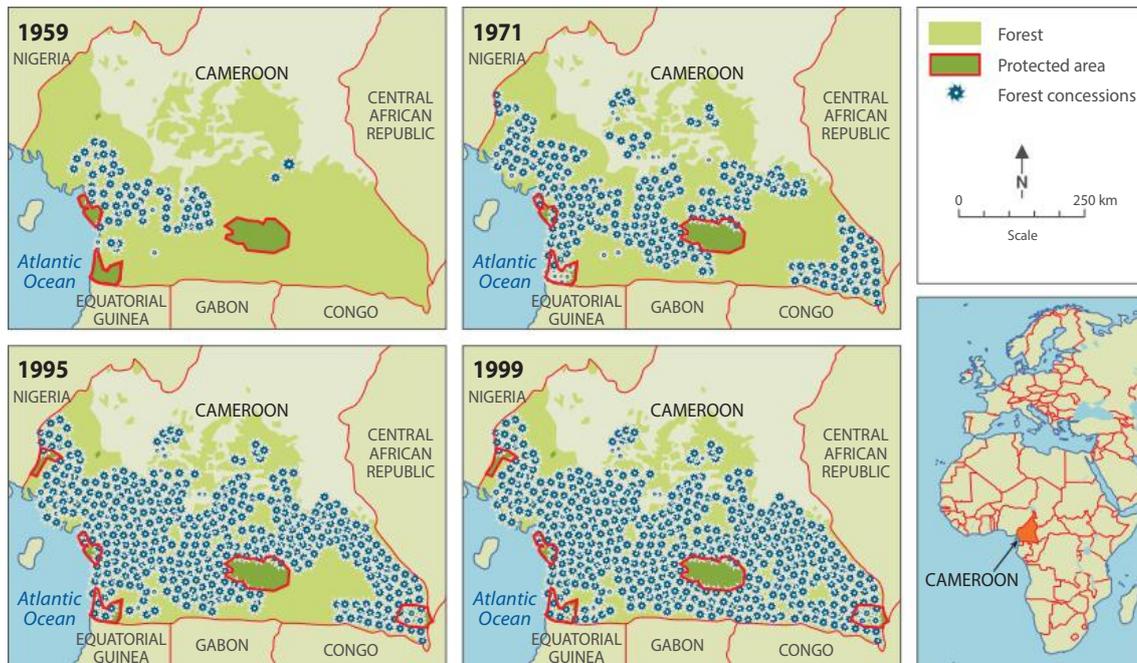
Over recent years Cameroon has recorded some of the highest rates of deforestation within the forests of the Central Africa. Agriculture and logging are the main direct causes of this forest loss. Historically, 'slash and burn' subsistence agriculture and small-*scale* commercial farming of cash crops including cocoa and coffee have been the main cause of deforestation. However, since the 1980s the large-*scale*, commercial monoculture of rubber, palm oil, tea, sugar cane and bananas have increased as contributing factors, and have caused the loss of approximately 30 per cent of the original forest cover. More recently, the use of palm oil for biofuel has driven the expansion of this land use, as can be seen in figure 8.25.

Logging has played a significant role in undermining Cameroon's forests. Small-*scale* informal logging, deemed 'artisanal sawing', has been traditionally carried out in the forestlands near large towns in Cameroon to meet the timber needs of local people, though fuelwood and charcoal comprise the largest market for forest products. 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, and the industry reached its peak in the 1990s. The growth in concession allocation and consequent deforestation is evident in figure 8.26. Between 1986 and 2004, forest land cover was lost at a rapid rate as the income from the forestry sector experienced a fivefold increase.

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 in Cameroon. Some examples of factors having a significant impact on Cameroon's deforestation are outlined on the following page.



▲ **Figure 8.25** A palm oil plantation in development in south-western Cameroon



▲ **Figure 8.26** The increase in forest logging concessions in southern Cameroon, 1959–99

- ▶ 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 such as subsistence agriculture.
- ▶ Corrupt practices are endemic in Cameroon's forestry sector. One of the most highly criticised past practices was the allocation of logging permits under the *petits titres* system: the granting of such 'concessions' on 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. 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.
- ▶ 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.

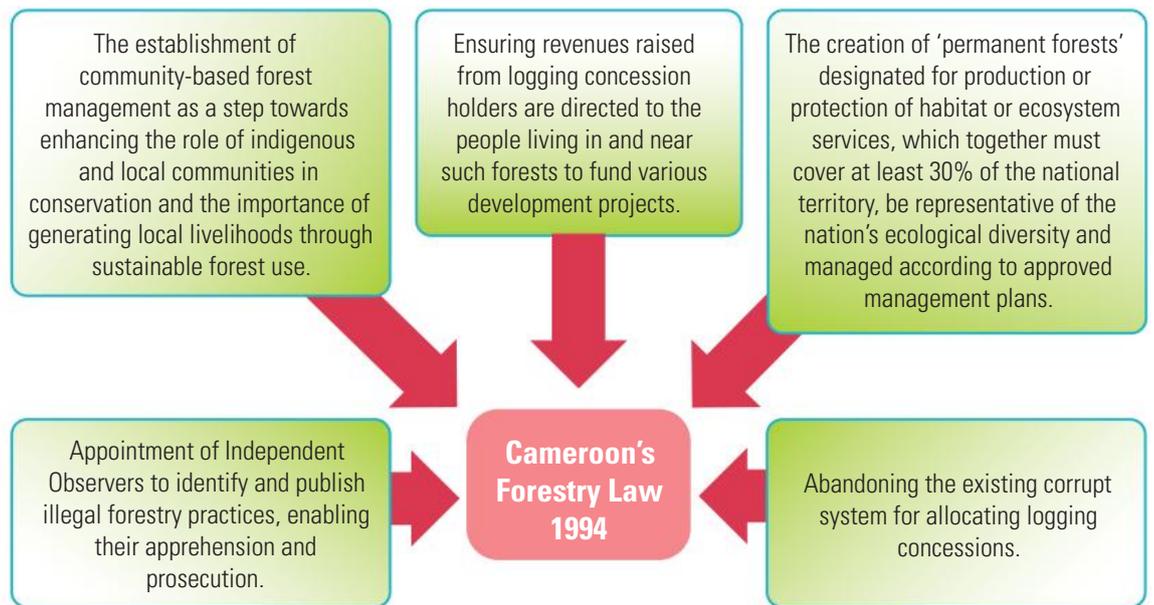
- ▶ Government policies and management have often influenced deforestation through pricing policies to encourage cash cropping, providing infrastructure in and to remote forest areas, changing the value of the currency which boosted logging operations, and failing to protect the rights of local forest-dependent communities.

Concern over the rapid rate of forest loss triggered the introduction of the forestry reforms of the Forestry Law in 1994. Some of the key aspects of the reforms are shown in figure 8.27 (overleaf).

Despite the forest reforms, deforestation rates initially continued to rise and peaked at over 1 per cent by 2010. However, Cameroon's forest management has seen an improvement in forest governance since 2011:

- ▶ 73 per cent of forestlands were devoted to production and 20 per cent to conservation and water protection, while 1 per cent was devoted to 'social services'
- ▶ 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
- ▶ 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.

Despite these successes, there have been some failures in Cameroon's efforts to address deforestation.



▲ **Figure 8.27** Key aspects of Cameroon's Forestry Law of 1994 (and related legislation)

The efforts to direct revenue raised from logging concession fees to the people living in and near such forests has only been partially successful due to poor forest management. While the work of Independent Observers has led to the prosecution of the perpetrators of illegal forest activities, between 2001 and 2007 fewer than 15 per cent of the fines were paid and many fines are negotiated down. Only 39 per cent of forested areas were covered by a management plan by 2010, and a review of these plans found them generally to be of poor quality. Over the period 1990–2010, total forest area declined — from over 24 million hectares to under 20 million hectares. Furthermore, the rate of deforestation was above the average rate for the Central African *region*, for the African continent and the global average for this period.

While there have been some successes, the reforms of the 1994 Forestry Law have been hampered by a lack of technical and workforce capacity for monitoring forest activities, in addition to the entrenched corruption. A 2003–04 evaluation suggested about three-quarters of Cameroon's forests had been disturbed to some degree, and the Forest and Environment Sector Program, in its assessment of the effectiveness of the reforms, gave Cameroon a 45 per cent rating for the implementation of its Forestry Law.

▶ ACTIVITIES

1. Use the internet to investigate and evaluate the two REDD programs in Cameroon:

- ▶ Mt Cameroon, south-west *region* of Cameroon
- ▶ Payment for Services in the south and east of Cameroon.

Include an evaluation of the programs.

2. Summarise for Cameroon:

- ▶ its location and land cover, including a location map and a map of its forests
- ▶ *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*.

Conclude with an evaluation of the efforts to manage deforestation.

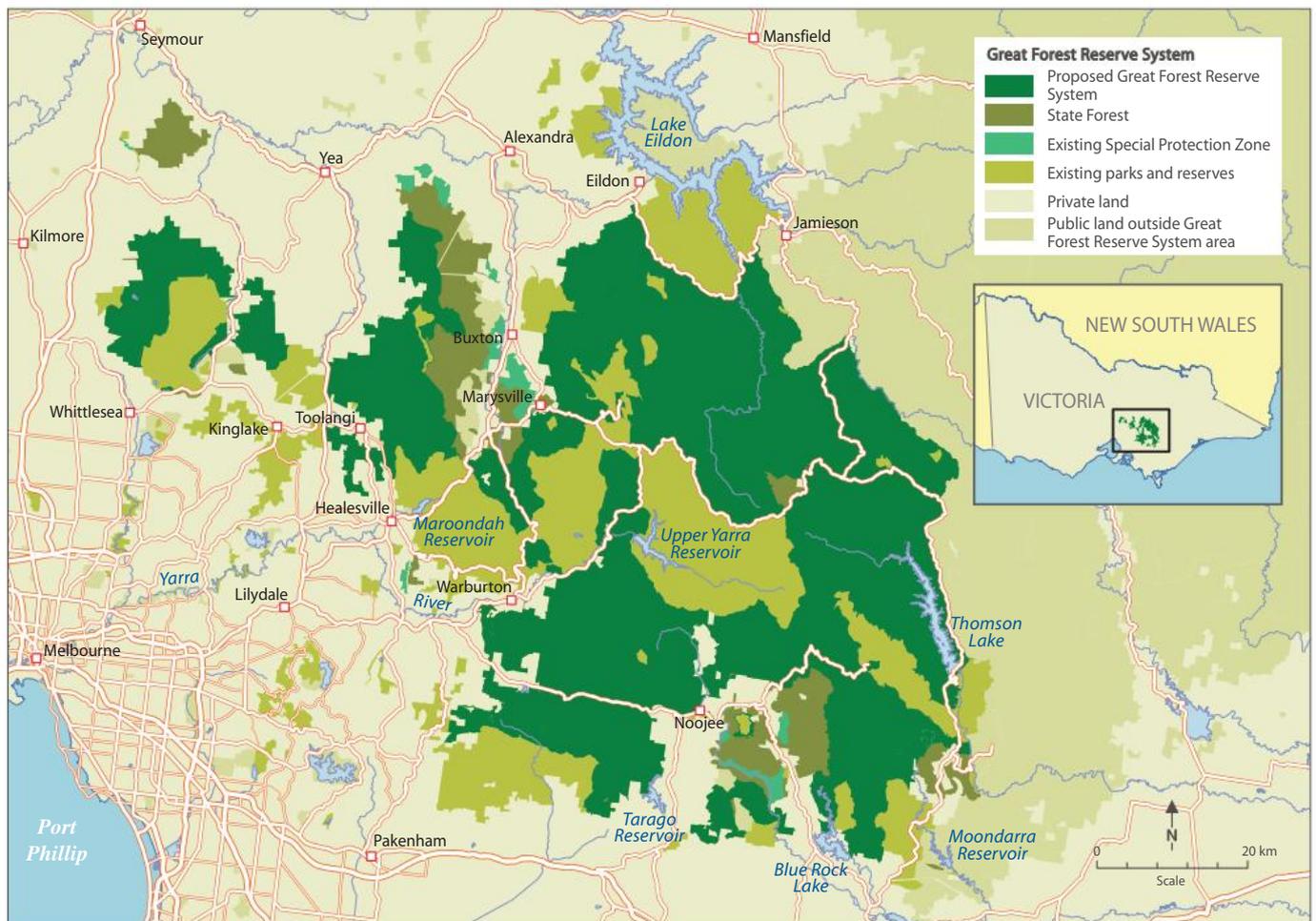
3. Access the World Resources Institute interactive map of Cameroon. View the different types of land use and land cover that can be accessed from this site.

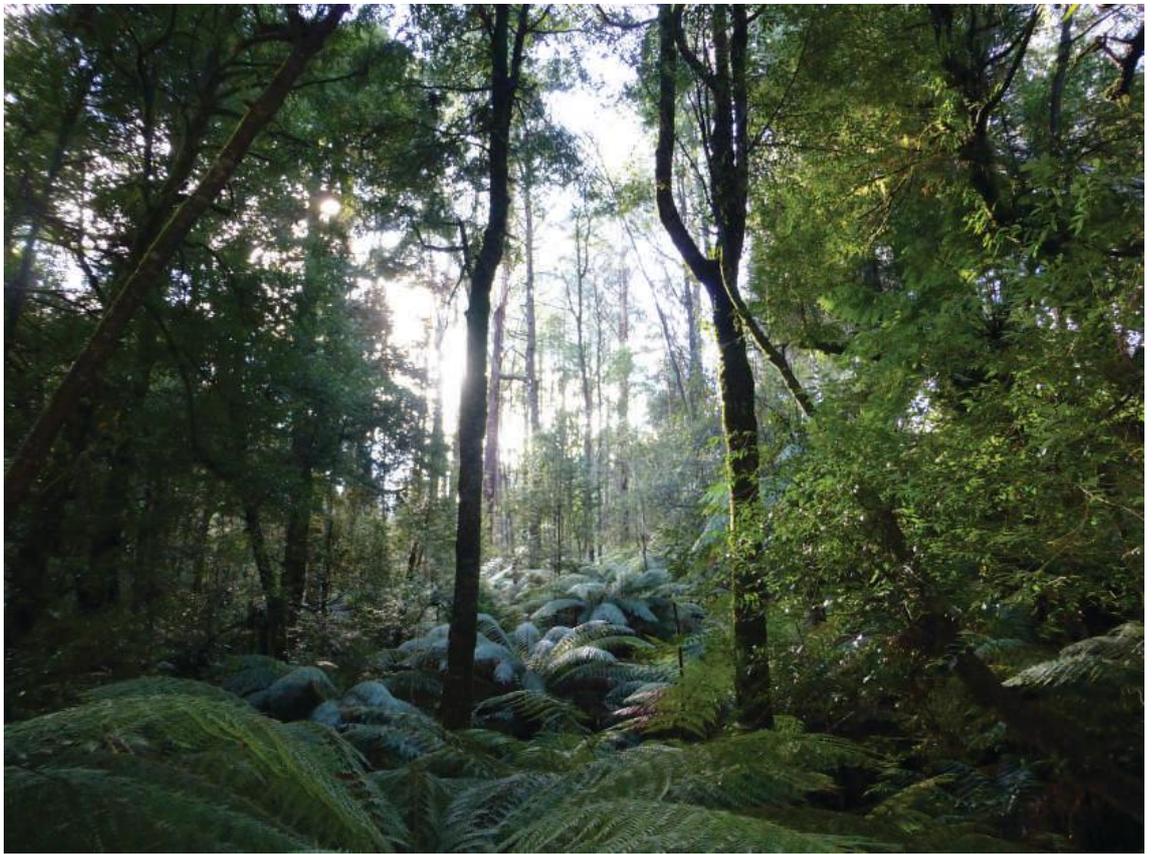
Case study: The forests of the Central Highlands of Victoria

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. 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. The logging occurs under a 20-year Regional Forest Agreement established in 1998, and is conducted by VicForests.

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 will add 355 000 hectares to existing national parks and reserves, and will connect the existing forests of the *region* and step up the level of protection afforded to the remaining old growth forests (see figure 8.28).

▼ **Figure 8.28** The Proposed Great Forest National Park, Central Highlands of Victoria





▲ **Figure 8.29** 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 interactive map of the *region* to supplement the information provided in this text. Create a report on the proposed Great Forest National Park, including:
 - a. an outline of the *region'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*.



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.

9

Land cover change: desertification

Introduction

Life on Earth is dependent on air, water and land. Land, and its surface layer of soil, is an important link in the water cycle, filtering, storing and releasing water. It helps regulate climate by absorbing and re-radiating the sun's energy and storing carbon. The land supplies people with 99.7 per cent of their food kilojoules as well as many energy resources, landscapes and landforms.



▲ **Figure 9.1**
A farmer struggling with a badly degraded landscape in Niger, Africa

The Earth's crust is up to 40 kilometres thick, but it is the thinnest layer (0.0003 per cent of the entire radius of the planet) that is the soil layer. Although soil is regarded as a renewable resource, the natural *process* of soil formation can take up to 500 years to replace just 25 centimetres of topsoil. It is estimated that by 2030 the world's demand for food will increase by 50 per cent, but to *sustainably* manage such growth will require careful management of farmland and soils.

Universally, soil is being lost from our agricultural *regions* at 10 to 40 times faster than the rate of soil formation through the *process* of land degradation. There are many different types of land degradation. These include wind and water erosion, soil salinity and water logging, deforestation, pest invasions, soil and water pollution, weed infestation and desertification.

Globally, 1.9 billion hectares of land is degraded; this has a negative impact on more than 1.5 billion people. There is a strong *spatial association* between countries with large-scale land degradation and low levels of economic development, especially in *places* where people's livelihood is directly linked to the land, as in figure 9.1.

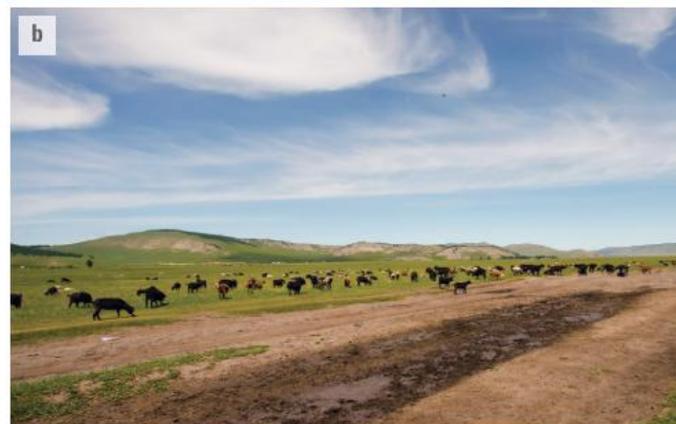
What is desertification?

Desertification is the loss of previously productive land in specific dryland *regions* of the world. It is an extreme form of land degradation — a *process* of land becoming more arid and desert-like. It is the result of the combination of both natural *processes* and human activities. Desertification is responsible for large-scale *changes* in land cover. Currently, 169 countries are affected by desertification. Their *distribution* can be seen in figure 9.2.

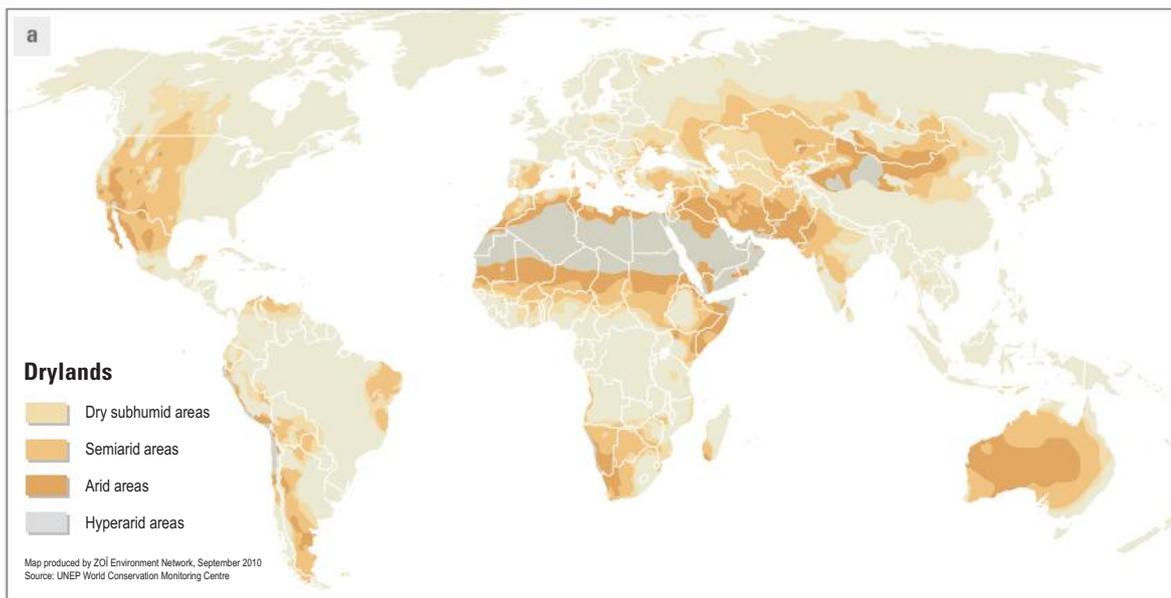
What are drylands?

Drylands are *regions* of the world that are climatically zoned as arid, semiarid and dry subhumid. They are defined by the United Nations Convention for Combating Desertification (UNCCD) as having a growing season of between one and 179 days. Deserts, or hyperarid zones, are not included as they usually cannot support rain-fed agricultural production. The classification and features of the different types of drylands can be seen in figure 9.3.

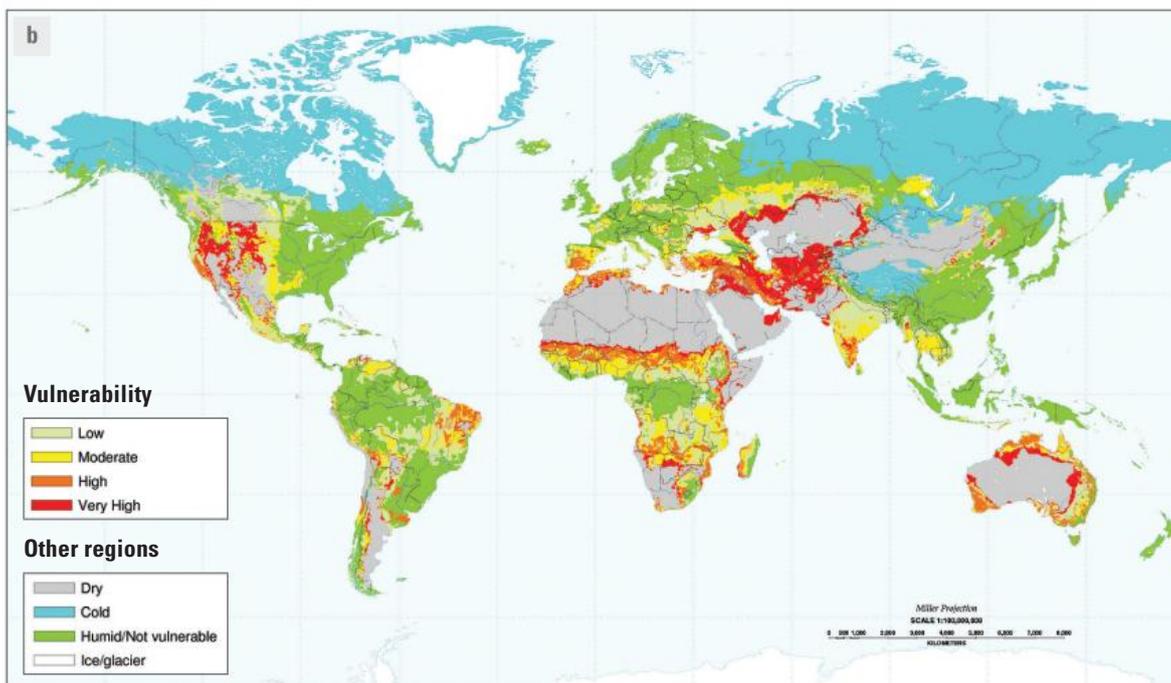
Approximately 40 per cent of the world can be classified as drylands covering a range of different landscapes and environments, from grasslands, forests and agricultural lands to urban centres. *Places* such as Cairo, Mexico City and, in Victoria, Horsham and Swan Hill are all located in drylands. Figure 9.4 illustrates typical dryland *regions* of Mongolia and Australia.



▲ **Figure 9.4** Typical dryland landscapes in Australia (a) and Mongolia (b)



◀ **Figure 9.2**
(a) Global distribution of hyperarid and dryland areas



◀ **Figure 9.2**
(b) Regions vulnerable to desertification

▼ **Figure 9.3** Classification of hyperarid and dryland areas

TYPE AND EXAMPLES OF HYPERARID AND DRYLANDS	ECOSYSTEM	CLIMATE	AREA (million square kilometres)	PERCENTAGE	LENGTH OF GROWING SEASON (days)
Hyperarid (Sahara Desert, Africa; Gibson Desert, Australia)	Desert	No seasonal rainfall pattern. Very little human activity possible.	9.8	6.6	Nil
Arid (Sahel region, Africa; Patagonia, South America)	Semi-desert	Annual precipitation highly variable. Average between 200 and 300 millimetres	15.7	9.6	1–59
Semiarid (Mongolia, Asia; western New South Wales, Australia)	Grasslands	Highly seasonal rainfall between 500 and 800 millimetres. Moderately variable from year to year.	22.6	15.2	60–119
Dry subhumid (south-west Western Australia; mid-west region, U.S.A)	Rangelands*	Rainfall more reliable and rain-fed** agriculture widely practised.	12.8	8.7	120–179
			60.9 (total)	40.3 (total)	

*Rangelands are *places* where there is a mixture of grasses, shrubs and scattered trees.

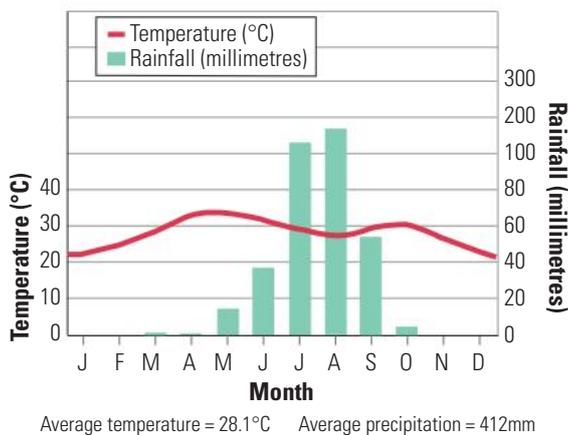
**Rain-fed farming relies totally on rainfall and there is no irrigation.

Geographic characteristics of drylands

There are a number of geographic features that distinguish drylands from other environments. The main features are described below.

- ▶ The predominant feature of drylands is water scarcity, with low, irregular and unpredictable precipitation, seasonally, annually and spatially. Figure 9.5 illustrates the climate patterns for Zinder, a semiarid location in Niger.
- ▶ Precipitation can often be in the form of short, heavy falls which are not readily absorbed by the soil; this means that up to 90 per cent of rain is evaporated. In arid and semiarid zones more water is evaporated than falls over the average year.

▼ **Figure 9.5** Climograph for Zinder, Niger

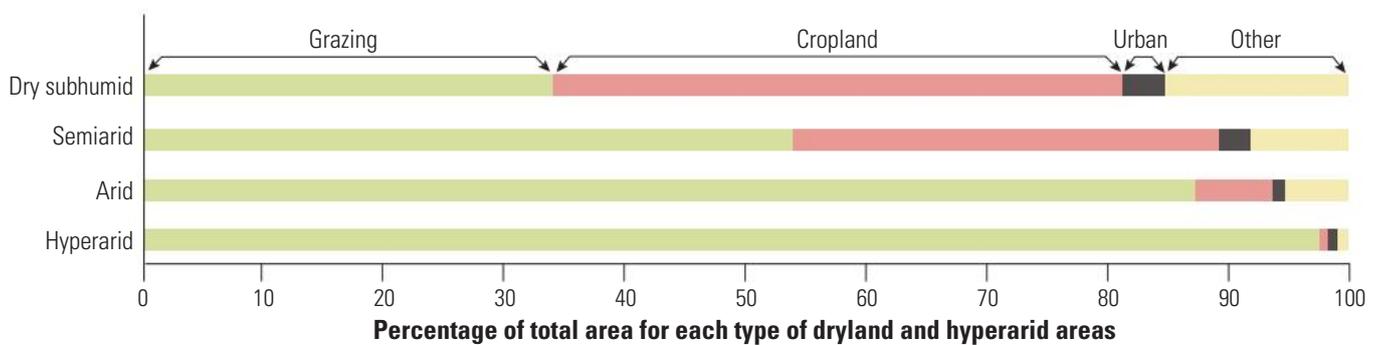


- ▶ Dryland areas are generally very windy as there is less dense vegetation to reduce wind speeds.
- ▶ Strong winds and bare soils produce frequent dust storms; soil fertility tends to be poor, with little organic matter and low soil moisture.
- ▶ It can take 5–10 times longer for the natural regeneration of vegetation and soils in drylands compared to other *places* that receive greater and more reliable rainfall.
- ▶ Dryland ecosystems are prone to desertification as they are vulnerable to over-exploitation and inappropriate land use by people.

Economically, drylands support 44 per cent of the world's food production systems and 50 per cent of the world's livestock. They are home to one-third of global population. However, indicators of wellbeing, such as Gross National Income per capita (GNI) and education levels, are all lower in dryland *regions* compared to other environments where rainfall is higher and more reliable.

Typical land uses in drylands can be seen in the following graph, figure 9.6.

▼ **Figure 9.6** Land uses in drylands and hyperarid areas



▶ ACTIVITIES

1. Why is desertification considered a global-scale issue?
2. Why are drylands important?
3. Refer to figure 9.1. List the possible difficulties people would have farming in this environment.
4. Use figure 9.2 to describe the *distribution* of those *regions* of the world with a high risk of desertification.
5. Use figure 9.2 to describe the *spatial association* between the *distribution* of *regions* with a high risk of desertification and the different types of drylands.
6. Identify the characteristics of drylands that make them vulnerable to desertification (see figure 9.4).
7. List three differences between drylands and hyperarid or desert *regions*.
8. Refer to the climograph for Zinder, figure 9.5, and use data from the graph in your answers.
 - a. Using an atlas or Google Earth describe the location of Zinder.
 - b. Which months receive the most/least rainfall?
 - c. Given that 92 per cent of the precipitation that falls in Zinder each year is in the form of thunderstorms, what impacts might this have on the environment?
 - d. Describe the seasonal variation in temperatures for Zinder.
9. How might the climate pattern of Zinder influence the type of agriculture that takes place in this *region*?
10. Refer to figures 9.3 and 9.6. What is the relationship between the types of dryland, the length of the growing season and land use?

What is the *process* of desertification?

Desertification is the *process* by which land in dryland *regions* becomes more arid and desert-like. There is no one single cause of desertification; rather it is the interconnection of many factors, including human activities and climatic variations. In dryland *regions*, the combination of drought and desertification is responsible for *changing* 12 million hectares of land into desert-like environments each year. This same area has the potential to produce 20 million tonnes of grains per year. There is a wide range of direct and indirect factors contributing to the *process* of desertification.

Environmental factors

The loss of vegetation cover is the main cause of desertification as, in many *regions*, wood is the main energy source for cooking, heating and construction. For example, between 50 and 90 per cent of energy used in Africa is derived just from wood clearing, as seen in figure 9.7. Grazing animals, such as cattle, sheep and goats, also contribute to the decline in vegetation cover, especially grasses and small shrubs. Trees are often considered by farmers to compete with crops for water, soil nutrients and space, and are therefore removed. Deforestation exposes soils to wind and water erosion.

Prolonged drought contributes to the loss of vegetation and animals, and subsequently increases people's vulnerability to poverty. The drought in the Sahel *region* of Africa, in 2014, affected the livelihoods of 20.2 million people across the countries of the western Sahel, many of whom were still recovering from previous droughts. Drought does not necessarily cause desertification and the land can usually recover afterwards. However, extended periods of drought

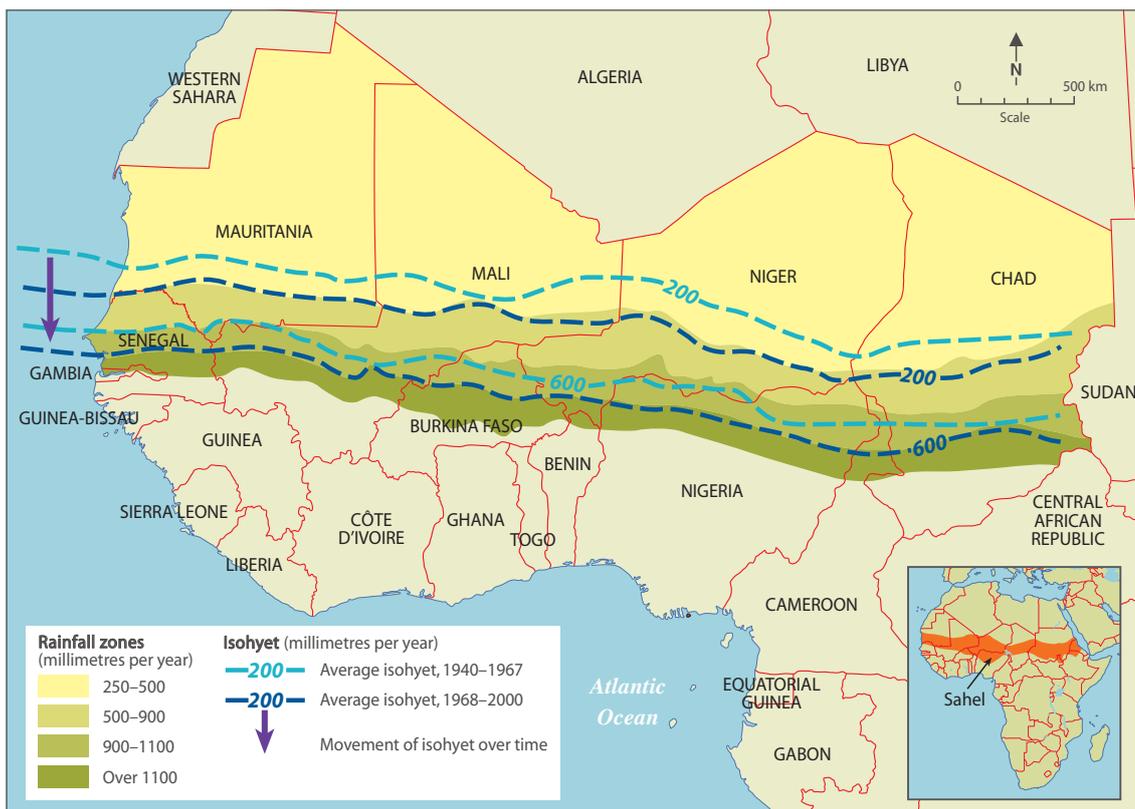
and *unsustainable* use of the land can contribute to desertification, as the *processes* of deforestation and soil erosion occur at a faster rate than soil recovery.

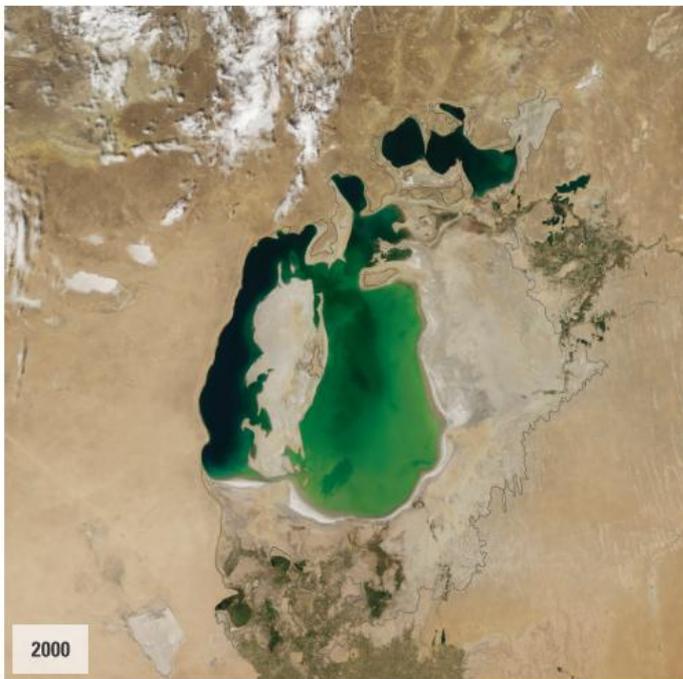
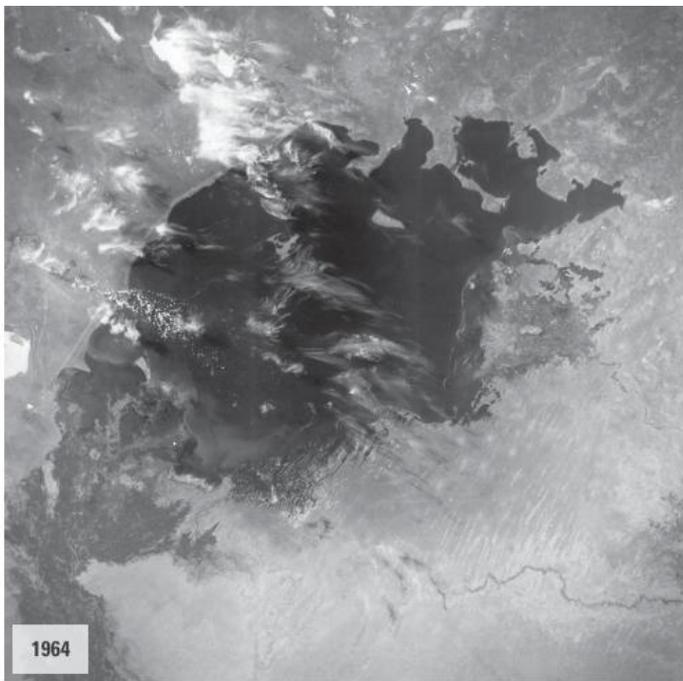
Climate *change* is also compounding the problem. Increased temperatures stress vegetation while *changing* patterns in the amount and the *distribution* of rainfall, and more severe storms, can lead to further erosion of already fragile soils. A desertified *region* can also *change* climate at the local *scale*. Without vegetation cover there is lower humidity, fewer clouds, more sun and, thus, higher temperatures and less precipitation. Figure 9.8 shows the *change* in climate patterns in the Sahel *region* of Africa.



▲ **Figure 9.7** Collecting firewood for fuel is a major cause of desertification around the world.

▼ **Figure 9.8** Changing climate patterns in the Sahel





Excessive water added to soils can cause water-logging or rising watertables which create a *movement* of toxic salts towards the surface and into the roots zone of plants. This results in a *change* in land cover as vegetation dies off and the land becomes degraded. Nearly one-third of the world's irrigated land is at risk from salinity, such as 50 per cent of farmland in Turkmenistan, 23 per cent in China and 20 per cent in Pakistan.

The use of irrigation, in *places* where sufficient water is available, can also contribute to desertification, as has been the case for the Aral Sea in central Asia. Once the fourth largest lake in the world, the former lake has now shrunk by 90 per cent and created the Aralkum Desert, the youngest human-made desert in the world, with an area of 45 000 square kilometres. The progressive shrinking of the Aral Sea is shown in figure 9.9. During the 1960s, the former Soviet Union created a large-*scale* irrigation scheme to grow cotton and other crops around the Aral Sea. Water was diverted from the Syr Darya and Amu Darya rivers, cutting off the supply to the Sea. By 2005 the water level had dropped 23 metres. High evaporation rates and minimal inflow of water caused the salinity level of the water to rise. The shrinking of the lake brought a *change* in land cover as the salty seabed, heavily polluted with chemicals from agricultural run-off, was exposed. The native vegetation cover was reduced by 40 per cent which then exposed soils to wind erosion. In all, six million hectares of agricultural land became desertified. Further impacts of the drying out of the Aral Sea are described below.

- ▶ There has been an increase in dust and salt storms, with salt making up to 30–40 per cent of dust volume in summer and as much as 90 per cent in winter.
- ▶ At the local *scale*, weather patterns have *changed* with shorter and hotter summers and longer, colder winters. Precipitation has reduced significantly which has had an impact on populations and agriculture in the *region*.
- ▶ A once-thriving commercial fishing industry collapsed, with annual catches dropping from 43 430 tonnes to zero in just 20 years.
- ▶ Declining soil quality has required additional inputs of fertilisers which have then further polluted any surface and groundwater resources.
- ▶ As little as one-fifth of the irrigation actually reaches the crops, evaporating or soaking through the irrigation channels. Much of the irrigated land now suffers from salinity, which requires more fresh water to help flush the soils out.
- ▶ The health of people in the *region* has deteriorated significantly. Salty and dusty air and polluted waters have increased infant mortality rates and the incidence of heart and kidney disease, and cancers have increased.

Efforts to help restore the Aral Sea saw Kazakhstan build a dam in 2005 between the now separated northern and southern parts of the sea (see figure 9.9). Any water that does flow in will stay in the North Aral Sea. The South Aral Sea is considered to be 'beyond saving'.

▲ **Figure 9.9** The changing *distribution* of water in the Aral Sea

Liz and husband Tony,
at Abreha We Atsbeha,
northern Ethiopia



CAREER PROFILE

Elizabeth (Liz) Rinaudo

Volunteer Assistant, Farmer-Managed Natural Regeneration

Although I have not formally studied Geography since Year 10, the Rural Science degree I completed included geology, agricultural geology, pastoral systems, agricultural ecology and an emphasis on understanding the whole system rather than a single part of it. As my husband Tony and I worked in Niger Republic for 17 years, it became really important to understand the interactions between people, the climate and the land, and what was needed to start to repair the damaged ecosystems — studies that current Geography courses offer in formal education in secondary and university levels.

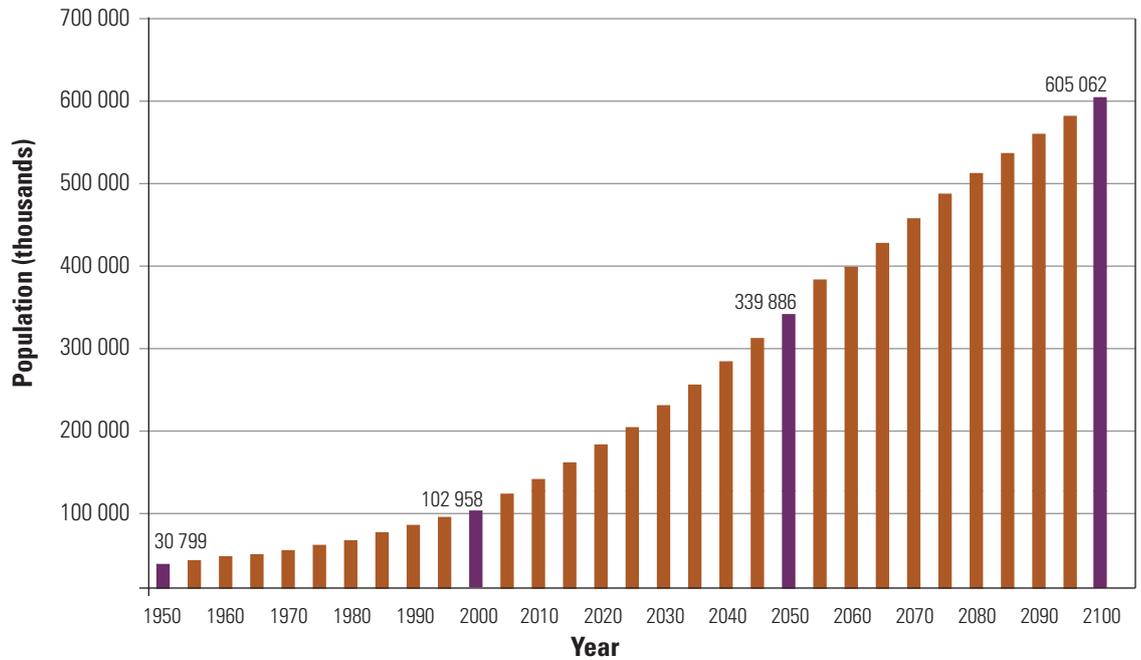
My work has been very diverse. In Niger (1981–99), I was part of a team that was working to improve agricultural productivity and increase the resilience of the environment and the human population to the many challenges that faced them. These included plant, human and animal diseases; insect pests; erratic rainfall patterns producing both droughts and floods; high temperatures; and social and economic factors.

Since 2012, I have worked as a volunteer assistant promoting the uptake of Farmer-Managed Natural Regeneration of trees.

I travel with my husband to many developing countries and together we participate in conferences, run workshops and encourage government, non-government, community-based, faith-based and research organisations to take up environmental restoration and implement Farmer Managed Natural Regeneration.

I use a lot of Geography skills and knowledge in my work — the water cycle, the impact of weather, geology, topography, human activity and the nutrient cycles — all influence soil degradation and restoration. When the farmers understand that deforestation disrupts the water cycle and the soil nutrient cycles, reducing both physical and biological resources and increasing natural disasters (such as flash flooding, droughts and landslides), it strengthens their enthusiasm to change the way they manage forests and land.

The study of Geography is an excellent base for anyone who wants to work in rural areas in less developed countries because it is such a broad-based discipline which brings together the understanding of physical and human factors that have an impact on the environment.



Social factors

Some 2.3 billion people in nearly 100 countries live in drylands. Rapid population growth drives an increasing need for dryland ecosystems to provide food, water, animal feed, building materials and fuelwood. Across the Sahel *region* of Africa the population increased by 30 per cent in just ten years from 2000 to 2010 (see figure 9.10). The United Nations Food and Agriculture Organization (FAO) predicts the demand for food will increase by 60 per cent by 2050. To meet this demand, an additional 120 million hectares of land will be needed, more than the entire area of Victoria and New South Wales combined. Unless either crop yields and/or the amount of land under cultivation increase significantly or the population growth is lessened, then food insecurity may result. The two most important methods to help slow population growth are ending child marriages or delaying the start of child-bearing years and providing voluntary family planning. Both of these steps aid in the empowerment of women.

Economic factors

Poverty is both a cause and a consequence of desertification. In *places* where there are few, if any, alternative sources of income to subsistence farming, people often have no choice but to *change* the way they use the land to meet their needs. This may mean decreasing the length of the fallow (soil-resting) period and continually overcropping and overgrazing. Such *unsustainable* farming practices can result in significant land cover *change*, as can be seen in figure 9.11.

Overgrazing

Allowing too many cattle, sheep or goats to graze the same area of land reduces the vegetation cover. Grazing becomes *unsustainable* when there is insufficient time for plants to recover, exposing the soil to trampling, compaction and erosion, as can be seen in figure 9.12.

Mongolia, now the world's second-largest exporter of cashmere wool, has seen an 80 per cent loss in vegetation cover due to overgrazing by the rapidly growing population of cashmere goats.

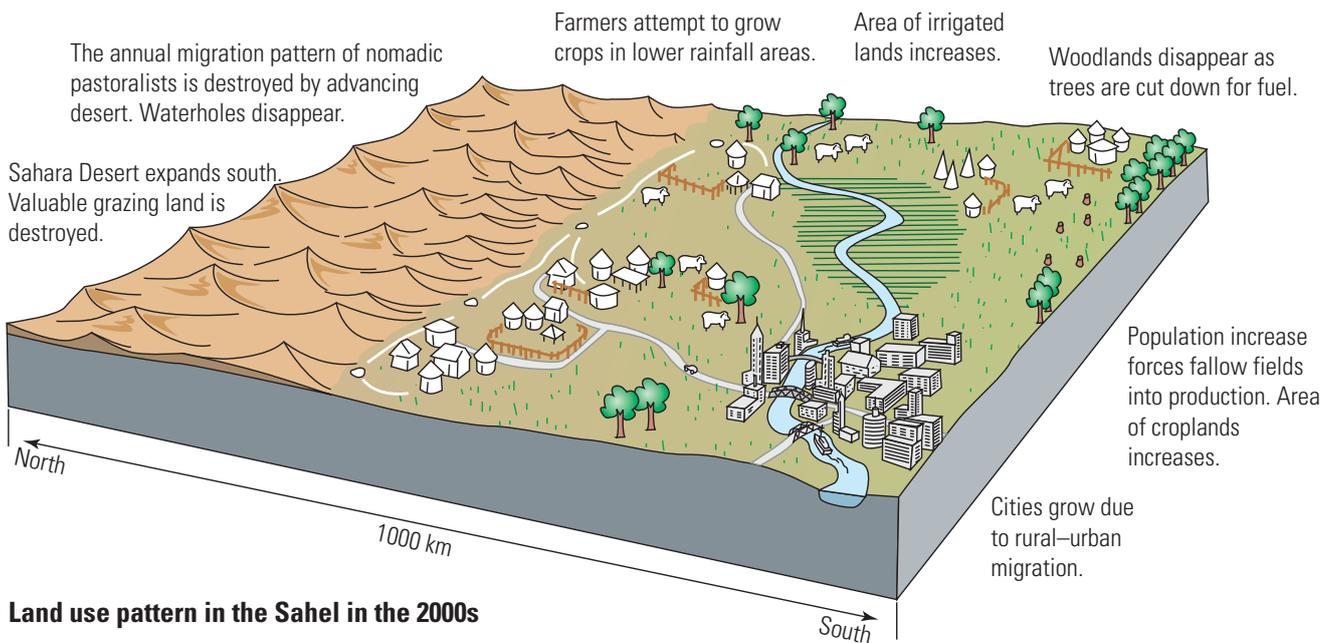
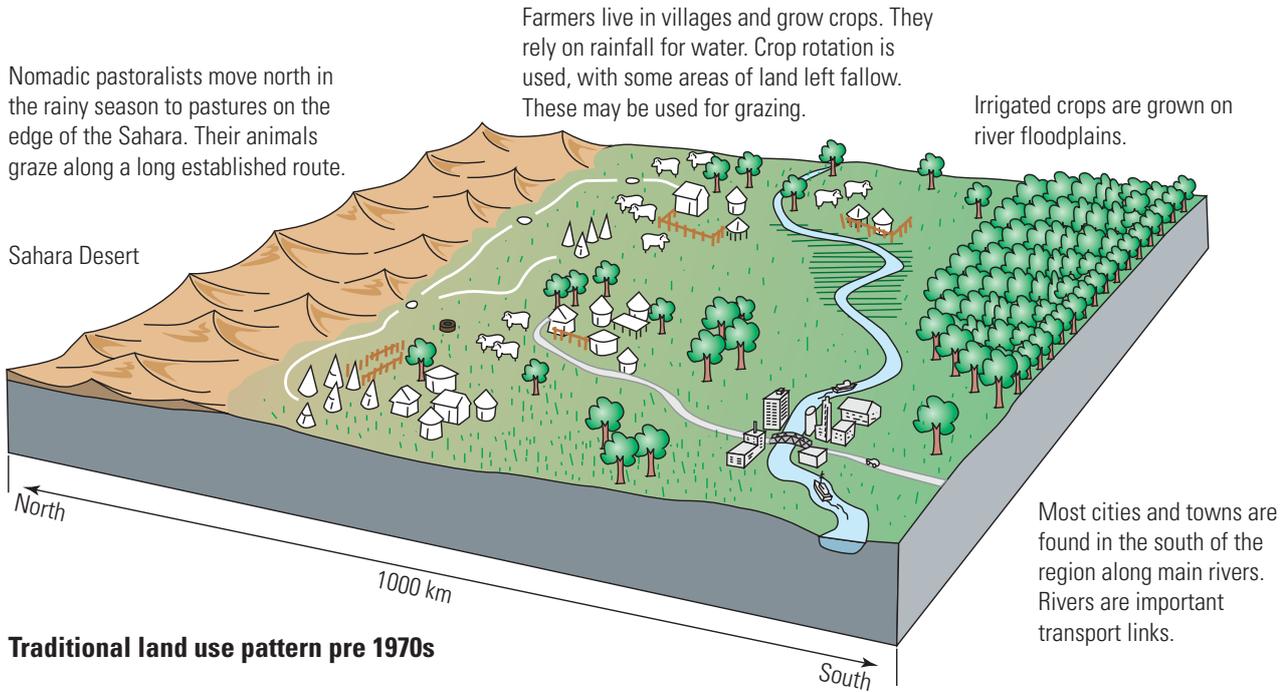
In dryland *regions*, increases in herd populations have occurred for a number of reasons:

- ▶ Animals are a form of wealth and status among many groups of people.
- ▶ As populations increase, there is a need for more animals — for milk, meat, skins and other products.
- ▶ Improvements in veterinary care, vaccinations and breeding programs have improved the health and life span of animals.
- ▶ Animals can be reared for export, thus improving both the local and national economies. Often farmers might keep larger herds to hedge against the risk of falling prices.



▲ **Figure 9.12** A badly eroded landscape in Niger

▼ **Figure 9.11** Land cover *change* in the Sahel



Overcultivation

Overcultivation occurs when the same land is used repeatedly without the benefit of soil rest and recovery. Consequently, soil fertility declines, vegetation fails, and the land becomes barren and vulnerable to degradation. Increasing pressures to produce more food, the expansion of cropping into marginal lands that are unsuitable for farming, and the frequency of drought have been contributing factors.

Political factors

In some *places* in the world, for example Niger and Mali, governments are often under pressure to provide even the basic human needs. Therefore, environmental concerns get little attention or money allocated to them. Often there are insufficient or inappropriate laws, especially dealing with land and resource ownership.

Nomadic farming is a traditional method of grazing animals in drylands as it allows the herders to move in response to rain and the availability of animal pasture. Sixty-five per cent of drylands are rangelands, more suited to grazing than cropping. Over the past decades, government policies and tighter border controls between countries have restricted the *movement* of nomadic herders. In Inner Mongolia, the Chinese government introduced new methods of managing

Deforestation

Vegetation plays a critical role in protecting land from degradation and especially desertification. Deforestation occurs in drylands when farmers remove unwanted trees from cropland, trees are cut down for firewood or animals graze on low-lying plants and shrubs. The loss of vegetation land cover can then have an impact on other aspects of the environment as figure 9.14 illustrates.

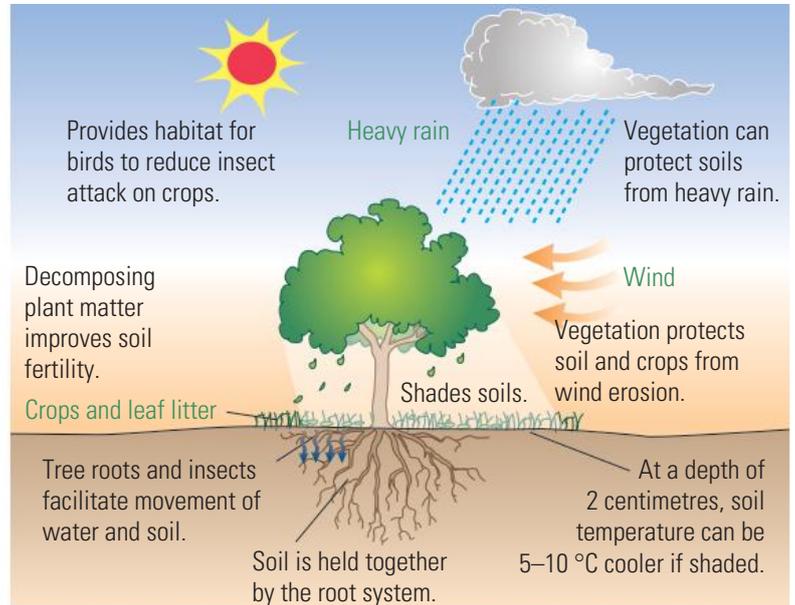
Soil erosion

Land that is unprotected by vegetation is exposed to both wind and water erosion. Short, heavy downpours of rain strip the top fertile layers of soil and wash it away, as can be seen in figure 9.1. Strong winds are responsible for lifting unprotected soil and *moving* it long *distances*. Scientists have tracked soils blown from northern Africa to *places* such as North America (see figure 9.15), London and the island of Crete in the Mediterranean Sea.

In hot and dry conditions, exposed soils can develop a crusted surface which further reduces water infiltration. Any rain that falls on a compacted surface will tend to run off quickly and not be available for plant roots.

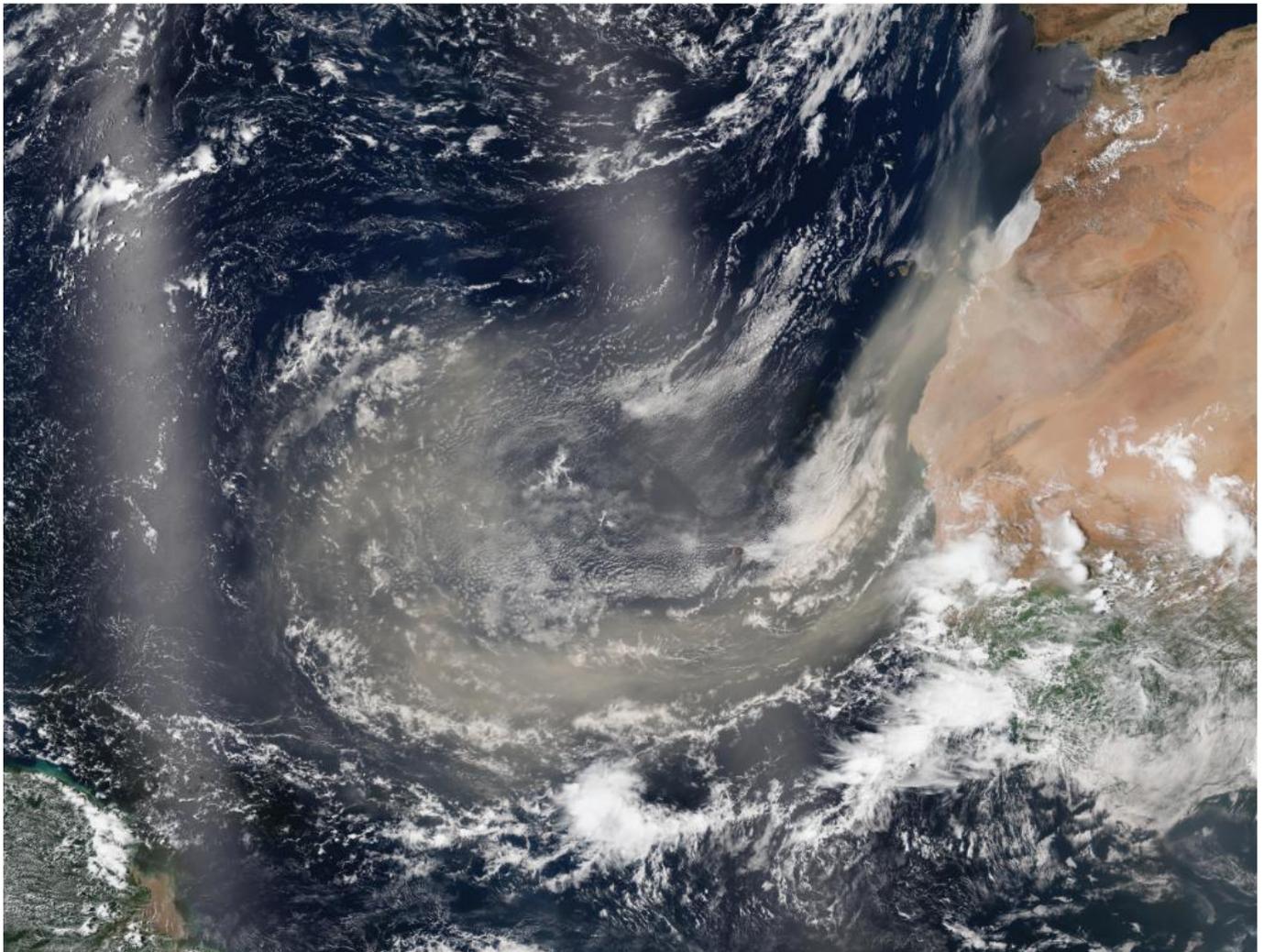
Loss of biodiversity

Land degradation results in the loss of habitat and a decline in biodiversity. This has a flow-on effect; for example, once trees are removed there is a drop in the bird population that would normally eat insect pests. *Changes* in land cover occur when grazing animals such as sheep selectively eat certain species of plants. These fail to grow back and are often replaced with more woody shrubs, weeds, or nothing at all.

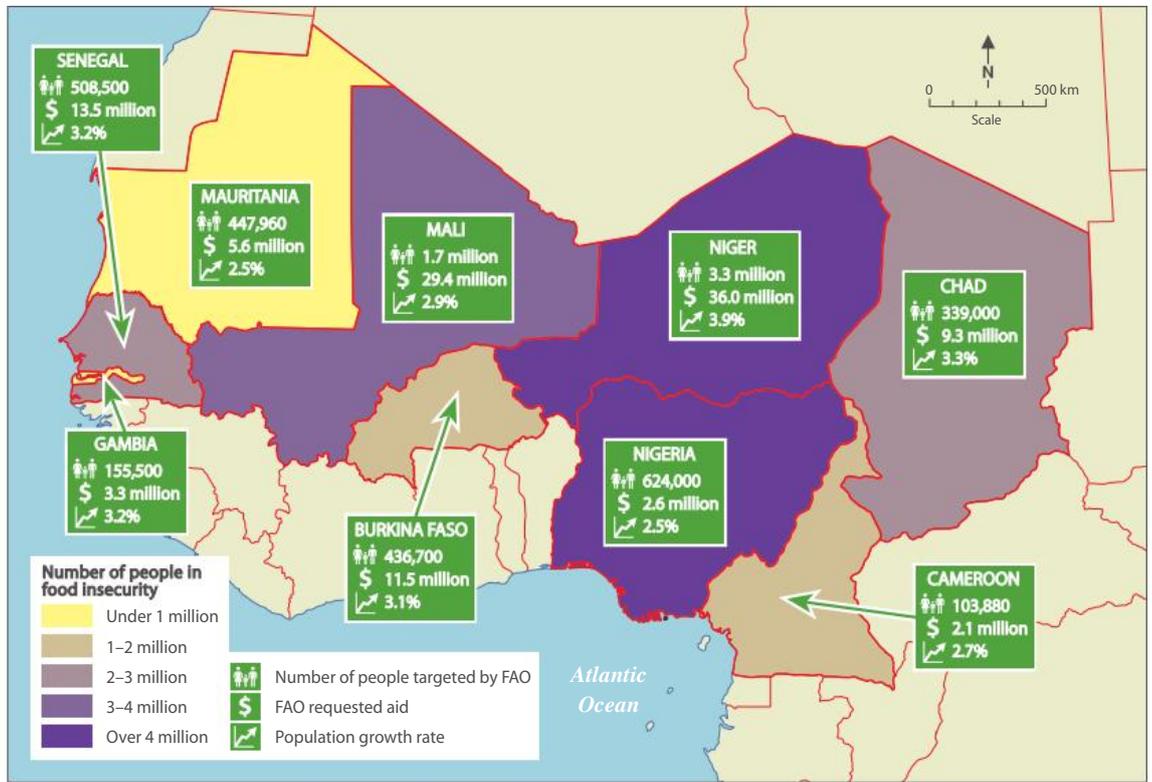


▲ **Figure 9.14** The importance of vegetation in drylands

▼ **Figure 9.15** Satellite image of dust cloud over the Atlantic Ocean



► **Figure 9.16**
Distribution of food insecurity
in western Sahel, 2014



Economic losses

Agriculture is the main livelihood for many people living in drylands. The loss of land through recurring desertification contributes to increasing poverty levels. In South America's Patagonia *region*, many haciendas (sheep stations) have been abandoned as sheep farming is no longer economically *sustainable*. At its peak, stocking rates were 60 per cent over the estimated carrying capacity of the land resulting in large-scale degradation. Desertification is now affecting 84 per cent of southern Patagonia.

Human wellbeing

As land cover deteriorates and food production declines there are the growing threats of food insecurity, reduced incomes, poor diets and related illnesses. New patterns of migration can emerge. Traditional seasonal migration allowed people to cope with dry periods, but increasing population pressures and land degradation have reduced this *movement*. Instead, people may abandon rural life and move to *places* of higher rainfall or into rapidly expanding urban areas. These people are essentially 'environmental refugees' driven off their land due to declining productivity. In Mali, in the Sahel, an estimated 42 per cent of conflicts that occur are between herders and farmers disputing access to water and grasslands as expanding cultivation blocks nomadic routes.

Eighty per cent of the Sahelian population rely on the land and its natural resources for a living. Thus they are highly vulnerable to natural disasters or human-induced land degradation. There has been a cyclic pattern of drought and famine over the past decade. In 2014, an estimated 20.2 million people suffered from food insecurity across the western *region*, which warranted the need for United Nations Food and Agriculture Organization [FAO] assistance. Figure 9.16 shows the *distribution* of food insecurity in the *region*.

► ACTIVITIES

1. With the use of an atlas, list the countries that would most likely be affected by the sand storm shown in figure 9.15, if it were to continue to be blown west. What are the likely impacts of the sand storm on people and *places*?
2. Explain the phrase 'poverty is both a cause and a consequence of desertification'.
3. In what ways can animals contribute to desertification?
4. Using figure 9.14, explain the role of vegetation in reducing land degradation.
5. Copy the table below. Complete the table with explanations and specific examples.

IMPACTS OF DESERTIFICATION

Short-term impacts on people	Short-term impacts on the environment
Long term impacts of desertification on people	Long term impacts on the environment

Case study: Desertification in Niger

Niger is a land-locked country in the western part of the Sahel (see figure 9.17). It is one of the poorest countries in the world with a GNI per person of US\$49. Much of the country is classified as hyperarid or desert, with 75 per cent receiving less than 300 millimetres of rainfall. Consequently, 80 per cent of the population and most of the food production areas are concentrated on 10–15 per cent of the land area, in a narrow band in the south, as figure 9.17 shows. Most crops are rain fed, with considerable variation in yields from year to year.

Over the past 20 years Niger has experienced four severe and three catastrophic droughts. The 2010 drought saw the loss of 25.5 per cent of the country's cattle population (the second most important export after uranium), 36.8 per cent of sheep, 31.3 per cent of goats and 2.6 per cent of camels.

Niger's population growth rate of 3.9 per cent will see a doubling of its population within 25 years. Droughts, locust plagues, large-scale deforestation, high food prices and political instability all contributed to the country's land degradation problem. Despite this, Niger by 2014 had experienced a net gain in tree cover over the past 20–30 years and, in the Maradi and Zinder regions, successfully reversed the process of desertification. Farmers have converted approximately five million hectares of degraded land back into productive farmland.

Combating desertification at the local scale: Farmer-Managed Natural Regeneration

After severe droughts and famines across the Sahel in the 1970s and 1980s, the world spotlight became focused on projects to combat desertification with tree planting. Conventional methods for combating desertification focused on revegetation by setting up tree nurseries and 'food for work' schemes whereby local villagers were paid to look after seedlings and planting in return for payment in basic food items.

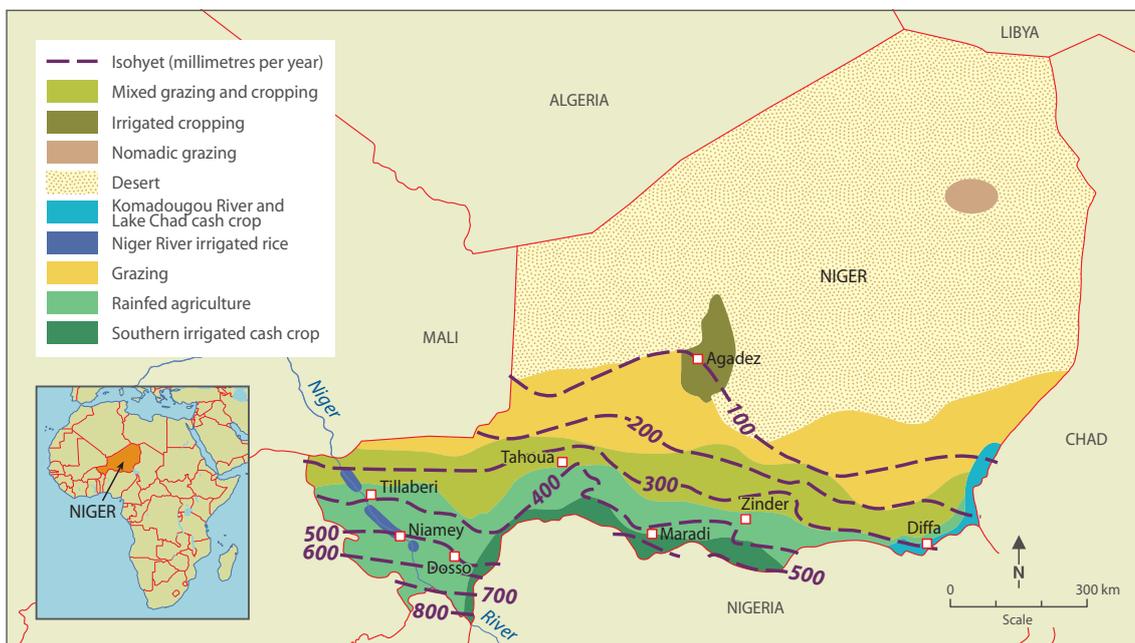
Often these projects failed for one or more reasons, including the following.

- ▶ The scheme was expensive to run and required a lot of time and labour.
- ▶ International experts were used to set up, manage and teach, with little input from local farmers.
- ▶ Exotic or introduced species were selected that were not always suitable for local conditions.
- ▶ There was a lack of reliable water supply to maintain growth once seedlings were transplanted.
- ▶ New plants suffered damage from pests, grazing animals, drought and sandstorms.
- ▶ When project funding stopped, the project was often abandoned.

By the early 1980s Niger was experiencing widespread desertification, which contributed to failed crops, the mass *movement* of people off the land and a declining economy. The turning point was the observation by an Australian agronomist and missionary, Tony Rinaudo, described in the following paragraph. (See the career profile on page 125 on Elizabeth (Liz) Rinaudo, Volunteer Assistant, Farmer-Managed Natural Regeneration.)

Traditional farming methods required cutting down any shrubs or trees seen as competitors for the limited water and soil nutrients. But beneath the soil, the living stumps of many native trees were like an 'underground forest'. The stumps would re-grow or coppice, only to be chopped down again.

The challenge for Tony and his team was to convince farmers to keep these tree roots and allow the trees to coppice. Then, by selectively pruning the strongest stems, the trees would grow back. Shoots from roots grow more rapidly than saplings raised from seeds and transplanted. Crops could continue to be grown around the trees in a system known as agroforestry. Crops would benefit from the shade and improved soil conditions provided by the trees. The prunings from stems and branches could be used for fuelwood, or



▲ Figure 9.17 Agriculture land use patterns in Niger

animal fodder, while some species could provide edible nuts, seeds, fruits and leaves, medicines and food dyes. Farmers themselves decided on which tree species to coppice and the tree density in their fields, anything from 40 to 150 trees per hectare. This system became known as Farmer-Managed Natural Regeneration or FMNR. Essentially this was a way in which farmers themselves, with minimal effort and cost, could combat desertification and improve their living conditions.

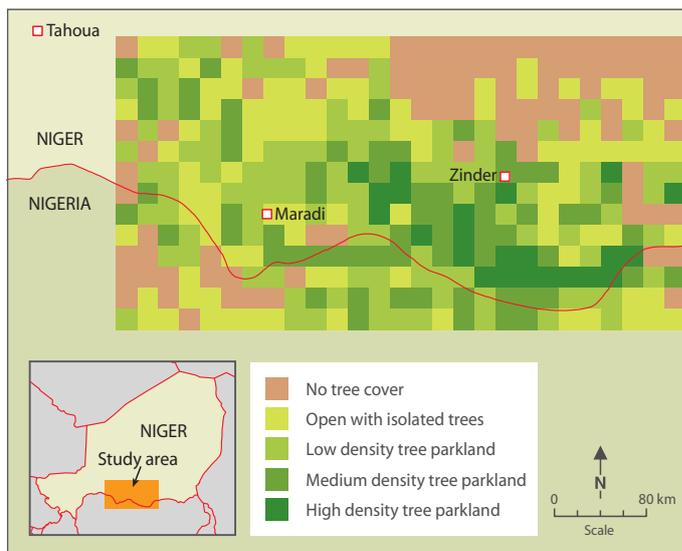
Resistance came from farmers who had perceived trees in a field as 'pests' and who had to *change* lifelong practices. Trials began and, despite being ridiculed, the volunteer farmers persevered and were able to harvest fuelwood and an increased crop yield. With repeated droughts and famines the FMNR method was tied

to a 'food for work' aid project. Between 80 000 and 100 000 people were exposed to the method during this time. However, once aid funding finished, two-thirds of the newly regenerated trees were ripped out and farmers reverted to old farming methods.

To compound the problem, the law in Niger stated that trees belonged to the government. People could be fined for cutting branches in their field, hence it was easier to slash and burn any stumps before they re-grew. There was no incentive to keep trees. After some negotiations, the head of the forestry department in the Maradi district offered to suspend enforcement of the forestry rules. This gave farmers both the incentive to persist and 'ownership' of the trees on their property, and so FMNR began to take hold. The method spread quickly by word of mouth from those who achieved improved yields and incomes. By 2004 the government *changed* the laws to grant tree ownership to land owners. Aid agencies and NGOs assisted by training farmers and fieldworkers to teach others the method. In 2006, over 5 million hectares of southern Niger showed a large-scale *change* in vegetation cover, evident in figure 9.18.

FMNR is now practised across a wide area of the Sahel effectively *changing* the land cover of the *region*, restoring its biodiversity and productivity. The long-term benefits are both numerous and *sustainable* (see figure 9.19). Climate *change* and population pressures, however, will continue to erode any advances in food production and so a much broader range of options still needs to be adopted.

▼ **Figure 9.18** Distribution of tree cover and density, southern Niger

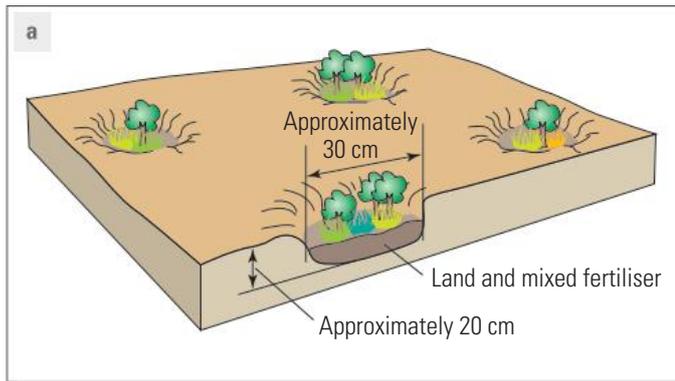


▼ **Figure 9.19** The benefits of FMNR

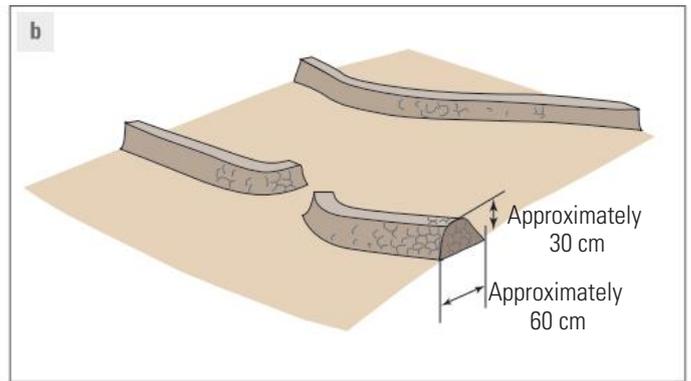
ENVIRONMENTAL	ECONOMIC	SOCIAL
Faster and more effective growth of vegetation than traditional tree nurseries and replanting.	Program is cheap and does not require any aid money or financial assistance from the government.	FMNR was able to spread through communities by word of mouth and personal success stories.
Can be practised at any <i>scale</i> in a short period of time.	Fast results; within the first year money could be made from selling wood clippings. Many villages now set up wood markets.	Pruning technique is simple and easily learnt. A sharp blade is the only tool required.
In the past tree cover averaged 1–2 trees per hectare; there is now an average of 40 trees per hectare. Trees provide shade, soil nutrients and help reduce erosion.	A survey of favoured tree species identified 93% were important for medicine and 90% provided food.	Program is completely controlled by the farmers who make their own decisions as to how many trees, how many branches to prune etc.
<i>Sustainable</i> land use management that can continue to be practised. Can easily be adapted to other <i>places</i> using suitable indigenous plants.	Economists estimate the additional income earned from tree products could add US\$1000 a year to every household.	Women and children's workload and time spent collecting fuel wood is reduced.
In well-treed areas, the watertable in wells started to rise enabling people to obtain water more easily.	Before FMNR grain yields would average 150–300 kilograms per hectare; they have now increased to over 500 kilograms per hectare without adding artificial fertiliser or irrigation.	Increased harvests improved diets. Additional money earned could be spent on food, health care and education.
Reduced erosion and improved soil fertility in fields where trees have re-grown. Improved biodiversity as insects, birds and animals returned.	Often women could benefit financially by earning additional income from sale of fruits, nuts and seeds. The leaves from one mature baobab tree can earn up to US\$70 a year; the fruit can be sold as juice.	Improved incomes led to a reduction in the <i>movement</i> of young men from rural areas to urban areas in search of work. This creates more stable communities.
Additional soil and water conservation programs helped reduce degradation.	Communities more economically resilient to droughts, floods and other disasters as they were able to harvest and store more food or sell products from trees to purchase food.	People became more empowered and had more control over their livelihoods. Assists in breaking the 'vicious cycle of poverty'.

Local scale: Water and soil conservation methods

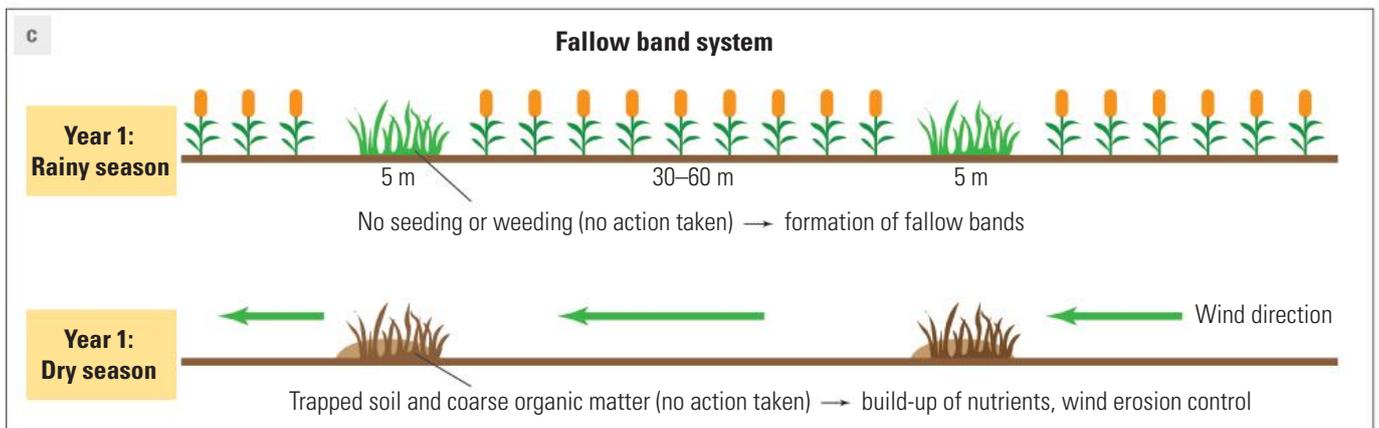
Successful restoration of desertified lands in other *places* in the Sahel has come about from using new agroforestry methods combined with new soil and water conservation methods. These methods are complementary to each other and maximise the collection and use of water while improving soil moisture and reducing erosion. Three of these are shown in figure 9.20.



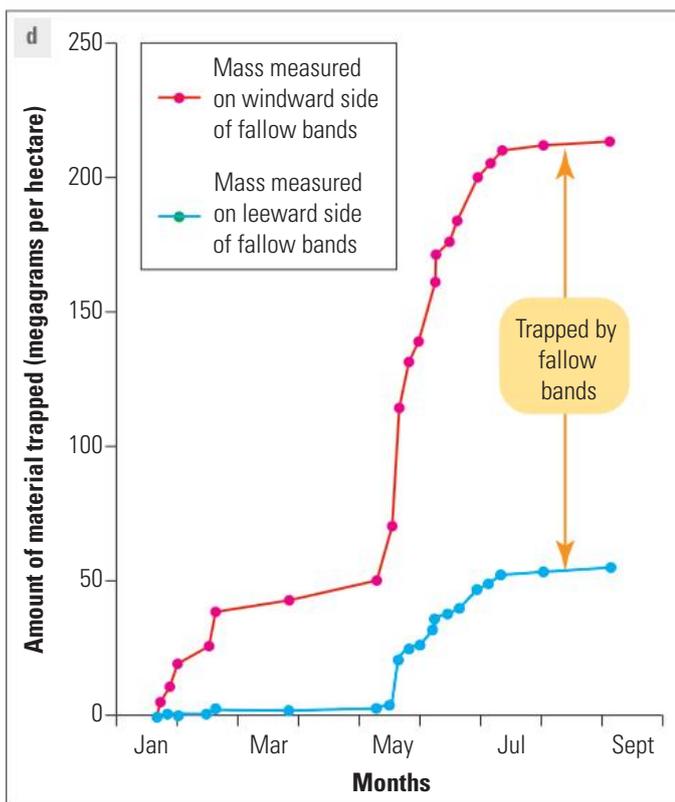
▲ **Figure 9.20** (a) Planting in zai pits. During the dry season a series of zai pits (holes) are dug by hand across the field. The pits are then filled with manure, planted and watered.



▲ **Figure 9.20** (b) Stone contour banks. Low banks of stones are built along contour lines on a slope and crops planted behind the banks. Any topsoil or water that moves down the slope is trapped behind the walls and can be used by the plants. The contour banks also act as wind breaks.



▲ **Figure 9.20** (c) Fallow band system. During the rainy season, bands of weeds are permitted to grow between crop rows. These are positioned to be at right angles to the prevailing winds. During the dry season, the fallow bands act to trap any wind-blown soil. The following year, the fallow bands are used for cultivation while new fallow bands are created in the direction of the prevailing winds.



◀ **Figure 9.20** (d) Benefits of the fallow band system

▶ ACTIVITIES

1. Identify one example each of a physical, political, economic and social factor that contributed to the uptake of the FMNR method of farming.
2. Refer to the information in figure 9.19. In what ways is the FMNR considered a *sustainable* response to desertification?
3. Refer to figure 9.18. How has spatial technology been used to collect data in the field?
4. Calculate the approximate area of land covered by the FMNR method.
5. Using the information provided in figures 9.20 (a), (b) and (c), construct a table to show the advantages and disadvantages of the three techniques for managing soil and water conservation.
6. Refer to figure 9.20 (d). Describe the *changes* in yields with the application of the fallow band method.

Combating desertification at the *regional scale*: Great Green Wall Initiative of Africa

The largest desertification project in Africa is the Great Green Wall Initiative (GGWI). It is a large-scale reforestation program that stretches in a band 15 kilometres wide across 11 countries in the Sahel, from Senegal in the west to Djibouti in the east, a *distance* of over 7775 kilometres. Figure 9.21 shows the location of the 'green wall'. It is not actually a 'wall of trees' but rather a zone of native vegetation that is 'recreating' much of the vegetation land cover that has been lost. The goal is both to try to reduce the rate of desertification and to improve the livelihoods of those people living in the *region*. Starting in 2011 and with the support of the African Union, European Union and the World Bank, by 2015 more than \$1.8 billion has been invested into the program.

A range of different native plants species are used, chosen for their ability to withstand drought as well as providing local communities with a source of income from the sale of seeds, nuts, fruits and animal fodder. Critical to the plan's success is the perception that the vegetation is worth more kept alive than cut down and burnt. In Senegal, more than 27 000 hectares of degraded land have been restored through the planting of over 11 million trees. The tree belts have the ability to reduce wind erosion and trap wind-blown sediment. Shade, nutrients from leaf litter and the slow infiltration of rain water all assist in the soil restoration *process*.



▲ **Figure 9.21** The Great Green Wall is designed as *regional* response to desertification in the Sahel.

Critics of the GGWI note there are difficulties with the ownership of plant resources. Who is responsible for the planting, watering and upkeep of trees or for protecting new plants from animals? Of greater concern is the fact that the initiative is dependent on external funding and is a 'top down' rather than a 'bottom up' approach. In Nigeria, more than 425 000 seedlings were planted in the state of Kano in 2013 but less than 20 per cent could be accounted for. This was blamed on the slow release of funds, and a lack of water at the shelter belt site. There is only a limited time period of two to three months of rain, which is the best time to plant. Animal damage is very common and fencing requires the use of valuable wood resources. In Kebbi state, Nigeria, in 2014, only 30 per cent of trees remained from a planted tree belt of 84 kilometres, the rest eaten by cattle.

▶ ACTIVITIES

1. In what ways is the FMNR considered a *sustainable* response to desertification?
2. Refer to figure 9.15. How has spatial technology been used to collect data in the field?
3. Calculate the approximate area of land covered by the FMNR method.
4. Explain the difference between a 'top down' and a 'bottoms up' approach to managing the restoration of degraded lands.
5. 'The Great Green Wall Initiative is more than just a wall of trees.' Discuss.

Case study: Desertification in China

It is now estimated that only 2 per cent of China's original forest cover remains after centuries of deforestation practices. As a result the country has lost significant biodiversity and suffers from land degradation in all of its forms. Land affected by desertification is estimated to cover 25 per cent, or 2.6 million square kilometres of the landmass, *distributed* mostly in the north and north-west of the country. Increasing pressure on the land to support a growing population has seen the available cropland per capita and rangeland per animal decrease by a factor of three. Within China, arid and semiarid *regions* can support only one to two people per square kilometre; however, this figure is more usually 10 people per square kilometre, which is an *unsustainable* density. The expansion of cropland into areas receiving as little as 200 millimetres of rainfall in conjunction with highly erodible sandy soils and a windy climate have combined to create severe land degradation. This has influenced declining productivity and increasing poverty in *the region*. The *distribution* of dryland types can be seen in figure 9.22.

The number and frequency of dust storms and sand storms originating in the drylands of Inner Mongolia has increased over time. They impact greatly on Beijing and other *places* as far away as Japan and South Korea. Seventy per cent of the storms originate from rural fields, characterised by poor vegetation cover. According to researchers, the storms are capable of depositing an average of 35 tonnes of sand on a single square kilometre. Since the 1970s, the number of days with sand storms has multiplied by 3 to 4 times. Known

as the 'Yellow Dragon' the sandstorms, visible in figure 9.23, occur each spring seriously adversely affecting the health of people and daily living conditions.

The number of sandstorms originating in Mongolia have increased sixfold in the past 50 years and now average 24 per year, with 80 per cent occurring between March and May. Finer particles of dust are blown further *distances* to Korea, Japan and the United States. Sandstorms reduce visibility, shut down airports, create breathing difficulties and smother everything with a layer of sand and dust. Crops, power lines and buildings are badly damaged. Figure 9.24 shows the extent of a sandstorm over China in 209.

Climate *change* is contributing to declining rainfall and falling watertables. Rainfall has decreased by 10 per cent and many small lakes have dried up while grasslands have turned into sand fields. As part of the government's anti-desertification efforts, 178 000 people have been forced to relocate and give up their traditional grazing lifestyle to live in purpose-built towns.



▲ **Figure 9.22** The *distribution* of dryland types in China



▲ **Figure 9.23** The yellow glow of a severe sandstorm over Beijing



▲ **Figure 9.24** The scale of a sandstorm over China

Combating desertification at the national scale: The Great Green Wall of China

China has embarked on the world's largest afforestation scheme to combat desertification. Officially known as the Three North Shelterbelt Project, but often called the 'Great Green Wall of China' (GGW), it is an ambitious project to halt the expansion of the country's desert *regions*. Between 1978 and 2014, over 50 billion trees have been planted. At the completion of the project, planned for 2050, a series of forest shelterbelts containing over 1 billion trees will be planted for a *distance* of 4500 kilometres along the edges of China's northern, north-western and north-eastern desert *regions* (see figure 9.25). This area includes 98 per cent of the land affected by desertification. The trees are planted manually by local farmers and volunteers as well as by aerial seeding.

The GGW will create a *land cover change* by increasing forest cover over the *region* from 5 to 15 per cent, and across the entire country to 42 per cent by 2050. As much of the *region* is characterised by open flat grasslands, as seen in figure 9.4 (b), wind speeds can be high and the shelterbelts will act as wind breaks, reducing the loss of valuable topsoil.

In the more arid *regions* it is hoped that vegetation will help stabilise sand dunes and compensate for the 3600 square kilometres of grasslands lost to the spreading of the Gobi Desert. This then will reduce the frequency and the severity of sandstorms. Finally, by reducing the rate of desertification and restoring land it is hoped that food production, incomes and livelihoods will improve.

Benefits of the scheme

- ▶ From 1977 to 2014, tree cover in the Three North *region* increased from 5 per cent to 12 per cent; across the entire country, forest cover increased from 13 per cent in 1992 to 21 per cent in 2015.
- ▶ In Zhangbei County, the annual number of wind storms and the average wind speeds in the local area have reduced, whereas humidity and frost-free days have increased in the 40 years since the start of the project.

- ▶ Improved crop yields and requirements for wood have been met.
- ▶ According to the Chinese government, between 40 000 and 70 000 square kilometres of desertified land is being restored each year. By comparison, the area of Tasmania is 90 000 square kilometres.

Drawbacks to the scheme

Only 15 per cent of trees planted in China's dryland *regions* since 1949 have survived due to the following reasons:

- ▶ Many were grown from cuttings, rather than seedlings, so they have a life expectancy of approximately 40 years. Ninety per cent of 33 000 hectares of forest on the Bashang plains are dead or dying of old age.
- ▶ Some species planted were unsuited to the soil and climatic conditions. In some *places*, forests did not exist originally and trying to create forests in semiarid *regions* without sufficient rainfall or suitable soils is doomed to failure. Native grasses and shrubs are generally more drought tolerant and effective at holding the soil.
- ▶ Planting single species (monoculture) plantations makes them vulnerable to disease. In Ningxia, in north-western China, disease killed 1 billion poplar trees in the space of 12 months.
- ▶ Government policy has been restrictive, focusing on planting forests rather than managing forests. Hence the preference given to plant species such as poplar trees which grow quickly and get quick results, often at the expense of creating a mixed forest which improves biodiversity and creates a fully functioning ecosystem.
- ▶ Forests of the same age require vast quantities of water. In Minqin, north-west China, groundwater levels have dropped 12–19 metres since the start of the GGW project.
- ▶ China plans to spend a further \$34.9 billion by 2020 to fund further afforestation programs.



▲ **Figure 9.25** Location of the Three North Shelterbelt Project *region*

▶ ACTIVITIES

1. Use the internet to find a climograph for Hohhot, Inner Mongolia. Compare this with the climograph for Zinder (figure 9.5), using figures in your answer. Are all drylands hot?
2. Refer to figure 9.24. Using the *scale*, calculate the total area of China affected by the heavy sandstorm. Suggest a reason why the dust travels further than the sand.
3. Describe the *spatial association* between the *distribution* of the Three North Region (see figure 9.25) and the *distribution* of drylands as shown in figure 9.22.
4. Evaluate the *sustainability* of the Great Green Wall of China response.
5. Compare the Great Green Wall of Africa and the Great Green Wall of China. In what ways are they similar and different?
6. How effective are large-*scale* desertification reclamation schemes compared to small, local-*scale* projects?

Combating desertification at the global scale: The United Nations

Practical solutions to desertification already exist and are being used across a range of *scales* by different communities. At their core is the need to sustainably manage our drylands by promoting a range of different water and soil conservation methods, agroforestry and revegetation schemes. These then must be supported by appropriate government support. At the international level this requires financial, educational and technical support by governments, NGOs and other organisations.

Global recognition of the *scale* of desertification and its socioeconomic impacts in the 1970s led to the United Nations developing a framework for tackling the issue. By the mid 1990s, desertification was actually increasing and the devastating droughts in the Sahel through this period highlighted the need for a new approach. In 1994 the United Nations Convention for Combating Desertification (UNCCD) was formed. Primarily, the UNCCD initiates action and encourages *regions* and individual countries to develop their own action plans for 'preventing dryland degradation and mitigating the effects of drought in affected areas in order to support poverty reduction and environmental *sustainability*'.

The UNCCD has had success with the following measures:

- ▶ the signing of the agreement by 194 countries, with 26 countries in Africa developing National Action Plans
- ▶ raising the awareness and importance of desertification as a global issue, for example World Desertification Day is on the 17 June each year (see figure 9.26)

- ▶ fostering *regional* cooperation in the Mediterranean, Africa, South America and Asia
- ▶ linking actions for combating desertification with poverty reduction, gender equality, community participation and science-based land management
- ▶ setting up a framework for financing development plans for combating desertification.

Now, more than two decades later, there are still several limiting factors to the UNCCD convention. Desertification has not been halted. The number of countries suffering dryland degradation has increased from 110 in the early 1990s to 168 in 2013. Degraded land increased from 15 per cent to 25 per cent of all land globally, between 1991 and 2011. Funding for programs is reliant on donations from the developed nations of the world, many of whom have done little to help.

In 2012 the UNCCD recommended setting a target of Zero Net Land Degradation. The goal is '*sustainable* land use for all and by all'. Degradation is to be avoided and once-degraded lands restored to their productive level. The following targets are listed:

- ▶ Target 1: Zero net land degradation by 2030
- ▶ Target 2: Zero net forest degradation by 2030
- ▶ Target 3: Drought policies and drought preparedness implemented in all drought-prone *regions/countries* by 2020.

▶ **Figure 9.26**

The logo for the 2015 World Desertification Day



Conclusion

Desertification remains one of the most important and threatening land-cover *changes* in the world. With increasing competition for the finite amount of land on the planet from other land uses, the prevention of further degradation and the *sustainable* management of our soil, water and vegetation resources is the most logical way of meeting these future demands. While there is no one solution or method, a combination of several will achieve environmental and economic benefits. By restoring degraded lands, improved production and wellbeing can be achieved for the millions of poor people living in dryland *regions*.

'Despite mankind's many accomplishments, we still owe our existence to a 15-centimetre layer of topsoil and the fact that it rains.' (Monique Barbut, Executive Secretary of UNCCD)

▶ ACTIVITIES

1. What difficulties does a large, global-scale organisation such as the UNCCD have in achieving its goals?
2. Evaluate the likely effectiveness of the UNCCD Zero Net Land Degradation policy.
3. Why is it so difficult to reduce the threat and impacts of desertification?

Fieldwork: Land degradation in the local area

Investigate a *place* in your local community that is suffering from land degradation such as soil erosion or weed infestation. This could be within the school grounds, at a local park, in an area of vacant land or along a railway or road embankment, creek or river bank.

Visit your fieldwork site to take photographs, measurements and field sketches. Historic photographs of the site will enable estimates of the rate of degradation. Perhaps contact the local council for additional information about the site, such as management plans or policies on weed eradication.

Complete a report on your site. Include the following:

- ▶ location map
- ▶ description of site, sketch map of location/*distribution* of degradation
- ▶ annotated photographs of the type/s of degradation
- ▶ causes of land degradation
- ▶ impacts of land degradation
- ▶ current management of the degradation (signs, fencing, revegetation, earth works)
- ▶ proposal of how the area could be improved (include sketches, map overlays, annotated photographs).



Glossary

- abiotic:** relating to the physical world
- ablation:** the loss of snow and ice on a glacier by melting and evaporation
- accumulation:** the addition of snow and ice to a glacier; the opposite of ablation
- ad hoc development:** improvised or one-off development
- afforestation:** the establishing of a forest in a *region* that has not previously been forested
- agrarian societies:** communities that are based on farming
- agricultural revolution:** the transition from the Paleolithic lifestyle, characterised by sustenance through hunting and gathering, to an agriculture-based lifestyle. This transition occurred at different times in different communities across the world.
- agroforestry:** a system of farming which integrates the growing of trees and crops
- agronomist:** a person who is trained in agricultural sciences
- amenity:** a desirable or useful feature or facility of a *place*; the pleasantness or attractiveness of a *place*
- arid:** severe dry conditions to the point of hindering plant growth
- baseflow:** water that enters a stream channel due to seepage from groundwater
- binding agreement:** an agreement which has legal basis
- biodiversity:** the variety of living organisms, including all plants, animals and microorganisms, in a particular *region*
- biome:** a type of natural environment, encompassing its biotic components of plants and animals as well as the physical landscape they inhabit. Forests, woodland, woodlands, savannah, grasslands, desert and tundra are all examples of different biomes.
- 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:** relating to the living world
- boreal forest:** a forest biome characterised by coniferous trees, located within subarctic *regions* of the Northern Hemisphere
- brownfield:** land development of industrial or contaminated sites
- bushmeat:** meat procured from wild animals
- cadastre:** a register of property showing the extent, value, and ownership of land for taxation
- carbon sequestration:** the absorption and subsequent storage of carbon dioxide from the atmosphere, such as by plants through photosynthesis
- carbon sink:** a carbon sink is a natural or artificial reservoir that accumulates and stores some carbon-containing chemical compound for an indefinite period
- carbon source:** activities that release 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
- Catchment Management Authority:** under the *Catchment and Land Protection Act 1994* (the CaLP Act), Victoria is divided into ten catchment *regions* with a Catchment Management Authority (CMA) established for each *region*. CMAs are provided with *regional* waterway, floodplain, drainage and environmental water reserve management powers under the *Water Act 1989*.
- chain of custody (of timber):** see *forest certification*.
- clearfelling:** the complete clearance of existing natural vegetation for timber harvesting or to make land available for infrastructure or agriculture
- climax community or forest:** see plant succession
- closed forest:** see forest canopy cover
- commercial (farm or plantation):** farming for profit, as opposed to farming for sustenance of the household
- commodities:** products that are commonly sold on global markets
- conservation:** careful management and use of resources so these resources will not be depleted over time
- continental shelf:** the seabed which extends from a continent; covered by relatively shallow water during interglacial periods but exposed during glacial periods
- control:** used in an experiment as a constant or standard that is unchanged for comparison with results
- coppice:** trees that if cut down are capable of producing new growth from their stumps or roots
- coupe clearfelling:** the felling of sections of the forest, called logging coupes
- cryconite:** a mineral composed of windblown sediments that comprise a combination of small rock particles, soot, dust and microbes; it is grey to black in colour

- 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 (depending on the type of forest) of its original cover
- desktop research:** the collection of secondary data or that which has already been collected. To most people it suggests published reports and statistics and these are certainly important sources.
- 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.
- ecosystem services:** the direct and indirect contributions ecosystems make to human wellbeing 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.
- ecosystem:** a community of biotic or living organisms, including plants, animals and microorganisms, in conjunction with the abiotic, or nonliving, components of their environment (things like air, water and mineral soil), interacting as a system
- elevation:** height above sea level
- emerging economies:** human communities which have progressed economically and reached a certain level of economic development, but are not yet considered an industrialised society
- flow regime:** the variability of the flow of a river throughout a year
- food insecurity:** when people do not have reliable access to sufficient, safe, nutritious and affordable food
- food security:** when people have both the physical and economic access to safe and nutritious food to meet their dietary needs and lifestyle at all times
- forest canopy cover:** the density of 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, 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:** forests subjected to modification through human activities such as selective logging, replanting and fuelwood collection, with forest loss of up to 30 per cent
- forest fragmentation:** the slow deterioration of a forest resulting from the clearing of pockets of forest 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, leading eventually to deforestation.
- forest protected areas:** reserves designated specifically for forest protection, such as national parks
- 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.
- fuelwood collection:** the collection of twigs, branches, logs and bark as a source of fuel. This, along with its use 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 genetic makeup of a species
- geologic time:** long time *scales*, covering periods of hundreds of thousands of years and more
- glacier retreat:** when the rate of ablation exceeds the rate of accumulation, glacier retreat is the likely outcome
- glacier:** a mass of land ice flowing downhill
- global warming:** an increase in the mean global temperature
- government subsidies:** financial assistance provided by government to promote or encourage particular activities or sectors. The support may be provided through cash grants, interest-free loans, and tax breaks.
- greenfield development:** converting natural lands into a built environment
- greenfield:** land development of undeveloped conservation or agricultural sites
- greyfield:** land development of large unused tracts of retail strips, often surrounded by asphalt
- growing season:** the period of time in a year when temperatures and rainfall allow for the optimum growth of plants and plants
- habitat fragmentation:** the break-up of continuous vegetated areas into a smaller number of isolated habitats inhibiting the *movement* of animal and bird species
- ice sheet:** a mass of land ice that is sufficiently deep to cover the topography beneath it
- impervious surface:** a surface which does not allow penetration of water or other substances
- indigenous vegetation:** species that occur naturally in a specific *region*
- industrial societies:** human communities which have reached a high level of economic development through the implementation of advanced technologies, and rely on the industrial sector for a large proportion of their economic activity
- infill development:** the rededication of land in an urban environment, usually open space, to new construction
- infiltration:** the *process* in the water cycle whereby water on the surface enters the soil or other porous materials
- 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:** transport and communication networks, energy frameworks and systems for water and waste disposal and treatment
- intact forest:** *see* primary forest
- intensive land use:** land used to generate a high output
- internally displaced people (IDP):** a person who is forced to flee their home but stays within the borders of their own country. As such they are not considered a refugee.

land cover: the physical material at the surface of the Earth

land degradation: a *change* in the condition or quality of land, vegetation cover, soil and water resources that reduces its quality or productivity. It is 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 classification: a consistent system for collecting and presenting land information

land use intensification: increasing use of land to generate higher outputs such as housing people at higher densities or coping with more traffic

land use: the use people make of the Earth's surface

Landsat satellite images: images procured by satellites

LGA: local government area

liveability: the sum of the factors that add up to a community's quality of life

local character: the qualities that make one local area distinct from another; encompasses a range of physical components of the built environment

logging concession: a licence or permit, dispensed by a government authority, allowing the holder to harvest a particular area of forest

marginal land: land that is generally of poor quality, low productivity and low value

Median House Price: the midway point of all the houses/units sold at market price over a set period (e.g. monthly, yearly, quarterly)

midden: a prehistoric refuse heap which marks an ancient settlement, chiefly containing bones, shells and stone implements

monocentric city: a singular centre or nucleus of activity in an urban form

monoculture: the cultivation of a single crop on a farm or within a *region*

moraine: eroded material transported and deposited by a glacier

moulin: a vertical cylindrical shaft 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

native vegetation: plant species that are indigenous to Australia

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 non-profit basis

non-wood forest products: forest products other than timber including fruits, nuts, bark, honey, leaves, fungi, insects, game and bushmeat, gums and resins

old growth forest: *see* primary forest

open forest: *see* forest canopy cover

overcropping: continuous cropping of the land that leads to a loss in soil fertility

overgrazing: continually grazing animals on the same land without sufficient time for vegetation and soils to recover

Paleolithic lifestyle: Stone Age communities characterised by hunting and gathering

peat: a brown material consisting of partly decomposed vegetable matter forming a deposit on acidic, boggy, ground, which is dried for use in gardening and as fuel

perennial: lasting or existing for a long or apparently infinite time; enduring or continually recurring

peri-urban zone: also referred to as the rural–urban fringe; the zone of transition from the city and its suburbs to the countryside

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 overlays.

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' as it forms or recovers from a disturbance

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. It excludes tree food crops.

polycentric city: multiple centres or nuclei of activity in an urban form

porous: allowing liquid or air to pass through pores in the material

potable: safe to drink

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; also called 'intact' or 'old growth' or 'climax' forest

primary industry: an industry, such as mining, agriculture, or forestry, that is concerned with obtaining or providing natural raw materials for conversion into commodities and products for the consumer

qualitative data: cannot be expressed as a number. Data that represent nominal *scales* such as gender, socioeconomic status, religious preference are usually considered to be qualitative data.

quantitative data: anything that can be expressed as a number, or quantified

Ramsar Convention: an international treaty for the conservation and sustainable utilisation of wetlands, recognising the fundamental ecological functions of wetlands and their economic, cultural, scientific and recreational value. It is named after the city of Ramsar in Iran, where the Convention was signed in 1971.

reference: a permanent benchmark with 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
- regenerated forest:** *see* secondary forest
- regrowth forest:** *see* secondary forest
- remnant vegetation:** areas of bushland that remain as they were prior to development or other alteration
- remote sensing:** the production of aerial images through aerial photographs, satellite, radar, laser scanners or drones
- riparian zone:** the land located along the bank of a river
- run-off:** water that flows over the surface of the land
- rural areas:** those 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 resulting in an idle and derelict farming landscape of diminished visual and agricultural value
- Sahel:** a semiarid *region* that stretches across Africa from the Atlantic Ocean in the west to the Red Sea in the east. It is a zone of climate transition from the hyperarid Sahara Desert in the north and more watered *regions* to the South.
- salinity:** the salt content of soils. While salt is a natural component of soils and water, the build-up of salts as a result of over-irrigating or soil erosion creates problems for agriculture.
- secondary data:** the data that have been already collected by and 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 reseeded with native species; also referred to as 'regrowth' or 'regenerated forests'. Such forests will eventually develop into a climax community which may be indistinguishable from a primary forest, though this may take hundreds of years.
- selective logging:** selecting specific trees for felling within a forest
- slash and burn:** a type of farming practised by communities with low levels of technology, which involves the cutting and burning of the existing vegetation of forests or woodlands to create fields. It is a type of subsistence agriculture
- 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.
- subsistence agriculture:** agriculture predominantly for the sustenance of the farming household
- sustainable development:** a *process* that envisions a desirable future state for human societies in which living conditions and resource-use continue to meet human needs without undermining the integrity, stability and beauty of natural biotic systems
- terrestrial:** things related to the land
- top-down, bottom-up approach:** a top-down approach usually means that a government or NGO organises and manages an aid project; a bottom-up approach starts with the people affected who manage their own aid projects with possibly some assistance
- transmigration programs:** large-scale resettlement programs
- urban areas:** centres of higher-density population where the majority of the workforce is employed in secondary industries such as processing and manufacturing of raw goods; tertiary activities such as finance, education and design; services such as health and entertainment; *processes* such as processing and manufacturing of raw goods; tertiary activities such as finance, education and design; or services such as health and entertainment
- urban growth boundary:** the legal extent of a metropolitan area where certain types of development and subdivision are allowable
- urban renewal:** program of land redevelopment seeking to revitalise urban areas
- urban sprawl:** the uncontrolled expansion of urban areas
- vicious cycle:** a chain of events where each link creates a new problem that intensifies the original problem
- waterlogging:** when the watertable is close to the surface of the soil layer and the soils are fully saturated with water. Vegetation usually fails to grow due to a lack of oxygen in the soil.
- wildfires:** bushfires
- workforce capacity:** ability of a government or organisation to provide sufficient staffing levels to accomplish its work
- zones:** the separation of land uses enforced through legislative controls by state and local governments



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UNIT
3

Changing the Land

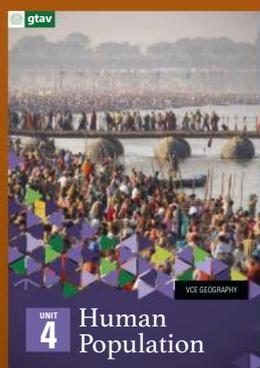
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Developed and published for the VCE Geography Study Design 2016–2020, *Changing the land* is a comprehensive course book that provides topical case studies that enable students to understand and apply geographical concepts, key knowledge and skills.

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. A study of land cover change involves an investigation of deforestation, desertification, and melting glaciers and ice sheets.

Written by experienced VCE Geography teachers, the book incorporates text, case studies, spatial technologies, fieldwork, rich data and 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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