SECTION 1

Ecosystems

All life on Earth depends on the functioning of ecosystems. As a species, humans are unique because they have the ability to destroy whole ecosystems. For the first time in human history we are on the brink of catastrophic environmental change in the form of climate change. If humans fail to act, there is the danger that the Earth's systems will collapse and bring about changes that will radically alter our planet.

However, we also have the capacity to protect and restore ecosystems. Now, more than ever, we need to understand the nature of the interactions taking place within the Earth's biophysical environment so that we can sustainably manage the Earth's ecosystems. To do this, we must better understand the way that ecosystems function and the way they are responding to environmental stress such as climate change.

In this section, we investigate biophysical interactions that lead to diverse ecosystems and their functioning, the vulnerability and resilience of ecosystems, the importance of ecosystem management and protection, as well as the traditional and contemporary strategies used to manage those ecosystems.

Outcomes

Students:

H1 explain the changing nature, spatial patterns and interaction of ecosystems

H2 explain the factors that place ecosystems at risk and the reasons for their protection

H5 evaluate environmental management strategies in terms of ecological sustainability

H6 evaluate the impacts of, and responses of people to, environmental change

H7 justify geographical methods applicable and useful in the workplace, and relevant to a changing world

H8 plan geographical inquiries to analyse and synthesise information from a variety of sources

H9 evaluate geographical information and sources for usefulness, validity and reliability

H10 apply maps, graphs and statistics, photographs and fieldwork to analyse and integrate data in geographical contexts

H11 apply mathematical ideas and techniques to analyse geographical data

H12 explain geographical patterns, processes and future trends through appropriate case studies and illustrative examples

H13 communicate complex geographical information, ideas and issues effectively, using appropriate written and/or oral, cartographic and graphic forms

Overview

In Section 1, the focus is on ecosystems at risk: their functioning, management and protection.

Chapter 1 Ecosystems at risk

Chapter 2 Coastal dunes

Chapter 3 The Great Barrier Reef

Note: students are required to study two ecosystems at risk.

1.0.0 Port Douglas—coastal dunes and rainforests are both ecosystems that may be at risk.

CHAPTER

1 Ecosystems at risk

At the beginning of the twentieth century there were 1.6 billion people on Earth and while pollution and environmental degradation were common, the problems were generally local. Today, the world's population has grown to more than 7.5 billion and the environmental problems resulting from this rapid growth affect the whole planet. Whole ecosystems are at risk and as habitats are destroyed, the species of plants and animals that depend on them become extinct.

The United Nations estimates that by 2050, the world's population will be 9.7 billion and the global economy will be at least five times its present size. To sustainably manage and protect the global environment, its habitats and biological diversity, solutions must be found that address the impacts of population and overuse of natural resources.

Human impact on the biophysical environment is not a recent event. Many indigenous peoples behaved in ways that transformed ecosystems in the past and led to the extinction of species. Such impacts were usually followed by long periods of environmental stability during which the biophysical environment adjusted to human impact. Some experts argue that the Earth's ecosystems are in fact 'human artefacts': ecosystems modified by thousands of years of human use.

> **But man is a part of nature, and his war against nature is inevitably a war against himself.**
>
> **Rachel Carson, *The Silent Spring*, 1962**

1.0.1 Rainforests are one of the most at risk ecosystems on Earth.

UNIT 1.1

Ecosystems and their functioning

Ecology is a science that examines the interactions between organisms and their living (biotic) and non-living (abiotic) environment. The key word in this definition is ‘interactions’. Groups of organisms interact with each other and their biophysical environment. Collectively, they form an ecological system or ecosystem. Ecosystems are dynamic; this means that they are constantly changing and adapting.

By identifying characteristic patterns of interaction, it is possible to distinguish different types of ecosystems. An ecosystem is defined as an identifiable system of interdependent relationships between living organisms and their biophysical environment.

1.1.1 Fungi are an example of recyclers that ensure nutrients are returned to an ecosystem.

Ecosystems

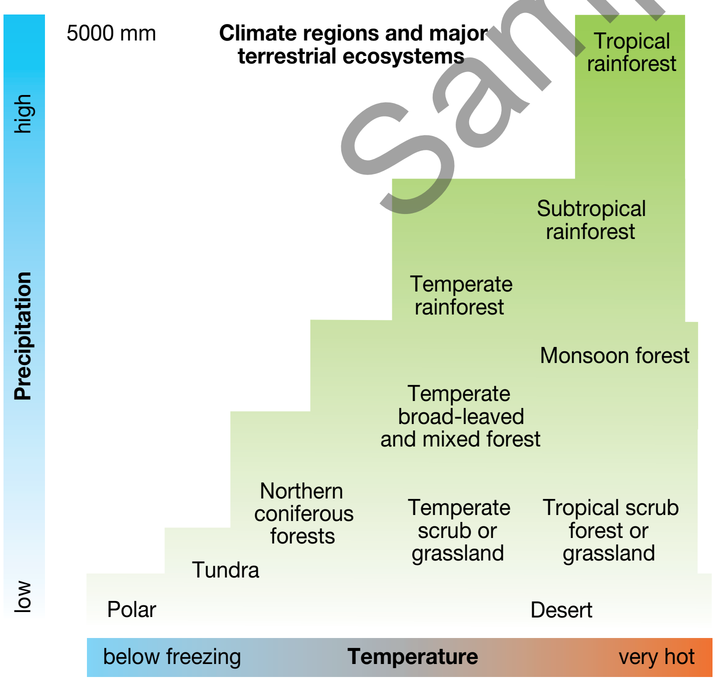
Ecosystems are systems through which incoming solar energy is captured and channelled through a hierarchy of life forms. Each ecosystem has its own characteristic plant and animal community. Plants, both on land and in the sea, convert sunlight (via photosynthesis) into storable—and edible—chemical energy. Animals feed on these plants and on other animals. The quest for food is the central organising principle within ecosystems.

An important feature of each ecosystem is the set of processes by which nutrients are retained and recycled. Living things do not create new matter. Instead, they recycle nutrients obtained from air, soil, water and other organisms, using solar energy to build and maintain themselves. The fungi shown in Figure 1.1.1 are just one example of the process of natural recycling.

Variations in ecosystems

Components of any ecosystem can vary naturally or as a result of human intervention. Each variation will in turn affect other components and processes within the ecosystem. Over time, a small variation or modification may be magnified (increased) throughout the system as a whole. This will make the ecosystem different from any other and/or will make it react in different ways to stimuli.

Environmental conditions vary and there have been substantial fluctuations in environmental conditions over the past 10 000–18 000 years. These changes include variations in the global climate and sea level; for example, until about 10 000 years ago sea levels were considerably lower. The conditions prevailing now have only existed for a relatively short period: 1500 years.



1.1.2 Precipitation and temperature interact to determine the characteristics of an ecosystem. This graph demonstrates the wide variety of ecosystems that result from the various combinations of this relationship.

Classifying ecosystems

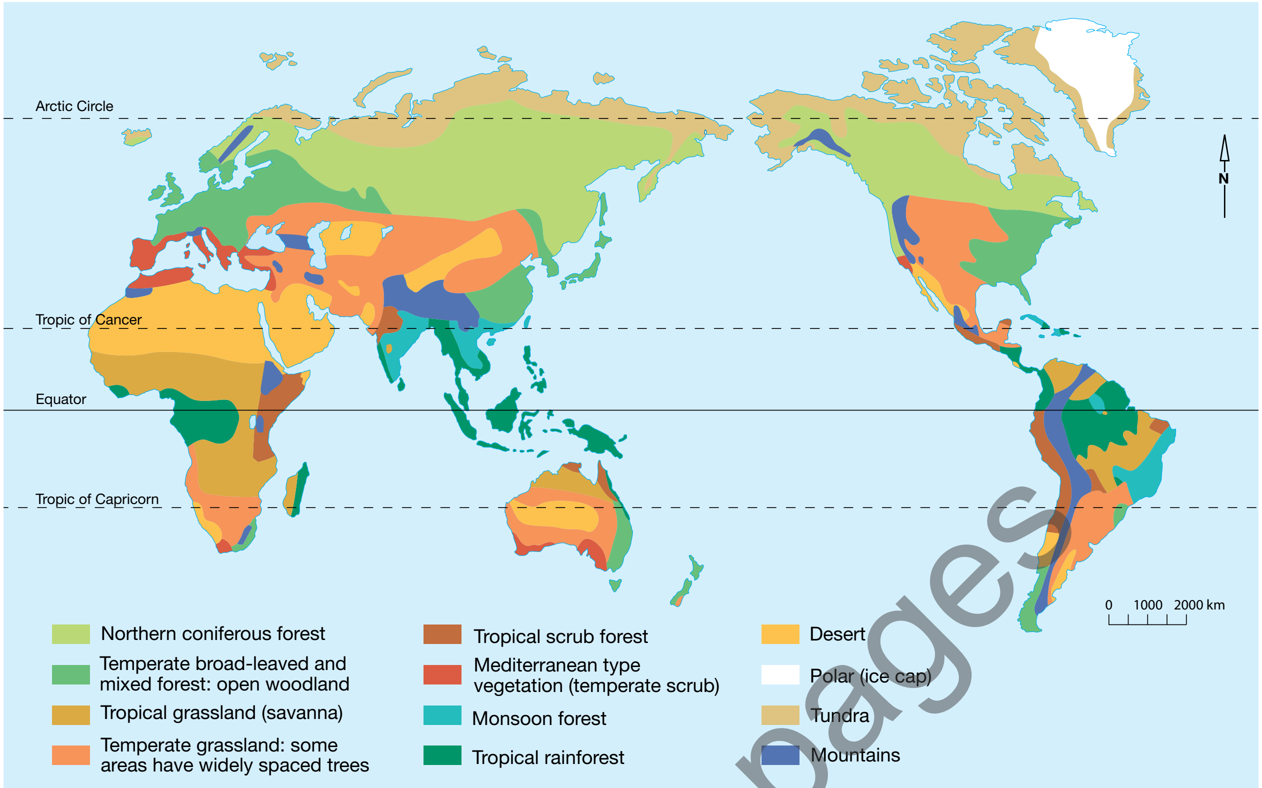
Ecosystems are usually classified according to their dominant feature and are named according to climate (for example, polar ecosystems), physical features (for example, mountain ecosystems) or vegetation (for example, rainforest ecosystems). The smaller the scale of an ecosystem, the more likely it will be named after a physical feature.

Terrestrial ecosystems

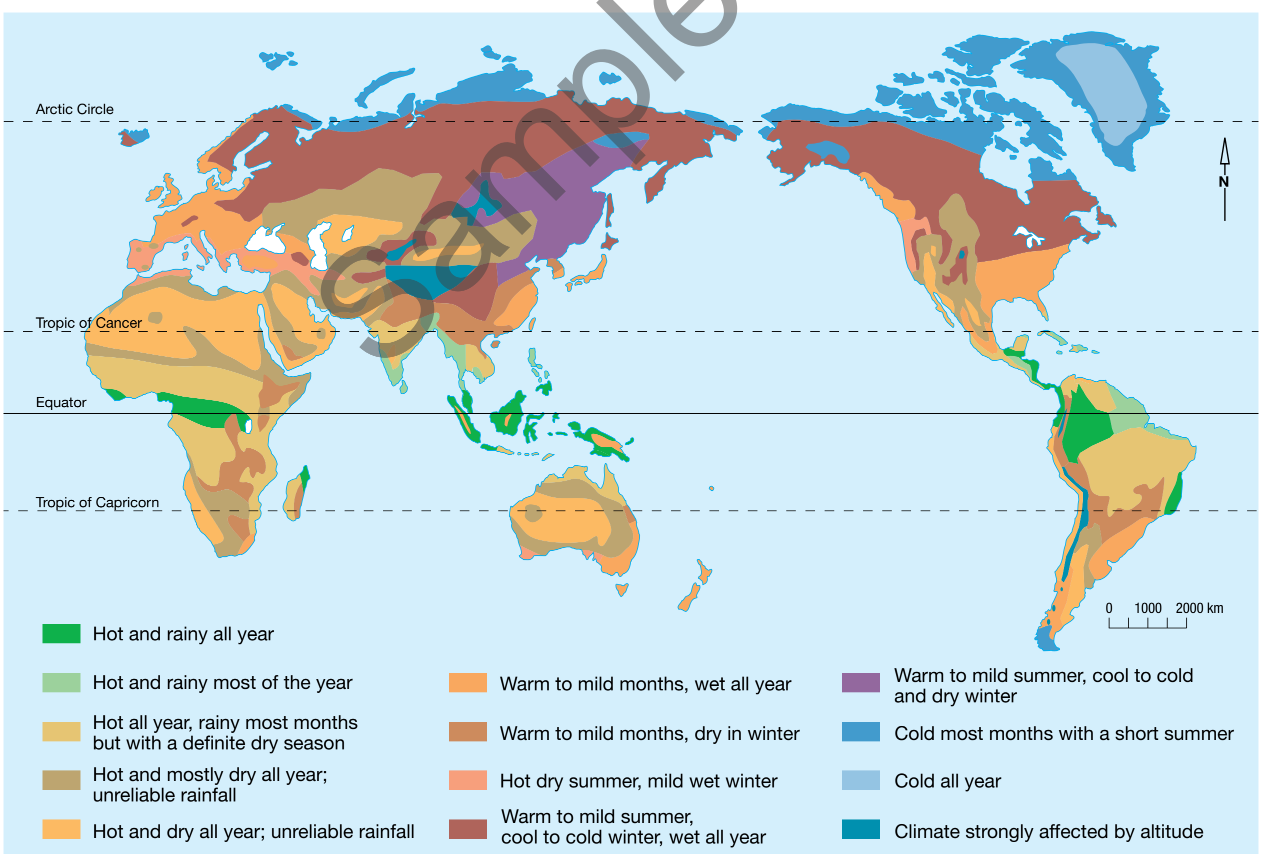
Land-based ecosystems (forests, grasslands and deserts) are called terrestrial ecosystems or biomes. The differences between terrestrial ecosystems arise from variations in average temperature and precipitation, as shown in Figure 1.1.2.

Location of terrestrial ecosystems

The location of terrestrial ecosystems is closely linked to world climate patters as shown in Figures 1.1.3 and 1.1.4.



1.1.3 The world's major terrestrial ecosystems



1.1.4 Worldwide climatic patterns

Characteristics of terrestrial ecosystems

The characteristics of the major terrestrial ecosystems are outlined in Figure 1.1.5.

Characteristics of major terrestrial ecosystems	
Ecosystem	**Characteristics**
Polar	■ Permanent ice cap, in places up to 5 km deep ■ No plant growth; no animal life away from coast
Tundra	■ Covered with ice and snow for much of the year; permanently frozen subsoil; 1–3 month growing season ■ Treeless; shrubby or mat-like vegetation ■ Most extensive in Northern Hemisphere
Northern coniferous forest (taiga)	■ Long winters with a thick cover of snow; short summers but with long, often warm days ■ 3–4 month growing season ■ Dominated by conifer trees; thick layer of needles on the ground ■ Occurs on large continental landmasses
Temperate grassland	■ Erratic rainfall; fires occur ■ Dominated by grasses and annuals (plants that complete their life cycle and set seed within a single growing season) ■ Often exploited for grazing sheep and cattle
Temperate broad-leaved and mixed forest	■ Warm, mild growing season that varies with latitude; moderate precipitation evenly distributed throughout year; large seasonal differences and changes in day length; rich topsoil ■ Some trees evergreen, some deciduous; well-developed understorey
Mediterranean-type vegetation	■ Long, hot, dry summers; mild winters with reliable rainfall; growth often stops in summer drought ■ Open forest with stunted tree growth; woodland and shrubland; many bushes and shrubs; tough evergreen leaves that are often spiny ■ Known as chaparral in North America, *matorral* in Chile and maquis in the Mediterranean area; also found in parts of southern Western Australia and parts of South Africa
Desert	■ Very little rain; true desert has less than 100 mm precipitation per year and arid areas less than 250 mm; high summer daytime temperatures (often >37°C); large temperature difference between day and night ■ Widely scattered shrubs; water-conserving plants and non-drought-adapted ephemerals (which grow and set seed quickly on rare occasions when water is available); some very dry, sandy deserts have almost no plant growth ■ Generally located between 20° and 35° north and south of the Equator
Tropical grassland (savanna)	■ Low rainfall but seasonal heavy storms can occur; frequent fires; thin soil ■ Grasses with scattered clumps of trees, grading into either open plain or woodland
Tropical scrub forest	■ Rainfall not abundant; high evaporation ■ Thorny shrubs and trees ■ Grades into tropical grassland and savanna
Monsoon forest	■ In the tropics but with distinct wet and dry seasons ■ Trees less closely spaced than in rainforest; many trees shed their leaves in the dry season
Tropical rainforest	■ Warm and humid; frequent rain; average temperature is 25°C all year; no true seasons; little change in day length; growth throughout the year; infertile clay soil ■ Closed canopy; little understorey; large number of plant species (great diversity) competing for available light; trees often have large trunks and buttressed roots; many epiphytes (plants that grow on other plants) and vines; little leaf litter
Mountain	■ Increasing altitude produces a decrease in temperature, similar to the effect of increasing latitude ■ Vegetation types vary with altitude; beyond a certain height, trees do not grow and the vegetation resembles tundra

1.1.5 Characteristics of major terrestrial ecosystems

Aquatic ecosystems

Ecosystems that are water based are called aquatic ecosystems. Examples include ponds, lakes, rivers, oceans, coral reefs, estuaries, and coastal and inland wetlands. The differences between aquatic ecosystems arise from variations in the amount of nutrients dissolved in the water, salinity, depth of sunlight penetration, and average temperature.

Size of ecosystems

An ecosystem may vary in size from a small pond to a vast area of rainforest or an entire ocean. Whether large or small, ecosystems rarely have distinct boundaries. This can complicate ecosystem management when there are definite boundaries, such as national parks or international borders. Individual ecosystems blend into adjacent ecosystems via a zone of transition or ecotone. An ecotone contains organisms common to both ecosystems, but may also have organisms unique to that area. As a result, the ecotone often has greater biodiversity than surrounding ecosystems.

The ecosphere

The ecosphere is the collection of living and dead organisms (the biosphere), interacting with one another and their non-living environment. The ecosphere represents the aggregate of the world's ecosystems.

The study of ecology

The study of ecology is concerned with interactions that occur at five levels of organisation: organisms, populations, communities, ecosystems and the ecosphere as shown in Figure 1.1.6.

Organisms

An organism is simply any form of life. While there are a number of ways to classify organisms, the simplest distinction is between producers (plants), consumers (most animals) and decomposers (such as bacteria that feed on dead animal and plant matter). Plants range in size from microscopic, single-celled phytoplankton to the giant sequoia trees of North America. Animals range in size from microscopic zooplankton to the 30-metre-long blue whale. Decomposers range in size from microscopic bacteria to large fungi, such as mushrooms.

Species and populations

A group of organisms of the same species living together is known as a population. Populations are said to be dynamic: over time their size, distribution, age structure and genetic make-up adapt in response to changes in environmental conditions.

A species is a single type of organism that has the ability to reproduce its own kind. Estimates of the number of species on Earth vary from 5 million to 30 million and as high as 50 million. The majority of animal species are insects, mites and nematodes (worms). So far, only 1.4 million species have been identified and named.

Habitats

The area in which an organism or population lives is known as its habitat. The characteristics of a terrestrial (land-based) habitat are determined by the interaction between temperature and precipitation. Together with the soil, this interaction produces an environment that allows a particular combination of life forms to develop. An aquatic habitat is characterised by features such as temperature, nutrient levels, turbidity (light intensity), salinity and water currents.

Communities

Several populations interacting with each other within a particular habitat are called a community. Ecosystems are sometimes defined in terms of communities of plants and animals that live together in a common habitat. An ecosystem can be referred to as the combination of a community and its non-living environment: an ever-changing (dynamic) network of biological, chemical and physical interactions that sustains a community and allows it to respond to changes in environmental conditions.

1.1.6 The various components of the ecosphere are all interrelated. In order to manage these ecosystems sustainably we must first understand the way these components interact.

Activities

Understanding the text

1 Define the term ecology.
2 Explain why ecosystems are described as ‘systems through which incoming solar energy is captured and channelled through a hierarchy of life forms’.
3 Distinguish between terrestrial and aquatic ecosystems.
4 Describe the biosphere.
5 Describe the ecosphere. What are its components?
6 Define what is meant by these ecological terms: population, species, habitat and community.
7 Define the terms food chain, and food web.

Working geographically

8 Examine Figures 1.1.3 and 1.1.4. Write a report describing the relationship between the distribution of major terrestrial ecosystems and the world pattern of climate.
9 Study Figure 1.1.5 and select two of the ecosystems listed. Conduct research into these ecosystems and prepare a short report comparing the location, flora and fauna of each.
10 Using Figure 1.1.7 and the information contained in the text, outline the relative productivity of the ecosystems shown in the graph.

Productivity of ecosystems

The productivity of an ecosystem can be expressed in two ways:

- the amount of biomass produced in an area—the mass of new living matter produced per square metre of land (or within a volume of water) per unit of time
- energy flow—the amount of energy (in kilojoules) that is ‘locked into’ all the organisms in an area per unit of time.

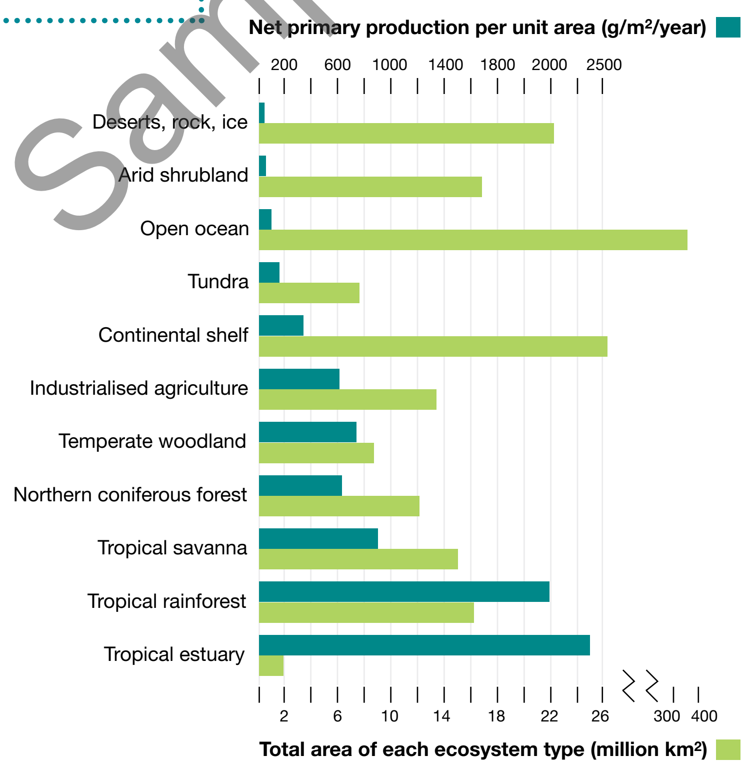
Both rates depend on the quantity of available energy and nutrients in the environment, and the efficiency with which energy and matter are incorporated into producers and passed up the food chain or food web. Figure 1.1.7 compares the productivity of some of the world’s major ecosystems.

Energy flows and nutrient cycling

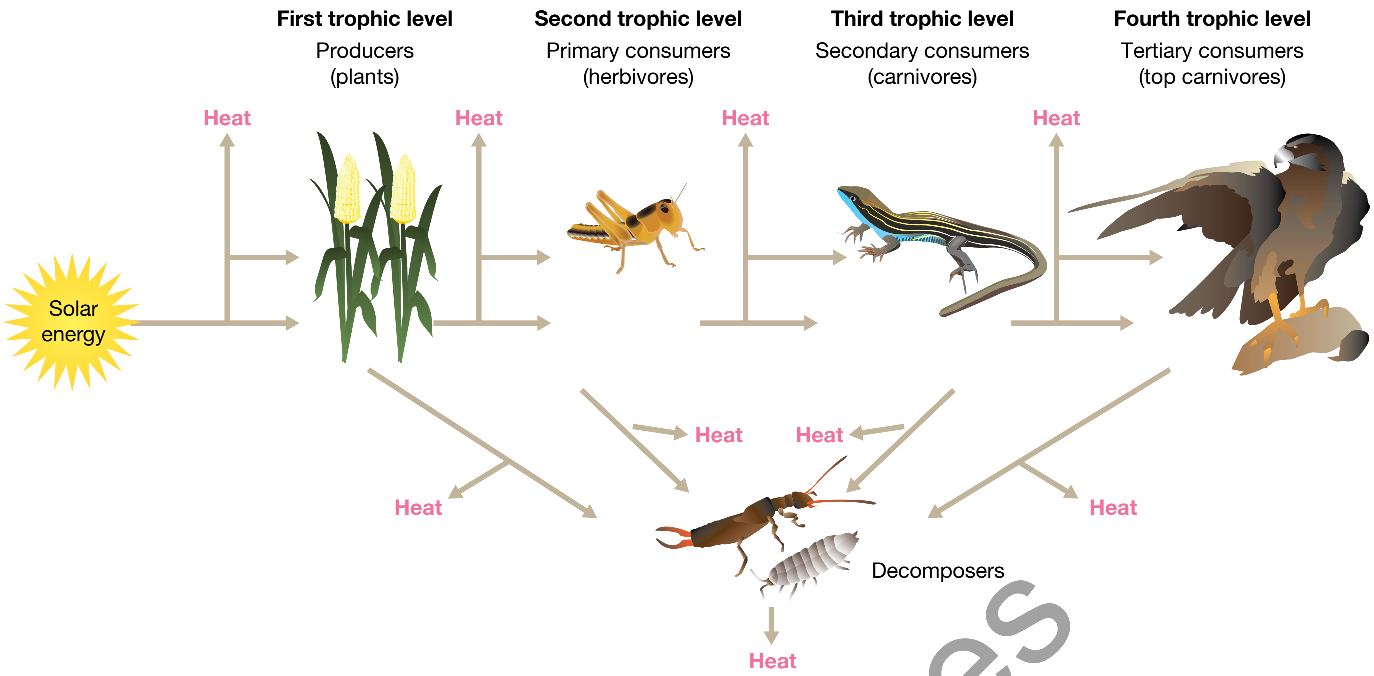
Producers, consumers and decomposers form a chain that facilitates the flow of energy from the Sun, through plants, to animals within the ecosystem. At each level of the food chain, energy (heat) is lost to the atmosphere. Food chains also facilitate the recycling of nutrients from producers, to consumers, to decomposers, then back to producers.

Organisms that share the same types of food in a food chain belong to the same trophic level. Producers belong to the first trophic level, primary consumers to the second, secondary consumers to the third, and so on. A simplified food chain, showing energy and nutrient transfers and the different trophic levels, is shown in Figure 1.1.8.

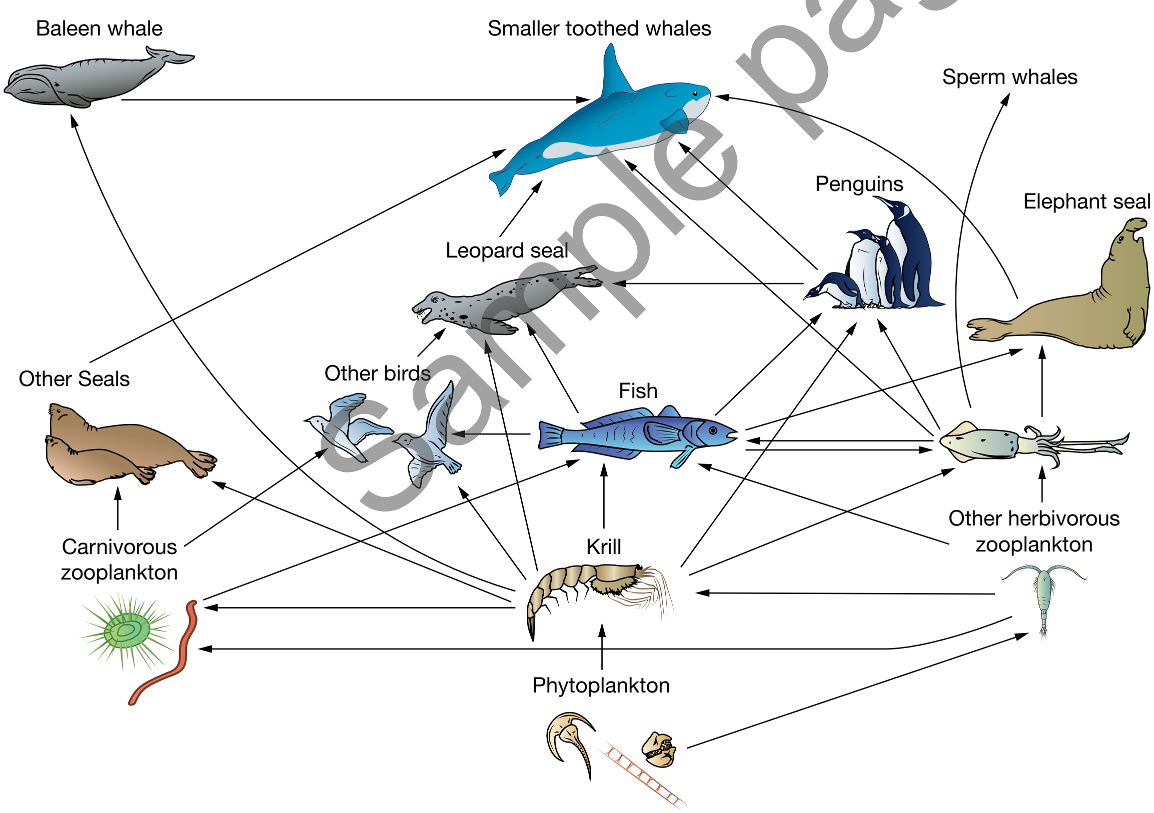
Simple food chains are rare. Organisms in a natural ecosystem are usually part of a complex network of interacting food chains, called a food web as shown in Figure 1.1.9. The various elements of the biome transfer energy by consuming each other: herbivores consume plants and are then, in turn, consumed by carnivores, with carnivores being consumed by larger carnivores.



1.1.7 This graph shows the relative productivity and size of key ecosystems. As the graph indicates, ecosystems of low productivity (such as deserts) require larger areas in order to be sustainable.



1.1.8 This ecosystem model demonstrates the role of solar energy and nutrient transfers within an ecosystem. The Sun is the source of energy in the ecosystem.



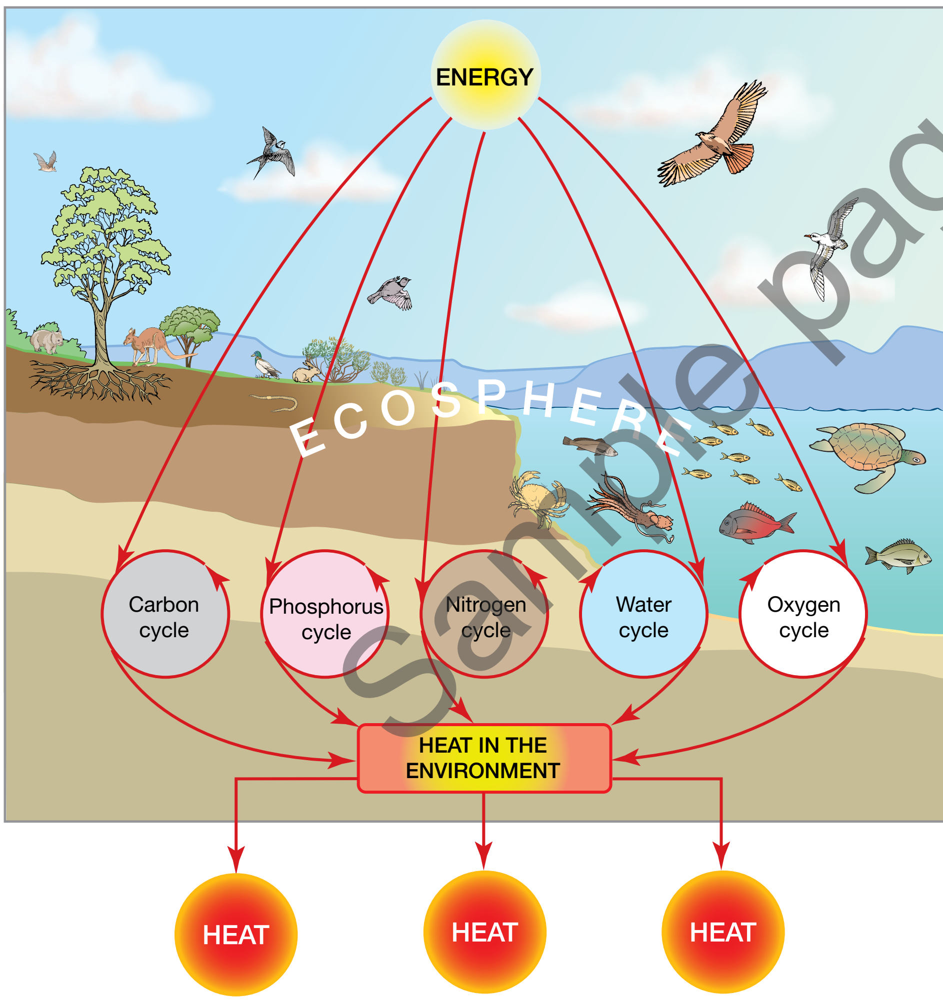
1.1.9 This is a simplified food web for Antarctica. In reality food webs are usually highly complex and involve numerous interactions of many smaller food chains.

Energy and nutrients

The Sun is the primary source of energy within ecosystems. The energy of the Sun is used by plants (producer organisms) to turn carbon dioxide and water into glucose and oxygen via a process known as photosynthesis. Plants then use the glucose as an energy source to make other substances. They also use glucose, in combination with dissolved nutrients, as a building block. Herbivores (primary consumers) consume these nutrients, using them for growth and energy for life and movement. When herbivores are consumed by carnivores, these nutrients pass up through the food web until they reach the largest carnivores, or tertiary consumers.

This process enables nutrients to be recycled from the non-living environment (reservoirs in the atmosphere, hydrosphere and lithosphere) to the living environment and then back to the non-living environment. These nutrient cycles are driven by the Sun, either directly or indirectly. They include the carbon, oxygen, nitrogen, phosphorus, sulphur and water cycles, as shown in Figure 1.1.10.

At each trophic level, significant amounts of nutrients and energy are lost, which results in the number of tertiary consumers in all ecosystems being small compared with the number of primary consumers. Ecosystem with the lowest levels of nutrients support the fewest consumers. Figure 1.1.11 shows the amount of energy lost as nutrients move up the levels of a food chain as well as the significant decrease in the number of organisms that occur at each successive trophic level.

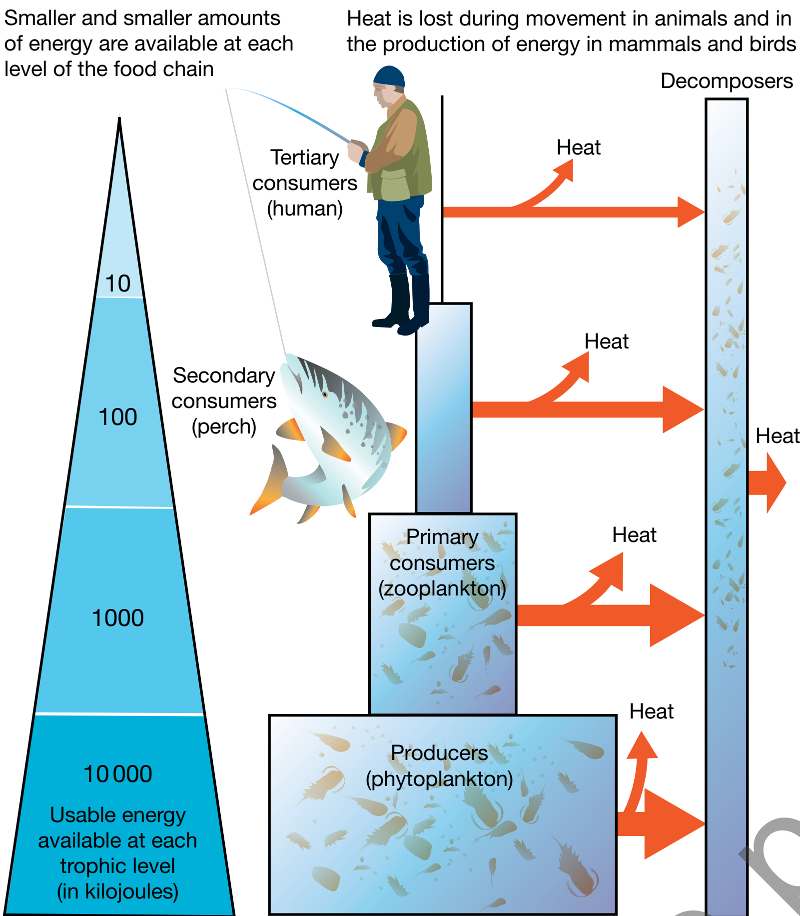


1.1.10 Recycling is an essential process in all ecosystems. Each cycle shown in this diagram is vital for the effective functioning of an ecosystem.

The carbon cycle

Carbon is the basic building block of the compounds necessary for life. Most land plants obtain their carbon by absorbing carbon dioxide directly from the atmosphere, through pores in their leaves. Phytoplankton are microscopic plants in aquatic ecosystems, which obtain their carbon from atmospheric carbon dioxide that has been dissolved in water.

Plants, via photosynthesis, convert the carbon found in carbon dioxide into glucose. The glucose is then used as an energy source and for plant growth. If the plant is consumed, the energy is then passed up the food chain. Oxygen is also given off as a by-product of photosynthesis. Figure 1.1.12 illustrates the functioning of the carbon cycle.



1.1.11 The energy constantly being lost from the system at each level of the food chain can be shown as a pyramid. This energy is lost as animals consume energy in search of food and in the production of heat during plant growth. Tertiary-level consumers are the least energy efficient and thus form the smallest number of animals in the ecosystem.

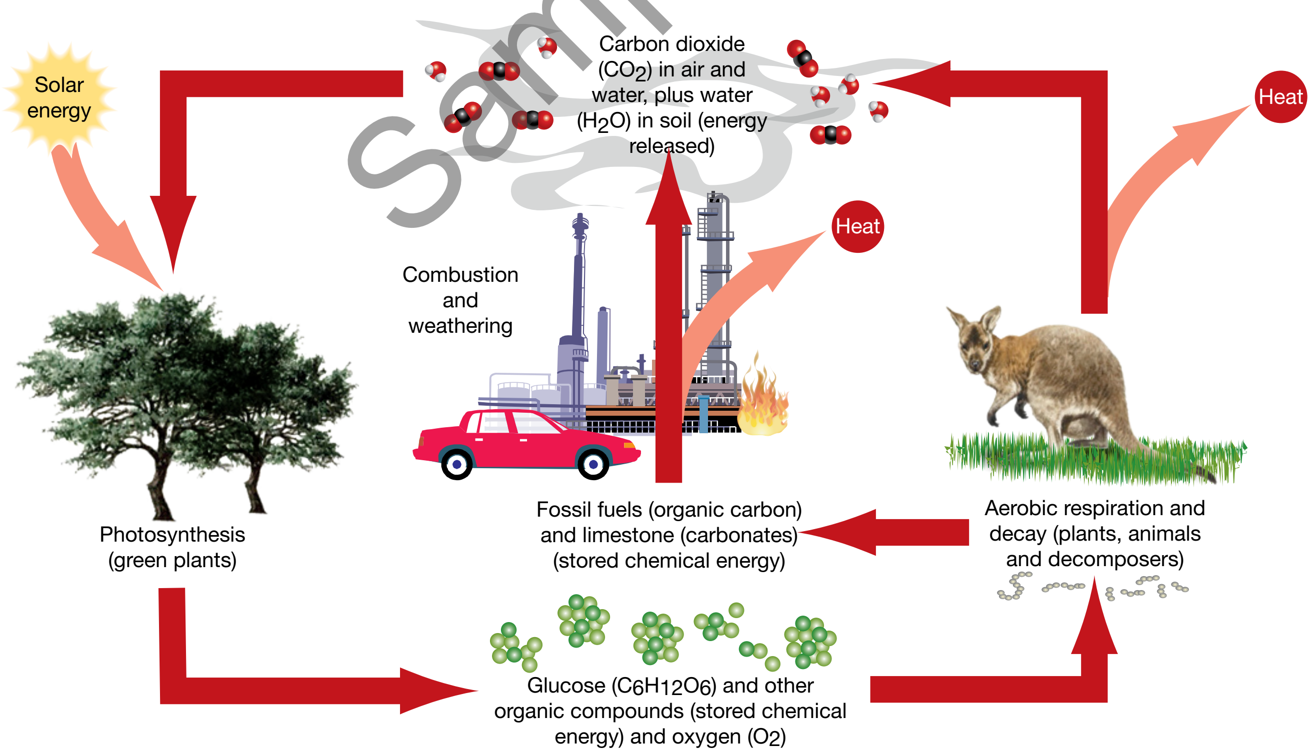
Activities

Understanding the text

1. Describe the meaning of 'trophic level'.
2. Outline the ways that nutrients are recycled in an ecosystem.
3. Explain the role of decomposer organisms in the biotic cycle of an ecosystem.
4. Outline the ways in which the productivity of ecosystems is measured.

Working geographically

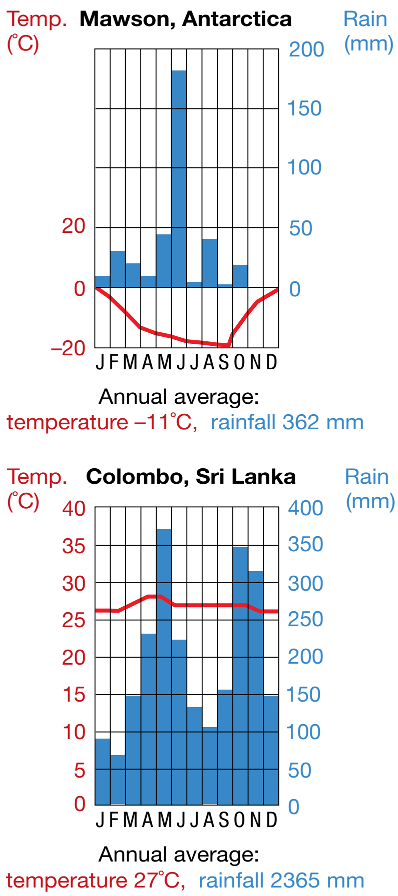
5. Write a report explaining the operation of food webs. Explain why an understanding of the operation of an ecosystem's food web would be essential for the sustainable management of that ecosystem.
6. Study Figure 1.1.11. With the aid of an annotated diagram, explain what happens to the amount of usable energy at successively higher trophic levels.
7. Study Figure 1.1.12. Explain the operation of the carbon cycle.
8. Using the internet and other resources in the library, undertake research into one of the cycles that operates in an ecosystem (carbon, oxygen, nitrogen, phosphorus, sulphur or water). With the aid of a diagram, explain the operation of the selected cycle.



1.1.12 Simplified diagram of the carbon cycle

UNIT 1.2

Factors affecting the functioning of ecosystems



1.2.1 Mawson, located in Antarctica (a polar ecosystem), receives very little precipitation. Whereas Colombo, located in Sri Lanka (an equatorial region), receives high precipitation. The variations in temperature and precipitation create two very different environments in these locations.

The four components of the biophysical environment are the atmosphere, hydrosphere, biosphere and lithosphere. In any ecosystem, the way these four spheres interact with each other affects how the ecosystem develops and functions.

Time is also an important consideration in understanding how ecosystems function. Natural changes in the biosphere can take place over tens of thousands of years, which allows time for the natural systems to adjust. Human-induced changes are typically too rapid for these natural adaption processes. For example, while the world's climate naturally changes over time, human activities (such as the burning of fossil fuels) have significantly altered the world's climate in a very short period.

The atmosphere

The atmosphere, effectively the air surrounding the Earth's surface, is the main source of the climatic factors that impact on ecosystem functioning. Temperature and the amount of rainfall determine the characteristics of all elements within the ecosystem and the speed at which they function.

Examples of the effect of the atmosphere on ecosystems are diverse. The warm, moist climate of rainforest ecosystems accelerates the rate of plant growth, the decay of dead material and the take-up of minerals, which is the main reason why they are dynamic. The atmosphere is also the source of nutrients—nitrogen, carbon (as carbon dioxide) and oxygen as well as water. Circulation patterns within the atmosphere also determine the spread of pollutants.

The hydrosphere

The hydrosphere includes the water on the Earth's surface, and is closely linked to the atmosphere since it is the atmosphere that determines the nature of the water cycle in a particular area. For example, polar ecosystems are cold deserts with annual rainfalls of less than 250 mm and very little available freshwater, as shown in Figure 1.2.1. Because of the extreme cold and the low precipitation, polar ecosystems function very slowly. In tropical rainforests, the relatively large volumes of rainfall increases the speed at which elements cycle through the ecosystem, which leads to high levels of biodiversity.

This same vigorous hydrological cycle can also increase levels of destruction, since it quickly leaches soils and erodes the land, as shown in Figure 1.2.2. If people have removed trees from the ecosystem, these processes can cause silting of neighbouring rivers and the destruction of river ecosystems.

1.2.2 While water is vital for life in an ecosystem, it can also cause destruction, such as erosion of landscapes.

Large bodies of water, such as oceans and lakes, moderate the temperatures of adjoining landmasses because water heats and cools more slowly than land.

The lithosphere

The lithosphere is the crust or solid part of the Earth. It determines the nature of soils and provides habitats for many of the decomposer organisms that recycle the minerals essential to the plants that form the basis of the food web. The lithosphere stores mineral nutrients as well as water within the spaces between the soil particles, where it is available for use by plants.

The capacity of the soil to perform these two functions helps to determine the nature of particular ecosystems. In areas of non-porous clays, wetlands may develop because water is trapped close to or above the surface, as seen in Figure 1.2.3. In areas with sandy soils, water drains away quickly, leaving an extremely dry soil profile. In these areas if rainfall is low, xerophytic (drought-resistant) plant communities, such as cacti, dominate.

Climatic factors affect the role that soils play in an ecosystem. An example is the permafrost soils of tundra ecosystems shown in Figure 1.2.4. In this very cold climate the soil remains frozen for most of the year. This means that decomposer activity is virtually non-existent and moisture is unavailable to plants. The vegetation characteristic of this ecosystem includes small tussock grasses. At the other extreme are the leached soils of the tropical rainforest ecosystems as illustrated in the soil profile shown in Figure 1.2.5.

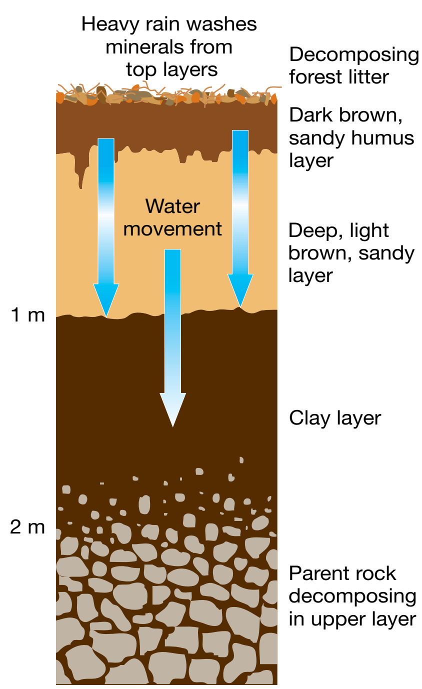
1.2.3 Where non-porous soils are found, wetlands are a common feature of the environment.

1.2.4 In the extremely cold climate of the tundra the soil remains frozen throughout the year, creating permafrost.

Landforms also affect ecosystems. Small variations in elevation can result in marked differences in plant communities. This is due to changes in moisture availability. Average temperatures decrease with increasing altitude, so the climate and ecosystems of mountains often differ markedly from those of nearby valleys and plains.

The biosphere

The biosphere is the domain on or near the Earth's surface where environmental conditions enable solar energy to produce the chemical processes necessary for life. It comprises all living and dead organisms (the biotic components of ecosystems) found near the Earth's surface. These exist in parts of the atmosphere, hydrosphere and upper lithosphere. Nearly all life on Earth exists in a narrow zone that extends from about 200 metres below the surface of the sea to about 9000 metres above sea level.



1.2.5 This is the soil profile of a rainforest. A soil profile shows the structure of the layers of soil. Despite being a highly productive system, rainforest soils are generally quite poor below the topsoil. The thin layer of topsoil is constantly being renewed with rotting vegetation (humus). This makes it very fertile. However, heavy rainfall leaches the nutrients out of the lower layers. This creates poorer soils further down the profile.

1.2.6 **A** Autotrophic organisms, such as the button grass shown here, create their own food and are often referred to as producers. **B** Heterotrophic organisms, such as wallabies, which are herbivores, consume the resources of an ecosystem.

The biosphere consists of two types of organisms: those that can manufacture their own food (autotrophs) and those that cannot (heterotrophs), as shown in Figure 1.2.6.

Autotrophic organisms

Autotrophic organisms are self-sufficient manufacturers of food. They use solar energy (light), water, carbon dioxide and nutrients from the soil to manufacture the organic (carbon-based) compounds that they use as a source of energy and nutrients. Most autotrophic organisms are green plants that make organic compounds via photosynthesis. These organisms are the lowest trophic level in the food chain and form the base of any food web. They are often referred to as 'producers'.

Heterotrophic organisms

Heterotrophic organisms are consumers, which are organisms that cannot make their own food. As well as the obvious herbivores (plant eaters), carnivores (meat eaters) and omnivores (both plant and meat eaters), this group includes the decomposers (such as worms, fungi and bacteria). Decomposers break down the remains of living matter, enabling minerals to return to the soil where they are again available to autotrophic organisms.

Bioaccumulation

Non-biodegradable toxic substances released into the environment make their way through the food chain and accumulate in organisms at the highest level of the food chain. This process, known as bioaccumulation, can affect the survival of individual organisms and populations of organisms.

Synthetic (human-made) chemicals (such as PCBs used to make plastics and electrical insulators, or the pesticide DDT), some radioactive materials and some toxic mercury and lead compounds become increasingly concentrated in biological tissues at successively higher trophic levels in food chains and webs. These chemicals have properties that favour bioaccumulation. This means that they are selectively stored in biological tissues, such as fat or bone, and degrade slowly, if at all, by natural processes.

Figure 1.2.7 illustrates how DDT becomes amplified in the food chain of an estuarine ecosystem. If each phytoplankton stores thousands of units of fat-soluble DDT in its fatty tissue, then a large fish that eats 10 of the smaller fish will receive and store tens of thousands of units of DDT.

A bird or human that eats the fish can then take in hundreds of thousands of units of DDT.

The accumulation and amplification of toxic substances in an organism can kill it directly, reduce its ability to reproduce, or weaken it to a point where it is vulnerable to diseases, parasites and predators.

Adapted from T. Miller, Living in the Environment, Wadsworth, Belmont

SPOTLIGHT

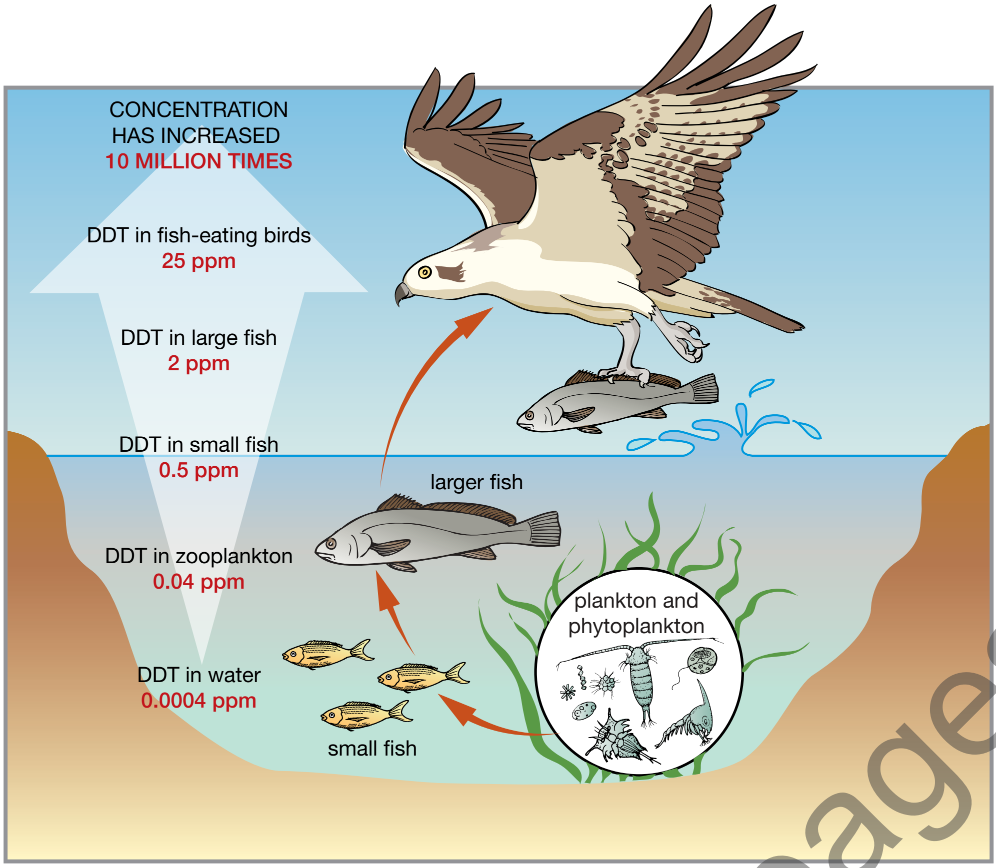
Dioxin contamination leads to fishing ban in Sydney Harbour

Dioxins are chemical compounds that are highly toxic. The World Health Organization has found that they are a cause of several types of cancer and developmental and reproductive disorders. They are known as persistent environmental pollutants, meaning that they remain in the environment for a very long time. In waterways, dioxin tend to settle into the sediments on the sea floor and gradually accumulate there.

In February 2006, the NSW Government placed an indefinite ban on commercial fishing within Sydney Harbour. The ban followed a scientific investigation that found dangerously high levels of dioxin in a fish caught in the harbour. Recreational fishing is still permitted but strict guidelines to limit the amount of seafood caught and eaten from areas west of the Sydney Harbour Bridge were implemented and remain in effect today.

Much of the dioxins in the Harbour originate from around Homebush Bay. While this area is today dominated by high density housing, for decades chemical works, paint factories and other heavy industries lined the foreshore of the bay.

These industries discharged large amounts of pollutants into the bay, including dioxins. These pollutants have settled into the thick sediments to create a toxic cocktail. It was previously believed that the toxins were locked into the mud and posed little threat to aquatic species other than the bottom dwellers of the bay, such as prawns. However, it is now clear that the toxins have gradually spread out of the bay in a toxic plume that has increased dioxin levels in a range of different species throughout the harbour.



1.2.7 This diagram demonstrates the impact of the pesticide DDT in an estuarine ecosystem. The concentration of the toxic DDT in the fatty tissue of organisms is amplified by 10 million times in this food chain (ppm = parts per million).

Activities

Understanding the text

1. Explain the difference between autotrophic and heterotrophic organisms.
2. Outline the different types of heterotrophic organisms.
3. Explain the effect of bioaccumulation on ecosystems.

Working geographically

4. Write an extended response outlining the role of the biosphere, atmosphere, hydrosphere and lithosphere in ecosystem functioning.
5. Review the Spotlight on dioxins in Sydney Harbour and complete the following activities.
   a. Outline the source of dioxins in Sydney Harbour.
   b. Explain the impact of dioxins on the functioning of Sydney Harbour.
6. Research the current situation in relation to dioxins in Sydney Harbour and write a 10-step guide on how to prevent poisoning.

UNIT 1.3

Vulnerability and resilience of ecosystems

All ecosystems function in a state of dynamic equilibrium, which is a continual state of balanced change. This dynamic, but balanced, state is the result of the interactions between elements in the ecosystem: the atmosphere, lithosphere, hydrosphere and biosphere. Change occurs because the interactions between minerals, energy and communities vary over time.

The interdependence of these four elements also means ecosystems are vulnerable. A change beyond the limit of the equilibrium, in any of these elements, means that the system as a whole cannot exist in its original state. All ecosystems are vulnerable, but the level of vulnerability depends on how small a change in any element is likely to upset the equilibrium overall. Ecosystems are not equally at risk and some are more resilient than others.

Causes of ecosystem vulnerability

All ecosystems have some ability to withstand stress. They tend to resist being disturbed or altered and will restore themselves to their original condition if not disturbed too drastically. Ecosystems are able to maintain themselves within a tolerable range of conditions.

A number of factors affect an ecosystem's vulnerability to stress. These include location, extent, biodiversity and linkages.

Location

The location of an ecosystem affects its functioning. At a global scale, latitude, distance from the sea and altitude play decisive roles in determining climate and ultimately the nature of particular ecosystems.

The microclimatic features of a location can be significant enough to create a range of distinctive ecosystem types within relatively small areas. The aspect of a slope is one such microclimatic variable, since the aspect will affect the amount of sunlight and rain it receives.

Extreme or unique ecosystems

Some ecosystems are located in environments considered extreme: deserts (extreme heat and/or aridity), the polar-regions and high mountain peaks (extreme cold), hypersaline lagoons (extreme salinity) and areas of nutrient deficiency. Organisms capable of living in such conditions have adapted to survive the extreme conditions and are therefore highly specialised. The more specialised an organism is within a particular set of environmental conditions, the more vulnerable it will be to changes in those conditions.

Corals are highly specialised organisms that flourish in the relatively shallow, nutrient-deficient waters of the tropics. Any increase in nutrient levels promotes the growth of algae. This, in turn, reduces the amount of sunlight available for coral growth. If the elevated nutrient levels are sustained the corals become stressed, reefs contract in size and the number of coral species declines. Corals are also sensitive to changes in water temperature. They normally flourish at temperatures between 25°C and 29°C, depending on their location. This narrow temperature range is very close to their upper lethal temperature. An increase of just a few degrees above the usual summer temperature can be devastating. The coral polyp dies, leaving only the white calcium carbonate skeleton. This is known as coral bleaching. One consequence of global warming will be the widespread destruction of coral reef ecosystems.

Proximity to humans

Proximity to large concentrations of people is another important contributing factor to ecosystem vulnerability. As populations grow, so does the demand for land as shown in Figure 1.3.1. Urban, industrial and agricultural land uses affect and sometimes destroy natural ecosystems, while the oceans, rivers and the atmosphere become dumping grounds for pollutants. For coral reef ecosystems, run-off that has been polluted by sewage, agricultural fertilisers and land clearance is a major source of excess nutrients and increased turbidity.

1.3.1 Proximity to human activity is a factor in the vulnerability of an ecosystem.

Extent

The extent (size) of an ecosystem is the result of a variety of factors. Recent research has shown that the boundaries of ecosystems tend to overlap each other. For example, river ecosystems extend beyond the river channel to include the whole drainage system. Human activity in the drainage basin can impact on the river itself even when it occurs some distance from the channel. It may, for example, increase soil erosion. A study of the Flathead River in Montana in the western United States showed that stoneflies and other creatures living in shallow wells on the floodplain of the river, up to 2 kilometres away from the river, mated along the river banks before returning to lay their eggs in the wells. While at the riverbank they were preyed upon by fish. This means the floodplain and the river cannot be considered as separate systems.

Ecosystems that are restricted to relatively small areas or have already been extensively disturbed are especially vulnerable. Tropical rainforests have relatively small populations of a large number of species confined to relatively small, localised communities. The loss of even a small area of rainforest can lead to the extinction of plant and animal species. Savanna grasslands have large populations of a relatively small number of species spread over much larger areas. The loss of a small area of grassland may not result in the extinction of species. However, the large herbivores typical of these regions require extensive grazing areas.

Biodiversity

When ecosystems are diverse, there is a range of pathways for the ecological processes, such as nutrient recycling. If one pathway is damaged or destroyed, an alternative may be found and the ecosystem can continue to function at its normal level. If the level of biodiversity is greatly diminished, for example through the extinction of a species, the functioning of the ecosystem is put at risk. The greater the level of diversity means the greater the opportunity to adapt to change.

Biodiversity is usually considered at three levels: genetic diversity, species diversity and ecosystem diversity.

Genetic diversity

Genetic diversity is the variety of genetic information contained in all the individual plants, animals and microorganisms. Genetic diversity occurs within and between populations of species as well as between species.

A high level of genetic diversity favours the survival of a species, because it increases the chance that some members of the species will have characteristics that aid their survival if the population experiences stress. Genes have costs as well as benefits; a British study has shown that peach potato aphids that are resistant to common pesticides (a genetic benefit) are less able to survive British winters (a cost of genetic variation) than aphids that are not resistant to pesticides. (This situation may change with global warming.)

Species diversity

Species diversity is a measure of the number of species at each trophic level of an ecosystem. The greater the species diversity, the more robust the ecosystem: if the population of one producer or consumer organism declines dramatically there are likely to be other producers or consumers available that can fulfil a similar function in the ecosystem. Species diversity in an ecosystem can be seen in Figure 1.3.2.

1.3.2 Species diversity increases an ecosystem's resilience.

Ecosystem diversity

Ecosystem diversity refers to the diversity within an ecosystem in terms of habitat differences, biotic communities and the variety of ecological processes.

Linkages

Interdependence, or linkages, is related to species diversity. The greater the level of interdependence within an ecosystem the greater its ability to absorb change. For example, the loss of a primary consumer from a food web is unlikely to have a major impact on secondary consumers if there is a range of alternative primary consumers on which to feed.

Ecosystems that have low levels of interdependence are much more vulnerable to change. For example, there are few linkages up through the food chain of the oceans around Antarctica. Krill are the dominant primary consumer organism and the main source of energy (food) for some species of whale. There are no intermediary stages in the food chain. Any reduction in the supply of krill (from large-scale commercial harvesting, for example) will directly impact on the number of whales that the ecosystem can support.

Interdependence can take very subtle forms. Some flowering plants can be fertilised by only one species of insect. This insect may, in turn, be dependent on some other organism for part of its life cycle. Anything that jeopardises this third organism will affect the reproductive success of the flowering plant, making it far more vulnerable than if it could be fertilised by multiple species.

Some primary consumers have highly specific food sources, and many parasitic organisms depend on specific hosts. This makes these organisms vulnerable to disturbances in their ecosystems. However, the same characteristics can be exploited by humans in the biological control of pest species. For example, in Lord Howe Island, the introduced species Crofton weed has smothered vegetation and overtaken hillsides. In response, a rust fungus from Mexico has been introduced to help control the weed. Large consumer animals may range across a number of small, localised ecosystems, having genetically adapted to the variations in all of them.

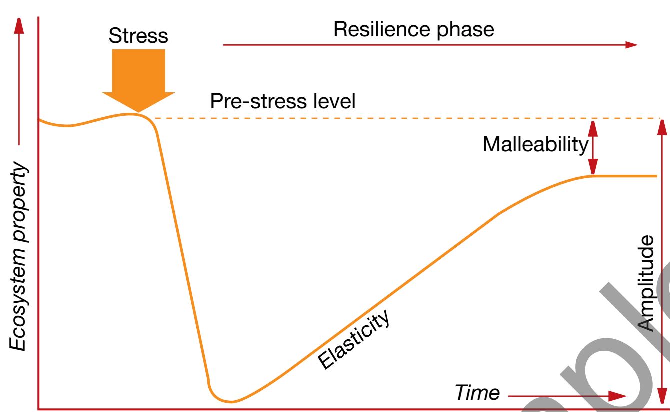
Resilience

Resilience is the ability of an ecosystem (or a component of an ecosystem) to adapt to a changing environment and to restore function and structure following an episode of natural or human-induced stress.

Ecosystems rich in biodiversity generally have greater resilience than those with little diversity. They are able to recover more readily from naturally induced stress (including drought and fire) and human-induced habitat destruction. The more successful a species is at regeneration and adaptation, the less vulnerable it is to changes in its ecosystem. Long-term ecosystem degradation occurs when the magnitude and duration of the stress exceed the ability of the component to repair itself.

In some cases, natural sources of stress play an important role in the functioning of ecosystems. Stress-dependent organisms and processes rely on changes in their environment to produce or stimulate a growth of their systems. Some eucalypt species, for example, rely on fire to initiate a stage in their reproduction cycle and many perennial desert plants rely on the occasional fall of rain to activate their growth cycle.

As with change, resilience is a natural part of ecosystem functioning. Figure 1.3.3 illustrates the impact of stress on ecosystem functioning. The intensity and duration of stress is important in terms of the effect it has on an ecosystem.



Elasticity represents the rate that an ecosystem can recover after stress or disturbance.

Amplitude refers to the maximum level of strain before it becomes impossible for the ecosystem to recover.

Malleability is the difference between the ecosystem's final recovery level and the pre-stress level—the greater the difference, the less resilient is the ecosystem.

1.3.3 The impact of stress on the functioning of ecosystems

Natural and human-induced environmental stress

Ecosystems are constantly adjusting in response to changes within the total environment. These adjustments could be in response to changes in the availability of water, average temperature or many other natural events. In nature, these changes usually take place very slowly. The biome gradually adapts as animals and plant species that have characteristics unsuited to the change die out and those more suited to the new environment remain alive to breed and pass on their characteristics to successive generations. This process is known as natural selection.

Sudden natural disasters have occurred from time to time throughout the Earth's history and have caused whole species to die out almost instantly because they had no time to adapt. Such occurrences are rare. This is not the case in respect to human-initiated stress. The damming of a river, the draining of a wetland or the clearing of vast tracts of natural vegetation for agriculture are sudden and drastic changes that can result in a loss of habitat and the destruction of a species (their extinction).

The ability to instigate large-scale environmental change means that people are able to push the state of dynamic equilibrium beyond its limits. As a result, people have created situations where they are required to maintain a state of equilibrium by utilising resources found elsewhere. The maintenance of an agricultural monoculture may rely on inputs of fossil fuel and fertiliser, pesticides and herbicides.

Activities

Understanding the text

1. Describe the concept of dynamic equilibrium.
2. Explain how location can make an ecosystem more vulnerable.
3. Describe the relationship between vulnerability of ecosystems and extent.
4. Explain why genetic diversity decreases the vulnerability of an ecosystem.
5. Explain the idea of interdependence.
6. Identify the kinds of ecosystems that have greater resilience.
7. Under what conditions does long-term degradation occur?

Working geographically

8. Explain the process shown in Figure 1.3.3.

Without them the monoculture would collapse. Today, human activities destroy or seriously threaten species and, more importantly, destroy or degrade their habitat.

Figure 1.3.4 outlines the nature of changes affecting ecosystems. Figure 1.3.5 outlines some of the effects of environmental stress.

Changes affecting ecosystems		
	Catastrophic	**Gradual**
Natural sources of environmental stress	■ Drought ■ Flood ■ Fire ■ Volcanic eruption ■ Earthquake ■ Landslide ■ Change in stream course ■ Disease	■ Natural climatic changes ■ Immigration/invasion of new species ■ Adaptation/evolution ■ Ecological succession ■ Disease
Human-induced sources of environmental stress	■ Deforestation ■ Overgrazing ■ Ploughing ■ Erosion ■ Pesticide application ■ Fire ■ Mining ■ Toxic contamination ■ Urbanisation ■ Water and air pollution ■ Loss and degradation of wildlife activity	■ Anthropogenic (caused by humans) climate change ■ Irrigation: salinisation and waterlogging of soils ■ Soil compaction ■ Depletion of groundwater ■ Water and air pollution ■ Loss and degradation of wildlife habitat ■ Elimination of pests and predators ■ Introduction of exotic species ■ Overhunting/overfishing ■ Toxic contamination ■ Urbanisation ■ Excessive tourism

1.3.4 Changes affecting ecosystems by cause and rate

DID YOU KNOW?

The International Union for the Conservation of Nature estimates that there are 948 species in Australia vulnerable to extinction. This includes 62 species of mammals, 119 fish, 52 birds, 43 reptiles and 47 amphibians.

Effects of environmental stress		
Organism level	**Population level**	**Community–ecosystem level**
■ Physiological and biological changes ■ Psychological disorders ■ Behavioural changes ■ Fewer or no offspring ■ Genetic defects in offspring ■ Cancers	■ Population increase or decrease ■ Change in age structure (old, young and weak may die) ■ Survival of strains genetically resistant to stress ■ Loss of genetic diversity and adaptability ■ Extinction	■ Disruption of energy flows: • Decrease or increase in solar energy uptake and heat output • Changes in trophic structure in food chains and webs ■ Disruption of chemical cycles: • Depletion of essential nutrients • Excessive addition of nutrients ■ Simplification: • Reduction in species diversity • Reduction or elimination of habitats • Less-complex food webs • Possibility of lowered stability • Possibility of ecosystem collapse
		Adapted from G.T. Miller, *Living in the Environment*.

1.3.5 Some of the effects of environmental stress

Environmental impacts of human activity

The impacts of human activity operate within the context of an interdependent global environment. Global or international cooperation is needed to address the threats to the world's biophysical environment.

The causes of environmental degradation in today's world include massive population growth; poverty and the crippling burden of debt in the developing world; non-sustainable consumption and environmentally damaging waste generation in the developed world; non-sustainable agricultural practices in many countries; and environmentally damaging industrialisation and exploitation of natural resources. If humans are to deal effectively with environmental degradation we will need to address these issues.

1.3.6 Widespread land clearing results in habitat loss.

Species introductions

These may be either deliberate or accidental. Introduced species can wipe out local flora and fauna, either by preying on them or by out-competing them for food and space. This disrupts the flow of energy within ecosystems, the effects of which are magnified throughout the food chain.

Habitat destruction

Destruction of habitat, as seen in Figure 1.3.6, is now considered the major threat to biodiversity. Habitat loss takes several forms, including outright loss as it is converted to human use, as well as degradation and fragmentation where native species are deprived of food, shelter and breeding areas and are squeezed into smaller and smaller areas of undisturbed land.

1.3.7 Endangered species, such as the African elephant, continue to be hunted by poachers despite such hunting being illegal.

Hunting

Hunting can lead to the uncontrolled exploitation of and trade in wildlife. It has decimated some species, such as the Amur Tiger, where around 450 are left in the wild. The Thylacine or Tasmanian Tiger was hunted to extinction. Overfishing has destroyed the herring and cod fisheries of the developed world. Large mammals, such as the African elephant shown in Figure 1.3.7, are still targeted by poachers. Despite the global ban imposed on ivory trading in 1989, enough people in the developed world are prepared to offer high prices for the ivory, which results in ongoing poaching.

Pollution

Pollution is a major threat in aquatic and land-based ecosystems. Acid rain, for example, has been held responsible for a serious decline in aquatic (lake) ecosystems and forest ecosystems in northern and eastern Europe.

Activities

Understanding the text

1 Explain what natural selection is.

2 Explain why humans need to develop a global approach to environmental management.

3 Outline the main causes of environmental degradation today.

4 Describe the impact of species introductions.

Working geographically

5 Study Figure 1.3.4. Write a short report on the causes of changes to environmental functioning created by human activities.

CASE STUDY

Natural and human-induced stress

The following are examples of either natural or human-induced environmental stress.

Mt St Helens eruptions

In 1980, Mt St Helens (see Figure 1.3.8 A) had been dormant for over a century, in April–May scientists had become concerned about tremors beneath the mountain. Aerial observers had noted an opening on the summit of Mt St Helens where ice quickly blackened with ash. What caused most concern was the development of a bulge on the side of the mountain's northern slope.

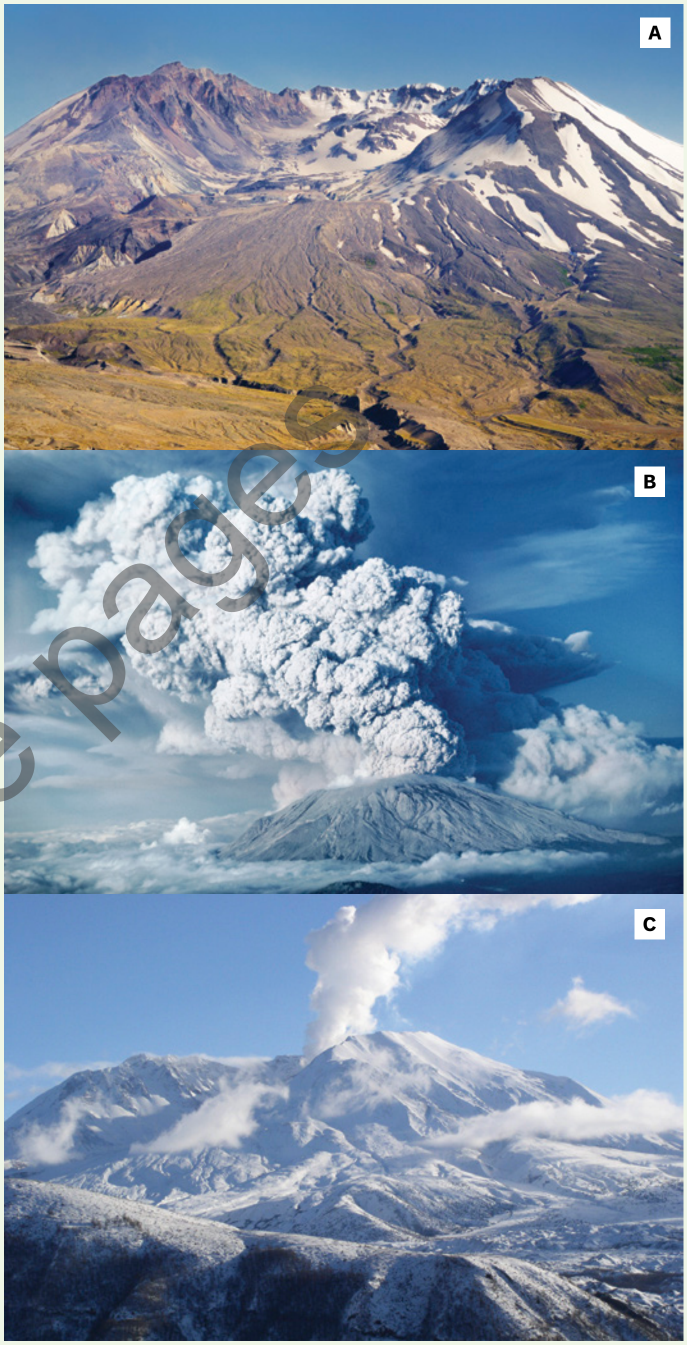
On 18 May at 8.32 a.m., an earthquake measuring 5.1 on the Richter Scale rocked the earth directly below the mountain. The earthquake initiated an avalanche, which was followed by a massive blast of gas, rock, ash and ice shown in Figure 1.3.8 B. One part of the avalanche slammed into Spirit Lake, causing the water level to rise 60 metres. Another mass of debris crashed down into the Toutle River, filling it to a depth of 45 metres in minutes.

The effects on the surrounding ecosystem were devastating:

- 120 metres of the summit vanished, leaving in its place a crater 2 kilometres wide, 4 kilometres long and 1.5 kilometres deep, as seen in Figure 1.3.8 C.
- 380 square kilometres of land to the north of the mountain was devastated by the blast and covered by hot volcanic debris
- large areas of coniferous forest were destroyed (see Figure 1.3.9) and countless numbers of wild animals were killed
- volcanic ash, carried by the prevailing winds, was spread for 1500 kilometres to the west
- 100 people lost their lives.

Within just a few years of the eruption scientists found evidence that pioneering flora and fauna were starting to colonise the ash-grey volcanic landscape seen in Figure 1.3.10. Plants such as lupin, Indian paintbrush, pearly everlasting and fireweed took root among the coarse grey rock. Willow and elder trees had grown to a height of 1–2 metres. The roots and decaying leaves and stems of the vegetation provided the organic material needed to convert volcanic grit into sustaining soil.

The plants and trees had adapted to the extremes of season and altitude, and were equipped to stake a claim in the harsh conditions. Lupins played a key role; bacteria on their roots released nitrogen, necessary to all plants. Alders produced winged seeds that could ride the wind. Birds and animals helped the process by eating, transporting and depositing seeds in their droppings. Burrowing gophers penetrated the ash blanket and brought former topsoil to the surface.

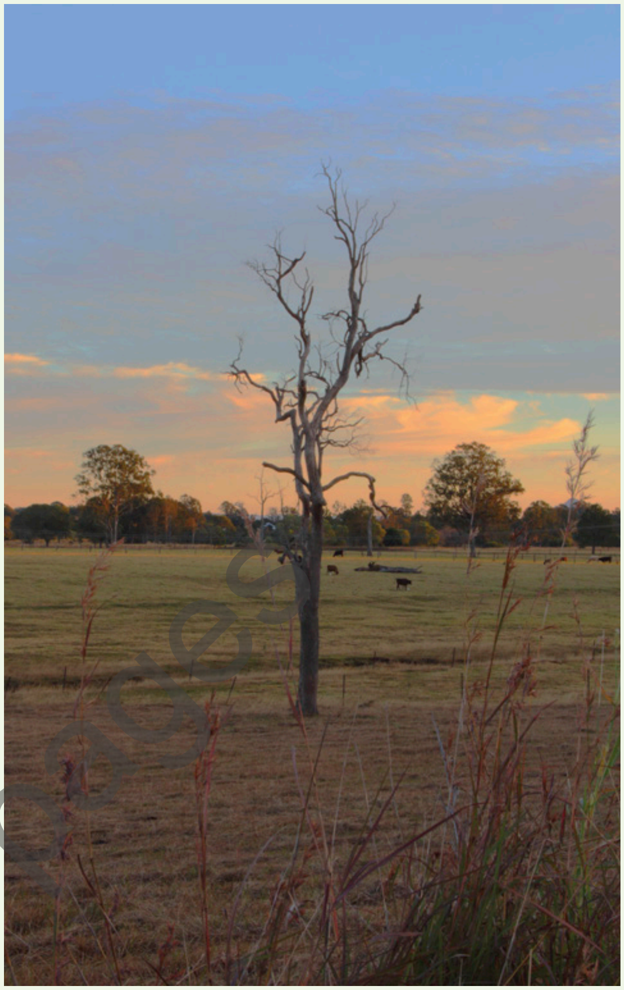


1.3.8 The Mt St Helens eruption was a source of natural stress. **A** Mt St Helens prior to the eruption. **B** Mt St Helens erupting. **C** Mt St Helens following the eruption.

The area represents a miniature fast-forward version of what happened over vast time frames in our planet's evolution. Scientists have enjoyed an unparalleled opportunity to observe the cycles of regeneration.

1.3.9 The environmental impact of the eruption

1.3.10 In the years following the eruption, the environment slowly recovered.



1.3.11 Mundulla Yellows is a disease that kills eucalypt trees.

Mundulla Yellows

First discovered around the tiny South Australian town of Mundulla, the disease Mundulla Yellows has been responsible for the death of thousands of eucalypt trees across Australia (see Figure 1.3.11).

It was originally thought that the disease was caused by a virus and was a natural phenomenon. The disease causes leaves on the trees to yellow, hence the name. Eventually the trees will die.

Researchers have found that trees growing close to roads are more at risk from the disease than those growing in natural bushland. Following this finding, scientists began to research the link between roads and the disease. They discovered that the disease may be linked to crushed limestone, which is commonly used as a road base. The lime changes soil conditions, increasing pH and salt levels while making soil less iron rich. In 2004 researchers demonstrated that by implanting trees with iron, the effects of the disease could be reduced. These findings support the link with the road base.

Victorian scientists have also been looking at links between the increase in Mundulla Yellows and human activities. One interesting finding has been the correlation between increased levels of carbon dioxide (associated with the greenhouse effect) and the rise in the incidence of the disease. Preliminary research indicates that an increase in carbon dioxide in soils and in the atmosphere makes trees more susceptible to Mundulla Yellows.

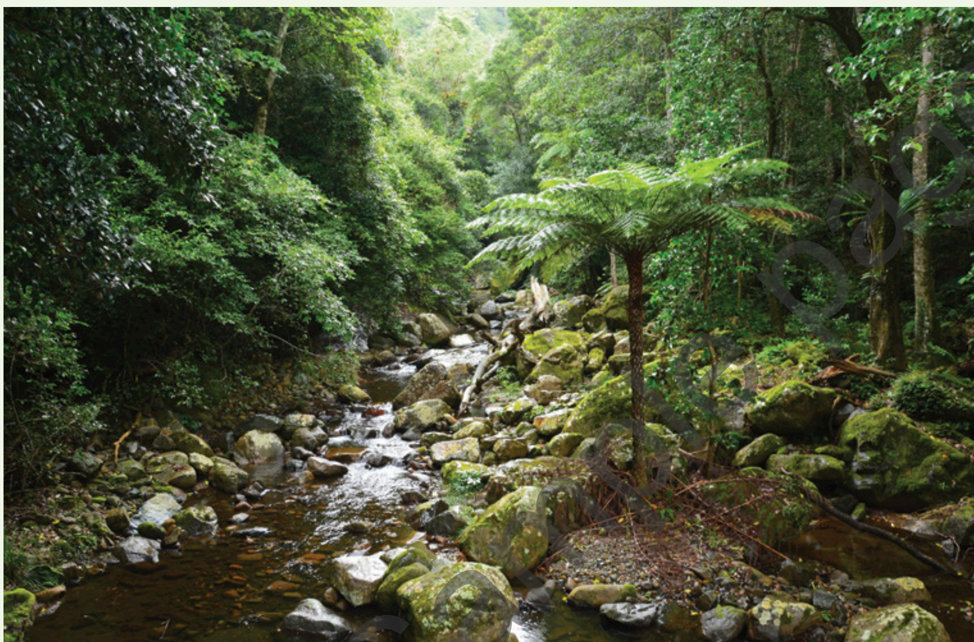
Minnamurra Rainforest

Minnamurra Rainforest is a small pocket of rainforest located on the South Coast of New South Wales, near Kiama, as shown in Figure 1.3.12. The extent, biodiversity and location of the rainforest all work together to make this a vulnerable ecosystem.

The forest is located close to urban development and is surrounded by farms. This increases the level of pollutants entering the system and has led to significant weed infestation, particularly lantana, which infests much of the forest.

Minnamurra is a remnant forest of only about 160 hectares, meaning that it is a remaining small portion of what was once a much larger forest, in fact less than 10 per cent of the original forest remains. This significantly increases the vulnerability of the ecosystem because weeds, pests and disease are more easily spread throughout the whole forest.

The biodiversity of the forest is threatened by the non-endemic (introduced) species, such as lantana, that have invaded the forest and created pockets of monocultures. Additionally, with such a small extent the number of individuals of species that can be supported by the forest is significantly reduced.



1.3.12 The location, extent and biodiversity of Minnamurra Rainforest increase its vulnerability.

Activities

Understanding the text

1 Explain the implications of resilient ecosystems and their ability to recover from catastrophic natural stress events.

2 a Describe the impact of the disease Mundulla Yellows.

b Explain the possible links between human activities and the disease.

3 Explain, using illustrative examples, the impact of natural stress on ecosystem vulnerability.

4 Write a short report explaining why Minnamurra Rainforest can be considered vulnerable.

UNIT 1.4

Human-induced modifications to ecosystems

People are part of the biosphere and play a role in maintaining or disturbing the dynamic equilibrium of any ecosystem.

Human-induced change has a long history. In Europe, Africa, the Americas, Asia and Australia early hunters are believed to have destroyed remaining populations of megafauna (such as the mammoth, woolly rhinoceros and giant wombat) that were already threatened by climate change. In Australia, more than 40 000 years of fire-stick farming gradually changed the forest ecosystems so that fire-resistant species now dominate. However, it was the cultivation of crops and the domestication of animals, beginning around 10 000 years ago, that heralded the beginning of large-scale human impact on biodiversity and human-induced ecological destruction.

The planet is an ecosphere that is an amalgamation of a large number of interrelated ecosystems. These ecosystems are made up of a series of smaller interrelated communities.

Humans simplify natural ecosystems in order to grow food, build habitats and remove or extract resources. Unwanted species, both plants and animals, are removed, and other species are provided with an environment made favourable for their survival by human intervention.

Large amounts of money, time and energy are used to maintain these simplified ecosystems and protect them from pests, droughts, floods and other disturbances. The great environmental challenge now facing humans is how to maintain a sustainable balance between the simplified human ecosystems and the neighbouring, more complex, natural ecosystems on which the simplified ecosystems depend.

SPOTLIGHT

Samarco dam disaster

In November 2015, a dam failed at the Samarco mine, north of Rio de Janeiro in Brazil. The incident at the mine, which is partly owned by the Australian mining company BHP Billiton, is the single biggest environmental disaster of its kind in Brazilian history.

The dam was designed to trap tailings, which are the liquid wastes associated with the mining process. When the dam collapsed, it sent a torrent of water, mud and sediments down the valley (see Figure 1.4.1). Nineteen people were killed in the mudslide. Toxins released from the dam flowed down the Doce River and its catchment, contaminating the drinking water of more than 200 towns. The dam was modified in 2011 and it is thought that these changes destabilised the dam wall leading to the collapse.

Brazilian environmental authorities estimate that will take up to 30 years to rehabilitate the environment. BHP Billiton has already spent over $6.5 billion in rehabilitation costs and is expecting to pay much more into the future.

1.4.1 The collapse of a dam at the Samarco mine in Brazil sent a torrent of toxic mud down the Doce River.

Human modifications to natural vegetation

Removal

Removal involves clearing native vegetation and disruption of ecological processes. Replacement land uses include urban settlement, transport, industrial development and extractive industries, such as mining. Native vegetation will not return without complete reconstruction of the ecosystem, including soil replacement.

Replacement

Replacement is when native vegetation is removed and then replaced with intensively managed systems: agriculture, horticulture (gardening) and plantation forestry. This involves partial disruption of processes. Native vegetation (or components of it) can return after intensive management ceases, although this may require management to restore natural processes.

Utilisation

Utilisation refers to the exploitation of native vegetation, with some consequent degree of modification: forestry (in native forests), pastoralism and recreation in natural areas. This corresponds to a partial removal of the natural vegetation and a partial disruption of processes.

Conservation

Conservation involves the maintenance of natural vegetation for conservation and scientific purposes with minimum deliberate modification of natural processes. Lands designated as national parks and nature reserves fall into this category. In addition, there are substantial areas of vacant or uncommitted government-owned land and indigenous-owned lands. Designation for nature conservation does not preclude past or inadvertent modification. There are no direct or deliberate impacts on the native vegetation as a result of this land use, but there may be indirect impacts from land use activities on adjacent lands.

Adapted from R. Hobbs and A. Hopkins in D. Saunders, A. Hopkins and R. How, Australian Ecosystems, Surrey, Bently & Sons, Sydney

1.4.2 Human modification to natural vegetation

Globally, environmental damage is extensive. There are massive areas affected by severe marine and river pollution, and radioactive and chemical contamination, as well as a large number of cities with air-quality problems.

The use of ecosystems by humans is best described as degrees of modification to natural vegetation as outlined in Figure 1.4.2.

1.4.3 In 2016, ISIS fighters deliberately set oil wells in the Qayyarah oil fields of Iraq ablaze.

Nature of human-induced modifications

Human-induced modifications to ecosystems may be either intentional or inadvertent. In some cases they are the result of negligence.

Intentional ecosystem change

It is not always easy to distinguish between the intentional and unintentional modification of ecosystems. In many instances, human-induced ecosystem change is the unintended consequence of human activities. Such changes often occur because of an inadequate or incomplete knowledge of ecosystem functioning.

Some intentional modifications result in unintended consequences over the longer term. When Indigenous Australians burnt the bush to clear away undergrowth and aid hunting, they did so intentionally. It was part of the means by which they survived. The unintended consequence of this management practice was the long-term effect it had on Australia's pattern of vegetation. The process of natural selection and evolutionary change resulted in a mix of plant species capable of withstanding the effects of regular burning.

While we often have difficulty in determining what is intentional and what is unintentional, some instances of human-induced change are unarguably intentional. These examples are often a result of human conflict. For example, in 2016 the Qayyarah oil fields around the Iraqi city of Mosul were set ablaze by ISIS fighters (see Figure 1.4.3). The ISIS fighters, a terrorist organisation, had occupied the city for many months prior but by mid-2016 Iraqi government forces had launched an attack to retake the city. As part of their defence strategy and to cause further harm, the ISIS fighters lit the oil wells surrounding the city. The fires bellowed toxic smoke into the atmosphere. It was not until April 2017 that the fires were eventually extinguished.

Inadvertent ecosystem change

Meeting the needs and wants of a rapidly increasing human population is bringing about large-scale environmental change. In the natural world, the explosion of a population in any part of the biosphere is compensated for by an adjustment somewhere else in the biosphere. For example, an excess of grasshoppers means that the plants on which they feed are placed under stress and die. Denied a source of food, the number of grasshoppers dies back to a sustainable level. Equally, an abundance of grass will lead to more grasshoppers to keep the grass in check.

Unlike other species, humans have the ability to transfer resources from one region to another and to modify ecosystems in order to sustain continued population growth. The issue is whether such modifications will continue to lead to inadvertent changes, as outlined in Figure 1.4.4. The population sprawl around large cities such as Sydney is a result of the need to house the increasing urban population in accordance with the value systems of that society. The impact such sprawl has on ecosystems is rarely considered by those who inhabit it.

Inadvertent effects of human activities on ecosystems at risk	
Human activity	**Inadvertent effect**
Farming	■ Reduction of biodiversity and the encouragement of excessive population growth of one species ■ Destruction of habitats and ecosystem linkages ■ Soil erosion ■ Irrigation disrupting the hydrological cycle ■ Pesticides and fertilisers affecting nitrate and phosphate levels, causing poisoning and/or algal growth
Mining and quarrying	■ Removal of lithosphere, and total ecosystem destruction, especially with open-cut, or strip, mining ■ Interference with hydrological cycle
Forestry, especially clear-felling	■ Total habitat destruction ■ Loss of biodiversity ■ Soil erosion and loss of fertility ■ Reduction of planetary capacity to remove carbon from the atmosphere
Use of fossil fuels	■ Increased carbon dioxide and other gases in the atmosphere ■ Development of acid rain
Industry	■ Consumption of resources ■ Pollution of groundwater by wastes ■ Build-up of heavy metals in food chain (bioaccumulation) ■ Development of acid rain
Improved medical science	■ Excess of births over deaths, leading to destruction of an ecosystem's dynamic equilibrium ■ Excessive demands for food, especially where cropping of marginal lands is involved
Urbanisation	■ Total destruction of habitat ■ Fragmentation of habitat and destruction of ecosystem linkages ■ Pollution of atmosphere and hydrosphere ■ Increased run-off from hard surfaces ■ Pollution through disposal of waste ■ Destruction of the ozone layer through introduction of chlorofluorocarbons (CFCs), for example, into the atmosphere
War	■ Total destruction of ecosystems

1.4.4 Inadvertent effects of human activities on ecosystems at risk

1.4.5 The Deepwater Horizon oil rig explosion in the Gulf of Mexico led to the biggest oil spill in history.

Ecosystem change caused through negligence

Many environmental disasters are the result of human negligence. The damage to the environment is not deliberate, but poor planning or lack of care and maintenance can bring about devastating impacts. For example, in 1986 a reactor at the Chernobyl nuclear power plant in what is now Ukraine melted down, leading to a radioactive cloud spreading across northern Europe. The environmental consequences are still being felt today.

In 2010, the Deepwater Horizon oil rig exploded in the Gulf of Mexico, as shown in Figure 1.4.5. This killed 11 people on the rig and led to the largest oil spill in history. It is estimated that around 8 billion litres of oil flowed into the Gulf of Mexico, destroying habitats. A 2014 study estimated that around 800 000 sea birds were killed by the spill. The impact continues as toxins continue to harm on the environment.

Measuring the effects of human activity on ecosystem functioning

There is no standard to measure the effects of human activity on ecosystem functioning other than to look at the ecosystem itself and note changes. Some studies assess the effects of human activity in terms of the number of plant and animal species that have been lost. Other studies, especially those that look at specific ecosystems (for example, rainforests), consider lost area of habitat or loss of biodiversity. These measures are dependent on having a known starting point, known as a 'baseline', otherwise they simply become educated guesses.

The magnitude of change

In terms of ecosystem functioning, magnitude of change refers to the extent to which an ecosystem has been stretched beyond its state of dynamic equilibrium. The change might be slight or it could be so extreme as to totally destroy the ecosystem, leaving an area lifeless. More commonly, change could involve the development of a replacement ecosystem, as in the case of the urban environment.

Measuring the magnitude of change requires a comparison between known data and whatever benchmark data may be available. It is preferable for the benchmark data to have been collected before the change commenced.

The rate of change

The rate of ecosystem change is largely related to two factors: rapid world population growth, especially in the countries of the developing world, and the ever-increasing demand for the world's resources, disproportionately by countries of the developed world.

Much of the continuing environmental degradation is taking place in countries of the developing world, and it is in these countries that population is growing most rapidly. Therefore, it is easy to assume that population is the main cause of the degradation. However, that is not the only explanation. Maintaining the economic system of the developed world often involves a shift of resources from the countries of the developing world to the countries of the developed world. The destruction of the world's tropical rainforests is probably the best-known example of this. The rate of forest loss has reached an alarming rate, threatening whole ecosystems. As a consequence, the rate of species loss has accelerated. Developing countries in many parts of the tropical world are forced to rely on the exploitation of raw materials in order to generate enough foreign exchange to pay for imported goods and repay debts. The technology that enables them to do this is often supplied and owned by transnational corporations (TNCs) based in developed countries.

Many countries of the developing world, especially those with tropical rainforest, have rates of deforestation exceeding 0.8 per cent each year. By comparison, the forests of the countries of the developed world are largely stable or increasing in area. In other words, rich countries are preserving their own environment at the expense of poor countries.

Human populations and ecosystem change

Population pressure is closely related to the rate of ecosystem change. Governments need money to implement social and economic programs that aim to improve diet, health and education standards. They also often encourage TNCs to invest in resource-based developments, especially mining and forestry, or offer concessions to establish industry, often with few environmental controls.

The need for foreign exchange also means that governments encourage the growing of cash crops for export, such as palm oil, coffee, tea, cocoa, strawberries or cut flowers. These crops often require irrigation and potentially damaging inputs of fertilisers and pesticides. They also occupy prime agricultural land that once supported subsistence farmers. This can mean that more and more marginal land is brought into production to feed a displaced rural population. The reduced availability of agricultural land can also mean that the traditional fallow cycles are shortened and the soil no longer has time to recover between crop cycles.

Impact of aid programs

Aid programs and infrastructure development can also create problems. Consideration needs to be given to the issue of equity in aid: does it benefit the donor country more than the recipient, and the rich more than the poor? In addition, the provision of, for example, a permanent water supply can encourage nomadic herders to settle in one place, which then becomes seriously overgrazed and environmentally degraded. Inappropriate irrigation schemes can contribute to problems with salinisation, destroying the productivity of land that was in any case marginal. Although most aid projects are now assessed for environmental impact, the temptation remains for governments to seek quick results.

Activities

Understanding the text

1 Outline examples of indigenous people modifying ecosystems.

2 Compare intentional and inadvertent human change.

3 Describe why humans, in comparison with other species, have a greater ability to impact on the environment.

4 Explain what is meant by magnitude of change.

5 Define what a benchmark is.

6 Describe the two factors that are related to ecosystem change.

7 Explain how population pressures impact on environmental change.

8 Describe how the need for foreign exchange affects the environment.

9 Explain how aid programs can contribute to environmental degradation.

Working geographically

10 Study Figure 1.4.2 and outline the ways in which people modify natural vegetation. Comment on the ability of the affected ecosystems to recover in each case.

11 Using the information in Figure 1.4.4, write a discussion on the inadvertent effects of human activities on ecosystems.

12 Study the Spotlight on the Samarco dam disaster.

- a Describe the impact of the disaster.
- b Using the internet, conduct research and prepare a short report on the current situation with the Doce River.

13 Conduct research into the Deepwater Horizon explosion. Prepare a digital presentation on the impact of the disaster on the environment of the Gulf of Mexico.

14 Conduct a class debate on the topic that human populations are the major cause of environmental degradation.

15 Write an extended response outlining the impact of human populations on the environment.

Population increase and land degradation

Apart from processes such as these, which are in themselves destructive, the fact remains that a growing population needs a growing food supply and access to fuel and water. The intensification of agriculture and fuelwood collection in marginal lands is resulting in widespread land degradation and, in some instances, desertification.

Central to this process of land degradation is the loss of soil due to increased rates of erosion. Research by scientists at the University of Sheffield in the United Kingdom found that around one third of the globe's arable land has been lost due to erosion and pollution. This is the land that supports agriculture and is the most productive. It takes between 100 and 2500 years to build up around 2.5 centimetres of topsoil. Human mismanagement can result in the loss of this amount of topsoil in less than a decade.

The countries of the developing world have much faster rates of population growth than the countries of the developed world. It will take many years before zero population growth can be achieved and so the rate of ecosystem change will continue to grow unless collective global action is taken.

Human versus environmental needs

In the developed world, human use of an ecosystem is often based on the short-term exploitation of natural resources, especially soil. The production of food and fibres ultimately diminishes the productivity of the land.

Harvesting of crops removes a large amount of organic material that would otherwise decompose and return nutrients to the soil. It also removes the protective cover that organic matter provides for the soil. This cover prevents excessive erosion and nutrient leaching. Contamination of the ecosystem from chemicals used in the production process can render a soil unsuitable for further production. Productivity needs to be considered in terms of environmental needs as well as human needs.