

## Section 5.2

### Methods of Mechanized Agriculture

#### Mechanized Agriculture and Crop Production

**agriculture** the practice of raising plants and livestock for food or other human needs

Agriculture is the practice of growing and raising plants or livestock for food and other human needs. Mechanized agriculture refers to the use of machines that use fossil fuels to supply the energy they need to work. Mechanized agriculture requires large areas of flat land for machines to work efficiently. **Figure 5.7** shows an example of the type of farming that is mostly associated with mechanized agriculture: monocultures.

#### Monocultures: Advantages and Disadvantages

**monoculture** the growth of a single crop, usually on a large area of land

A **monoculture** is the growth of a single crop on a large area of land. Corn, cotton, wheat, rice, and soybeans are examples of monoculture crops. Since the seeds used to grow each crop are all the same species, a monoculture has low genetic and biological diversity. Monocultures have several advantages that make them attractive to farmers. The process of ploughing, irrigating, fertilizing, applying pesticides, and sowing seeds is simpler and less expensive than it would be for growing multiple crop species together at the same time. This makes caring for and harvesting the crop simpler and less expensive as well.



**Figure 5.7** Soybeans, like the ones shown here, are often grown as monoculture crops.

**Inferring** Why is mechanized agriculture well-suited to the development of monocultures?

The increased crop yields made possible by monocultures carry with them several disadvantages as well. For example, growing the same crop in the same soil year after year removes soil nutrients that then must be replaced. As a result, monocultures require the use of synthetic nutrient-supplying fertilizers. Because monocultures lack biodiversity, they are more vulnerable to pests and diseases that are specific to the crop that is growing. To prevent losses of their crops, and therefore income, farmers of monocultures must use pesticides to help reduce pests and the damage they can cause.

### The Use and Effects of Synthetic Fertilizers

When a crop is harvested, the nutrients that have been absorbed by the mature plants are removed from the field with the crop. Since many of those nutrients come from the soil, and since plants cannot grow without them, they must be replaced if another crop is to be grown in the same field. The three soil nutrients that are most often depleted are nitrogen, phosphorus, and potassium. Other nutrients needed in smaller amounts include boron, manganese, and zinc. Farmers who use monocultures replace these nutrients with synthetic fertilizers, which are products of the petrochemical industry. Scientists estimate that 25% of the world's crop yield can be directly attributed to the use of synthetic fertilizers. The use of synthetic fertilizers increased greatly in the last few decades of the 20th century. As the world population increases, scientists predict that fertilizer use will increase even more.

A chief concern about the widespread use of synthetic fertilizers is its impact on aquatic ecosystems. The action of rainwater can dissolve and carry fertilizers in rivers, lakes, and other bodies of water. When the concentrations of nutrients such as phosphorus and nitrogen become too high, algae reproduce in large numbers very quickly. This population explosion of algae is often called an *algal bloom*, shown in **Figure 5.8A**. Eventually the algae die, and bacteria in the water begin to decompose them. During this process, the bacteria use large amounts of oxygen, thus reducing the amount of oxygen in the water. Low oxygen levels cause fish and other aquatic organisms to die quickly and in large numbers. This is often referred to as a *fish kill*, shown in **Figure 5.8B**.



**Figure 5.8 (A)** An explosion in the population of algae can result when nutrient levels in aquatic ecosystems become too high. **(B)** Bacteria that decompose algae deplete oxygen levels in the water. Fish and many other aquatic organisms cannot survive without oxygen.

#### Pause and Reflect

4. What is mechanized agriculture?
5. Why do monocultures depend on the use of synthetic fertilizers?
6. **Critical Thinking** How do you think the use of synthetic fertilizers could affect a person who catches and sells fish for a living?

## Case Study Effects of Pesticides on Human Health

**pesticide** any chemical used to kill or control populations of unwanted fungi, animals, or plants

### Use of Synthetic Pesticides

Many types of organisms can affect the health and growth of agricultural crops. A **pesticide** is any chemical used to kill or control populations of unwanted organisms. In agriculture these unwanted organisms, generally referred to as “pests,” are most often plants (weeds), insects, or fungi. Synthetic pesticides are those that are made by humans, as opposed to naturally occurring pesticides that are produced by plants to defend themselves against bacteria, fungi, and animal pests.

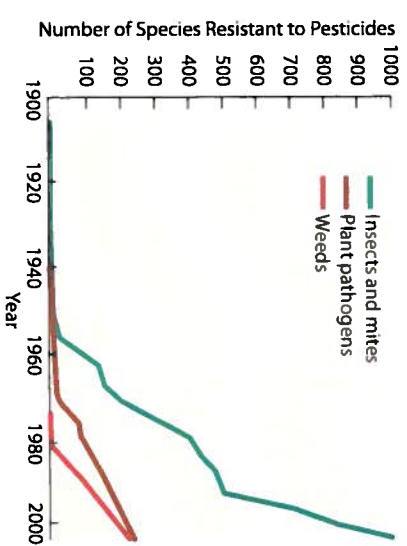
The use of synthetic pesticides prevents the loss of crops and food supplies to pests or infection. The cost of applying synthetic pesticides is balanced by the savings that result from the reduced need to tend the fields and the increased yields, which result in greater profits for farmers.

### Effects of Synthetic Pesticides on Ecosystems

Although the use of pesticides by farmers prevents loss of crops and food supplies to pests or infection, pesticide use can have negative effects on the environment.

- Pesticides are designed for one or several specifically targeted pest species. Since pesticides are poisons, however, other species also may be affected unintentionally. These organisms are often called non-target organisms. Many pesticides are sprayed broadly and destroy populations of beneficial insects as well as pests. Non-target organisms affected by pesticides commonly include insects, fish, birds, plants, and soil organisms.

- Over time, some pest populations become resistant to pesticides, as shown in **Figure 5.9**. In any given population of pests, there are some individuals who are naturally resistant to a pesticide due to their genetic make-up. These individuals survive when the pesticide is applied. When they reproduce, they pass along the genes that allow them to be resistant to the pesticide to their offspring. Some species of insect pests can produce a new generation each month. With each new generation, more and more members of the population have the genes for resistance. In these cases, within five years, 99% of individuals in the population are able to survive exposure to the pesticide.



**Figure 5.9** Many pests have developed resistance to pesticides. Because insecticides were the first pesticides to be used widely, insects show resistance earlier than other pest populations. More recently, plant pathogens and weeds are also becoming resistant to pesticides.

bioaccumulation—see section 10.1 on page 313

- Many pesticides break down into substances that are less harmful within days or weeks of applying them. However, some pesticides do not break down easily and remain highly toxic. Because they stay in the environment for years, even decades, and move freely through air, water, and soil, they often show up far from the point of original application. Some of these compounds have been discovered far from any possible source and long after they were most likely used. Polar bears, for example, have been shown to have concentrations of certain pesticide compounds 3 billion times greater than the seawater around them.

The effects of pesticides on human health can be divided into two categories: acute effects and chronic effects. Acute effects include poisoning and illnesses caused by high doses and accidental exposures. Chronic effects result from long-term exposure to low levels of pesticides in the air, water, or food. Chronic effects can include cancers, nervous system disorders, and decreased fertility in both men and women.

The World Health Organization (WHO) estimates that 25 million people are poisoned by pesticides each year, and 20 000 die as a result. Most illness and death comes from occupational exposures in developing countries, where people use pesticides without wearing protective clothing and often without a proper understanding of the health risks.

When properly applied, most pesticides pose little danger to the person using them. In developed countries such as Canada, the Pest Management Regulatory Agency (PMRA) is responsible for pesticide regulation. Under the Pest Control Products Act, pesticides are strictly regulated to make sure they pose minimal risk to human health and the environment. Through this Act, Health Canada registers pesticides after a thorough science-based evaluation that ensures any risks are acceptable. As well, pesticides are re-evaluated every 15 years to ensure they meet scientific standards and support sustainable pest management. In many parts of the developing world, on the other hand, regulations for the use of pesticides may be poorly enforced.

For most people, the most critical health problem is unintentional exposure to very small quantities of pesticides. Studies of farmers who are exposed to pesticides over many years show that they have higher levels of certain kinds of cancers compared to the general public. There are also questions about the effects of chronic, low-level exposures to pesticide residues in food or through contaminants in the environment.



Working with plants and pesticides in a greenhouse, this scientist is wearing proper protective gear, including protective clothing, gloves, and a respirator.

In U.S. studies of a wide range of foods between 1994 and 2000, 73% of conventionally grown food had residue from at least one pesticide and were six times as likely as organic foods to contain multiple pesticide residues.

### Research and Analyze

1. Do research on pesticide drift. What is it? How does it affect human health? Choose one actual incident and explain what happened and how people were affected. What steps can be taken to reduce or eliminate pesticide drift?
2. Do research about bioaccumulation. What evidence is there of bioaccumulation in the tissues of fish, birds, and mammals? What evidence is there of bioaccumulation of pesticides in the tissues of humans? What are some possible health effects?

### Communicate

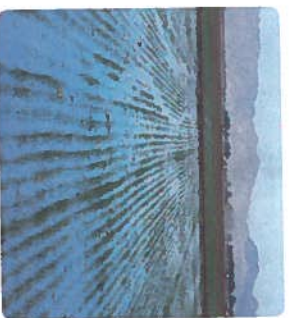
3. Explain why is it important that agencies such as PMRA regulate pesticides.

## Irrigation

**Irrigation** adding water to an agricultural field to allow certain crops to grow where the lack of water would normally prevent their cultivation

Crop irrigation accounts for 70% of water consumption around the world. Agricultural water use varies from one place to another due to variations in rainfall, soil type, and farming methods. In Canada, about 8% of water is used for crops. In India, over 90% of water is used for agricultural purposes. However, in Kuwait, where water is especially scarce, only 4% is used for crops. Just as the amount of water used to irrigate crops varies from one area of the world to another, the method of irrigation also varies.

**Figure 5.10** Irrigation Methods



**Surface irrigation** (also called flood irrigation) supplies water to crops by having the water flow over the field in canals or ditches. The land has a small downhill slope so that the water flows from the source into the fields. This type of irrigation can be inefficient. As much as half of the water can be lost through evaporation. Much of the rest runs off before plants can absorb it.

### Surface Irrigation

**Spray irrigation** uses a sprinkler system to spray water into the air above the plants. Sprinkler systems can also be inefficient. As much as 35% of the water can evaporate in the air before it ever reaches the soil.



### Spray Irrigation

**Drip irrigation**, also called trickle irrigation, uses a series of pipes with strategically placed openings to deliver water directly to the roots of plants. Although this method conserves water, it requires an extensive network of pipes.



### Drip Irrigation

The amount of water used for irrigation and for livestock to drink continues to increase throughout the world. Future agricultural demand for water will depend on factors such as the following:

- the cost of water for irrigation
- the demand for agricultural products
- government policies
- the development of new technology
- competition for water from a growing human population

## Pause and Reflect

7. What is a pesticide?
8. What are two effects that synthetic pesticides can have on ecosystems?
9. **Critical Thinking** If you were a farmer, what factors would you consider when deciding how to irrigate your crops? Explain your reasoning.

## Genetically Modified Crops

Genetic engineering involves taking a small section of DNA called a gene from one organism and inserting it into another organism. The DNA can be taken from any source—even an entirely different species. An organism with a genetic make-up (DNA) that has been altered by scientists in this way is a *genetically modified organism (GMO)*.

In agriculture, two kinds of genetically modified organisms have received attention. One involves inserting genes from a specific type of bacterium. The bacterial genes produce a material that destroys the gut of insects that eat it. Crops that have been genetically modified to contain these bacterial genes are called *Bt* crops. (*Bt* is short for the type of bacterium used, *Bacillus thuringiensis*.) It is likely that some of the food you eat and clothes you wear were grown from *Bt* crops, because these commonly include soybeans, potatoes, corn, and cotton.

A second kind of genetic engineering involves inserting a gene for herbicide resistance into the DNA of crop plants such as corn, soybeans, and canola. By planting a herbicide-resistant crop, a farmer can plant the crop with very little preparation of the field to rid it of weeds. When both the crop and the weeds begin to grow, the field is sprayed with a specific herbicide that will kill the weeds but not harm the crop because the crop plants contain genes that allow it to resist the herbicide's effects.

**Table 5.1** lists several kinds of traits that have been modified by genetic engineering and the kinds of crops involved. Worldwide, 70% of soybeans, 49% of cotton, 26% of corn, and 21% of canola are genetically modified.

**Table 5.1** Some Genetically Modified Crops and Their Altered Traits

Modified Trait	Crop
Insect resistance	Tomato, potato, corn, cotton
Herbicide resistance	Corn, canola, cotton, flax, alfalfa, sugar beet, sugar cane, rice, radish
Insect and herbicide resistance	Corn, cotton
Virus resistance	Zucchini, papaya

### Mini-Activity 5-3

### Benefits and Risks of Genetically Modified Crops

- Research more about the benefits and risks of genetically modified (GM) crops.
- How do GM crops benefit farmers?
  - How have they benefited the world's food supply?
  - What are some of the risks associated with GM crops?
  - What happens if pests become resistant to GM crops?
  - How can superweeds be created and how can they negatively affect ecosystems?

- What is known about the long-term effects on human health of consuming foods that contain GM ingredients?
- Present the results of your research in a format approved by your teacher. Hold a class debate about the benefits and risks of GM crops. You may consider having classmates take on different roles during the debate, including farmer, consumer, manufacturer, and scientist.

Summary

- Agriculture is the practice of raising plants or livestock for food and other human needs.
- A monoculture is a single crop that is grown on a large area of land.
- Synthetic fertilizers replace soil nutrients removed by plants.
- Farmers use synthetic pesticides to prevent loss of crops and food supplies to pests or infection.

Review Questions

1. Use a T-chart to organize the advantages and disadvantages of monocultures. **K/U C**
2. Why are synthetic fertilizers used? **K/U**
3. Make a flowchart to organize the events that occur if too many nutrients enter an aquatic ecosystem. **C**
4. Suppose you are an official for the Pest Management Regulatory Agency (PMRA) who is going to recommend whether an agricultural pesticide can remain on the market or should be banned. **T/I A**
  - a) What are some facts you would need to make your recommendation?
  - b) How would you go about finding the facts?
  - c) Who would you want to talk to about the pesticide before making your recommendation? Why?
5. Identify the type of irrigation shown below. Choose one other type of irrigation and compare it to the type shown below. **K/U**



6. Do non-farmers have an interest in how water is used for irrigation? Why or why not? Under what conditions should the general public be involved in making these decisions with farmers who are directly involved? **T/I A**
7. Explain how crops can be genetically modified to be insect resistant. **K/U**
8. What are the advantages of herbicide-resistant crops? What problems could result from the repeated planting and growth of herbicide-resistant crops? **K/U A**

- Worldwide, agriculture accounts for the greatest use of water. Crop irrigation accounts for 70% of water consumption.
- Genetic engineering has allowed scientists to insert specific pieces of DNA into the genetic make-up of organisms. An organism with a genetic make-up (DNA) that has been altered is called a genetically modified organism.

9. In one study, a population of houseflies regularly exposed to the pesticide Cyfluthrin was removed from the poultry CAFO where they lived and taken to a lab. There, the population was divided into three groups, each group was exposed to a specific dose of Cyfluthrin, and the rate of mortality was recorded for each dose. Also in the lab, a population of the same species of housefly that had never been exposed to Cyfluthrin was exposed to a standard dose of the pesticide. The mortality rate for this population was also recorded. The results of the experiment are shown in the data table below. **T/I A**

Population	Dosage Level of Cyfluthrin (ng/cm <sup>2</sup> )	Mortality Rate (%)
Houseflies from poultry facility – Group 1	8.3 (standard dose)	0
Houseflies from poultry facility – Group 2	83	10
Houseflies from poultry facility – Group 3	830	62
Houseflies from regular population	8.3 (standard dose)	100

- a) Explain what happened to the three groups of houseflies from the poultry facility after they were exposed to Cyfluthrin in the lab. What is the significance of the dosage level the flies were exposed to?
- b) What happened to the houseflies from a regular population when they were exposed to the standard dose of Cyfluthrin?
- c) What do the results of this experiment show? Why are they important to both farmers and non-farmers?

Sustainable Agriculture

The shift to mechanized agriculture and monocultures has dramatically increased the amount of food that farmers are able to grow. Despite the gains that result from growing food on such large scales, there have been negative consequences as well. With respect to the environment, these include loss of topsoil, pollution of air and water, and an increased need for synthetic chemicals. In economic terms, these consequences include increasing costs of materials and energy. In social terms, these consequences include lowered standards for living and working conditions for people who work on the farm or in the production facilities.

Today, many people—in science, business, government, and communities large and small—believe that the current practices of mechanized agriculture are not sustainable in the long term. **Sustainable agriculture** is the practice of growing and producing food in ways that meet the needs of the present while also enhancing the health of farmland, human ecosystems, and natural ecosystems so that the needs of people years into the future can also be met. Sustainable agriculture addresses environmental, economic, and social needs throughout the process of food production.

Polyculture

One of the main differences between mechanized agriculture and sustainable agriculture is the use of **polycultures**. Unlike monocultures, polycultures contain a diversity of crops grown on the same plot of land, as shown in **Figure 5.11**. Polycultures mimic natural ecosystems, allowing for increased biodiversity not just of the crops planted, but also the species that visit the crops. Polycultures help conserve topsoil, while at the same time reduce the need for water, fertilizers, and pesticides.



In a two-year study done by scientists in China, farmers grew a mixture of rice varieties in the same fields. Some of the varieties were resistant to a fungus that spreads easily in rice plants. By mixing the disease-resistant rice with the types that are vulnerable to the fungus, farmers increased crop yield by 89% and reduced infection from the fungus by 94% compared to rice plants grown in a monoculture. By the end of the study, farmers could grow rice in polycultures without any fungicide.

**Companion planting** is planting two or more plant species close to each other so that some benefit, such as pest control, nutrient absorption, or higher yield, occurs. Companion planting is a type of polyculture. One example of companion planting used by many Aboriginal peoples is the “three sisters”: corn, beans, and squash. The corn provides a good structure on which the beans can grow up; the beans return nitrogen to the soil, which benefits the squash; and the squash provides dense leaf coverage and ground cover, which helps keep weeds from growing.

**sustainable agriculture** producing food to meet the needs of the present without compromising the ability of future generations to meet their needs

**polyculture** an agricultural practice in which diverse species are raised in the same area

**Figure 5.11** This polyculture includes day lilies, beans, corn, and raspberries.

**companion planting** planting two or more plant species close to each other so that some benefit occurs

## Soil Conservation

Conserving soil and maintaining soil fertility in a sustainable manner are important to all farmers no matter which agricultural methods they practise. Soil conservation involves both reducing soil erosion and maintaining soil fertility. One of the best ways to conserve soil is to reduce the loss of topsoil due to erosion. Strip cropping, shown in **Figure 5.12**, involves planting alternating strips of one type of crop with another crop that totally covers the soil, called a *cover crop*. Examples of cover crops include clover, rye, and alfalfa. A cover crop helps reduce soil erosion and water run-off. Another way to reduce erosion is to leave the stalks, stems, and leaves of plants on the land after a crop is harvested. Some farmers plant cover crops right after harvesting to save topsoil.



**Figure 5.12** In strip cropping, farmers plant one type of crop, such as corn, soybeans, cotton, or sugar beets, in alternating strips with a cover crop.

### Soil Fertility

Retaining topsoil is the best way to maintain soil fertility. Restoring the nutrients that are lost as crops grow and are harvested is another important part of keeping soil fertile. Mechanized farming relies on synthetic fertilizers to restore lost nutrients. Now farmers are looking at more sustainable ways to maintain soil fertility.

One method involves crop rotation. **Crop rotation** is the practice of growing different crops at different times on the same land in order to preserve nutrients in the soil. A usual rotation sequence is for farmers to plant a crop that removes nutrients from soil, such as corn or cotton, one year. The next year they plant the same areas with legumes, such as beans or peas. Legumes add nitrogen back into the soil.

### Organic Fertilizers

Farmers who are practising sustainability are less likely to use synthetic fertilizers when they need to replace lost soil nutrients. Instead they may choose from a variety of organic fertilizers. These include compost, mulch, and green manure. **Compost** is produced when micro-organisms in soil break down organic matter, such as leaves, food wastes, and crop residues, in the presence of oxygen. Aside from adding nutrients to soil, compost can also help reduce soil erosion and help control pests. **Mulch** is a general term for a protective ground cover that can include manure, wood chips, straw, seaweed, leaves, and other organic products. Like compost, mulch adds nutrients to soil. It also helps to reduce soil erosion and maintain soil temperature and moisture.

Replacing synthetic fertilizers with green manure can help reduce the amount of nutrients in surface water run-off, while still nourishing soil. *Green manure* is produced by growing vegetation such as grasses or legumes on a field and then ploughing it into the topsoil at a later time. This increases the amount of nutrients and organic matter in the soil for the commercial crop that will be planted next.

## Integrated Pest Management

**Integrated pest management (IPM)** is a system that uses biological organisms, chemical substances, and crop rotation to control pest populations. IPM is often used in mechanized agricultural systems, and it is considered an important aspect of sustainable agriculture as well.

The goal of IPM is to keep pest populations at a low enough level so that the farmer does not experience economically unacceptable losses. Chemical pesticides are used only when other options have failed to control pest populations. IPM uses biological methods, such as natural predators, parasites, or disease-causing organisms, to help keep pest populations in check. As shown in **Figure 5.13**, one type of parasitic wasp invades the eggs of the European corn borer, a damaging insect that feeds on sweet corn, peppers, snap beans, and apples. The wasp can be used as part of an IPM system to combat the European corn borer.

Rotating crops, changing planting times, and using resistant varieties of crops are also part of an IPM system. Steps in IPM include identifying pests, monitoring their population levels, and deciding when action must be taken to control the pest. Deciding which control method to use and evaluating its success are also part of IPM.



**Figure 5.13** This parasitic wasp is invading the eggs of a European corn borer. The wasp is an example of biological pest control.

**Integrated pest management (IPM)** a system that uses biological organisms, chemical substances, and crop rotation to help keep pest populations under control

### Pause and Reflect

10. What is sustainable agriculture?
11. How does strip cropping help maintain soil fertility?
12. **Critical Thinking** Why do you think many farmers, no matter which agricultural methods they practise, use integrated pest management?

### Mimi-Activity 5-4

#### Biological Pest Control

Choose one of the examples of biological pest control in the list on the right and research the ecological and economic advantages and disadvantages of its use. Write a short summary of when and how the species is used to fight pests. If you were a grower, would you choose to use the method you researched as part of your IPM? Why or why not?

- using nematodes to control crop damage from grubs
- using ladybird beetles (ladybugs) to control aphids
- spraying *Bacillus thuringiensis* (Bt) to control the tomato hornworm, corn rootworm, or cabbage loopers
- spraying neem (an extract from the *Azadirachta indica* tree) to control various crop pests and diseases

drip irrigation—see section 5.2 on page 144

wastewater—see section 10.2 on page 318

## Irrigation Practices Used in Sustainable Agriculture

Drip irrigation delivers water directly to the roots of plants. Since specific amounts of water are released just above plant roots, nearly all of the water is used by the plants. A 90% efficiency rate is possible with a well-designed and maintained drip irrigation system. The use of drip irrigation systems can also reduce fungal diseases, because the amount of water on plant leaves is less than the amount when other irrigation systems are used. One drawback of drip irrigation is that the initial cost is more than for other irrigation systems.

In some parts of the world, recycled water is used to irrigate crops. Recycled water is water from wastewater treatment plants that has been treated so it is safe to use. The use of recycled water for irrigation benefits the environment by reducing the amount of water drawn from the ground, wetlands, and other ecosystems. In Canada, recycled water is used for irrigation on a small scale and is applied to non-food crops.

## Renewable Energy Resources and Sustainable Agriculture

Another aim of sustainable agriculture is to reduce the use of fossil fuels and replace them with renewable sources of energy, such as solar power, wind power, or hydropower. The farm shown in **Figure 5.14** uses solar power to help reduce the use of fossil fuels. Some farms obtain all of their energy from renewable sources. Some farmers may also use the natural gas produced from farm waste as a renewable energy source.

**Figure 5.14** This family farm has installed solar panels on the roofs of its outbuildings.



### Mini-Activity 5-5

#### Buying Local

Farmers are not the only participants in sustainable agriculture—consumers are as well. One factor that has become an important part of sustainable agriculture is buying food that is grown in nearby locations. Many grocery stores now provide information about the source of foods, especially fruits and vegetables. Some studies show that buying foods from local sources reduces the amount of fossil fuels used to transport food.

- Research more information about how far food in a local grocery store has travelled to reach the shelf.

- What other factors should a consumer consider when determining whether buying locally grown food is more sustainable than buying food shipped a longer distance?
- How does buying local support sustainable agriculture? How does it benefit the environment? How does it benefit local culture or society?
- Identify any disadvantages or controversies associated with buying food grown locally.

## Organic Farming

In many countries, including Canada, the United States, France, and Australia, food or other products that are labelled organic meet strict standards defined by the government. An **organic product** is one that has been produced without the use of synthetic fertilizers or pesticides, hormones, antibiotics, synthetic additives, genetically modified ingredients, or irradiation.

In Canada, about 2% of farms are certified organic farms. About 40% of those organic farms are in Saskatchewan, Manitoba, and Alberta. In 2011, the largest growth in organic farming occurred in Ontario and Québec. Aside from producing food or other products according to organic standards, organic farmers also use sustainable practices to increase biodiversity, maintain soil fertility, reduce soil erosion, conserve energy, and conserve water with innovative irrigation practices.

Typically, it takes three to five years for a farmer in Canada to make the change from conventional to organic farming profitable. Organic foods, which carry a label like the one shown in **Figure 5.15**, are becoming increasingly accepted as the benefits of sustainable agriculture become more widely understood. Besides farmers' markets and natural food stores, many large supermarkets now carry organic produce and other foods.



**Figure 5.15** Labels like the one shown here identify products such as fruits, vegetables, grains, dairy products, eggs, and meats as certified organic.

### Pause and Reflect

13. What are the benefits of using recycled water to irrigate crops?
14. Why do farmers save seeds?
15. **Critical Thinking** Why do you think a consumer would be motivated to buy an organic product?

### Mini-Activity 5-6

#### What's in a Label?

There are many different claims on food labels today, such as certified organic, non-GMO ingredients, all natural, free-range, cage-free, free-run, raised without the use of antibiotics, raised without the use of hormones, and grain-fed. These claims and others may appear on plant and animal products.

- Examine some of the claims that appear on food labels in your local grocery store or examples provided by your teacher.

- Research what these claims mean. Is there a defined standard for each of the claims? If not, what does the claim really mean?
- How would you know if a claim is misleading or not?
- Which agency or agencies oversee the regulation of claims on food labels in Canada?

**organic product** a product that has been produced according to standards defined by government or independent agencies

# Case Study Native and Heritage Varieties

The fruits and vegetables you see in the grocery store are dominated by a small number of *hybrid* varieties. Hybrids, which are created by crossing two plant lines, are bred to enhance certain characteristics such as size, appearance, or longer shelf life. However, hybrids may be less flavourful and less nutritious. Hybrid crops often cannot produce fertile seeds. This means that farmers must purchase new seeds each year from the commercial seed market, much of which is controlled by large corporations.

### Advantages of Native and Heritage Varieties

An alternative to growing hybrids is to plant native and heritage varieties of crop plants. Heritage (or heirloom) varieties are usually defined as being at least 50 years old, and are often linked to a particular region. Both native species and heritage varieties are non-patented, naturally pollinated plants that produce fertile seeds.

Native and local heritage varieties are adapted to a region's environmental conditions. These adaptations give them increased resistance to pests and disease, which in turn means they require less maintenance and irrigation. Native and heritage varieties that are well chosen for a site grow better with less investment of money and resources.

Genetic diversity refers to the variation naturally found among individuals. This diversity is important because when environmental conditions change, there is more chance that some individuals will survive. Maintaining more plant varieties in the gene pool through continuing to grow native and heritage crops gives us greater genetic diversity to draw on if changing conditions or drastic events ever threaten agricultural productivity.

### Seed Libraries and Seed Banks

To help maintain genetic diversity, mechanisms for distributing and preserving seeds have been established. *Seed libraries* provide seeds and information about heritage plant varieties. Members grow these varieties, and then promote further seed sharing via seed swaps. *Seed banks*, which are not generally open to the public, preserve seeds in case some major disaster destroys other seed reserves. Some seeds can be kept for decades by drying and storing them in cold conditions. There are currently about 6 million seed samples stored in seed banks worldwide. However, this represents only a fraction of the world's biodiversity. A combination of seed banking, seed sharing, and the increased planting of native and heritage crops may be the best way to preserve this diversity for the future.



Inside the Svalbard Global Seed Vault in Norway, seeds are stored in boxes in freezing temperatures.

### Analyze and Conclude

1. In a group, brainstorm how you could encourage people to plant and purchase heritage crops in your community. Give at least three detailed ideas.
2. With a partner, analyze the pros and cons of either hybrids or heritage crops. Record your points in a PMI chart.

### Communicate

3. Suppose Canada was proposing to establish a seed bank. Write a rough draft of a letter you could send to your local member of Parliament to express your support or lack of support for this proposal.

## Reviewing Section 5.3

### Summary

- Sustainable agriculture is the practice of producing food to meet the needs of the present without compromising the ability of future generations to meet their needs.
- Practices used in sustainable agriculture include polyculture, planting cover crops, using organic fertilizers, using integrated pest management, using green manure, and reducing reliance on fossil fuels.
- Conserving soil and maintaining soil fertility in a sustainable manner are important to all farmers no matter which type of agricultural methods they practise.

### Review Questions

1. Use a Venn diagram to compare and contrast sustainable agriculture practices and conventional mechanized agriculture practices. **KU C**
2. Explain why companion planting is a type of polyculture. **KU**
3. Study the data in the table below. **TI A**

### Soil Cover and Soil Erosion

Crop System	Average Annual Soil Loss (tons/hectare)	Rainfall Run-Off (%)
Bare soil (no crop)	41.0	30
Corn, planted continuously	19.7	29
Wheat, planted continuously	10.1	23
Rotation: corn, wheat, clover	2.7	14

- a) Which crop system results in the least amount of soil loss annually?
  - b) Which crop system results in the least amount of rainfall run-off?
  - c) Why is it important to reduce rainfall run-off from farms?
4. Make a table to show the similarities and difference among compost, mulch, and green manure. **KU C**
  5. What is IPM and how is it used to control pests? **KU**
  6. Which of the three types of irrigation discussed in section 2 is best suited to the practices of sustainable agriculture? Explain your reasoning. **KU**
  7. As a consumer, would you consider buying food that is certified organic, even if it may be more expensive than the same non-organic product? Why or why not? **A C**

- Soil conservation involves using a variety of ways to reduce soil erosion and restore soil fertility.
- Integrated pest management (IPM) is a system that uses biological organisms, chemical substances, and crop rotation to help keep pest populations under control.
- A specific type of farming that uses sustainable agriculture practices is organic farming. In many countries, including Canada, the United States, France, and Australia, food or other products that are labelled organic meet strict standards defined by the government.

8. In Indonesia, after years of farmers applying pesticides to control brown planthoppers (an insect that destroys rice crops), the insects developed resistance to the pesticides. In 1986, the government banned the use of 56 of 57 pesticides, forcing farmers to allow natural predators to combat the pests and spraying only when absolutely necessary with chemicals specific to planthoppers. The table below compares data from when farmers used chemicals to manage the pests to when they switched to biological control. **TI A**

### Alternative Pest-control Strategies

	Pest Management Using Chemicals	Pest Management Using Biological Control
Number of times pesticide used in rice season	4.5 applications	0.5 applications
Cost to farmers per hectare	7.5 rupiah (local currency)	2.5 rupiah
Cost to government per hectare	27.5 rupiah	2.5 rupiah
Rice yield per hectare	6 tons	7.5 tons

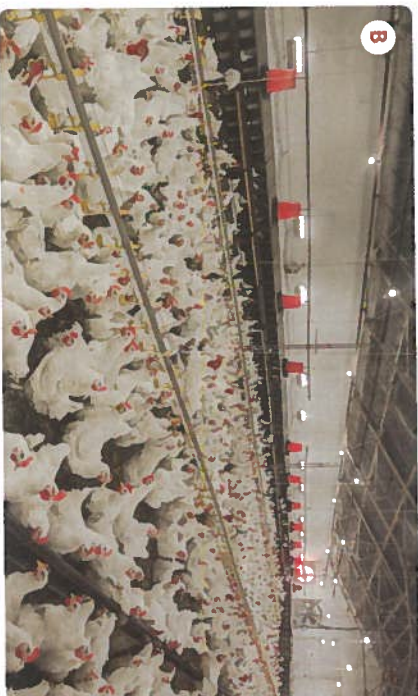
- a) How did the change in pest control affect costs to farmers and the government?
  - b) How did the change affect yield?
  - c) Would you agree with the Indonesian government, which declared the program a success? Explain.
9. What criteria should be used to determine whether farmers should use sustainable practices? How would your response differ if you were a farmer, a farmer's neighbour, someone downstream of a farm, or someone far from farming regions? **A C**

## Livestock Production

### Methods of Raising Livestock

Meat from cows, hogs, chickens, and other animals is an important source of protein, iron, fats, and other nutrients that give us the energy to lead productive lives. Dairy products are also a key protein source: globally, we consume more than twice as much dairy as meat. Meat and dairy consumption have quadrupled since the 1970s, with China representing about 40% of that increased demand.

About 50% of livestock are raised by grazing on rangelands and enclosed pastures, as shown in **Figure 5.16A**. Rangelands are ecosystems dominated by grasses, wildflowers, and shrubs on which livestock roam and feed. Enclosed pastures are fenced areas covered by grasses and legumes such as alfalfa and clover, on which livestock graze. The other 50% of livestock are raised in confined animal feeding operations (CAFOs) and feedlots. CAFOs, shown in **Figure 5.16B**, are energy-intensive industrialized systems where animals are housed and fed for rapid growth. Animals are confined to giant enclosures with up to 10 000 hogs or 1 million chickens in a barn complex, or 100 000 cattle in a feedlot.



**Figure 5.16 (A)** Rangelands can be found in several different ecosystems, including grasslands, woodlands, and deserts. **(B)** These chickens are housed and fed within this enclosed coop.

### Advantages of Rangelands, Enclosed Pastures, and CAFOs

The most important advantage of raising livestock using these methods is that they increase meat and dairy production. Since the late 1960s, meat production has doubled globally. In Canada, both rangelands and pastures are an important part of the grazing industry, chiefly for beef cattle. Rangelands and seeded pastures provide food for livestock. They also provide ecosystem services including providing habitat for wildlife, reducing soil erosion, and regulating the flow and quality of water. Agriculture and Agri-Food Canada helps to maintain rangelands and pastures so that they remain in a healthy state.

Aside from increased production, CAFOs can reduce the risk of overgrazing on rangelands and yield higher profits. Due to the lower cost associated with efficient housing of animals, the cost of meat, milk, and eggs is lower. CAFOs also provide employment at the local level.

### Disadvantages of Rangelands, Enclosed Pastures, and CAFOs

- Rangelands can be overgrazed. *Overgrazing* occurs when livestock are allowed to eat so much of the grasses and other plants on rangelands that the ecological health of the habitat is damaged. Overgrazing can lead to a decrease in important plants on which animals graze, an increase in weeds, and an increase in soil erosion. When rangelands are overgrazed in dry areas, a series of ecological and climate change events can lead to **desertification**, as shown in **Figure 5.17**.
- Allowing livestock to graze on rangelands also can affect biodiversity. To increase the productivity of rangelands, management techniques may specifically eliminate certain species of plants that are poisonous or not useful as food to grazing animals. In some cases, the populations of native animals are reduced if they are a threat to livestock through predation or by spreading disease. In addition, the selective eating habits of livestock tend to reduce certain species of native plants and encourage others.
- CAFOs require specially prepared mixtures of soy, corn, and animal protein that maximize animals' growth rate. These mixtures are not the normal food that animals would eat. These foods require large inputs of energy, mostly from fossil fuels, to produce. As a result of this and other factors, it takes about 16 times as much fossil fuel energy to produce a kilogram of beef from a CAFO than it takes to produce a kilogram of vegetables or rice.
- CAFOs fatten animals quickly and efficiently, but create enormous amounts of waste and expose livestock to unhealthy living conditions. The animal waste contributes nutrients to surface water run-off, which can pollute aquatic ecosystems. Bacteria in the animal waste can also pollute both surface water and ground water.
- CAFOs require the constant use of antibiotics, which are mixed in the animals' daily feed. The antibiotics are needed, because the chances of developing infections and diseases are so high due to having so many animals living in such close quarters together. In the United States, the amount of antibiotics added to animal feed each year is about eight times the amount of antibiotics used to treat human illnesses.



**Figure 5.17** Overgrazing contributed to the desertification and soil erosion shown here.

### Pause and Reflect

16. What are the different ways in which livestock can be raised?
17. What is overgrazing?
18. **Critical Thinking** What types of problems do you think could result from using antibiotics in raising livestock?

### Mini-Activity 5-7

#### Livestock and Greenhouse Gases

The United Nations Food and Agriculture Organization estimates that livestock produce 20% of the world's greenhouse gases. This is more than is produced by transportation. Do research to find answers to the following questions.

- Which greenhouse gases do livestock release?
- Does the way in which the livestock are raised affect how much of a particular greenhouse gas they release?

- How much do these gases contribute to global climate change?
- What are some solutions to reduce the amount of greenhouse gases released by livestock?

Present the results of your research in a format approved by your teacher.



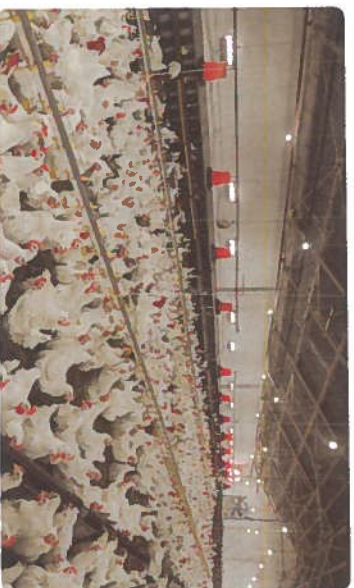


Summary

- Meat from cows, hogs, chickens, and other animals is an important source of protein, iron, fats, and other nutrients that give us the energy to lead productive lives. Dairy products are also a key protein source.
- About 50% of livestock is raised by grazing on rangelands and enclosed pastures. The other 50% is raised in confined animal feeding operations and feedlots.
- Rangelands, enclosed pastures, and CAFOs have benefits and risks.

Review Questions

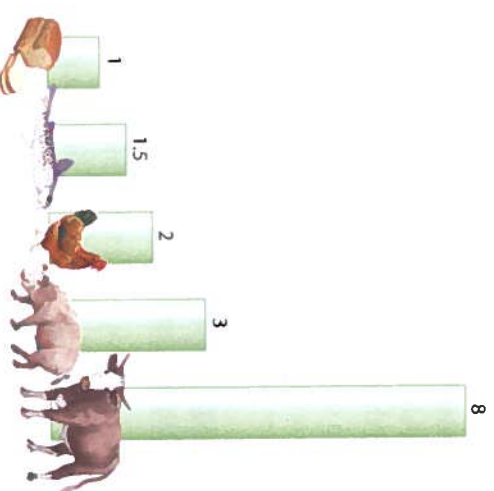
1. Identify and describe the three main ways livestock are raised. **KU**
2. Make a table to show the advantages and disadvantages of rangelands. **KU C**
3. Study the photo below and explain why CAFOs add antibiotics to animal feed. **KU**



4. Identify and describe two systems that are alternatives to CAFOs. **KU**
5. Suppose you have just received 10 hectares of good pasture. This area is equal to about the size of 20 soccer fields. You think you would like to keep some cows on the land and sell their milk to make money. How many cows will give you the most profit? For example, if you keep 10 cows, each cow will have one hectare of pasture on which to graze. If you keep 50 cows, you will get five times more milk, but each cow will have only 0.2 hectare of pasture. You do not want to spend money on extra food. What questions must you ask before you can calculate the optimum number of cows that could graze on your land for an indefinite period? Assume that you want to manage the pasture and cows sustainably, with the least amount of inputs as possible. **TI A**

- *Overgrazing* occurs when livestock are allowed to eat so much of the grasses and other plants on rangelands that the ecological health of the habitat is damaged.
- Confined animal feeding operations require large inputs of energy and the constant use of antibiotics; they create enormous amounts of waste.
- Methods of raising livestock sustainably include rotational grazing, raising wild species, small pasture operations, raising livestock organically, and using polyculture systems.

6. What are the benefits and risks of confined animal feeding operations? **KU**
7. Suppose you are a farmer who wants to start a CAFO. What conditions would make this a good strategy for you, and what factors would you consider in weighing its costs and benefits? What would you say to neighbours who wish to impose restrictions on how you run the operation? **A C**
8. What is rotational grazing? What are its benefits? **KU**
9. The diagram below shows the number of kilograms of grain needed to produce one kilogram of bread or one kilogram of weight gain in an animal. **A C**
  - a) Which source of animal protein is the most efficient to produce?
  - b) Which source of animal protein is the least efficient to produce?
  - c) After considering the information in the diagram, would you make any changes to your dietary choices? Why or why not?



Fisheries and Aquaculture

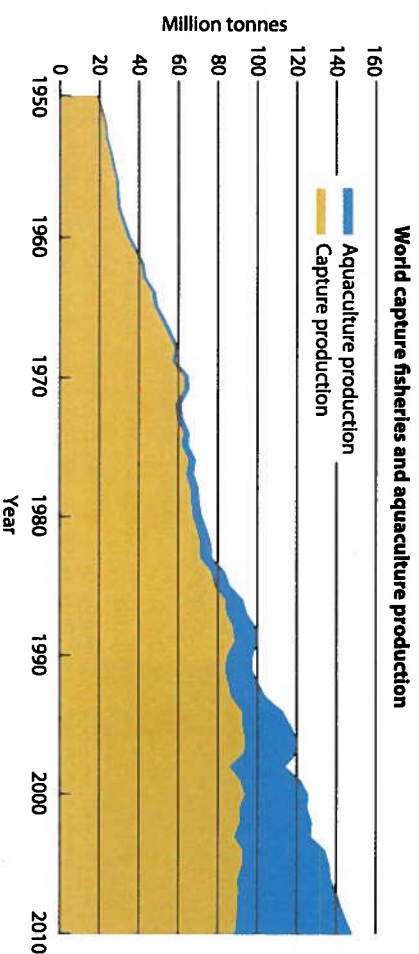
Fish and Seafood Are Major Sources of Protein

We currently harvest about 95 million tonnes of wild fish and seafood every year. (Seafood includes lobsters, shrimp, crabs, clams, and scallops.) Of this amount, we eat about two thirds directly. The remaining third is used as feed in aquaculture operations. **Aquaculture** is commonly called “fish farming,” and it is the breeding, raising, and harvesting of animals in specially designed aquatic environments.

Fish and seafood are the main source of animal protein for about 1.5 billion people in developing countries. In developing countries, people eat mainly locally caught fish. In developed countries, industrial-scale fishing provides most fish and seafood. The development of freezer technology on ocean-going ships allowed annual catches to increase every year by about 4% between 1950 and 1988.

As shown in **Figure 5.19**, aquaculture is becoming increasingly important as a source of fish and seafood production. Salmon farming has been particularly successful. Norway, Chile, Scotland, and Canada are the leading countries in salmon production. New Brunswick produces about 40% of all Canadian salmon.

The production of salmon from aquaculture has increased rapidly. In 1988, less than 20% of the salmon sold were from aquaculture, compared to over 65% in 2004. During the same time period, the production of wild-caught salmon has been relatively constant.



Source: Food and Agriculture Organization of the United Nations

Overfishing of Marine Fisheries

The United Nations estimates that 70% of the world’s marine (ocean) fisheries are being **overexploited** or are in danger of being overexploited. A 2009 study by Dr. Boris Worm of Dalhousie University and Dr. Ray Hilborn from the University of Washington found that 63% of the fish stocks they analyzed worldwide were declining in numbers. They concluded that exploitation would need to be reduced to avoid the collapse of vulnerable fish stocks. In marine ecosystems in which efforts were made to limit overfishing, they found improvement—a sign that the efforts were working.

Aside from scientific studies, another sign that marine resources are being overexploited is the change in the kinds of fish being caught. The commercial fishing industry has been trying to market fish species that were previously viewed as unacceptable to the consumer. Examples of “newly discovered” fish in this category are monkfish and orange roughy.

**aquaculture** the breeding, raising, and harvesting of animals in specially designed aquatic environments

**Figure 5.19** The number of fish captured rose steadily until about 1987. Since then, the amount has stayed almost constant. Aquaculture has continued to increase, so total production continues to increase.

*Inferring* Why do you think that the number of captured fish has remained about the same since 1987?

**overexploit** to harvest so much of a resource that its existence is threatened

## Case Study How Can Aquaculture Affect Natural Ecosystems?

In many aquaculture operations, fish and seafood are raised in pens that are close to shore in marine environments, like the ones shown here.

Raising fish in concentrated settings can affect the natural ecosystems in which they are located. For example, increased nutrients are released into the surrounding water from uneaten food and the wastes produced by the fish. This can cause local algal blooms that affect the surrounding natural ecosystem. Shellfish, such as clams and oysters, are especially vulnerable when oxygen levels in the water drop. Net pens anchored near shore also allow the spread of diseases, antibiotics, and other pollutants into surrounding ecosystems.



Many aquaculture pens are located close to shore in marine environments. Fish or seafood raised in these pens are fed and managed like livestock.

Sea lice, parasites that infect both farmed and wild fish, have affected salmon raised in aquaculture pens around the world. Sea lice are also a threat to wild salmon where salmon fishing is an important part of the economy. Scientists estimate that in the early 2000s, sea lice associated with salmon farms near Vancouver Island accounted for 90% of the deaths of juvenile wild salmon after deaths from other known causes were counted. A new approach to treating farmed salmon for sea lice has reduced the impact of sea lice on wild populations in the area. There are still concerns, though, that the sea lice are becoming resistant to the parasite treatments.

Another way that near-shore aquaculture operations may affect natural ecosystems is through escaped fish. For example, many of the salmon species raised in farms are not native to the waters in which they are raised. Sooner or later, some of these fish escape. When Atlantic salmon from aquaculture pens escape into the Pacific Ocean, they compete for food with wild Pacific salmon. In other areas, escaped fish may compete with wild individuals for mates, disturb habitat, or become invasive.

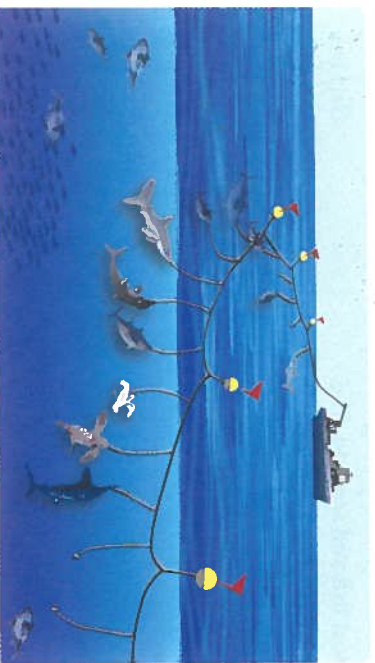
Currently, about 60% of all aquaculture production takes place in freshwater ecosystems, and production is growing rapidly. Aquaculture of freshwater species typically involves the construction of ponds, which allows for the

### Effects of Overexploitation on Sustainability

Because wild fish in the open ocean are a shared resource belonging to no single country, the competition to catch them is high. Rising numbers of boats, along with more efficient technology, allow for the exploitation of a shrinking resource. Boats as big as ocean liners travel thousands of kilometres, using global satellite positioning equipment (GPS), sonar, spotter planes, and other technology to locate and catch large numbers of fish and seafood. This helps meet the growing demand for these sources of protein. **Figure 5.20** shows three main industrial fishing techniques and how they affect the sustainability of ocean ecosystems.

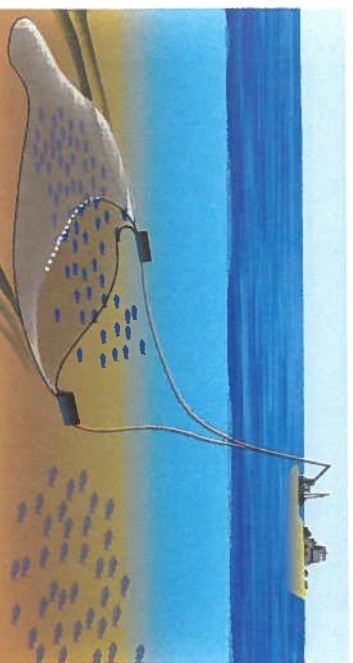
Thought Lab 5C,  
Overfishing and  
Moratorium of Cod  
Fishery, on page 167

**Figure 5.20** Different fishing methods can affect the sustainability of marine ecosystems in different ways.



Longline fishing boats set cables up to 130 km long with hooks every 2 m to catch fish such as tuna, halibut, and swordfish. In the process, longlines also catch unintended animals such as sea birds, turtles, sharks, and dolphins. These unintended captures are called *by-catch*. The loss of marine organisms as by-catch can have significant effects on local populations as well as endangered species. Researchers in Costa Rica believe that longline fishing led to a 60% reduction in the shark population in Costa Rican waters between 1999 and 2009. Another study found that about 250 000 loggerhead and 60 000 leatherback turtles, both endangered species, are accidentally caught in longlines every year.

Trawlers drag heavy nets across the ocean bottom to catch fish and seafood, including cod, flounder, shrimp, and scallops. As the heavy net is dragged across the ocean floor, it damages large areas of habitat. Organisms that live on the ocean floor, such as corals, sponges, and other fish, are killed. As well, clouds of sediment stirred up from the enormous net remain in the water long after the trawler has passed. Some scientists suggest that trawling is more damaging to marine ecosystems than any other type of industrial fishing.



Pots and traps are wire or wooden cages used to catch seafood such as crab, shrimp, and lobster, as well as fish such as cod and Chilean sea bass. Pots and traps are set out along the ocean bottom—usually attached to a line with floating buoys at the surface. By-catch includes small-sized individuals of the target species. Habitat damage can occur when pots or traps are dragged along the bottom when harvested. Traps that are abandoned still trap fish and seafood and can lead to increased death rates in a given area. In the Gulf of Mexico, abandoned traps had enough of an impact on the blue crab fishery that efforts were made to remove the traps.

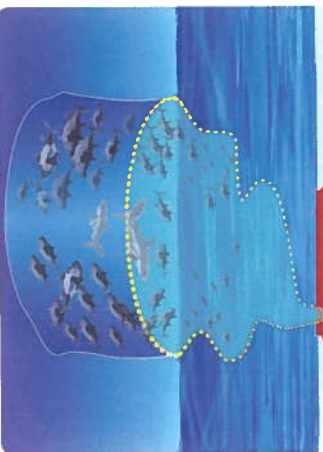


### Pause and Reflect

19. What is aquaculture?
20. What are some of the disadvantages of longline fishing?
21. **Critical Thinking** How do you think overfishing affects the ecological, economic, and social sustainability of a local area?

## Harvesting Fish and Seafood Sustainably

There are several methods to harvest wild-caught fish that have low rates of by-catch and minimal impact on the environment. For example, fish that feed near the surface in schools, including herring, anchovies, and mackerel, are caught in purse seines, shown in **Figure 5.21**. A spotter plane finds schools of fish. Then the fishing boat traps them in a large circular net called a purse seine. By-catch rates are low, and since the nets do not touch the bottom, no damage occurs.



**Figure 5.21** Purse seine fishing is considered to be a low-impact method of catching fish.

Another low-risk method of fishing is hook and line fishing, which has many fewer hooks per line than longlines. This method is used to catch salmon, Pacific cod, flounder, mackerel, and octopus. Diving for scallops, sea cucumbers, sea urchins, or octopus also has no known by-catch and produces minimal damage to the sea bottom. Swordfish caught using harpoons also has no known by-catch and does not damage the seafloor.

## Sustainable Aquaculture

Aquaculture in land-based ponds or warehouses, shown in **Figure 5.22**, can reduce many of the problems associated with aquaculture pens in marine and freshwater ecosystems. This is especially true when raising herbivorous fish, such as catfish, carp, or tilapia, which consume less feed than do carnivorous species.

One ecologically balanced system uses four carp species that feed at different levels of the food chain. The grass carp feeds largely on vegetation, while the common carp is a bottom feeder. It feeds on decomposing material that settles on the bottom. Silver carp and bighead carp are filter feeders that eat plankton from the water. Agricultural wastes such as manure, dead worms, and rice straw are used to fertilize the ponds and encourage algal growth. This integrated polyculture system typically boosts fish yields by 50% or more per hectare compared with monoculture systems.

Another system integrates agriculture and aquaculture more closely. In China, for example, certain species of fish are raised in rice paddies. These fish help fight rice pests, such as the golden snail, by consuming them. This system of rice-fish farming increases the yield of rice and provides extra income to farmers when they sell the fish.



**Figure 5.22** In some enclosed land-based ponds, water from the pond does not mix with natural water sources.

### Mini-Activity 5-9

#### What to Choose from the Menu?

Consumers like you can increase the sustainability of fisheries by being aware of which species are harvested sustainably and which are not. SeaChoice is a national program that helps Canadian businesses and consumers make seafood choices that support sustainability. SeaChoice works with the Monterey Bay Aquarium in California to rank the sustainability of both wild-caught and aquaculture fish.


- Examine the brochure provided by your teacher.
- What do the terms *best choice*, *good alternative*, and *avoid* mean?
- What factors are considered when determining the sustainability of each species of fish or seafood? Have you eaten any of the fish in any of the categories?
- Would you make different choices about which fish you will consume now? Why or why not?

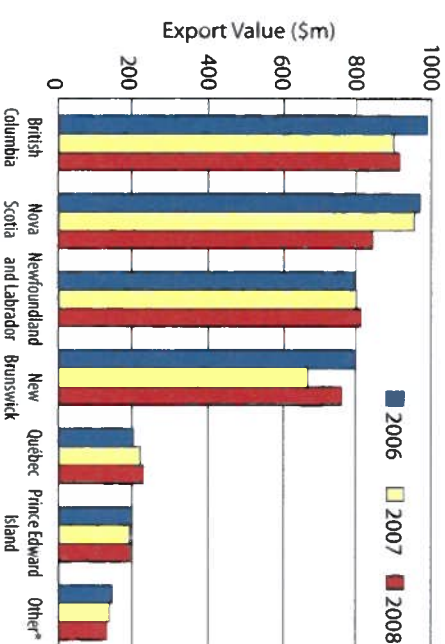
## Reviewing Section 5.5

### Summary

- We currently harvest about 95 million tonnes of wild fish and seafood every year.
- Fish and seafood, including lobsters, shrimp, crabs, clams, and scallops, are the main source of animal protein for about 1.5 billion people in developing countries.
- Fish and seafood are the only wild-caught meat sources still sold commercially on a global scale. Aquaculture is becoming increasingly important as a source of fish and seafood production.
- The United Nations estimates that 70% of the world's marine fisheries are being overexploited or are in danger of being overexploited as the number of fishers increases.

### Review Questions

1. From which sources do we get our fish and seafood? **K/U**
  2. What does it mean if a fishery is overexploited? **K/U**
  3. Infer how the overexploitation of a fish such as herring could affect the sustainability of the ecosystem of which they are a part. (Hint: Think about the food web the herring are part of.) **T/I**
  4. How has technology influenced the fishing industry? **K/U**
  5. Use a Venn diagram to show the similarities and differences between longline fishing and trawling. **K/U**
  6. Infer how the clouds of sediment kicked up from trawlers (shown in the photograph below) can affect marine ecosystems. **T/I**
- 
7. How can pots and traps affect both the ecological and economic sustainability of a region? **K/U**
  8. Make a concept map to organize information about how to harvest fish and seafood sustainably. **K/U**
9. Rising numbers of boats, along with more efficient technology, allow for the exploitation of a shrinking resource. Boats as big as ocean liners travel thousands of kilometres, using global satellite positioning equipment (GPS), sonar, spotter planes, and other technology to catch large numbers of fish and seafood.
  - Fishing using purse seines, hook and line fishing, and diving are considered sustainable fishing methods.
  - Aquaculture in land-based ponds or warehouses can reduce many of the problems associated with aquaculture pens in marine and freshwater ecosystems.
    9. Make a sketch that shows how the aquaculture system that uses four species of carp is a sustainably balanced system. **K/U**
    10. The graph below shows the export value in millions of dollars of fish and seafood from different provinces. **T/I**



\*Ontario, Manitoba, Saskatchewan, Alberta, Northwest Territories, Yukon, Nunavut.  
Source: Statistics Canada, International Trade Division.

- a) Which two provinces led exports between 2006 and 2008?
  - b) About how much money did Newfoundland and Labrador and New Brunswick earn from exports in 2008, respectively?
  - c) Why is it important to all of the provinces and territories in Canada to make efforts to fish sustainably?
11. Why is it important to be an educated consumer? **A**

# Chapter 5 SUMMARY

## Section 5.1 Plants and Soil

Soil is an important resource that is a source of nutrients, minerals, and water for plants.

**Key Terms**  
soil topsoil  
soil profile humus

### Key Concepts

- Plants need certain factors and conditions, including light, water, and soil, in order to survive in their environment.
- Soil is a thin covering over the land made up of a mixture of minerals, organic material, living organisms, air, and water that together support the growth of plant life.
- A soil profile is a series of horizontal layers in soil that differ in chemical make-up, physical properties, particle size, and the amount of organic matter they contain.

## Section 5.2 Methods of Mechanized Agriculture

Monocultures and the use of synthetic fertilizers and pesticides are part of mechanized agricultural practices.

**Key Terms**  
agriculture pesticide  
monoculture irrigation

### Key Concepts

- Agriculture is the practice of raising plants or livestock for food and other human needs.
- A monoculture is a single crop that is grown on a large area of land.

## Section 5.3 Sustainable Agriculture

Sustainable agriculture is the production of food to meet the needs of the present without compromising the ability of future generations to meet their needs.

**Key Terms**  
sustainable agriculture compost  
polyculture mulch  
companion planting integrated pest management (IPM)  
crop rotation organic product

### Key Concepts

- Sustainable agriculture is the practice of producing food to meet the needs of the present without compromising the ability of future generations to meet their needs.
- Practices used in sustainable agriculture include polyculture, planting cover crops, using organic fertilizers, using integrated pest management, using green manure, and reducing reliance on fossil fuels.
- Conserving soil and maintaining soil fertility in a sustainable manner are important to all farmers no matter which type of agricultural methods they practise. Soil conservation involves using a variety of ways to reduce soil erosion and restore soil fertility.
- Integrated pest management (IPM) is a system that uses biological organisms, chemical substances, and crop rotation to help keep pest populations under control.
- A specific type of farming that uses sustainable agriculture practices is organic farming. In many countries, including Canada, the United States, France, and Australia, food or other products that are labelled organic meet strict standards defined by the government.

## Section 5.4 Livestock Production

Raising livestock can have significant effects on both terrestrial and aquatic ecosystems, so it is important to understand methods of raising livestock sustainably.

**Key Terms**  
desertification rotational grazing

### Key Concepts

- Meat from cows, hogs, chickens, and other animals is an important source of protein, iron, fats, and other nutrients that give us the energy to lead productive lives. Dairy products are also a key protein source.
- About 50% of livestock is raised by grazing on rangelands and enclosed pastures. The other 50% is raised in confined animal feeding operations and feedlots.

## Section 5.5 Fisheries and Aquaculture

The harvesting or raising of fish and seafood for human consumption can affect the sustainability of aquatic ecosystems in a variety of ways.

**Key Terms**  
aquaculture overexploit

### Key Concepts

- We currently harvest about 95 million tonnes of wild fish and seafood every year.
- Fish and seafood, including lobsters, shrimp, crabs, clams, and scallops, are the main source of animal protein for about 1.5 billion people in developing countries.
- Fish and seafood are the only wild-caught meat sources still sold commercially on a global scale. Aquaculture is becoming increasingly important as a source of fish and seafood production.

- The United Nations estimates that 70% of the world's marine fisheries are being overexploited or are in danger of being overexploited as the number of fishers increases.
- Rising numbers of boats, along with more efficient technology, allow for the exploitation of a shrinking resource. Boats as big as ocean liners travel thousands of kilometres, using global satellite positioning equipment (GPS), sonar, spotter planes, and other technology to catch large numbers of fish and seafood.
- Fishing using purse seines, hook and line fishing, and diving are considered sustainable fishing methods.
- Aquaculture in land-based ponds or warehouses can reduce many of the problems associated with aquaculture pens in marine and freshwater ecosystems.

# Chapter 5 REVIEW

## Knowledge and Understanding

Choose the letter of the best answer below.

1. Which condition is *not* required by a plant for its survival?
  - a) carbon dioxide for cellular respiration
  - b) oxygen for cellular respiration
  - c) sufficient space for growth
  - d) sunlight for photosynthesis
  - e) water intake for photosynthesis
2. Which statement about soil is *false*?
  - a) Many plants anchor their roots in soil.
  - b) Decomposing plant and animal matter can be found in a soil sample, as well as living organisms.
  - c) Most of a plant's roots are found in the topsoil layer.
  - d) Humus, organic matter from the decomposition of animal and plant materials, gives soil a black colour.
  - e) The proportions of the components that make up soil are always the same, even in different soil types.
3. A property of soil that describes the size and number of spaces found among the soil particles is known as
  - a) density
  - b) ductility
  - c) porosity
  - d) malleability
  - e) volume
4. Which statement about our food sources is correct?
  - a) Agriculture is the practice of raising plants or livestock for food and other human needs.
  - b) A monoculture consists of multiple crops growing on a large land area.
  - c) Livestock and fisheries do not provide us with protein.
  - d) Plants provide food for only a few organisms on Earth.
  - e) Different areas in a monoculture on a farm require different amounts of pesticides.
5. Synthetic fertilizers
  - a) are made by people using natural, freshly harvested, plant-based resources
  - b) commonly contain nitrogen, phosphorus, and potassium
  - c) do not affect crop yield
  - d) are always safe for use in aquatic ecosystems
  - e) are useful for fish, since they increase the oxygen levels in the water
6. An integrated pest management system
  - a) uses only living organisms to control pest populations in a safe manner
  - b) starts with the application of chemicals to destroy as many pests as possible, and then relies on biological organisms to maintain control of the pests
  - c) helps to control pest populations by rotating crops, using biological organisms, and using chemicals
  - d) can only be started in an area where adult insects have not mated yet
  - e) is only considered to be sustainable if all pests in an area are destroyed so that the farm will make a profit on crop sales during that growing season
7. Livestock that are raised organically
  - a) are raised without growth hormones
  - b) require low doses of antibiotics in their diet to prevent the occurrence of disease
  - c) regularly need to consume foods high in animal by-products to get enough protein
  - d) are fed food that contains genetically modified ingredients
  - e) are usually fed food that has been grown using either synthetic or natural fertilizers
8. An example of a sustainable method of harvesting wild-caught fish is
  - a) dragging heavy nets across the ocean bottom
  - b) using wire or wood cages to catch cod
  - c) setting up cables with hooks every 2 metres to catch tuna
  - d) using a purse seine when a spotter plane finds schools of fish
  - e) using sediment clouds to send fish to the surface so that they can be humanely harvested

## Answer the questions below.

9. Identify and describe two factors that affect soil pH.
10. Describe why humus is such an important component of soil for agricultural use. Provide three supporting details in your response.
11. Name two living organisms found in the soil, and state how plants benefit from these two organisms.
12. Define the term *mechanized agriculture* and indicate why monocultures are associated with mechanized agriculture.
13. What are two advantages and two disadvantages of growing monocultures?

14. Provide two reasons why surface irrigation can be an inefficient method of delivering water to crops.

15. What is a genetically modified organism? Give one example of a use for this type of organism in agriculture.

16. Sustainable agriculture is a practice that lets us produce enough food to meet our present needs without affecting the food-producing ability of future generations.

- a) Define *polyculture* and briefly explain three ways that it is a sustainable agriculture practice.
- b) List three other examples of sustainable agriculture practices.

17. The “three sisters” are shown in the photo below. Identify the three plants and explain why this is an example of companion planting.



18. Identify three types of organic fertilizers, and give a brief description of each type.

19. What is aquaculture? Give an example of how aquaculture is used in Canada.

20. There is evidence that the world's marine fisheries are being overexploited.
  - a) What does *overexploited* mean?
  - b) How might the marketing of orange roughy (shown in the photo below) indicate that overexploitation in marine fisheries is likely occurring?



21. Give an example of how the integration of aquaculture and agriculture in a sustainable manner is used in China.

22. Contrast the main method of obtaining wild-caught fish in developing countries with the method used in developed countries.

## Thinking and Investigation

23. Ocean dead zones are areas at the bottom of oceans that have such a low oxygen content that organisms that normally live there, such as lobsters, crabs, and various types of fish, usually die. Faster-moving fish might be able to swim away from a dead zone. These dead zones, usually found along coastlines, have several causes, including the presence of fertilizer in run-off. The nutrients in the fertilizer lead to algal blooms. The algae eventually die, sink to the bottom of the ocean, and are decomposed by micro-organisms that need oxygen.

- a) Predict the effects that large-scale dead zones could have on an ocean ecosystem.
  - b) Predict the effect that large-scale dead zones could have on commercial fishing operations.
  - c) Describe a method of reducing the nitrogen run-off with the spring rains on the east coast of Florida.
  - d) How might natural disasters, such as Hurricane Katrina, contribute to ocean dead zones?
24. Windbreaks are tall walls of vegetation that are planted in rows in a variety of locations, such as fields, agricultural areas, and near houses, to help block the wind. The photo below shows windbreaks in an agricultural setting.



- a) Explain how a windbreak helps conserve soil in agricultural areas.
- b) How can windbreaks help protect crops?
- c) Name two possible disadvantages of using windbreaks in agricultural areas.

25. There are many types of irrigation methods that a farmer can use, depending on the soil conditions, how much water is available, and on the amount of money that is available to purchase and/or maintain a system. Copy and complete the chart below, recommending the best type of irrigation system to use for each condition. Provide at least one reason for each recommendation.

Condition	Suggested Irrigation System	Reason(s) for Your Selection
Sandy soil	Drip irrigation	Sand lets water through readily. Continuous water flow would just seep through the sand. Slower drip will give the plants time to absorb the water.
Clay soil		
Areas with frequent high winds		
Water is in short supply		

26. The photo below shows a farming area that is using a “no-till” approach to sustainable agriculture. No-till refers to the fact that there is no ploughing at the end of the growing season. In the photo, note the area where the soil is covered by the previous year’s crop residues. Special equipment is needed to deposit seeds in the ground without disturbing the crop residues.

a) Infer two reasons why the no-till approach is a sustainable agriculture practice.

b) What are two possible drawbacks of no-till agriculture?



27. The climate in Northern Ontario permits the growth of hay and some grains. How is this beneficial to the local ranches?

28. The table below summarizes comparisons between wild-caught salmon and salmon raised in aquaculture farms.

- a) Why might farm-raised fish have more fat in their bodies?
- b) Omega-3 fatty acids are healthy for you. Based on the nutritional information in the table, would you conclude that wild or farm-raised fish are healthier for you to eat?
- c) Is the flesh colour of the salmon important to control in fish farms? Explain your answer.
- d) Explain why disease is more prevalent in farmed fish than in wild fish.
- e) The table gives no indication that the harvesting of wild-caught fish harms the environment. Do you agree or disagree with this the table on this issue? State at least two supporting details.
- f) Would you buy wild or farmed fish, based on this table? Keep in mind that many wild fish are overexploited, and many fishing techniques harm the environment. Your response should be at least one paragraph in length.

### Wild vs. Farmed Salmon Comparison

	Wild	Farm-raised
Nutrition	Higher ratio of Omega-3 to Omega-6 fatty acids	Lower levels of protein and much fatter
Coloration	Naturally orange or red because of diet	Given pigments to turn colour from natural white
Disease	Low levels of sea lice, disease, and contaminations	High levels of sea lice, disease, and pesticides; given large amounts of antibiotics
Environment	Populations affected by escaped farmed fish	Excess waste and disease harm natural ecosystem
Price	Slightly higher price	Cheaper because already in nets

### Communication

29. There is a lot of food waste in grocery stores, as well as in many Canadian homes. We tend to expect our produce to be flawless, and if it is not, we might toss it in the garbage. In a paragraph, describe how this wasteful action affects the environment.

30. Write a short paragraph explaining why you would or would not support each of the following:

- a) an increase in genetically modified foods
- b) an increase in polyculture
- c) an increase in small pasture operations
- d) an increase in industrialized fishing techniques
31. Harpooning is used to harvest large fish such as bluefin tuna.

a) Is this an example of a sustainable fish harvesting practice? Provide support for your answer.

b) How do animal-rights activists usually view harpooning? Research this topic if needed, and indicate whether you agree with harpooning animals for food.

32. Make a chart listing three benefits of farmers using synthetic pesticides, as well as three risks of using these pesticides to prevent crop losses. Based on this chart, explain whether you support the use of synthetic pesticides in agriculture.

33. DDT is a pesticide that was readily used in North America until about 40 years ago. DDT is fat-soluble, highly toxic, and does not break down easily. It moves freely in the air, water, and soil. Using this information, sketch a simple terrestrial or aquatic food chain that shows how DDT concentrations might change along the food chain.

34. Did You Know? Reread the quotation by Wendell Berry on page 135. What does the quotation mean to you? Write a song, poem, or blog entry, or make a painting or drawing to express your ideas.

### Application

35. In 2003, a researcher at the University of Guelph developed the Barcode of Life project. The DNA of different organisms is coded and entered into a database. Species of organisms that cannot be identified due to physical damage or missing parts (such as fish skin, fins, and heads) can then be identified by using a small piece of tissue. Studies have shown that some restaurants in North America are serving cheap fish and labelling them as more expensive fillets, and fish that are overexploited are being sold as fish that are plentiful. Explain how the Barcode of Life project can assist with this marketing problem.

36. Many school cafeterias do not compost their food scraps. Make a list of foods that are commonly discarded in the garbage but could be composted. Plan a compost program for a school, including a brief description of how students could be involved in the composting process. Also provide at least two uses at the school for the resulting nutrient-rich soil.

37. The recycling of animal waste as fertilizer is economical and is generally considered an environmentally sustainable practice. However, care must be taken that manure does not run off into water sources, since it can be contaminated with *E. coli* and other bacteria. In 2000, the well water of Walkerton, Ontario, was contaminated with *E. coli*. Research more information about this event.

- a) Summarize the impact of the event on public health.
- b) What was the source of the contamination?
- c) What other factors contributed to the contaminated water reaching the public?
- d) What steps were taken to avoid something like this happening again?

38. You have likely noticed stickers on various fruits and vegetables, such as the one in the apple photo below.

Research the meaning of these PLU codes. Use the results of your research to answer the following questions.

- a) What does a four-digit number, such as 4011, mean?
- b) What does a five-digit number mean when the first digit is 8?
- c) What does a five-digit number mean when the first digit is 9?
- d) Indicate whether you would consider purchasing produce whose PLU starts with 4 or 8, and provide support for your response.



### Pause and Reflect

How could you incorporate what you have learned in this chapter into your daily actions or choices?

## Section 6.1

### Forestry Management

#### Canada's Forests

forest an ecosystem in which the dominant plants are trees

A forest is an ecosystem in which the dominant plants are trees. Nearly 50% of Canada's land is covered by forests. Forests in Canada provide habitat for about two thirds of the species in Canada and make up 10% of forests worldwide. In particular, the variety of forests in Canada, shown in

Figure 6.1, play an important role in water filtration, reducing the impact of climate change, and producing both timber and non-timber products.

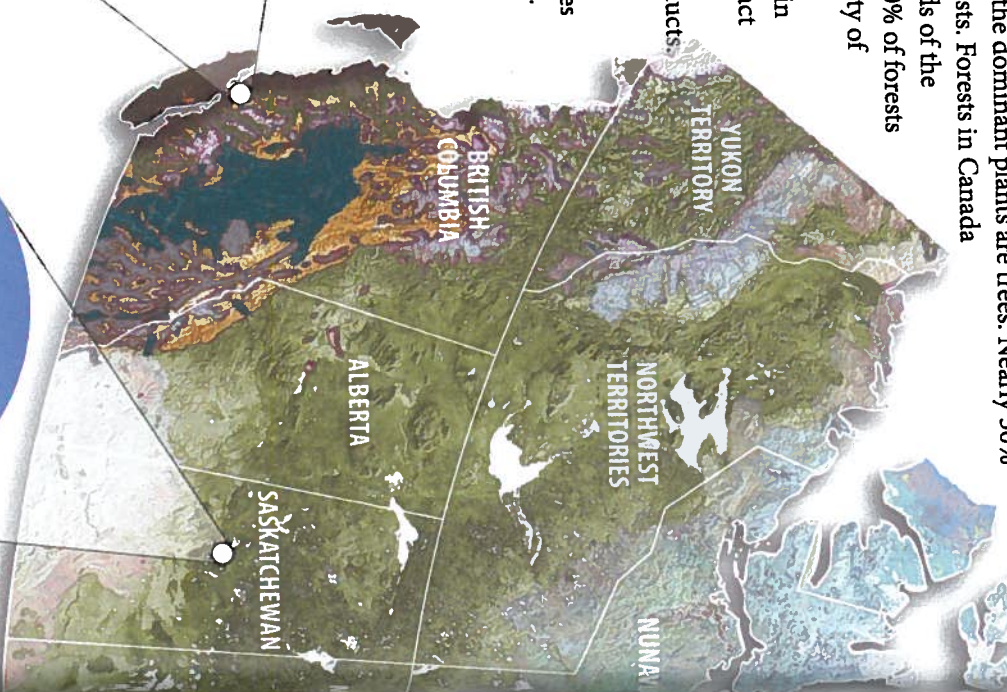
**Figure 6.1** About 400 million hectares of Canada's land is covered by forests.



**Temperate Rainforest**  
The temperate rainforest on the southwest coast of Canada consists of western hemlock, western red cedar, yellow cedar, firs, and spruce trees. Mosses and other small plants grow on larger trees. The forest floor is covered with ferns and wildflowers. Brown bears, grizzly bears, black-tailed deer, frogs, and slugs all live in the temperate rainforest.



**Boreal Forest**  
The main tree species in boreal forests include spruce, birch, pine, larch, poplar, and fir. Canada's boreal forest supports more than 300 species of birds, as well as large populations of wolves, woodland caribou, and grizzly bears.



#### Map Key

- Boreal Forest
- Deciduous Forest
- Acadian Forest
- Carolinian Forest
- Subalpine Forest
- Columbia Forest
- Montane Forest
- Temperate Rainforest

#### NON-FOREST

- Tundra
- Grassland

**Acadian Forest**  
The Acadian forest, found in the Atlantic Provinces, is made up of sugar maple, yellow birch, eastern hemlock, and balsam fir trees. As in other forests, mosses and other fungi, ferns, and wildflowers grow on the forest floor. Deer, foxes, bobcats, and birds all depend on the Acadian forest for habitat.



**Carolinian Forest**  
The Carolinian forest in southern Ontario makes up only 1% of Canada's landmass. However, it has a higher number of species than any other ecosystem in Canada. Tree species include oak, black walnut, and hickory. Birds, flying squirrels, and snakes are some of the animals that live in the Carolinian forest.



#### Mini-Activity 6-1

#### Canada's Forests

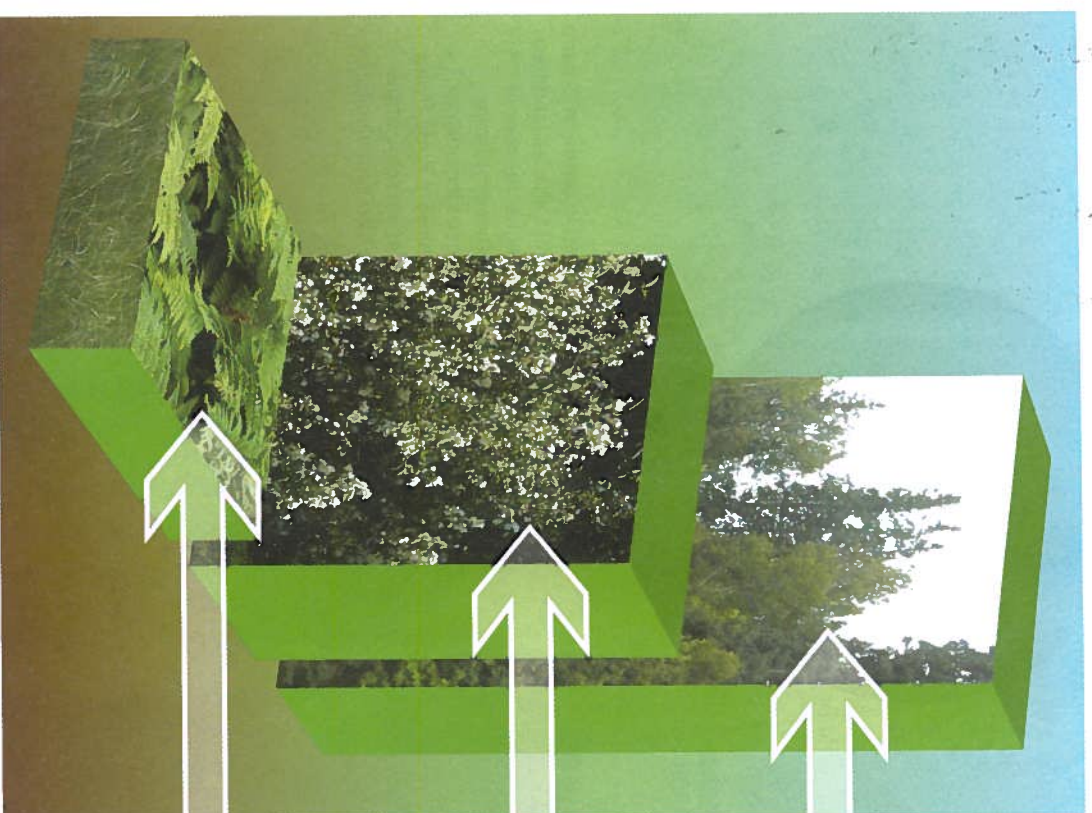
Choose one of the eight types of forests found in Canada. Do research to find the following information:

- its abiotic and biotic characteristics
  - examples of ecosystem services the forest provides
  - its role in the local, provincial or territorial, and/or federal economy
  - examples of past and present controversies or issues involving the forest
- Present your findings in a format approved by your teacher.



## Basic Structure of Forests and Their Biodiversity

Worldwide, there are many different types of forests, including boreal forests, deciduous forests, temperate rainforests, and tropical rainforests. Although the abiotic and biotic factors that make up each type of forest differ, most forests have the same basic structure. As shown in **Figure 6.2**, forests are made up of three main layers: the canopy, the understory, and the forest floor.



**Figure 6.2** The basic structure of a deciduous forest such as this one is very similar to the structure of other types of forests.

*Inferring* What examples of adaptations would you observe in the animals that live in the different forest layers?

### The Canopy

The canopy is made up of the leaves and branches of tall, mature trees. The crowns (tops) of these trees receive most of the sunlight that reaches the forest. The thick mass of leaves and branches form an umbrella-like cover that shades the rest of the forest. The canopy is habitat for animals such as birds and insects, as well as for other kinds of plants. (In tropical rainforests, many species of monkeys live in the canopy and may spend their entire lives there.)

### The Understory

The understory is made up of young trees, shrubs, and bushes that are adapted to living in shade. Trees such as dogwoods, berry shrubs, and Canada yew thrive in the understory of many forests. Animals such as insects, snakes, birds, and bats all live in the understory. (In tropical rainforests, larger mammals such as jaguars also live in the understory.)

### The Forest Floor

The forest floor is made up of decomposing leaves and trees, animal droppings, and other organic matter. (In tropical rainforests, decomposition occurs very quickly due to the high temperatures and humidity.) The breakdown of all this material is an important part of the nutrient cycle in a forest ecosystem. Nutrients such as nitrogen and phosphorus are released into the soil and are taken up by existing plants and by new seedlings. Ferns, mosses, wildflowers, and fungi all grow on the shaded forest floor. Birds, rodents, and amphibians also live on the forest floor.

## Ecosystem Services of Forests

Forests provide ecosystem services that include the following:

- reducing soil erosion
  - storing carbon
  - cycling nutrients such as carbon, nitrogen, and phosphorus
  - purifying water
  - providing habitats for millions of species on Earth
- Forests also provide timber and non-timber resources.

## Forests and Timber Resources

Cut trees are a source of wood used as timber. **Timber** is wood that is used for construction and carpentry. Cut trees are also a source of firewood used for heating and cooking. In addition, cut trees are a source of the wood pulp used to make paper products and some building materials, such as pressboard. The forest industry in Canada employs about 230 000 people. In 2011, the forest industry contributed 57 billion dollars to Canada's economy.

## Forests and Non-timber Resources

Non-timber forest resources are biological products that do not come from timber. **Table 6.1** shows some examples of non-timber resources that come from forests.

timber wood that is used for construction and carpentry

**Table 6.1** Non-timber Resources

<p><b>Food</b></p> <p>Forest-based foods, such as mushrooms, wild ginseng, wild leeks, wildflowers, blueberries and other fruits, and nuts, are often collected from different types of forests and sold worldwide. In 2009, Canadian maple sap products brought in over 350 million dollars. Canada produces 85% of the world's maple syrup.</p>	
<p><b>Medicine and Personal Care Products</b></p> <p>Medicinal plants and plant extracts are collected from forests. For example, the chemotherapy drug paclitaxel is extracted from Canada yew trees. The essential oils of conifer trees are a popular ingredient in lotions and other personal care products.</p>	
<p><b>Wood-carving and Craft-making Materials</b></p> <p>Materials for wood-carving, craft-making, and florist supplies, such as dried greenery, also come from forests. Many First Nations make canoes using bark from birch trees.</p>	
<p><b>Tourism</b></p> <p>Forest-related tourism is a multi-billion dollar industry worldwide. People may spend time in forests at home and abroad to hike, backpack, watch birds, ski, snowshoe, or simply enjoy the sights, sounds, and smells. Canada's forests provide almost 400 million hectares of beautiful scenery in which people can connect with nature physically, emotionally, and spiritually.</p>	

**silviculture** a branch of forestry related to the development and management of forests

## Silviculture Methods

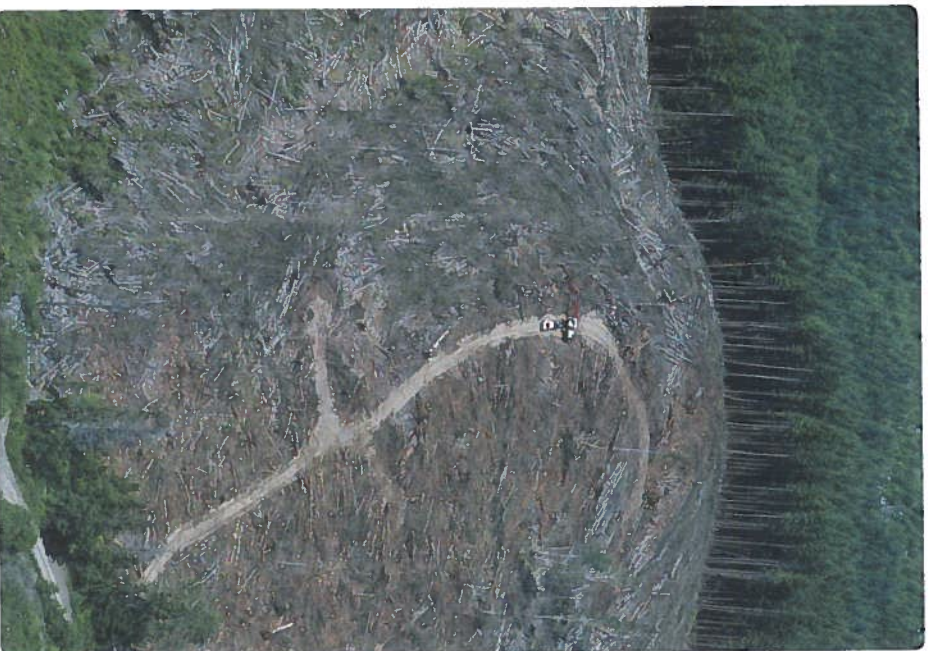
**Silviculture** is the practice of developing and managing forests for the timber products they can supply now and in the future. Common silviculture methods include clearcutting, selective cutting, and shelterwood systems. The system used to harvest timber and regenerate trees for a part of a forest depends on several factors. These include the tree species, the ages of the trees, and the conditions of the site. As well, foresters and other people who work in the industry must take into consideration the ecosystem services provided by forests when managing an area of forest.

Some terms that are often used to describe forests and trees include *old-growth forest*, *even-aged forest*, *uneven-aged forest*, and *mature trees*. An *old-growth forest* is one that has developed for at least 120 years without a severe disturbance such as a fire, windstorm, or logging. An *even-aged forest* is one in which the ages of the trees are within 10 to 20 years of each other. An *uneven-aged forest* is made up of trees with vastly different ages, which results in a complex mix of forest layers. A *mature tree* is one that has grown to reach its greatest economic value for its size and use.

### Clearcutting

**Clearcutting**, shown in **Figure 6.3**, removes most or all of the trees from a chosen area. This method of silviculture is often used to manage an even-aged forest.

**clearcutting** a silviculture method in which most or all of the trees from a chosen area are removed



**Figure 6.3** Clearcutting

#### Advantages

- mimics a large-scale natural disturbance, such as a fire, flood, windstorm, or disease
- stumps, branches, and some fallen trees are left on the forest floor as habitat and to conserve nutrients in soil
- often safer for forest workers
- efficient and cost-effective, because all harvesting is done at one time

#### Disadvantages

- habitat loss for species living in all three layers of the forest
- loss of large tracts of carbon-storing trees
- damage to structure and composition of soil
- increased surface-water run-off and soil erosion, especially if done on steep slopes
- takes a long time for trees to regenerate
- reduces the recreational and aesthetic value of a forest

## Selective Cutting

**Selective cutting**, shown in **Figure 6.4**, involves cutting and removing medium-aged or mature trees individually or in small clusters every 10 to 20 years. This method of silviculture is often used in uneven-aged forests.

#### Advantages

- mimics a small-scale natural disturbance, such as damage caused by trees that are uprooted or knocked down by wind
- preferred method for cutting on steep slopes or in places where permanent tree cover is needed
- retains habitat for species such as certain birds
- more aesthetically appealing than clearcutting
- individual trees of high economic value can be chosen and removed, leaving behind trees that can naturally regenerate the forest

#### Disadvantages

- costs may be higher than with clearcutting
- risk of damage to remaining trees and plants during harvest
- some animal species may decline after selective cutting occurs

**selective cutting** a silviculture method that involves cutting and removing medium-aged or mature trees individually or in small clusters every 10 to 20 years



**Figure 6.4** Selective cutting

## Shelterwood System

The **shelterwood system**, shown in **Figure 6.5**, involves removing trees in a series of cuts over a period of 10 to 30 years. This method of silviculture leaves one third to one half of the mature trees standing.

#### Advantages

- remaining trees provide seeds for new trees and shelter for seedlings and saplings
- remaining forest, although thinner, is still aesthetically appealing
- encourages regrowth of species that are sensitive to wind and sun, such as spruce and fir

#### Disadvantages

- young trees may be damaged during harvest of older trees
- more roads must be built into the forest
- planning and harvesting may be more costly than other methods

**shelterwood system** a silviculture method that involves removing trees in a series of cuts over a period of 10 to 30 years



**Figure 6.5** Shelterwood system

## Pause and Reflect

1. Identify and briefly describe the three main layers of a forest.
2. What factors may play a role in deciding which silviculture method is used to harvest and regenerate trees?
3. **Critical Thinking** Why would a forester take environmental, economic, and social factors into account before deciding which silviculture method to use?

## The Importance of Sustainable Forestry

Managing forests through sustainable practices is important to current and future generations. As we continue to learn more about the importance of forests and the ecosystem services they provide, governments, which manage a country's publicly owned forests, and private landowners worldwide are turning to sustainable management practices. The following list outlines the goals of sustainable forestry management practices.

- **Protect Biodiversity** Identifying and protecting forest areas that have high biodiversity, such as the Amazon rainforest, the boreal forests of Canada, and old-growth forests worldwide, helps to keep these ecosystems healthy.
- **Harvest Timber Sustainably** Selective cutting and another silviculture method called *strip cutting* are sustainable management practices. Strip cutting, shown in **Figure 6.6**, involves clearcutting a small strip of trees along a natural contour of the land. Using this method, trees grow back within a few years, and then a new strip of trees is cut down nearby.

### Did You Know?

"It's really amazing. You plant a seed; it germinates and, looking so fragile, and within a very short time, it becomes a huge tree. It gives you shade and if it's a fruit tree it gives you fruit... to build and transform lives."

—*Wangari Maathai (1940–2011), Founder of Kenya's Greenbelt Movement*

**Figure 6.6** Strip cutting involves clearcutting a strip of trees along a natural contour of the land.



- **Leave Organic Material in Place** After trees are harvested, it is important to leave some organic material behind. Organic material includes dead trees, fallen trees, dead limbs, and the tops of trees; these are usually left lying on the forest floor after a harvest. Leaving this material in place provides habitat for wildlife and allows nutrients to be recycled.
- **Regenerate After Harvesting** Planting tree plantations on deforested land replaces harvested trees. When managed well, tree plantations can produce timber at a fast rate. Tree plantations are managed as even-aged forests that are clear-cut and then replanted on a regular basis. Tree plantations can help reduce cutting in old-growth forests. They also store carbon and provide habitat for wildlife.
- **Certify Sustainably Managed Forests** Timber and other wood products that come from sustainably managed forests can be certified by several different agencies. This enables consumers to actively support sustainable management practices.
- **Value Ecosystem Services** Including the ecosystem services of forests as part of their economic value is being recognized as important. These services are often referred to as *natural capital*. For example, a 2009 report by the Canadian Boreal Initiative estimated that boreal forests and bogs in Canada store about 150 billion tonnes of carbon. This storage decreases the costs associated with carbon being released into the atmosphere by about 580 billion dollars per year. Recreational use of Canada's boreal forests is worth about 4.5 billion dollars per year.

## Society and Sustainability: Third-party Certifications

People who work in the forest industry are not the only ones who can help with maintaining sustainable forests. Consumers can as well. You and other members of society can reduce the use of wood products, which lessens the demand for timber and wood pulp. Recycling paper reduces the number of trees cut, as well as the energy and water needed to process trees into pulp and paper. Buying products made from recycled or repurposed wood products also makes a difference. Another factor to consider when making purchases is whether a wood product is certified as sustainable.

There are several independent agencies that certify wood products as sustainable. These include the Canadian Standards Association Sustainable Forest Management (CSA SFM), the Forest Stewardship Council (FSC), and the Sustainable Forestry Initiative (SFI). By volunteering to participate, companies that make wood products agree to meet the standards set forth by these agencies. In return, the companies may use labels such as those shown in **Figure 6.7**. Labels from all three of these agencies are used throughout Canada, which has the largest area of sustainable forest that is certified by independent agencies.



**Figure 6.7** These labels help consumers identify wood products that are sustainable.

*Applying What other products do you know or have you seen that have sustainability-related labels?*

### Pause and Reflect

- Describe one way that sustainable forestry benefits the forest industry.
- Describe one way that sustainable forestry benefits society.
- Critical Thinking** How can being an informed consumer contribute to sustainability, both for the industries that make products and for you personally?

### Mini-Activity 6-2

#### Certification Labels

Examine the certification label provided to your group by your teacher. Use the Internet or other resources provided by your teacher to determine exactly what the certification label means.

- From which agency is the label?
- Does 100% of the product contain materials that met the standards of the certification agency? If not, is a percent designated on the label?

- Does the product contain mixed sources? If so, what does this mean?
- What does chain-of-custody certification mean? With your group members, discuss the label and answer the questions. As a class, discuss the value of these labels to the consumer and to the sustainability of ecosystems.

 Inquiry Lab 6C, Annual Growth Rings of Trees, on page 196

# Case Study Selective Cutting on Pinkerton Mountain

Pinkerton Mountain is in the Cariboo Mountains in British Columbia. As the name suggests, the Cariboo Mountains are home to mountain caribou (*Rangifer tarandus caribou*), shown in the photo on the right. These animals have one main food source: tree lichen. This hair-like lichen hangs from the branches of evergreen trees that live on the mountain's steep slopes. Commercial logging of these trees can have a huge impact on mountain caribou survival. As a result, silviculture practices must make caribou habitat a top priority. In 1998, scientists at the University of Northern British Columbia set up a long-term study on Pinkerton Mountain. They wanted to find out how different harvesting practices affect caribou habitat.

## Results of the Experiment

The Pinkerton Mountain study had a control area and two experimental areas. The control area was a section of unlogged forest. Trees in the experimental areas were removed using two selective cutting techniques that mimic natural forest disturbances on the mountain: group selection and single-tree selection. In the single-tree selection area, only individual trees were removed. Overall, no more than 30% of the trees were harvested.

After 10 years, scientists measured the amount of tree lichen growing at caribou grazing level. They found that the same amount of lichen grew in each area. They also assessed which species of lichen was most common in each area. In the control area, one species of lichen was most common; in the experimental areas, a different species was most common. Since caribou often prefer one species of tree lichen to another, such a change could have an impact on their diet and, thus, on their survival.

In this case, the caribou actually preferred the species that thrived in the experimental areas. Therefore, scientists concluded that changes to lichen growth due to the two selective cutting methods used in the experiment did not affect the mountain caribou.



## Research and Analyze

1. This study showed that changes to lichen growth due to selective cutting did not affect the mountain caribou. Describe three other factors that foresters might consider when harvesting trees on Pinkerton Mountain.
2. Suppose you are the owner of a commercial logging company that operates in the Cariboo Mountains. You learn that selective cutting can help protect mountain caribou habitat. Do research to learn more about the advantages and disadvantages of selective cutting for commercial logging. Include information about its environmental, economic, and social impacts. Use a risk-benefit analysis to decide if selective cutting is the best method to harvest trees in the Cariboo Mountains.

## Communicate

3. The Pinkerton Mountain study did not investigate clearcutting. Write a short opinion paper of two or three paragraphs to explain how you think clearcutting could affect tree lichen and, therefore, caribou, in the Cariboo Mountains.

## Reviewing Section 6.1

### Summary

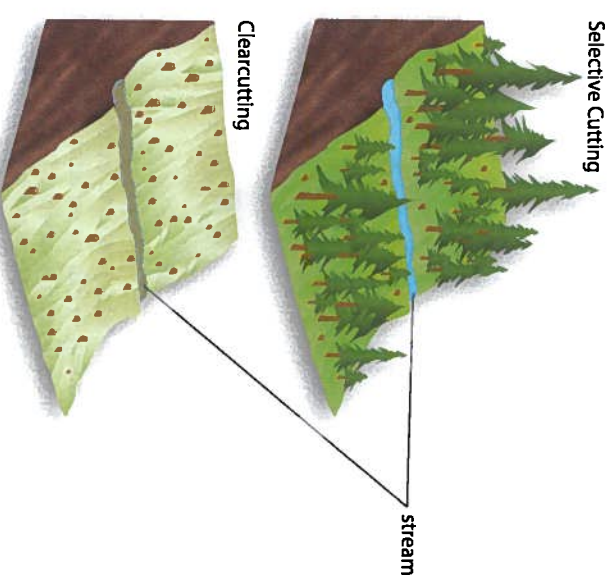
- A forest is an ecosystem in which the dominant plants are trees. Most forests are made up of three main layers: the canopy, the understory, and the forest floor.
- Forests provide many ecosystem services, including being a source of timber and non-timber resources.
- Silviculture is the development and management of forests. Silviculture methods include clearcutting, selective cutting, and shelterwood systems.

### Review Questions

1. Identify each layer of a forest and describe several ecosystem services provided by that layer. **K/U A**
2. Paper and pulp are the fastest-growing sectors of the wood products market, as developing countries such as China and India catch up with the use rates of North America, Europe, and Japan. **K/U A**
  - a) What effect could this have on the ecosystem services provided by forests?
  - b) What are some ways to reduce paper use?
3. Some conservationist groups argue that watershed protection and other ecosystem services of forests are more economically valuable than timber. Some timber companies argue that continued production supports stable jobs and local economies. **7/E A A**
  - a) If you were a judge trying to come up with a compromise between the two groups that balanced ecological and economic sustainability, what questions would you ask both groups? What evidence would help you arrive at a compromise?
  - b) How would you gather this evidence? How would you identify bias from any source?
4. List at least four non-timber resources that you use in your daily life. Explain how you might be affected if these resources were no longer available. **A C**
5. Copy the table below into your notebook and complete it. **K/U**

	Advantages	Disadvantages
Clearcutting		
Selective cutting		
Shelterwood system		

6. Describe three ways to manage forests more sustainably. **K/U**
7. What does it mean if a wood product is certified as sustainable? **K/U**
8. The illustrations below show models of two silviculture methods that could be used to harvest trees from the same area. Which method do you think would be better to use? Why? **A**
9. Suppose you own 40 acres (about the size of 30 soccer fields) of uneven-aged forest land. The wooded area is a temperate deciduous forest, which includes tree species such as oak, maple, elm, walnut, and beech. Would you harvest trees from your land? Why or why not? If you would, which type of silviculture method would you use? Explain your reasoning. **A C**
10. How do you and other consumers exert power and influence each time you choose one product over another when you shop? **7/E A**



## Urban Forestry

Urban forestry is a field of science that deals with the long-term planning, planting, and maintenance of forests, trees, and green spaces in urban environments. The trees and green spaces of urban forestry provide several important ecosystem services.

**urban forestry** the long-term planning, planting, and maintenance of forests, trees, and green spaces in urban environments

- **Figure 6.8** shows three examples. In addition to these services, urban forests
  - help to purify city air by removing dust and various polluting gases, including carbon dioxide
  - act as buffers to reduce noise pollution
  - increase the aesthetic, and often the economic, value of homes and communities
  - serve as a source of fresh, locally grown food from individual and community gardens
  - help to reduce energy consumption by providing shade and windbreaks

**Figure 6.8** There are several important ecosystem services provided by urban forests and green spaces.

**Applying** What other ecosystem services do urban forests provide?



Trees and wooded areas in cities provide habitat and food for a variety of organisms. This blue jay, along with other bird species, lives in wooded areas in urban settings year-round. These spaces can be especially important to migrating birds, which use them as a place to rest and fuel up for the remainder of their flight. Squirrels, deer, and raccoons are just a few of the mammals that live in urban forests.

Urban parks provide space for people to exercise, relax, meditate, and connect with nature. Walking, jogging, or playing organized games in the park are great ways to exercise for free or for very little expense. Cycling on bike paths in parks or through cities is a popular way for people to exercise under the shade provided by trees.



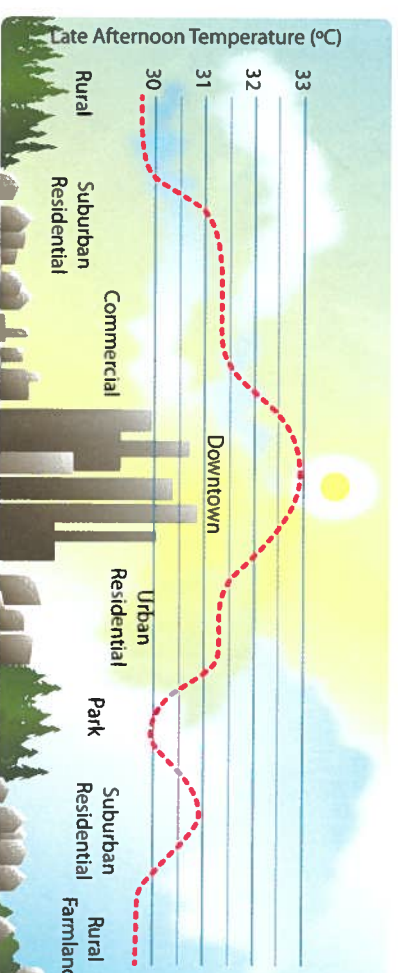
Water from rain and heavy storms easily pools on the concrete and asphalt surfaces of urban areas. This increases the risk of flooding and the movement of pollutants from streets and parking lots into streams, ponds, and other local waterways. Rain gardens are designed to catch surface run-off from storms. They are usually planted in low-lying areas, and they help by increasing the amount of water absorbed into the ground. As well, they provide habitat for wildlife and usually require little maintenance once planted.



## Reducing the Heat Island Effect

As urban areas develop, the landscape changes from open land covered with plants to surfaces covered with concrete and asphalt. Land is cleared to make roads, parking lots, and sidewalks. Block-long stretches of concrete buildings often cover much of the downtown part of a city.

Large areas of concrete and asphalt absorb a lot of heat during the day. **Figure 6.9** shows that temperatures in the downtown part of a city can be up to 3°C higher than in surrounding rural areas. This **heat island effect**, as it is called, leads to an increase in energy use for summer cooling. In regions where energy is supplied mainly from fossil fuels, this means an increase in greenhouse gases and a decrease in air quality.



**heat island effect** an effect in which urban areas are higher in temperature than surrounding rural areas due to the heat absorbed by concrete and asphalt

**Figure 6.9** The heat island effect leads to increased energy consumption, increased emissions of air pollutants and greenhouse gases, and decreased water quality.

Urban forests can reduce the heat island effect. For example, trees and other plants provide shade. As well, when water evaporates from pores in plant leaves, air is cooled. Notice in **Figure 6.9** that the surface temperature during the day is lower in areas that have trees compared to downtown areas with no plants.

Green roofs such as the one shown on the opening pages of this chapter are also an effective way to help reduce the heat island effect. A green roof is a roof that has a layer of plants growing on its surface. Green roofs may be made up of a simple layer of grass or other ground cover, a flower or vegetable garden, or a complex mixture of plants and trees. Green roofs absorb heat and act as insulators for buildings, reducing the need for cooling in the summer and heating in the winter.

### Mini-Activity 6-3

### Cool Your School

Many schoolyards are heat islands, due to the high concentration of heat-absorbing materials used for roofs, parking lots, and playgrounds. One study done in Waterloo, Ontario, showed that the average surface temperatures of 15 schoolyards ranged from 48.4°C to 55°C. These temperatures were greater than that of the surrounding land area by as much as 5°C. Survey your schoolyard with the heat island effect in mind.

- Which structures may be contributing to the heat island effect?

- How could you design a procedure to collect data to analyze?
- Based on your results, what changes could be made to reduce the heat island effect, and how could they be implemented?
- What factors could keep the changes you suggested from being made?
- If your school was planned with temperature reduction in mind, identify a schoolyard elsewhere in or near your community that could benefit from your ideas.

## Managing Urban Forests Sustainably

Many types of jobs and professions are involved in the planning and maintaining of plants in an urban setting. These include urban foresters, urban forestry technicians, and landscapers, who perform the duties described in **Figure 6.10**.

**Figure 6.10** Ways to manage urban forests sustainably include surveying site conditions, planting native plants, and keeping plants healthy.

**Inferring** Why do you think it is important for urban foresters to have information about site conditions before deciding what to plant in the area?

### Choosing the Site

Part of the planning stage involves choosing a site with the right conditions to ensure the short- and long-term health of plants. These conditions include

- the type of soil in which the plants will grow
- the amount of sunlight or shade
- the amount of water and drainage
- the amount of pedestrian traffic



### Keeping Plants Healthy

An important part of keeping plants healthy in an urban environment includes pruning, watering, fertilizing, and deciding when to remove dying or dead plants. Another important part is protecting plants in wooded areas during construction projects. This helps reduce the impact of changing environmental conditions due to the construction.



### Planting Native Plants

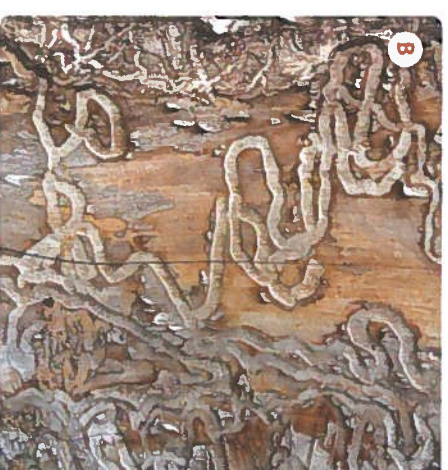
Planting the right kinds of plants for the site is also important for urban forestry management. **Native plants** are plants that have been growing naturally in an ecosystem without any action, past or present, from humans. Native plants are better adapted to local site conditions. They are often better suited to resisting drought, disease, and insect pests. As a result, native plants tend to need less water and less maintenance, which saves time, money, and resources. They also increase biodiversity by attracting and supporting bees, butterflies, birds, and other native wildlife species. As well, native plants tend to provide better erosion control and climate control than non-native plants.



## Integrated Pest Management

Managing diseases and pests can be a big part of keeping plants healthy in an urban setting. Plants must be monitored for evidence of infestation by insect pests or infection by bacteria or fungi. Areas near and where plants grow must be monitored for the appearance of non-native pests or invasive species. These organisms can cause severe damage and can be costly both economically and aesthetically. Integrated pest management plans are developed, and then must be implemented and evaluated.

The emerald ash borer, shown in **Figure 6.11A**, is a beetle whose larvae destroy the tissues that move water and food in all parts of ash trees. Since 2002, the emerald ash borer has been spreading throughout southwestern Ontario, including the city of Toronto. The beetle is a serious threat to all species of ash trees, which are commonly used to line city streets and are found throughout urban areas. One way to stop the spread of the beetle is to cut down all infested trees within a certain radius. As part of the management plan for the emerald ash borer, more than 80 000 ash trees were cut down in Essex County in 2004.



**Figure 6.11 (A)** The emerald ash borer is a threat to a large area of North America, from Canada to the midwestern and eastern United States. **(B)** Emerald ash borer larvae chew through the inside layer of a tree, leaving a characteristic pattern of damage.

In Toronto, the urban forestry management plan initially focussed on using insecticides to eradicate the beetle. However, since 2011, management efforts have been geared toward trying to reduce its impact. These include removing existing ash trees, educating the public, and developing a tree-planting replacement program. Some estimates suggest that the cost to all affected North American cities from the loss of trees, replanting efforts, and general impact of infestation will be in the billions of dollars.

As urban areas grow and expand, urban foresters consider how plants can be integrated into future development. Foresters also identify sites that are suitable for reclaiming as forests and green spaces, and suggest ways to increase their sustainability. Researching and providing long-term plans to municipalities is an important part of urban forestry management.

## Pause and Reflect

7. Define *urban forestry*.
8. Why is it important to manage urban forests sustainably?
9. **Critical Thinking** What role could native plants play in integrated pest management in urban forests?

## Case Study National Urban Parks

A national park is an area of scenic, historical, or scientific importance that is set aside and maintained by the federal government. Most national parks are kept in their natural state far from urban areas.

For example, Quttinipraq National Park in Nunavut includes the most remote, fragile, and northerly lands in North America. Parks Canada describes Fundy National Park as “Atlantic’s sanctuary ... that encompasses some of the last remaining wilderness in southern New Brunswick ... [along] with [the] world’s highest tides.” Ontario’s St. Lawrence Islands National Park is the smallest national park in Canada and is accessible only by boat.

Unlike the national parks that are located outside of and often far from cities, there are many smaller urban parks throughout Canada’s cities. Urban parks are usually managed by local governments. However, many countries—including Canada—are now establishing larger national urban parks to conserve important natural and cultural areas.

### Rouge National Urban Park

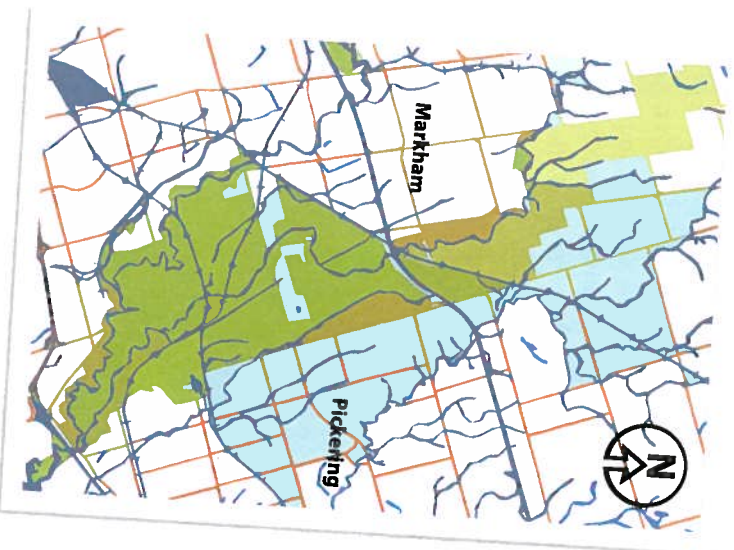
In 2011, the federal government announced that it would create a national urban park in the Rouge Valley in the eastern part of the Greater Toronto Area. The federal budget of 2012 committed 143.7 million dollars over 10 years for the development of the park, with 7.6 million dollars per year after that for the park’s continuing operations. The provincial government, non-profit organizations, and community groups also co-operated in the formation of the new park.

The proposed area for Rouge National Urban Park is 5600 hectares, which is the size of nearly 14 000 football fields. The park is also within a short distance (about 100 km) of 20% of Canada’s population. The vision for the park is that it will be a “people’s park,” where visitors can experience the area’s unique natural and cultural heritage with no entrance fees.

The park represents diverse natural environments. These include freshwater marsh, rivers, forest, and wetlands. As well, the park will protect the habitats that connect the Oak Ridges Moraine and Lake Ontario. Living in these diverse habitats are 760 plant species, 55 species of fish, 19 species of reptiles and amphibians, 225 bird species, and 27 mammal species. The park will also incorporate the City of Toronto’s only working farms and promote sustainable farming techniques.

The Rouge Valley also represents more than 10 000 years of human history, so it will preserve and highlight important cultural heritage sites. These include artifacts and habitation sites from early nomadic hunter-gatherer tribes; the Toronto Carrying Place, an Aboriginal portage trail also used by the fur traders; and Bead Hill, a 17th-century Seneca village. The vision for Rouge National Urban Park is not only to conserve important ecosystems, but also to restore fragile habitats and provide engaging educational experiences for visitors.

Map of Rouge National Urban Park



### Santa Monica Mountains National Recreation Area

Santa Monica Mountains National Recreation Area, in Greater Los Angeles, represents the successful co-operation of a large number of landowners and stakeholder groups to preserve this natural and culturally significant area for future generations. The size of 63 000 football fields, it is the largest national urban park in the United States.

The park was established in 1978 and is made up of many individual parks and nature sanctuaries. These habitats include coastal marine ecosystems and one of the world’s best examples of a Mediterranean climate ecosystem. The park is also home to nearly 2000 plant and animal species, including pumas.

Visitors can find relief from the heat of the city in the cooler mountains and enjoy more than 100 km of hiking and walking trails. As well, the park’s numerous archeological sites showcase the different human communities that have made the area their home over the past 10 000 years.

Santa Monica Mountains National Recreation Area—Backbone Trail



### Research and Analyze

1. Research what is currently happening with the Rouge National Urban Park. Consider the following questions: Is the project on schedule and on budget? Has the original plan for the park changed? Have there been any controversies during the park’s development? If so, how were these issues resolved?
2. Research another possible location for a national urban park in Canada. Outline a short proposal for the new park. Include details such as the site boundaries, important natural and cultural resources that would be included, and which agencies would fund and manage the park.
3. Research another national urban park that is not discussed in this Case Study. Describe how that park was established and any issues that may have arisen as the park was developed.
4. Choose one of the urban parks discussed in this case study or the one you researched in question 3. Make a table that lists at least five ecosystem services the park provides to its city or region. Include specific details for each service you list.

### Communicate

5. In pairs or a small group, brainstorm the advantages that a national urban park can provide to the residents of a city. Create a brochure to promote national urban parks to the general public.

# Case Study Naturalization

**Naturalization** is an environmentally sustainable technique that is used to create or re-create natural landscapes. Naturalized landscaping uses native plants. This decreases the need for maintenance and creates habitat for wildlife. Naturalization should not be confused with simply abandoning a site and allowing plants to regrow. A successful naturalization project takes research, planning, and management.

## Brampton Valleys Re-naturalization

In 2003, the City of Brampton, Ontario, began a project to naturalize 160 hectares of the city's watershed lands along Fletcher's Creek and the Humber River tributaries. The goal was to restore these valleys to their natural state, before they were altered by agriculture and development.

The city committed 8.8 million dollars over 10 years to plant 24 000 trees, 200 000 shrubs, and 100 000 other flowering plants. As shown in the photos, the project has been successful in restoring plant communities, creating fish and wildlife habitats, and stabilizing these important flood-plain lands.



Before naturalization



After naturalization

## Glenridge Quarry Naturalization Site

Glenridge Quarry Naturalization Site is located in St. Catharines, in Ontario's Niagara Region. The site was originally a limestone quarry, but was used as a municipal landfill from 1976 to 2001. After the landfill was closed, the city decided to naturalize the site, with the goal of creating sustainable habitats that would also provide recreational and educational opportunities.

The plan for the site used local natural habitats as a guide. It also used ecological principles in its design: low energy consumption, re-use of natural materials, and recycling of building materials. Today, the Site has trails, boardwalks, and picnic areas for visitors to enjoy, and is connected to the Bruce Trail, which is Canada's longest trail system. The naturalization project at Glenridge Quarry has received numerous Canadian and international awards.

## Research

1. Research ways that schoolyards can be naturalized and whether there are any organizations that can help. Design a plan for naturalizing a portion of your school's property. Include the native plants you would use in your design.
2. Research an area of land in your community that could be a candidate for naturalization. Create a table to list the benefits and challenges involved in naturalizing your chosen site.

## Communicate

3. Write a proposal to present the plan you designed in question 1 to your local school board or to your municipal government. Include a brief description of your plan, the benefits of naturalization, and the advantages the project will bring to the community.

## Reviewing Section 6.2

### Summary

- Urban forestry deals with the long-term planning, planting, and maintenance of forests, trees, and green spaces in urban environments.
- Urban forests provide ecosystem services such as habitat and food for other organisms, space for people to relax and exercise, reducing the heat island effect, buffering noise, and acting as natural air purifiers.
- Urban forests and green spaces, including green roofs, play an important role in reducing the heat island effect.

### Review Questions

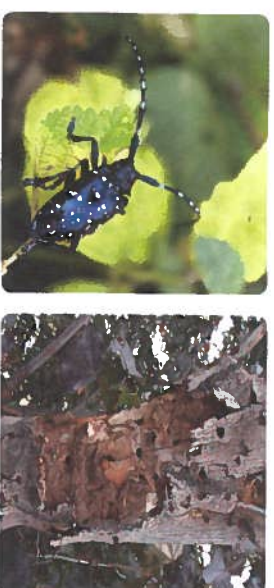
1. Use a graphic organizer of your choice to show the ecosystem services provided by urban forests. **C**
2. Choose one or more of the ecosystem services provided by urban forests and explain its importance to or effect on the environment, the economy, and the local community. **TH C**
3. Which ecosystem service is the urban park in the photo below providing? **A**



4. Explain the heat island effect. **KU**
5. List three actions that can be taken to reduce the heat island effect. **KU**
6. Choose one location in your community, such as your own yard, an empty lot, your school, or a group of buildings. Make a list of changes that could be made to increase the sustainability and ecosystem services provided by the area. Use the following questions as a guide. **TH A C**
  - a) How could native plants be incorporated into the area?
  - b) How could run-off be reduced?
  - c) Would a community garden be appropriate? Why or why not?
  - d) Could a green roof be incorporated? Why or why not?

- Methods of managing urban forests sustainably include choosing site conditions, planting native plants, and keeping plants healthy.
- Integrated pest management is an important part of managing urban forests sustainably.
- As urban areas grow and expand, urban foresters consider how plants can be integrated into future development and suggest ways to increase their sustainability.

7. The Asian long-horned beetle (*Anoplophora glabripennis*), shown in the left photo below, is native to northeast Asia. As an invasive species introduced to North America in the 1990s, it poses a serious threat to various urban tree species, including elm, birch, poplar, and maple. The larvae and adult beetles damage trees by feeding on sap, budding leaves, and bark. The photo on the right shows damage to a tree caused by these beetles. Infested trees are weakened and eventually die. The beetle was found in the Greater Toronto Area in 2003, where maple trees make up 50% of the trees that line streets. The City Forester's Office of Toronto counts on alert citizens to report sightings of the beetle or evidence of its infestation on trees. Write a public service announcement to encourage citizens to help reduce the threat of this invasive species. **A C**



8. Explain why planting trees around buildings helps reduce costs associated with indoor temperature regulation in both the summer and the winter. **A**
9. Make a concept map that organizes information about the methods used to manage urban forests sustainably. **KU C**



## Section 6.1 Forestry Management

Forests provide many important ecosystem services, and managing forests through sustainable practices is important to current and future generations economically, ecologically, and socially.

**Key Terms**  
 forest  
 timber  
 silviculture  
 clearcutting  
 selective cutting  
 shelterwood system

**Key Concepts**

- A forest is an ecosystem in which the dominant plants are trees. Most forests are made up of three main layers: the canopy, the understory, and the forest floor.

- Forests provide many ecosystem services, including being a source of timber and non-timber resources.
- Silviculture is the development and management of forests. Silviculture methods include clearcutting, selective cutting, and shelterwood systems.
- As we continue to learn more about the importance of forests and the ecosystem services they provide, governments and private landowners worldwide are turning to sustainable management practices.
- Companies that make wood products can apply to various independent agencies for permission to apply a label that identifies their products as being managed and manufactured in a sustainable manner.

## Section 6.2 Urban Forestry

Urban forests and green spaces in cities provide important ecosystem services, and as urban areas grow and expand, urban foresters consider how plants can be integrated into future development to increase sustainability.

**Key Terms**  
 urban forestry  
 heat island effect  
 native plant

**Key Concepts**

- Urban forestry deals with the long-term planning, planting, and maintenance of forests, trees, and green spaces in urban environments.

- Urban forests provide ecosystem services such as habitat and food for other organisms, space for people to relax and exercise, reducing the heat island effect, buffering noise, and acting as natural air purifiers.
- Urban forests and green spaces, including green roofs, play an important role in reducing the heat island effect.
- Methods of managing urban forests sustainably include choosing site conditions, planting native plants, and keeping plants healthy.
- Integrated pest management is an important part of managing urban forests sustainably.
- As urban areas grow and expand, urban foresters consider how plants can be integrated into future development and suggest ways to increase their sustainability.

## Knowledge and Understanding

Choose the letter of the best answer below.

- Which statement about forests is false?
  - The dominant plants in forests are trees.
  - The tundra rainforest is one of several types of forests.
  - The basic structure of most forests consists of the canopy, the understory, and the forest floor.
  - Different abiotic and biotic factors make up different types of forests.
  - A forest is an ecosystem.
- In which part of a forest do shade-loving young trees and shrubs thrive?
  - the canopy
  - the forest floor
  - the understory
  - the branches
  - None of these areas support the growth of trees that thrive in the shade.
- Timber from trees, such as spruce, maple, oak, or pine, might be used
  - to build frames for houses
  - by wood crafters to make carvings
  - as fuel to keep warm or cook food
  - in a pulp mill to make paper products
  - All of these are correct.
- Selective cutting is often used on uneven-aged forests. Which statement about selective cutting is true?
  - It is a cheaper way to harvest trees than other methods.
  - Foresters can remove individual trees that are worth a lot of money.
  - It is often the safest way for workers to harvest trees.
  - It has the same effect on the forest as a forest fire burning through the area.
  - Soil erosion will occur if the cut is on a steep slope.
- The field of science that deals with the long-term planning, planting, and maintenance of forests, trees, and green spaces in urban environments is
  - urban forestry
  - selective cutting
  - shelterwood cutting
  - silviculture
  - dendrochronology
- Which is *not* an ecosystem service provided by forests?
  - increased soil erosion
  - carbon storage
  - cycling of nutrients such as nitrogen and phosphorus
  - water purification
  - providing habitats for millions of species on Earth
- The practice of developing and managing forests for the timber products it can supply now and in the future is
  - agriculture
  - ecosystem management
  - integrated pest management
  - silviculture
  - urban forestry
- Which statement is false?
  - A mature tree does not grow anymore.
  - An old-growth forest has developed for over at least 120 years.
  - Trees that are all within 10 to 20 years of age of each other are part of an even-aged forest.
  - An uneven-aged forest has trees of significantly different ages growing in it.
  - Clearcutting is usually used to manage an even-aged forest.

Answer the questions below.

- Decomposing matter in the forest floor is an important part of the forest ecosystem. Explain how this rotting matter benefits new seedlings and existing forest plants.
- List four non-timber forest resources.
- Briefly describe two advantages that shelterwood cuttings have over clearcutting methods of tree harvesting.
- Define *sustainable forestry*.
- Identify three ecosystem services that are provided by plants in an urban environment.
- Urban areas tend to have daytime temperatures that are higher than the daytime temperatures recorded in surrounding rural areas.
  - What is this temperature differential known as?
  - Explain why it occurs.
- What is integrated pest management and how might it be used to help maintain healthy trees in an urban area?
- Identify three site conditions that are usually evaluated by an urban forester before a decision can be made regarding what to plant in the area.

## Thinking and Investigation

- 17.** Infer the types of forestry practices that could be used to maintain features of old-growth forests while harvesting trees.
- 18.** A 2012 study published in the academic journal *Science* reported that death rates among trees 100 to 300 years old are increasing compared to past years. The accelerated death rates were found in old trees across many ecosystems in many areas of the world, including forests and urban areas in Brazil, Europe, Canada, and Africa. The scientists who conducted the study compared the death of these large, old trees to the plight of endangered species such as rhinoceroses, whales, and elephants.
- What ecosystem services are lost when large, old trees like the ones used in the study die?
  - Infer some of the possible causes of the accelerated death rates of these trees.
  - What information would you need to collect to determine whether the causes you listed in part (b) are valid?
- 19.** Without forests, there would not be any non-timber-related products. If you were going to defend this statement, what reasoning would you use to support it? Include at least three facts in your response.
- 20.** Wildfires are usually considered to be very destructive. However, the Ontario Ministry of Natural Resources will conduct a prescribed fire in a forested area as a managed forest practice. The goals of this practice include silvicultural site preparation and maintaining a healthy ecosystem, in which fire is part of the natural processes. For example, this practice could be used to regenerate jack pine populations, as heat from a fire is needed for the cones to open and release the seeds.
- Describe a simple lab procedure that you could conduct outdoors on the cones of jack pines to determine the effects of fire intensity on the viability of the cones. **Do not conduct this proposed investigation.**
  - Could your results in part (a) be used to predict whether cones exposed to fire and heat in the upper canopy are more viable than those in the lower canopy? Explain the reasons for your response.
  - What would you use as an appropriate control for your proposed investigation?
  - Identify three safety procedures that would have to be followed if this investigation were to be conducted outdoors.

- 21.** Giant sequoias, such as the one shown below, can grow to have diameters over 6 m and height over 100 m. These trees can be grown from seed. The seeds are placed in a refrigerator for about a month to simulate the colder weather, and then left near a warm source for a bit of time to ensure that the seeds germinate. The trees require rich, moist, well-drained soil. They have delicate feeder roots that are needed to obtain water—if these roots are broken, the tree will likely die.



- Based on your knowledge of urban forestry and the information provided above, do you think that someone could germinate a giant sequoia seed and successfully get it to grow as a seedling in a suburban backyard with dimensions of, say, 25 m by 30 m? Provide support for your response.
- What other information would an urban forester need to determine whether a giant sequoia could be grown successfully in an urban green space?

## Communication

- 22.** Plants in an urban environment provide many ecosystem services, including removing carbon dioxide from the air. In a well-structured paragraph consisting of four or five sentences, describe some other ecosystem services that plants provide.
- 23.** Silviculture can be beneficial to the forest industry as well as the consumer. For example, lower costs might be incurred by the forest industry when a large number of trees are harvested through clearcutting methods. This savings can be passed along to the consumer via lower lumber prices. State one other benefit of silviculture, and give a reason to support your answer.
- 24.** More than 80 000 ash trees were cut down in Essex County in 2004 to stop the spread of the emerald ash borer. Provide a list of the environmental costs associated with this management method.

- 25. Did You Know?** Research more information about Wangari Maathai. What is the Greenbelt Movement? Why was she awarded a Nobel Peace Prize? How does the quote on page 182 emphasize the importance of sustainable forestry? Use the information you find during your research to write a mini-biography of Wangari Maathai.

## Application

- 26.** A study by the University College, London, showed that in Toronto, rates of type 2 diabetes were lower in areas that had greater access to parks and other green spaces. Another study completed by a team of Ontario scientists showed that decreased mortality rates in urban areas were associated with access to green spaces. Other studies have shown that access to green spaces in urban areas is also associated with better mental health and less physical illness. Suppose that the development and maintenance of a new urban park would cost taxpayers a lot of money. How could the mayor's office use the facts in this paragraph to justify some of these economic costs?

- 27.** Research more information about the advantages and disadvantages of tree plantations. Include environmental, economic, and social aspects of the issue. Present the results of your research in a table.

- 28.** If you have ever walked on concrete or asphalt in your bare feet, you know that it absorbs a lot of heat from the sunlight that shines on it. These surfaces also transmit heat to the ground under the pavement and release that heat at night, which further increases the heat island effect. Cool pavement, shown in the diagram below, is made with materials that reflect more sunlight so that less heat is absorbed. Cool pavement materials also have pores that let water drain through, which helps to cool the ground under the pavement. How does the use of cool pavement reduce the heat island effect?



- 29.** Research more information about how forest thinning can help prevent or reduce the seriousness of a forest fire. Use the following questions to help guide your research.

- Does thinning of forests and prescribed burning help prevent catastrophic wildfires? Why or why not?
- Is there an ecological advantage to thinning forests and/or using prescribed burns to reduce fuel for fires? Explain your answer.
- Are prescribed burns part of Parks Canada's forest management program? Why or why not?

- 30.** Suppose you are buying lumber for a small building project. At the store, you compare prices of different types of lumber. The lumber that is labelled as sustainable is about 20% more expensive than the same lumber that is not labelled sustainable. Which lumber would you buy? Why?

- 31.** Research more information about the long-term effects of clearcutting forests on human health. Present the results of your research in a bulleted list with a brief explanation next to each effect.

- 32.** A typical schoolyard is shown in the photograph below. Provide at least three options that you could present to the school council to change this concrete schoolyard into a green schoolyard. You may use a sketch to help you with your response.



- 33.** Describe three actions that you, as a consumer, can take to encourage businesses to carry wood products that are more sustainable.

## Pause and Reflect

How could you incorporate what you have learned in this chapter into your daily actions or choices?