CHAPTER 1

# An Introduction to Environmental Science

**Lesson 1**
**Our Island, Earth**

**Lesson 2**
**The Nature of Science**

**Lesson 3**
**The Community of Science**

Space Shuttle ***Endeavour*** as seen by astronauts on the International Space Station, February 2010; layers of Earth's atmosphere, including the stratosphere (white), are visible.

# Central CASE

# Fixing a HOLE in the SKY

**WHAT HAPPENS** to the chemicals that humans release into the atmosphere? Sometimes, they seem to do nothing. Other times, however, the effects are devastating ... and life-threatening.

In the atmosphere, reactions constantly take place between oxygen atoms (O), oxygen gas ($O_2$), and ozone ($O_3$). Ultraviolet light from the sun breaks oxygen gas into two oxygen atoms: $O_2 \rightarrow 2O$. These oxygen atoms collide and react with oxygen gas, forming ozone: $O + O_2 \rightarrow O_3$. And oxygen atoms collide with ozone, releasing two oxygen molecules: $O + O_3 \rightarrow 2O_2$.

Despite the constant reactions between O, $O_2$, and $O_3$, a certain amount of ozone remains concentrated within a layer of the atmosphere known as the stratosphere. This concentrated area of ozone, called the "ozone layer," blocks harmful ultraviolet (UV) rays from reaching Earth's surface. UV rays can cause skin cancer, cell mutations, and other harmful effects in organisms including humans.

In the 1960s and '70s, Dutch scientist Paul Crutzen began to investigate and form hypotheses about the regulation of atmospheric ozone levels. He suspected that gases from fertilizer and jet exhaust had the potential to significantly deplete the ozone layer and warned that human activities could damage the atmosphere.

Meanwhile, English scientist James Lovelock invented an instrument that could detect atmospheric chemicals including CFCs, or chlorofluorocarbons. CFCs are synthetic compounds of carbon, fluorine, and chlorine atoms that were once found in many manufactured products—from shaving cream cans to asthma inhalers, refrigerators to air conditioners. The amount of CFCs Lovelock found in the atmosphere made it clear that CFCs did not break down well. They remained intact in our atmosphere.

Two scientists in California, Mario Molina and Sherwood Rowland, heard about Lovelock's findings and began to investigate what effect CFCs might have on the atmosphere. They looked at how CFCs move through the atmosphere and react with other chemicals. They also tried to calculate exactly how many CFCs were being released. What they found out was frightening: CFCs had the potential to destroy Earth's protective ozone layer.

When Molina and Rowland published their results in 1974, Paul Crutzen recognized the significance of these findings and began to model the process of ozone depletion in more detail. In 1985, Molina, Rowland, and Crutzen's concerns were shown to be justified: Scientists discovered that the ozone layer over Antarctica had become dangerously thin, so thin that it was called an "ozone hole." For their research, Molina, Rowland, and Crutzen shared the 1995 Nobel Prize in Chemistry.

With the discovery of the ozone hole, most nations agreed to phase out the use of CFCs and other ozone-destroying chemicals. Nonetheless, CFCs can remain in the atmosphere for up to a century. The ozone hole continues to appear over Antarctica every year from August to October. Scientists estimate it will take until 2050 for the ozone layer to recover significantly. Without the efforts of the entire scientific community, however, the problem could have been much worse.

## BIGQUESTION

**Q: How do scientists uncover, research, and solve environmental problems?**

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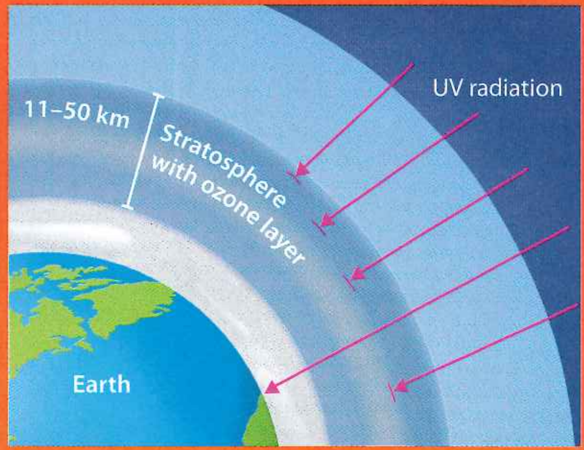
- Extend the Reading
- Take It Local
- 3-D Geo Tour



# LESSON 1 Our Island, Earth

**Guiding Question:** How does environmental science help us understand the natural world?

**Knowledge and Skills**

- Explain the focus of environmental science.
- Describe the recent trends in human population and resource consumption.

**Reading Strategy and Vocabulary**

**Reading Strategy** Create a KWL chart for each of the vocabulary terms in this lesson. Before you read, fill in what you know and what you want to learn. After reading, fill in what you learned.

**Vocabulary** environment, environmental science, environmentalism, natural resource, renewable natural resource, nonrenewable natural resource, sustainable, fossil fuel, ecological footprint

**VIEWED FROM SPACE,** our home planet resembles a small blue marble suspended against a vast inky-black backdrop. Earth may seem vast here on its surface, but an astronaut's perspective reveals that Earth and its natural systems are limited. It has become clear that as our population and technological powers increase, so does our ability to change our planet and possibly damage the very systems that keep us alive.

## Our Environment

**Environmental scientists study how the natural world works, and how humans and the environment affect each other.**

From space, Earth looks simple—blue oceans, green and brown land masses, white clouds—but this is not a complete picture of the environment. The **environment** includes all the living and nonliving things with which organisms interact. It includes the continents, oceans, clouds, and icecaps visible in the photo of Earth from space, but it also includes the animals, plants, forests, and farms that you cannot see from such a great distance. The environment includes remote areas rarely visited by people, but it also includes all of the buildings, urban centers, and houses that people have built, as well as the complex webs of social relationships that shape our daily lives.

**Humans and the Environment** Unfortunately, *environment* is often used to mean the nonhuman or "natural" world. But humans are part of nature. Like all other species on Earth, we interact with our environment and rely on a healthy, functioning planet for everything we need—including air, water, food, and shelter. Without a healthy environment, we cannot survive. Studying environmental science reminds us that we are part of the natural world and how we interact with it matters a great deal.

**Understanding Human Influences** Many people today enjoy longer life spans, better health, and greater material wealth than ever before. We can fly around the world with ease and cure previously incurable diseases with a pill. However, these improvements have often harmed the natural systems that sustain us, destroying habitats and polluting the water and atmosphere. The discovery that synthetic chemicals were harming Earth's ozone layer served as a wake-up call, illustrating how human influences can ultimately threaten long-term health and survival.

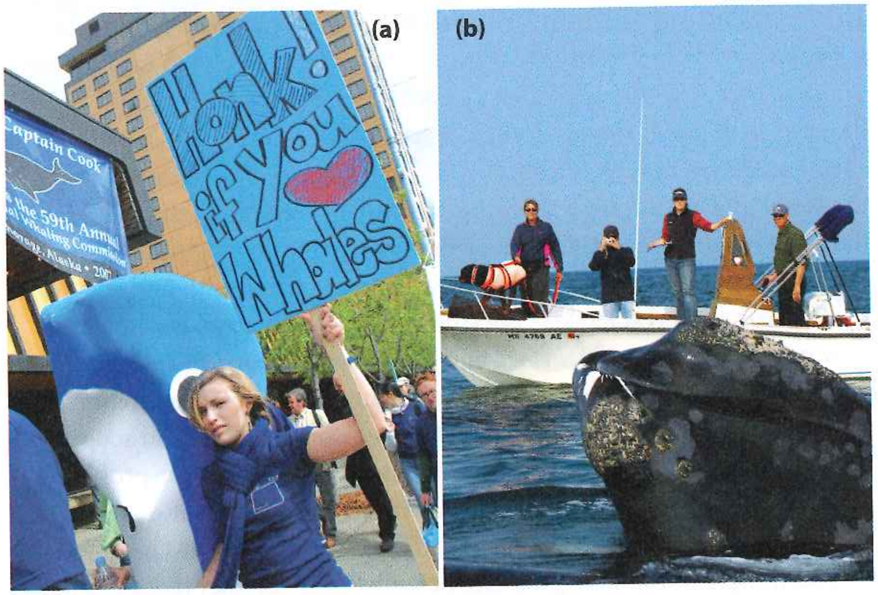
**Environmental science** is the study of how the natural world works, how our environment affects us, and how we affect our environment. Understanding interactions between humans and the environment is the first step toward solving environmental problems. The size and scope of these problems can seem overwhelming. However, with these problems also come countless opportunities for devising creative solutions. In the case of ozone depletion, a very real and effective solution has been found to a seemingly impossible problem. Scientists now predict that within fifty years, ozone depletion will be reversed and the ozone hole will be gone.

Environmental scientists study issues that are important to our world and its future. Right now, global conditions are changing quickly, but so is our knowledge and understanding of the natural world. With such large challenges and opportunities, this particular moment in history is a very exciting time to be studying environmental science.

✓ Reading Checkpoint *Why do people need the natural world?*

**FIGURE 1 Humans in the Environment** For better or worse, people—just like every other species—affect the environment. Unlike other species, however, our actions have the ability to do great harm, or great good, on a global scale.

**FIGURE 2 Environmentalism or Environmental Science?** Can you tell which is which? **(a)** Environmentalists protest commercial whaling in Anchorage, Alaska, in 2007. **(b)** Environmental scientists from the New England Aquarium, in Boston, Massachusetts, collect data on right whales that will help them understand how the whales live in the wild.




**Environmental Science vs. Environmentalism** Many environmental scientists are motivated by a desire to develop solutions to environmental problems. Studying our interactions with our environment is a complex endeavor that requires expertise from many disciplines, including ecology, earth science, chemistry, biology, economics, political science, and others. Environmental science is thus an *interdisciplinary* field, one that borrows techniques from numerous disciplines and brings research results from these disciplines together.

Although many environmental scientists are interested in solving problems, it would be incorrect to confuse environmental science with environmentalism, or environmental activism. They are *not* the same, as shown in **Figure 2.** Environmental science is the pursuit of knowledge about the workings of the environment and our interactions with it. **Environmentalism** is a social movement dedicated to protecting the natural world—and, by extension, people—from undesirable changes brought about by human actions. Although environmental scientists may study many of the same issues environmentalists care about, they try to maintain an objective approach in their work, avoiding bias whenever possible. *Bias* is a preference or viewpoint that is personal, not scientific. Attempting to remain free from bias, open to whatever conclusions the data demand, is a hallmark of the effective scientist.

## Population Up, Resources Down

**In the last several hundred years, both human population and resource consumption have increased dramatically.**

Inhabitants of an island must cope with limited materials, whether food, water, or other supplies. On our island Earth, human beings, like all living things, ultimately face environmental constraints. Specifically, there are limits to many of our **natural resources,** materials, and energy sources found in nature, that humans need to survive.


**FIGURE 3 Natural Resources** Natural resources lie along a continuum from always available and completely renewable to nonrenewable. Completely renewable resources, such as sunlight and wind energy, will always be there for us. Nonrenewable resources, such as oil and coal, exist in limited amounts that could one day be gone. Resources such as timber, soil, and fresh water can be renewed naturally if we are careful not to use them faster than nature can replace them.

**Renewable or Nonrenewable?** Nature "makes" natural resources in different ways and at varied speeds. Some natural resources, such as fruits and grains, are naturally replenished, or renewed, over short periods. These resources are **renewable natural resources.** In contrast, resources such as coal and oil are **nonrenewable natural resources** because they are naturally formed much more slowly than we use them. Once nonrenewable resources are completely depleted, or used up, they are gone forever.

▶ ***A Renewability Continuum*** As shown in **Figure 3,** the renewability of natural resources can be visualized as a continuum. Some renewable resources, such as sunlight, wind, and wave energy, are essentially available at all times. Nonrenewable resources, such as coal and oil, are at the other end of the continuum—for example, it takes millions of years of intense heat and pressure to form oil, but only a few hours to burn through a tank of gasoline.

▶ ***Sustainability*** In between these two extremes are natural resources such as fresh water, timber, and soil. These resources can renew themselves, but it takes some time—not millions of years like nonrenewable resources, but still months, years, or decades. These types of renewable resources may become nonrenewable if they are not used at a sustainable rate. Resource use is considered **sustainable** if it can continue at the same rate into the foreseeable future.

If nonrenewable resources and the "in between" resources like timber and water are used unsustainably, then we can run out of them. For example, lakes and reservoirs can dry up if the freshwater supplies are drained faster than rainfall and snowmelt can refill them. In recent years, consumption of natural resources has increased to unsustainable levels, driven by the growth of the largest human population in history.

Reading Checkpoint *How do we use resources sustainably?*

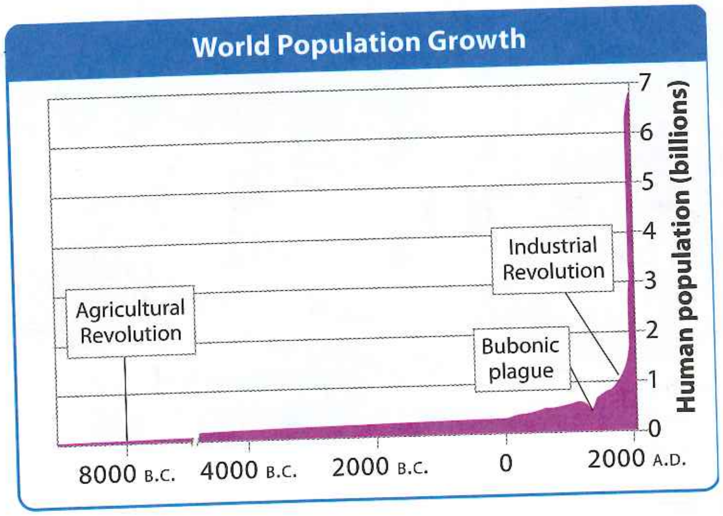



**FIGURE 4 Human Population Growth** For almost all of human history, our population was low and relatively stable. It increased significantly due to two events: the Agricultural Revolution and the Industrial Revolution. The only significant drop in population occurred when 25 million people died of bubonic plague in the 1300s.

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- Graph It An Introduction to Graphing

## Human Population Growth

For nearly all of human history, only a few million people lived on Earth at any one time. Although past populations cannot be calculated precisely, **Figure 4** gives you some idea of just how recently and suddenly our population has grown to about 6.8 *billion* people. We add about 78 million people to the planet each year—that's more than 200,000 people each day. Today, the rate of population growth is slowing, but our absolute numbers continue to increase and shape our interactions with one another and with our environment.

**▶ *The Agricultural Revolution*** The remarkable increases in population size can be attributed to two events in recent human history. The first was the transition from a hunter-gatherer lifestyle to an agricultural way of life. This change began around 10,000 years ago and is known as the *Agricultural Revolution.* As people began to grow crops, raise domestic animals, and live in villages, they found it easier to meet their nutritional needs. As a result, they began to live longer and to produce more children who survived to adulthood.

**▶ *The Industrial Revolution*** About 300 years ago in the early 1700s, the second event, known as the Industrial Revolution began. The *Industrial Revolution* describes the shift from rural life, with animal-powered agriculture, and handmade manufacturing, to an urban society powered by nonrenewable energy sources. These nonrenewable energy resources, such as oil, coal, and natural gas, are known as **fossil fuels.** The Industrial Revolution introduced many improvements. Medical technology advanced, sanitation improved, and agricultural production increased with the use of fossil-fuel-powered equipment and chemical fertilizers. Humans lived longer, had healthier lives, and over time, enjoyed new technologies like telephones, automobiles, and computers.

**FIGURE 5 Less Time, More Power** Technologies developed during the Industrial Revolution have made many tasks easier, but many of them require the use of nonrenewable resources. For example, **(a)** horses used to power plows, like this one from 1903, but **(b)** today gasoline powers plows.

**(a)**

**(b)**

**FIGURE 6 Too Many People, Too Little Space** For residents of Mumbai, India, there simply aren't enough resources to go around. Many people live in extreme poverty within slums. This slum, Dharavi, is the largest in Mumbai. It is estimated to have a population of around 1 million people—the densest population of any city on Earth.

**The Problem With Population Growth** At the outset of the Industrial Revolution in England, population growth was regarded as a good thing. For parents, high birthrates meant more children to support them in old age. For society, it meant a greater pool of labor for factory work. British economist Thomas Malthus had a different opinion, however. Malthus claimed that unless population growth was controlled, the number of people would outgrow the available food supply until starvation, war, or disease arose and reduced the population. Malthus expressed his ideas in *An Essay on the Principle of Population*, published in 1798.

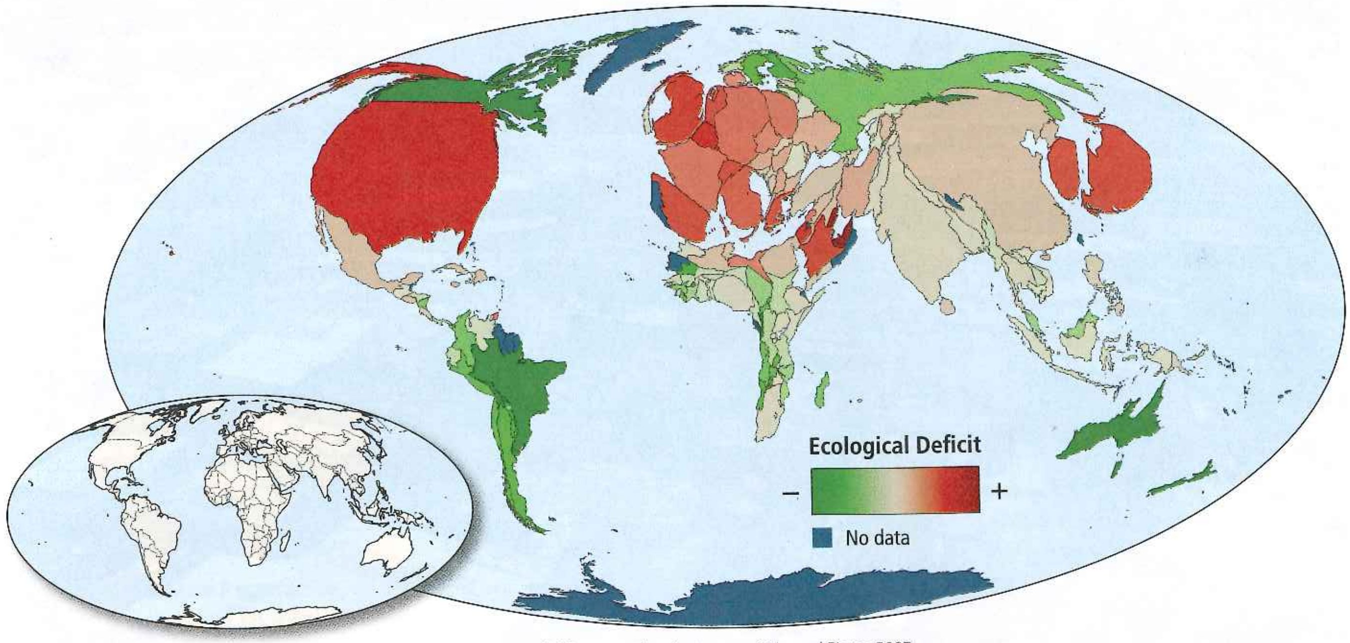
More recently, biologists Paul and Anne Ehrlich of Stanford University have warned that population growth will have disastrous effects on human welfare. In his book *The Population Bomb*, published in 1968, Paul Ehrlich predicted that the rapidly increasing human population would unleash famine and conflict that would consume civilization by the end of the twentieth century. Luckily for us, Ehrlich's forecasts have not materialized on the scale he predicted. Some, such as economist Julian Simon, think this dire prediction unlikely and maintain that technology can stretch our resources. However, concerned scientists warn that a global population crisis is still possible.

**Ecological Footprints** Population growth unquestionably leads to many environmental problems. However, it is not just the number of people on Earth, but how much we consume, that is to blame. Resource consumption can be quantified using the concept of the "ecological footprint," developed in the 1990s by environmental scientists Mathis Wackernagel and William Rees. An **ecological footprint** expresses the environmental effects of an individual or population in terms of the total amount of land and water required: (1) to provide the raw materials the individual or population consumes and (2) to dispose of or recycle the waste the individual or population produces. The ecological footprint concept is most commonly applied to humans, but every organism and natural or synthetic object has a footprint.

your world • your turn •

**WHAT DO YOU THINK?**

What do you think accounts for the variation in sizes of ecological footprints among societies? Do you think that nations with larger footprints should have to reduce their effects on the environment, to leave more resources available for nations with smaller footprints?




Map adapted from 2003 World Consumption Cartogram, © Jerrard Pierce 2007.

**FIGURE 7 Relative Footprints** In this map, nation sizes have been altered to indicate their relative ecological footprints. Nations in red have positive ecological deficits, meaning that they have ecological footprints greater than the global average. These nations appear bloated on the map. In contrast, nations in shades of green have negative deficits and appear shrunken because their ecological footprints are below average.

There is no universal way to calculate an ecological footprint. When looking at the footprint for a potato, for example, one group of researchers may include only the resources needed to grow the potato, while another group of researchers might include the resources needed to cook the potato as well. When comparing footprints, however, it does not matter what approach is used to calculate footprint values as long as it is used consistently. In this way, ecological footprints can be enormously useful as a tool to compare resource use across individuals or populations.

For example, by one set of calculations, the average American has an ecological footprint about 3.5 times that of the global average. Residents of other nations, such as Canada, Chile, and Australia, however, are consuming resources at a rate less than the global average. **Figure 7** shows one research group's summary of how footprints compare across the globe.

# Map it

## Comparing Ecological Footprints

The map in **Figure 7** uses data from the Global Footprint Network and *CIA World Factbook* to compare resource consumption in the world's nations. Each nation's shape has been stretched in proportion to its relative ecological footprint size. Color also serves to indicate how a nation compares to the world average.

1. **Interpret Maps** Describe how color is used in the map. What does green indicate? What does red indicate?
2. **Interpret Maps** Use the Internet or an atlas to identify five of the nations shown in the darkest shades of red.
3. **Infer** Use the Internet or other reference material to look up the ten nations with the largest gross national product (GNP), a measure of a nation's wealth. How does the wealth of a nation relate to its relative ecological footprint?

**The Tragedy of the Commons** What will happen if we use resources globally at an unsustainable rate? Increased resource use can cause what Garrett Hardin of the University of California at Santa Barbara called a *tragedy of the commons.* According to Hardin, unless resources are regulated, we will eventually be left with nothing.

▶ ***The Original "Commons"*** Hardin bases his argument on a scenario described in an 1833 English pamphlet describing public pastures, or "commons," that were open to unregulated community grazing. Hardin argues that the commons model, in which a resource is left unregulated, motivates individuals to increase their resource consumption. If the common is open to public use, why would anyone turn it down? But as more and more people acted in their own self-interest, in this case by adding animals to graze upon the pasture, a problem arose: The animals ate the grass faster than it could regrow. Eventually, no grass was left and all of the animals suffered. Hardin argues that when resources are unregulated, everyone takes what he or she can until the resource is depleted. No *one* takes responsibility, so *every*one eventually loses. As shown in **Figure 8,** tragedies of the commons still occur today.

▶ ***Learning From the Past*** How can the tragedy of the commons be avoided? The most obvious solution, perhaps, is for people sharing a common resource to voluntarily organize, cooperate, and enforce responsible use. Some have argued that this type of management is often impractical, and that private ownership of natural resources is the better option. With resource privatization, a regulating body, such as a government, gives each person a share of the resource that he or she controls instead of leaving resources open to everyone. While this strategy has potential with discrete resources such as minerals, fish, or farmland, privatization does not work as well with continuous, global resources such as the oceans or the ozone layer.

It is important for individuals and governments to consider every kind of solution for the diverse problems facing us today. One way or another, environmental scientists warn, we must address the rate at which resources are consumed—and soon.

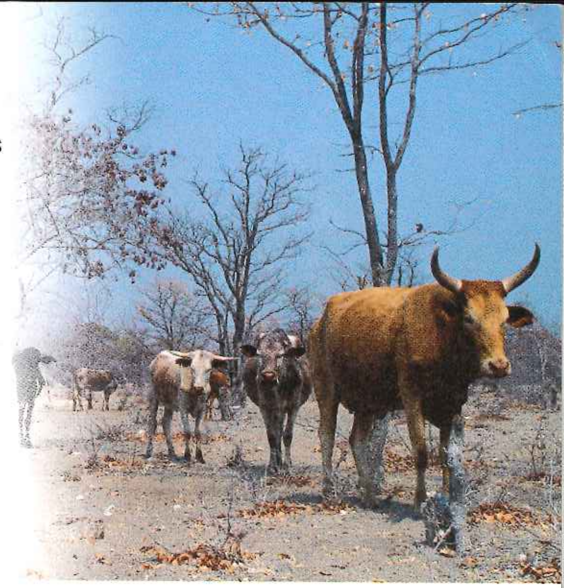


**FIGURE 8 A Modern-Day Tragedy of the Commons** Many parts of southern Africa are experiencing a tragedy of the commons today. Vast forested regions have been cleared to enable farming and ranching. Improper techniques coupled with overuse, however, are causing the land to dry up, making it unsuitable for the very crops and animals it was intended for.

## LESSON 1 Assessment

1. **Apply Concepts** Ecology is the study of how organisms interact with their environments. How is environmental science different from ecology? In what way is ecology part of environmental science? Explain.
2. **Form an Opinion** Do you think it is possible to have the benefits of the Agricultural and Industrial revolutions without the environmental costs? Explain why or why not.
3. **THINK IT *THROUGH*** Suppose you make your living fishing for lobster. You and everyone else are free to set out as many traps as you like. As more and more traps are set up, however, fewer and fewer lobsters are caught. Soon, lobster catches are too small to support your families. A meeting is coming up where you and your fellow lobster fishers will present possible solutions to this problem. What will you propose to combat this tragedy of the commons and restore the fishery?