CHAPTER 1

A Context for Sustainability

Sustainability is a concept that, over the past two decades, has continued to gain traction in a wide range of institutions and sectors, from national to local governments, from agriculture to tourism, and from manufacturing to construction. Domestically and internationally, sustainability is employed as a key criterion in governmental and business decisions, in consumer choices, and in individual lifestyles. As a concept and practice, sustainability is invoked to address issues as diverse as energy production, building design, waste disposal, urban planning, social welfare, and local and national economies. Universities and schools are applying sustainability to guide changes to their campuses, curriculum, governance, investments, procurement policies, and relationships to their local communities. In short, sustainability is a framework upon which increasing numbers of individuals and organizations ground their decisions and policies. In this chapter, we take a closer look at the concept of sustainability and the context in which it has developed.

THE RATIONALE FOR SUSTAINABILITY

There are at least 70 documented definitions of *sustainable development* or its sister term *sustainability*. Our goal here is neither to list all the contenders nor to add to their numbers. Rather, we provide a sense of the basic principles of sustainability, first through a series of hypothetical scenarios and second through a brief explanation of how the concept was developed.

Sustainability Interlude

At its most basic, the concept of sustainability is relatively straightforward. In our first scenario, our hero—call him Lucky—has been given a trust fund of one million dollars that receives 10 percent interest a year. This gives Lucky an annual income of $100,000 in interest. In order to use this trust fund sustainably, Lucky must take out no more than $100,000 from the fund each year. If he does that, then the fund will never diminish, and the original million dollars will continuously produce income for Lucky and his descendents. Thus, we have identified the essence of sustainability: using a resource no faster than the resource can replenish itself.

For our second scenario, suppose that the fund is no longer something as static

BOX 1.1 **Sustainability Is Being Adopted by a Growing Number and Variety of Organizations**

One can see increased focus on sustainability in political and corporate contexts. Several countries have articulated policies centered on sustainability, using it as a framework on which to base integrated strategies covering the environment, the economy, and quality of life. For example, the United Kingdom embraces sustainability as part of its national policy as articulated in "Securing the Future—The UK Sustainable Development Strategy." Similarly the European Union Sustainable Development Strategy describes the EU's approach to sustainable development and the seven key challenges facing its implementation.

A significant number of Fortune 500 corporations, including Nike, Coca-Cola, Dell Computer, and Starbucks Coffee are embracing sustainability as a strategy in the form of corporate social responsibility (CSR). Sustainability is a framework for ecological, economic, and social policies and programs that continues to grow in importance and is finding application in an ever wider range of circumstances. For example, the highly successful green building movement started by the U.S. Green Building Council in the United States is based on the concept of sustainability, providing a useful template for implementation in other sectors.

and homogenous as a pile of cash. Instead, it is a mixture of resources each with different and varying growth rates, and those growth rates prove very difficult to predict. Some years the interest could be well over $100,000. Other years it could be much less. In this case, Lucky must watch the fund closely to be able to respond to any unforeseen changes. The added complexity of the fund makes the prospect of withdrawing beyond sustainable levels more likely when the needs for these resources are great.

For our third scenario, suppose a much larger fund was left to Lucky and seven billion of his closest relatives and friends—call them collectively the Global Population. In this situation, responding to changes in the growth rates of the fund's resources becomes much more difficult, as communication between all the recipients and coordination of activity is well nigh impossible. In turn, not everyone will agree about which of those resources or benefits are important or about who has a claim to them. Under such circumstances sustaining the original capital in the fund and receiving a fair share of the interest for each of the seven billion participants is a mighty challenge.

The concept of sustainability itself is fairly straightforward. Achieving sustainability in the real world presents a daunting and complex challenge.

A Response to a Crisis

The concept of sustainability has its roots in what might be called "the crisis of development," that is, the failure since World War II of international development schemes intended to improve the lot of impoverished peoples around the world. The proportion of those living in abject poverty has remained relatively steady over the past 60 years, around 1 in 5 people. The poor continue to live on the edge of survival, with shortened lifespan, abominable living conditions, malnutrition, disease, and little prospect for a better future. Often they live in countries crushed by the burden of debt, with poor infrastructure, almost no educational system, the lack of a functioning justice system, and in the shadow of omnipresent violence. Simultaneously the world is facing environmental crises and resource shortages that compound the problem for the world's poorest and place stress on even the wealthier nations as energy prices rise, climate patterns shift, and the Earth's store of biodiversity dwindles.

In 1983 the United Nations convened the World Commission on Environment and Development to address these problems. This Commission (later called the Brundtland Commission after its chair, Norwegian Prime Minister Gro Harlem Brundtland) set about the task of developing ways to address the deterioration of natural resources and the decrease of the quality of life on a global scale. In its 1987 report, the Brundtland Commission described this problem as stemming from a rapid growth in human population and consumption and a concomitant decline in the capacity of the earth's natural systems to meet human needs (see Figure 1.1).

After describing the problem, the Brundtland Commission identified two main imperatives needed to correct this imbalance. First, the basic needs of all human beings must be met and poverty eliminated. Second, there must be limits placed on development in general because nature is finite. The commission also provided a definition for sustainable development that is still widely cited today: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."[1]

The Brundtland definition provides a new vision of development—optimistic in tone but laced with challenges and contradictions. It suggests that we have a moral responsibility to consider the welfare of both present and future inhabitants of our planet—a serious task indeed. It would mean that wealthier, more technologically sophisticated societies would have to contribute through a wide range of assistance programs to help poorer nations develop the capability to provide the basic needs of their population. However, we cannot use up the world's resources in the effort. Future generations have to be considered, as well.

Most definitions of sustainability propose that the welfare of present and future generations can be achieved only by balancing environmental protection and restoration with a healthy economy and social justice. The following section briefly describes some of the issues that are forcing a rethinking of conventional approaches to policy, production, and consumption with this balance in mind.

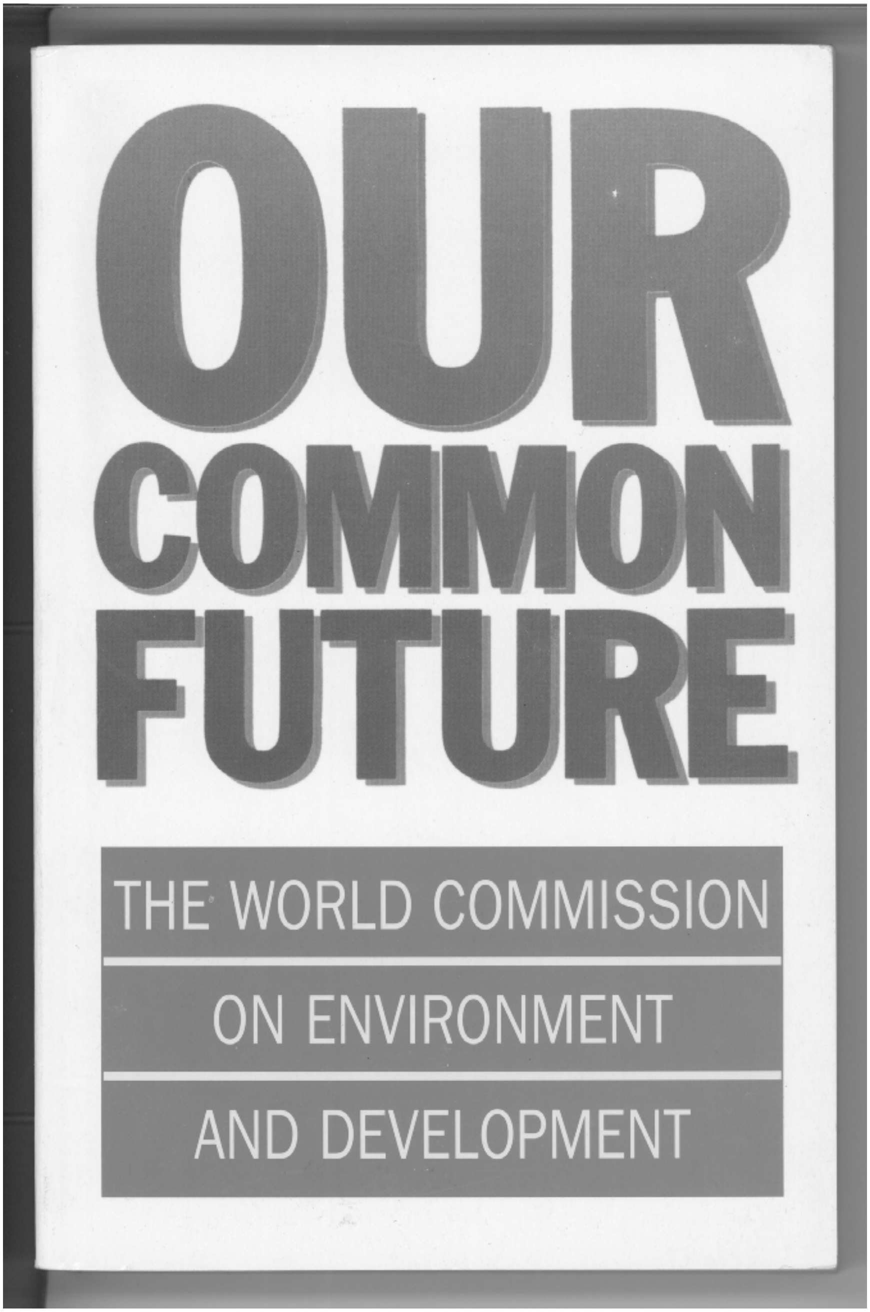

FIGURE 1.1 The report of the Brundtland Commission was published in 1987 with the title *Our Common Future*, and it was responsible for popularizing the sustainability concept.

BOX 1.2 Some Additional Definitions of Sustainability

Although the Brundtland definition of sustainability is the one most often cited, there are a wide variety of other variants, some short and some long, A few of these are listed here to give a flavor of the different points of view of its meaning.

> "A transition to sustainability involves moving from linear to cyclical processes and technologies. The only processes we can rely on indefinitely are cyclical; all linear processes must eventually come to an end."
>
> Dr. Karl Henrik-Robert, MD, founder of The Natural Step, Sweden

> "Actions are sustainable if:
>
> There is a balance between resources used and resources regenerated.
>
> Resources are as clean or cleaner at end use as at beginning.
>
> The viability, integrity, and diversity of natural systems are restored and maintained.
>
> They lead to enhanced local and regional self-reliance.
>
> They help create and maintain community and a culture of place.
>
> Each generation preserves the legacies of future generations."
>
> David McCloskey, Professor of Sociology, Seattle University

"Clean air, clean water, safety in city parks, low-income housing, education, child care, welfare, medical care, unemployment (insurance), transportation, recreation/cultural centers, open space, wetlands . . ."

Hazel Wolf, Seattle Audubon Society

"Leave the world better than you found it, take no more than you need, try not to harm life or the environment, make amends if you do."

Paul Hawken, *The Ecology of Commerce*

"Sustainable development is a 'metafix' that will unite everybody from the profit-minded industrialist and risk-minimising subsistence farmer to the equity-seeking social worker, the pollution-concerned or wildlife-loving First Worlder, the growth-maximising policy maker, the goal-oriented bureaucrat and, therefore, the vote-counting politician."

Sharachchandra Lélé

CONTEMPORARY CHALLENGES

Numerous books and articles have been devoted to each of the challenges covered in this section. The content provided here is a brief overview of each of the issues discussed. We encourage the interested reader to review the notes and references for further reading suggestions. However, the information provided here should be sufficient to understand the discussion and examples in the later chapters. Many of these examples appear to be primarily about the environment. However, approaching these problems in the context of sustainability requires looking at the social and economic impacts of any attempts to address them.

Population and Consumption

In recent decades, global population has grown at an astonishing rate. The world's population doubled in about 44 years, from 3.4 billion in 1965 to 6.8 billion in 2009, and is projected to reach 9.4 billion by 2050.[2] Much has been said about the role of population growth as the cause of many global problems (see Figures 1.2 and 1.3). The resources required to feed, clothe, and house the earth's still rapidly growing human population are enormous. To make matters more complicated, per capita consumption has also been growing even faster than population, so that even if population growth slows, each generation of human beings uses more resources than the last.

In general, developing countries tend to have higher population growth, while industrialized countries tend to have higher per capita consumption. However, per capita consumption in developing countries, especially India and China, has been climbing in the past few decades. The higher level of consumption not only diminishes global natural resources but also increases waste production and pollution. Indeed, the world's wealthiest countries have less than 20 percent of the world's population, yet contribute roughly 40 percent of global carbon emissions and are responsible for more than 60 percent of the total carbon dioxide that fossil fuel combustion has added to the atmosphere since the Industrial Revolution began. To pursue sustainability, the so-called "twin horns of the dilemma," population and consumption, must both be addressed.

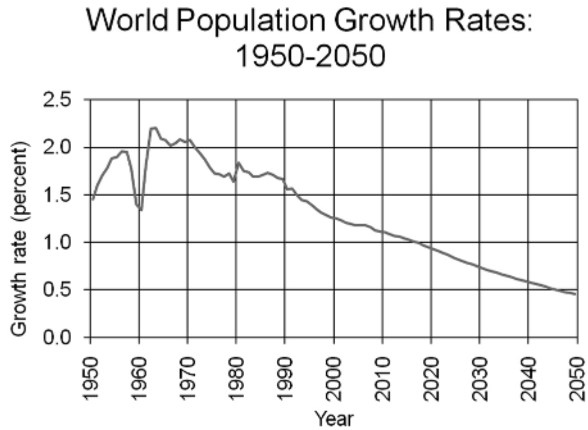

FIGURE 1.3 If there is any good news about population growth, it is that the rate of growth is decreasing, from over 2.0 percent in 1970 to about 1.1 percent at present. Projections are that the rate of growth will continue to fall to under 0.5 percent in 2050. *(Source: U.S. Census Bureau, International Data Base, June 2010 Update)*

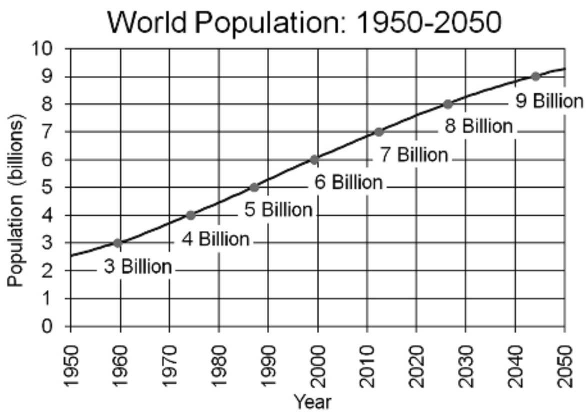

FIGURE 1.2 World population in 2011 is about 7 billion, increasing by about 75 million people each year. *(Source: U.S. Census Bureau, International Data Base, June 2010 Update)*

Climate Change

In 1988, the World Meteorological Organization (WMO) and the United Nations (UN) established the Intergovernmental Panel on

BOX 1.3 The Challenge of Decreasing Population Growth: Thailand

In the 1970s Thailand had one of the highest rates of population growth in the world—roughly twice the global average. Understanding the strain that this rate of growth would put on national resources, the government in coordination with the nongovernmental organization the Population and Community Development Association (PDA) began a provocative and innovative campaign to encourage its citizens to adopt contraceptives. One challenge was making the technology—including condoms, oral contraceptives, and injectable contraceptives—available to the population. This challenge was addressed with government financing to make these contraceptives available for free.

The larger challenge, however, was getting the people to use these technologies. Thai citizens were reluctant to talk openly about matters regarding sex. These inhibitions proved to be barriers to education about—and adoption of—contraceptives. The response to this challenge was an aggressive social marketing campaign led by economist Mechai Viravaidya, who has come to be known as Mr. Contraception. Viravaidya explained, "I wanted to remove the taboo, take birth control out of the realm of the secretive and make it fun" (Sexes 1981). To that end, the government and the PDA developed a public awareness campaign that included balloon-blowing contests in which public officials would inflate and pop condoms, a distribution program in which police would distribute condoms during traffic jams (which Viravaidya called "Cops and Rubbers"), and a contraceptive-themed chain of restaurants used to finance family-planning services. In addition, family-planning services were closely linked to economic development programs to emphasize the connection between family planning and economic welfare.

The program has been quite successful, reducing Thailand's growth rate to less than a quarter of its peak rate in the 1970s. In addition, the program has been credited for greatly reducing the spread of HIV/AIDS. In 2007, the PDA received a Gates Award from the Bill and Melinda Gates Foundation in recognition of its accomplishments in the area of family planning and HIV/AIDS reduction. The methods were unorthodox, but Thailand's family planning program has become an internationally admired example of how public awareness campaigns can be used to address the challenges of sustainability. We will discuss these ideas in greater detail in Chapters 9 and 10.

Climate Change (IPCC) to assess the scientific, technical, and socioeconomic information relevant to climate change. The Fourth Assessment Report of the IPCC, published in 2007, concludes that the globally averaged surface temperatures have increased by 0.3 ± 0.1°C (0.6 ± 0.2°F) over the twentieth century. The globally averaged surface air temperature is projected by models to warm 0.8 to 3.2°C (1.4° to 5.8°F) by 2100.[3]

At first glance, these temperatures may not seem like much, but they would result in major environmental and social changes. Sea level rise is perhaps the most discussed with models projecting 0.30 to 2.9 feet (0.09 to 0.88 meters) increase by 2100, which would put low-lying coastal areas, such as the Mississippi River delta, most coastal cities, and many island nations at risk. Many cities and nations (e.g., The Netherlands) already devote considerable resources to flood control. Sea level rise exacerbates this problem. The temperature shift would also change regional climactic patterns.

IPCC projections indicate that the warming would vary by region and be accompanied by both increases and decreases in precipitation. Ecologically, such changes would place added stress on many of the world's most highly valued ecosystems (e.g., coral reefs). In a social and economic context, even slight temperature increases would mean a shift and even decreases in agricultural production (see Figure 1.4). No doubt some of those changes would be positive, such as longer growing seasons in northern regions. However, traditionally fertile regions may become too hot or too dry to continue to support agriculture. Adjusting an agricultural system in response to these climactic shifts would be a major undertaking. As ecosystems change, insect populations will shift as well. Some projections suggest that mosquito-borne diseases will become problems in many new areas of the world.

Changes in the Earth's climate are the rule rather than the exception, and there is ample evidence that, over the past several million years, there have been significant shifts in the Earth's average annual temperature. Such a historical perspective can perhaps provide some comfort. On a geological scale, atmospheric greenhouse gases are likely to go back to pre-industrial levels over the next several million years. However, human beings do not live at a geological scale, and the potential for climate change has profound implications for every aspect of human activity on the planet. Shifting temperatures, diminished agricultural output, more violent storms, rising sea levels, and melting glaciers will displace people, affect food supplies, reduce biodiversity, and greatly alter the quality of life.

Nonrenewable Resource Depletion

Evidence to date seems to indicate that we have maximized our ability to extract oil and

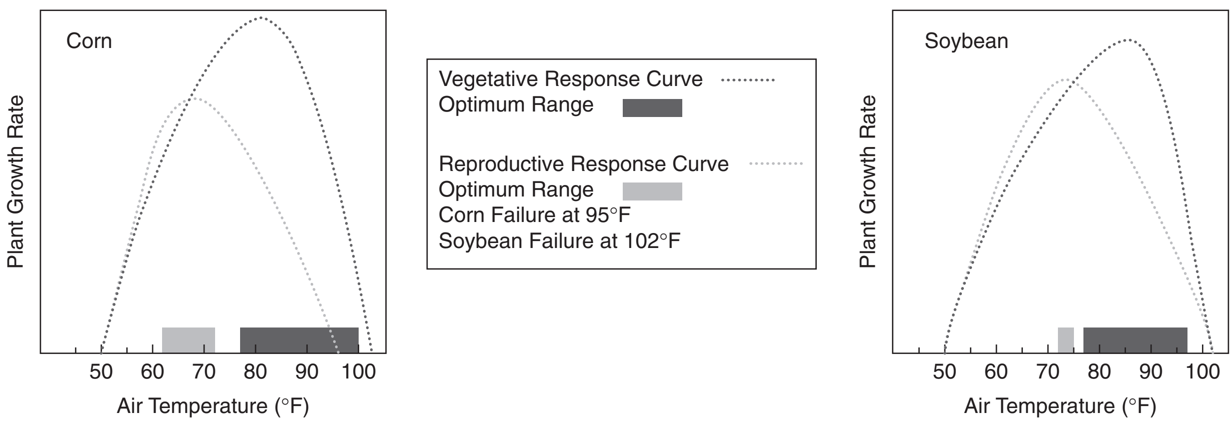

FIGURE 1.4 Rising temperatures have the potential to dramatically affect food production. As indicated in this graphic, growth of corn and soybeans drops off with higher temperatures and reproduction ceases at temperatures above 95°F for corn and above 102°F for soybeans. *(Source: U.S. Department of Agriculture)*

that we are in an era of probably far higher prices for oil-based products, among them gasoline, diesel, jet fuel, and oil-based polymers. A similar scenario is playing out with other key nonrenewable resources, most notably metals. Researchers Robert Gordon, M. Bertram, and Thomas Gradel suggest that the supply of copper, zinc, and other metals—even if recycled—may soon fail to meet the needs of the global population.[4] In other words, even the full extraction of metals from the Earth's crust and extensive recycling programs may not meet future demand if all countries try and attain the same standard of living enjoyed in developed nations.

Gordon and colleagues found that all of the copper in ore, plus all of the copper currently in use, would be required to bring the world to the level of the developed nations for power transmission, construction, and other services and products that depend on copper. Globally, the researchers estimate that 26 percent of extractable copper in the Earth's crust is now lost in nonrecycled wastes, while lost zinc is estimated at 19 percent. While copper and zinc are not at risk of depletion in the immediate future, the researchers believe scarce metals, such as platinum, are at risk of depletion in this century because there is currently no suitable substitute for their use in devices such as catalytic converters and hydrogen fuel cells. Further, because the rate of use for metals continues to rise, even the more plentiful metals may face similar depletion risks in the not too distant future. While there is a renewed emphasis on recycling and efficiency, such measures will only slow down the rate of depletion.[5]

Loss of Biodiversity

Biodiversity can be measured on several scales. For example, ecologists talk about a diversity of habitats (e.g., wetlands, hardwood forests), a diversity of species, and the genetic diversity within one population. Thus, biodiversity expresses the range and variety of life on the planet, considering the relative abundance of ecosystems, species, and genes. Human diversity includes cultures and languages as well. These diverse ecosystems and species provide numerous services and resources, such as protection and formation of water and soil resources; nutrient storage and cycling, pollution breakdown and absorption, food, medicinal resources, wood products, aquatic habitat, and undoubtedly many undiscovered applications.[6] Thus, one might view biodiversity as a stock of potential solutions to problems—past, present, and those not yet encountered or even predicted. From this view, preserving biodiversity has a high priority. Once lost, species cannot be replaced by human technology, and potential sources of new foods, medicines, and other technologies may be forever forfeited.

Most of the time when people talk about loss of biodiversity, they mean loss of species. Species loss occurs primarily because of habitat loss or degradation, as humans burn down, plough up, build upon, pave over, or pollute massive acreages of forests, scrublands, grasslands, wetlands, and coral reefs. Over half the world's wetlands and original tropical and temperate forests are already gone. Rainforests, which support 60 percent of the world's species, are disappearing at a rate of 15 million hectares per year.[7] Of course any harvesting of resources for consumption involves changing the original ecosystems. Resource managers work to restore or maintain **ecosystem services** and biodiversity, while still utilizing products from these systems. If all species are not retained in the managed system, are there enough? Given the vast number of species, we probably do not even know what we are losing.

Loss of biological diversity is also occurring because of the introduction of exotic (invasive) species, which overtake and outcompete indigenous flora and fauna. Pollution of air, land, and water as well as overfishing, overhunting, and overharvesting are also major problems. Finally, as noted previously, climate change increasingly appears to be playing a significant role in species decline, and its contribution will likely increase precipitously in the near future.

An estimated 1.7 million species have been scientifically documented out of a total estimated number of between 5 million and 100 million species. However, habitat loss and climate change are causing such a rapid extinction of many species that some biologists are predicting the loss of 20 percent of existing species over the next 20 years. Given these trends, some suggest that half of all living mammal and bird species today will be extinct within 300 years. Other studies are even more alarming: potentially half of *all* species may become extinct within the next century.[8] Species extinction on such a massive scale undoubtedly will jeopardize the welfare of future generations, and will severely constrict their opportunities.

Overfishing

The Earth's ocean ecosystems contain the majority of all life found on earth, including 22,000 species of fish and ocean mammals, ranging in size from the 150-ton, 40-meter long blue whale to very small fish that feed on microscopic phytoplankton. Oceans were once thought to hold inexhaustible resources. Historical accounts of the seas' bounty abound. For example in the waters off of Newfoundland, early explorers reported fish populations so large that they could catch them simply by dipping weighted baskets over the side of the ship. Another account from the same period describes the number of cod in those waters as seeming "to equal that of the grains of sand which cover this bank."[9] Despite this richness, the Newfoundland fishery collapsed in the 1990s leading to a fishing moratorium, putting a severe economic strain on the region where the only employment, and much of the food, was related to fishing. The fishery has still not recovered and may never return to enable fishing to return to Newfoundland.

This pattern is not unusual in fisheries. When overharvesting decreases populations of particular fish to a point where further fishing was no longer profitable, new fisheries would be sought.[10] The approach was commercially viable at least in the short term until no more unexploited fisheries could be found. In the 1980s geographical expansion could no longer make up for the loss of productivity in overexploited fisheries.

There is some disagreement regarding the pervasiveness and severity of collapse in commercially important marine species, but there is broad agreement on the tendency for these species to be overexploited.[11] In a report published by the UN Food and Agriculture Organization, scientists reported that 52 percent of fish stocks are fully exploited, meaning that catch rates are at or near the populations' estimated reproductive rate. Another 17 percent are overexploited, meaning that fish are being caught at rates faster than the populations can reproduce. Seven percent are depleted (i.e., no longer able to support fishing industries), and 1 percent are recovering from depletion.[12]

BOX 1.4 Indirect Effects of Overfishing: Jamaica

When a population of fish becomes overfished, the ability of that population to reproduce decreases, which means that the ability for fishers to benefit economically in a future from those species also decreases. The impact of overfishing goes further, however. For example, in Jamaica decades of fishing pressure has resulted in the decrease of a number of herbivorous fishes, which graze on algae growing on corals. These fishes perform the ecological function of keeping the algae levels on coral reefs low. The long-spined sea urchin (*Diadema antillarum*), prominent on most Caribbean reefs in the early 1980s, performed this same function.

With several species performing similar ecological functions, a coral reef is said to be resilient because changes to any one of the grazing species will not significantly change the reef as a whole. In the case of Jamaica, when the numbers of herbivorous fish decreased because of fishing pressure, the long-spined sea urchins were still able to keep the reefs from becoming overcome with algae. However, as the reefs became more and more dependent on grazing from just one species, they also became less resilient. In other words, a change in the long-spined sea urchin population would mean major changes to the reefs. That change happened in 1983 when a disease broke out killing up to 97 percent of the long-spined sea urchins in the Caribbean (Lessios 1988). The reefs lost the only grazer left, and as a result, corals were smothered by algae growth (Hughs 1994).

In this case, fishing pressure caused the reefs to lose resilience, becoming more susceptible to natural disturbances, such as disease. These impacts—combined with others, including hurricanes and increased nutrients from development—resulted in highly degraded ecosystems. It is not difficult to see how such changes can translate into social and economic changes as well. While Jamaica has a rich fishing history, the most significant economic benefit that Jamaica's reefs provide today comes from tourism, which accounts for more than half of Jamaica's gross domestic product. Many of Jamaica's tourists value seeing high-quality reefs through SCUBA, snorkeling, or glass bottom boat rides. As Jamaica's reefs continue to degrade, those tourists are likely to choose different destinations with healthier reefs, resulting in the loss of income for Jamaica.

The example of Jamaica's reefs remains a much studied case of how subtle changes to an ecosystem can decrease resilience, making that system more susceptible to major problems in the future. The importance of resilience, in ecological, social, and economic contexts, is addressed in more detail in Chapter 7.

The methods used by large commercial fishing are destructive in two ways: they result in overfishing and they degrade the ocean bottom. While overfishing reduces fish numbers directly, the damage done by bottom trawling can destroy habitat, decreasing a fish population's capacity to recover. In addition, declines in specific species of an ecosystem can cause widespread changes in the entire system. Box 1.4 illustrates how these changes can ripple through an ecosystem and affect social and economic systems as well. Other stresses on marine systems, such as increased pollution and climate change, can further decrease an ecosystem's ability to persist in the face of increased fishing pressure.

Eutrophication

One of the most serious forms of pollution affecting waterways and marine systems is the overenrichment of water bodies with nutrients from agricultural and landscape fertilizer, urban runoff, sewage discharge, and eroded stream banks. Nutrient oversupply fosters algae growth, or algae blooms, which block sunlight and cause submerged vegetation to die. This ecological response to the overabundance of nutrients is called eutrophication. Decomposing algae further absorb dissolved oxygen, depriving aquatic species such as fish and crabs. Eventually, algal decomposition in a completely oxygenless, or anoxic, water body can release toxic hydrogen sulphide, poisoning organisms and making the lake or seabed lifeless.

Eutrophication has led to the degradation of numerous waterways around the world. Perhaps the most famous example is the "dead zone" in the Gulf of Mexico at the mouth of the Mississippi River. Flowing for more than 2,000 miles through the eastern United States, the Mississippi River picks up sediment, fertilizer, and sewage from the agricultural heart of America. When those nutrients reach the Gulf of Mexico, the process of algal growth and decomposition creates an area of almost 6,000 square miles—an area about the size of Connecticut—in which oxygen levels are too low to support most animals (see Figure 1.5).

The reversal of eutrophication in the Black Sea provides a hopeful example. In a situation not unlike the Gulf of Mexico dead zone, the Danube River flows through 11 countries,

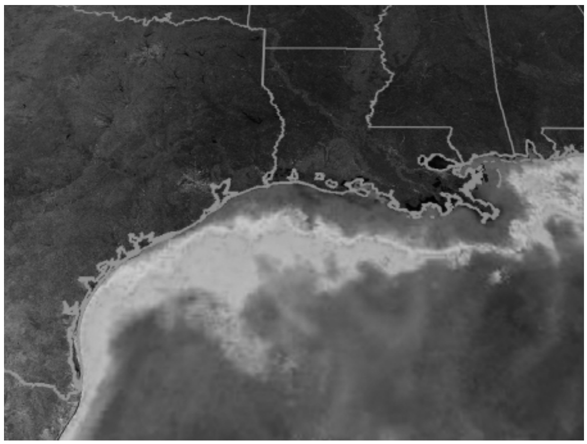

FIGURE 1.5 Nutrients from farming and sewage are transported down the Mississippi water shed to the Gulf of Mexico, resulting in eutrophication and the creation of an enormous dead zone, with very low oxygen levels and which is very inhospitable to life. As shown in this satellite image, the dead zone stretches from the southernmost coastal region of Texas as far east as Florida's Gulf Coast *(Source: National Oceanic and Atmospheric Administration)*

carrying a high level of nutrients from agricultural and industrial waste and urban runoff into the Black Sea. Nutrient levels from the Danube increased dramatically from the 1960s to the 1980s largely because of the adoption of industrial farming techniques involving heavy use of fertilizer. The resulting eutrophication created the largest dead zone in the world. However, in 1989 the collapse of the communist regimes in Eastern Europe meant that many of the farmers on the Danube could no longer afford to purchase such large quantities of fertilizer. As a result, the nutrient load coming from the Danube decreased, and within six years the dead zone itself began to decrease. Recovery remains gradual, but it provides researchers with cautious hope regarding the ability to dead zones to become biologically viable again.[13]

Desertification and Acidification

In arid and semiarid regions, land degradation can result in the destruction of natural vegetative cover, which promotes desert formation—a process called desertification. As a result of this process, soil fertility decreases, putting strain on ecosystems as well as agricultural production. Loss of vegetation may reduce an area's ability to absorb water, resulting in flooding or the siltation of water supplies in nearby areas. The United Nations Convention to Combat Desertification, formed in 1996 and ratified by 179 countries, reports that over 250 million people are directly affected by desertification.[14] Furthermore, drylands susceptible to desertification cover 40 percent of the Earth's surface, putting at risk a further 1.1 billion people in more than 100 countries dependent on these lands for survival. For example, China, with a rapidly growing population and economy, loses about 300,000 acres of arable land each year to drifting sand dunes.

Acidification represents another form of degradation. In this process, air pollution in the form of ammonia, sulphur dioxide, and nitrogen oxides, mainly released into the atmosphere by burning fossil fuels, is converted into acids. The resulting acid rain is well known for its damage to forests and lakes. The acidity of polluted surface and groundwater dissolves minerals in soil and rinses them away. This reduces the amount of nutrients available to vegetation. In addition, acid rain can release substances in the soil that are toxic to vegetation. The decreased nutrients and increased toxics can result in slowed growth or death. Many species of animals, fish, and other aquatic animal and plant life are sensitive to water acidity. The toxic substances released by the acid rain also flow into nearby water bodies and can harm microorganisms and affect the food chain.

As with eutrophication, acid rain is often produced in an area different from the one it affects. Therefore, reducing the effect of acidification often requires a regional approach. Europe experienced a significant decrease in acid rain in the 1990s as a result of European directives that forced the installation of desulphurization systems and discouraged the use of coal as a fossil fuel. Nonetheless, a 1999 survey of forests in Europe found that about 25 percent of all trees had been damaged, largely because of the effects of acidification. As you will see in Chapter 6, the United States has also taken great measures to decrease acidification.

Poverty

Poverty describes the absolute or relative lack of basic goods and services. While poverty is a very broad and variable term, it is helpful as a starting point for discussion of the human social and economic needs that are part of our definition of sustainability. In particular, we find useful the concept of "*absolute* poverty," which is "a condition characterized by severe deprivation of basic human needs, including food, safe drinking water, sanitation facilities, health, shelter, education, and information."[15] Absolute poverty can be defined as the absence of any two of the following eight basic needs:[16]

- *Food*: Body Mass Index must be above 16.
- *Safe drinking water*: Water must not come solely from rivers and ponds, and must be available nearby (less than a 15-minute walk each way).
- *Sanitation facilities*: Toilets or latrines must be accessible in or near the home.
- *Health*: Treatment must be received for serious illnesses and pregnancy.
- *Shelter*: Homes must have fewer than four people living in each room. Floors must not be made of dirt, mud, or clay.
- *Education*: Everyone must attend school or otherwise learn to read.
- *Information*: Everyone must have access to newspapers, radios, televisions, computers, or telephones at home.
- *Access to services*: Access to typical services such as education, health, legal, social, and financial (credit) services.

For the purpose of global aggregation and comparison, the World Bank defines absolute poverty as an income of less than $1.25 per day. Poverty estimates released in August 2008 showed that about 1.4 billion people in the developing world were living on less than $1.25 a day in 2005, down from 1.9 billion in 1981.[17] This amounts to a reduction of absolute poverty from 1 in 2 people in 1981 to 1 in 4 people in 2005.[18] This is significant progress. The challenge is to continue with this progress without continuing to degrade ecosystems.

Overall poverty goes beyond absolute poverty to include social discrimination and lack of participation in decision making. This is an important aspect in the context of sustainability. Reducing overall poverty will not simply require more resources reaching those who do not have enough. It will also require adequate political systems that empower people to make choices that affect their own lives.

Ecosystem Services and Quality of Life

Ecosystems provide a wide range of goods and services to humankind at no cost. These goods and services would otherwise be technically difficult and costly to replace. They include production of food and potable water, control of climate and disease, support from the major global-geochemical and nutrient cycles, crop pollination, spiritual and recreational benefits, and the maintenance of biodiversity. In a study conducted by Robert Costanza and his colleagues in 1997, the economic value of these services was estimated to be almost double the global Gross Domestic Product.[19] The conversion of forests and habitat by agriculture, extraction, and development, together with human impacts on seas, oceans, lakes, rivers, and other bodies of water causes a reduction in the wide range of services provided by ecosystems.

THE ETHICAL CONTEXT OF SUSTAINABILITY

The directive of the Brundtland Commission to meet "the needs of the present without compromising the ability of future generations to meet their own needs" proposes a novel ethical concept. It frames the rights of both present and future peoples, juxtaposes the rights of future versus present generations, and suggests that everyone's needs should be fulfilled before the wants of some are addressed. This view raises several questions. For example, can future individuals have rights? How is it possible to address the needs of future peoples when the needs of the vast majority of the world's present population are not being met? What exactly are the "needs" that must be met, and how might these be prioritized?

Another lens through which to view the issue of future generations is that our ancestors have greatly benefited us and that we have a similar obligation to the future. The Japanese concept of *On* is close to that of obligation. *On* requires that one make past payment to one's ancestors by giving equally good or better conditions or things to posterity. Future persons may be thought of as proxies for past generations to whom present people owe debts. These debts are repaid by providing as much or more to future generations as our ancestors did for us.[20]

In addition to the positive benefits that must be passed on to future generations, harmful consequences must not be passed on. Many of the present day's technologies are likely to pose ominous threats to future generations: genetic engineering, nanotechnology, chemicals, antibiotics, pesticides, and nuclear reactors and their fuel cycles, to name but a few. The resources we take, the products we make, and the resulting waste streams pose enormous challenges for future generations. Consequently if sustainability suggests an obligation to the well-being of future generations, how to deal with technology development and application must be an issue of great concern.

THE THREE-LEG MODEL OF SUSTAINABILITY

It should be clear by now that sustainability is a broad term encompassing a number of different concepts and goals. While the key to sustainability is integrating all of these concepts and goals, the concepts must first be understood before they can be integrated. To facilitate that process, we have divided them into three sets of interconnected concepts: social, ecological, and economic. Social sustainability generally refers to the consequences of a process to the social fabric of a community. It involves culture, justice, decision-making opportunities, and equity. Ecological sustainability focuses on the health of the ecosystems that support both human and nonhuman life. Economic sustainability focuses on the economic viability of a process, project, enterprise, or community.

Sustainability can be considered on a wide range of scales, from a single development to multinational or global policies. To better understand these three legs, consider a proposed tourism development in a developing country. To assess the development's social sustainability, one would look into the impacts of tourism on the local community. How will the influx of tourists disrupt or enhance local traditions and values? What are the social costs associated with the development, and who will have to bear those costs? Will the wealth generated be distributed so as to foster social justice? Who will run the businesses, and will the community have decision-making power?

To assess the development's ecological sustainability, one would focus on the impacts of the development on the local ecosystem. How will new construction and added visitors affect the quality of the ecosystems that support local life? How will such a development affect nonhuman species in the area? Changes in water, air, noise, lights, soil composition, or migration routes could have direct and local impacts as well as indirect and regional impacts.

To assess the economic sustainability, one would focus on the economic viability and impact of the project. Will the enterprise be profitable in the long term? Will these profits be secured without externalizing costs to local, regional, or global stakeholders? What types of jobs and business opportunities will be created, and what will their long-term impacts be?

For sustainability to be the outcome, these three systems must be balanced. Hence the popular depiction of sustainability as a three-legged stool: to serve its function well, the three legs of the sustainability stool must be roughly of equal length (see Figure 1.6).

The ecological, economic, and social legs of sustainability are easy enough to distinguish in theory. In reality, the social and economic component are fully embedded in Earth's ecological systems and could not exist without a thriving global environment. Therefore, the three-legged stool metaphor is perhaps most useful if it is not viewed in an overly rigid way, but simply as a tool for beginning to understand the vast and complicated topic of sustainability. Its faults notwithstanding, the three-legged stool provides a way of breaking up the concepts that comprise sustainability

FIGURE 1.6 The three-legged stool model is one of the more popular models used for understanding and exploring the concept of sustainability. *(Source: Texas State Energy Conservation Office)*

into understandable—if not mutually exclusive—parts. Therefore, Chapters 4 through 6 of this text are organized according to these three components. Before focusing on the ethical issues relevant to sustainability, however, we will take a closer look at the role of technology in the development of society and the role, or roles, it will likely play in the context of sustainability.

CONCLUSION

Sustainability is a concept and practice that has been applied to guide citizens, organizations, government, and corporations onto a path where both present and future generations have the opportunity for a high quality of life. At its core, sustainability is about ethics. It calls on us not only to consider the condition of those less fortunate than us who share the planet, but also the potential condition of future populations who cannot participate in our decision-making processes.

Clearly we are at a significant fork in the road, with the consequences of climate change and resource depletion on the horizon. Our welfare and the fate of future generations are on the line. Sustainability forces us to think through the consequences of our behavior and act responsibly.

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ENDNOTES

1. The Brundtland Report (1987) was published by the World Council on Economic Development (WCED) under the title *Our Common Future*. The report is named after Gro Harlem Brundtland, then prime minister of Norway and chair of the Brundtland Commission. Four years after its establishment, the Brundtland Commission produced the final report that provided the classic definition of sustainable development.
2. United States Census Bureau, Population Division: www.census.gov/ipc/www/idb/worldpopgraph.php.
3. The Fourth Assessment Report of the IPCC (2007) can be found at www.ipcc.ch.
4. Gordon, Bertram, and Graedel (2006).
5. "Materials Prices Dictate Creative Engineering," (2006).
6. See "Global Environmental Problems: Implications for U.S. Policy," (2003).
7. "Tropical habitats disappearing fast," (2008).
8. Levin and Levin (2002).
9. Roberts (2007).
10. Myers and Worm (2003).
11. See for example, Hutchings (2000), Jackson (2001), Essington et al. (2006), and Worm et al. (2006).
12. FAO (2006).
13. See Mee (2006).

14. The website of the United Nations Convention to Combat Desertification is www.unccd.int.
15. United Nations (1995).
16. Gordon (2005).
17. It was not until 1993 that the World Bank established the absolute poverty level at a certain number of dollars per capita per day, about $1.08 at that time. Extrapolating this back to 1981 would result in absolute poverty of $0.90 per person. As noted in the text, the 2005 rate was $1.25 per day. See Ravallion, Chenm and Sangraula (2008) for more details on the World Bank methodology used for this purpose.
18. Ravallion, Chenm, and Sangraula (2008).
19. Costanza et al. (1997).
20. Shrader-Frechette (1981).