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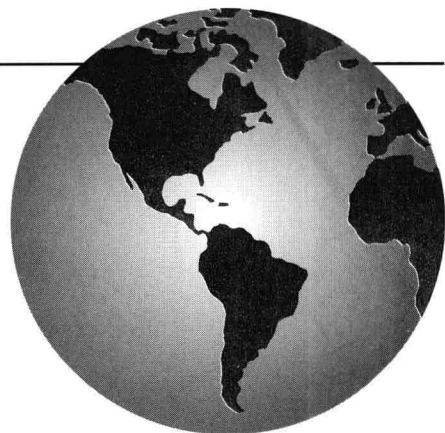
SCIENCE, LAND USE, AND EARTH SYSTEMS



WILLIAM M. MARSH
JOHN M. GROSSA, JR.

ENVIRONMENTAL GEOGRAPHY

SCIENCE, LAND USE,
AND EARTH SYSTEMS



WILLIAM M. MARSH

The University of Michigan—Flint

JOHN GROSSA, JR.

Central Michigan University



JOHN WILEY & SONS, INC.

New York Chichester Brisbane Toronto Singapore

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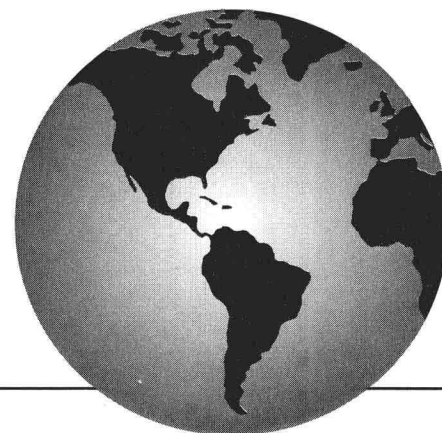
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ISBN 0-471-50396-7

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

PREFACE



No field is more central to the study of human occupation of earth than geography. Modern environmental science, with its focus on land use, pollution, and environmental impact is firmly rooted in the geographic tradition. In fact, without geography's contributions, environmental science would not exist as we know it today. Yet these contributions are not featured in most "environmental" texts available to undergraduate instructors.

So we set ourselves to the task of building an environmental text with geographic perspective, coverage, and presentation style. It draws on the traditional themes of geography including the concept of an integrated planet, the principles of space, scale and distributions, the idea of landscape as the product of human-environment interplay and the perspective of earth as a dynamic planet where geographic knowledge enables us to see our environment, its opportunities, constraints, and risks with the insight of an educated person.

We realized that if the story is different the book should embrace a different design. Accordingly, we devised a new set of graphics that we hope not only help the content but make for a more interesting textbook. The team that worked with us to build these graphics deserves special credit. Keith B. King prepared the computer renditions, Robert G. Chipman fashioned the hand drawings, Laura D. Gotro patiently prepared the screens, and Nina L. Marsh managed and prepared the final art package.

The book is organized into 16 chapters of 20-25 pages each. Although the chapters form a logical sequence, individual chapters provide fairly complete treatments if read

independently. Therefore, reading assignments can be arranged to suit different course organizational schemes. In addition, there is an abundance of supplemental material available. The list is headed by Martin Kaufman's companion book, *A Critical Thinker's Guide to the Environment*, followed by Jack Kinworthy's *Instructor's Manual and Test Bank* and various teaching aids utilizing the book's graphics.

It took several years to build this book and many people contributed to its development through their comment and review: John Adams, Adegoke Ademiluyi, Jim Ashbaugh, Donald Duckson, Edward B. Evenson, Steven Hamburg, Richard Hill-Rowley, Martin Kaufman, Jack Kinworthy, Greg Knight, Nina L. Marsh, Walter Martin, Earnie Montgomery, Henry Moon, Paul Nowak, David O'Keeffe, Marvin Parker, William C. Rense, Randall L. Repic, Antonio Segovia, Roger Sharpe, Colin E. Thorne, Hartmut S. Walter, Steve White, and Robert Yuill.

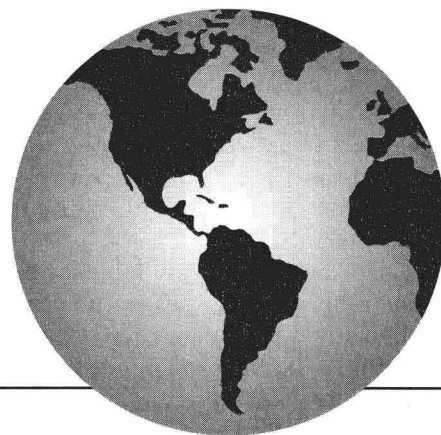
In addition to the graphics team, several people deserve thanks for their production and editorial efforts: Becky Pettengill, Barry Harmon, Frank Lyman, Bonnie Cabot, Laura Ierardi, Mary Ann Price, Lois Bridenstien, Lori Kreiner, and Janice Mogg.

Nina L. Marsh was an invaluable source of information and counsel throughout the project. She and Carol Grossa are due special thanks as our wives for their unfailing support.

W.M.M.
Flint, Michigan

J.G., Jr.
Mt. Pleasant, Michigan

INTRODUCTION



If the space program has given us nothing else, it has given us invaluable perspective on Earth. It has shown that Earth is unique among the nine planets that orbit the sun. Unlike Jupiter, Saturn, Uranus, and Neptune, it has a stable, hard surface that is able to support the weight of oceans, glaciers, and living matter. Unlike Mercury and Venus, it is not blistering hot, scorched dry of all but rock. Unlike Mars, the Earth is insulated by a thick, oxygen-rich atmosphere, with a modest surface temperature and abundant liquid water.

Earth is a glorious planet, unimaginably diverse and constantly changing. Its history is punctuated with dramatic events that have altered the course of environmental development—some advancing life, some setting it back. These events have been driven both by external factors, such as asteroid collisions, and internal ones, such as massive volcanic eruptions and, most recently, the explosion and spread of human population armed with technology.

Humans have a short tenure on earth as a species, and a considerably shorter one as a significant environmental change agent. Earth is at least 4.5 billion years old. Life has been here 3 billion years or more, and advanced terrestrial life, such as vascular plants, has been around for about 500 million years. Humans equipped with agriculture and living in permanent settlements date back only about 12,000 years. The Industrial Revolution and the growth of cities with millions of people are less than 250 years old. Although humans have modified the environment since the origin of agriculture, the types and scales of environmental change we see today—the changes that cause us serious concern—are only one to two centuries old.

Set in the scale of Earth time, humans are a sudden flash, like the great asteroid collision and related climate change 65 million years ago that so dramatically altered the environment that it ended the dinosaurs. Could we be living in the midst of a similarly dramatic event driven by our own species? In 1900 world population was 1.5 bil-

lion people; it is now approaching 6 billion and growing by 1 billion every twelve years. The pace of change is dizzying as development lurches ahead and the planet's environment is retrofitted with human infrastructures. It is an exciting time to be on earth, but it is also a scary time, because we may be caught in the whirlwind of one of earth's great environmental events.

No matter how we look at our place in earth history, some monumental questions loom before us as the twentieth century draws to a close. Are we a species out of control, staged to overrun the planet and consume ourselves out of house and home? Are we unique because of our ability to use technology to solve the survival problem so that our species can ignore the ecological rules governing other species? Are we insightful and wise stewards with a capacity to foresee the perils, make adjustments to curb our growth, and design a sustainable future for ourselves and the earth as a whole? The answers to these questions will likely unfold in your lifetime.

This book is about the earth, its environment, our use, misuse, and abuse of the environment, and where we seem to be headed as a species on the planet. The book opens with an overview of the modern environmental dilemma and the contributing factors. Geographic perspective is important because there are no longer a handful of environmental crises scattered around the world, relatively isolated from one another. Local and regional problems have grown in both magnitude and scale, merged together, and taken on global proportions. America's military commitment to Kuwait for the purpose of protecting world oil supplies readily illustrates the scale of one of the world's principal environmental problems: energy.

Chapter 2 examines the open space remaining in the world, those vast frontier regions such as the deserts and tropical rainforests where human occupation and environmental impact have traditionally been light. Pressure

to use these lands is mounting rapidly and extensive tracts are now being settled and developed. The frontier environments may be the test cases signaling the next phase in the human planetary event. The next two chapters set the ecological framework, examining the earth's systems of materials and energy and then exploring the nature of ecosystems, the building blocks of the biogeographical environment.

Chapters 5, 6, and 7 examine the principal human elements of the global environment: population, agriculture, and energy. No human force is more prominent in the modern environment than our population, and no land use is more widespread and environmentally demanding than agriculture. The number of humans in the world is increasing by more than 90 million persons a year and most of the growth is taking place in the world's poor countries. At this rate, we grow a population equal to that of the United States and Canada combined every three years.

Chapters 8, 9, 10, and 11 explore the earth's air and water systems, including their use, physical modification, and pollution by humans. These two systems are essential to life and are highly susceptible to abuses by human activities, especially where those activities exceed nature's self-renewing capabilities. Chapter 12 addresses hazardous waste, a serious problem related to rising energy

use, increased consumption of manufactured goods, and the introduction of new technologies involving exotic chemical substances. Chapter 13 takes up one of the most valuable but least appreciated components of the environment, soil. There is no secret about where the earth's most favorable soils are located—farmers have already found them, and under twentieth-century farming pressure, most of these soil reserves are declining rapidly.

The push for new land to house people, grow crops, and provide wood and mineral resources has taken a serious toll on the earth's rich reservoir of biological species. The tropical forests, which hold half or more of the earth's species, are being cleared at alarming rates with serious ecological consequences. This is covered in Chapter 14. Chapter 15 reviews the world's open lands and the effort to preserve and manage them as parks, national forests, and other public spaces.

The final chapter comes back to the issues raised in the opening chapter. After a less-than-cheery prognosis, it examines some of the global efforts being made to find an environmentally sustainable system for the planet. The chapter ends with a brief overview of environmental remote sensing surveillance and geographic information systems. These will be absolutely essential if we expect to build effective management programs for the global environment.

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INTRODUCTION

In the 1960s world leaders cited poverty, disease, and malnutrition in less-developed countries as the root problems of the world—with the exception, of course, of nuclear war. They told us these problems could be solved through economic development and health programs. What underdeveloped countries needed, the developed world concluded, was a strong dose of Western know-how. It was a time of technological and economic optimism.

We believed that famine and malnutrition could be solved with new crops and improved agricultural techniques. That diseases could be cured and life extended with new drugs and health practices. And that the quality of life could be improved by economic growth, diversification, and more consumer goods for the world as a whole. The concept of limited resources was not generally considered seriously.

What few leaders understood or were willing to admit was that these problems were really symptoms of a much larger problem—namely, an organism driving toward an imbalance with its environment. For humans, environment is represented directly or indirectly by most of the planet; hence, the problem translates to humans approaching an imbalance with earth. We appear to have reached the threshold of our most critical challenge to survival on the planet.



THE GLOBAL CONTEXT AND SETTING

To look at this issue knowledgeably, we should start with some basic facts about the earth. Earth has a surface area of about 510 million square kilometers (197 million square miles), of which close to 70 percent is water and the remainder is land (Figure 1.1). The vast majority of the water is saltwater. Freshwater is limited to the land masses, and if glaciers and snowfields are excluded, freshwater covers only 1 percent or less of the earth's

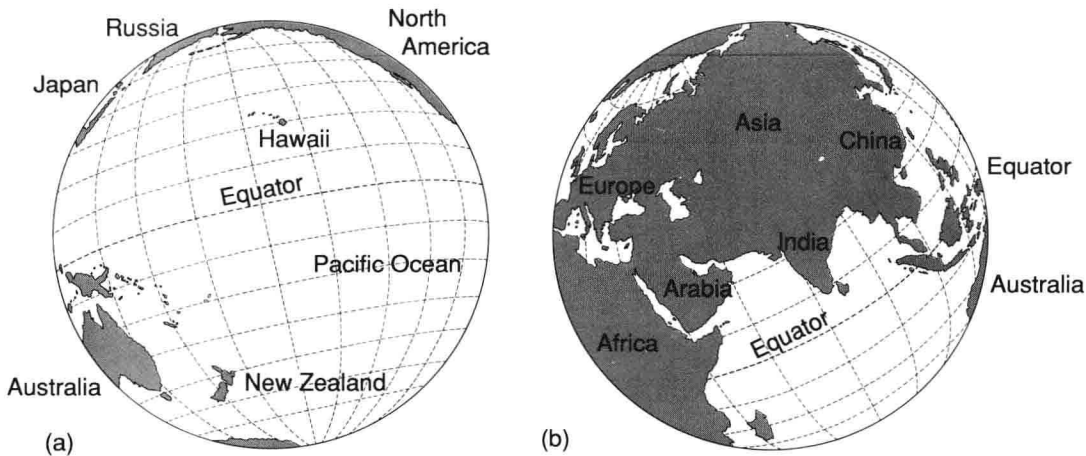


FIGURE 1.1 Two views of earth: (a) the hemisphere of water and (b) the hemisphere of land.

surface. But like so many geographic features of the earth, the distribution of water is changing. In the last several centuries, for example, the area of freshwater has shrunk as land use has obliterated wetlands and filled lakes and harbors. Even the shapes and sizes of the continents and oceans are changing, but over a much longer time frame.

Because of the gradual flow of rock deep within the earth, the earth's outer shell or crust, which contains the continents and the ocean basins, shifts slowly about in a process called **plate tectonics**. Over the past 200 to 300 million years this has led to an uneven distribution of land and water over the earth. The **Northern Hemisphere**, which represents the half of the earth north of the equator, contains roughly twice the land area of the **Southern Hemisphere** (Figure 1.2a). Not only that, but the land is distributed differently in the two hemispheres. In the Northern Hemisphere, most land (Eurasia and North

America) is located in the midlatitudes, whereas most land in the Southern Hemisphere (South America, Australia, and part of Africa) is found in the low latitudes (which helps explain the large area of tropical rainforests in the Southern Hemisphere). The only exception is Antarctica, which is centered on the south pole.

Global Coordinate System

The designation of low, middle, and high latitudes is based on the reference lines drawn across the globe by map makers. There are two sets of lines: **meridians** run north and south; **parallels** run east and west. These lines form a grid network known as the **global coordinate system**. Both parallels and meridians are numbered in degrees. The equator is the zero-degree parallel. Northward and southward from the equator, numbers increase to a maximum of 90 degrees at the north

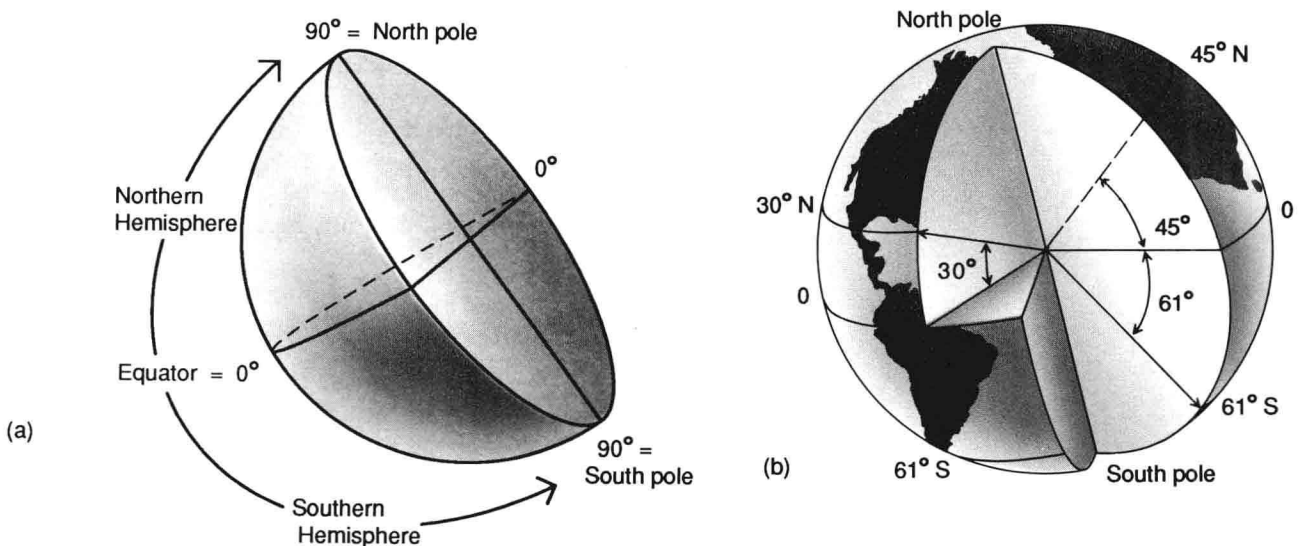


FIGURE 1.2 (a) The Northern and Southern hemispheres; (b) The concept of latitude illustrated by angles north and south of the equator.

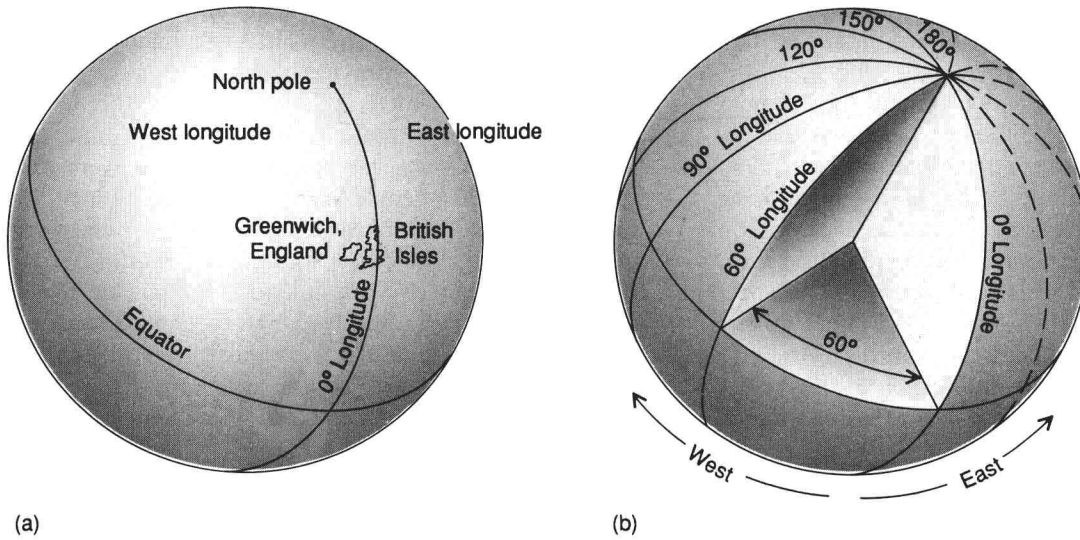


FIGURE 1.3 (a) The concept of east and west longitude represented by (b) degrees east and west of the Prime Meridian at 0° longitude.

and south poles. Locations measured according to the system of parallels are designated as degrees **latitude** north or south of the equator. For example, *45 degrees north latitude* is represented by the parallel halfway between the equator and the north pole in the North Hemisphere (Figure 1.2b).

The system of meridians also begins with a zero-degree line. This line is called the **Prime Meridian** or **Greenwich Meridian** (because it runs through the town of Greenwich, England) (Figure 1.3a). All locations east of this line are designated *east longitude* and those west of this line are designated *west longitude*. The system ends on the opposite side of the earth from the prime meridian at 180 degrees longitude (Figure 1.3b). With this system, a second set of hemispheres can be defined. The **Eastern Hemisphere** includes Europe, Africa, and Asia; the **Western Hemisphere** includes North America, South America and most of the Atlantic and Pacific Oceans.

Zones of Latitude

The earth's bioclimatic environment is arranged roughly into several great belts of latitude. Much of our discussion in the following chapters uses this framework. Three broad zones of latitude can be defined in both hemispheres: the **high latitudes**, which cover the upper 23.5 degrees latitude; the **middle latitudes** between 66.5 degrees and 23.5 degrees latitude; and the **low latitudes**, which lie between 23.5 degrees and the equator. Latitude 23.5 degrees is significant because it marks the highest latitude that receives direct solar radiation—that is, where the sun's rays hit the earth's surface perpendicularly (at a 90-degree angle). In the Northern Hemisphere the parallel at 23.5 degrees is called the **Tropic of Cancer**. In the Southern Hemisphere it is called the **Tropic of Capricorn** (Figure 1.4). Latitude 66.5 degrees marks the **Arctic** and

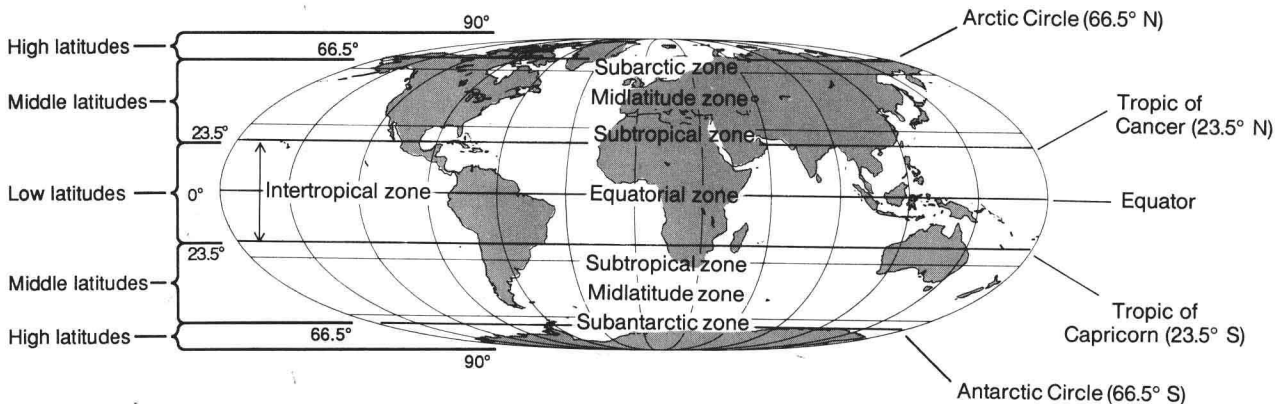


FIGURE 1.4 The subdivision of the earth into zones of latitude. Notice the relatively large amount of land area in the Northern Hemisphere midlatitude zone.

Antarctic circles, above which are the only locations on earth to experience day-long (24 hours) light and day-long dark each year.

Used correctly, the term *tropics* refers to the Tropic of Capricorn and the Tropic of Cancer. It follows that the zone between 23.5 degrees south latitude and 23.5 degrees north latitude should be the **intertropical zone**, and indeed many scientists do follow this convention. However, the term *intertropical* has declined in usage, and today **tropics** or **tropical zone** seems to be the preferred term for this zone. Most of the land area in the tropics is found in South America, Africa, and southern Asia. The **equatorial zone** is the narrow middle belt of the tropics, extending about 10 degrees latitude north and south of the equator (Figure 1.4).

Within the broad belt of the middle latitudes, three additional zones are often designated, although their locations are somewhat arbitrary. Just above the tropics is the **subtropical zone**, which extends from 23.5 to 35 degrees latitude. Much of the American South, the Mediterranean region, Australia, and southern China lie in this zone.

The **midlatitude zone** is the center belt. Its limits are somewhat arbitrary, but 35 to 55 degrees is usually given for it. Very little land in the Southern Hemisphere lies in this zone, whereas large areas of the Northern Hemisphere lie in the midlatitude belt in North America, Europe, and Asia. Beijing, Tokyo, London, Paris, Berlin, Moscow, New York, Philadelphia, Chicago, Montreal, Buenos Aires, and Sydney all lie in this zone.

The **subarctic zone** lies between 55 degrees and the Arctic and Antarctic circles. The bulk of the land in this zone is occupied by Russia, Canada, and the United States (Alaska), and settlements are sparse throughout. Beyond 66.5 degrees north and south are the **arctic** and **antarctic zones**, the uppermost parts of which (generally given as above 75 degrees latitude) are the **polar zones** where populations are exceedingly light or absent over vast tracts (Figure 1.4).

Where People Live

About 90 percent of the world's 5.7 billion people inhabit roughly 30 percent of the earth's land area. The remaining 70 percent of the land is either lightly inhabited or uninhabited. The lightly inhabited areas are occupied mainly by traditional societies engaged in fishing, hunting, gathering, herding, and some crop farming. These societies are found in three principal environments: deserts and grasslands of Asia and Africa; tropical forests of South America, Africa, and Southeast Asia; and the cold lands of North America and Asia. Although these societies have occupied these remote environments in relative harmony with nature for thousands of years, some are now giving way to modern land uses and other lifestyles as their homelands are being probed and exploited by various forms of development.

The bulk of humanity lives in the midlatitude and subtropical zones. In the Northern Hemisphere, the principal zone of human occupation lies between the twentieth and fiftieth parallels, which includes most of the United States, Europe, and Russia as well as Japan, China, and India, and contains nearly 4 billion people. More than half of the world's people live within 100 kilometers (60 miles) of the sea. Nine of the ten largest cities in the world are located on the sea coasts, and the world's most populous countries in terms of population density are coastal nations (for example, the Netherlands, Bangladesh, and Japan). If we add inland waters (lakes, rivers, etc.), the relationship to water is all the more impressive. The Mississippi River, the Great Lakes, the Chang River, the Seine River, the Volga River, and the Nile, for example, are the sites of many large cities including St. Louis, Chicago, Shanghai, Paris, Moscow, Cairo, and the homes of more than a billion people.



POPULATION AND EARTH'S CARRYING CAPACITY

Since the 1960s, when the Peace Corps was created and the United States and the Soviet Union were competing for global influence, the world situation has changed dramatically. One of the most sobering changes is the number of human beings, from about 3 billion in 1965 to about 5.7 billion today. All the major world centers of population have grown and many have spread into new lands. Remarkably, agricultural production has kept pace with population growth. However, between 1965 and 1992, *per capita* agricultural production has increased by only 0.5 percent for the world as a whole, and since 1990, *per capita* agricultural production has declined by about 1 percent. Since 1965 more than 200 million people have died of hunger or hunger-related diseases, and the quality of life, by some estimates, actually declined for 1 to 2 billion people. Today, as many as 1 billion people (18 percent of humanity) are incapable of vigorous work and good health because of malnourishment (Figure 1.5a).

Population Growth

For a variety of reasons, humans are unable to control their numbers. Thus, each day more land and resources are needed, some of which are nonrenewable. The result is denuded soils, demolished rainforests, depleted fuel reserves, depleted aquifers, depleted grasslands, and eradicated plant and animal species. It is no longer radical to say that the human population machine is literally consuming its own habitat. In the extreme it is like a farmer who eats his seeds as a solution to hunger.

It took more than 100,000 years for the human population to reach 2 billion people (in 1930) but only 46 years to raise that number to 4 billion. The current world pop-



(a)



(b)

FIGURE 1.5 The contrasting state of land and life today: (a) African famine victims and (b) a stable agriculture landscape in India.

ulation is increasing by more than 90 million a year. Optimists argue that the planet can support 10–12 billion people, twice the current number. Idealists, such as some religious leaders, think the planet is capable of supporting 40 billion. Pessimists or realists—depending on how you define them—argue that world population has already exceeded a reasonable limit, defined as an environmentally sustainable population.

The more pessimistic of this group argue that we are beyond the point of recovery because the momentum of the population explosion is too great and the planet's resources have already been irreparably damaged. The less pessimistic of this group argue that it might be possible to slow growth and recover the remaining resources, but to achieve a sustainable balance between humans and resources would require a colossal effort with much sacrifice and decades of time.

Carrying Capacity

The number of people the earth can support is called its **carrying capacity**. It is defined by the size of the population that can live in a long-term, **sustained balance** with the environment. This balance assumes a reasonable quality of life and a living environment at local, regional, and global scales that does not degrade over time (Figure 1.5b). It includes not only sustained food production with conservation of soil and water resources, but maintenance of other life forms and environmental features that are not of direct and immediate economic value. It also means living with a capacity to sustain disturbances from nature such as hurricanes and earthquakes, without permanent destruction to life systems.

Is human/earth sustainability possible in our times? Without population control it is very doubtful, even with



FIGURE 1.6 *Consumer habits of the industrial nations are spreading across the world to poor nations with large and rapidly growing populations.*

optimistic improvements in food production and environmental management. It is especially doubtful when we consider that most societies are also striving to increase consumerism. Thus, not only are there more people, but also each person is consuming more goods and services, which in turn demands more resources and creates more waste, that is, pollution (Figure 1.6).

Earth is not an infinite bounty of resources. Through experiments with expanding animal populations in finite ecosystems biologists have shown that population rapidly outgrows resources. This leads to malnutrition, pollution, and social stress. Both environment and organisms decline, resulting ultimately in extermination through massive die-offs. But in animal populations this trend is

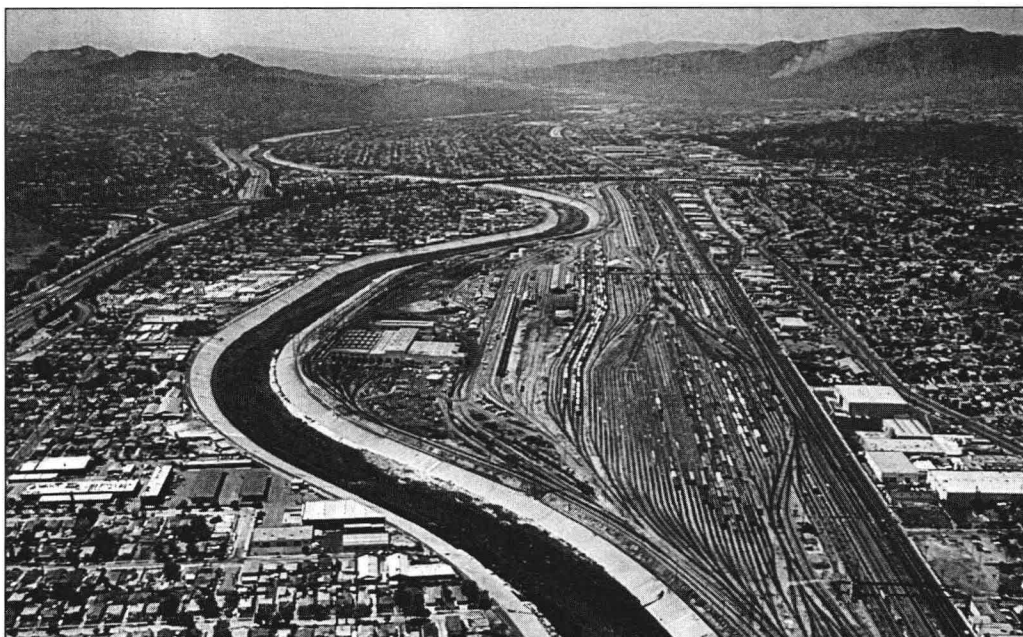


FIGURE 1.7 *Photograph illustrating the industry and associated transportation facilities needed to support a modern consumer economy.*

associated with declining consumption rather than the increasing consumption associated with humans.

In addition, modern consumerism depends on market competition, and competition depends on innovations. Innovation demands technological advancements: new tools, new materials, new techniques—all of which bring to the environment things that it has not seen before. These things—technical processes, machinery, chemicals, and new land uses—are often incongruent with the environment; that is, the environment cannot process them efficiently without damage to ecosystems, water systems, or air systems (Figure 1.7).



THE FOUR ELEMENTS OF THE DILEMMA

Thus, as we consider the tenuous state of the environment, we must highlight four critical factors. First and foremost is **population**, for without massive human populations and the living space, water, energy, and food they demand, problems of the environment would be relatively small or nonexistent. The second is **technology**, represented by all those things of cultural origins—including food production and pesticides, industry and hazardous wastes, expressways and automobiles—that enable us to reach further into the environment in more profound and exotic ways. The third is **consumerism**, the ability of each person to utilize greater and greater shares of resources, including wood, metal, plant fiber, medicines, water, and air itself.

Fourth is **sustainability**, or the ability to build land-use systems that are environmentally enduring and balanced. **Land use** is defined as the human activity that takes place on the land—for example, agriculture, residential, transportation, and industry. **Land-use systems** are interconnected, interdependent sets of land uses such as mining, transportation, and industry. Land uses that deplete resources without provisions for renewal are not sustainable. Much of our agriculture is not sustainable today because we use excessive amounts of energy and cultivation practices and pesticides that damage the soil. Of greatest concern is that soil is being lost to erosion much faster than it is being replaced by nature and constructive farming practices. To make up for lost soil fertility, commercial fertilizer is added in increasing amounts while the soil is pushed toward greater crop yields. This results in a downward spiraling and unsustainable system.



SCOPE OF ENVIRONMENTAL GEOGRAPHY

Environmental geography covers the issues of environmental degradation, quality of the global environment, and the condition of life. It is actually made up of many fields of geography including physical geography, human geography, regional geography, economic geogra-

phy, and others that deal with different parts of the environment, human population, land use, and their interrelations. The scope of environmental geography is shaped by our concern over the condition of the environment and the quality of life for humans and other organisms. At the center of concern are human activities that degrade the environment and reduce its potential to support life. These activities are generally referred to as **environmental impacts** and they tend to fall into two categories: environmental pollution and environmental disturbance.

Environmental Pollution

Pollution is degradation of the environment as a result of contamination of some sort. The contamination may take the form of foreign substances, such as pesticide residues in food chains or bacteria in water systems, or it may take the form of greatly increased levels of naturally occurring substances, such as sediment in streams or plant nutrients in soil. Pollution may be **acute**, as in the case of highly poisonous substances such as chlorine or arsenic being released suddenly into the environment in amounts that seriously damage or kill organisms; or **chronic**, as in the case of less toxic or nontoxic substances like fertilizer residues being released into groundwater at slower rates with less immediately harmful effects. Chronic pollution may, nonetheless, have serious effects because contaminants or their effects might build up over time or act in combination with other substances to produce harmful impacts.

Environmental Disturbance

Disturbance is physical disruption of the environment, such as forest clearing, strip mining, and soil plowing. Our capacity to both pollute and disturb the environment has increased enormously in this century with new technology, increasing consumption rates, and rapidly increasing world population. Most environmental problems involve both disturbance and pollution of the environment. In many instances, they are geographically connected—as one often accompanies or follows the other at a particular place. This is illustrated by the clearing of land for modern agriculture. Disturbance takes place when trees are cut and uprooted and plants and animals are displaced. This is followed by pollution as contaminants in the form of pesticides and chemical fertilizers are introduced to the ground, air, and water as part of the farming operation.

Technology

The driving force in both pollution and disturbance is the population explosion and the astounding capacity of humans to alter the land, water, and air environment. The enabling factor in environmental change is technology. It